WALKER AGGREGATES INC.

PROPOSED UPPER'S QUARRY

LEVEL 2 WATER STUDY REPORT

October 2021

PROPOSED UPPER'S QUARRY

LEVEL 2 WATER STUDY REPORT

WALKER AGGREGATES INC.

WSP PROJECT NO.: 161-11633-00
DATE: OCTOBER 2021

SUITE 700
55 KING STREET
ST. CATHARINES, ON, CANADA L2R 3H5

T: +1 905 687-1771
F: +1 905 687-1773
wsp.com

October 29, 2021

Mr. Kevin Kehl
Walker Aggregates Inc.
2800 Thorold Townline Road
P.O. Box 100
Thorold, ON L4V 3Y8

Subject: Proposed Upper's Quarry
Level 2 Water Report
WSP Project No. 161-11633-00

Dear Mr. Kehl:

We are pleased to provide the Level 2 Water Report to meet the study requirements for the Walker Aggregates Inc (WAI) proposed Upper's Quarry (Site). This report provides background information on the Site and physical setting, details of our investigation, an interpretation of the monitoring data collected since 2011 and numerical groundwater modeling to predict the proposed quarry effects. A proactive monitoring program and recommended mitigation measures are also included in the report.

Like other deep dewatered bedrock excavations on the Niagara Peninsula, there is a predicted reduction in the available drawdown in the bedrock aquifers in the vicinity of the proposed quarry. However, the proposed quarry dewatering is not predicted to adversely impact surface water features within the study area due to the presence of relatively thick, low hydraulic conductivity overburden soils. The predicted aquifer impacts can be mitigated where private drinking water wells are situated within close proximity to the Site.

We trust that this report satisfies your requirements.

Yours truly,
WSP Canada Inc.

Kevin Fitzpatrick

Kevin Fitzpatrick, P.Eng.
Senior Project Engineer

Suite 700
55 King Street
St. Catharines, ON, Canada L2R 3H5

T: +1 905 687-1771
F: +1 905 687-1773
wsp.com

SIGNATURES

Kevin Fitzpatrick, P.Eng. (Geological)
Senior Project Engineer

Leigh Davis, M.A.Sc., P.Eng.
Project Engineer / Hydrogeologist

Peter Hayes, P.Geo.
Senior Hydrogeologist / Environmental Specialist

Javeed Khan, M.Eng., P.Eng., PMP
Senior Project Manager / Hydrologist

J. Stephen Ash, P.Eng., P.Geo.
Senior Engineer, Geotechnical

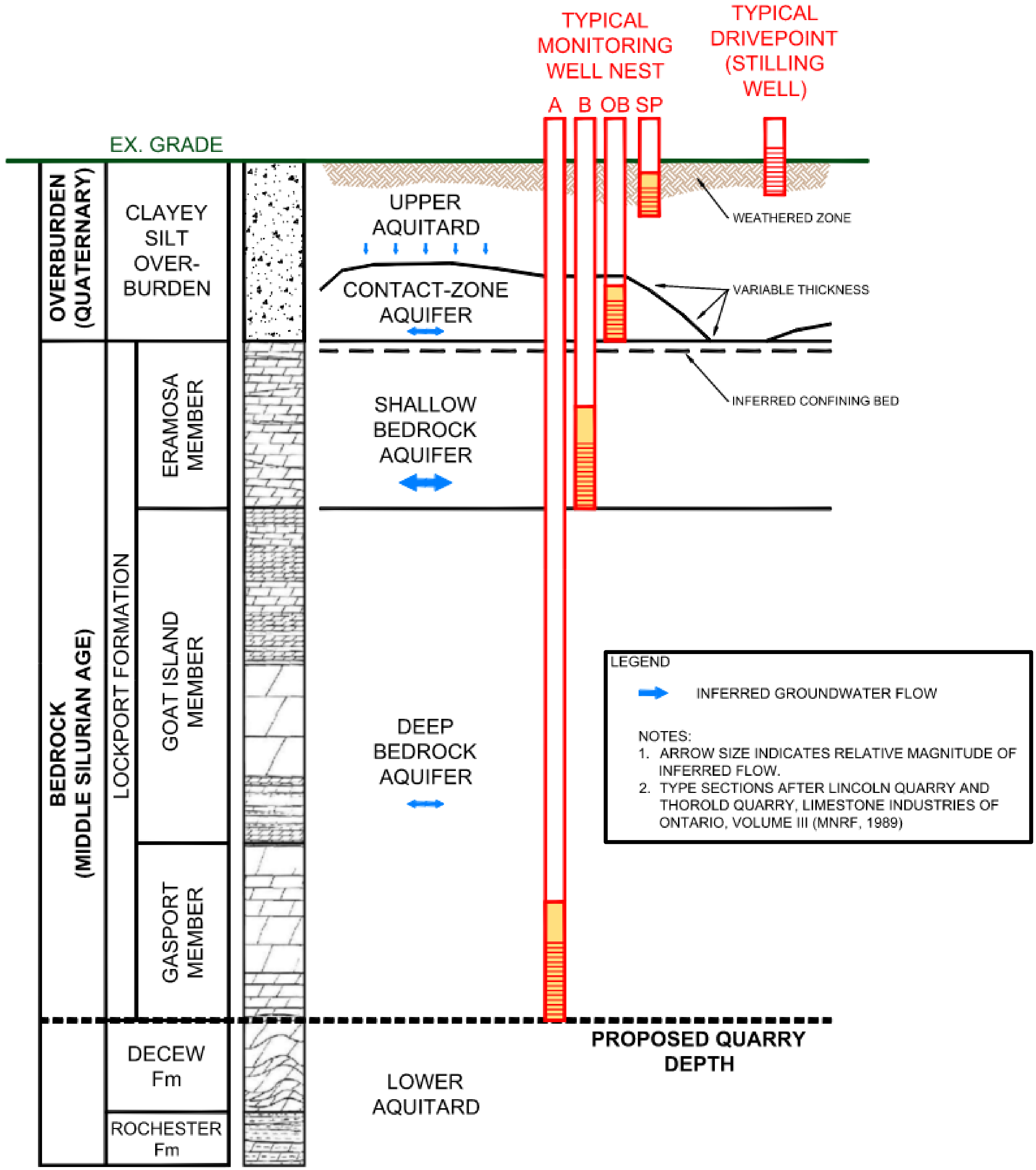
EXECUTIVE SUMMARY

The proposed Upper's Quarry (Site) is situated approximately 200 metres (m) west of the urban boundary of the City of Niagara Falls in Part of Lots 119, 120, 136 and 137 in the geographic Township of Stamford. The quarry will be developed below the natural groundwater table and in order to maintain dry working conditions, the proposed quarry will operate a dewatering system. Walker Aggregates Inc. (WAI) is required to obtain a Category 2, Class A Licence (Quarry Below Groundwater) for the Site under the Aggregate Resources Act (ARA) and to apply for amendments to the Official Plan for the Region of Niagara and the Official Plan and Zoning By-law for the City of Niagara Falls. This Level 2 Water Report has been completed to meet the study requirements for the proposed quarry licence and amendment applications.

The work program included a review of published studies and available water monitoring data to assess the local geology and hydrogeology. Investigative drilling programs were then conducted to improve the understanding of the local geology, as well as to establish a groundwater monitoring well network. Hydraulic testing programs were undertaken during borehole advancement and following the completion of the monitoring network using several standard methods. Groundwater and surface water monitoring was completed to characterize baseline water quality and to document surface water / groundwater interactions. A residential water well survey was also completed within the un-serviced area between the urban boundaries of the City of Niagara Falls and the City of Thorold to identify potential groundwater users. The current monitoring network includes a total of 60 monitoring wells, 10 private water wells and 11 surface water stations. Finally, a steady-state numerical groundwater flow model was constructed and calibrated to simulate baseline late summer / autumn conditions at the Site and used to predict the effects of the proposed quarry dewatering.

Hydrogeology

The hydrogeological conceptual model is depicted in the schematic cross section below. In this part of Niagara Region overburden consists of thick layers of poorly draining glaciolacustrine clayey silts to silty clays forming an upper aquitard which restricts infiltration of precipitation and limits groundwater discharge to surface features. The two principal aquifers within the study area from which groundwater users obtain their water supply are the *contact aquifer* and the *shallow bedrock aquifer*. The contact aquifer occurs within a discontinuous lower basal till unit overlying the dolostone bedrock. The named bedrock formations which host the shallow bedrock aquifer differ across the study area from north to south due to the natural dip angle of the rock. At the Site, the shallow bedrock aquifer is composed of the Eramosa member dolostone. South of the Site, the shallow bedrock aquifer is composed of the Guelph Formation, while north of the Site, it is composed of the Goat Island member. A *deep bedrock aquifer* is also present at the Site within the deeper Gasport member dolostone but it is generally not utilized for local water supply purposes due to adequate yields available in the shallower aquifers. With the exception of a limited number of deep wells and shallow dug-type supply wells, water well users within the study area obtain their water supply from the shallow bedrock aquifer.


TYPICAL MONITORING WELL NEST
TYPICAL DRIVEPOINT (STILLING WELL)
A
B
OB
SP
EX. GRADE
OVERBURDEN (QUATERNARY)
CLAYEY SILT OVER-BURDEN
UPPER AQUITARD
WEATHERED ZONE
CONTACT-ZONE AQUIFER
VARIABLE THICKNESS
INFERRED CONFINING BED
BEDROCK (MIDDLE SILURIAN AGE)
LOCKPORT FORMATION
ERAMOSA MEMBER
SHALLOW BEDROCK AQUIFER
GOAT ISLAND MEMBER
DEEP BEDROCK AQUIFER
GASPORT MEMBER
DECEW Fm
ROCHESTER Fm
LOWER AQUITARD
PROPOSED QUARRY DEPTH
LEGEND
INFERRED GROUNDWATER FLOW
NOTES:
1. ARROW SIZE INDICATES RELATIVE MAGNITUDE OF INFERRED FLOW.
2. TYPE SECTIONS AFTER LINCOLN QUARRY AND THOROLD QUARRY, LIMESTONE INDUSTRIES OF ONTARIO, VOLUME III (MNRF, 1989)

Long-term constant rate pumping tests which simulate quarry dewatering were completed as part of this study. Groundwater response was observed at most shallow bedrock wells up to a distance of 1.5 km from the pumping wells. This response to the long-term pumping tests therefore provides a high degree of confidence in the aquifer properties to characterize the subsurface conditions for the Site and surrounding area. The bulk aquifer properties estimated from the pumping test results are also consistent with published values for fractured dolostone bedrock in the greater Niagara area.

Deeper bedrock pumping tests for this study area were completed in the DeCew and Rochester Formations which underlie the deep bedrock aquifer. These two formations constitute a lower aquitard that restricts groundwater flow, thereby acting as a base for the more active flow in the overlying aquifers. The proposed quarry floor coincides with the top of this aquitard.

Surface Water

The Site is situated within the Beaverdams Creek subwatershed. The un-named watercourse which bisects the Site (referred to as Existing Watercourse in this report) is an intermittently flowing tributary of Beaverdams Creek. The headwaters of the Existing Watercourse originate southeast of the Site near the Niagara Falls moraine, with flow from south to north within the Site boundary. Across the Site, the gradient within the Existing Watercourse channel is shallow, at less than 1%.

Baseline groundwater level data indicate that there is minimal groundwater contribution to surface water features in the study area. Groundwater contribution was measured within the Existing Watercourse in the area north of the Upper's Lane where the upper aquitard is thinner. Groundwater contribution in this portion of the Existing Watercourse is calculated to be less than 0.1 L/s, notably lower than the average spring flow rates of about 300 L/s at upstream station SW3. Further north of the Site within Beaverdams Creek and the Welland Canal South Turn Basin reservoir, groundwater contribution is calculated to be approximately 11% of the average annual water surplus.

Hydrographs of the baseline surface water monitoring data corroborate the interpretation that flows within many of the study area watercourses is intermittent and that significant flow only occurs after precipitation or snowmelt events. Some stagnant water is present within portions of the Existing Watercourse throughout the year in areas which are mapped as wetlands.

Groundwater Use

A significant portion of the study area falls within the urban service areas of the City of Niagara Falls and the City of Thorold. A residential water well survey was completed for eighty-six (86) parcels situated within the un-serviced portion of the study area between 2018 and 2019. A survey response rate of over 70% was achieved. Of the property owners who responded to the survey, approximately 45% indicated a well as their only water source, 17% indicated a cistern as their only water source, and the remaining respondents indicated both a cistern and well were in use. For combined cistern and well users, over 70% indicated that the cistern is used for domestic supply, and the well is either no longer in use or used only for lawn / garden watering. Therefore, approximately half of the surveyed residents within the un-serviced area use a cistern for domestic water supply.

A search of the Ministry of Environment, Conservation and Parks (MECP) Permit-to-Take-Water (PTTW) database indicates that there are three (3) permitted groundwater users within the study area, including (i) the Niagara Falls Golf Club southeast of the Site for their irrigation system, (ii) the Mountain Road Landfill for a groundwater containment system located northeast of the Site, and (iii) the Walker Brothers Quarry sump for quarry dewatering located north of the Site. No PTTWs were found for the known dewatering operations along the Welland Canal at the Thorold Stone Road tunnel northwest of the Site and Townline Road / Main Street Tunnels southwest of the Site, or the Queenston-Chippewa Power Canal to the east of the Site.

Impact Assessment

The predicted available groundwater drawdown was assessed at full quarry development. This represents the full extent of dewatering conditions prior to quarry rehabilitation. Following quarrying the excavation areas will be allowed to fill with groundwater and precipitation with a final Site end use as a series of lakes. The impact assessment considers the effects of both the proposed quarry under full development as well as final rehabilitation. Cumulative impacts, including both permitted and non-permitted groundwater users have also been considered.

Groundwater Quantity and Quality

The predicted available drawdown in the shallow and deep aquifers at full quarry development indicates that the proposed quarry will impact a defined portion of the groundwater quantity in the study area aquifers. However, much of the study area is either currently serviced, or planned for future servicing. As such, impacts on groundwater use occur within a relatively limited un-serviced area between the urban boundaries of the City of Niagara Falls and City of Thorold. These predicted quantity impacts on groundwater users are discussed below. Unacceptable groundwater quality impacts are not predicted.

Surface Water Quantity and Quality

No measurable effects to surface water quantity are predicted within the study area as a result of the proposed quarry dewatering, as the baseline data indicate that there is minimal groundwater contribution to surface water features due to the presence of the thick silt and clay soils of the upper aquitard.

Beechwood Golf and Country Club is the only permitted surface water user within the study area. The Golf Club obtains surface water from the turn basin reservoir in Beaverdams Creek for irrigation purposes. This permitted surface water user will not be impacted by the proposed quarry since the future quarry discharge will ultimately maintain flows to this feature.

Surface water quality within the Existing Watercourse and Beaverdams Creek is predicted to be improved by the proposed quarry discharge during the operational phase. The baseline surface water quality monitoring results indicate that the ambient surface water quality in these features is generally poor as a result of existing anthropogenic sources. The proposed quarry dewatering discharge will be directed to the Existing Watercourse north of the Site, with groundwater inflows accounting for approximately 86% of the flow volume in low flow periods during the summer / autumn months. Most baseline groundwater parameter concentrations are lower than those of the baseline surface water quality; as such, the quarry discharge would improve water quality within the watercourse. Quality and quantity monitoring of the quarry sump discharge has been included in the proposed monitoring program, and a trigger mechanism and contingency plan has been developed to mitigate potential impacts.

Baseline groundwater and surface water temperature data from the Existing Watercourse and Beaverdams Creek indicate that the proposed quarry discharge will have a moderating effect and not adversely impact surface water temperatures in these features.

Once the proposed quarry is rehabilitated, it is predicted that groundwater discharge would passively flow from the final lakes to the reach of the Existing Watercourse (and the Welland Canal South Turn Basin reservoir) north of the Site. Monitoring of the surface water quality during lake-filling has been included in the recommended monitoring program.

Groundwater Discharge Areas

Areas of potential impact occur where groundwater discharge through the upper aquitard is observed, including along the reach of the Existing Watercourse north of the Upper's Lane, and the Welland Canal South Turn Basin reservoir north of the Site. At these locations, there is a predicted overall reduction in the groundwater discharge at full quarry development. However, the future quarry discharge will be directed to these surface water features and as a result, surface water flow rates will in fact increase during the operational phase of the proposed quarry. This discharge from the quarry dewatering compensates for any reduction in groundwater baseflow. As a result, no impact to surface water quantity due to the reduction of groundwater discharge to these features is predicted.

At final rehabilitation, the Welland Canal South Turn Basin reservoir reverts to a groundwater discharge area similar to baseline conditions. Passive surface discharge from the final quarry lakes to the turn basin reservoir compensates for any decrease in direct groundwater discharge.

Local Groundwater Users

Residents that currently rely on cisterns will not be impacted by the proposed quarry dewatering. The severity of the impacts to water well users in the un-serviced portion of the study area during the operational phase of the proposed quarry is dependant on available drawdown in the individual wells and the proximity to the proposed quarry. The numerical model predicted available drawdown at full quarry development, together with the pre-quarry baseline available drawdown information and the water well survey information were used to formulate a detailed well mitigation plan. This plan will ensure that the limited number of impacted groundwater users in the un-serviced area will have adequate future groundwater supplies.

Groundwater users near the final lakes are predicted to have a sufficient available drawdown to meet their needs after final quarry rehabilitation.

Recommendations

To mitigate the impacts of the proposed quarry, the following recommendations should be implemented upon licence approval:

- ➔ A proactive and long-term groundwater and surface water monitoring program will be completed during the quarry operational and rehabilitation phases, until stable conditions are observed after quarry dewatering has ceased and lake-filling is complete;
- ➔ A well interference and mitigation plan will be implemented proactively prior to quarry operation;
- ➔ A spill action plan will be developed and administered throughout all phases of quarry operations; and
- ➔ A trigger mechanism and contingency plan, which includes procedures for mitigating potential impacts from the proposed quarry discharge to the Existing Watercourse will be implemented.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1 INTRODUCTION

1.1 BACKGROUND

The proposed Upper's Quarry (Site) is situated in the City of Niagara Falls in Lots 119, 120, 136 and 137 in the geographic Township of Stamford. This assessment also takes into account potential extraction of the portion of Upper's Lane and Part of the unopened road allowance between Lots 120 and 136 (geographic Township of Stamford), where they exist between Thorold Townline Road and Beechwood Road, all in the City of Niagara Falls, Regional Municipality of Niagara. See the Site Location Map, **Figure 1**. The proposed limits of extraction are shown on **Figure 2**. The Site lands (with the exception of Upper's Lane and the unopened road allowance) have been acquired over time by Walker Aggregates Inc. (WAI) and cover an area of approximately 106 ha. Additional lands to west of the Site within the City of Thorold are also owned by WAI, as shown on **Figure 2**. These additional lands in the City of Thorold are not proposed for aggregate extraction.

The proposed quarry will be developed below the natural groundwater table and in order to maintain dry working conditions, the quarry will operate a dewatering system. WAI is required to obtain a Class A Licence (Quarry Below Groundwater) for the Site under the Aggregate Resources Act (ARA). A Niagara Region Official Plan Amendment, City of Niagara Falls Official Plan Amendment and City of Niagara Falls Zoning By-law Amendment are also required to permit industrial extraction at the Site.

WSP Canada Inc. (WSP) was retained by WAI to prepare this Level 2 Water Report to meet the study requirements for the proposed quarry licence application.

1.2 EVALUATION REQUIREMENTS

In the Aggregate Resources of Ontario Provincial Standards (Ministry of Natural Resources and Forestry (MNRF), August 2020), Part 2.5 outlines the following requirements for a Water Report to meet the study requirements for a Category 2 Class A quarry below groundwater:

> *Water Report Level 1:*
> *Determine the potential for impacts to ground water and surface water resources and their uses (e.g. water wells, ground water aquifers, surface water courses and bodies, springs, discharge areas) and identify if the proposed site is in a Wellhead Protection Area for Quantity (WHPA-Q) set out in an applicable source water protection plan under the Clean Water Act. If so, identify applicable source water protection policies and mitigation measures that will be implemented at the site.*
>
> *Water Report Level 2:*
> *Where the results of Level 1 have identified a potential for impacts from the aggregate site on ground water and/or surface water resources and their uses, an impact assessment is required. The assessment is to determine the significance of the effect and the potential for mitigation.*
>
> *The assessment must address the potential effects of the operation on any ground water and surface water features located within the zone of influence, including but not limited to:*

a) water wells (includes all types e.g. municipal, private, industrial, commercial, geothermal and agricultural)

b) springs (e.g., place where ground water flows out of the ground)

c) ground water aquifers;

d) surface water courses and bodies (e.g., lakes, rivers, brooks)

e) wetlands

The assessment must include but not be limited to the following:

f) a description of the physical setting including local geology, hydrogeology, and surface water systems;

g) proposed water diversion, discharge, storage and drainage facilities;

h) water budget (e.g. how water is managed on-site);

i) the possible positive or negative impacts that the proposed site may have on the water regime;

The Level 2 water report must also contain:

j) monitoring plan(s); and

k) technical support data in the form of tables, graphs and figures, usually appended to the report.

This report addresses the Level 1 and Level 2 Water Report requirements for the proposed quarry. In addition, the study included herein may also be used in support of a future Permit-to-Take-Water (PTTW) application for quarry dewatering as well as the Environmental Compliance Approval (ECA) for Industrial Sewage Works application for quarry discharge to the environment.

Additional requirements considered in the preparation of this study include the Provincial Policy Statement (2014), the Growth Plan (2019), the Clean Water Act (2006), the consolidated Niagara Region Official Plan (2014), the Official Plan for the City of Thorold and the Official Plan (OP) for the City of Niagara Falls (1993, Amended 2017). With regard to the OP, Policy 11.1.49 states

A new mineral aggregate operation or an expansion to an existing operation that is located within any area identified as a Bedrock Resource Area on Appendix 4 to this Plan may be permitted through applications to amend this Plan and/or the Zoning By-Law within NPCA regulated wetlands greater than 2 ha in size, floodways and erosion hazard areas and environmentally sensitive areas designated EPA, subject to the following:

b) Completion of a hydrogeological study in accordance with policy 11.1.27;

Since the Site is situated within a designated Bedrock Resource Area, OP Policy 11.1.49 is applicable. Policy 11.1.27 states

Development or site alteration shall not have an adverse impact on ground or surface water quality or quantity. The City, in consultation with the appropriate agencies, may require a hydrogeological study or an environmental impact study for development or site alteration for any proposal that may impact, either locally or cross-jurisdictionally, on:

a) the quantity and quality of surface and groundwater;

b) the functions of groundwater recharge and discharge areas, aquifers and headwaters;

c) the natural hydrologic characteristics of watercourse such as base flow;

d) surface and groundwater such that other natural heritage features are negatively affected;

e) natural drainage systems and stream forms; and

f) flooding or erosion.

This Level 2 Water Report was completed, in part, to address OP Policy 11.1.27.

1.3 OBJECTIVES AND SCOPE

The principal objectives of this Level 2 Water Report are as follows:

- ➔ Characterize the baseline groundwater and surface water conditions and uses;
- ➔ Establish a baseline water budget for the Site and local study area;
- ➔ Provide input to the proposed quarry design and end use, particularly related to water management at the Site;
- ➔ Predict potential effects of the proposed quarry on water resources within the study area; and
- ➔ Implement a proactive environmental monitoring program to confirm the predicted effects of the proposed quarry that includes a trigger mechanism and contingency measures to ensure compliance with the Site Plan and other permits.

The study area extends to the Niagara Escarpment brow to the north, the Queenston-Chippewa Power Canal to the east, the Welland River to the South, and the modern Welland Canal to the west. This area roughly coincides with the extent of **Figure 1**. Historical information provided by others under separate cover was incorporated into this report as referenced. Studies for more distant sites within the local study area are outlined in the geology discussion (**Section 2.4**).

1.4 STATEMENT OF QUALIFICATIONS

This Level 2 Water Report was completed by a project team at WSP Canada Inc. Curriculum vitae are provided in **Appendix A**.

1.5 STUDY METHODOLOGY

The main objective of the study was to develop an understanding of the hydrogeological conditions within the study area in order to predict the potential effects of the proposed quarry on hydrogeologic features of interest. The work program included a review of published studies and available water monitoring data to assess the local geology and hydrogeology and to identify gaps in the conceptual understanding of the Site.

Additional drilling programs were conducted to improve the understanding of the local geology, as well as to establish a groundwater monitoring well network. A hydraulic testing program was undertaken both during borehole advancement as well as after the completion of the monitoring network using a variety of field methods. Finally, groundwater and surface water monitoring were completed to characterize baseline water quality and to study surface water / groundwater interactions.

1.5.1 WATER WELL SURVEY

To establish an initial database of local groundwater users, a search of the MECP Water Well Record database was undertaken to identify well records located between the approximate existing service areas (per Niagara Region 2016 Master Servicing Plan) in the vicinity of the Site. A residential water well survey of this area was conducted by WAI representatives and WSP staff between summer 2018 and winter 2019 in accordance with the MECP technical guidance (MECP, 2008).

The results of the well record database search and water well survey are included in **Appendix B**, with further discussion provided in **Section 2.5.4**.

1.5.2 DRILLING PROGRAMS

Boreholes were advanced during two separate drilling programs at the Site. The locations of boreholes completed as part of this undertaking are shown in the Site Plan, **Figure 2**, while the locations of surface water stations are shown on **Figure 3A**. Available borehole logs and monitor construction details are included in **Appendix C**.

2004

Prior to the current study, Jagger Hims Limited (now WSP) advanced five (5) boreholes as part of an initial resource assessment for the Site. Of these original boreholes, BH03-2 was retrofitted during the initial drilling program undertaken as part of the current study. The resource assessment boreholes dating from 2004 were completed as open holes in the bedrock; the retrofit included the installation of two smaller diameter riser pipes within the open hole, with the screen and filter pack installed at selected intervals aligned with the current monitoring network configuration. The retrofitted wells are referred to as BH03-2A and BH03-2B. The original and retrofit borehole logs and monitor construction details are included in **Appendix C**. Continuous monitoring of the retrofitted wells was initiated for the current study.

2011

More recently, four (4) boreholes were advanced by others during 2011 at the four corners of the proposed quarry footprint, referred to as well nests MW11-1 through MW11-4. The initial boreholes are believed to have been completed as open holes in the bedrock. The available logs indicate that geophysical testing was completed in the open holes to establish bedrock lithology. Later, the initial boreholes were retrofitted by installing two riser pipes within the open hole, with screen and filter packs installed at selected intervals. The screen intervals were identified as ‘A’, the deep bedrock roughly corresponding to the base of the Gasport member of the Lockport Formation and the underlying DeCew and Rochester Formations, and ‘B’, the shallow bedrock corresponding to the Eramosa member of the Lockport Formation. Separate overburden ‘OB’ series wells were installed at each of the four nests, with screen intervals completed to the top of bedrock. The available monitor construction details and borehole logs are included in **Appendix C**. In 2012, dataloggers were installed in each well (12 wells in total) and set to record water level elevations at 4-hour intervals. The datalogger water level data and periodic manual water level measurements were incorporated into this study, included in **Appendix E**. These wells have therefore established a continuous water level record at the Site since 2012.

2016

In the summer of 2016, WSP completed a drilling program at the Site as part of this study to install monitoring well nests MW16-5 through MW16-19 in order to establish an improved groundwater monitoring network. A total of thirty-two (32) wells were installed at these fifteen (15) nests. The well nests typically consist of three (3) wells screened at selected intervals as shown in the schematic section on **Figure 2A** and described below:

- ➔ Interval 'A' corresponds solely to the base of the Gasport member of the Lockport Formation (i.e., the deep bedrock aquifer). We note that this is equivalent to the proposed final quarry depth (excavation will not be completed into the identified DeCew Formation).
- ➔ Interval 'B' corresponds to the Eramosa member of the Lockport Formation (i.e., the shallow bedrock aquifer). Hydraulic (packer) testing of the boreholes during installation consistently demonstrated a permeable zone in this interval. Further discussion of the hydraulic testing is provided below.
- ➔ Interval 'OB' roughly corresponds to the interval of overburden immediately overlying the top of bedrock; in studies by others, this interval is typically referred to as the contact-zone or contact aquifer.

We note that although the 2011 well nests use the same A / B nomenclature, the intervals screened differ from the screen intervals selected as part of the current study. In particular, the MW11 nest 'A' series wells are generally screened from the base of the Gasport member across the DeCew / Rochester contacts, whereas the remainder of the 'A' series wells were screened solely at the base of the Gasport member bedrock. As such, the hydraulic properties, water levels and chemistry of the MW11 nest 'A' wells reflect the properties of the screened interval.

Four (4) well nests along Townline Road along the west property boundary include only a single contact aquifer 'OB' monitoring well. These wells were installed to provide additional information for the design of the Realigned Watercourse.

During the initial drilling program, drivepoints (i.e., stilling wells) were also installed at four (4) 'SW' series surface water stations and five (5) 'DP' series stations. The purpose of these stations is to monitor surface water elevations with dataloggers, as the screens are installed above ground surface to intersect surface water flow (refer to borehole logs in **Appendix C**). The 'SW' series stations differ from the 'DP' series as they are situated downstream of hydraulic control structures (i.e., culverts) and were strategically chosen to calculate stage-discharge relationships for conversion of datalogger water level data to estimated flow rates.

Finally, monitoring well nest MW11-3 was decommissioned and replaced with nest MW11-3R as part of the initial drilling program. The detailed Site survey completed as part of the current study indicated that the original well nest had been installed slightly outside of the property boundary and was re-located.

Pumping well PW1 was installed in October 2016 by licensed water well driller Country Water Systems of Thornton, ON. Pumping well PW1 was completed as an open hole in the bedrock, extending from approximately 2.1 m below the bedrock contact (6.1 mbgs) to the base of the Gasport member at approximately 45.4 mbgs. A copy of the water well record (tag no. A191572) is provided in **Appendix C**. Two long-term pumping tests have been completed since well installation. The results of the first test completed in winter 2017 lead to the supplemental drilling program completed in the spring of 2017.

2017

The supplemental drilling program in 2017 included the installation of four (4) well nests situated near surface features that could potentially be impacted by dewatering of the proposed quarry. One (1) complete well nest, MW17-20, was installed in the vicinity of the mapped wetland to the east of the Site, at address 5584 Beechwood Road. An 'SP' series standpipe was also installed at this nest to facilitate monitoring of the shallow weathered overburden. The designation 'SP' was chosen for this depth interval to distinguish from the existing 'OB' series wells. In general, the screened intervals for 'SP' series standpipes are less than 3 m below ground surface. In addition to nest MW17-20, drivepoint DP6 was installed at this property within the footprint of the mapped wetland, to facilitate monitoring of the water levels within the wetland feature. The wells and drivepoint completed during the supplemental drilling program were installed with the permission of the property owner. Three (3) additional well nests, MW17-21 to MW17-23, were also installed to the west of the Site during the supplemental drilling program in the vicinity of the woodlot feature west of Townline Road. These nests only consist of 'B', 'OB' and 'SP' series wells / standpipes and are intended to monitor the shallower units to monitor potential impacts of quarry dewatering on the woodlot feature. An 'SP' series standpipe was also added at well nest MW16-9 for this purpose.

Finally, well MW16-5AR was installed in the vicinity of well nest MW16-5 to confirm the drawdown observed in the deep bedrock aquifer during the pumping test. MW16-5A was left in place.

Both the initial and supplemental drilling programs and monitoring well installations undertaken as part of the current study were completed by Orbit Garant Drilling Inc. of Sharon, Ontario. Boreholes advanced through the overburden were completed with hollow-stem augers (108 mm inner diameter) to allow measurement of in-situ geotechnical parameters and detailed soil logging.

Boreholes that were advanced into bedrock were completed with an HQ (64 mm diameter) diamond drill bit. The 'A' series boreholes were continuously cored from the bedrock surface to the interpreted depth of the DeCew Formation. Rock core was placed into core boxes and stored at the Site for review by a senior geological engineer. Descriptions included stratigraphy, percent recovery and rock quality designation (RQD). Rock core photos are included in **Appendix C-3**.

Monitoring wells were generally constructed of 51 mm diameter PVC riser pipe and a 10 slot (0.25 mm) well screen of varying lengths to accommodate the interval screened. The borehole annulus around the screen was filled with number 2 silica sand to a nominal height above the screen to provide a filter pack. The remainder of the borehole annulus was sealed with bentonite pellets and / or grout. A lockable protective steel casing was cemented in place at the surface. Dedicated inertial lift sampling equipment (Waterra) was installed and the wells were developed to set the filter pack. Cluster MECP well records were submitted for the separate drilling programs.

The wells and drivepoints included in the current monitoring network were surveyed by WSP to establish ground surface and top of pipe elevations to a geodetic datum and UTM location coordinates. The elevation data is provided in **Table C-1**, **Appendix C**.

1.5.3 HYDRAULIC TESTING PROGRAM

Several standard methods were used to perform the hydraulic conductivity testing at the Site, as summarized below. A complete description of the testing and results is provided in **Appendix D**.

Packer testing was completed during borehole advancement at selected ‘A’ series wells to assess relative hydraulic conductivity of discrete bedrock intervals as part of the initial drilling program, undertaken between October 5, 2016 and November 28, 2016. After each ~3 m (10’) drill run, the recently drilled interval was sealed off from the remaining borehole annulus by an inflatable rubber packer. Similar to a falling head slug test, water was injected into the packer interval to a reference elevation, and the decrease in the head was monitored over time as the excess water dissipated into the bedrock interval fracture network. We note that the results of the packer testing were used to assess the relative hydraulic conductivities of the bedrock with depth to enhance the conceptual understanding of the hydrostratigraphy at the Site.

Single well response tests were completed to determine local in-situ hydraulic conductivity for selected monitoring wells. Tests were not completed on the DeCew / Rochester Formation aquitard wells due to slow recovery; instead, the logger data for the water level recovery following well installation were used to estimate hydraulic conductivity. The Hvorslev analytical method was used to analyze the slug test data, and the analyses were confirmed using AquiferTest software.

A long-term pumping test was completed at pumping well PW1 between February 8 – 16, 2017, to estimate the bulk transmissivity of the shallow bedrock aquifer and to simulate dewatering of the proposed quarry. Prior to the long-term test, a stepped-rate test was completed on February 7, 2017 to assess the pumping well efficiency and linear / non-linear well losses, as well as to determine an appropriate pumping rate for the long-term test.

During the tests, groundwater elevations were monitored at pumping well PW1 and existing Site monitoring wells screened in the overburden and bedrock. Water levels were recorded using dataloggers augmented with periodic manual measurements. Field measurements for pH, conductivity and temperature, as well as a sample of the pumping well discharge were collected during each day of pumping. The discharge flow rate from the pumping well was monitored using a continuous flow measuring device, confirmed with periodic manual flow rate measurements.

Most of the shallow bedrock wells across the Site showed a response to the pumping test. Drawdown was also observed in the contact aquifer at well nest MW16-9 west of the Site near the un-named woodlot and at well nest MW16-7 along the southern property boundary. These observations lead to the completion of the supplemental drilling program to install additional well nests close to nearby surface features that could potentially be affected by drawdown due to the proposed quarry dewatering. Monitoring of the shallow (<3 m depth) weathered overburden was facilitated with the addition of ‘SP’ series standpipes at selected well nests.

Following the supplemental drilling program, additional short-term pumping tests were completed to assess the hydraulic connection between the shallow bedrock aquifer and contact aquifer / shallow weathered overburden in the vicinity of the identified surface features. Five ~8-hr duration tests were completed between September 5 – 13, 2017 by WSP field staff. For each test, a Grundfos Redi-Flo pump was installed within the well screen in the ‘B’ series well at each nest. Groundwater levels within the ‘B’ series wells, and nested ‘OB’ and ‘SP’ wells were monitored during the tests with automated data loggers augmented with periodic manual measurements.

Seven (7) permeameter tests were completed in the shallow weathered overburden between July 12 and 13, 2018 by WSP field staff to estimate vertical hydraulic conductivity and groundwater recharge rates using the Nova Scotia method.

Finally, additional long-term pumping tests were completed at PW1 and the private drinking water well at 5205 Beechwood Road in the northeast portion of the Site in February / March 2019. The purpose of the additional test at PW1 was to monitor the response to pumping at the newly installed monitoring wells, using a higher pumping rate than previous pumping tests for a longer period of time. The purpose of the pumping test at the 5205 Beechwood well was to obtain additional aquifer data from the northeast portion of the Site where the pumping test at PW1 did not show a significant influence. A stepped-rate test was also performed on the 5205 Beechwood well to assess the well efficiency.

The additional tests were conducted using a similar procedure to the 2017 pumping test at PW1, while monitoring the Site wells plus selected private wells. Similar to the 2017 pumping test at PW1, most shallow bedrock wells showed a response to the pumping test at PW1 in 2019. Drawdown was also observed in the contact aquifer and underlying deep bedrock (Goat Island / Gasport members) at the same locations noted in the 2017 test.

1.5.4 GROUNDWATER MONITORING

The baseline groundwater monitoring program completed for this study consisted of the following:

- ➔ Continuous groundwater level monitoring using dataloggers installed at fourteen (14) ‘A’ series deep bedrock aquifer wells, eighteen (18) ‘B’ series shallow bedrock aquifer wells, twenty-three (23) ‘OB’ series contact aquifer wells, and five (5) ‘SP’ series shallow weathered overburden standpipes included in the monitoring network. The well locations are shown on the Site Plan, **Figure 2**. Loggers were programmed to collect data every four (4) hours. One barologger was installed at nest MW11-1 to correct for atmospheric pressure changes over time.

- ➔ Continuous groundwater level monitoring using dataloggers installed at ten (10) off-Site private supply wells identified during the water well survey. The locations of the private supply wells are shown on the Site Plan, **Figure 2**. Loggers were programmed to collect data concurrently with the Site monitoring well loggers.

- ➔ Periodic manual water level measurements at each monitoring well were made over the course of the baseline monitoring period, generally occurring on a quarterly basis and / or prior to sampling events. The manual measurements were used to confirm the datalogger water levels. The manual water levels were measured with an electric contact gauge. The datalogger and manual water level measurements are depicted in the hydrographs included in **Appendix E**. Water level data notably affected by hydraulic testing over the short test period are not included on the hydrographs for clarity.

- ➔ Four (4) groundwater sampling events were completed during the baseline monitoring period, occurring in December 2016, May 2017, March 2018 and July 2020. Monitoring wells were purged of at least three (3) standing water volumes prior to sampling, except for the MW11 ‘A’ series wells where, owing to the slow water level recovery following well installation, direct samples were collected. All samples were collected into laboratory prepared bottles and submitted under standard chain-of-custody procedures to BureauVeritas (formerly Maxxam Analytics Inc.) of Mississauga, Ontario, for analysis of general parameters, major ions, nutrients and organic indicators, dissolved metals and selected volatile organic compounds (VOCs). Where required, samples were field filtered using an in-line 0.45 µm filter and decanted to bottles with the appropriate preservatives. Field measurement of pH, conductivity and temperature was also completed prior to sampling. During each sampling event, one blind duplicate sample was collected for every ten (10) wells sampled for quality assurance / quality control (QA / QC) purposes. The groundwater chemical results are included in **Appendix F**.

As noted in bullets 1 and 2 above, there are a total of sixty (60) monitoring wells and ten (10) off-Site private water wells included in the current monitoring network. The extent of baseline water level and chemistry data has expanded with the installation of additional wells over several drilling programs.

1.5.5 SURFACE WATER MONITORING

The baseline surface water monitoring program completed for this study consisted of the following:

- ➔ Continuous water level monitoring using dataloggers installed at four (4) 'SW' series and seven (7) 'DP' series stations included in the monitoring network. The locations of the surface water stations are shown on **Figure 3A**. Loggers were programmed to collect data every four (4) hours.
- ➔ Periodic manual water level measurements at each station were made over the course of the baseline monitoring period, generally occurring on a quarterly basis and / or prior to sampling events. The manual measurements were used to confirm the datalogger water levels. The manual water levels were measured with an electric contact gauge. The datalogger and manual water level measurements are depicted in the hydrographs included in **Appendix E**.
- ➔ Six (6) flow measurements were made following precipitation events of varying magnitudes at the four (4) 'SW' series stations. As noted previously, these stations were strategically chosen for development of stage-discharge relationships as they are situated downstream of hydraulic control structures. The presence of the static hydraulic controls allows for consistent and reliable flow measurements between precipitation events. The stage-discharge curves and estimated flow rates for the datalogger data are included in **Appendix E**.
- ➔ Three (3) surface water sampling events were completed during the baseline monitoring period, occurring in December 2016, May 2017 and March 2018. Samples were collected from stations where there was sufficient surface water flow except DP6 (wetland east of the Site) and DP7 (woodlot west of the Site), as these two stations are only intended for water level measurement. Grab samples were collected from downstream to upstream locations using a decontaminated bottle, decanted into laboratory prepared bottles and submitted under standard chain-of-custody procedures to BureauVeritas (formerly Maxxam Analytics Inc.) of Mississauga, Ontario, for analysis of general parameters, major ions, nutrients and organic indicators, total metals and selected VOCs. Field measurement of pH, conductivity, temperature and dissolved oxygen was also completed prior to sampling. During each sampling event, one blind duplicate sample was collected for QA / QC purposes. The surface water chemical results are included in **Appendix G**.

1.5.6 GROUNDWATER NUMERICAL FLOW MODEL

A steady-state numerical groundwater flow model was constructed to simulate baseline hydrogeological conditions at the Site. The model was calibrated using the available baseline groundwater and surface water elevation data for autumn conditions, as well as the results of the various hydraulic tests completed to estimate the hydrogeological properties of the overburden and bedrock units. The calibrated baseline model was then modified to predict the effects of the proposed quarry dewatering on water features at both full quarry development and at final rehabilitation.

MODFLOW-USG (Panday et al, 2017) was used as the numerical simulation code for the groundwater model. MODFLOW-USG (**U**n-**S**tructured **G**rid) is similar to the more traditional MODFLOW (USGS 1988-2005) code; however, it allows for more robust grid refinement in areas of increased interest. MODFLOW-USG is capable of simulating steady-state three-dimensional groundwater flow in the unconfined and confined aquifers in the local study area.

Companion programs, such as ZoneBudget (Harbaugh, 1990 and updates) and mod-PATH3DU (Muffels et al, 2018) were used during the construction and calibration process to assess mass balance and groundwater flow directions within the model. Groundwater Vistas version 7 was used as the pre- and post-processor for the model construction and calibration process. The parameter estimation software PEST (Doherty, 2016) was also used during the calibration and model prediction process.

The numerical groundwater model report is included as **Appendix H**.

2 PHYSICAL SETTING

2.1 PHYSIOGRAPHY, TOPOGRAPHY AND LAND USES

The Site is situated within the Haldimand Clay Plain physiographic region, extending from the Niagara Escarpment in the north to Lake Erie in the South (Chapman and Putnam, 1984) (refer to Key Map on **Figure 1**). This physiographic region is characterized by low topographic relief and poorly drained soils. During the last glaciation, the area was inundated by glacial Lake Warren and resulted in the deposition of up to several tens of metres of massive stratified clay and silt deposited on the underlying Silurian age dolostone.

The Niagara Falls moraine situated approximately 1.5 kilometres (km) south of the Site (shown in **Figure 3**) has an influence on the topography and drainage of the study area. The crest of the moraine is at approximately 187 metres above sea level (masl) to 188 masl. At the Site, the topography is relatively flat, with the ground surface dipping from 185 masl along Townline and Beechwood roads to the Existing Watercourse meander belt which ranges from approximately 178 masl at the south property boundary to 176 masl at the north property boundary. The Site scale topographic contours are shown in more detail on **Figure 3A**. The Vinemount moraine is also present within the study area, situated north of and running parallel to the Niagara Escarpment brow, as shown on **Figure 3**. The Vinemount moraine is more distant than the Niagara Falls moraine from the Site and does not influence the drainage in the immediate vicinity of the Site.

The current land use within the Site boundary is agricultural, rural residential and institutional (Bible Baptist Church). Along Lundy's Lane to the south, there are a number of commercial properties (hotels, small businesses). The City of Niagara Falls urban boundary extends to the recently completed Fernwood subdivision to the east of the Site (shown on **Figure 2**), accessible from Garner Road. To the west, a secondary plan of subdivision has been approved for the Rolling Meadows development. Currently, only a portion of the Rolling Meadows secondary plan has been developed with access from Davis Road; however, this development will ultimately extend to the western boundaries of the additional properties owned by WAI to the west of Townline Road. Other features of interest are the large un-named woodlot to the west of Townline Road which partially covers additional lands owned by WAI. Two additional woodlots are present east of Beechwood Road east of the Site; an un-named woodlot which partially covers 5584 Beechwood Road, and the Fernwood Woodlot Park.

2.2 WATER BUDGET

To estimate the water budget, temperature and precipitation data from the Niagara College weather station (operated by Weather Innovations Consulting LP) and the Welland-Pelham climatological station (operated by Environment Canada) were used. The 30-year climate normal and yearly water budget data for 2008 through 2020 are included in **Appendix I**.

As shown in **Table I-1**, the 30-year climate normal (1961-1990) for total annual precipitation for the study area is 953 mm. Using the Thornthwaite Mather methodology, the estimated annual evapotranspiration is 644 mm, yielding an average water surplus of 309 mm/year available for surface water runoff and recharge to the groundwater system. As shown in **Tables I-2 through I-15** the average annual precipitation averaged 974 mm between 2008 and 2017, marginally above the 30-year climate normal.

Notable dry years include 2007 (723 mm), 2010 (625 mm), 2016 (659 mm), 2018 (779 mm) and 2020 (723 mm), while 2017 (1,130 mm) was notably wetter than normal.

2.3 DRAINAGE

As noted previously, the study area is characterized as poorly drained owing to the relatively impermeable nature of the surficial soils and low topographic relief. The Site is situated within the Beaverdams Creek subwatershed (NPCA, 2013), as shown on **Figure 3**. The approximate area of the subwatershed is 15.5 square kilometres (km^2). The un-named watercourse which bisects the Site (referred to as Existing Watercourse in this report) is an intermittently flowing tributary of the Beaverdams Creek. The headwaters of the Existing Watercourse originate southeast of the Site near the Niagara Falls moraine, with flow from south to north within the Site boundary. Across the Site, the gradient within the Existing Watercourse channel is shallow, at less than 1%.

Beaverdams Creek is hydraulically connected to the portion of the Welland Canal between Locks 7 and 8, operated by the St. Lawrence Seaway Management Corporation (Lock 7 location shown on **Figure 3**; Lock 8 is far to the south of the study area near Lake Erie). Stage elevations within this portion of Beaverdams Creek are subject to canal operational requirements. Most notably, Beaverdams Creek is virtually dry with limited areas of standing water during the winter months whenever the canal is drained for maintenance. The use of Beaverdams Creek as a reservoir for the canal operation (referred to as the Welland Canal South Turn Basin, shown on **Figure 3**) has led to the creation of wetland complexes along the watercourse.

The Beaverdams Creek wetland complex and much of the Existing Watercourse meander valley and associated wetland complex have been mapped as wetland regulated by the NPCA; however, none of these features are classified as Provincially Significant Wetland (PSW). There are a number PSW complexes within the more distant study area, situated south of the Niagara Falls moraine and are labelled on **Figure 3**. An additional wetland feature is also present east of Beechwood Road, largely coinciding with the previously mentioned un-named woodlot at 5584 Beechwood Road, as shown on **Figure 3A**. This wetland is also not classified as a PSW but is mapped as NPCA regulated wetland. Unlike the wetland complexes present along Beaverdams Creek and the Existing Watercourse, the wetland feature east of Beechwood Road is “off-line” from any nearby surface watercourses and drainage swales which cross the agricultural fields. Drivepoint DP6 was installed within this wetland feature to monitor the hydroperiod. Further discussion is provided in **Section 2.3.1** below.

The Welland River subwatershed is situated in the southern portion of the study area, as shown on **Figure 3**. The Welland River is a significant low-gradient watercourse flowing from west to east and draining much of the Niagara Peninsula above the escarpment brow to the Niagara River in the east. Within the local study area, the Welland River and Beaverdams Creek subwatersheds are separated by the Niagara Falls Moraine. The headwaters of Thompson Creek, the only named tributary of the Welland River within the local study area, originate on the south slope of the moraine. The Welland River, particularly the lower reach south of the Site, has undergone significant anthropogenic changes in the past. The river by-passes underneath the modern Welland Canal south of the community of Port Robinson via syphon in the southwestern portion of the study area. When first constructed, the entire reach of the Welland River from Port Robinson to the mouth at the Niagara River was used as the upper part of the Welland Canal. Finally, during the construction of the Queenston-Chippewa Power Canal which diverts water from the Niagara River upstream of the falls to Sir Adam Beck hydroelectric station, the reach of the Welland River from the canal to the Niagara River was channelized, and the flow direction was reversed. Currently, the Welland River no longer drains to the Niagara River, but rather to the Queenston-Chippewa Power Canal. Based on river cross sections provided by NPCA, the Welland River is inferred to be underlain by a considerable thickness of clayey silt overburden. Historical mapping suggests that the channelized portion of the river has a depth of approximately 4.3 m (14 feet).

Two smaller east-to-west draining subwatersheds are situated to the north of the Site, including Shriners Creek and Ten Mile Creek, as shown on **Figure 3**. Six Mile Creek is also present, although it is not mapped as a separate subwatershed. All of these surface watercourses drain water west to the Welland Canal. Of note, the Six Mile Creek watercourse was historically relocated to facilitate extraction in the Walker Brothers Quarry (shown on **Figure 1**).

In order to permit extraction of the bedrock resource, the portion of the Existing Watercourse that transects the Site must be relocated. Complete details of the Realigned Watercourse design and mitigation measures are included under separate cover as part of the application. The focus of the Existing Watercourse baseline monitoring data and analysis presented herein is primarily to characterize the groundwater / surface water interaction within the study area, as well as to identify potential effects of the future quarry dewatering and discharge to the surface water quality of the Existing Watercourse.

2.3.1 SURFACE WATER HYDROGRAPHS AND FLOW

Baseline conditions in the Existing Watercourse and Beaverdams Creek were monitored extensively as part of this study. A discussion of the observed surface water flows is included in this section; further analysis of groundwater / surface water interaction is included following the hydrogeology discussion, in **Section 2.5.3** below.

The locations and designations of the surface water stations are shown on **Figure 3A**.

Stage-discharge relationships were developed for each of the four “SW” series stations such that the continuous water level data could be converted to estimated flow rates. The stage-discharge relationships and surface water hydrographs for stations SW1 through SW4 are shown on **Figures E-25 through E-32**, **Appendix E**. The surface water hydrographs for stations DP1 through DP7 are shown on **Figures E-33 through E-39**, **Appendix E**. On the surface water hydrographs, the light-blue curve represents the creek stage (left axis of hydrograph), while the dark blue curve represents the calculated flow rate in Litres/second (L/s) (right axis of hydrograph). Precipitation data are also shown above the hydrograph for reference. Of note, the surface water hydrographs at the ‘DP’ stations show water level data only; stage-discharge relationships were not developed for these locations as there are no hydraulic controls and the channel slope and intermittent flow makes accurate flow measurement difficult.

Station SW1 monitors flow along Beaverdams Creek from the east of the Site. None of the flow passing though this station originates from the Site itself, and this station is considered a background / upstream monitoring station for the Beaverdams Creek reservoir / wetland complex present to the north of the Site. The catchment area for this upstream station is approximately 3.26 km^2. The hydrograph on **Figure E-26** shows that flow within this upstream branch of the Beaverdams Creek is intermittent, with flow occurring only following large precipitation or melt events. During 2017, the estimated total flow at SW1 is approximately 112,844 cubic metres (m^3), with daily average flow rates ranging between 150 L/s to no measurable flow. When the catchment area is considered, this results in a total runoff of 35 mm/year. As shown on **Table I-12**, the estimated water surplus during 2017 is about 474 mm. Therefore, a runoff coefficient of 7% is calculated for 2017.

Surface water flow rates within Beaverdams Creek downstream of the Site and the associated confluence with the Existing Watercourse could not be established as Beaverdams Creek forms a reservoir in this area.

Station SW2 monitors flow within a relatively small catchment which is hydraulically separated from the main channel of the Existing Watercourse. This catchment drains the Bible Baptist Church property east of the Site and a small area east of Beechwood Road, with a total area of 0.11 km^2 (11 hectares (ha)). The hydrograph on **Figure E-28** confirms that flow within this tributary is also intermittent. During 2017, the estimated total flow at SW2 is approximately 12,288 m^3, with daily average flow rates ranging between 10 L/s to no measurable flow. When the catchment area is considered, this results in a total runoff of 114 mm/yr, or a runoff coefficient of 24% using the 2017 water surplus.

Station SW3 monitors flow from the Existing Watercourse upstream (south) of the Site, from south of Lundy's Lane and the Fernwood subdivision footprint to the southeast of the Site. The catchment area for this upstream station is approximately 4.23 km^2 (423 ha). The hydrograph on **Figure E-30** indicates that this station is inundated with water throughout the year. However, the stage-discharge relationship suggests that flow only occurs following precipitation and melt events. For the rest of the year, the surface water present at SW3 appears to be stagnant. During 2017, the estimated total flow at SW3 is 1.19 Mm^3, with daily average flow rates ranging between 1,100 L/s and no measurable flow. When the catchment area is considered, this results in a total runoff of 317 mm/year, or a runoff coefficient of 67% using the 2017 water surplus.

Station SW4 is situated in the centre of the proposed quarry footprint and monitors flow from the SW3 catchment, as well as the agricultural lands south of Upper's Lane. The catchment area for this station is approximately 6.18 km^2 (618 ha). Based on the hydrograph on **Figure E-32**, flow typically occurs after precipitation or melt events, with the exception of the late summer / early autumn when dry conditions occur. During 2017, the estimated total flow at SW4 is 0.93 Mm^3, with daily average flow rates ranging between 1,200 L/s and no measurable flow. When the catchment area is considered, this results in a total runoff of 213 mm/year, or a runoff coefficient of 45% using the 2017 water surplus.

Station DP1 is situated north of the Site, in Beaverdams Creek (Welland Canal South Turn Basin) east of Townline Road. The turn basin receives discharge and runoff from a catchment area of approximately 11.08 km^2 (1,108 ha). The hydrograph on **Figure E-33** shows that except for the winter months when the canal is drained, surface water is present in the turn basin. There is a culvert under Townline Road that is exposed when the canal is drained; however, the culvert is submerged during the rest of the year and it is not possible to obtain a flow rate. When water is present in the turn basin, the stage appears to fluctuate by $\pm$0.3 m, attributed to canal operations.

Station DP2 is situated within the Existing Watercourse meander valley at the north Site boundary, monitoring flow from the SW4 catchment as well as the agricultural fields north of Upper's Lane. The catchment area for this station is approximately 6.53 km^2 (653 ha).

Station DP3 is situated within the Existing Watercourse meander valley at the south Site boundary, monitoring flow from the SW3 catchment as well as the agricultural fields south and southeast of the Site. The catchment area for this station is approximately 4.42 km^2 (442 ha).

Station DP4 is situated within a small tributary of the main channel of the Existing Watercourse, monitoring overland runoff from a relatively small agricultural field southeast of the Site. The catchment area for this station is approximately 0.22 km^2 (22 ha). The hydrograph on **Figure E-36** shows that the stage elevation is above ground surface only during significant precipitation or melt events, which is not unexpected.

Station DP5 is situated within a small tributary of Beaverdams Creek, separate from the Existing Watercourse catchment. The station is located near the north Site boundary in the northeastern corner of the Site, and monitors flow from the SW2 catchment as well as overland runoff from the agricultural fields in the vicinity of the Bible Baptist Church property. The catchment area for this station is approximately 0.19 km^2 (19 ha). The hydrograph on **Figure E-37** shows that the stage elevation does remain above the ground surface for extended periods of the year, except for the drier summer and autumn months. It is noted that this station receives a limited amount of discharge from the rural residence at address 5205 Beechwood Road within the Site boundary.

Station DP6 is situated within the un-named wetland and woodlot feature east of the Site, at address 5584 Beechwood Road. There is no observable channel which this wetland feature drains to. The purpose of this drivepoint is to measure the hydroperiod for the wetland. The hydrograph shown in **Figure E-38** shows that the stage elevation is only above grade during the winter (likely the result of snow / ice accumulation) and spring freshet. The station is typically dry June through November.

Station DP7 is situated within the un-named woodlot feature west of the Site, partially covering the additional lands owned by WAI west of Townline Road. There is no mapped wetland associated with this woodlot feature, and there is no observable channel draining the area near DP7. There appears to be one or more surface watercourses which intersect the woodlot on the western side of the woodlot, but those lands are under separate ownership and were not accessible during the course of this study. The purpose of DP7 is to measure periods of the year (if any) that the stage elevation is above ground surface, and to gain a better understanding of groundwater / surface water interaction in this area. Based on the ground surface contours, the woodlot is situated at a local topographical high. The hydrograph shown on **Figure E-39** shows that the stage elevation is above grade during the winter (probably the result of snow / ice accumulation) and spring freshet.

It is noted that the NPCA source protection report suggests that recharge to the groundwater system is less than 50 mm/year within the Beaverdams Creek subwatershed; therefore, on average, a response equivalent to at least 424 mm of runoff should have been observed at each of the staff gauges in 2017. The 2017 runoff amounts calculated above are less than the amount estimated using the NPCA recharge estimate of 50 mm/year.

In summary, the hydrographs for the surface water stations generally corroborate previous interpretations that flow within the Existing Watercourse occurs intermittently during precipitation or melt events. Some stagnant water is present within the Existing Watercourse throughout the year in areas which are mapped as wetlands by the NPCA. The estimated runoff coefficients vary between the different catchments, likely due to local ground surface topography and surficial soils.

2.4 GEOLOGY

The following description of the geology at the Site is based on recent data acquired during the baseline monitoring program completed by WSP augmented with data obtained during previous investigations completed for other sites.

2.4.1 OVERBURDEN

Study area overburden geology and thickness maps (depth to bedrock in metres) are provided on **Figures 4 and 5**, respectively. A simplified map of overburden thickness at the Site scale is provided on **Figure 5A**.

Regionally, the overburden largely consists of a relatively thick layer of poorly draining glaciolacustrine clayey silt to silty clay with a discontinuous lower basal till unit overlying the dolostone bedrock. Much of the City of Niagara Falls urban area to the northeast of the Site is underlain by sand and gravel overburden of glaciolacustrine origin. More recent alluvial deposits are present along the local watercourses including the Welland River to the south of the Site and Beaverdams Creek and tributaries. Significant areas of modern fill / spoil (i.e., anthropogenic deposits) related to the numerous large-scale historical excavations are present along the modern (and historic) Welland Canal, Queenston-Chippewa Power Canal, Mountain Road Landfill Site to the northeast and Brown Road Landfill Site to the south. Finally, the underlying Paleozoic bedrock is exposed within a narrow band along the Niagara Escarpment.

Overburden thickness in the study area was calculated using the available data from the Site and other studies noted above, as well as the MECP water well database. The bedrock surface was interpolated using GIS software, and then subtracted from the ground surface interpolated from the 2010 Digital Elevation Model (DEM) contours released by NPCA. In areas where the bedrock surface was interpolated above the ground surface, overburden thickness was assumed to be nil. This occurs not unexpectedly at the Walker Brothers Quarry north of the Site. It is noted that the interpolated overburden thickness shown on **Figure 5** is generally consistent with the overburden thickness mapping completed as part of the NPCA Source Protection report (NPCA, 2013).

In the study area, the glaciolacustrine clay plain slopes gently southward from the Niagara Escarpment towards the Welland River. South of the escarpment, the bedrock surface also dips to the south / southwest; as such, the overburden thickness generally increases as one moves south from the escarpment in the study area, from less than 1 m thick at the escarpment brow to nearly 25 m thick along the Welland River as shown on **Figure 5**. The exceptions include the meander valleys formed by the various watercourses present in the study area where erosion has reduced the overburden thickness to between 5 m to 10 m or less (less than 2 m observed in the Existing Watercourse at the north end of the Site). Conversely, the overburden thickness increases along the Niagara Falls moraine (shown on **Figure 3**) to over 15 m thick. Within the northern portion of the study area, the Vinemount Moraine (shown on **Figure 3**) does not notably rise above the surrounding ground elevation. Finally, there are localized increases in overburden thickness at the Mountain Road Landfill Site to the northeast, the Montrose Occurrence (excavation spoil) to the southeast and the Brown Road Landfill Site to the south.

2.4.2 BEDROCK GEOLOGY

2.4.2.1 REGIONAL SETTING

Study area bedrock geology and topography maps (masl) are provided on **Figures 6 and 7**, respectively. Regionally, the area is underlain by Ordovician and Silurian age shale, sandstone, limestone and dolostone. The Niagara Escarpment is the dominant bedrock feature in the area, with many bedrock outcrops along the escarpment brow where the overburden is thinnest. The Paleozoic aged bedrock is the subject of on-going research by the OGS. For example, the former members of the Lockport

Formation have been given formational status within the Lockport Group (Cramer et al, 2011). For this study, the naming convention follows that of the Paleozoic bedrock Map 2344 (Liberty et al, 1976) as it has been in long-term use at the existing Walker Brothers Quarry. The naming convention for bedrock stratigraphic units in this report are defined from youngest to oldest below.

Group (Age)	**Formation / Member**	**Description**
Salina Formation (Upper Silurian Age)		The Salina Formation consists of argillaceous dolostone and shale and abundant gypsum nodules. This formation subcrops south of the Site and is only present in the study area south of the Welland River. The Salina Formation is mined for gypsum elsewhere in southern Ontario but is not suitable for aggregate production and generally not considered a drinking water source due to water quality and quantity issues.
Lockport Group (Middle Silurian age)	**Guelph Formation**	The Guelph Formation is a hard, fresh, brownish-grey, vuggy, medium grained reefal dolostone with saccharoidal texture. The Guelph Formation has a gradational lower contact with the underlying Eramosa member and subcrops south of the Site. Due to the thickness of the overburden, there is relatively little information on the Guelph Formation in the study area and there is some uncertainty in the Paleozoic bedrock mapping. This formation was encountered in two boreholes during a previous drilling program conducted at the site (JHL, 2004). Like the Eramosa member, the Guelph Formation is also an excellent source of high-specification aggregate where it is extracted close to surface and is the primary bedrock aquifer for drinking water where it subcrops south of the Site.
	Lockport Formation -	
	Eramosa Member	The Eramosa member is a hard, fresh, brownish-grey medium grained dolostone with saccharoidal texture and a petroliferous odour when broken. It is thin to medium bedded and often blocky in appearance with occasional shale layers and rare styolites. Based on Site borehole data, the Eramosa member subcrops north of the Site, although historically has been interpreted to subcrop south of the Site (as shown in Paleozoic bedrock Map 2344). Published values in the literature suggest that the full unit thickness may be up to 10 m; however, thicknesses of 20 m were observed at the southern portion of the Site. The Eramosa member is an excellent source of high-specification aggregate, and where it subcrops, is the primary bedrock aquifer for drinking water.

Group (Age)	**Formation / Member**	**Description**
Lockport Group (cont'd) (Middle Silurian age)	**Goat Island Member**	The Goat Island member is a hard, fresh, grey to brown, fine-grained dolostone with a weak petroliferous odour when broken and can locally be up to 8 m thick. It is medium bedded and has occasional white chert and gypsum nodules. It is much harder than the underlying shales and sandstones and forms the cap rock of the Niagara Escarpment. The lower contact with the Gasport member is typically gradational. The Goat Island member is well suited for aggregate production, though high-specification use can be limited where abundant chert is present. The Goat Island member is the primary bedrock aquifer where it subcrops north of the Site.
	Gasport Member	The Gasport member is a hard to medium hard, fresh, grey to dark grey fine to medium grained fossiliferous dolostone with a saccharoidal texture and can locally be up to 14 m thick, although it is normally significantly thinner. The Gasport member is well suited for aggregate production, though typically not for concrete stone. On the Niagara Peninsula, the Gasport member is not particularly noted for drinking water since most wells are completed in shallower bedrock.
Clinton Group (Middle Silurian age)	**DeCew Formation**	The DeCew Formation is a medium hard, dark grey, fine-grained, fresh argillaceous dolostone with occasional shale partings and can locally be up to 4 m thick. This unit is normally not suitable for aggregate production nor as a drinking water source due to groundwater quality issues related to the underlying Rochester Formation shale. The proposed quarry excavation depth coincides with the interpolated top of the DeCew Formation.
	Rochester Formation	The Rochester Formation is a dark grey, dolomitic to calcareous shale, which frequently splits along bedding planes and can locally be up to 14 m thick. On the Niagara Peninsula, the Rochester shale is associated with the presence of naturally occurring hydrogen sulphide gas. This unit is not suitable for aggregate production nor as a drinking water source due to the sulphur nature of the groundwater. For this study, the Rochester Formation is considered a lower no-flow hydraulic boundary.

Group (Age)	**Formation / Member**	**Description**
Clinton Group (cont'd) (Middle Silurian age)	**Irondequoit Formation**	The limestone, dolostone and sandstone formations of the lower Clinton Group can collectively be up to 12 m in thickness. These units are not suited for aggregate production and are generally not used as a drinking water source within the study area owing to their depth below the Rochester shale.
	Reynales Formation	
	Thorold Formation	
Cataract Group (Lower Silurian Age)	**Grimsby Formation**	The red and grey sandstone and shale formations that form the Cataract Group can be over 30 m thick in some areas. Historically, the Grimsby and Whirlpool formation sandstones were quarried for building stone in Niagara Region; however, this group is generally not suitable for aggregate due to the limited exposure and depth of formation below other unsuitable units. The Cataract Group is also rarely used as a drinking water source due to the depth of formation, although one user is known to exist near the existing Walker Brothers Quarry below the escarpment.
	Cabot Head (Power Glen) Formation	
	Whirlpool Formation	
Queenston Formation (Upper Ordovician age)		The red shales of the Queenston Formation are the oldest and thickest bedrock in the study area and form the base of the Niagara Escarpment. This formation is not suitable for aggregate (with the exception of ceramic brick production below the escarpment) and is generally considered a poor source of drinking water owing to both quantity and quality issues.

Figure 6 illustrates the existing Paleozoic bedrock mapping with the interpolated contacts of the various bedrock units described in the above table. Based on bedrock coring completed for this study, the interpolated Eramosa member and Guelph Formation contacts appear to extend further north than the contacts shown on Paleozoic bedrock Map 2344 (Liberty et al, 1976) would suggest.

For this study, the bedrock surface has been interpolated using GIS software and the available data from the Site and other studies noted above, as well as the MECP water well database. The interpolated bedrock topography is shown on **Figure 7**. As expected, the bedrock surface generally dips from the escarpment (approximately 176 masl in the vicinity of the Walker Brothers Quarry) to the south (approximately 155 masl near the Brown Road Landfill Site) at a rate of approximately 0.2%. The bedrock topography shown on **Figure 7** suggests that local bedrock highs of approximately 180 masl are present to the east and west of the Site, with the Existing Watercourse running in the area between. An apparent bedrock high of approximately 182 masl to 184 masl is also present to the northeast of the Site near the QEW as shown on **Figure 7**. The locations of these topographic highs and the headwaters of the majority of surface watercourses in the study area suggest that bedrock topography likely played a role in the formation of the present-day watercourse meander valleys, despite the presence of a thick layer of overburden. It is noted that the Site-specific interpolated bedrock topography shown on **Figure 7** is generally consistent with the regional bedrock topography mapping completed as part of the NPCA Source Protection report (NPCA 2013).

Conceptual regional cross sections centred on the Site showing the topography, overburden thickness and bedrock strata are provided on **Figure 8** (North-South) and **Figure 9** (East-West). The cross section stratigraphic contacts are interpolated based on boreholes completed as part of this study and other studies listed at the outset of this section. A discussion of the regional groundwater flow is included in **Section 2.5.1**.

In summary, the bedrock surface is exposed along the Niagara Escarpment in the vicinity of the Walker Brothers Quarry. Overburden thickness decreases near Beaverdams Creek north of the Site near the inferred Eramosa / Goat Island member contact, as well as at the inferred local bedrock highs present to the east and west of the Site. The overburden is thickest south of the Site along the Niagara Falls moraine and within the Niagara Falls urban boundary east of the Site. The proposed quarry depth to the top of the DeCew Formation is shown on the cross sections on **Figures 8 and 9** for reference.

2.4.2.2 LOCAL SETTING

Bedrock was encountered at each deep borehole location completed during the drilling programs completed as part of this study. A summary of the stratigraphic contact information for each borehole is provided in **Table C-3**, **Appendix C**. Photos of the available rock core are provided in **Appendix C-3**. The Site-scale bedrock topography is shown on **Figure 10**, and the local topography, overburden thickness and bedrock strata are shown on cross sections A-A', B-B' and C-C', included as **Figures 11, 12 and 13**, respectively. The cross-section locations are shown on the Site Plan, **Figure 2**.

The bedrock strata encountered in the boreholes are described below from youngest (Lockport Formation, Eramosa member) to oldest (DeCew Formation).

Lockport Formation, Eramosa Member

The upper contact of the Eramosa member with the overburden ranges in depth from 1.2 mbgs (MW16-18) to 10.7 mbgs (MW16-8). The bedrock depth is generally shallowest in the vicinity of the Existing Watercourse and the two bedrock highs previously noted in **Section 2.4.2.1**. The Site scale bedrock topography (top of Eramosa member in masl) is shown on **Figure 10**. The top of the Eramosa member ranges in elevation from a high of 180.9 masl at MW17-21 west of the Site and 181.0 masl at MW17-20 east of the Site on the two bedrock highs, to a low of 170.9 masl at MW16-16 within the Existing Watercourse meander valley at the southern boundary of the Site.

The thickness of the Eramosa member is variable owing to the irregular upper erosional surface. At the Site, the thickness of the Eramosa member ranges between 17.4 m at MW16-8 in the southwest to 5.2 m at MW16-10 in the northwest.

Lockport Formation, Goat Island Member

The contact of the Goat Island member ranges in depth from 10.4 mbgs (MW16-6) to 28.0 mbgs (MW16-8). The stratigraphic contact data from the Site boreholes suggest that the contact of the Goat Island member dips to the southwest, ranging in elevation from 171.1 masl at MW16-6 in the northeast to 158.0 masl at MW16-8 in the southwest.

The thickness of the Goat Island member is variable across the Site, ranging from 16.3 m at MW17-20 in the east to 4.9 m at MW16-8 in the southwest.

Lockport Formation, Gasport Member

The top of the Gasport member ranges in depth from 19.3 mbgs (MW11-3R) to 36.3 mbgs (MW17-20). The stratigraphic contact data from the Site boreholes suggest that the contact of the Gasport member also dips to the southwest, ranging in elevation from 164.3 masl at MW11-3R in the northeast to 146.0 masl at MW16-8 in the southwest.

The thickness of the Gasport member is variable across the Site, ranging from 15.4 m at MW16-8 in the southwest to 8.7 m at MW16-10 in the northwest.

DeCew Formation

The contact of the DeCew Formation ranges in depth from 29.4 mbgs (MW11-3R) to 48.3 mbgs (MW16-8). The stratigraphic contact data from the Site boreholes suggest that the contact of the DeCew Formation also dips to the southwest, ranging in elevation from 149.2 masl at MW11-3R in the northeast to 136.5 masl at MW16-8 in the southwest.

Stratigraphic Interpolation

Planar bedrock contacts were interpolated for the various units encountered. Additional details of the interpolation may be found in **Appendix H**.

2.4.3 NATURAL GAS

Natural gas was observed during drilling in most deep boreholes completed for this study. These boreholes were advanced to the contact of the Gasport member and DeCew Formation. The gas manifested as a “bubbling” in the water column during drilling and groundwater sampling which dissipated quickly following well development / purging as the natural water level in the monitoring well exerts a hydrostatic pressure greater than the natural gas pressure at the well.

Naturally occurring gas seeps are common on the Niagara Peninsula, and have been observed from Albion Falls in the City of Hamilton to the west, to the community of Gasport in New York state to the east (for which the deep Lockport member is named). The seeps do not yield an economic quantity of gas due to their low rate of flow, and it is expected that over time, the natural gas pressure will likely dissipate as the proposed quarry footprint expands. Some existing quarries along this transect do report the presence of natural gas seeps but are not known to be safety concerns for quarry operations. Nonetheless, appropriate safety precautions will be taken for workers and structures as part of the proposed future operations at the Site.

During the excavation, precision blasting is used to minimize the propagation of enhanced fracturing of the bedrock beyond the Site boundary. As such, it is predicted that migration of gas from the deeper bedrock to the shallow bedrock aquifer will not occur as a result of the proposed quarry. In southern Ontario, there have been no known cases of gas migrating to drinking water wells in the vicinity of the numerous quarries which operate within similar bedrock stratigraphy as that of the Site.

2.5 HYDROGEOLOGY

2.5.1 REGIONAL GROUNDWATER SETTING

The regional groundwater setting is described in the Niagara Peninsula Source Protection Area Updated Assessment Report (NPCA, 2013) as summarized in the following table. A conceptual diagram is depicted in **Figure 2A**.

Hydrogeologic Unit		Description
Overburden	**Upper Aquitard**	Fine-textured glaciolacustrine clay and silt overburden deposits. At the Site, the water table occurs in the upper weathered zone of this aquitard and is monitored by the 'SP' series standpipes.
	Contact-Zone Aquifer	Discontinuous basal till layer that underlies the glaciolacustrine clay and silt and overlies the upper weathered bedrock. The contact aquifer is not continuous across the study area and generally does not occur along the Niagara Escarpment or below local watercourse meander valleys. This aquifer is considered to vary between confined and unconfined depending on the thickness of the overlying aquitard. At the Site, this aquifer is monitored by the 'OB' series monitoring wells.
Bedrock	**Shallow Bedrock Aquifer**	Shallow bedrock consisting of the Guelph Formation dolostone south of the Site, the Eramosa member dolostone at the Site and the Goat Island member dolostone north of the Site. This aquifer is continuous across the study area and varies between semi-confined to confined depending on the thickness of the overlying aquitard. At the Site, this aquifer is monitored by the 'B' series monitoring wells. Recent studies have demonstrated that the Eramosa member is subject to karstification in areas of bedrock outcrops and thin overburden (NPCA, 2013). Within the study area, this member is buried under a thick sequence of glaciolacustrine clays and tills. There is currently no evidence of karst features, such as large apertures or solution-enhanced fractures, based on the Site borehole data (refer to core photos provided in **Appendix C**).
	Deep Bedrock Aquifer	At the Site, consists of the Goat Island and Gasport dolostone members of the Lockport Group. This aquifer is confined and typically has a lower hydraulic conductivity compared to the shallow bedrock aquifer at the Site. There is interpreted to be no confining layer between the shallow and deep bedrock aquifers. At the Site, this aquifer is monitored by the 'A' series monitoring wells, except for three wells noted below.
	Lower Aquitard	DeCew Formation argillaceous dolostone and Rochester Formation shale bedrock units. At the Site, the lower aquitard is monitored at three 'A' series wells, MW11-1A, MW11-2A and MW11-4A.

The two principal aquifers within the study area from which groundwater users obtain their water supply are the contact-zone (contact) aquifer within the overburden and the shallow bedrock aquifer. A deep bedrock aquifer is also present but is generally not used for water supply purposes owing to adequate shallower aquifers.

Since the contact and shallow bedrock aquifers are typically confined and the water level rises above the top of the aquifer, the “water table” within these aquifers is referred to as a potentiometric surface. The potentiometric surfaces for the contact aquifer and the shallow bedrock aquifer are illustrated on **Figures 14 and 15**, respectively. The potentiometric surfaces shown in these figures were interpolated from high-quality Site monitoring well data and available water level data from representative overburden monitoring wells at additional sites. Lower-quality static water level data included in the MECP water well records were also incorporated. The MECP water well records were first parsed to remove wells with no associated static level and where the well location accuracy was unreliable (location code 6 to 9, or “lot centroid”).

Where available, autumn water level data were used for the monitoring wells. The static water levels for the MECP water well records are understood to have been obtained following well installation and represent a snapshot in time (which could occur at any time of the year, and the data for similar months could have been collected years apart).

Regionally, the water table is inferred to exist within the shallow clay and silt of the upper aquitard where the overburden is thicker, distinct from the underlying contact aquifer potentiometric surface. The contact aquifer includes the discontinuous basal till layer that overlies the upper weathered bedrock and may be unconfined or confined depending on the thickness of the overlying aquitard. In some locations within the local study area, such as along the Niagara Escarpment or below local watercourse meander valleys, the water table within the shallow soils of the upper aquitard is inferred to converge with the potentiometric surface of the contact aquifer (i.e., there is no significant vertical hydraulic gradient between the water table and the contact aquifer potentiometric surface). It is in these areas of convergence that the contact aquifer is interpreted as unconfined.

The relationship between the potentiometric surfaces of the contact aquifer and shallow bedrock aquifer is inferred to be variable based on the Site data. In some localized areas, there is a distinct separation between the two potentiometric surfaces with an inferred low hydraulic conductivity confining bed separating the two aquifers. In other areas, there is virtually no difference between the two potentiometric surfaces and the two aquifers are inferred to converge. Further discussion of Site-specific observations is provided below.

As shown on **Figure 14**, the study area potentiometric surface within the contact aquifer is generally highest along a line coincident with the QEW in Niagara Falls and along the axis of the Niagara Falls moraine. An inferred regional groundwater divide also occurs along the Niagara Falls moraine. Groundwater to the east / southeast of the contact aquifer groundwater divide flows towards the Niagara River and the Welland River. Groundwater to the northwest of the divide flows towards the Welland Canal and the Niagara Escarpment. Sub-regional groundwater divides are also inferred to be present west and east of the Site, coincident with the two bedrock highs identified on **Figure 10**. Groundwater flow between these two sub-regional divides is inferred to flow towards the Existing Watercourse meander valley. The interpolated potentiometric contours shown on **Figure 14** are typically a subtle reflection of the topography and are generally consistent with the potentiometric surface mapping completed as part of the NPCA Source Protection report (NPCA, 2013).

The shallow bedrock aquifer is continuous across the entire Niagara Peninsula, but the named bedrock formations which host the shallow bedrock aquifer differ across the study area from north to south due to the natural dip angle of the rock. At the Site, the shallow bedrock aquifer is composed of the Eramosa member dolostone. In the southern portion of the local study area, the shallow bedrock aquifer is composed of the Guelph formation, while to the north, it is composed of the Goat Island member. It is inferred to vary between confined and unconfined in the study area depending on the thickness and hydraulic conductivity of the overburden. As shown on **Figure 15**, the potentiometric contours within the shallow bedrock aquifer appear to be a subtle reflection of bedrock surface topography, as a local potentiometric high is mapped at the north end of the City of Niagara Falls urban area in the vicinity of the bedrock high mapped on **Figure 7**. A smaller localized potentiometric high also occurs southeast of the Site. Groundwater is inferred to flow radially away from these localized highs. The interpolated shallow bedrock aquifer potentiometric surface shown on **Figure 15** is generally consistent with potentiometric surface mapping completed as part of the NPCA Source Protection report (NPCA, 2013).

Within the shallow bedrock aquifer, interference with the groundwater potentiometric surface is introduced by the presence of the Welland Canal, which is completed into bedrock in the study area, as well as the permanent dewatering of the Townline Road tunnel under the canal in Welland, south of the Welland River. To the east, the Queenston-Chippewa Power Canal is completed into the Lockport Group bedrock and also drains the shallow bedrock aquifer, effectively acting as a long linear drainage feature. The power canal is lined over a portion of its depth, but a significant rock face is exposed such that interaction between the water in the canal and the shallow bedrock aquifer can be observed as seeps in the deep canal walls. In addition to the features noted above, there are four (4) known groundwater dewatering systems currently in operation which are inferred to have an influence on the potentiometric surface in the shallow bedrock aquifer, as outlined in **Section 2.5.4.4** below.

The deep bedrock aquifer consists of the deeper Gasport member dolostone. At the Site, the hydraulic conductivity of this unit is typically lower than that of the shallow bedrock aquifer, but higher than the lower aquitard. Within the vicinity of the Site, the deep bedrock aquifer is generally not utilized for water supply due to the presence of the shallow bedrock aquifer which provides adequate supply. Regional interpolation of the potentiometric surface for the deep bedrock aquifer was not presented due to the lack of water wells screened solely within this unit.

In addition to the inferred confining bed between the contact aquifer and shallow bedrock aquifer, there are two other aquitards within the study area: the fine-textured glaciolacustrine clay and silt overburden deposits (upper aquitard) and the DeCew / Rochester Formation bedrock units (lower aquitard). Flow within both aquitards is inferred to be primarily vertical, although minimal flux occurs due to the relatively low hydraulic conductivity of the aquitard material. For most of the study area, the water table is inferred to occur within the upper aquitard, and infiltration (groundwater recharge) to the contact and shallow bedrock aquifers is restricted. The lower aquitard restricts vertical flux of groundwater between the Lockport Group (i.e., the deep bedrock aquifer) and the lower Clinton Group bedrock formations, thereby acting as a base for active groundwater flow in the deep bedrock aquifer.

2.5.2 *LOCAL GROUNDWATER SETTING*

The overburden and bedrock units relevant to this study have been divided into five hydrostratigraphic units based on the regional groundwater setting interpretation above. Water level hydrographs are included in **Appendix E**. The water level data during the long-term pumping tests is not shown on the hydrographs in **Appendix E** to avoid attributing the drawdown observed during the tests to natural variability in the groundwater levels. Hydrograph data for the wells where drawdown was observed during the pumping tests are included in **Appendix D**. As noted in **Section 1.6.3**, various methods were used to perform the hydraulic conductivity testing at the Site. The description of the tests performed and their results is provided in **Appendix D**. An analysis of the test results and important observations from the hydraulic testing program are discussed below.

2.5.2.1 SHALLOW WEATHERED OVERBURDEN

The shallow weathered overburden generally consists of the weathered clayey silt soils of the upper aquitard to a depth of approximately 3 metres below ground surface (mbgs). There are five 'SP' series standpipes completed in the shallow weathered overburden at the Site.

Groundwater Elevations

The groundwater hydrographs for the five shallow weathered overburden standpipes are shown in **Figure E-10** (MW16-9SP), and **Figures E-21 through E-24** (MW17-20SP through MW17-23SP). Water level data are available starting in mid 2017.

Based on a comparison of the daily precipitation record and groundwater hydrographs for the 'SP' wells, there does not appear to be a significant response in water levels following individual precipitation events; however, all of the groundwater elevations within the standpipes show an increase during the late winter / spring freshet and a decrease during the summer months.

Vertical Hydraulic Gradients

Groundwater elevations from the 'SP' series standpipes are shown on **Figures 16 and 17** for comparison to the potentiometric surface within the contact aquifer for October 1, 2017 and May 1, 2018, respectively.

Near the wetland / woodlot feature east of the Site at MW17-20SP (**Figure E-21**, **Appendix E**), the water levels in the shallow weathered overburden are consistently 1 m to 2 m above levels in the contact aquifer, indicating that a downward vertical hydraulic gradient exists at this location. Further discussion of vertical hydraulic gradients is provided in **Section 2.5.3** below.

Near the woodlot feature west of the Site, the data from the shallow weathered overburden also display this seasonal pattern. North of this woodlot feature, the water levels in the shallow weathered overburden at MW16-9SP (**Figure E-10**) and MW17-23SP (**Figure E-24**) are consistently 1 m to 2 m above levels in the contact aquifer. South of the woodlot feature, the water levels in the shallow weathered overburden at MW17-21SP (**Figure E-22**) and MW17-22SP (**Figure E-23**) are similar to levels in the contact aquifer except during the summer and autumn when the water levels within the shallow weathered overburden are 1 m to 2 m above levels in the contact aquifer. These data indicate that there is a consistently strong downward vertical hydraulic gradient north of the woodlot feature in the area of low bedrock topography, and a seasonal downward hydraulic gradient south of the woodlot feature in the area of high bedrock topography. South of the woodlot feature, an upward hydraulic gradient occurs during the winter months when the groundwater levels within the contact aquifer show a greater increase than those of the shallow weathered overburden.

Hydraulic Properties

Single well response tests were completed at these standpipes to assess the horizontal hydraulic conductivity in this unit, which ranged between 10^{-8} centimetres/second (cm/s) to 10^{-7} cm/s, with a geometric mean of $5x10^{-8}$ cm/s (refer to **Appendix D.3**). These test results are consistent with the range of published values for weathered clayey silt soils and are likely lower for the underlying unweathered clayey silt. As an overall unit, the overburden is considered a confining aquitard based on the low hydraulic conductivity range relative to the underlying hydrogeological units present at the Site. In areas where the interpolated overburden thickness is less than 2 m (within the Existing Watercourse meander valley in the north portion of the Site and Beaverdams Creek / Welland Canal South Turn Basin reservoir to the north / northwest of the Site as shown on **Figure 5A**), the weathered portion of the overburden directly overlies the bedrock, and the contact and shallow bedrock aquifers are considered to be semi-confined to unconfined in these areas, with little resistance to vertical groundwater movement.

Permeameter tests were also completed in the shallow topsoil (up to 0.3 mbgs) at seven locations across the Site to assess the vertical hydraulic conductivity / anisotropy (refer to **Appendix D.6**). The hydraulic conductivity values ranged between $6x10^{-7}$ cm/s to $1x10^{-5}$ cm/s. These permeameter test results are one to two orders of magnitude above the geometric mean horizontal hydraulic conductivity noted above, which yields an anisotropy (ratio of vertical to horizontal hydraulic conductivity, i.e., K_V/K_H) of greater than ten. As noted above, the permeameter tests were completed to a depth of 0.3 m; therefore, the notably high anisotropy ratio is likely due to higher horizontal hydraulic conductivity within the top 0.3 m of overburden, likely a result of agricultural activities at the Site and a greater degree of weathering. Within the underlying unweathered clayey silt, the vertical hydraulic conductivities are typically lower in similar settings, with an anisotropy of less than 0.1.

2.5.2.2 CONTACT AQUIFER

The contact aquifer consists of the inferred intermittent basal till deposit present in localized areas overlying the bedrock. There are twenty-three 'OB' series wells which are interpreted to be completed into this hydrostratigraphic unit at the Site.

Groundwater Elevations

The groundwater hydrographs for the contact aquifer wells are shown on **Figures E-2 through E-24** (MW11-1OB through MW17-23OB). Water level data is typically available starting in winter 2016, although some wells have data starting in 2012.

There appears to be a muted response to precipitation events, with a change on the order of 0.5 m to 1.0 m during some precipitation events. In addition, most of the wells exhibit a seasonal variation on the order of 1 m to 3 m between the spring and late summer. Both of these patterns indicate greater variations than observed for the shallow weathered overburden and suggest that recharge of the contact aquifer is not only related to infiltration through the overlying upper aquitard, but also lateral groundwater flows from further afield. The interpolated potentiometric contours and groundwater flow directions shown on **Figure 14** suggest that there is likely a regionally significant groundwater recharge area occurring in the northeast / east of the study area. Along the meander valley at MW16-16 in the south to MW16-19 in the north, the seasonal variation is less, at about 1 m to 1.5 m.

The potentiometric surface for the contact aquifer on October 1, 2017, and May 1, 2018, is shown on **Figures 16 and 17**, respectively. The seasonality of the water table between the late autumn and spring is notable; most May water table elevations are 1 m to 2 m above the October elevations. The inferred groundwater flow direction in the contact aquifer is a subtle reflection of the ground surface topography, with flow from the elevated areas east and west of the Site towards the Existing Watercourse meander valley. Although the overall potentiometric surface elevation fluctuates seasonally, this flow pattern appears to be consistent throughout the year.

Vertical Hydraulic Gradients

Downward vertical hydraulic gradients to the shallow bedrock aquifer are observed at most of the wells screened in the contact aquifer and within the Existing Watercourse meander valley south of Upper's Lane. The distinct separation between the potentiometric surfaces within the contact and shallow bedrock aquifers suggests the presence of a low hydraulic conductivity confining bed separating the two aquifers across most of the Site. Stronger downward vertical hydraulic gradients are observed west of the Site at MW11-4OB, MW16-8OB, MW16-10OB, MW16-13OB, MW17-21OB, MW17-22OB and MW17-23OB. Conversely, predominantly upward hydraulic gradients are only observed within the Existing Watercourse meander valley at MW16-18OB and MW16-19OB north of Upper's Lane.

At well nests MW11-3 and MW17-20 situated east of the Site, the groundwater elevations in the contact and shallow bedrock aquifers are similar throughout the year, which suggests that the inferred confining bed is locally absent and the two aquifers are hydraulically connected at these locations. Further discussion of the hydraulic gradients observed at well nest MW17-20 is provided in **Section 2.5.3** below.

Stage elevations from the surface water stations are shown on **Figures 16 and 17** for comparison to the potentiometric surface within the contact aquifer. Most surface water stations were dry during the October 2017 event which suggests minimal groundwater / surface water interaction during the late summer / autumn. In May 2018, the surface water stage in the Existing Watercourse meander valley is consistently below the adjacent groundwater elevation within the contact aquifer, which suggests that groundwater discharge to the creek likely occurs during the late winter / spring freshet. This interpretation is consistent with the observed upward vertical hydraulic gradients in the meander valley north of Upper's Lane as discussed above. It is inferred that regardless of season, groundwater within the local contact aquifer ultimately discharges to Beaverdams Creek, which consistently has the lowest stage elevation within the Site vicinity.

Hydraulic Properties

Single well response tests were completed at selected contact aquifer wells to assess the horizontal hydraulic conductivity in this unit. Values ranged between 10^{-7} cm/s to 10^{-4} cm/s, with a geometric mean of 5×10^{-6} cm/s (refer to **Appendix D.3**). Tests could not be conducted at five 'OB' series well due to dry conditions. The test results are consistent with the range of published values for till soils with varying amounts of sand and gravel. The contact aquifer geometric mean horizontal hydraulic conductivity is higher than that of the shallow weathered overburden, but generally lower than that of the shallow bedrock aquifer, the most productive aquifer within the study area. The discontinuous nature of the basal till at the bedrock contact limits the use of this unit as a regional drinking water supply aquifer, as noted in the NPCA Source Protection study (NPCA, 2013).

During the long-term constant rate pumping tests in 2017 and 2019, drawdown was observed at contact aquifer wells MW16-9OB and MW17-23OB west of the Site near the un-named woodlot and MW16-7OB at the southern boundary of the Site. As noted previously, the observations from the early winter 2017 pumping test prompted the installation of additional contact aquifer and shallow bedrock aquifer wells during the supplemental drilling program completed in spring 2017. To confirm the degree of vertical hydraulic connection between the shallow weathered overburden, contact aquifer and the shallow bedrock aquifer, short-duration pumping tests were completed at five well nest locations (refer to **Appendix D.5**). Four of these tests west of the Site were conducted in the vicinity of the un-named woodlot (MW16-9 and MW17-21 to MW17-23) and one test east of the Site was conducted in the vicinity of the mapped wetland / woodlot feature (MW17-20).

These short-term pumping test results confirm that there is no observable vertical hydraulic connection between the shallow bedrock aquifer and the contact aquifer at locations MW16-9 and MW17-23 near the un-named woodlot west of the Site. Therefore, the observed responses to the PW1 pumping tests at contact aquifer wells MW16-9OB and MW17-23OB are inferred to be the result of a combination of lateral and vertical groundwater flow elsewhere between the contact aquifer and the shallow bedrock aquifer.

Furthermore, the short-term pumping test results established that the unweathered clayey silt of the upper aquitard acts as a confining layer such that drawdown within the contact or shallow bedrock aquifers does not translate to the upper 3 m of shallow weathered overburden at either the wetland / woodlot to the east of the Site or the woodlot to the west of the Site. Therefore, due to the lack of vertical hydraulic connection, these natural features are not anticipated to be impacted by future drawdown as a result of the proposed quarry dewatering.

2.5.2.3 SHALLOW BEDROCK AQUIFER

Near the Site, the shallow bedrock aquifer consists of the Eramosa member dolostone of the Lockport Formation. There are eighteen ‘B’ series wells which are completed into this hydrostratigraphic unit at the Site. Most of these wells are screened near the base of the Eramosa member or at the contact with the underlying Goat Island member.

<u>Groundwater Elevations</u>

The groundwater hydrographs for the shallow bedrock aquifer wells are shown on **Figures E-1 through E-24** (MW11-1B through MW17-23B). Water level data are typically available starting in winter 2016, although some wells have data starting in 2012.

The response to precipitation events is muted in the shallow bedrock aquifer in comparison with the contact aquifer. Most of the wells exhibit seasonal variation on the order of 1 m to 2 m between the spring and late summer. Less variation is observed within the Existing Watercourse meander valley north of Upper’s Lane at MW16-18B and MW16-19B, on the order of 0.5 m between spring and late summer.

The shallow bedrock aquifer potentiometric surface on October 1, 2017, and May 1, 2018, is shown on **Figures 18 and 19**, respectively. Closer to the northern Site boundary, seasonality does not have as dramatic effect on the potentiometric surface in the shallow bedrock aquifer. However, a seasonal difference of 1 m to 2 m is observed southwest and southeast of the Site near the bedrock highs. The inferred flow direction in the shallow bedrock aquifer is a subtle reflection of the bedrock topography, with flow from the bedrock highs east and west of the Site towards the Existing Watercourse meander valley. Like the contact aquifer, this flow pattern is observed throughout the year and is not affected by the seasonal potentiometric surface fluctuations.

Vertical Hydraulic Gradients

Upward vertical hydraulic gradients between the deep and shallow bedrock aquifers are observed at BH03-2 (A to B), MW11-1 (A to B), MW11-2 (A to B), MW11-3R (A to B), MW11-4 (A to B) and MW16-5 (A to B). Downward hydraulic gradients are observed at MW16-6 (B to A), MW16-9 (B to A), MW16-13 (B to A) and MW17-20 (B to A). Weak vertical hydraulic gradients are observed at MW16-7 (B to A). Deep bedrock aquifer groundwater elevations were not at static conditions to establish vertical hydraulic gradients at MW16-6, MW16-8, MW16-9, MW16-10 and MW16-13. It is apparent from these observations that there is a downward hydraulic gradient through the bedrock where the bedrock high occurs to the west of the Site and where the groundwater elevations within the shallow bedrock aquifer are highest near MW17-20 to the east of the Site. Upward hydraulic gradients occur elsewhere below the Site.

The reservoir stage elevation at DP1 in Beaverdams Creek northwest of the Site is shown on **Figures 18 and 19** for comparison to the potentiometric surface in the shallow bedrock aquifer. It is inferred that groundwater within the shallow bedrock aquifer ultimately discharges to the Beaverdams Creek and turn basin reservoir, which consistently has the lowest stage elevation within the Site vicinity. Similar to the contact aquifer, groundwater from the shallow bedrock aquifer is also inferred to discharge to the meander valley of the Existing Watercourse north of Upper's Lane due to the presence of upward gradients at MW16-18 and MW16-19. The exception is the late autumn when the potentiometric surface is seasonally lowest. The baseline calibrated numerical groundwater model suggests that groundwater discharges to the Beaverdams Creek and turn basin reservoir at a rate of approximately 300 m^3/day (3.5 L/s) (refer to **Section H.6**, **Appendix H** for a discussion of the baseline calibrated model water balance).

Hydraulic Properties

The packer test results completed during the advancement of selected deep boreholes indicate that the most hydraulically conductive hydrostratigraphic unit at the Site is the shallow bedrock aquifer (refer to **Appendix D.2**). From a conceptual standpoint, it is expected that the hydraulic conductivity of the Eramosa member bedrock underlying the Guelph Formation south of the Site is lower in comparison with the Eramosa member bedrock that subcrops at the Site due to enhanced weathering of the exposed bedrock surface.

Single well response tests were completed at selected shallow bedrock aquifer wells to assess the horizontal hydraulic conductivity of this unit, which ranged between about 10^{-5} cm/s to 10^{-2} cm/s, with a geometric mean of $2x10^{-4}$ cm/s (refer to **Appendix D.3**). These test results are similar to the published range for sound limestone / dolomite (Domenico & Schwartz, 1998).

During the long-term constant rate pumping tests conducted at PW1 in 2017 and 2019 (location shown on the Site Plan, **Figure 2**), a drawdown of nearly 6 m was induced in the pumping well (refer to **Appendix D.4 and D.7**). Drawdown was observed at most shallow bedrock aquifer wells up to 1.5 km away from the pumping well. The drawdown cone extended below the Existing Watercourse to the east but was not observed to extend beyond Beaverdams Creek to the north of the Site. The rapid recovery of the groundwater elevation at the pumping well and observation wells is notable, particularly at the more distant monitoring wells. The analysis of the step test results for PW1 suggests that non-linear head losses due to turbulent flow in the aquifer and / or pumping well are substantial, which lowers the overall well efficiency, estimated to be on the order of 30% for the duration of the pumping tests.

In 2019, an additional long-term constant rate pumping test was also completed in the northeast portion of the Site at the 5205 Beechwood private supply well (designated **R9**, shown on the Site Plan, **Figure 2**). The sustained pumping rate from this well was 15 Litres/minute (L/min), much lower than the observed rates of 573 L/min and 750 L/min for the two tests at PW1. The resulting maximum drawdown at the 5205 Beechwood residential well was approximately 3.2 m (compared to nearly 6 m at PW1). As a result, the radius of influence from this test was much lower than observed for the PW1 tests, and only extended to about 400 m from **R9**. It is inferred that this well is completed within the upper 2 m to 3 m of the shallow bedrock aquifer based on field depth measurements (i.e., the well is only partially open across the shallow bedrock aquifer).

Several analyses were completed on the pumping test results, utilizing various aquifer models, as described in **Appendix D.4**. A bulk transmissivity of 50 m^2/day is adopted for the shallow bedrock aquifer based on the pumping test results at PW1. Zones of enhanced hydraulic conductivity were interpreted to surround PW1 and likely within the Existing Watercourse meander valley north of Upper's Lane. Assuming an average shallow bedrock aquifer thickness of 17.4 m, the hydraulic conductivity is calculated as 2.9 metres/day (m/day) ($3.4x10^{-3}$ cm/s). A storage coefficient of $1x10^{-5}$ is also adopted. These hydrogeological properties are similar to the range of published values for fractured dolostone bedrock (Domenico & Schwartz, 1998).

2.5.2.4 DEEP BEDROCK AQUIFER

At the Site, the deep bedrock aquifer consists of the Gasport member of the Lockport Formation. A total of ten (10) 'A' series Site monitoring wells are screened across the lower portion of the Gasport member.

Groundwater Elevations

The groundwater hydrographs for the deep bedrock aquifer wells are shown on **Figures E-1, E-4, E-6 through E-11, E-14 and E-21**. Water level data are typically available starting in winter 2016.

The majority of the deep bedrock aquifer wells show no response to precipitation events. Long recovery periods of a year or more following sampling are observed at most wells. Following the April 2018 sampling event, groundwater levels in most deep bedrock aquifer wells appear to have stabilized to static conditions and indicate a muted response to seasonal fluctuations observed in the overlying hydrostratigraphic units. Slow water level recovery at MW16-9A, MW16-10A and MW16-13A inhibits specific interpretation with the available data set.

At MW16-7A, the initial water levels and recovery time were similar to the other deep bedrock aquifer wells. However, since approximately mid-June 2017, the water levels in the deep bedrock aquifer well have been virtually identical to those of the shallow bedrock aquifer well and the rapid water level recovery after sampling in April 2018 indicates an influence from a more hydraulically conductive zone than expected for the well depth. As such, the integrity of the well seal is suspect at this location. Further monitoring of MW16-7A will be completed. It is noted that during the 2019 pumping test at PW1, drawdown was observed at MW16-7A; however, during the 2017 test, no drawdown was observed at this well.

The deep bedrock aquifer potentiometric elevations on October 1, 2017, and May 1, 2018, are shown on **Figures 20 and 21**, respectively. As shown on the figures, there is a variance of up to 30 m between the potentiometric elevations in this unit as a result of the low recovery rates of some deep bedrock aquifer wells following well installation and purging / sampling. As such, potentiometric contouring was not completed and the groundwater flow pattern within the deep bedrock aquifer was not established.

It should be noted that the shallow bedrock aquifer is the most conductive stratigraphic unit within the study area, and most private bedrock supply wells are interpreted to be screened in this unit in the vicinity of the Site. Potential effects from future quarry dewatering should propagate to a larger radius within the shallow bedrock aquifer as compared to the deep bedrock aquifer. The deep bedrock aquifer, while impacted, has significantly fewer groundwater users and the quarry dewatering effects are predicted to propagate at a much smaller radius from the future quarry excavation due to the lower hydraulic conductivity of this unit.

<u>Hydraulic Properties</u>

Single well response tests were completed at four of the deep bedrock aquifer wells. The horizontal hydraulic conductivity ranges between 10^{-8} cm/s and 10^{-6} cm/s, with a geometric mean of 2×10^{-7} cm/s (refer to **Appendix D.3**). These test results are at the lower end of the range of published values for limestone / dolostone bedrock (Domenico & Schwartz, 1998).

During the winter 2017 long-term constant rate pumping test at PW1, drawdown was observed within the deep bedrock aquifer only at well MW16-5A at the northern boundary of the Site. It was suspected that the well seal may not have set correctly during installation. As such, replacement well MW16-5AR was installed during the supplemental drilling program in spring 2017 near MW16-5A. MW16-5A was not decommissioned in order to observe and compare the water levels and groundwater chemistry from the two wells. The groundwater hydrographs on **Figure E-6** show a consistent difference in water levels of approximately 4 m between the two wells. However, as shown in **Table F-1**, the geochemical signature of groundwater samples collected from these two wells in March 2018 is nearly indistinguishable. During the 2019 pumping test at PW1, drawdown was again observed in MW16-5A as well as replacement well MW16-5AR. From these results, it is concluded that the drawdown observed during the pumping tests in the deeper bedrock at nest MW16-5 is indeed representative of in-situ conditions. Packer testing completed at MW16-5A during monitoring well installation indicates that the relative hydraulic conductivities of the deeper Goat Island / Gasport member bedrock at this well are one to two orders of magnitude greater in comparison to the other three deep wells where packer testing was conducted. As such, there is likely a higher degree of hydraulic connectivity between the shallow and deep bedrock aquifers at nest MW16-5.

2.5.2.5 LOWER AQUITARD

The DeCew / Rochester Formations form a lower aquitard that is inferred to act as a lower no-flow boundary for the study area; that is, as a base for the Guelph Formation / Lockport Group groundwater flow system. There are two existing wells (MW11-2A and MW11-4A) and one decommissioned well (MW11-3A) completed into these lower bedrock units at the Site. Monitoring well MW11-1A is screened across the DeCew Formation, but not the Rochester Formation. These wells were all completed by others in 2011 / 2012 before the current study. Electronic data loggers were installed in these wells shortly after installation, and as a result a larger water level data set is available, as shown in the hydrographs in **Appendix E**.

Groundwater Elevations

The groundwater hydrographs for the lower aquitard wells are shown on **Figures E-2, E-3, and E-5**. Water level data is available starting in 2012.

Like the deep bedrock aquifer, the lower aquitard wells show no response to precipitation events and no seasonal fluctuation. Long recovery periods of approximately 1 to 3 years are observed following the well installations in 2012. Following sampling completed as part of the current study, recovery periods of 6 months to over a year are observed.

Based on static groundwater elevations, it is interpreted that upward hydraulic gradients from the aquitard into the overlying deep bedrock aquifer occur at each of the three well locations.

Hydraulic Properties

The hydrographs for these aquitard wells all suggest a long recovery period of approximately three years following initial drilling. Similar rates of recovery are observed for wells screened in the Rochester Formation at the Walker Brothers Quarry north of the Site, which provides confidence that these water levels are representative of a "tight" aquitard in which there is minimal groundwater flow occurring. Single well response test analyses completed on the post-installation water level data yield horizontal hydraulic conductivity values ranging between $2x10^{-10}$ cm/s to $4x10^{-10}$ cm/s, with a geometric mean of $3x10^{-10}$ cm/s (refer to **Appendix D.3**). These results are at the lower end of the range of published values for shale bedrock (Domenico & Schwartz, 1998).

2.5.3 GROUNDWATER / SURFACE WATER INTERACTION

The purpose of this section is to quantify the degree of groundwater and surface water interaction within the local study area. The primary factor that determines the rate of groundwater flow between two areas is the hydraulic conductivity of the intervening material. Where the material has a high hydraulic conductivity, the flow is high. Conversely, where lower hydraulic conductivity material is present, flow still occurs, but at a lower rate.

At the Site, the un-weathered portion of the upper aquitard (i.e., a low hydraulic conductivity layer of material) restricts flow between surface water features above and the contact aquifer and the shallow bedrock aquifer below. As a result, surface water features within the local study area that are underlain with a thick layer of clay and silt overburden are not predicted to be negatively impacted by the proposed quarry dewatering. Site observation data discussed below confirm that minimal groundwater and surface water interaction is occurring.

The flow per unit area (q) through the upper aquitard can be calculated for the surface water features in the local study area using Darcy's Law, as shown in **Equation [1]** below.

$$q = K_V \cdot \frac{(h_{stage} - h_{con})}{T} \quad \text{......} \quad \textbf{[1]}$$

In **Equation [1]**, K_V is the vertical hydraulic conductivity of the upper aquitard, h_{stage} is the water stage elevation at surface, h_{con} is the groundwater elevation in the aquifer and T is the thickness of the upper aquitard.

When the calculated flow is negative, there is an upward hydraulic gradient and groundwater discharge is occurring to the surface. When the calculated flow is positive, there is a downward hydraulic gradient and groundwater recharge to the aquifer is occurring.

For the calculations below, the geometric mean conductivity value from the response tests completed in the shallow weathered overburden is used to represent the upper aquitard vertical hydraulic conductivity.

Baseline water level data from 2017 and 2018 are used in the calculations below. The annual precipitation amounts for both years fall outside of one standard deviation of the historical average annual precipitation. Water level data from these “very wet” and “very dry” years therefore represents two extremes which could potentially be experienced during the operational phase of the proposed quarry.

2.5.3.1 EXISTING WATERCOURSE AND ASSOCIATED WETLAND COMPLEX

The amount of discharge / recharge along the Existing Watercourse can be calculated at four well nests within the Site boundary, as shown on **Figure 2** (from south to north): MW16-16, MW16-17, MW16-18 and MW16-19. Upstream at MW16-16, hydrographs are available for the contact aquifer (**Figure E-17**) and the stage elevation in the Existing Watercourse at surface water station DP3 (**Figure E-35**). At intermediate location MW16-17, a hydrograph is only available for the contact aquifer (**Figure E-18**), while at MW16-18, hydrographs are available for both the contact and shallow bedrock aquifers (**Figure E-19**). Downstream at MW16-19, groundwater hydrographs are available for both the contact and shallow bedrock aquifers (**Figure E-20**) and the stage elevation in the Existing Watercourse at surface water station DP2 (**Figure E-34**). On the groundwater hydrographs noted above, both the ground surface and nearby creek bed elevations are shown for reference. The thickness of the upper aquitard is estimated from the borehole logs included in **Appendix C-1**.

MW16-16 / DP3

At the upstream portion of the Existing Watercourse within the Site boundary, the groundwater elevation within the contact aquifer at MW16-16 is typically elevated above the creek bed in the spring and late autumn / winter months. During 2017 (a ‘very wet’ year), the groundwater elevation remained above the creek bed for the summer; conversely, during 2018 (a ‘very dry’ year), the groundwater elevation was below the creek bed, which is not unexpected. The creek stage elevations at DP3 indicate that the creek stage is typically 0.1 m to 0.2 m above the creek bed during spring and late autumn / winter months, but dry conditions are common during the summer (especially during the dry year in 2018) when the groundwater level at DP3 is below the base of the watercourse, which is consistent with the contact aquifer hydrograph for MW16-16. These observations show that an upward vertical gradient between the contact aquifer and the Existing Watercourse exists at MW16-16 / DP3 near the south end of the Site, except for the summer months when an upward hydraulic gradient occurs.

To provide an estimate of groundwater discharge during spring conditions, a stage elevation equal to the creek bed elevation of 177.7 masl is used; while a groundwater elevation of 178.7 masl is used, equivalent to the maximum groundwater elevation observed during spring conditions between 2017 and 2018. The thickness of the upper aquitard is 7.2 m based on the borehole log for MW16-16.

Using these values with **Equation [1]**, the estimate of groundwater discharge as baseflow to the Existing Watercourse at MW16-16 during the baseline monitoring period during the spring is 2 mm/year. The distance between upstream station SW3 and MW16-16 is about 750 m. Assuming a similar discharge rate along this reach and an average meander valley width of 20 m yields a groundwater discharge of less than 0.1 L/s. Baseflow from groundwater discharge is therefore a small component of flow relative to the average spring flow rates of about 300 L/s at upstream station SW3.

MW16-17

About 850 m downstream at MW16-17, the groundwater elevation within the contact aquifer at MW16-17 is only elevated above the creek bed during the spring and late autumn / winter months during both 2017 and 2018 (wet and dry years). These observations show that an upward vertical gradient exists between the contact aquifer and the Existing Watercourse at MW16-17 with the exception of the summer months, similar to upstream conditions.

A stage elevation equal to the creek bed elevation of approximately 177.0 masl is used, while a groundwater elevation of 177.6 masl is used (the maximum water table elevation during spring conditions between 2017 and 2018). The thickness of the upper aquitard is 5.7 m based on the borehole log for MW16-17.

Using these values with **Equation [1]**, the estimate for groundwater discharge to the Existing Watercourse at MW16-17 during the baseline monitoring period during the spring is 2 mm/year. Assuming a similar discharge rate along this reach and an average meander valley width of 20 m yields a groundwater discharge of less than 0.1 L/s. As noted previously, this is a small amount when compared to average spring flow rates at upstream station SW3.

MW16-18

A further 1,250 m downstream at MW16-18, both the groundwater elevations within the contact aquifer and shallow bedrock aquifer at MW16-18 are elevated above the creek bed during the spring and late autumn / winter months. During 2017 (wet year), groundwater elevations in both aquifers typically remained above the creek bed; however, during 2018 (dry year), both were below the creek bed. These observations show that an upward vertical gradient between the contact and shallow bedrock aquifers and the Existing Watercourse exists for the entire year, except during drier years.

A stage elevation equal to the creek bed elevation of approximately 176.0 masl is used. The maximum groundwater elevation during the baseline period of 176.8 masl is used in the calculation to provide a conservative estimate. The thickness of the upper aquitard is 1.3 m based on the borehole log for MW16-18B.

Using these values with **Equation [1]**, the estimate for groundwater discharge to the Existing Watercourse at MW16-18 during the baseline monitoring period during the spring is 10 mm/year. Assuming a similar discharge rate along this reach and an average meander valley width of 20 m yields a groundwater discharge of less than 0.1 L/s. As noted previously, this is a small amount when compared to average spring flow rates at upstream station SW3.

MW16-19 / DP2

At the downstream portion of the Existing Watercourse within the Site boundary, both the contact and shallow bedrock aquifer groundwater elevations at MW16-19 are consistently elevated above the creek bed regardless of the season or annual precipitation amount. The stage elevations at DP2 indicate that conditions within the watercourse vary between inundated and dry in close correlation with recent precipitation events; the watercourse is inundated shortly after the precipitation event, but the surface water flow typically dissipates within a period of one day. This pattern appears throughout the year and is not restricted to spring or late autumn / winter months nor does it appear to depend on annual precipitation amount, although maximum stage elevations during the summer of 2018 (dry year) were typically lower than those of 2017 (wet year). These observations show that an upward vertical gradient between the contact and shallow bedrock aquifers and the Existing Watercourse exists for the entire year, regardless of the annual precipitation amount.

To calculate discharge, a stage elevation equal to the creek bed elevation of approximately 175.1 masl may be used. The maximum groundwater elevation during the baseline period of 176.7 masl was used in the calculation. The thickness of the upper aquitard is 1.2 m based on the borehole log for MW16-19B.

Using these values with **Equation [1]**, the estimate for groundwater discharge to the Existing Watercourse at MW16-19 during the baseline monitoring period during the spring is 21 mm/year. Assuming a similar discharge rate along this reach and an average meander valley width of 20 m yields a groundwater discharge of less than 0.1 L/s. As noted previously, this is a small amount when compared to average spring flow rates at upstream station SW3.

Summary

The baseline water level data indicate that there is minimal groundwater discharge to the Existing Watercourse that occurs within the Site boundaries. The exception is north of the Upper's Lane where the upper aquitard is thinner. North of Upper's Lane, groundwater discharge to the watercourse is conservatively estimated to range between 10 mm/year and 21 mm/year for the baseline monitoring period, with discharge generally occurring year-round. However, groundwater discharge to the Existing Watercourse is equivalent to less than 0.1 L/s during the spring, a small amount compared to the average spring flow rates at upstream station SW3. The area of continual groundwater discharge to the Existing Watercourse is highlighted on the baseline potentiometric surface maps for the contact and shallow bedrock aquifers, **Figures 16 through 19**.

2.5.3.2 BEAVERDAMS CREEK AND ASSOCIATED WETLAND COMPLEX

The amount of discharge / recharge along Beaverdams Creek can be calculated at two surface water stations north of the Site, as shown on **Figure 3A**. Station SW1 is situated upstream where the creek flows through a culvert under Beechwood Road, and station DP1 is situated downstream within the Welland Canal South Turn Basin reservoir. Hydrographs are available for both stations (**Figures E-26 and E-33**). There are no monitoring wells completed within the vicinity of either surface water station. As shown on **Figure 2**, the private supply well at 9602 Beaverdams Road (designated **R7**) is situated approximately 60 m northeast of station SW1. Monitoring of this well began in February 2019; available water level data is shown in the hydrograph on **Figure E-46**. The private supply wells at 4680 Townline Road (**R6**) and 1024 Beaverdams Road (**R1**) are situated 150 m north and 200 m northeast of station DP1, respectively (their locations are not shown on **Figure 2** as they are just north of the plot extent). Monitoring of **R1** began in September 2018 while monitoring of **R6** began in February 2019; the water level data is shown in the hydrographs on **Figures E-40 and E-45**. Private wells **R1** and **R7** are drilled bedrock wells interpreted to be screened at least partially into the shallow bedrock aquifer; private well **R6** is a historic dug well interpreted to be completed to the top of bedrock and hydraulically connected to the contact aquifer. The thickness of the upper aquitard is estimated from the overburden thickness mapping on **Figure 5A** and MECP well record 7278404 for **R1**.

A tributary of Beaverdams Creek (separate from the Existing Watercourse) is also present in the northeastern portion of the Site. Upstream at MW16-6, hydrographs are available for both the contact and shallow bedrock aquifers (**Figure E-7**) and the stage elevation in the tributary of Beaverdams Creek at surface water station SW2 (**Figure E-28**). Downstream, groundwater hydrographs are available for both the contact and shallow bedrock aquifers at MW11-3R (**Figure E-4**) and the stage elevation in the tributary of Beaverdams Creek at surface water station DP5 (**Figure E-37**). It is noted that well nest MW11-3R is situated approximately 100 m east of the tributary and DP5 but is the closest monitoring well nest. On the groundwater hydrographs noted above, both the ground surface and nearby creek bed elevations are shown for reference. The thickness of the upper aquitard is estimated from the borehole logs included in **Appendix C-1**.

SW1 / R7

At the upstream portion of the main channel of Beaverdams Creek northeast of the Site, the groundwater elevation within the shallow bedrock aquifer at **R7** was approximately 177.5 masl in the early spring of 2019. This elevation is approximately 2 m above the creek bed at SW1 and about 2.4 m above the groundwater elevation within the shallow soil below the creek. The creek stage elevations at SW1 indicate that conditions within the creek vary between inundated and dry in close correlation with recent precipitation events; the creek is inundated shortly after the precipitation event, but the surface water typically dissipates within about a day. During 2017 (wet year), the stage in the creek remained above the creek bed for much of the winter / spring; however, flow was only observed following precipitation events. The creek water level data show that an upward hydraulic gradient between the shallow bedrock aquifer and Beaverdams Creek exists at SW1 northeast of the Site based on the groundwater elevations at the nearest bedrock well (**R7**) that are higher than groundwater elevations below the creek.

A stage elevation equal to the creek bed elevation of 175.3 masl is used; a groundwater elevation of 177.5 masl is inferred based on the data from **R7**. The thickness of the upper aquitard is estimated to be approximately 4 m based on the overburden thickness map in **Figure 5A**.

Using these values with **Equation [1]**, the estimate for groundwater discharge as baseflow to the upstream portion of Beaverdams Creek northeast of the Site during the baseline monitoring period during the spring is about 9 mm/year. Assuming a similar discharge rate for 1 km upstream of SW1 and an average meander valley width of 20 m yields a groundwater discharge of less than 0.1 L/s. Baseflow from groundwater discharge is therefore a small component of flow relative to the average spring flow rates of about 50 L/s at SW1.

DP1 / R1 / R6

Near the downstream portion of the main channel of Beaverdams Creek northwest of the Site (i.e., the Welland Canal South Turn Basin reservoir), the groundwater elevation in the contact aquifer at **R6** was approximately 175.4 masl in February 2019. The shallow bedrock aquifer groundwater elevation at **R1** reached a maximum of approximately 173.9 masl in December 2018. The ground surface elevation around the perimeter of the reservoir at DP1 is interpreted to be approximately 173.2 masl based on the 2010 DEM released by NPCA. The hydrograph for DP1 indicates that when inundated, stage elevations typically range between 173.3 masl and 173.5 masl. The reservoir water level data show that an upward gradient between the contact and shallow bedrock aquifers and reservoir exists for at least part of the year.

A stage elevation equal to the ground surface elevation at the perimeter of the reservoir of approximately 173.3 masl is used; a groundwater elevation of 175.4 masl is inferred based on the data from **R6**. The thickness of the upper aquitard is interpreted to vary across the reservoir area. The MECP well record for **R1** indicates a clay overburden thickness of approximately 9.4 m. The field-measured depth of the dug well **R6** was approximately 2.2 m; this well is inferred to have been completed close to the top of bedrock within the contact aquifer. The interpolated overburden thickness map on **Figure 5A** suggests that in some areas of the reservoir, the upper aquitard is less than 1 m thick. For this calculation, a thickness of 1 m is adopted.

Using these values with **Equation [1]**, the estimate for groundwater discharge to the reservoir northwest of the Site during the baseline monitoring period is 34 mm/year. The estimated discharge is equivalent to about 11% of the average annual water surplus at the Site.

MW16-6 / SW2

At the upstream portion of the Beaverdams Creek tribuary at the east Site boundary, the groundwater elevation within the contact aquifer at MW16-6OB is typically at or marginally above the creek bed in the spring and late autumn / winter months. The hydrograph for SW2 indicates that water is present within the creek typically only during the spring and late autumn / winter; however, flow is only observed following major precipitation events. These observations show that an upward gradient between the contact aquifer and the tributary of Beaverdams Creek exists at MW16-6 / SW2 at the east Site boundary, except for the summer months.

A stage elevation equal to the creek bed elevation of 181.2 masl is used; a groundwater elevation of 181.5 masl is used, equivalent to the maximum groundwater elevation observed between 2017 and 2018. The thickness of the upper aquitard is 4.4 m based on the borehole log for MW16-6OB.

Using these values with **Equation [1]**, the estimate for groundwater discharge to the Beaverdams Creek tributary at SW2 during the baseline monitoring period is 1 mm/year. Assuming a similar discharge rate for 200 m upstream of SW2 and an average meander valley width of 5 m yields a groundwater discharge of less than 0.1 L/s. Baseflow from groundwater discharge is therefore a small component of flow relative to the average spring flow rates of about 5 L/s at SW2.

MW11-3R / DP5

At the downstream portion of the Beaverdams Creek tributary at the north Site boundary, the groundwater elevation within the contact aquifer at MW11-3OBR is typically below the creek bed elevation at DP5. The hydrograph for DP5 indicates that the creek stage is typically above the creek bed for the spring and late autumn / winter. During the summer, water is typically only present at surface at this station following major precipitation events and hydraulic gradients are typically downward. These observations demonstrate that there is likely no upward gradient between the contact aquifer and the tributary of Beaverdams Creek near the northeast Site boundary.

Summary

The baseline water level data indicate that groundwater discharge occurs between the contact aquifer and the main channel of Beaverdams Creek to the north of the Site during the spring and late autumn / winter months. Groundwater discharge to the creek / reservoir is estimated to range between 9 mm/year and 34 mm/year for the baseline monitoring period. Therefore, groundwater discharge to Beaverdams Creek / turn basin reservoir north of the Site is equivalent to about 11% of the average annual water surplus at the Site. It is interpreted that minimal groundwater discharge occurs along the tributary of Beaverdams Creek within the eastern portion of the Site.

2.5.3.3 OTHER STUDY AREA WETLANDS

5584 Beechwood Wetland (East of Site)

With the exception of the wetland complexes associated with the Existing Watercourse and Beaverdams Creek, the mapped wetland feature east of the Site at 5584 Beechwood Road is the closest wetland in proximity to the proposed quarry footprint. As noted previously, this wetland feature is interpreted to be an "off-line" feature with no distinguishable surface water drainage channels and is not classified as a PSW. Well nest MW17-20 is situated just west of the wetland feature as shown on **Figure 2**, while drivepoint (stilling well) DP6 is situated within the wetland footprint at the northeast corner of the 5584 Beechwood property boundary as shown on **Figure 3A**. Hydrographs for well nest MW17-20 are shown on **Figure E-21** and the stage elevation within the wetland feature is shown in the hydrograph for DP6, **Figure E-38**. Monitoring of MW17-20 and DP6 began in July 2017. A summary of the seasonal average baseline conditions for the wetland is depicted on the schematic cross sections using the 2017 data (wet year) on **Figure 22A** and using the 2018 data (dry year) on **Figure 22B**. Of note, spring 2019 data is used on **Figure 22A** as these monitoring locations had not yet been installed in the spring of 2017.

The seasonal average water levels on **Figures 22A and 22B** show that a downward hydraulic gradient exists between the pooled water in the wetland (when present), the shallow weathered overburden (i.e., to a depth of 3 mbgs), and the underlying contact aquifer throughout the entire year. Pooled surface water is typically only observed during the winter and spring months, although during wetter years (such as 2017), pooled water may persist into the early summer months. When present, the pooled water at surface is subject to a downward vertical hydraulic gradient and percolates through the upper aquitard, infiltrating to the contact aquifer (i.e., groundwater recharge). Using an upper aquitard thickness of 5.1 m (based on the borehole log for MW17-20OB) and a vertical hydraulic conductivity of approximately $1x10^{-7}$ cm/s (based on the response test results for MW17-20SP), monthly groundwater recharge rates for each season during the baseline monitoring period have been calculated, as shown on the cross sections. During 2017 (wet year), groundwater recharge rates varied between 2 mm/month and 3 mm/month, with the highest rates observed during the summer. During 2018 (dry year), groundwater recharge rates also varied between 2 mm/month and 3 mm/month, with the highest rates observed during the winter. Of note, pooled water was not present within the wetland during the summer and autumn of 2018; as such, the groundwater recharge rates were zero. Overall, annual groundwater recharge rates of 29 mm/year for 2017 and 15 mm/year for 2018 were observed, which is the equivalent of about 5% to 9% of the average annual water surplus at the Site.

In summary, the baseline data indicate that this wetland feature does not receive groundwater discharge, but rather relies on direct precipitation to maintain conditions within the wetland. Furthermore, unlike the Existing Watercourse and Beaverdams Creek wetland complexes discussed previously, the wetland feature at 5584 Beechwood acts as a recharge area to the groundwater system.

Provincially Significant Wetlands (South of Site)

There are several other PSW features situated within the southern portion of the study area, south of the Niagara Falls moraine, as shown on **Figure 3**. These features include (from closest to the Site to farthest): Warren Creek wetland complex, Thompson Creek Wetland complex, South Allanburg Slough Forest wetland complex and East Welland River wetland complex. It is noted that there are multiple wetland areas associated with each of these named features; however, only the closest portion to the Site is considered for the following discussion.

As shown on **Figure 5**, each of these PSW features are underlain by a significant thickness of silt and clay overburden, ranging between 14 m and 20 m thick. Similar to the wetland at 5584 Beechwood, these wetlands are inferred to act as recharge areas to the groundwater system.

2.5.3.4 WOODLOT FEATURE WEST OF TOWNLINE ROAD

Groundwater and stage elevations in the vicinity of the woodlot feature west of Townline Road are monitored at five locations: MW16-9, MW17-21, MW17-22, MW17-23 and DP7. Hydrographs for the contact and shallow bedrock aquifers are shown on **Figures E-10 and E-22 through E-24**. The stage elevation at drivepoint (stilling well) DP7 is shown on **Figure E-39**.

The upper aquitard thickness in the vicinity of the woodlot ranges between 5.6 m to the north at MW17-23 to 2.3 m to the east at MW17-22 in the vicinity of the bedrock high. The overburden contains more silt content at MW17-21 and MW17-22 in comparison to the other two well nests in the vicinity of the woodlot. The geometric mean horizontal hydraulic conductivity from the single well response tests at the ‘SP’ wells is about 4×10^{-8} cm/s.

The hydrograph for DP7 shows that during winter / spring, pooled water accumulates up to a depth of 15 cm in the vicinity of the drivepoint. The hydrographs for the four well nests show that groundwater elevations within the shallow weathered overburden and the contact aquifer remained below ground surface throughout the baseline monitoring period. At MW17-21 and MW17-22, the groundwater elevation in the shallow bedrock aquifer remained below the top of bedrock throughout the baseline monitoring period. As such, this woodlot is under-drained under baseline conditions, and it is predicted that the proposed quarry development will not have an impact on this woodlot feature.

2.5.4 GROUNDWATER USE

There are no municipal well fields in operation on the Niagara Peninsula or the study area, all of the urban areas are supplied via surface water intake. As such, there are no well-head protection areas (WHPAs) within the study area. The DeCew Falls Water Treatment Plant (WTP) has intakes on Lake Gibson, which is diverted from the Welland Canal. The Intake Protection Zones (IPZs) encompass a portion of the Welland Canal near Allanburg and Lake Gibson west of the study area. The water levels in these features are controlled and therefore will not be impacted by the proposed quarry dewatering.

Outside of the serviced areas, water supply is obtained via private drinking water wells and / or cisterns.

2.5.4.1 MECP WATER WELL RECORD SEARCH

A search of the MECP Water Well Record database was undertaken to identify well records located between the approximate existing service areas (per Niagara Region 2016 Master Servicing Plan) in the vicinity of the Site. The results of the search are shown on **Figure 23**, and summarized in **Table B-1**, **Appendix B**.

A total of eighty-eight (88) water well records (or their associated land parcel) plot within the search area. Of these well records, fifty-seven (57) are reported as domestic supply, three (3) are reported as livestock, five (5) are reported as irrigation, two (2) are reported as public supply, one (1) is reported as industrial, seven (7) are reported as commercial, five (5) are reported as observation wells or test holes and eight (8) are reported abandoned or unknown. Land parcels which are not associated with a well record likely use cisterns or dug wells for supply or have a drilled well with no record.

A detailed review of the water well records was completed, and it is inferred that eleven (11) of the water well records are plotted incorrectly based on the drillers sketch included on the original well log. The incorrectly plotted wells include six domestic wells, one public well, the industrial well and three abandoned wells.

The correctly plotted public well is mapped within the parcel at 13065 Highway 20, formerly a motel which is currently a vacant lot. The public well was installed in 1970, six years after a commercial well had been installed on the same property. It is inferred that the latter well was incorrectly identified as a public well (instead of a commercial supply well). There are no municipal groundwater supply systems servicing the Niagara Region as the municipally serviced areas obtain drinking water from Lake Ontario or Lake Erie.

A total of sixty-five (65) wells are reportedly screened within bedrock, eleven (11) within the overburden and twelve (12) unknown. Fresh water was reported in forty-five (45) wells, sulphur water was reported in twenty-two (22) wells and mineralized water was reported in six (6) wells. The water type at the remaining wells was not specified in the water well record. The recommended pumping rates vary significantly, ranging between 2 Imperial gallons per minute (Igpm) and 50 Igpm, with a median value of 8 Igpm (36 L/min).

2.5.4.2 WATER WELL SURVEY

A residential water well survey of unserviced parcels was undertaken between summer 2018 and winter 2019 in accordance with MECP technical guidance (MECP, 2008). The survey responses are summarized in **Table B-2**, **Appendix B**, and depicted graphically on **Figure 23**. A summary of the 2018 / 2019 survey is provided below:

- Attempts were made to deliver surveys to eighty-six (86) parcels with a municipal address that were identified within the survey area shown on **Figure 23**. This total does not include other lands owned by WAI. Six (6) of the parcels either did not have a mailbox / residence associated with them and were not accessible or were vacant; as such, these parcels could not be surveyed.
- The door-to-door surveys were conducted between June 2018 and July 2019. At least two attempts at contact were made: once during daytime hours, and a follow-up attempt during evening or weekend hours, where no response was received during the first attempt. If no contact had been established by the second attempt, a pre-stamped return envelope and survey package was left in the mailbox.
- Of the eighty (80) remaining properties, a total of fifty-eight (58) property owners responded either verbally in person during the door-to-door survey or mailed a completed survey package later. Twenty-two (22) surveys were not completed owing to no response from the property owner.
- Of the fifty-eight (58) property owners who responded to the survey either in person or by mail, twenty-seven (27) identified a well as their only water source, while ten (10) identified a cistern as their only water source. The Niagara Falls Golf Club is on the municipal supply for domestic uses but maintains groundwater wells as a source of irrigation. The remaining twenty-one (21) property owners indicated that they had both a cistern and well for their water supply. Fifteen (15) of these respondents indicated that the cistern is the only source for domestic water, and the well was either no longer in use or used only for lawn / garden watering.
- Based on well owner permission, detailed measurements, logger installation and sample collection were performed on selected private supply wells, including:

- 1024 Beaverdams Road **(R1)** 650 m northwest of Site;
- 5769 Beechwood Road **(R2)** 300 m southeast of Site;
- 10008 Lundy's Lane (Country Basket Garden Centre) **(R3)** 630 m south of Site;
- 13011 Highway 20 (Little Bros Service Centre) **(R4)** 780 m southwest of Site;
- 5114 Townline Road (Niagara Cricket Centre) **(R5)** adjacent to the west of Site;
- 4680 Townline Road (Beechwood Golf and Country Club) dug well **(R6)**, 500 m north of Site;
- 9602 / 9582 Beaverdams Road (Panoramic Properties) **(R7)** 100 m northeast of Site;
- 9941 Lundy's Lane (Lundy Manor Wine Cellars) **(R8)** 300 m south of Site; and
- 10148 Beaverdams Road **(R11)** 150 m north of the Site;
- 6169 Garner Road (Niagara Falls Golf Course) **(R12)** 1,600 m southeast of Site; and
- 4843 Garner Road **(R13)** 1,100 m northeast of Site.

Private supply wells **R9** and **R10** (shown on **Figure 2**) are situated within the Site boundary on land owned by WAI and will eventually be decommissioned as part of the proposed quarry.

2.5.4.3 PRIVATE SUPPLY WELL GROUNDWATER ELEVATIONS

Available groundwater elevation data for the private supply wells listed above are shown on **Figures E-40 to E-48**. Based on the field measured well depths and MECP water well records (where available), the monitored private supply wells are inferred to be completed within the shallow bedrock aquifer, except for dug well **R6** which is inferred to be completed within the contact aquifer. Of note, private well **R1** is interpreted to be situated north of the Eramosa member lower contact, and therefore is screened within the upper Goat Island member. There is currently limited continuous water level data for most private wells. However, the available data suggests that seasonal fluctuations of 1 m to 2 m are not uncommon in the private supply well water levels, which is consistent with the Site monitoring well data.

2.5.4.4 PERMITS-TO-TAKE-WATER

A search of the MECP PTTW database was undertaken as part of the current study to identify groundwater users within the study area. Potential impacts as a result of the proposed quarry are discussed in **Section 4**.

A total of ten (10) PTTWs are mapped within the study area, summarized as follows.

<u>Surface Water Takings</u>

- ➔ Four (4) PTTWs, nos. 0318-AB8RWR (General Motors plant), 4330-AT6LVR (Resolute Forest Products formerly Abitibi), and 7279-ANRLM4 / 7278-ANRLM4 (Thorold Co-Gen plant) authorize surface water takings from the Welland Canal;
- ➔ Two (2) PTTWs, nos. 7537-9P3Q22 (Oxy Vinyls Canada Co. at 1332 Townline Road) and 2701-9NBLH8 (Cytec Canada Inc.) authorize surface water takings from the Welland River; and
- ➔ PTTW no. 4050-A7LLXS (Beechwood Golf & Country Club) authorizes surface water takings from Beaverdams Creek.

Groundwater Takings

- ➔ PTTW no. 8470-9ZXR6N (Niagara Falls Golf Club) authorizes groundwater takings from three supply wells, up to a maximum rate of 3.4 ML/day (approximately 40 L/s). This is consistent with the information obtained during the 2018 / 2019 water well survey.
- ➔ PTTW no. 3434-AANR4T (Mountain Road Landfill Site) authorizes groundwater takings from thirteen pumping wells, up to a maximum rate of 1.01 ML/day (approximately 11.7 L/s). These pumping wells form a groundwater containment system for the landfill by maintaining a continuous inward gradient.
- ➔ PTTW no. 7738-8WBKPB authorizes groundwater takings for dewatering of the Walker Brothers Quarry. The maximum permitted rate is 14.4 ML/day (approximately 167 L/s).

East of the Site, a continuous pump-and-treat system is operated at the Recycling Centre near the QEW and Highway 420 interchange. No PTTW was found for this operation. Based on the available data, the system appears to pump approximately 25,000 L/day (approximately 0.3 L/s), which is below the threshold for requirement of a PTTW.

The groundwater takings noted above are inferred to have altered the regional potentiometric surface to some degree, dependant on the average annual pumping volume. Impacts from these operations may not be apparent in the regional potentiometric surfaces shown on **Figure 14 and 15** due to limited high-quality data prior to implementation. It is noted that no PTTWs were found for the dewatering operations along the Welland Canal at the Thorold Stone Road tunnel northwest of the Site and Townline Road / Main Street Tunnels in Welland southwest of the Site or dewatering associated with the Queenston-Chippewa Power Canal. It is acknowledged in the NPCA source protection report that these dewatering operations also have an impact on the regional potentiometric surface, although the exact extent of the impact is currently not well documented.

2.5.4.5 AVAILABLE DRAWDOWN

An important aspect for evaluation of the proposed quarry effects is the available drawdown within the shallow and deep bedrock aquifers. The available drawdown for a single well can be calculated by subtracting the aquifer base elevation from the elevation of the baseline static water level in the well. For the study area, the available drawdown in the shallow and deep bedrock aquifers has been calculated using ArcGIS by subtracting the elevation of the interpolated lower contact of the Gasport member bedrock from the potentiometric surface elevation shown on **Figure 15**.

For the study area, the available drawdown ranges from less than 3 m along the Niagara Escarpment north of the Site to over 20 m within the southern portion of the study area.

2.6 WATER QUALITY

This section summarizes the baseline water quality for the Site. Laboratory certificates of analysis are not included in this report but have been kept on file by the proponent.

Quality assurance and quality control (QA / QC) testing involved field procedures, field prepared blind duplicate samples and laboratory quality assurance testing. A blind duplicate sample was submitted for every ±10 samples for analysis of inorganic parameters to assess repeatability of laboratory results, summarized in **Table F-3** for groundwater results and **Table G-3** for surface water results. Chemical results were also reviewed for acceptable ion balances. The field and laboratory QA / QC program indicate that the chemical results were representative of actual conditions at the time of sample collection and are suitable for use in the assessment of baseline conditions.

2.6.1 GROUNDWATER

Groundwater chemical results from samples collected as part of the baseline study are presented in **Table F-1** for inorganic parameters and **Table F-2** for selected VOCs. The groundwater relative major ion ratios from March 2018 are plotted on the trilinear diagram included as **Figure 25**.

On-going monitoring of ambient groundwater quality has been completed by NPCA. Within the study area, ambient groundwater quality for the contact and shallow bedrock aquifers generally meets Ontario Drinking Water Quality Standards (ODWQS) (MECP 2006 and updates) for parameters with health-related standards. Exceptions include sporadic exceedances of some dissolved metals concentrations. Agricultural and / or septic system impacts are also observed regionally, resulting in elevated nitrate concentrations in the groundwater.

The results of the baseline monitoring program at the Site indicate that the groundwater within each hydrostratigraphic unit is typically hard with a neutral pH. Mineralization of the groundwater generally increases with depth, as evidenced by the elevated concentrations of total dissolved solids (TDS), major ions and conductivity in the deeper units relative to the shallow units. Elevated concentrations of nitrates and total phosphorus are typically present within the overburden; nitrate is typically not detected above the laboratory reported detection limit (RDL) within the bedrock, and the total phosphorus concentrations in the bedrock units are generally notably lower than those of the overburden.

Groundwater quality in the deep bedrock aquifer appears to be influenced by the underlying DeCew and Rochester Formation geochemistry, with naturally elevated concentrations of sulfur and sodium chloride. VOCs are typically only detected above the RDL in these lower two units, a naturally occurring phenomenon. Sporadic elevated concentrations of some dissolved metals are occasionally detected within each unit, with no apparent geographic or hydrostratigraphic correlation. These results are similar to the groundwater characteristics observed at the Walker Brothers Quarry north of the Site and are consistent with the characterization of the regional groundwater conditions included in the NPCA Source Protection report.

ODWQS exceedances are shown in **Tables F-1 and F-2**, **Appendix F**. At the Site, concentrations of TDS and hardness typically exceed the ODWQS within all the hydrostratigraphic units. Concentrations of sulphate, chloride, sodium and DOC are consistently elevated above the ODWQS within the deep bedrock aquifer and DeCew / Rochester aquitard, with occasional sporadic exceedances in the overlying units. Nitrate concentrations exceeded the ODWQS within the contact aquifer on one occasion; typically, concentrations within this unit are elevated but do not exceed the ODWQS. Sporadic exceedances of the ODWQS for dissolved metals were occasionally observed within each hydrostratigraphic unit. Concentrations of benzene, toluene and ethylbenzene typically exceed the ODWQS in the deep bedrock aquifer and lower aquitard. The ODWQS exceedances observed during the baseline monitoring are inferred to be related to ambient conditions within the deeper bedrock units, or the result of existing anthropogenic impacts on the overburden (i.e., agricultural activity, septic systems, etc.).

A trilinear diagram is used to graphically depict similarities in water quality from different sampling locations. The March 2018 groundwater relative major ion ratios are illustrated on the trilinear diagram, **Figure 25**. The anion chemical results are presented on the triangular graph in the lower right hand, while the cation chemical results are presented on the triangular graph in the lower left hand. The anion and cation results are combined on the diamond shaped graph in the centre. Water with similar chemical signatures will plot together on the trilinear diagram. The range of major ion ratios for each of the bedrock units at the Walker Brothers Quarry as well as the typical range for meteoric water (i.e., precipitation) is also shown on the trilinear diagram for reference.

In general, the major ion ratios for each unit at the Site are consistent with the typical ranges observed at the Walker Brothers Quarry. Within the shallow weathered overburden, groundwater is fresh and similar to precipitation. Within the more mineralized contact and shallow bedrock aquifers, the groundwater varies between fresh and sulphur type waters. The range of groundwater signatures for these two units on the combined plot varies between precipitation and Lockport dolostone influenced, which is not unexpected. The deep bedrock aquifer and lower aquitard groundwater is similar to the DeCew / Rochester groundwater observed at the Walker Brothers Quarry.

2.6.2 PRIVATE SUPPLY WELLS

As part of the residential water well survey, property owners with wells were requested to take part in a voluntary sample collection program. To date, only three well owners have given permission for sample collection: **R2** (5769 Beechwood Road), **R3** (10008 Lundy's Lane) and **R11** (10148 Beaverdams Road). Both **R2** and **R11** are shown on the Site Plan, **Figure 2**. Private well **R3** is south of Lundy's Lane out of the plot extent of **Figure 2**. The groundwater chemical results for these wells are included in **Table F-1**, and have also been plotted on the trilinear diagram, **Figure 25**.

The chemical results for **R2** suggest the groundwater is generally hard with elevated concentrations TDS and alkalinity. Concentrations of TDS, hardness, iron and manganese exceeded the ODWQS. The relative major ion ratios illustrated on the trilinear diagram indicate that the bedrock groundwater is fresh, similar to precipitation. The property owner indicated that this well is currently not in use.

The chemical results for **R3** are consistent with the use of a water softener, which was indicated by the property owner on the well survey. Sample collection was not possible upstream of the softener. Only the TDS concentration exceeded the ODWQS. The property owner indicated that this well is used for domestic supply, as well as livestock and garden watering.

The chemical results for **R11** suggest the groundwater is hard with elevated concentrations of TDS, most major ions, TKN, iron and strontium. Concentrations of TDS, hardness, chloride, sulphate, sodium and iron exceeded the ODWQS. The relative major ion ratios illustrated on the trilinear diagram indicate that the bedrock groundwater is similar to the Lockport dolostone range. The property owner indicted that this well is currently used for irrigation only; domestic supply is provided by cistern.

2.6.3 SURFACE WATER

Surface water chemical results from samples collected as part of the baseline study are presented in **Table G-1** for inorganic parameters and **Table G-2** for selected VOCs. The surface water relative major ion ratios from March 2018 are plotted on the trilinear diagram included as **Figure 25**.

On-going monitoring of ambient surface water quality has been completed by the NPCA. Within the study area, results from over two-thirds of the surface water quality stations operated by the NPCA suggest surface water conditions are poor or impaired, and only 5% of the stations regularly indicate good conditions. The main contaminants of concern are total phosphorus, E. coli, suspended solids and chloride, originating from sources including agricultural activities, poorly maintained septic systems, road salting activities and untreated stormwater runoff from urban areas.

The results of the baseline monitoring program at the Site indicate that the ambient surface water quality is generally in poor condition. The surface water is typically turbid with consistent elevated nutrient loads. Iron and manganese concentrations are typically elevated, and occasional elevated concentrations of other metals are also observed sporadically. VOCs were not detected within the surface water at the Site, although total oil and grease was detected above the RDL at most stations in March 2018. These results are consistent with the characterization of the regional surface water conditions included in the NPCA Source Protection report.

Provincial Water Quality Objectives (PWQO, MECP 1994 and updates) exceedances are shown in **Tables G-1 and G-2**. At the Site, concentrations of total phosphorus and iron typically exceed the PWQO at all stations. Other metals concentrations, including cobalt, copper, vanadium and zinc also regularly exceed their respective PWQO. One exceedance of the phenols PWQO was observed at DP2 in May 2017. The PWQO exceedances observed during the baseline monitoring are inferred to be the result of existing anthropogenic sources (i.e., agricultural field and urban stormwater runoff).

The March 2018 surface water relative major ion ratios are illustrated on the trilinear diagram, **Figure 25**. The ion ratio for the surface water at the Site is fairly consistent and is a mixture of precipitation and Lockport-influenced waters.

3 QUARRY DESIGN SUMMARY

The Site is bounded to the west by Townline Road, to the east by Beechwood Road and to the south by a hydro transmission corridor. A TransCanada natural gas pumping station and pipeline are in the northwest portion of the property. The proposed licensed area includes Part of Lots 119, 120, 136 and 137 in the geographic Township of Stamford, Regional Municipality of Niagara. The proposed limits of extraction are shown on **Figure 2**.

For the proposed extraction scenario, the total area to be licensed is approximately 103.64 ha, and the total proposed extraction area is approximately 89.1 ha. Excavation will proceed to a maximum depth of approximately 45 m below ground surface, corresponding to the geologic base of the Gasport member dolostone of the Lockport Group. In total, approximately 60 million tonnes of high-quality dolomitic bedrock are planned for extraction. The estimated life expectancy of the operational phase of the proposed quarry is between 40 and 50 years.

Two municipal road allowances separate the proposed quarry site into three extraction areas:

i. North Extraction Area: extraction area north of Upper’s Lane;

ii. Mid Extraction Area: extraction area south of Upper’s Lane and north of the unopened road allowance between Township Lots 120 & 136 in the former Township of Stamford, now in the City of Niagara Falls (“unopened road allowance”); and

iii. South Extraction Area: extraction area south of the unopened road allowance.

Subject to agreement with the City of Niagara Falls, Walker proposes to extract:

i. Upper’s Lane, between the North Extraction Area and the Mid Extraction Area; and

ii. the unopened road allowance between Lots 120 and 136, between the Mid Extraction Area and the South Extraction Area.

Walker owns all of the lands north and south of Upper’s Lane and the unopened road allowance between Thorold Townline Road and Beechwood Road, with exception of the Bible Baptist Church property which has secured access from Beechwood Road.   Subject to an agreement with the City, Walker proposes to extract this portion of Upper’s Lane and the unopened road allowance to maximize access to the aggregate resource and to create a more integrated operation and rehabilitation plan.

Therefore, WSP has modelled and assessed two extraction scenarios: (i) the “Proposed Extraction Scenario” wherein Upper’s Lane and the unopened road allowance are not to be extracted; and (ii) the “Alternate Extraction Scenario” wherein Upper’s Lane and the unopened road allowance are to be extracted.

The Existing Watercourse, a tributary of Beaverdams Creek, intermittently flows north through the central portion of the property from its headwater on the north slope of the Niagara Falls Moraine (shown on **Figure 3**). The watercourse is planned to be re-aligned to the west side of the property (Realigned Watercourse) prior to excavation of the Existing Watercourse.

3.1 PROPOSED DEVELOPMENT PHASES

To accommodate the re-alignment of the Existing Watercourse, the proposed Operational Plan includes five (5) phases of extraction within the three extraction areas.

Phase 1

Phase 1 is located west of the Existing Watercourse meander valley in the Mid and South Extraction Areas and includes two (2) sub-phases. Phase 1A includes the area between the Existing Watercourse meander valley and the proposed Realigned Watercourse corridor. The Realigned Watercourse corridor has been designated as Phase 1B.

Initial sinking cuts in each quarry cell will be completed in Phase 1A. A portable submersible pump will be installed within the excavation and will be relocated as necessary as the extraction proceeds. Once a portable crushing / screening plant is established on the quarry floor, extraction may proceed in Phase 1A and 1B concurrently.

In Phase 1B, the extraction will not be completed to the full quarry depth, but rather to an elevation of approximately 155 masl. The bedrock remaining in place will form a foundation for the proposed Realigned Watercourse. The design and construction of the Realigned Watercourse is included under separate cover as part of this application.

It is expected that once Phase 1A has been fully extracted, submersible pumps would be installed within each extraction area at the southwestern corner of the quarry floor.

Phase 2

Phase 2 is located within the North Extraction Area north of Upper's Lane and includes two (2) sub-phases. Phase 2A includes the area west of the Existing Watercourse meander valley, except the Realigned Watercourse corridor which is designated Phase 2B.

Phase 3

Phase 3 is located in the North Extraction Area and includes two (2) sub-phases. Phase 3A includes the Existing Watercourse meander valley and Phase 3B is the remaining area in the North Extraction Area to the east.

Extraction in Phase 3A will not commence until the Realigned Watercourse is commissioned and flow within the Existing Watercourse is diverted, based on approval from the appropriate regulatory agencies. As the construction of the Realigned Watercourse may require additional time, extraction in Phase 3B may proceed until approval to extract Phase 3A has been granted. Once the Realigned Watercourse has been commissioned, extraction in Phase 3A and 3B may occur concurrently. If extraction in Phase 3B does commence prior to Phase 3A, then a separate sinking cut would be required with a portable submersible pump to maintain dry working conditions.

Phase 4

Phase 4 is located in the Mid Extraction Area south of Upper's Lane east of Phase 1A. Extraction will not proceed until Phase 3 extraction is complete, and it is anticipated that the Realigned Watercourse will have been commissioned well before Phase 4 extraction proceeds.

Phase 5

Phase 5 is located in the South Extraction Area south of the unopened road allowance east of Phase 1A and 1B. Extraction will not proceed until Phase 4 extraction is complete.

3.1.1 ALTERNATE QUARRY DESIGN

An alternative quarry design was considered, where the Upper's Lane and unopened road allowances between the three quarry extraction areas are included in the limit of extraction, which would result in one contiguous quarry excavation. This potential scenario was modeled (refer to **Appendix H**) and given the limited difference in the overall quarry size the results indicate that there is no substantial difference in impacts if the additional bedrock resource within the road allowances is removed.

3.2 REHABILITATION

During the operational phases, the quarry excavation will be progressively rehabilitated in the direction of extraction by backfilling surplus overburden against the quarry walls with a suitable side-slope. Once the quarry excavation is complete, the dewatering sumps will be decommissioned, and the quarry cells will be allowed to fill naturally with precipitation and groundwater discharge. As such, the proposed end use of the quarry is a series of lakes, with a long-term average stage elevation of ±175.15 masl, a realigned watercourse corridor with enhanced wetlands and a deciduous woodland area. Discharge from the lakes to the Realigned Watercourse will be by gravity (i.e., no pumping) and governed by a constructed outlet.

3.3 PROPOSED WATER MANAGEMENT PLAN

Since the proposed quarry will be developed below the natural groundwater table, the quarry will be dewatered in order to maintain dry working conditions. Water that collects on the quarry floor from either direct precipitation or groundwater discharge will be pumped from the quarry floor sump in each extraction area to either the Existing Watercourse (during Phases 1 and 2) or the Realigned Watercourse (during Phases 3, 4 and 5). In addition, overland surface water flow from upstream catchment areas will be managed by the Realigned Watercourse and perimeter ditches (where required). The water management plan for both quarry dewatering discharge and surface water flow outlined below will be implemented to address stormwater management for the Site.

3.3.1 QUARRY DEWATERING MANAGEMENT

Dewatering of the proposed quarry will maintain groundwater levels within the quarry excavation at lower elevation than the surrounding groundwater levels within the overburden and bedrock. This will induce the movement of groundwater toward the quarry and discharge at the quarry face. Perimeter berms and ditches will prevent the flow of off-site surface water into the quarry; however, direct precipitation will also continue to fall on the quarry floor.

Within the quarry excavation footprint(s), a network of internal ditches will be constructed in the quarry floor to direct water to a sump. During the initial stages of Phase 1 extraction, it is anticipated that a series of transient sump locations may be required as the quarry face advances. Upon the completion of Phase 1A and 2A to the final quarry depth, permanent sumps will be established in the southwest corner of each quarry extraction area (i.e., the lowest point on the quarry floor due to the slope of the bedrock stratigraphy).

Water accumulating in the sumps and quarry floor ponds will be subject to increased evaporative losses, estimated to be approximately 800 mm/year (Map 17 – Mean Annual Lake Evaporation, Hydrogeologic Atlas of Canada, 1975). Additional losses of water for dust suppression and wash plant operations will also occur. Previous studies completed by others indicate that water losses of up to 5% of the annual tonnage can be expected. The losses due to increased evaporation have been accounted for in the predictive models.

Submersible pumps will be used to discharge water from the sump to the Existing Watercourse. The quarry discharge will be directed to a temporary sediment forebay adjacent to the Existing Watercourse to prevent erosion and minimize sedimentation downstream of the discharge point. The design of the temporary sediment forebay is included under separate cover as part of this application.

During an anticipated precipitation event of 25 mm or more, the quarry sump pump will be deactivated, and the quarry will not discharge to the watercourse until the excess water has dissipated. This will prevent quarry-induced flooding along the Existing Watercourse downstream (north) of the Site.

The proposed monitoring program included in **Section 5.1** includes daily discharge volume measurement and monthly sampling of the discharge for water quality analysis.

The proposed quarry dewatering involves the collection, transmission, treatment and discharge of water extracted from the proposed quarry as well as process water. A PTTW will be required to dewater the quarry. In addition, discharge of the sump a temporary sediment forebay then to the Existing Watercourse is considered an industrial sewage works under the broad definition included in Section 53 of the Ontario Water Resources Act (OWRA); therefore, WAI will also be required to obtain an Environmental Compliance Approval for Industrial Sewage Works (ECA (Sewage)). It is expected that the findings of this report would be used to support the study requirements for both future permit applications.

As part of both the PTTW and ECA (Sewage), there is typically a monitoring program and surface water management plan, in addition to reporting requirements. It is anticipated that monitoring and reporting requirements for these permits would be substantially met by the proposed monitoring program included in **Section 5.1**.

3.3.2 SURFACE WATER MANAGEMENT

During Phases 1 and 2 (and potentially part of Phase 3B), overland surface water runoff from upstream of the Site will continue to flow within the Existing Watercourse and its tributaries. Once appropriate approvals have been granted, flow from the Existing Watercourse will be permanently diverted to the Realigned Watercourse. The Realigned Watercourse will maintain the function of the Existing Watercourse by routing overland surface water flow from upstream of the Site to the Existing Watercourse channel at the north Site boundary.

Berms will be progressively constructed around the perimeter of the Site during the initial site preparation phase. As shown on **Figure 3A**, there are several tributaries of the Existing Watercourse and Beaverdams Creek which cross the Site boundary along the west and east sides. Construction of the perimeter berm will truncate these tributaries.

For tributaries along the western boundary of the Site, culverts will be installed through the berm to direct overland flow to the Realigned Watercourse to maintain baseline surface water flow conditions. Along the eastern Site boundary, shallow perimeter ditches / swales will be constructed outside of the perimeter berm to direct overland flow to either the Realigned Watercourse or other existing tributaries downstream of the Site.

During anticipated severe precipitation events, offsite runoff would continue to contribute to the Existing or Realigned Watercourses similar to baseline conditions. Quarry discharge would be temporarily deactivated to prevent downstream quarry-induced flooding.

4 IMPACT ASSESSMENT

Dewatering of the proposed quarry will induce a reduction in groundwater levels (i.e., drawdown) around the Site, referred to as the radius of influence. The purpose of this impact assessment is to identify water features within the radius of influence that may potentially be affected by the proposed quarry dewatering and the predicted degree of impact.

Section 1.2 lists the various hydrogeologic features which must be considered in a Level 2 Water Report. For this study, the following features are situated within the proposed quarry radius of influence and have been included in the impact assessment:

- groundwater quantity and quality in the shallow and deep bedrock aquifers;
- surface water quantity and quality in the Existing Watercourse, Beaverdams Creek and the Welland Canal South Turn Basin reservoir;
- groundwater discharge to the Existing Watercourse north of the Upper's Lane and the Welland Canal South Turn Basin reservoir;
- the wetland feature at 5584 Beechwood Road and PSWs south of the Site; and
- local groundwater users.

The predicted available drawdown was assessed at full quarry development. This represents the full extent of dewatering conditions prior to quarry rehabilitation. Following quarrying the excavation areas will be allowed to fill with groundwater and precipitation with a final Site end use as a series of lakes. The impact assessment considers the effects of both the proposed quarry under full development as well as final rehabilitation to a lake and Realigned Watercourse corridor. Cumulative impacts, including both permitted and non-permitted groundwater users, have also been considered.

The numerical groundwater modeling results completed for this study (included in **Appendix H**) were used as a basis for quantifying the effects of the proposed quarry on the features noted above.

The study area baseline conditions in were simulated using a steady-state numerical groundwater flow model calibrated to observed October conditions from the baseline monitoring program. The simulated groundwater flow conditions in the calibrated baseline model are a reasonable representation of observed conditions, and the model is considered sufficiently robust such that predictive model simulations for full quarry development and final rehabilitation can be interpreted with confidence.

4.1 FULL DEVELOPMENT CONDITIONS

4.1.1 GROUNDWATER CONDITIONS

4.1.1.1 DRAWDOWN

Numerical groundwater modeling was completed to simulate the predicted available drawdown in the shallow and deep bedrock aquifers as a result of the proposed quarry dewatering during the drier summer and fall months as shown on **Figure 26**. For details of the modeling, refer to **Appendix H**. The model predicted drawdown was subtracted from the baseline available drawdown shown on **Figure 24**. The existing and planned water system extent per the Niagara Region Master Servicing Plan (2016) and the City of Thorold Official Plan are also shown on the figures.

Future quarry impacts to groundwater users are limited to a relatively small portion of the currently un-serviced area located between the urban boundaries of the City of Niagara Falls and City of Thorold. Impacts will also be mitigated in the future given that a significant portion of this currently un-serviced area is planned for future servicing as part of the Rolling Meadows Secondary Plan. It is also noted that the majority of the un-serviced land parcels north of Thorold Stone Road are currently monitored as part of the environmental monitoring program for the Walker Brothers Quarry. Further discussion on the impact to local groundwater users is provided below.

An analysis of the water balance under full development conditions for both the Site and Beaverdams Creek subwatershed is provided in **Section H.7.2**, **Appendix H**. In summary, the full development Site water balance indicates that the predicted dewatering rate at full quarry development is approximately 4,268 m^3/day (approximately 1.6 Mm^3/year) in late summer / autumn conditions. The total inflow from recharge also increases due to the removal of the overburden within the quarry excavation footprint. However, the increase in total inflow from recharge is insufficient to equilibrate with the total outflow due to dewatering. As a result, the net lateral groundwater flow switches from marginally net outward flow under baseline conditions to a net inward flow at full quarry development, and accounts for approximately 86% of the predicted dewatering rate.

At the subwatershed scale, two notable changes to the water balance occur in response to the dewatering:

- ➔ The subwatershed net lateral groundwater flow switches from a net outflow of about 14 mm/year under baseline conditions, to a net inflow of about 44 mm/year at full quarry development.
- ➔ The Welland Canal South Turn Basin, a net gaining surface water feature under baseline conditions (about 7 mm/year), switches to a net losing surface water feature at full quarry development, at a rate of about 18 mm/year. It is anticipated that this change in net flow will have no impact on the water levels in the turn basin, since (1) the proposed quarry discharge will ultimately be directed to this surface water feature, and (2) the turn basin is hydraulically connected to the Welland Canal, which controls the stage at a relatively constant level (refer to the hydrograph for DP1, **Figure E-33**).

There is a negligible impact to the Existing Watercourse and Beaverdams Creek under full quarry development due to the presence of the thick silt and clay confining layer present throughout most of the study area. Similarly, the Realigned Watercourse will also not be impacted as it will be lined with a low hydraulic conductivity material. Under baseline conditions during the summer / autumn months, a simulated groundwater discharge of about 0.2 mm/year occurs along the Existing Watercourse and Beaverdams Creek. At full quarry development, these features are predicted to become a source of groundwater recharge, at a rate of about 0.3 mm/year. This net reduction equates to a flow rate of about 0.2 L/s. The rate would be lower during spring when the hydraulic gradient is lower (i.e., groundwater levels are seasonally high). These model results confirm there is limited groundwater / surface water interaction along these creeks either under baseline conditions or at full quarry development and is consistent with the interpretation that the creeks are sufficiently isolated from the underlying aquifers such that even under full quarry development, there is a negligible change in the water balance for these features.

The proposed quarry dewatering will also have an affect on the study area wetlands, further discussion is provided below.

4.1.1.2 GROUNDWATER QUALITY

No adverse groundwater quality impacts are predicted as a result of the proposed quarry. In general, chemicals or nutrients are not used during normal quarry operations. Limited quantities of fuel and petroleum products will be used on Site as part of the resource extraction. A spill action plan for these substances is included in the mitigation plan, further discussion is provided below.

4.1.1.3 GROUNDWATER USE

Groundwater users within un-serviced areas between the urban boundaries of the City of Niagara Falls and the City of Thorold may be impacted once dewatering at the proposed quarry is initiated. In addition, legacy groundwater well users within serviced areas which have not yet been connected to the municipal supply may also be impacted. The severity of the impact is dependant on available drawdown in the individual wells and the proximity to the proposed quarry. An assessment of the baseline available drawdown within the study area is provided in **Section 2.5.4.5**. As the predicted drawdown approaches the available drawdown, the capacity of existing wells is reduced. For this study, a minimum available drawdown of 3 m was considered necessary to maintain current use. The predicted area with less than 3 m of available drawdown due to the future quarry dewatering is shown on **Figure 26**.

An extensive survey of potential groundwater users within the un-serviced area has been completed as part of this study, as outlined in **Section 2.5.4.2**. A response rate of over 70% was achieved for the parcels included in the survey.

The numerical model predicted available drawdown at full quarry development, together with the pre-quarry baseline available drawdown information and water well survey information were used to formulate a detailed well mitigation plan. This plan will ensure that the limited number of groundwater users in the un-serviced area will have adequate future groundwater supplies. The proposed well mitigation plan is provided in **Section 5.2** below.

A search of all current permitted groundwater users in the study area has also been completed, as outlined in **Section 2.5.4.4**. Only the Niagara Falls Golf Club (PTTW no. 8470-9ZXR6N) uses groundwater for supply (i.e., irrigation); the remaining groundwater users obtained permits for dewatering purposes only. As such, Niagara Falls Golf Club is the only permitted groundwater user in the study area which could be impacted and has been included in the proposed well mitigation plan.

4.1.2 SURFACE WATER CONDITIONS

4.1.2.1 SURFACE WATER FLOW

The assessment of groundwater / surface water interaction under baseline conditions in the Existing Watercourse and Beaverdams Creek and their associated wetland complexes included in **Section 2.5.3** indicates that there is minimal groundwater contribution to these surface features due to the presence of the thick, low hydraulic conductivity silt and clay soils of the upper aquitard. Where the overburden is thickest, groundwater discharge to these surface water features is estimated to be less than 0.1 L/s. In the area where the overburden is thinner (i.e., the reach of the Existing Watercourse north of Upper's Lane and the Welland Canal South Turn Basin northwest of the Site), groundwater discharge is also estimated to be less than 0.1 L/s. The calibrated baseline model subwatershed water balance is generally consistent with these observations.

The full development model subwatershed water balance indicates that there is an overall reduction in discharge to the Existing Watercourse and Beaverdams Creek and associated wetlands. The change is relatively small, about a 1 mm/year reduction averaged over the subwatershed. However, the quarry dewatering discharge will be directed to these creeks, with a predicted rate of 4,268 m^3/day (50 L/s) during the summer / autumn months, about 101 mm/year averaged over the subwatershed. As a result, the surface water flow within the Existing Watercourse and Beaverdams Creek will increase during the operational phase of the proposed quarry. The Welland Canal South Turn Basin, a net gaining surface water feature under baseline conditions, is predicted to switch to a net losing surface water feature at full quarry development. But as discussed, the discharge from the quarry dewatering exceeds this deficit.

Under baseline conditions, pooled surface water in the 5584 Beechwood Road wetland is subject to a downward vertical hydraulic gradient and results in groundwater recharge through the silt and clay upper aquitard to the underlying aquifer. Observed baseline groundwater recharge rates range between 15 mm/year and 29 mm/year.

Groundwater recharge was estimated for full quarry development conditions, where the underlying bedrock aquifer acts as a drain (i.e., the vertical hydraulic gradient through the silt and clay aquitard is at the maximum theoretical value of 1.0). The full quarry development vertical gradients are depicted on **Figures 27A and 27B**, for wet and dry years respectively. Groundwater recharge rates range between 3 mm/month and 4 mm/month during wet years, and about 3 mm/month during dry years. Overall, annual groundwater recharge rates between 20 mm/year and 40 mm/year are predicted at full quarry development. This results in an increase in groundwater recharge at full quarry development, between 5 mm/year and 11 mm/year greater than baseline conditions. This increased loss from the wetland represents between 2% and 4% of the average annual water surplus at the Site and is therefore considered negligible. These results demonstrate that the thick, low hydraulic conductivity soils of the upper aquitard effectively seal surface water from percolating downward to the aquifer, similar to the findings of the hydrogeological study completed as part of the Fernwood subdivision development southeast of the Site (AMEC, 2002). Other PSW features within the study area are underlain by an even thicker deposit of clay and silt material which effectively seals surface water from percolating downward to the aquifer. Based on these results, it is predicted that the proposed quarry development will not have an adverse impact on any of these wetland features.

Similar to the wetland at 5584 Beechwood Road, the woodlot feature west of Townline Road is a groundwater recharge area and is already partially under-drained under baseline conditions. As such, it is predicted that the woodlot will not be impacted by the proposed quarry.

4.1.2.2 SURFACE WATER QUALITY

As noted in **Section 2.6.3**, concentrations of total phosphorus and iron consistently exceed the PWQO in the Existing Watercourse under baseline conditions. As such, the Existing Watercourse is considered a Policy 2 receiver for these parameters under the PWQO, where

> *"Water quality which presently does not meet the Provincial Water Quality Objectives shall not be degraded further and all practical measures shall be taken to upgrade the water quality to the Objectives."*

All other parameters included in the baseline monitoring program are generally below the PWQO in the Existing Watercourse. For these parameters, the Existing Watercourse is considered a Policy 1 receiver, where

> *"In areas which have water quality better than the Provincial Water Quality Objectives, water quality shall be maintained at or above the Objectives."*

The proposed quarry dewatering discharge will be directed to the Existing Watercourse. The discharge will be a mixture of:

- ➔ Runoff from direct precipitation. The runoff will have a "meteoric" type signature and has been estimated to average approximately 14% of the total discharge during summer / autumn months (refer to the full development water balance, **Section H.7.2**, **Appendix H**).
- ➔ Groundwater inflow from the contact and shallow bedrock aquifers will make up the balance of the discharge. The relative ion ratio for these waters are calcium and carbonate enriched as shown in the trilinear diagram, **Figure 25**. A portion of groundwater inflow will also originate from the deeper bedrock units, in which the groundwater is sodium and chloride enriched, and generally more mineralized. However, the relative hydraulic conductivity difference between the contact and shallow bedrock aquifers and the deeper bedrock suggests that only a small portion of the groundwater inflow to the proposed quarry excavation will originate from the deeper bedrock. This interpretation is consistent with the pumping well discharge during the 2019 constant rate test at PW1, where the chloride and sodium concentrations in the discharge were consistent with the baseline ranges in the contact and shallow bedrock aquifers rather than the deeper bedrock. Therefore, the 2019 pumping test water quality results are anticipated to be similar to the future quarry discharge water quality.

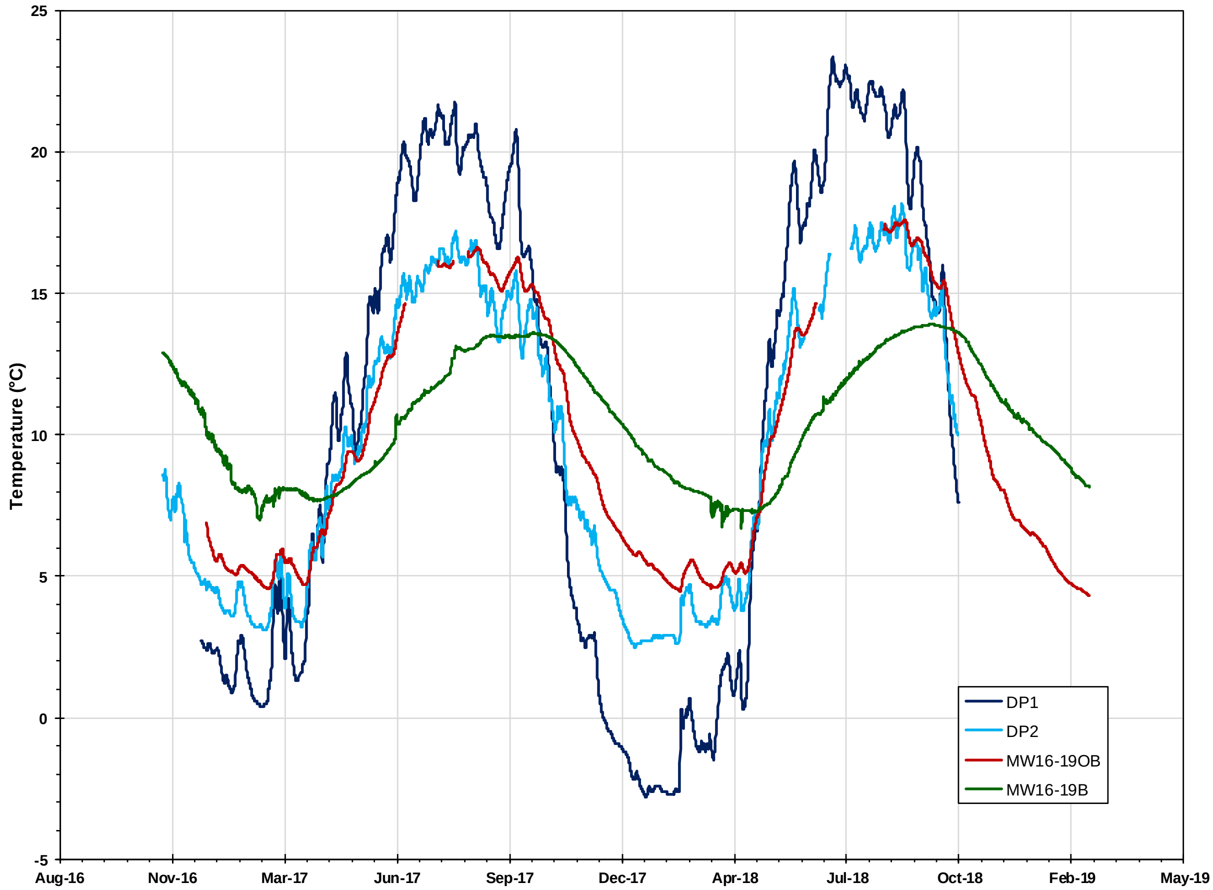
A comparison of the Existing Watercourse surface water and groundwater baseline water quality ranges for selected parameters is provided in the table below.

Parameter	PWQO	2019 PW1 Pumping Test Discharge	Baseline Median				
			Surface Water	Contact Aquifer	Shallow Bedrock Aquifer	Goat Island Member Bedrock	DeCew / Rochester Formation Bedrock
General Parameters							
pH (lab) (pH units)	**6.5 – 8.5**	7.59	7.98	7.90	7.64	7.52	6.68
Total Dissolved Solids		--	273	982	951	13,200	127,500
Total Suspended Solids		<2	27	--	--	--	--
Hardness		824	215	710	730	3,500	44,000
Turbidity	**(a)**	Visually clear	32	--	--	--	--
Hydrogen Sulphide (undissociated)	**0.002**	3.7	--	<0.005	0.9	0.6	1.8
Major Ions							
Chloride		150	85	46	74	9,000	75,500
Sulphate		352	68	240	310	780	1,000
Alkalinity	**(b)**	443	125	440	420	230	99
Calcium		188	55	98	140	950	9,350

Magnesium		88	17	110	91	270	4,850
Sodium		80	53	65	47	3,600	29,500
Potassium		4.0	4.0	3.2	3.1	51	435
Nutrients							
Nitrate		--	0.4	0.3	<0.1	<0.1	<1
Un-ionized Ammonia	**0.02**	<0.001	<0.001	--	--	--	--
Total Phosphorus	**0.03**	--	0.14	0.80	0.07	0.30	0.40
Metals *							
Aluminum	**0.075**	<0.01	0.009	0.006	<0.005	<0.005	<0.175
Boron	**0.2**	0.15	0.03	0.04	0.06	0.92	3.2
Total Chromium	**0.0089**	<0.001	<0.005	<0.005	<0.005	<0.025	<0.175
Cobalt	**0.0009**	<0.0002	0.0009	<0.0005	<0.0005	<0.0025	<0.0175
Copper	**0.005**	<0.001	0.0054	0.001	<0.001	<0.005	<0.035
Iron	**0.3**	0.73	2.15	<0.1	<0.1	<0.5	1.3
Lead	**0.025**	<0.001	0.0013	<0.0005	<0.0005	<0.0025	<0.0175
Molybdenum	**0.04**	<0.005	0.0008	0.0032	<0.0005	<0.0025	<0.0175
Nickel		<0.005	0.004	0.001	<0.001	<0.005	<0.035
Uranium	**0.005**	--	0.0008	0.0091	0.0018	0.008	<0.0015
Vanadium	**0.006**	<0.001	0.0030	0.0014	<0.0005	<0.001	<0.0175
Zinc	**0.03**	<0.01	0.010	0.011	<0.005	<0.025	<0.175

Notes: Concentrations in mg/L unless otherwise noted.
PWQO – Provincial Water Quality Objectives (MECP 1994 and updates)
Shaded values exceed the PWQO.
(a) Turbidity does not have a firm objective
(b) Alkalinity should not decrease by more than 25% of the natural concentration
* Total metals concentrations shown for 2019 pumping test and baseline surface water median; dissolved metals concentrations shown for baseline groundwater median.

In addition to water quality, temperature effects of the proposed quarry discharge on the Existing Watercourse and Beaverdams Creek have also been considered. The dataloggers that were installed to record water levels in the monitoring wells and surface water drivepoints also record temperature. Water temperature data for Beaverdams Creek (DP1) and the Existing Watercourse at the northern property boundary (DP2) are available since approximately November 2016. These data are included on the plot of water temperature shown below. For the groundwater temperature comparison, the data from nest MW16-19 shown on the plot below were chosen as this well nest has the thinnest overburden deposit encountered in the drilling program (i.e., groundwater at MW16-19 is the most susceptible to warmer surface temperatures during the summer months).



In southern Ontario, groundwater temperatures in the bedrock generally cycle within a relatively narrow range that tends to slightly lag the seasonal air temperature cycle. The plot of shallow bedrock aquifer groundwater temperature data from MW16-19B follows this pattern, ranging between approximately 8°C in early spring to approximately 14°C in early autumn. The plots of temperature data from MW16-19OB and DP2 are more similar, ranging from approximately 3°C in mid-winter to 17°C in mid-summer, since DP2 is located in a groundwater discharge zone. Finally, the plot of temperature data for DP1 follows a similar cycle to that of DP2, but the temperature extremes are more severe, ranging from approximately 0°C in mid-winter to 22°C in mid-summer.

The plot of temperature data above illustrates that the proposed quarry discharge to the Existing Watercourse and Beaverdams Creek will have a moderating effect on the surface water temperatures, since groundwater inflows are predicted to account for about 86% of the discharge volume in low flow periods during the late summer / autumn months when surface water temperatures are highest.

In summary, the proposed quarry discharge to the Existing Watercourse is predicted to generally improve surface water quality in the watercourse downstream of the Site. Concentrations of total phosphorus and metals (including boron, total chromium, cobalt, copper and iron) are predicted to be lower in the downstream water quality relative to upstream conditions. The proposed quarry discharge will also have a moderating effect on surface water temperature. Quality and quantity monitoring of the quarry sump discharge has been included in the proposed monitoring program, and a trigger mechanism and contingency plan has been provided in **Section 5.4**.

4.1.2.3 SURFACE WATER USE

A search of all current permitted surface water users in the study area has also been completed. The closest active surface water PTTW to the Site authorizes surface water takings by the Beechwood Golf & Country Club from Beaverdams Creek north of the Site (PTTW no. 4050-A7LLXS). As noted above in **Section 4.1.1.1**, the Welland Canal South Turn Basin northwest of the Site is predicted to experience under-draining as a result of proposed quarry dewatering, resulting in a net outflow of approximately 18 mm/year to the groundwater system. However, surface water levels within the turn basin are not anticipated to be impacted since (1) there is a direct hydraulic connection to the Welland Canal where the water levels are maintained at a consistent elevation, and (2) discharge from the proposed quarry dewatering will be directed to the Existing Watercourse and ultimately flow to Beaverdams Creek (i.e., the turn basin reservoir where Beechwood Golf & Country Club obtains their water). As such, the surface water takings at Beechwood Golf & Country Club will not be impacted by the proposed quarry.

The remaining permitted surface water users obtain takings from either the Welland Canal or the Welland River. As noted previously, water levels in the Welland Canal are maintained at a consistent elevation with water from Lake Erie. The Welland River is interpreted to receive the majority of its baseflow from surface runoff with minimal baseflow originating as groundwater discharge. Therefore, permit users on either the Welland Canal or Welland River will not be impacted by the proposed quarry.

4.2 FINAL REHABILITATION CONDITIONS

Numerical groundwater modeling was completed to predict the long-term steady-state effects of the proposed Site end use as a series of lakes. A final lake stage elevation of 175.15 masl was adopted in the rehabilitated model corresponding to an outlet spillway to be constructed at the northern limit of the Site.

4.2.1 GROUNDWATER CONDITIONS

Because the predicted average stage elevation of the final lakes is marginally lower than the existing groundwater potentiometric surface, the lakes will receive future groundwater discharge from the shallow bedrock aquifer. The predicted available drawdown in the shallow and deep aquifers at final rehabilitation is shown on **Figure 28**.

Both the area and magnitude of the drawdown under final rehabilitation conditions are significantly less than those predicted for the full quarry development conditions, and the predicted available drawdown is nearly identical to baseline conditions. Groundwater users which are in close proximity to the final lake are predicted to have a sufficient available drawdown to meet their water supply needs. Similar to full quarry development conditions, no adverse groundwater quality impacts are predicted under final rehabilitation conditions.

It is anticipated that shallower portions of the final lake could have water temperatures which are elevated above those of the groundwater during summer months and potentially influence groundwater temperatures outside of the quarry lake footprint. However, there is predicted to be a net inflow of groundwater to the final lake (refer to **Section H.8.2**, **Appendix H**). Water which enters the shallow bedrock aquifer would be subject to cooling by the large thermal mass of the bedrock (refer to **Section 4.1.2.2** above) such that any impact would be localized.

4.2.2 SURFACE WATER CONDITIONS

Surface water features, which were marginally net losing at full quarry development, revert to marginally net gaining under final rehabilitation conditions, which is similar to baseline conditions. There is a marginal reduction in baseflow to surface watercourses, from about 2 mm/year under baseline conditions to about 0.4 mm/year at final rehabilitation.

At full development, the Welland Canal South Turn Basin reservoir is predicted to switch to a groundwater recharge area; however, at final rehabilitation, it reverts to a groundwater discharge area, albeit with a reduction in groundwater discharge of 2 mm/year in comparison to baseline conditions during summer / autumn. However, the final rehabilitation model predicts that a steady flow of approximately 1,044 m^3/day (12 L/s) would passively discharge from the final lakes to the reach of the Existing Watercourse (and the Welland Canal South Turn Basin reservoir) north of the Site during the drier months. This added discharge (approximately 25 mm/year normalized over the subwatershed area) compensates for any reduction in groundwater baseflow. Based on these predictions, the surface water takings at Beechwood Golf & Country Club will not be negatively impacted under final rehabilitation conditions.

The shallow bedrock aquifer underlying the wetland feature at 5584 Beechwood Road is predicted to experience a permanent drawdown in the underlying bedrock of between 2 m to 3 m. From the cross-sections showing baseline conditions in the shallow bedrock aquifer (**Figures 22A and 22B**), this wetland feature is predicted to experience under-draining to the bedrock on a permanent basis. However, as noted in **Section 4.1.2.1** above, the wetland will not experience any adverse impacts at final rehabilitation due to the presence of the thick silt and clay upper aquitard.

As noted previously, when the quarry lakes reach their final stage elevation, a passive discharge of approximately 1,044 m^3/day to the Existing Watercourse north of the Site is predicted during the summer / autumn. This is similar to full development conditions when quarry dewatering discharge is directed to the creek, although the rate of discharge at final rehabilitation is lower. The passive discharge will be a combination of groundwater inflows and direct precipitation. As was demonstrated in **Section 4.1.2.2** above, discharge of the bedrock groundwater to the Existing Watercourse is anticipated to generally improve the surface water quality. Nonetheless, a surface water quality monitoring program in the lake after quarry decommissioning will be completed.

4.3 CUMULATIVE ASSESSMENT

As noted in **Appendix H**, known permitted groundwater users are included in the calibrated baseline, full development and final rehabilitation models to assess the cumulative impacts from the proposed quarry and existing permitted groundwater users. The combined pumping effects of the existing Walker Brothers Quarry and the proposed quarry at the Site have been accounted for in the predictive model simulations.

Non-permitted groundwater users include private domestic well users, and wells used for livestock watering or crop irrigation. Estimates of the annual demand for these non-permitted groundwater users are provided in the NPCA source protection report (NPCA, 2013). The estimated annual demand from non-permitted groundwater users averaged over the watershed area is less than 1 mm/year. As such, the cumulative impact from these additional non-permitted takings is interpreted to be negligible.

5 MITIGATION

To mitigate the impacts of the proposed quarry on the features noted in **Section 4**, the following measures are proposed:

- Maintain the current well network and continue the proactive and long-term groundwater and surface water monitoring program to confirm predicted effects of the proposed quarry dewatering. A future PTTW / ECA groundwater monitoring component satisfactory to the MECP will be incorporated into the program as required;
- Prior to extraction of bedrock resources, proactively implement a well interference and mitigation plan to ensure that the limited number of impacted groundwater users will have adequate future groundwater supplies;
- Develop and administer a spill action plan throughout all phases of quarry operations; and
- Implement a trigger mechanism and contingency plan, which includes procedures for mitigating potential impacts from the proposed quarry discharge to the Existing Watercourse.

5.1 PROPOSED MONITORING PROGRAM

The purpose of the proposed monitoring program is to:

- Proactively monitor groundwater and surface water resources during the operational and rehabilitation phases of the proposed quarry until stable lake elevations are reached and compare to baseline conditions;
- Maintain a record of daily water takings from the proposed quarry sump(s);
- Resolve potential water well interference claims with local groundwater users; and
- Provide documentation of the monitoring and assessment results and provide recommendations for operational or monitoring improvements if necessary.

The proposed monitoring program is summarized on **Table 1**. The monitoring locations are shown on **Figure 29**. As shown on **Table 1**, all monitoring well locations are to be included for both water level and water quality monitoring. It is noted that well nests MW16-17 and MW16-18, and surface water station SW4 are within the proposed quarry extraction footprint. These monitoring locations have been included in the proposed monitoring program but will eventually need to be decommissioned as the quarry excavation proceeds. Also, monitoring wells located around the perimeter of the Site may need to be retrofitted with extended riser pipes as the perimeter berms are constructed. Finally, well nest MW17-20 and the private wells are situated on privately owned lands and future monitoring is subject to homeowner consent.

Additional private supply wells may be incorporated to the monitoring program over time. PTTW applications / renewals typically require an updated water well survey to be completed. It is expected that over time, additional water well users within the study area may participate in the voluntary residential well monitoring program. Participation will be encouraged by WAI.

An annual monitoring report, summarizing all monitoring activities, an interpretation of the monitoring results and any recommendations, will be produced for each calendar year during the operational phase of the quarry until the license is surrendered after final rehabilitation is achieved and lake levels have stabilized.

5.2 PROPOSED WELL INTERFERENCE MITIGATION

5.2.1 SERVICED AREAS

A significant portion of the study area is within the urban boundaries of the City of Niagara Falls and City of Thorold. In addition, the Master Servicing Plan (Niagara Region, 2016) indicates that the urban areas, and portions of the study area outside of the urban boundaries, are serviced by the existing municipal water supply system.

The Rolling Meadows Secondary Plan area is not completely serviced at the time of this study, but the planning documents indicate that the water supply system will be extended to service the entire secondary plan area.

5.2.2 UN-SERVICED AREAS

Landowners for parcels outside of the serviced area rely on a mix of groundwater wells and / or cisterns for domestic supply, commercial, agricultural (including livestock watering and irrigation) and garden watering as identified in the 2018 / 2019 residential water well survey results presented in **Section 2.5.4.2**. A well interference and mitigation plan had been formulated to ensure that the limited number of impacted groundwater users in the un-serviced area will have adequate future groundwater supplies.

The Well Mitigation Area (WMA) is defined as the area outside of the existing water supply system which is predicted to experience a drawdown from the proposed quarry dewatering at levels which may impact the operation of existing private supply wells. The licensee (WAI), at their expense, will be required to restore water quantity / quality for any private water supply well adversely impacted by the proposed quarry operation. For simplification, the WMA has been broken down into five smaller areas, as summarized below. The WMA south areas are shown on **Figure 30A** while the WMA north areas are shown on **Figure 30B**.

WMA	Name	Parcels with Mailing Address / Structure				Table Reference
		Total	Cistern Users	Confirmed Groundwater Users	Assumed Groundwater Users	
1	Close Proximity	11	6	5	0	**Table 2** (South Areas)
2	City of Thorold Urban Area	17	3	3	11	
3	South Group	17	4	8	5	
4	North Group	41	19	10	11	**Table 3** (North Areas)
5	Walker Brothers Quarry Monitoring Area	20	0	12	8	

Existing residents in the WMA have been contacted through hand-delivered mailings and / or personal door-to-door visits. Although numerous attempts at contact were made for this study, some residents could not or did not provide a response to our queries for a water supply survey. In these cases, a drinking water well for domestic supply was assumed as a conservative measure. Appropriate mitigation measures were developed for all known and assumed water well users within the WMA on a case-by-case basis, as shown in **Table 2** (south areas) and **Table 3** (north areas). Conceptual cross sections for the un-serviced areas south, north and east of the Site showing selected water well users are provided on **Figures 31A, 31B and 31C**, respectively. Prior to extraction of bedrock resources within the proposed quarry, WAI will proactively implement the proposed well mitigation measures. A detailed summary of the proposed well mitigation measures for each of the five WMA areas is provided in the sections below.

5.2.2.1 WMA-1 – CLOSE PROXIMITY

Parcels within WMA-1 are predicted to experience the greatest decrease in available drawdown at full quarry development. Of the eleven (11) parcels with a mailing address / structure in WMA-1, there are six (6) cistern users and five (5) known water well users for domestic supply. The resident at 10148 Beaverdams Road obtains their domestic supply by a cistern but utilizes a well for irrigation. It is interpreted that the irrigation well will have a sufficient available drawdown (i.e., > 3 m) to maintain supply for irrigation at full quarry development. The water well user at 9941 Lundy's Lane is interpreted to have sufficient available drawdown if the existing well is deepened to the base of the Goat Island member bedrock and the existing treatment system is utilized.

The remaining four (4) well users will require well deepening into the deep bedrock aquifer or lower bedrock units to provide a sufficient water column to meet demand. The addresses of the users are as follows:

- ➔ 8980 Beaverdams Road (residence with one well)

- ➔ 9582 / 9602 Beaverdams Road (office / rental property with one well)
- ➔ 5584 Beechwood Road (residence with one well); and
- ➔ 5821 Beechwood Road (residence with one well).

The baseline groundwater chemical results indicate that groundwater from the deep bedrock aquifer and lower bedrock units may be of poorer quality. Depending on the intended use of the water well (i.e., domestic vs. irrigation), treatment of the well water will likely be required prior to consumption. Both well deepening and treatment systems would be provided by WAI with no expense for the groundwater users.

5.2.2.2 WMA-2 – CITY OF THOROLD URBAN AREA

Parcels within WMA-2 were separated into their own group since this currently un-serviced area is planned for future servicing as part of the Rolling Meadows Secondary Plan. If required, well mitigation measures for this area could be provided on an interim basis until servicing has been completed.

Of the seventeen (17) parcels with a mailing address / structure in WMA-2, there are three (3) cistern users, three (3) known water well users and eleven (11) assumed water well users for domestic supply. These parcels generally have predicted available drawdowns of at least 30 m. The baseline groundwater chemical results for this bedrock unit, as well as the results of the hydraulic testing, suggest that if necessary, water well users within WMA-2 could have their existing wells deepened to the base of the Eramosa member bedrock and maintain their existing quantity / quality of well water under full quarry development.

The exception is the known water well user at 5114 Townline Road (Niagara Cricket Centre). The existing well is currently used for irrigation and is included in the proposed monitoring program (R5). The existing well could be deepened to the deeper bedrock units and treatment provided, if necessary. Both well deepening and treatment systems would be provided by WAI with no expense for the groundwater users.

5.2.2.3 WMA-3 – SOUTH GROUP

The parcels within WMA-3 have predicted available drawdowns of at least 20 m. Of the seventeen (17) parcels with a mailing address / structure in WMA-3, there are four (4) cistern users, eight (8) known water well users and five (5) assumed water well users for domestic supply. The data suggest that if necessary, these well users could have their existing wells deepened and maintain the quantity / quality of well water under full quarry development.

The exception is the unconfirmed but assumed well user at 6070 Beechwood Road where it is predicted that the well could be deepened to the deeper bedrock units to provide adequate supply. If deepening is required, the well water may be of poorer quality and could require treatment, depending on the intended use (information on water well use was not provided during the water well survey). It is noted that the owner of a nearby property (9552 Lundy’s Lane) indicated that their water well is currently in use for garden watering only. The existing well at that location was noted to be approximately 26 m deep, which is interpolated to extend to the Goat Island member bedrock. If the well at 6070 Beechwood is of similar design and use, it is predicted that mitigation would not be required.

5.2.2.4 WMA-4 – NORTH GROUP

The parcels within WMA-4 have predicted available drawdowns of between 6 m and 22 m. Of the forty-one (41) parcels with a mailing address / structure in WMA-4, there are nineteen (19) cistern users, ten (10) known water well users and twelve (11) assumed water well users for domestic supply. If necessary, these well users could have their existing wells deepened and maintain the quantity / quality of well water under full quarry development.

5.2.2.5 WMA-5 – WALKER BROTHERS QUARRY MONITORING AREA

Parcels north of the Site that are included in the Walker Brothers Quarry monitoring program or are in close proximity to that quarry were placed into WMA-5. Of the twenty (20) parcels with a mailing address / structure in WMA-5, there are twelve (12) known water well users and eight (8) assumed water well users for domestic supply. The available information for WMA-5 suggests that the existing wells will not require deepening. However, there is the potential to have these existing wells deepened and maintain the quantity / quality of well water under full quarry development if required.

5.2.3 WATER WELL INTERFERENCE MITIGATION PLAN

A number of residential wells in the un-serviced area around the Site have been included in the proposed monitoring program to provide confirmation of predicted effects. The proposed monitoring program is comprehensive and will be able to assess potential impact to a well and allow proactive mitigation in advance of a well being adversely impacted. In the event a well interference claim is received, the licensee will be required to implement the following mitigation plan to protect the local groundwater users.

Prior To Extraction

A) Landowners shall be provided with a copy of the water well interference plan as well as the contact information for the licensee and MECP (Wells Help Desk 1-888-396-9355 or email wellshelpdesk@ontario.ca).

Water Well Interference Mitigation Plan

A) If a water well interference claim is received by the licensee the following actions will be taken:
   - The licensee will immediately notify MNRF and MECP of the complaint.
   - The licensee will contact a well contractor in the event of a well malfunction and residents will be provided a temporary water supply within 24 hours, if the issue cannot be easily determined and rectified.

B) The well contractor will contact the resident with the supply issue to rectify the problem as expediently as possible, provided landowner authorization of the work.

C) If the issue raised by the landowner is related to loss of water supply, the licensee will have a qualified hydrogeologist / well contractor determine the likely causes of the loss of water supply, which can result from a number of factors, including pump failure (owner's expense), extended overuse of the well (owner's expense), lack of well maintenance / well cleaning (owner’s expense) or lowering of the water level in the well from the quarry development (licensee expense). This assessment process would be carried out at the expense of the licensee and the results provided to the homeowner.

D) If it has been determined that the quarry caused the water supply interference (i.e., lowering of the water level), the quarry shall continue to supply water at the licensee's expense until the problem is rectified. The following mitigation measures shall be considered, and the appropriate measure(s) implemented at the expense of the licensee:

- adjust pump pressure;
- lowering of the pump to take advantage of existing water storage within the well;
- deepening of the well to increase the available drawdown, if the well deepening changes the water quality a water treatment shall be provided;
- widening of the well to increase the available storage of water;
- relocation of the well to another area on the property; or
- drilling multiple wells.

E) If the issue raised by the landowner is related to water quality, the licensee will have a qualified hydrogeologist / well contractor determine the likely causes of the change in water quality, and review monitoring results at the quarry and background monitoring results from the baseline well survey to determine if there is any potential correlation with the quarry. If it has been determined that the quarry caused a water quality issue, the quarry shall continue to supply water at the licensee's expense until the problem is rectified. The licensee shall be responsible for restoring the water supply by replacing the well or providing a water treatment system. The licensee is responsible for the expense to restore the water quality.

5.3 SPILL ACTION PLAN

WAI will develop and implement a detailed spill action plan (SAP) throughout all phases of quarry operations. Fuel and petroleum products are managed according to applicable Ontario regulations. No impact to surface or groundwater resources is anticipated from petroleum handling as a result of the proposed quarry.

5.4 DISCHARGE TRIGGER MECHANISM AND CONTINGENCY PLAN

The proposed monitoring program will allow a comparison of observed conditions throughout the quarry development to baseline conditions. The predicted effects of the quarry have been outlined above and are based on the numerical groundwater model simulations and baseline water quality. Should the observed quarry effects differ from those predicted, a trigger mechanism has been developed to trigger the implementation of appropriate contingency measures to mitigate impacts before they occur. The proposed quarry dewatering discharge will be directed to the Existing Watercourse, and ultimately flow to Beaverdams Creek. The discharge water will consist of a mixture of direct precipitation and groundwater inflows from the contact aquifer, shallow bedrock aquifer, deep bedrock aquifer and likely a small contribution from the underlying lower aquitard. The ratio of groundwater contribution from each unit is related to the relative hydraulic conductivities. Based on the hydraulic testing completed as part of this study, it is interpreted that the majority of the groundwater inflow will originate from the shallow bedrock aquifer. Therefore, it is predicted that the proposed quarry discharge will have similar water quality to the shallow bedrock aquifer baseline ranges. The observed 2019 pumping test discharge water quality, which is predicted to be similar to the future quarry discharge water quality, supports this interpretation.

Monthly sampling of the quarry sump discharge has been included in the proposed monitoring program, for the analysis of parameters with an associated PWQO, as well as selected parameters which aid in the assessment of influence from the various bedrock units. The proposed trigger mechanism for the sump discharge to the Existing Watercourse is to assess the monthly sump water quality results against the proposed list of trigger concentrations summarized in the table below.

Parameter	Proposed Trigger Concentration	Applicable Standard
pH (pH units)	6.5 – 8.5	PWQO / MISA
TSS	25	MISA
Hydrogen Sulphide (undissociated	0.002	PWQO
Total Oil and Grease	No visible sheen or odour	PWQO

Notes: Trigger concentrations in mg/L unless otherwise noted.

The shallow bedrock aquifer groundwater is more mineralized / harder than the surface water in the vicinity of the Site; however, it satisfies the PWQO for most parameters. The two exceptions are undissociated hydrogen sulphide and total phosphorus. A trigger for hydrogen sulphide has been included in the trigger mechanism for quarry discharge. In the case of total phosphorus, the median total phosphorus concentration in the baseline surface water quality currently exceeds the PWQO, making the Existing Watercourse a Policy 2 receptor for this parameter. It is predicted that the total phosphorus concentration in the future quarry discharge will be below that of the upstream surface water in the Existing Watercourse. As such, total phosphorus has not been included in the trigger mechanism.

The Municipal Industrial Strategy for Abatement (MISA) was also considered; as such, pH, total suspended solids (TSS) and total oil and grease have also been included in the proposed trigger mechanism.

The monthly sump discharge sample results will be compared with the background conditions in the Existing Watercourse (station SW3) and Beaverdams Creek (station SW1). If parameter concentrations in the sump discharge exceed the above trigger concentrations without a corresponding exceedance in the background surface water, then weekly sampling of the quarry sump will be initiated. Weekly sampling will continue until less than two parameter concentrations in the sump discharge exceed the trigger concentrations.

If weekly sampling is required for a period of more than four (4) weeks, contingency measures would be implemented to reduce concentrations in the future quarry discharge. Trigger exceedances for pH, TSS and total oil and grease would initiate a review of the design and operation of the quarry discharge sump. Where required, improvements would be made to reduce discharge concentrations.

At existing pits and quarries within southern Ontario, hydrogen sulphide is typically not routinely included in the trigger mechanism. In southwestern Ontario, where the bedrock geology can favour hydrogen sulphide in groundwater, an Effluent Objective for hydrogen sulphide has been included in site ECAs. A sump or holding pond with a large surface area normally allows enough off-gassing of the hydrogen sulphide to meet the Effluent Objectives. For the proposed quarry, the need for sufficient off-gassing of hydrogen sulphide will be taken into consideration during the design and construction of the internal ditch network and sump pond for the Site. It is anticipated that the hydrogen sulphide concentration in the discharge to the Existing Watercourse will be lower than the PWQO / trigger concentration as a result of the off-gassing. If the hydrogen sulphide concentrations in the discharge are found to consistently exceed the proposed trigger once the operational phase of the proposed quarry begins, then a review of the design and operation of the internal ditch network and sump pond would be completed with the objective of increasing the rate of off-gassing prior to discharge. Additional measures, such as aeration of the pond, could also be employed to enhance the off-gassing of hydrogen sulphide.

6 SUMMARY OF FINDINGS AND RECOMMENDATIONS

The following is a summary of the key findings of the Level 2 Water Report undertaken to meet the study requirements for the Category 2, Class A License (Quarry Below Groundwater) application.

- ➔ Hydrogeologic / hydrologic features of concern within the local study area include:
  - groundwater quantity and quality in the shallow and deep bedrock aquifers;
  - surface water quantity and quality in the Existing Watercourse, Beaverdams Creek and the Welland Canal South Turn Basin reservoir;
  - groundwater discharge to the Existing Watercourse north of the Upper's Lane and the Welland Canal South Turn Basin reservoir;
  - the wetland feature at 5584 Beechwood Road and PSWs south of the Site; and
  - local groundwater users.
- ➔ A steady-state numerical groundwater flow model was constructed to simulate baseline hydrogeological conditions at the Site, calibrated to observed baseline conditions in autumn (October). The calibrated baseline model was then modified to predict the effects of quarry dewatering on water features at both full quarry development and at final rehabilitation. Known permitted groundwater users are included in the models to assess the cumulative impacts from the proposed quarry and existing groundwater users.

Groundwater Quantity and Quality

- ➔ The predicted available drawdown in the shallow and deep bedrock aquifers at full quarry development indicates that the proposed quarry will impact a defined portion of the groundwater quantity in the study area aquifers. However, much of the study area is either currently serviced, or planned for future servicing. As such, impacts on groundwater use occur within a relatively limited un-serviced area between the urban boundaries of the City of Niagara Falls and City of Thorold. Groundwater quality impacts are not predicted.

Surface Water Quantity and Quality

- ➔ No measurable effects to surface water quantity are predicted within the study area as a result of the proposed quarry dewatering. The baseline data indicate that there is minimal groundwater contribution to the surface water features due to the presence of the thick silt and clay soils of the upper aquitard.
- ➔ Surface water quality within the Existing Watercourse and Beaverdams Creek is predicted to be improved by the proposed quarry discharge during the operational phase. The baseline surface water quality monitoring results indicate that the ambient surface water quality in these creeks is generally poor as a result of existing anthropogenic sources. The proposed quarry dewatering discharge will be directed to the Existing Watercourse, with groundwater inflows accounting for

approximately 86% of the flow volume in low flow periods during the summer / autumn months. Most baseline groundwater parameter concentrations are lower than those of the baseline surface water quality; as such, the discharge would improve water quality within the watercourse. Quality and quantity monitoring of the quarry sump discharge has been included in the proposed monitoring program, and a trigger mechanism and contingency plan has been developed to mitigate potential impacts.

- Baseline groundwater and surface water temperature data from the Existing Watercourse and Beaverdams Creek indicate that the proposed quarry discharge will have a moderating effect and not adversely impact surface water temperatures in the creeks.
- The proposed quarry will be progressively rehabilitated with the end use as a series of lakes. It is predicted that groundwater discharge would passively flow from the final lakes to the reach of the Existing Watercourse (and the Welland Canal South Turn Basin reservoir) north of the Site. Monitoring of the water quality during lake-filling has been included in the recommended monitoring program.
- Based on these predictions, the surface water takings at Beechwood Golf & Country Club will not be negatively impacted during the operational phase of the proposed quarry or under final rehabilitation conditions.

Groundwater Discharge Areas

- Areas of potential impact occur where groundwater discharge is observed, including the reach of the Existing Watercourse north of Upper's Lane, and the Welland Canal South Turn Basin reservoir north of the Site. At these locations, there is a predicted overall reduction in the groundwater discharge at full quarry development. However, the future quarry discharge will be directed to these surface water features and as a result, surface water flow rates will in fact increase during the operational phase of the proposed quarry. This discharge from the quarry dewatering compensates for any reduction in groundwater baseflow. As a result, no impact to surface water quantity due to the reduction of groundwater discharge to these features is predicted.
- At final rehabilitation, the Welland Canal South Turn Basin reservoir reverts to a groundwater discharge area similar to baseline conditions, albeit with a marginal reduction in the discharge rate. However, passive surface discharge from the final quarry lakes to the Existing Watercourse flows into the turn basin reservoir. This quantity of passive discharge compensates for any decrease in direct groundwater discharge.

Wetland Feature at 5584 Beechwood Road

- No measurable effects are predicted for the mapped wetland feature situated at 5584 Beechwood Road east of the Site. This feature is reliant on direct precipitation to maintain conditions within the wetland. Under baseline conditions, pooled surface water is subject to a downward vertical hydraulic gradient, resulting in groundwater recharge through the silt and clay upper aquitard to the underlying aquifer. At full quarry development, drawdown in the underlying bedrock aquifer is predicted to increase the rate of groundwater recharge by between 5 mm/year and 11 mm/year greater than baseline conditions. The increased losses from the wetland are equivalent to 2% to 4% of the average annual water surplus at the Site and are therefore considered negligible. The wetland feature at 5584 Beechwood Road is predicted to experience conditions similar to operating quarry conditions at final rehabilitation. Other PSW features within the study area south of the Site are underlain by even thicker deposits of clay and silt which effectively seal surface water percolation to the aquifer. Based on these results, it is predicted that the proposed quarry development and rehabilitation will not have a measurable effect on any of these wetland features.

Local Groundwater Users

- ➔ Residents that currently rely on cisterns will not be impacted by the proposed quarry dewatering. The severity of the impacts to water well users in the un-serviced portion of the study area during the operational phase of the proposed quarry is dependant on the available drawdown in the individual wells and the proximity to the proposed quarry. The numerical model predicted available drawdown at full quarry development, together with the pre-quarry baseline available drawdown information and the water well survey information were used to formulate a detailed well mitigation plan. This plan will ensure that the limited number of impacted groundwater users in the un-serviced area will have adequate future groundwater supplies. Any monitored impacts can be mitigated. Deepened replacement wells and, in some cases, treatment would be provided at the Licensee expense for affected private well users.
- ➔ The predicted average stage elevation of the quarry lake at final rehabilitation (175.15 masl) is marginally lower than the existing groundwater potentiometric surface. However, groundwater users near the final lake are predicted to have a sufficient available drawdown to meet their future needs. Monitoring will continue until the final lakes achieve stable levels for passive discharge into the Existing Watercourse.

Recommendations

To mitigate the impacts of the proposed quarry, the following recommendations will be implemented upon licence approval:

- ➔ A proactive and long-term groundwater and surface water monitoring program will be completed during the quarry operational and rehabilitation phases, until stable conditions are observed after quarry dewatering has ceased and lake-filling is complete;
- ➔ A well interference and mitigation plan will be implemented proactively prior to quarry operation;
- ➔ A spill action plan will be developed and administered throughout all phases of quarry operations; and
- ➔ A trigger mechanism and contingency plan, which includes procedures for mitigating potential impacts from the proposed quarry discharge to the Existing Watercourse will be implemented.

REFERENCES

Armstrong, D.K. and Carter, T.R., 2010. *The Subsurface Paleozoic Stratigraphy of Southern Ontario*. Ontario Geological Survey, Special Volume 7, 301p.

AECOM, 2008. *Environmental Constraints Analysis*. Prepared for Walker Aggregates, October 2008.

AMEC Earth & Environmental Limited, 2002. *Hydrogeological Investigation – Fernwood Development, Lundy's Lane, Niagara Falls*.

Bolton, T.E., 1957. *Silurian Stratigraphy and Paleontology of the Niagara Escarpment in Ontario*. Geological Survey of Canada Memoir 289, issued December, 1957.

Chapman, L.J. and Putnam, D.F., 1984. The Physiography of Southern Ontario. Ontario Geological Survey, Special Volume 2.

Conestoga-Rovers & Associates (CRA), 2015. *2014 Annual Operation, Maintenance and Monitoring Report.* Prepared for the Regional Municipality of Niagara, March 2015. CRA Project No. 074075.

Cramer, B.D., et al, 2011. *Revised Correlation of Silurian Provincial Series of North America with Global and Regional Chronostratigraphic Units and δ13Ccarb Chemostratigraphy*. Lethaia, Vol. 44, pp. 185-202.

Doherty, J. 2016. *PEST – Model-Independent Parameter Estimation and Uncertainty Analysis, User Manual: 6th Edition*. Watermark Numerical Computing, Queensland, Australia, April 2016.

Domenico, P.A., and Schwartz, F.W., 1998. *Physical and Chemical Hydrogeology*. John Wiley & Sons, New York, 506 p.

Freeze, R.A., Cherry, J.A., 1979. *Groundwater.*

Gartner Lee Limited (GLL), 1985. *Cyanimid Canada Inc., Hydrogeological Study, Welland Plant, Phase 1*. Prepared for Cyanimid Canada Inc., February 1985. GLL Project No. 84-26.

GLL, 2006. *Pre-Feasibility Assessment of Stream Relocation, Niagara Region*. Prepared for Walker Industries Holdings Limited, Aggregates & Construction Division, July 2006.

Golder Associates Ltd., 2012. *Physical Properties Testing of Aggregate Derived from Uppers Quarry Rock Core, Project No. 11-1152-0098*. Prepared for Walker Aggregates Inc., January 2012.

Harbaugh, A.W. 1990. *A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular three-dimensional ground-water flow model*. U.S. Geological Survey Open-File Report 90-392, 46pp.

Jagger Hims Limited (JHL), 2004. *Resource Assessment, Rolling Meadows Site, Townships of Thorold and Niagara Falls, Regional Municipality of Niagara*. Prepared for Walker Brother Quarries Limited, July 2004. JHL Project No. 0981023.02.

JHL, 2006. *Geotechnical Report, Abitibi Thorold Mill – Cogeneration Plant, Thorold, Ontario*. Prepared for Northland Power Inc., July 2006. JHL Project No. 1040244.01.

Liberty, B.A., Feenstra, B.H., and Telford, P.G., 1976. *Paleozoic Geology, Niagara, Southern Ontario*. Ontario Division of Mines, Map 2344, 1:50,000.

Meier, P.M., Carrera, J., and Sanchez-Vila, X., 1998. *An Evaluation of Jacob's Method for the Interpretation of Pumping Tests in Heterogeneous Aquifers*. Water Resources Research, Vol. 34, No. 5, pp. 1011-1025.

Ministry of the Environment, Conservation and Parks (MECP), 1994. *Water Management: Policies, Guidelines, and Provincial Water Quality Objectives.*

MECP, 2006. *Technical Support Document for Ontario Drinking Water Standards, Objectives, and Guidelines.*

MECP, 2008. *Technical guidance document for hydrogeological studies in support of Category 3 applications for Permit to take Water, Ministry of the Environment, April 2008.*

Ministry of Natural Resources, 1997. *Aggregate Resources of Ontario Provincial Standards, Version 1.0. Toronto: Ministry of Natural Resources, Natural Resource Management Division, June 1, 1997.*

Muffels, C., et al. 2018. *User's Guide for mod-PATH3DU. A groundwater path and travel-time simulator*. S.S.Papadopulos & Associates, Inc., Bethesda, MD and University of Waterloo, Waterloo, ON. Updated November 2018. Available at http://mp3du.sspa.com/man/.

Niagara Peninsula Conservation Authority (NPCA), 2013. *Updated Assessment Report, Niagara Peninsula Source Protection Area*. Prepared for Niagara Peninsula Source Protection Authority, November 2013.

NPCA, 2017. *Factors Affecting Water Level Fluctuations in NPCA Monitoring Wells*. December 2017.

Ontario Geological Survey (OGS), 1985a. *Aggregate Resources Inventory of Towns of Grimsby and Lincoln and the Township of West Lincoln, Regional Municipality of Niagara, Southern Ontario.* Ontario Ministry of Natural Resources, OGS ARIP 104.

OGS, 1985b. *Aggregate Resources Inventory of the Township of Wainfleet, Regional Municipality of Niagara, Southern Ontario.* Ontario Ministry of Natural Resources, OGS ARIP 115.

Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., and Hughes, J.D. 2017. *MODFLOW-USG Version 1.4.00: An Unstructured Grid Version of MODFLOW for Simulating Groundwater Flow and Tightly Coupled Processes Using a Control Volume Finite-Difference Formulation*. U.S. Geological Survey Techniques and Methods, book 6, chapter A45, 66pp.

Urban & Environmental Management (UEM) Inc. and WSP Canada Inc., 2018. *Walker Aggregates Inc. 2017 Walker Brothers Quarry Aggregate License, Environmental Compliance Approval for Industrial*

Sewage Works and Permit to Take Water Annual Monitoring Report. Prepared for Walker Aggregates Inc., March, 2018. WSP Project No. 131-22827-00.

WSP Canada Inc., 2014. *Niagara Tunnel Project, 2013-2014 Groundwater Monitoring Report*. Prepared for Ontario Power Generation, July 2014. WSP Project No. 111-53002-01.

WSP Canada Inc., 2015. *Mountain Road Landfill Site 2014 Annual Monitoring Report*. Prepared for the Regional Municipality of Niagara, May 2015. WSP Project No. 111-53076-00.

STATEMENT OF LIMITATIONS

WSP Canada Inc. ("WSP") prepared this report solely for the use of the intended recipient Walker Aggregates Inc., to support the regulatory review process for the proposed Uppers Quarry and in connection therewith, the report may be reviewed and used by Governmental Authorities participating in the review process in the normal course of their duties.

The report is intended to be used in its entirety.

The conclusions presented in this report are based on work performed by trained, professional and technical staff, in accordance with their reasonable interpretation of current and accepted engineering and scientific practices at the time the work was performed.

The content and opinions contained in the present report are based on the observations and/or information available to WSP at the time of preparation, using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by WSP and other engineering/scientific practitioners working under similar conditions, and subject to the same time, financial and physical constraints applicable to this project.

WSP disclaims any obligation to update this report if, after the date of this report, any conditions appear to differ significantly from those presented in this report; however, WSP reserves the right to amend or supplement this report based on additional information, documentation or evidence.

WSP makes no representations whatsoever concerning the legal significance of its findings.

The intended recipient is solely responsible for the disclosure of any information contained in this report. If a third party makes use of, relies on, or makes decisions in accordance with this report, said third party is solely responsible for such use, reliance or decisions. WSP does not accept responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken by said third party based on this report.

WSP has provided services to the intended recipient in a manner consistent with that degree of care, skill and diligence normally provided by members of the same profession performing the same or comparable services in respect of projects of a similar nature in similar circumstances.

In preparing this report, WSP has relied in good faith on information provided by others, as noted in the report. WSP has reasonably assumed that the information provided is correct and WSP is not responsible for the accuracy or completeness of such information.

The original of this digital file will be kept by WSP for a period of not less than 10 years. As the digital file transmitted to the intended recipient is no longer under the control of WSP, its integrity cannot be assured. As such, WSP does not guarantee any modifications made to this digital file subsequent to its transmission to the intended recipient.

This limitations statement is considered an integral part of the report.

TABLES

Table 1 Proposed Monitoring Program

Activity	Location and Geologic Unit	Frequency	Analysis / Measurement
Groundwater Monitoring			
Groundwater Level Monitoring	**Upper Aquitard Standpipes (5):** MW16-9SP, MW17-20SP *, MW17-21SP, MW17-22SP, MW17-23SP **Contact Aquifer Wells (23):** MW11-1OB, MW11-2OB, MW11-3OBR, MW11-4OB, MW16-5OB, MW16-6OB, MW16-7OB, MW16-8OB, MW16-9OB, MW16-10OB, MW16-11, MW16-12, MW16-13OB, MW16-14, MW16-15, MW16-16, MW16-17 †, MW16-18OB †, MW16-19OB, MW17-20OB *, MW17-21OB, MW17-22OB, MW17-23OB **Shallow Bedrock Aquifer Wells (18):** BH03-2B, MW11-1B, MW11-2B, MW11-3BR, MW11-4B, MW16-5B, MW16-6B, MW16-7B, MW16-8B, MW16-9B, MW16-10B, MW16-13B, MW16-18B †, MW16-19B, MW17-20B *, MW17-21B, MW17-22B, MW17-23B **Deep Bedrock Aquifer Wells (11):** BH03-2A, MW11-3AR, MW16-5A, MW16-5AR, MW16-6A, MW16-7A, MW16-8A, MW16-9A, MW16-10A, MW16-13A, MW17-20A * **Lower Aquitard Wells (3):** MW11-1A, MW11-2A, MW11-4A	Semi-Annually (May and October)	Water level measurement and logger download.
Groundwater Quality Monitoring	**Upper Aquitard Standpipes (5)** **Contact Aquifer Wells (23)** **Shallow Bedrock Aquifer Wells (18)** **Deep Bedrock Aquifer Wells (11)** **QA / QC:** 6 blind duplicates / trip blanks	Annually (May)	**<u>Groundwater List</u>** **Field measurements:** pH, conductivity, temperature **General Parameters:** pH, conductivity, TDS, hardness, sulphide **Major Ions:** alkalinity, chloride, sulphate, calcium, magnesium, sodium, potassium **Nutrients/Organic Indicators:** nitrate, nitrite, TKN, ammonia, total phosphorus, DOC, phenols **Dissolved Metals:** aluminum, arsenic, barium, boron, total chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, strontium, uranium, vanadium, zinc **VOCs:** BTEX compounds
	Lower Aquitard Wells (3)	Every 4 Years (May)	
Well Inspection	**All Wells (60)**	Semi-Annually (May and October)	Check well / logger condition.

* Well nest MW17-20 situated on privately owned land; access subject to resident consent.

† Well situated within quarry footprint, to be decommissioned as quarry excavation proceeds.

Table 1 Proposed Monitoring Program

Activity	Location and Geologic Unit	Frequency	Analysis / Measurement
Groundwater Monitoring *(cont'd)*			
Private Supply Well Monitoring **	**Private Supply Wells (11):** R1 to R8, R11 to R13	Annually (May)	Water level measurement and logger download. Sample collection for analysis of the **<u>Groundwater List</u>**.
Surface Water Monitoring			
Stage / Flow Measurement	**Beaverdams Creek (2):** SW1, DP1 **Existing Watercourse (7):** SW2, SW3, SW4 †, DP2, DP3, DP4, DP5 **East Wetland (1):** DP6 **West Woodlot (1):** DP7	Semi-Annually (May and October)	Water level stage measurement and logger download. Measure flow rate at all SW staff gauges (4). Check drivepoint / staff gauge and logger condition.
Surface Water Quality Monitoring	**Beaverdams Creek (2):** SW1, DP1 **Existing Watercourse (4):** SW2, SW3, SW4, DP2 **QA / QC:** 1 blind duplicate / trip blank		**<u>Surface Water List</u>** **Field measurements:** pH, conductivity, temperature, dissolved oxygen **General Parameters:** pH, conductivity, TSS, hardness, turbidity, sulphide, un-dissociated hydrogen sulphide (calculated) **Major Ions:** alkalinity, chloride, sulphate, calcium, magnesium, sodium, potassium **Nutrients/Organic Indicators:** nitrate, nitrite, TKN, ammonia, un-ionized ammonia (calculated), TOC, total phosphorus, phenols **Total Metals:** aluminum, arsenic, barium, boron, total chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, strontium, uranium, vanadium, zinc **VOCs:** BTEX compounds
Sump Discharge Monitoring	**Quarry Sump Discharge (1)**	Daily / Monthly	Record daily pumping volume. **Flow measurement device to be calibrated at least once annually by qualified hydrogeologist.* Monthly sample collection for analysis of the **<u>Surface Water List</u>**.

** Monitoring of private supply wells subject to resident consent.
† Station situated within quarry footprint, to be decommissioned as quarry excavation proceeds.

Table 2 Well Mitigation Plan - South Areas

Address	Comments	2018 / 2019 Survey		Domestic Supply	Well Other Use	Survey Comments	Monitoring Program	Data Source	Available Drawdown (m)			Proposed Mitigation
		Included	Responded						Existing Well	Interpolated	Predicted	
WMA-1 Close Proximity												
1. 8980 Beaverdams Road	Residence	✓	✓	Well	--	2 wells, one well in use for domestic				29	14	Deepen well to Gasport Mb and provide treatment if necessary.
2. 9582 / 9602 Beaverdams Road	Rural office and rental home	✓	✓	Well	Commercial	Well used for office and rental property	Upper's	Monitoring Data	10	27	< 3	Deepen well to Irondequoit Fm and provide treatment.
3. 9722 Beaverdams Road	Residence	✓	✓	Cistern	--	Cistern only						None required
4. 10138 Beaverdams Road	Residence	✓	✓	Cistern	Not in use	Cistern for domestic, well not in use						None required
5. 10148 Beaverdams Road	Residence	✓	✓	Cistern	Irrigation	Cistern for domestic, well used for irrigation only		WWR 6603989	26	28	3	Likely enough available water column to accommodate drawdown. Monitor well if owner allows it
6. 5329 Beechwood Road	Bible Baptist Church	✓	✓	Cistern	--	Cistern only						None required
7. 5584 Beechwood Road	Residence, hobby farm	✓	✓	Well	--	Well for domestic, livestock and lawn and garden watering.		Inferred from MW17-20	11	37	5	Deepen well to Goat Island Mb and provide treatment if necessary. Incorporate well into monitoring program.
8. 5769 Beechwood Road	Residence	✓	✓	Cistern	Not in use	Cistern for domestic, well not in use	Upper's					None required
9. 5821 Beechwood Road	Residence	✓	✓	Well	--	Well for domestic		Inferred from 5769 Beechwood Rd	17	39	13	Deepen well to Gasport Mb and provide treatment if necessary.
5021 Garner Road	Vacant lot	No mailbox	--	--	--							None required
10. 9941 Lundys Lane	Lundy Manor Wine Cellars	✓	✓	Well	Irrigation	1 well on property, used for vineyard and building	Upper's	Monitoring Data	7	40	18	Deepen well to Goat Island Mb. Continue monitoring.
11. 6200 Townline Road	Italo Canadian Centennial Club	✓	✓	Cistern	--	Cistern only						None required
WMA-2 City of Thorold Urban Area												
1. 13011 Highway 20	Little Bros Service Centre	✓	✓	Well	--	Well for domestic	Upper's	Monitoring Data	10	43	35	Deepen existing well. Property will eventually be serviced as part of Rolling Meadows.
2. 13029 Highway 20	Repairs 1 Fast	✓	✓	Cistern	--	Cistern only						None required
3. 13030 Highway 20	L8 Club & Express Inn	✓	✓	Well / Cistern	--	Cistern, 2 wells, 1 in operation - use not specified		WWR 7206054	12	42	34	Use existing cistern for domestic supply. Property will eventually be serviced as part of Rolling Meadows.
4. 13045 Highway 20	Golden Gardens Supply Co.	✓	✓	Well	--	Well for domestic		WWR 6601714	6	43	37	Deepen existing well. Property will eventually be serviced as part of Rolling Meadows.
5. 13055 Highway 20	Milan Garden Inn	✓				*Assumed drinking water well*		WWR 6601720	6	42	37	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
13058 Highway 20	Vacant lot	✓										None required
13065 Highway 20	Vacant lot	No mailbox	--	--	--							None required
6. 13071 Highway 20	Golf Inn Driving Range Hotel	✓				*Assumed drinking water well*		WWR 6601718		43	38	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
7. 13084 Highway 20	Residence	✓	✓	Cistern	--	Cistern only						None required
8. 13085 Highway 20	Anfra Tile & Stone					*Assumed drinking water well*		WWR 6601718	8	44	39	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
13105 Highway 20	Building has been demolished											None required
9. 13126 Highway 20	Residence					*Assumed drinking water well*		WWR 6601687	4	42	37	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
13127 Highway 20	Motel appears abandoned											None required
10. 13133 Highway 20	Residence					*Assumed drinking water well*				43	39	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
11. 13145 Highway 20	Lundys Farm Market					*Assumed drinking water well*		WWR 6602520	3	43	39	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
12. 13154 Highway 20	V Perri Excavating					*Assumed drinking water well*		WWR 6601692	3	45	41	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
13. 13155 Highway 20	Our Lady of Lourdes Convent					*Assumed drinking water well*		WWR 6601724	5	45	41	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
14. 13157 Highway 20	Residence					*Assumed drinking water well*		WWR 6601724	5	45	41	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
15. 13164 Highway 20	V Perri Excavating					*Assumed drinking water well*		WWR 6601692	3	45	41	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
16. 13165 Highway 20	Residence					*Assumed drinking water well*		WWR 6601724	5	46	42	If well exists, deepen well. Property will eventually be serviced as part of Rolling Meadows.
2301 Townline Road	House has been demolished											None required
17. 5114 Townline Road	Niagara Cricket Centre	✓	✓	Well	Irrigation	Well is not in use until April	Upper's	Monitoring Data	12	36	4	Deepen well to Gasport Mb and provide treatment, if necessary. Property will eventually be serviced as part of Rolling Meadows.

wsp

Table 2 Well Mitigation Plan - South Areas

Address	Comments	2018 / 2019 Survey		Domestic Supply	Well Other Use	Survey Comments	Monitoring Program	Data Source	Available Drawdown (m)			Proposed Mitigation
		Included	Responded						Existing Well	Interpolated	Predicted	
WMA-3 South Group												
1. 6060 Beechwood Road	Residence	✓	✓	Not specified	Not specified	Well use not specified		Well Survey	20	41	23	Deepen well to base of Goat Island Mb.
2. 6070 Beechwood Road	Residence	✓				*Assumed drinking water well*				41	23	If well exists, deepen well and provide treatment, if necessary.
3. 6393 Beechwood Road	Residence	✓				*Assumed drinking water well*		WWR 6603313	11	44	33	If well exists, deepen well.
4. 6508 Beechwood Road	Residence	✓				*Assumed drinking water well*				44	34	WWR 7246491 is for well abandonment, well may no longer exist. If well exists, deepen well.
6582 Beechwood Road	Farm	No mailbox	--	--	--							None required
5. 6771 Beechwood Road	Niagara Lawn & Garden Maintenance	✓	✓			*Assumed drinking water well*				44	38	If well exists, deepen well.
6. 6169 Garner Road	Niagara Falls Golf Club	✓	✓	Municipal	Irrigation / Commercial	Three wells, 2 for irrigation, 1 for shop. PTTW for GW takings.	Upper's	Monitoring Data	12	43	34	May need to eventually deepen well, continue monitoring.
7. 9552 Lundys Lane	Residence	✓	✓	Cistern	Garden	Cistern for domestic use, well used for gardening				41	23	Homeowner indicated existing well is 26 m deep, which is interpolated to be in Goat Island (no WWR available). Deepen existing well if necessary.
8. 9594 Lundys Lane	Residence	✓	✓	Cistern	--	Cistern only						None required
9. 9624 Lundys Lane	Residence	✓	✓	Cistern	--	Cistern only						None required
10. 9944 Lundys Lane	Residence	✓	✓	Well	Garden	1 well, used for domestic and gardening				42	26	Deepen existing well if necessary.
11. 10008 Lundys Lane	Country Basket Garden Centre	✓	✓	Well	Livestock / Garden	1 well, used for domestic, livestock and gardening	Upper's	Monitoring Data	5	42	29	Deepen existing well.
12. 9787 Nichols Lane	Residence	✓				*Assumed drinking water well*				43	32	If well exists, deepen well.
13. 9811 Nichols Lane	Residence	✓	✓	Not specified	Not specified	Well use not specified				43	31	Deepen existing well.
14. 9858 Nichols Lane	Residence	✓	✓	Well	--	Well for domestic		Well Survey	28	43	32	Data suggests existing well has sufficient available water column to accommodate drawdown.
15. 9961 Nichols Lane	Residence	✓	✓	Cistern	--	Cistern only						None required
16. 6666 Townline Road	Residence	✓	✓	Not specified	Not specified	Well use not specified		WWR 6603264	5	45	40	Deepen existing well.
17. 6848 Townline Road	Residence	✓	✓	Not specified	Not specified	Well use not specified		WWR 6601365	6	47	44	Deepen existing well.

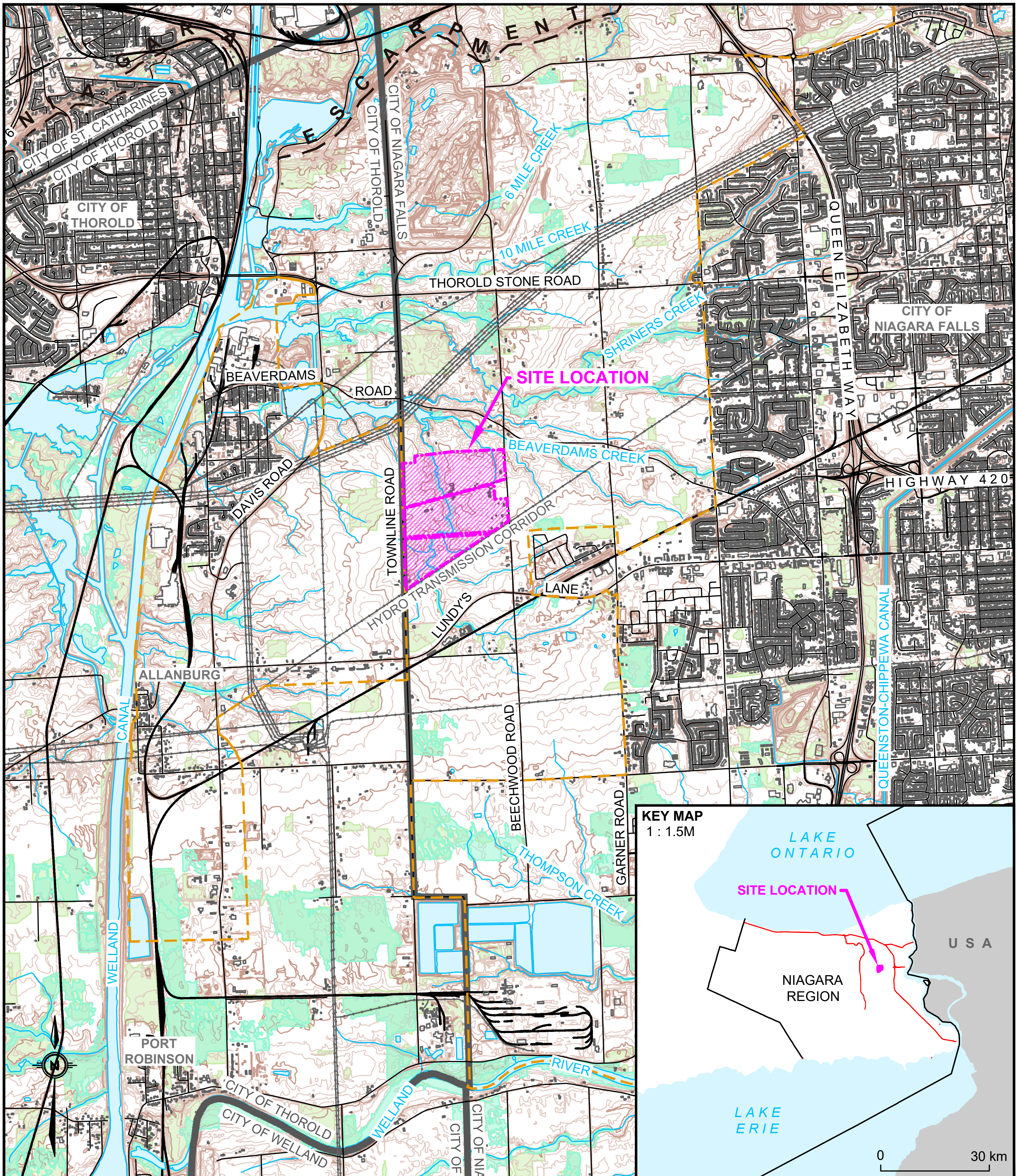
Table 3 Well Mitigation Plan - North Areas

Address	Comments	2018 / 2019 Survey		Domestic Supply	Well Other Use	Survey Comments	Monitoring Program	Data Source	Available Water Column (m)			Proposed Mitigation
		Included	Responded						Existing Well	Interpolated	Predicted	
WMA-4 North Group												
1. 1006 Beaverdams Road	Residence	✓	✓	Cistern	Garden / Lawn	Cistern for domestic, well for gardening/lawn				24	21	Deepen existing well if necessary.
2. 1021 Beaverdams Road	Residence	✓	✓	Well	--	Well for domestic, cistern for gardening				25	22	Deepen existing well if necessary.
3. 1024 Beaverdams Road	Residence	✓	✓	Well	--	Well for domestic	Upper's	Monitoring Data	8	24	21	Data suggests existing well has sufficient available water column to accommodate drawdown. Continue monitoring well.
4. 1067 Beaverdams Road	Residence	✓	✓	Cistern	Not in use	Cistern for domestic, well not in use						None required
5. 1098 Beaverdams Road	Residence	✓	✓	Well / Cistern	--	Well and cistern both used for domestic supply				24	21	Deepen existing well if necessary.
6. 1108 Beaverdams Road	Thorold Auto Parts & Recyclers	✓	✓	Cistern	--	Cistern only						None required
7. 8357 Beaverdams Road	Residence	✓				*Assumed drinking water well*				30	23	If well exists, deepen well.
8362 Beaverdams Road	House has been demolished	No mailbox	--	--	--							None required
8. 8395 Beaverdams Road	Residence	✓				*Assumed drinking water well*				30	22	If well exists, deepen well.
9. 8436 Beaverdams Road	Residence	✓				*Assumed drinking water well*				30	22	If well exists, deepen well.
10. 8522 Beaverdams Road	Residence	✓	✓	Cistern	Not in use	Cistern for domestic, well not in use						None required
11. 8698 Beaverdams Road	Van Der Weyden Greenhouses	✓	✓	Cistern	Not in use	Cistern for domestic, dug well not in use						None required
12. 8828 Beaverdams Road	Residence	✓				*Assumed drinking water well*				29	17	If well exists, deepen well.
13. 9301 Beaverdams Road	Residence	✓	✓	Well	--	Well for domestic		WWR 6603926 / Well Survey	10	26	6	Deepen existing well into Gasport Mb. Utilize existing treatment system.
14. 9337 Beaverdams Road	Paradise Pools	✓	✓	Cistern	Not in use	Cistern for domestic, well not in use						None required
15. 9417 Beaverdams Road	Residence	✓	✓	Well / Cistern	--	Cistern used for domestic supply, in addition to dug well. Drilled well used only occasionally, does not have a pump in it		WWR 6601335	10	25	6	Use existing cistern.
16. 4389 Beechwood Road	No visible structure on property, locked gate during survey.	No mailbox										None required
17. 4410 Beechwood Road	Residence	✓	✓	Cistern	Not specified	Cistern for domestic, well use not specified				20	11	Use existing cistern.
18. 4500 Beechwood Road	Residence	✓	✓	Well	--	Well for domestic		WWR 6604068 / Well Survey	9	23	9	Deepen existing well into Gasport Mb. Utilize existing treatment system.
4555 Beechwood Road	House appears abandoned	No mailbox	--	--	--							None required
19. 4642 Beechwood Road	Residence	✓	✓	Cistern / Well	--	Both cistern and well used for domestic supply				23	8	Use existing cistern.
20. 4255 Garner Road	Residence	✓	✓	Cistern / Well	Livestock / Garden	Cistern used for domestic supply. Well used for bee farm, domestic and gardening		WWR 6603214	13	23	16	Data suggests existing well has sufficient available water column to accommodate drawdown.
21. 4282 Garner Road	Residence	✓	✓	Not specified	Not specified	Well use not specified				23	17	Deepen existing well if necessary.
22. 4303 Garner Road	Residence	✓	✓	Cistern	Garden	Cistern for domestic, well for gardening		WWR 6602986	12	23	16	Data suggests existing well has sufficient available water column to accommodate drawdown.
23. 4326 Garner Road	Residence	✓	✓	Not specified	Not specified	Well use not specified				24	17	Deepen existing well if necessary.
24. 4486 Garner Road	Residence	✓	✓	Cistern	Garden	Cistern for domestic, well for gardening.				24	16	Deepen existing well if necessary.
25. 4491 Garner Road	Residence	✓				*Assumed drinking water well*				24	16	If well exists, deepen well.
26. 4622 Garner Road	Residence	✓				*Assumed drinking water well*				25	16	If well exists, deepen well.
27. 4694 Garner Road	Residence	✓	✓	Cistern	Garden	Cistern for domestic, dug well for gardening.				25	15	Use existing cistern.
28. 4722 Garner Road	Residence	✓	✓	Not specified	Not specified	Well use not specified				26	15	Deepen existing well if necessary.
29. 4750 Garner Road	Residence	✓	✓	Not specified	Not specified	Well use not specified				26	15	Deepen existing well if necessary.
30. 4810 Garner Road	Residence	✓				*Assumed drinking water well*		WWR 7048238	7	27	16	If well exists, deepen well.
31. 4843 Garner Road	Residence	✓	✓	Well	--	Well for domestic		WWR 6601336	8	27	15	Deepen existing well if necessary.
32. 5002 Garner Road	Niagara Honey	✓	✓	Well	--	Well for domestic				28	16	Deepen existing well if necessary.
33. 5484 Garner Road	Residence	✓	✓	Cistern	--	Cistern only						None required
34. 3219 Townline Road	Residence	✓	✓	Cistern	Not in use	Cistern for domestic, well not in use.						None required
35. 3237 Townline Road	Residence	✓	✓	Cistern	Lawn / Garden	Cistern for domestic, well for lawn/gardening				23	20	Deepen existing well if necessary.
36. 3269 Townline Road	Residence	✓				*Assumed drinking water well*				23	19	If well exists, deepen well.
37. 3279 Townline Road	Residence	✓	✓	Well / Cistern	--	Both cistern and well used for domestic supply				23	18	Use existing cistern.
38. 3285 Townline Road	Residence	✓				*Assumed drinking water well*				22	17	If well exists, deepen well.
39. 3295 Townline Road	Residence	✓				*Assumed drinking water well*				21	17	If well exists, deepen well.
40. 4580 Townline Road	Residence	✓				*Assumed drinking water well*				23	19	If well exists, deepen well.
41. 4680 Townline Road	Beechwood Golf & Country Club	✓	✓	Dug Well / Cistern	Golf Cart washing	Cistern for domestic, dug well only used occasionally for washing golf carts	Upper's			24	20	Provide a replacement drilled well for the shallow dug well.

Table 3 Well Mitigation Plan - North Areas

Address	Comments	2018 / 2019 Survey		Domestic Supply	Well Other Use	Survey Comments	Monitoring Program	Data Source	Available Water Column (m)			Proposed Mitigation
		Included	Responded						Existing Well	Interpolated	Predicted	
WMA-5 Walker Brothers Quarry Monitoring Area												
1. 2045 Garner Road	Residence					*Assumed drinking water well*		Monitoring Data (2155 Garner Rd)		<3	<3	Data suggests that if well exists, it is likely completed into a deeper bedrock unit.
2. 2155 Garner Road	Residence			Not specified	Not specified	Two wells, one currently in use, use not specified	WBQ	Monitoring Data	13	<3	<3	Data suggests existing well has sufficient available water column to accommodate drawdown.
3. 8865 Mountain Road	Gauld Garden Centre			Not specified	Not specified	Well use not specified	WBQ	Monitoring Data	13	<3	<3	Data suggests existing well has sufficient available water column to accommodate drawdown.
4. 1005 Old Thorold Stone Road	Residence			Not specified	Not in use	Well no longer used						None required
5. 1040 Old Thorold Stone Road	Commercial					*Assumed drinking water well*		WWR 6603286 (3547 Townline Rd)		14	12	Data suggests that if well exists, there is sufficient available water column to accommodate drawdown.
6. 1051 Old Thorold Stone Road	Residence			Not specified	Not in use	Well no longer used						None required
7. 1281 Old Thorold Stone Road	Inland Truck & Trailer Ltd					*Assumed drinking water well*		WWR 6601642	5	15	14	Data suggests existing well has sufficient available water column to accommodate drawdown.
8. 1040 Thorold Stone Road	Petro Canada / Tim Hortons					*Assumed drinking water well*		WWR 7248844	13	17	14	Data suggests existing well has sufficient available water column to accommodate drawdown.
9. 1061 Thorold Stone Road	1061 Speedway (go-carts)					*Assumed drinking water well*		Monitoring Data (3393 Townline Rd)		17	15	Data suggests that if well exists, there is sufficient available water column to accommodate drawdown.
10. 9332 Thorold Stone Road	Residence			Not specified	Not specified	Well use not specified	WBQ	Monitoring Data	9	19	13	Data suggests existing well has sufficient available water column to accommodate drawdown.
11. 9435 Thorold Stone Road	Residence			Not specified	Not specified	Well use not specified	WBQ	Monitoring Data	3	17	13	Deepen existing well.
12. 9536 Thorold Stone Road	Residence			Not specified	Not specified	Two wells, one currently in use, use not specified	WBQ	Monitoring Data	13	17	13	Data suggests existing well has sufficient available water column to accommodate drawdown.
13. 10056 Thorold Stone Road	Residence			Not specified	Not specified	Two wells, one currently in use, use not specified	WBQ	Monitoring Data	11	16	13	Data suggests existing well has sufficient available water column to accommodate drawdown.
14. 3299 Townline Road	Rankin Construction (Thorold Asphalt)					*Assumed drinking water well*				20	17	Data suggests that if well exists, there is sufficient available water column to accommodate drawdown.
15. 3305 Townline Road	Residence			Not specified	Not specified	Well use not specified	WBQ	Monitoring Data	7	20	16	Data suggests existing well has sufficient available water column to accommodate drawdown.
16. 3315 Townline Road	Residence					*Assumed drinking water well*				19	15	Data suggests that if well exists, there is enough available water to accommodate drawdown.
17. 3393 Townline Road	Residence			Not specified	Not specified	Dug well / barn well not used, drilled house well still in use, use not specified	WBQ	Monitoring Data	10	17	15	Data suggests existing well has sufficient available water column to accommodate drawdown.
18. 3547 Townline Road	Niagara Region Fleet Garage					*Assumed drinking water well*		WWR 6603286	5	14	12	Data suggests that if well exists, there is sufficient available water column to accommodate drawdown.
19. 4366 Townline Road	Residence			Not specified	Not specified	Three wells, two not in use. House well was monitored as part of WBQ program, but now inaccessible.	WBQ	Monitoring Data	5	21	16	Deepen existing well.
20. 4556 Townline Road	Residence			Not specified	Not specified	Well use not specified	WBQ	Monitoring Data	3	23	18	Deepen existing well.

FIGURES



LEGEND

- WOODLOT
- WETLAND
- HYDRO TRANSMISSION CORRIDOR
- APPROXIMATE URBAN BOUNDARY

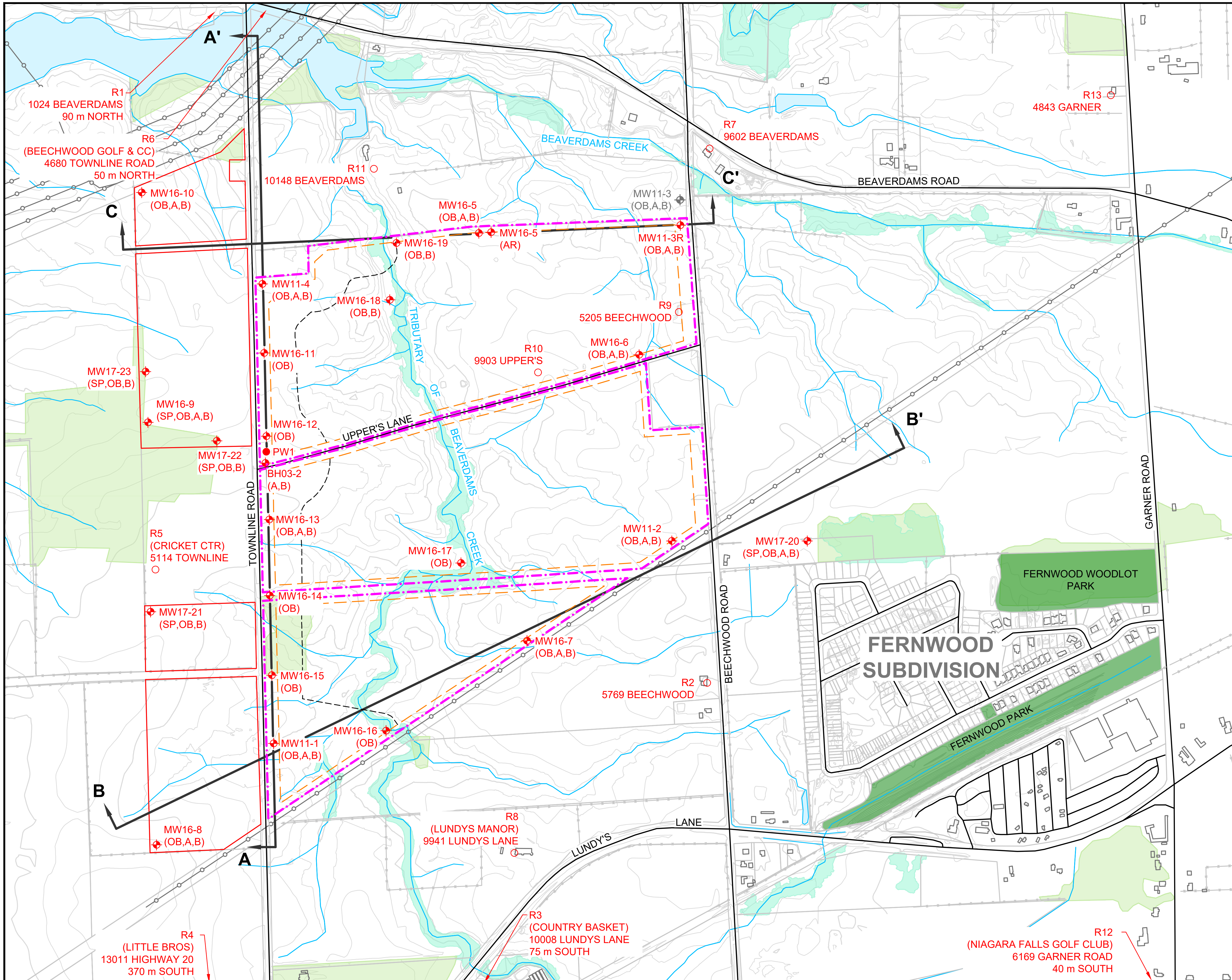
0 1,100 2,200 m

SITE LOCATION MAP

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021	PROJECT: 161-11633-00	SCALE: 1 : 55,000	DRAWN BY: JLD
		FIGURE No: 1	

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F1-LM.DWG



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- MW11-1 MONITORING WELL NEST LOCATION AND DESIGNATION
- MW11-3 DECOMMISSIONED MONITORING WELL NEST LOCATION AND DESIGNATION
- PRIVATE SUPPLY WELL LOCATION AND DESIGNATION
- PW1 PUMPING WELL LOCATION AND DESIGNATION
- A CROSS SECTION LOCATION AND DESIGNATION

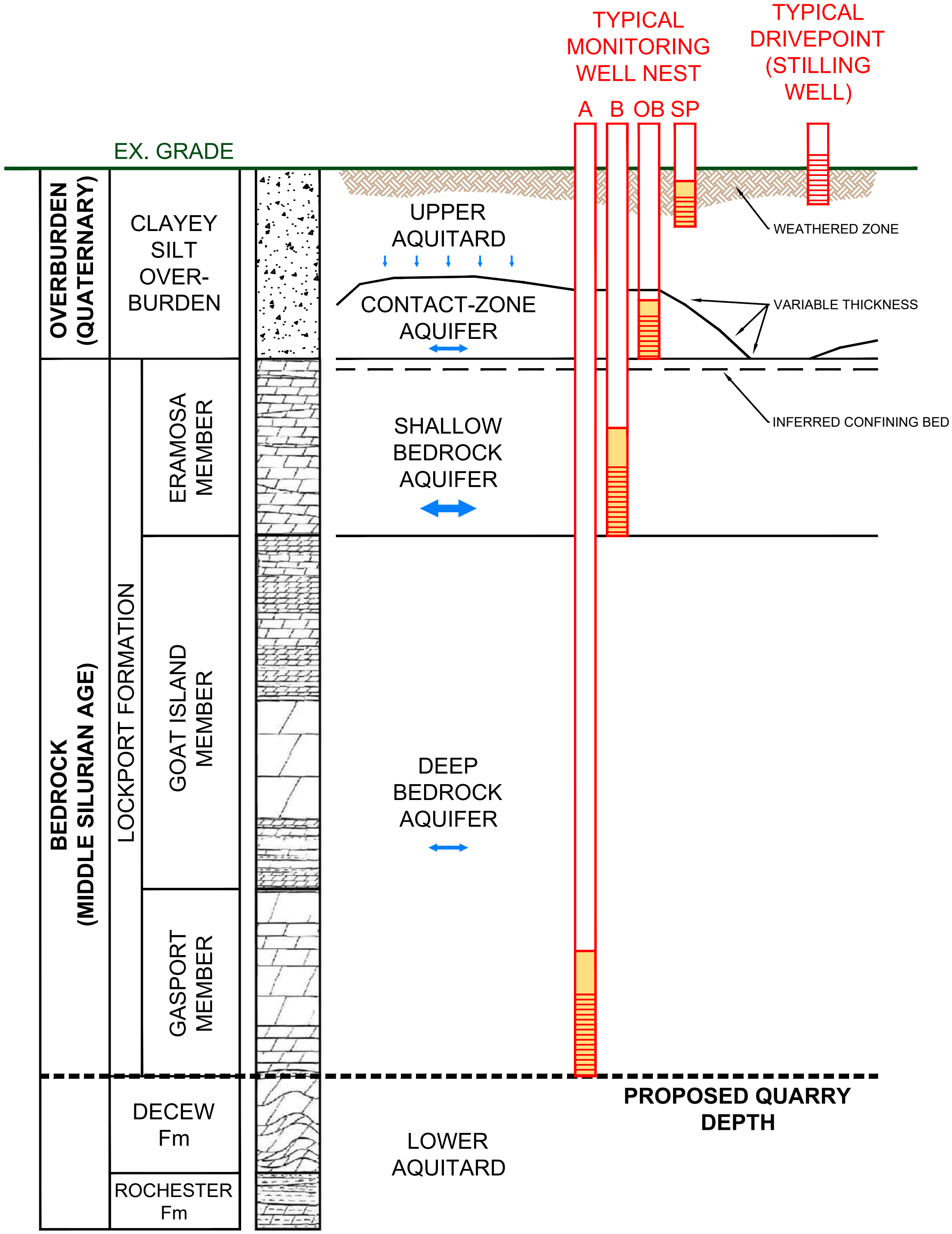
SITE PLAN

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 9,000
DRAWN BY:	JLD
FIGURE No:	2

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROGEOLOGY\GRAPHICS\161-11633-3-F2-SP.DWG



LEGEND

INFERRED GROUNDWATER FLOW

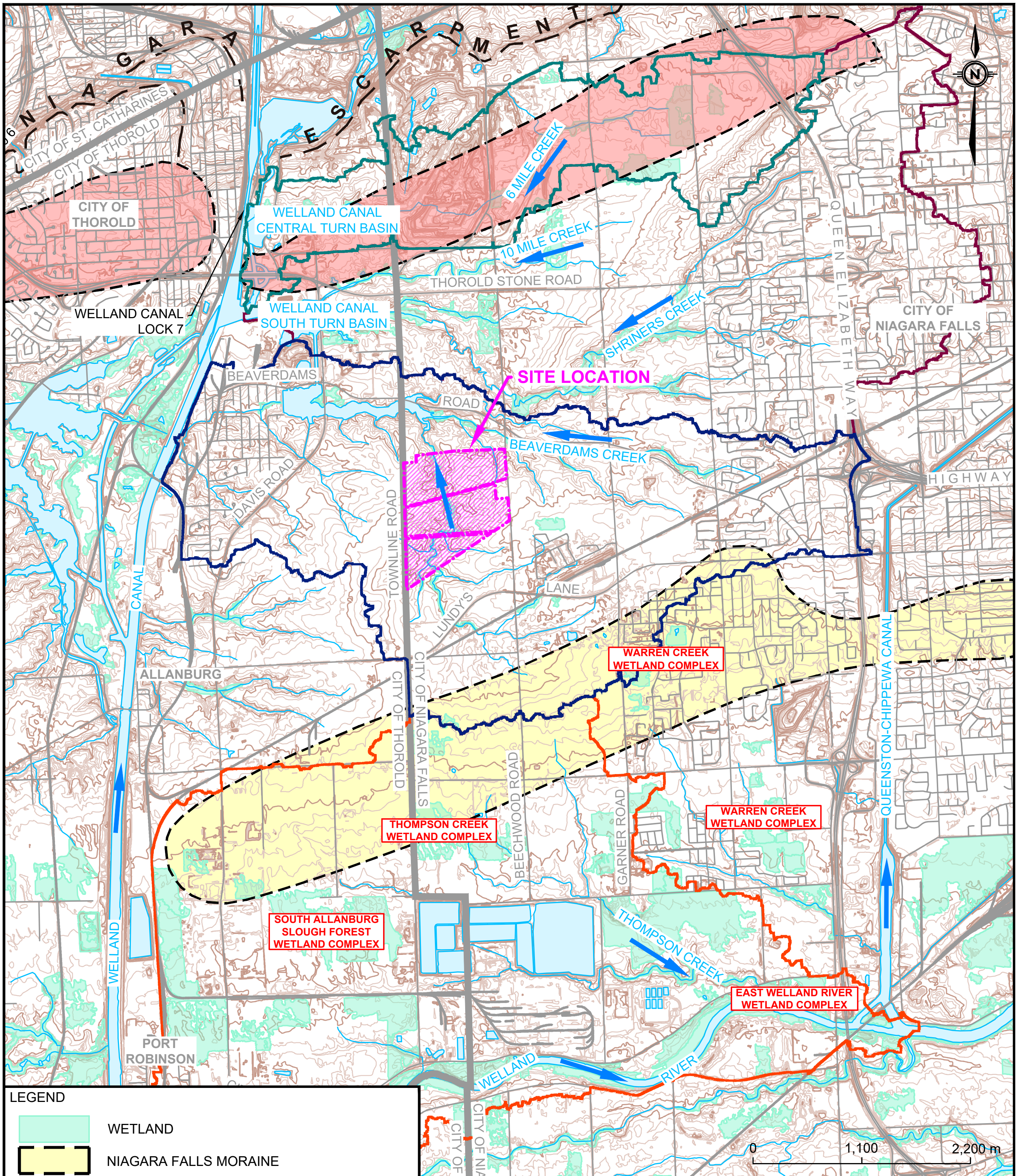
NOTES:

1. ARROW SIZE INDICATES RELATIVE MAGNITUDE OF INFERRED FLOW.
2. TYPE SECTIONS AFTER LINCOLN QUARRY AND THOROLD QUARRY, LIMESTONE INDUSTRIES OF ONTARIO, VOLUME III (MNRF, 1989)

CONCEPTUAL MODEL SCHEMATIC DIAGRAM

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

SCALE:	AS SHOWN
DRAWN BY:	JLD
DATE:	OCTOBER 2021
PROJECT:	161-11633-00
FIGURE No:	2A



LEGEND

- WETLAND
- NIAGARA FALLS MORAINE
- VINEMOUNT MORAINE
- SURFACE WATER FLOW DIRECTION

SUBWATERSHEDS (NPCA, 2009)

- BEAVERDAMS CREEK
- SHRINERS CREEK
- 10 MILE CREEK
- WELLAND RIVER

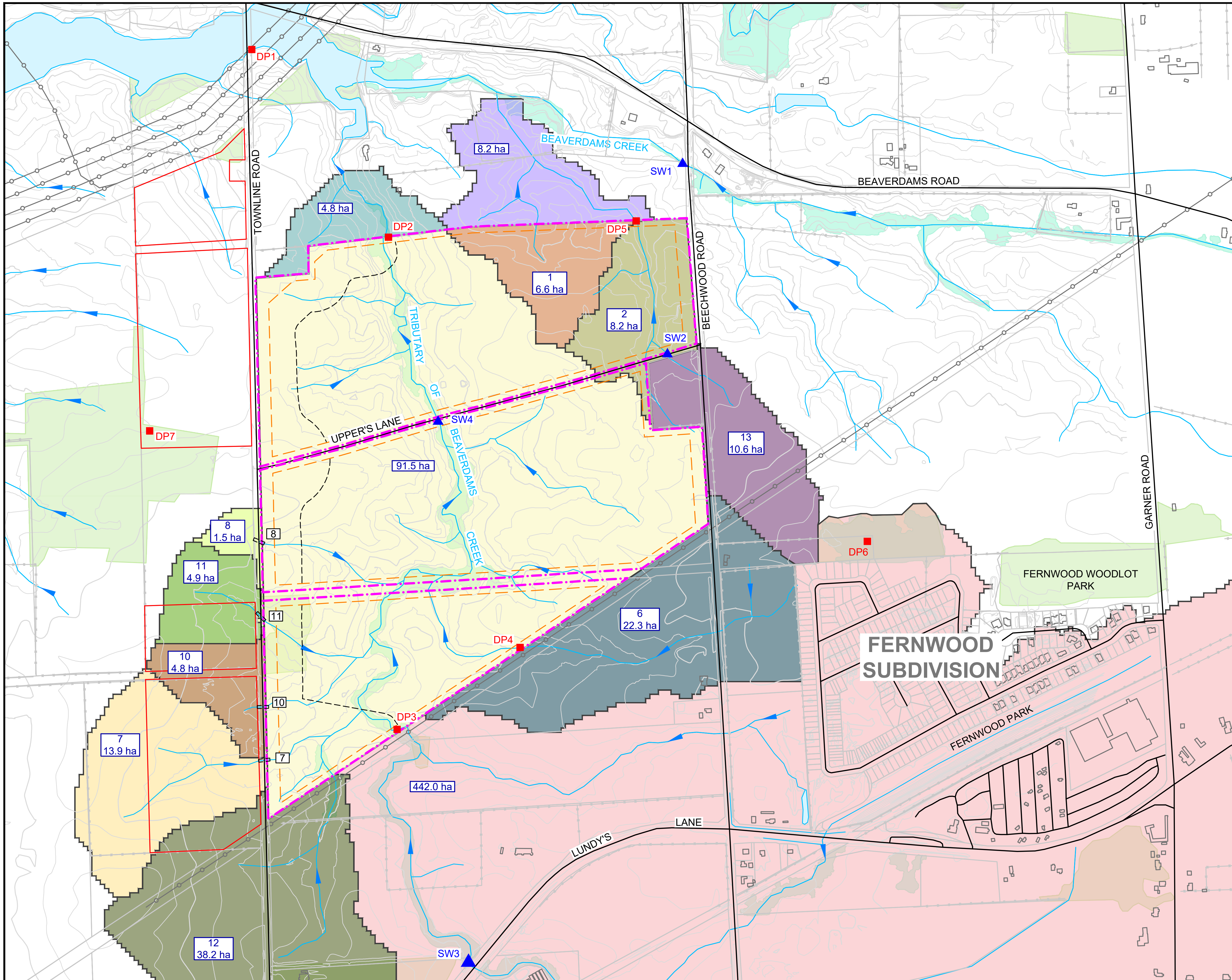
STUDY AREA SURFACE TOPOGRAPHY AND DRAINAGE

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

wsp

SCALE:	1 : 55,000
DRAWN BY:	JLD
DATE:	OCTOBER 2021
PROJECT:	161-11633-00
FIGURE No:	3

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F3-SW.DWG



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- SURFACE WATER COURSE AND FLOW DIRECTION (NPCA, 2010)
- INTERPOLATED SUBCATCHMENT AREA
- 8 1.5 ha — HEADWATER ASSESSMENT (REACH NO. AND AREA)
- 4 — EXISTING CULVERT LOCATION AND DESIGNATION
- GROUND SURFACE CONTOUR, 5 m INTERVAL (NPCA, 2010)
- GROUND SURFACE CONTOUR, 1 m INTERVAL (NPCA, 2010)
- FENCELINE
- UTILITY LINE
- DP1 — DRIVEPOINT (STILLING WELL) SURFACE WATER STATION LOCATION AND DESIGNATION
- SW1 — STAFF GAUGE SURFACE WATER STATION LOCATION AND DESIGNATION

0 180 360 m

NOTE: SUBCATCHMENT AREAS INTERPOLATED USING 2010 DEM RELEASED BY NPCA. HEADWATER AREAS 6 AND 7 MANUALLY ADJUSTED BASED ON FIELD OBSERVATIONS.

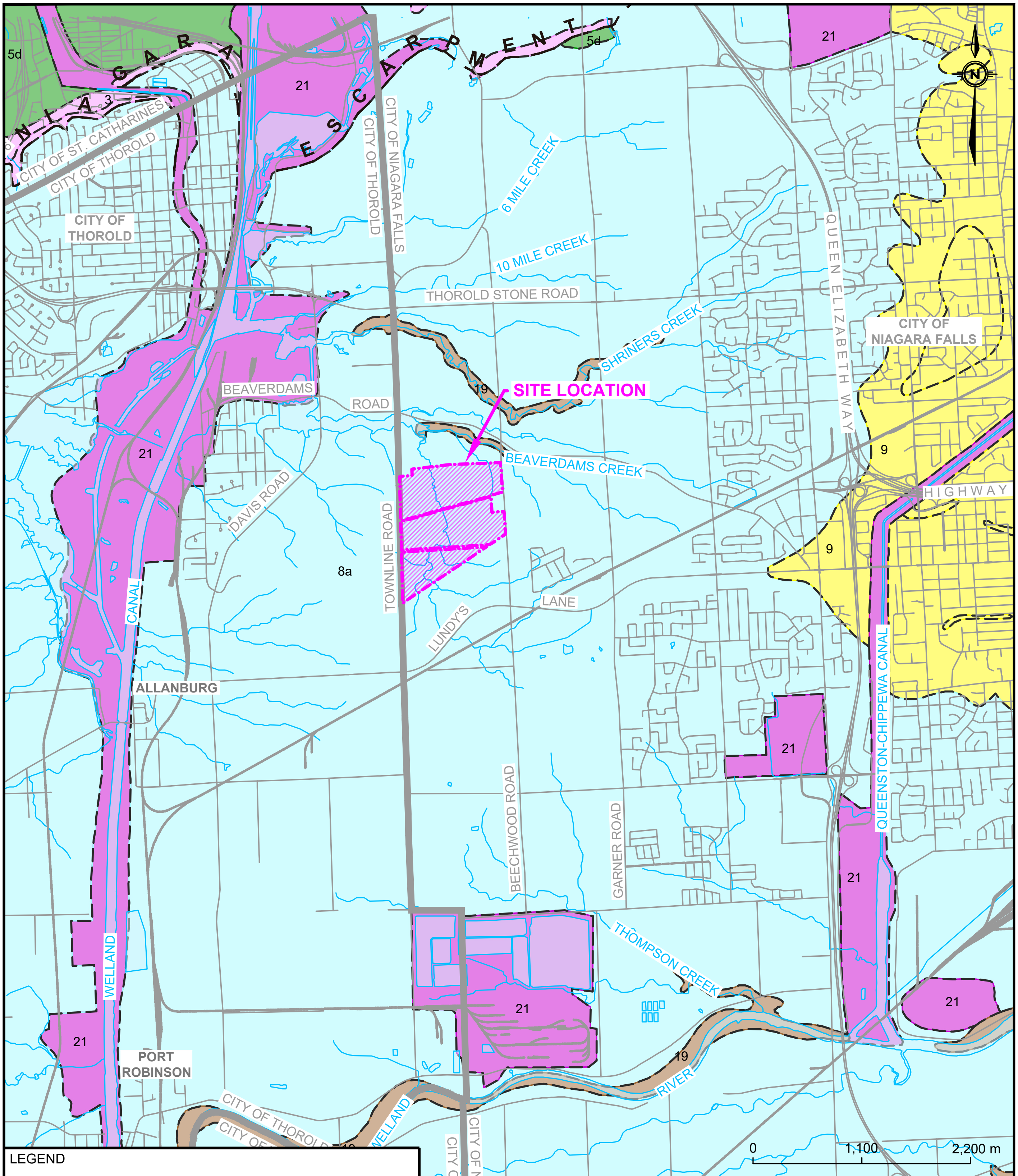
SITE SCALE SURFACE TOPOGRAPHY AND DRAINAGE

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 9,000
DRAWN BY:	JLD
FIGURE No:	3A

55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F3A-SW.DWG



LEGEND

3	PALEOZOIC BEDROCK
5d	GLACIOLACUSTRINE TILL
8a	GLACIOLACUSTRINE SILT AND CLAY
9	GLACIOLACUSTRINE SAND AND GRAVEL
19	MODERN ALLUVIAL
21	ANTHROPOGENIC

SOURCE: THE ONTARIO GEOLOGICAL SURVEY. 2003. SURFICIAL GEOLOGY OF SOUTHERN ONTARIO.

SURFICIAL GEOLOGY

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

wsp

SCALE: 1 : 55,000

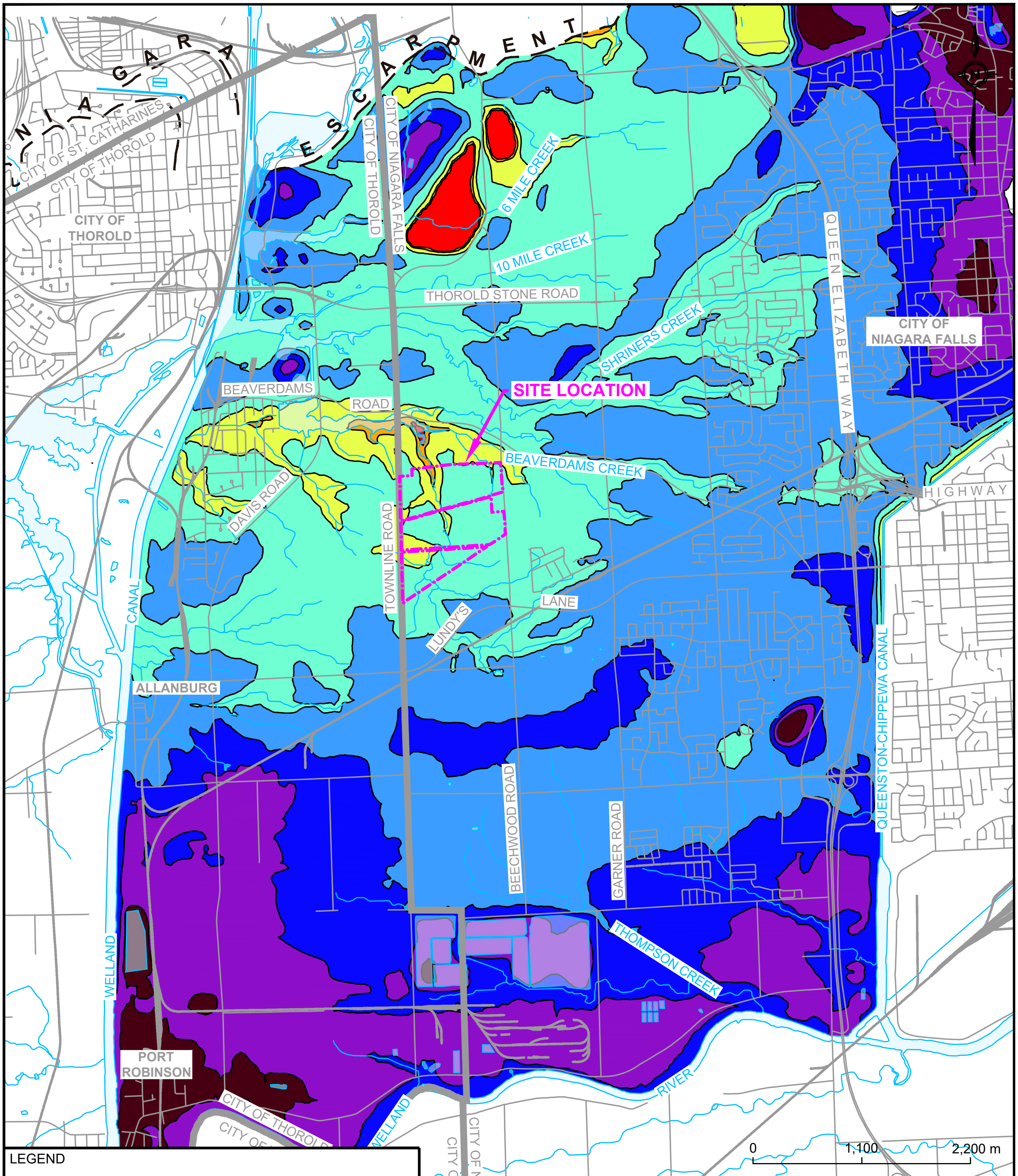
DRAWN BY: JLD

DATE: OCTOBER 2021

PROJECT: 161-11633-00

FIGURE No: 4

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F4-OB.DWG



LEGEND

INTERPOLATED OVERBURDEN THICKNESS (m)

< 1	20 - 25
1 - 2	> 25
2 - 5	
5 - 10	
10 - 15	
15 - 20	

INTERPOLATED OVERBURDEN THICKNESS

wsp

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

SCALE: 1 : 55,000

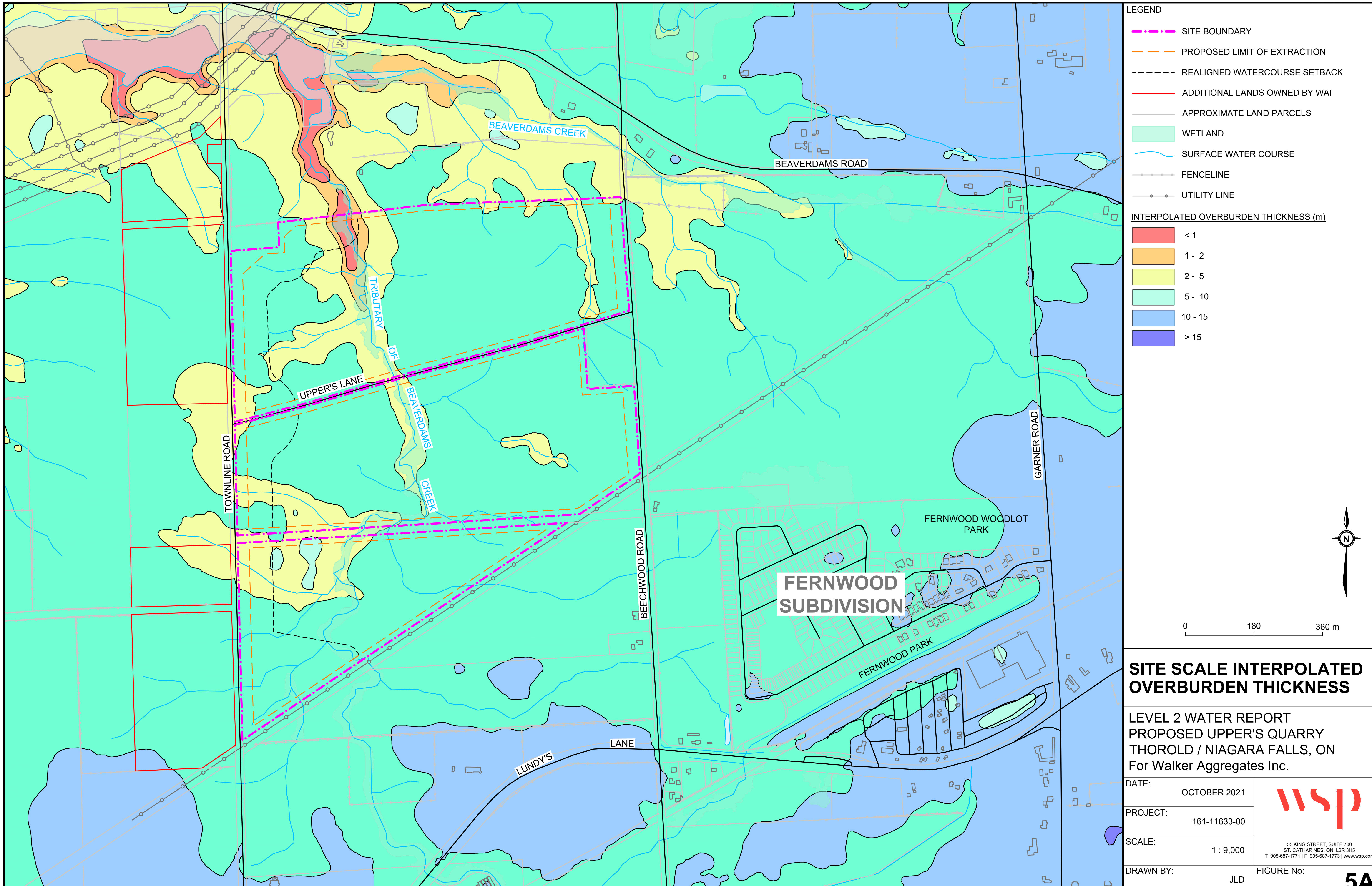
DRAWN BY: JLD

DATE: OCTOBER 2021

PROJECT: 161-11633-00

FIGURE No: 5

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F5-OB.DWG



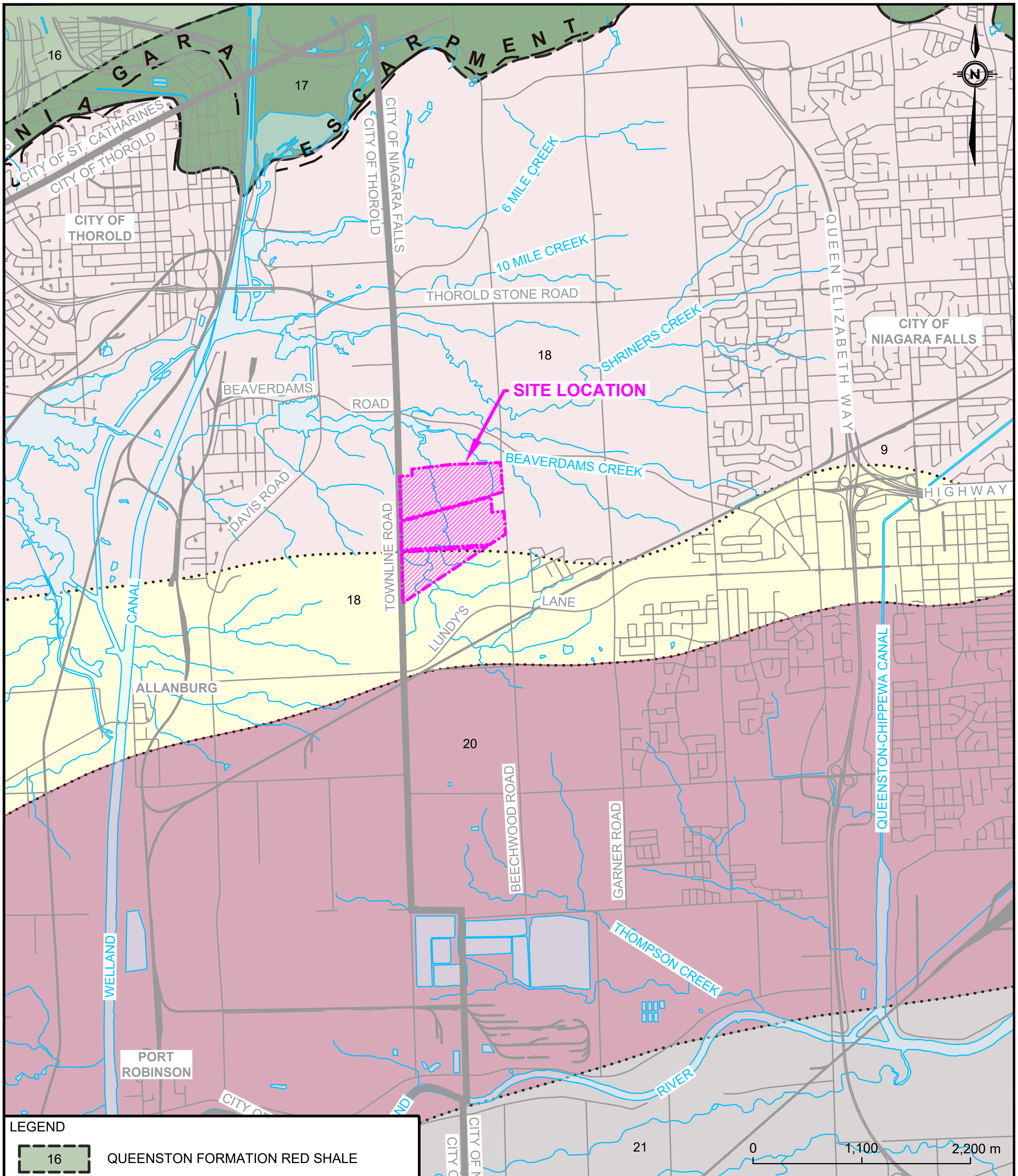
SITE SCALE INTERPOLATED OVERBURDEN THICKNESS

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 9,000
DRAWN BY:	JLD
FIGURE No:	5A

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F5A-OB.DWG



LEGEND

16	QUEENSTON FORMATION RED SHALE
17	CLINTON AND CATARACT GROUPS
18	LOCKPORT FORMATION - GOAT ISLAND / GASPORT MEMBERS
18	LOCKPORT FORMATION - ERAMOSA MEMBER
20	GUELPH FORMATION DOLOSTONE
21	SALINA FORMATION ARGILLACEOUS DOLOSTONE

SOURCE: PALEOZOIC GEOLOGY OF NIAGARA, MAP 2344 (LIBERTY ET AL, 1976).

PALEOZOIC BEDROCK GEOLOGY

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

SCALE: 1 : 55,000

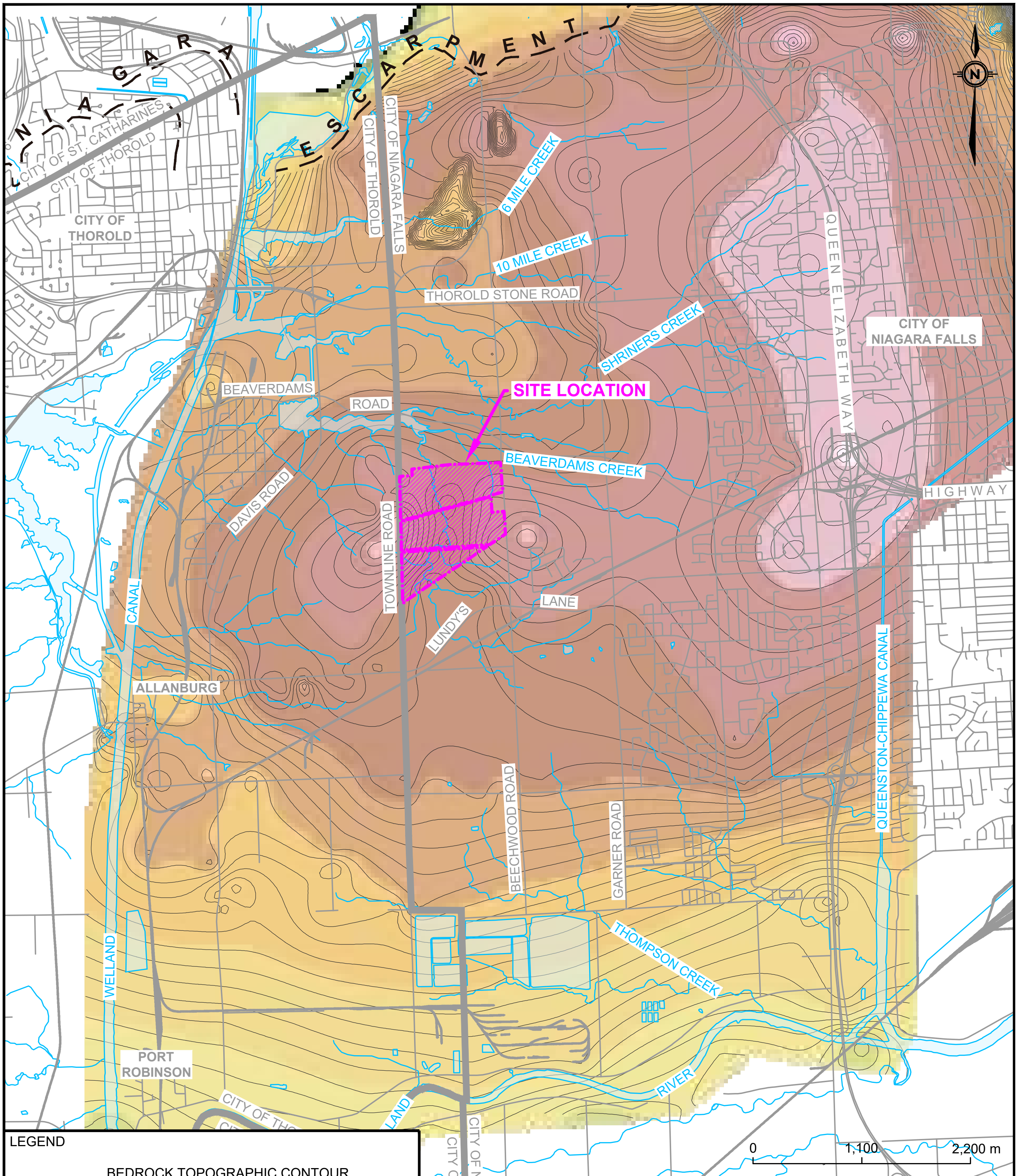
DRAWN BY: JLD

DATE: OCTOBER 2021

PROJECT: 161-11633-00

FIGURE No: 6

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F6-BR.DWG



LEGEND

BEDROCK TOPOGRAPHIC CONTOUR, 1m INTERVALS

INTERPOLATED TOP OF BEDROCK (masl)

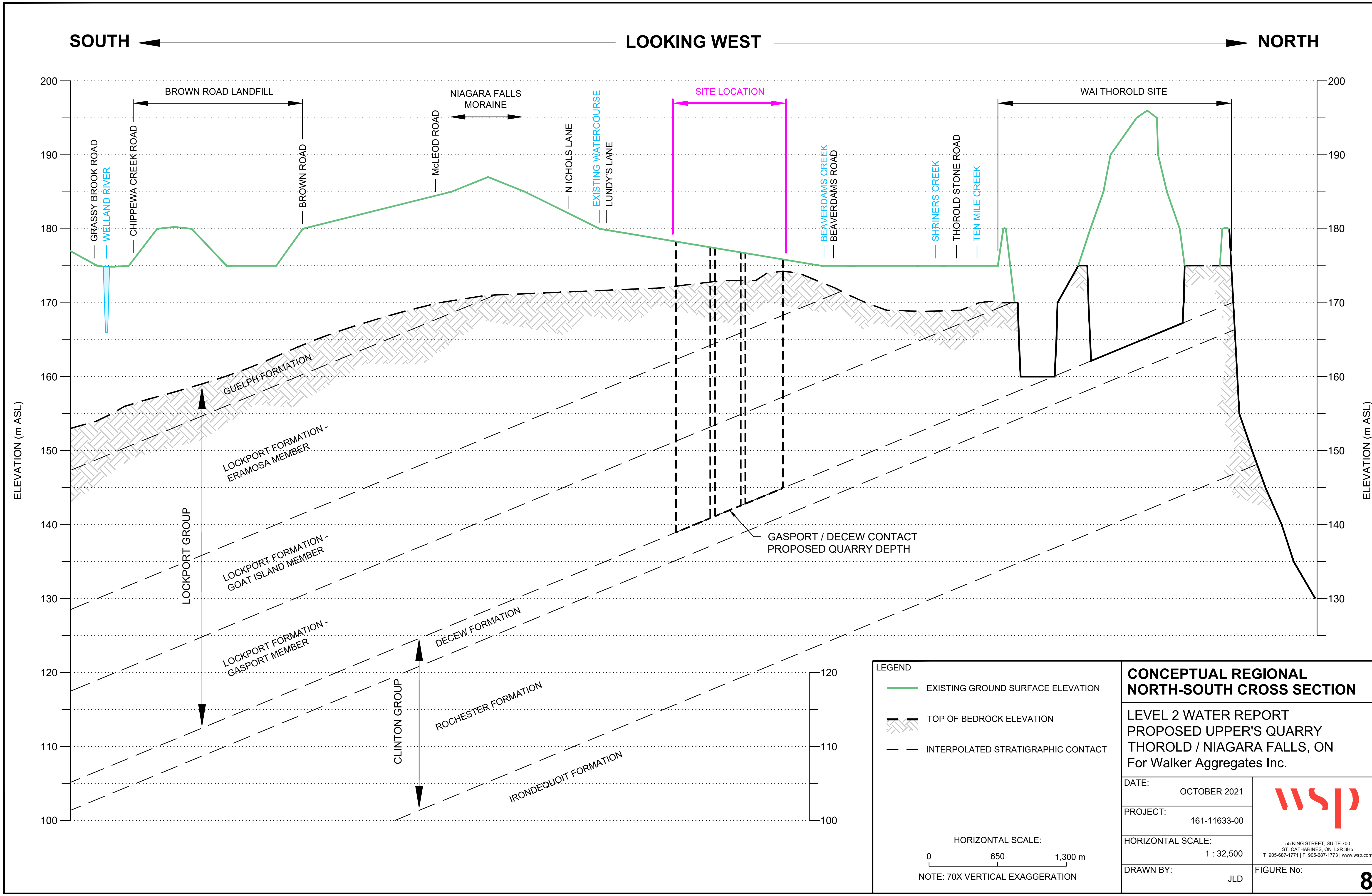
- 140 - 145
- 145 - 150
- 150 - 155
- 155 - 160
- 160 - 165
- 165 - 170
- 170 - 175
- 175 - 180
- 180 - 185
- 185 - 190

STUDY AREA INTERPOLATED BEDROCK TOPOGRAPHY

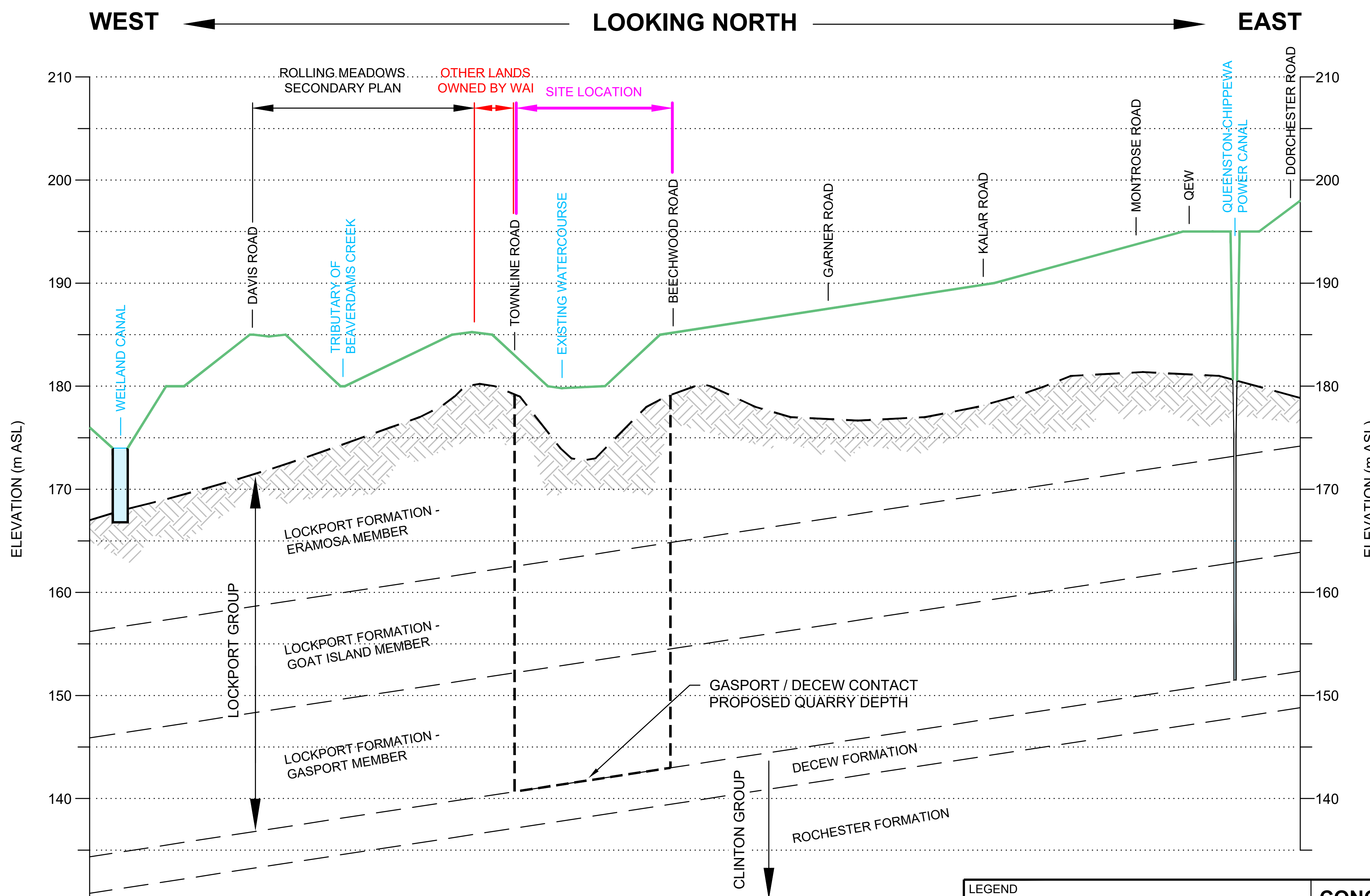
LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

SCALE:	1 : 55,000
DRAWN BY:	JLD
DATE:	OCTOBER 2021
PROJECT:	161-11633-00
FIGURE No:	7

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F7-BR.DWG



\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F8-CS.DWG



LEGEND

- EXISTING GROUND SURFACE ELEVATION
- TOP OF BEDROCK ELEVATION
- INTERPOLATED STRATIGRAPHIC CONTACT

HORIZONTAL SCALE:

0 650 1,300 m

NOTE: 70X VERTICAL EXAGGERATION

CONCEPTUAL REGIONAL EAST-WEST CROSS SECTION

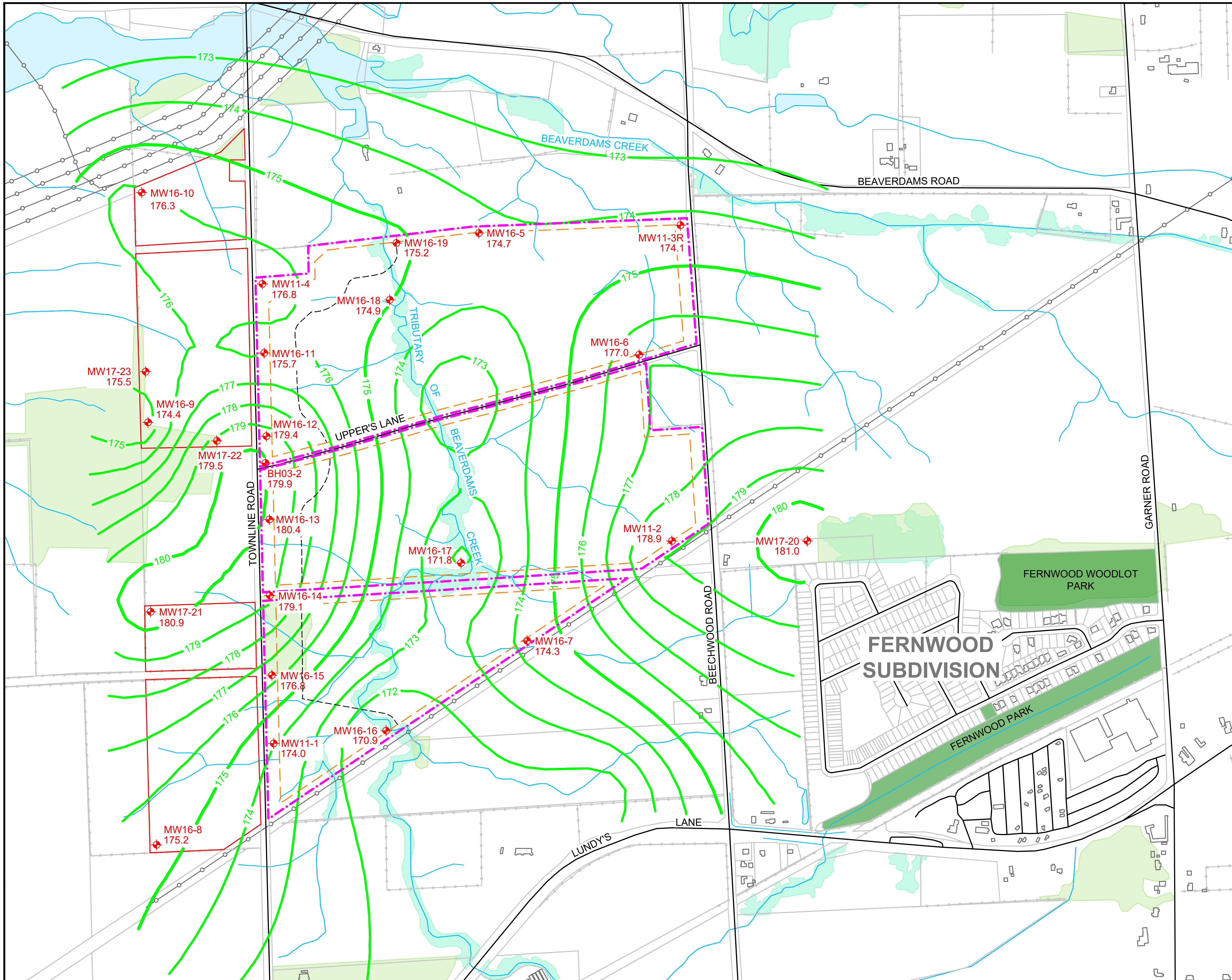
LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
HORIZONTAL SCALE:	1 : 32,500
DRAWN BY:	JLD

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

FIGURE No: 9

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F9-CS.DWG



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- FENCELINE
- UTILITY LINE
- MW11-1 MONITORING WELL NEST LOCATION AND DESIGNATION
- 174.0 TOP OF BEDROCK ELEVATION (masl)
- 174 INTERPOLATED TOP OF BEDROCK CONTOURS, 1m INTERVALS (masl)

0 180 360 m

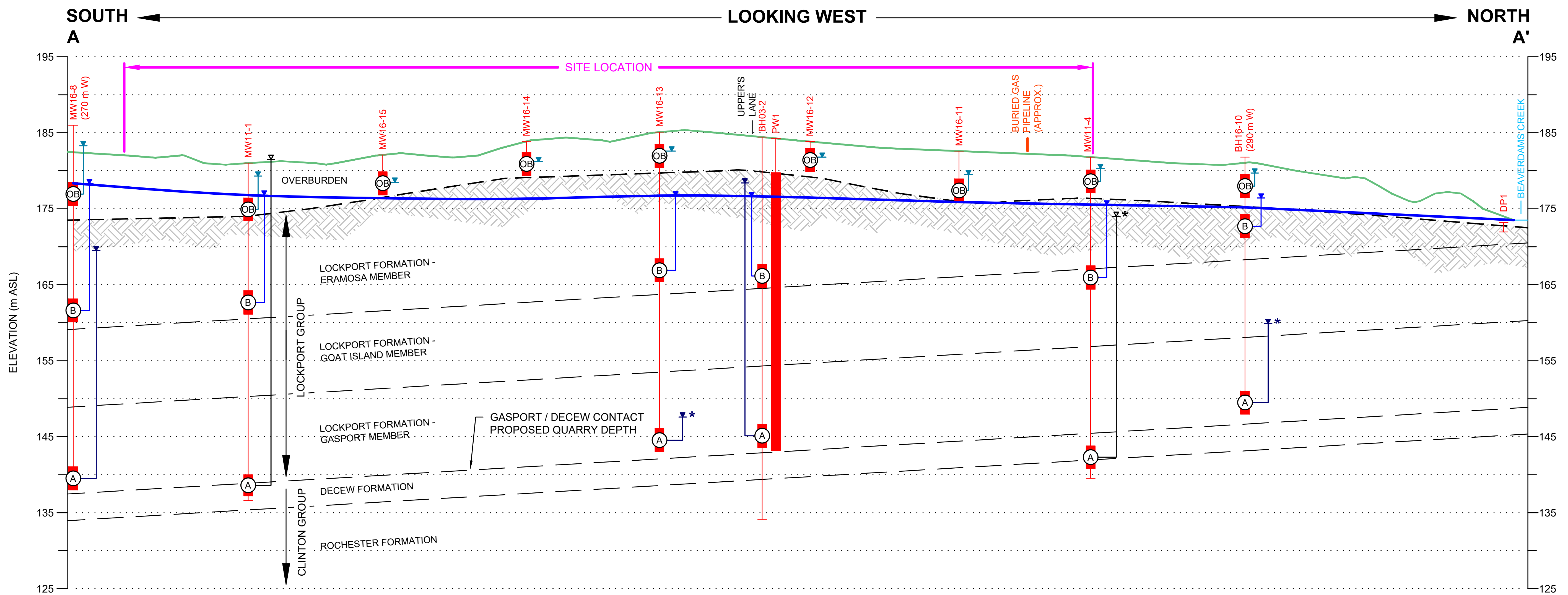
SITE SCALE INTERPOLATED BEDROCK TOPOGRAPHY

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 9,000
DRAWN BY:	JLD
FIGURE No:	10

55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\003 LEVEL 2 HYDROGEOGRAPHICS\161-11633-3-F10-BR.DWG



LEGEND

MW11-1	WELL NEST DESIGNATION
	EXISTING GROUND SURFACE ELEVATION
	SHALLOW BEDROCK AQUIFER POTENTIOMETRIC SURFACE, OCTOBER 1, 2017
	TOP OF BEDROCK ELEVATION
	INTERPOLATED STRATIGRAPHIC CONTACT
B	WELL SCREEN DESIGNATION

OCTOBER 1, 2017 GROUNDWATER ELEVATIONS

- CONTACT AQUIFER
- DEEP BEDROCK AQUIFER
- DECEW / ROCHESTER FORMATION AQUITARD
- * GROUNDWATER ELEVATION DATA NOT AVAILABLE FOR OCTOBER 1, 2017; DATA FROM NOVEMBER 2, 2017 SHOWN

NOTE: GEOLOGICAL CONTACTS HAVE BEEN INTERPOLATED AND MAY DIFFER FROM THAT DEPICTED.

HORIZONTAL SCALE:
0 110 220 m

NOTE: 10X VERTICAL EXAGGERATION

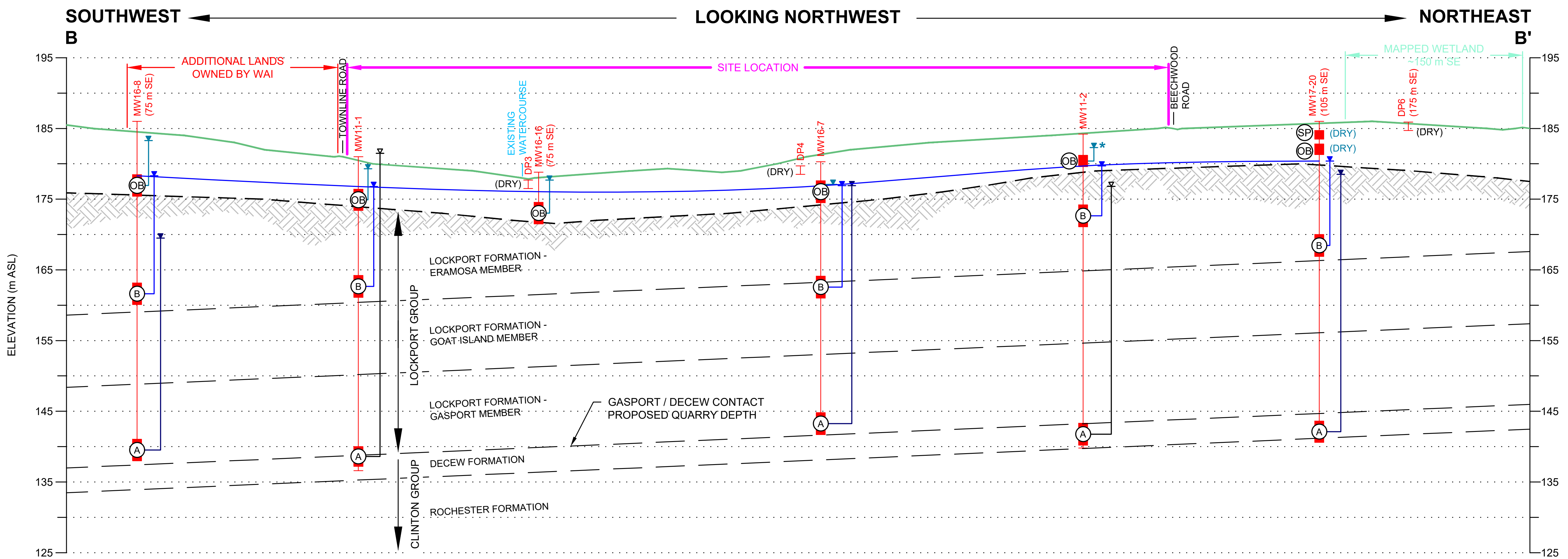
CROSS SECTION A-A'

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021
PROJECT: 161-11633-00
HORIZONTAL SCALE: 1 : 5,500
DRAWN BY: JLD
FIGURE No: 11

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F11-CS.DWG



LEGEND

MW11-1	WELL NEST DESIGNATION
	EXISTING GROUND SURFACE ELEVATION
	SHALLOW BEDROCK AQUIFER POTENTIOMETRIC SURFACE, OCTOBER 1, 2017
	TOP OF BEDROCK ELEVATION
	INTERPOLATED STRATIGRAPHIC CONTACT
B	WELL SCREEN DESIGNATION

OCTOBER 1, 2017 GROUNDWATER ELEVATIONS

- CONTACT AQUIFER
- DEEP BEDROCK AQUIFER
- DECEW / ROCHESTER FORMATION AQUITARD
- * GROUNDWATER ELEVATION DATA NOT AVAILABLE FOR OCTOBER 1, 2017; DATA FROM NOVEMBER 2, 2017 SHOWN

HORIZONTAL SCALE:

0 120 240 m

NOTE: 10X VERTICAL EXAGGERATION

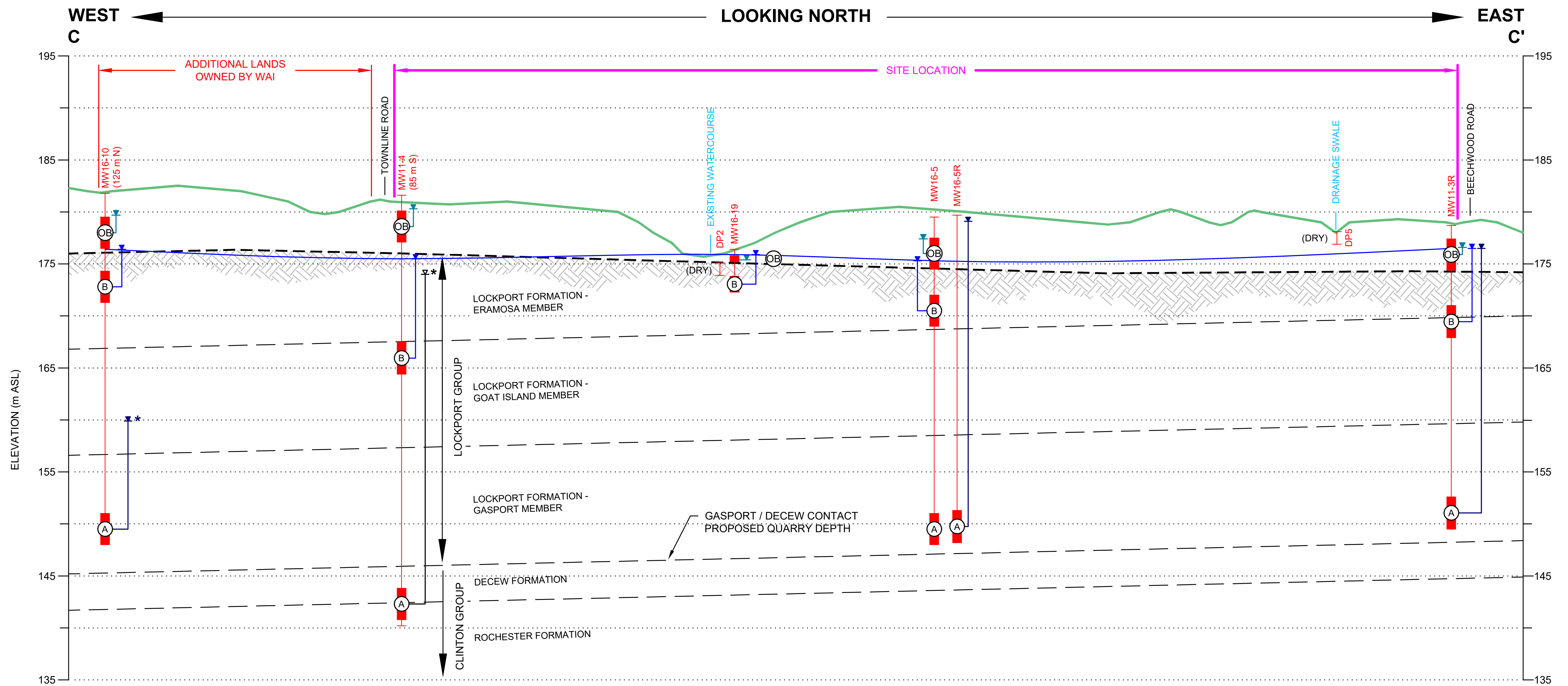
NOTE: GEOLOGICAL CONTACTS HAVE BEEN INTERPOLATED AND MAY DIFFER FROM THAT DEPICTED.

CROSS SECTION B-B'

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021	
PROJECT: 161-11633-00	
HORIZONTAL SCALE: 1 : 6,000	55 KING STREET, SUITE 700 ST. CATHARINES, ON L2R 3H5 T 905-687-1771 | F 905-687-1773 | www.wsp.com
DRAWN BY: JLD	FIGURE No: 12

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\0003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F12-CS.DWG



CROSS SECTION C-C'

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

LEGEND

- MW11-1 — WELL NEST DESIGNATION
- EXISTING GROUND SURFACE ELEVATION
- SHALLOW BEDROCK AQUIFER POTENTIOMETRIC SURFACE, OCTOBER 1, 2017
- TOP OF BEDROCK ELEVATION
- INTERPOLATED STRATIGRAPHIC CONTACT
- B — WELL SCREEN DESIGNATION

OCTOBER 1, 2017 GROUNDWATER ELEVATIONS

- CONTACT AQUIFER
- DEEP BEDROCK AQUIFER
- DECEW / ROCHESTER FORMATION AQUITARD
- * GROUNDWATER ELEVATION DATA NOT AVAILABLE FOR OCTOBER 1, 2017; DATA FROM NOVEMBER 2, 2017 SHOWN

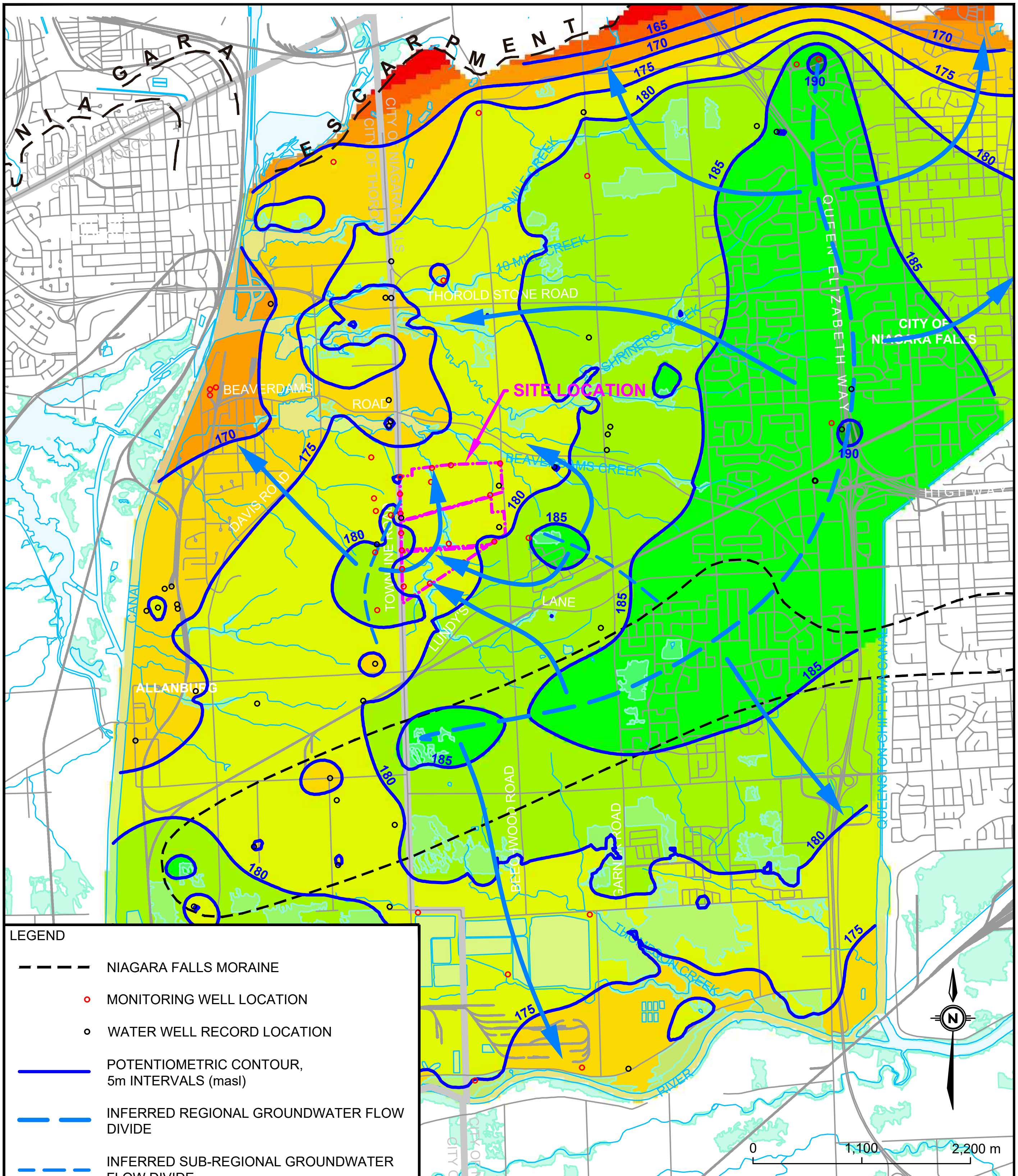
DATE: OCTOBER 2021	
PROJECT: 161-11633-00	
HORIZONTAL SCALE: 1 : 4,000	55 KING STREET, SUITE 700 ST. CATHARINES, ON L2R 3H5 T 905-687-1771 | F 905-687-1773 | www.wsp.com
DRAWN BY: JLD	FIGURE No: 13

HORIZONTAL SCALE: 0 80 160 m

NOTE: 10X VERTICAL EXAGGERATION

NOTE: GEOLOGICAL CONTACTS HAVE BEEN INTERPOLATED AND MAY DIFFER FROM THAT DEPICTED.

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\0003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F13-CS.DWG



LEGEND

- NIAGARA FALLS MORAINE
- MONITORING WELL LOCATION
- WATER WELL RECORD LOCATION
- POTENTIOMETRIC CONTOUR, 5m INTERVALS (masl)
- INFERRED REGIONAL GROUNDWATER FLOW DIVIDE
- INFERRED SUB-REGIONAL GROUNDWATER FLOW DIVIDE
- INFERRED GROUNDWATER FLOW DIRECTION

INTERPOLATED POTENTIOMETRIC SURFACE (masl)

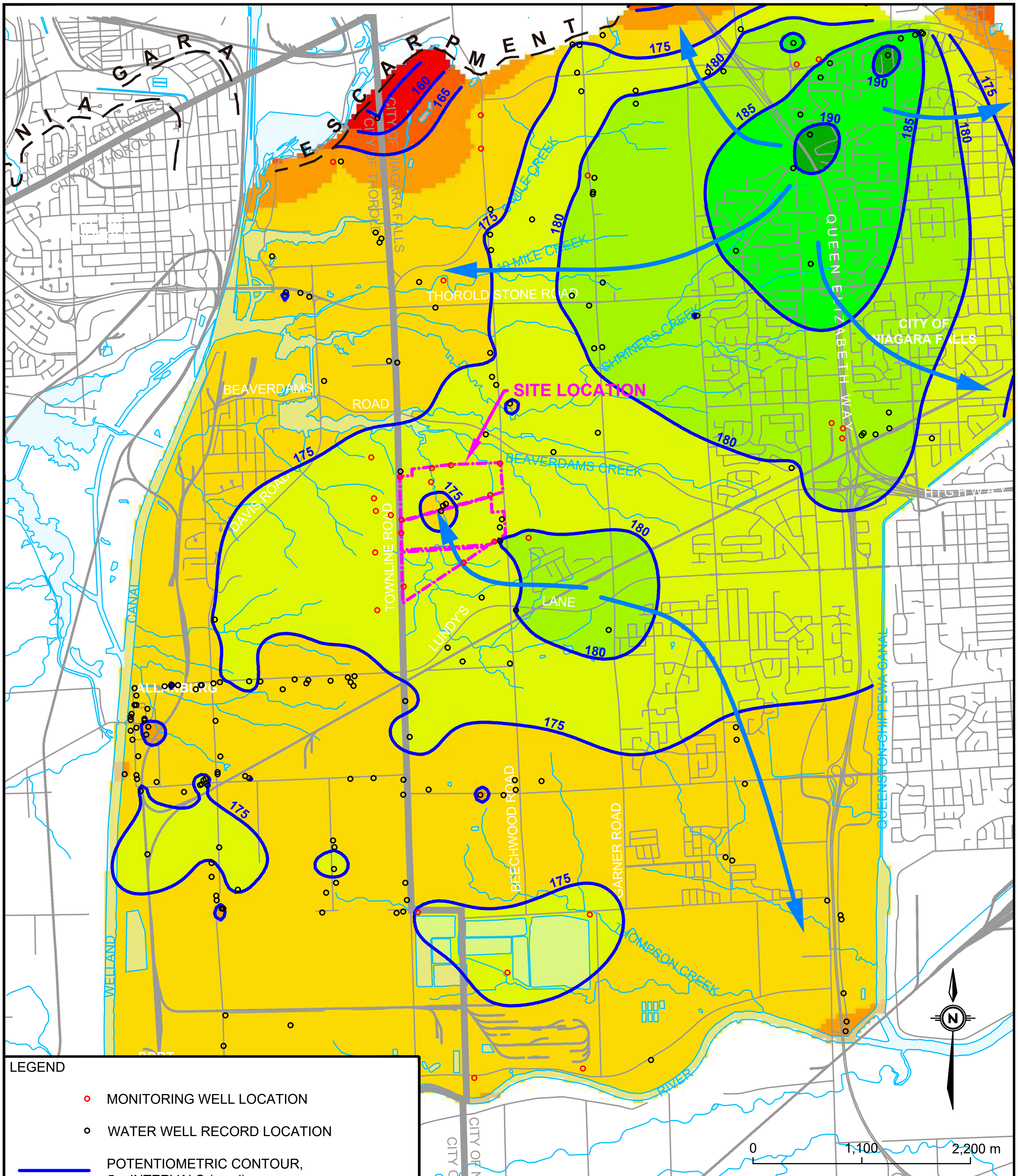
- < 160
- 160 - 165
- 165 - 170
- 170 - 175
- 175 - 180
- 180 - 185
- 185 - 190
- > 190

STUDY AREA CONTACT AQUIFER POTENTIOMETRIC SURFACE

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

wsp

SCALE: 1 : 55,000	DRAWN BY: JLD		
DATE: OCTOBER 2021	PROJECT: 161-11633-00	FIGURE No: 14	



LEGEND

- MONITORING WELL LOCATION
- WATER WELL RECORD LOCATION
- POTENTIOMETRIC CONTOUR, 5m INTERVALS (masl)
- INFERRED GROUNDWATER FLOW DIRECTION

INTERPOLATED POTENTIOMETRIC SURFACE (masl)

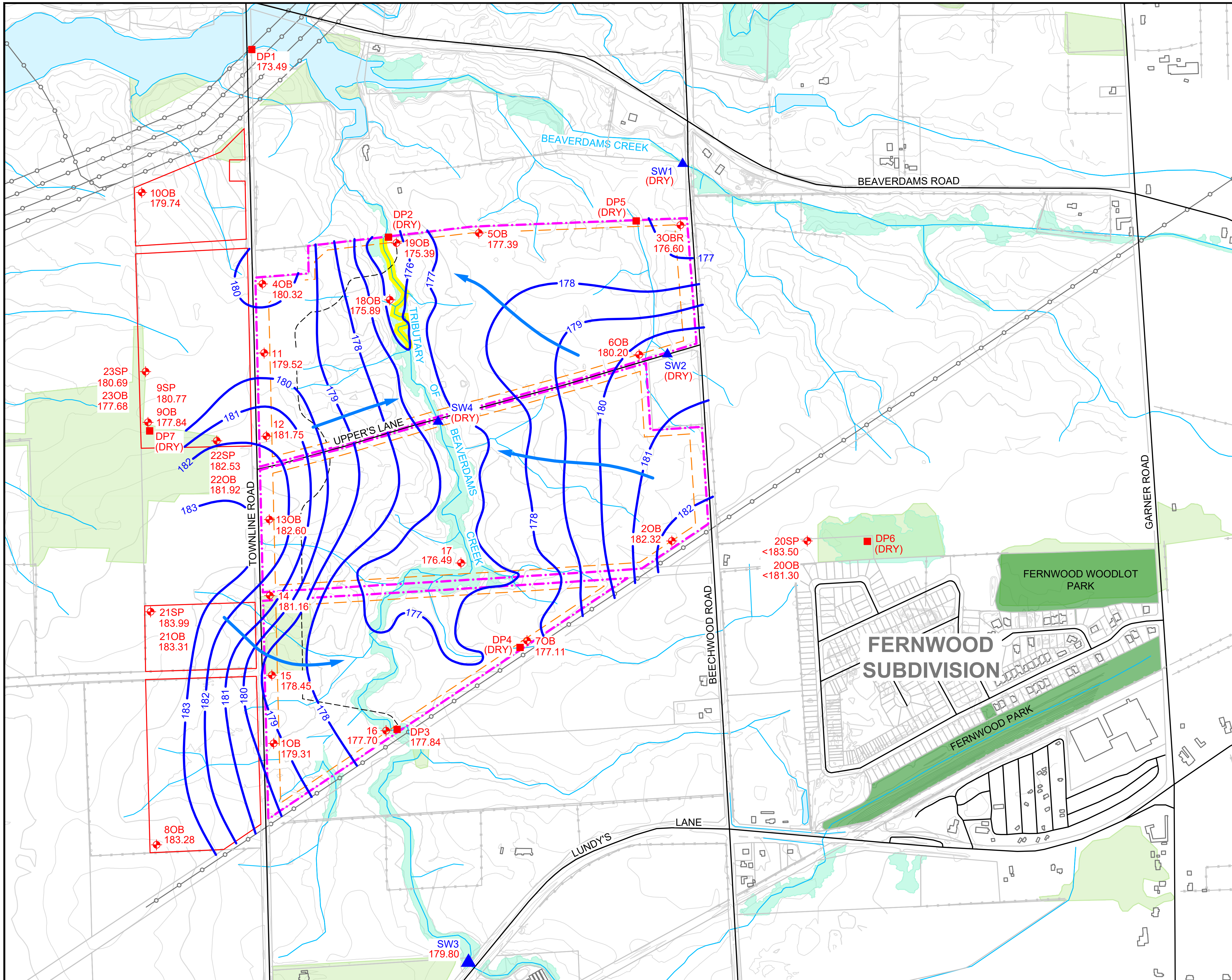
- < 160
- 160 - 165
- 165 - 170
- 170 - 175
- 175 - 180
- 180 - 185
- 185 - 190
- > 190

STUDY AREA SHALLOW BEDROCK AQUIFER POTENTIOMETRIC SURFACE

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021	PROJECT: 161-11633-00	SCALE: 1 : 55,000	DRAWN BY: JLD
		FIGURE No: 15	

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F15-GW.DWG



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- 1OB MONITORING WELL LOCATION AND DESIGNATION
- DP1 DRIVEPOINT LOCATION AND DESIGNATION
- SW1 STAFF GAUGE LOCATION AND DESIGNATION
- 179.31 GROUNDWATER ELEVATION, OCTOBER 1, 2017 (masl)
- 179 INTERPOLATED POTENTIOMETRIC CONTOURS (masl)
- INFERRED GROUNDWATER FLOW DIRECTION
- AREA OF INFERRED GROUNDWATER DISCHARGE TO EXISTING WATERCOURSE

N

0 180 360 m

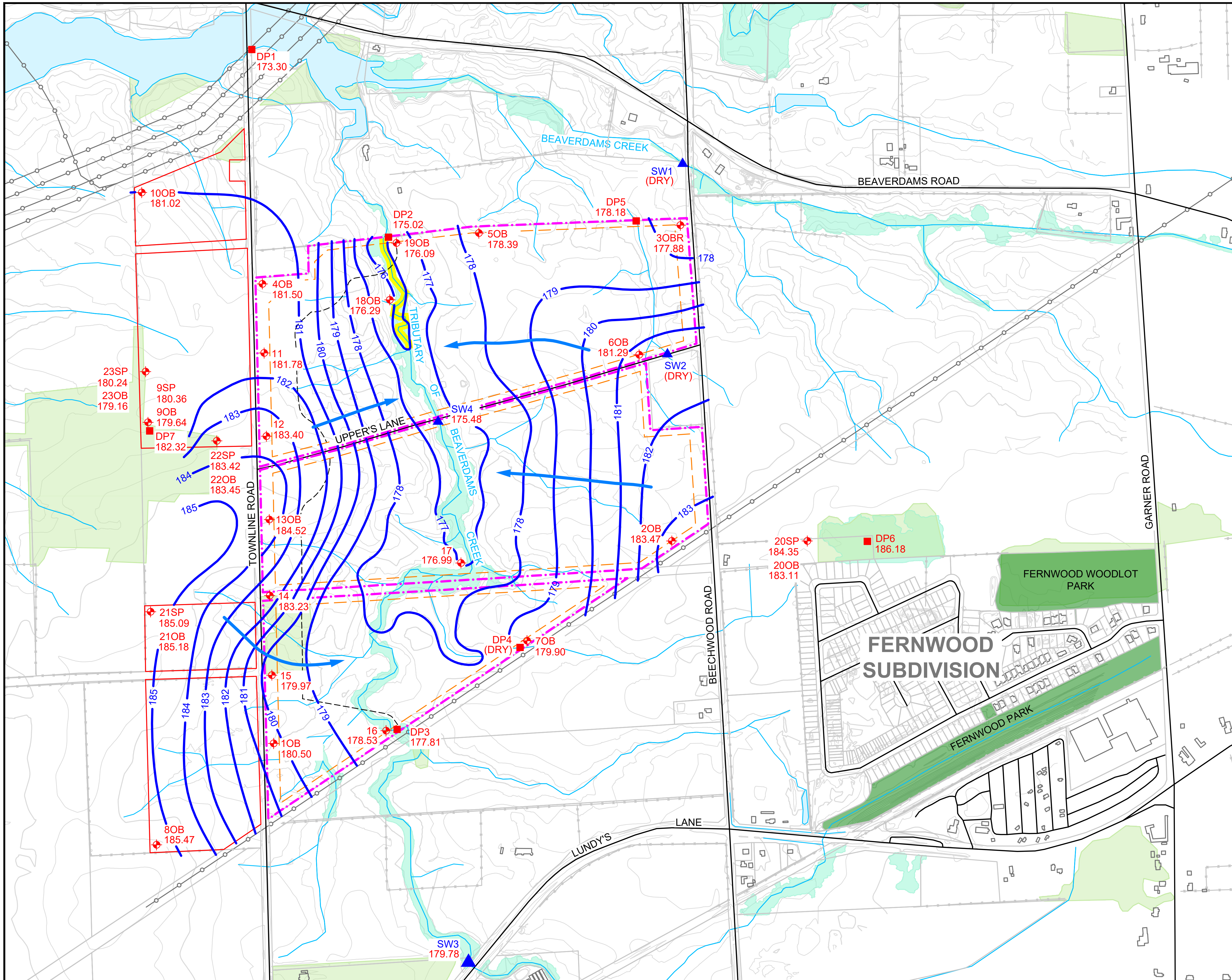
CONTACT AQUIFER POTENTIOMETRIC CONTOURS - OCTOBER 2017

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021		
PROJECT: 161-11633-00		
SCALE: 1 : 9,000		
DRAWN BY: JLD	FIGURE No: 16	

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\0003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F16-GW.DWG



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- 1OB MONITORING WELL LOCATION AND DESIGNATION
- DP1 DRIVEPOINT LOCATION AND DESIGNATION
- SW1 STAFF GAUGE LOCATION AND DESIGNATION
- 179.31 GROUNDWATER ELEVATION, MAY 1, 2018 (masl)
- 179 INTERPOLATED POTENTIOMETRIC CONTOURS (masl)
- INFERRED GROUNDWATER FLOW DIRECTION
- AREA OF INFERRED GROUNDWATER DISCHARGE TO EXISTING WATERCOURSE

N

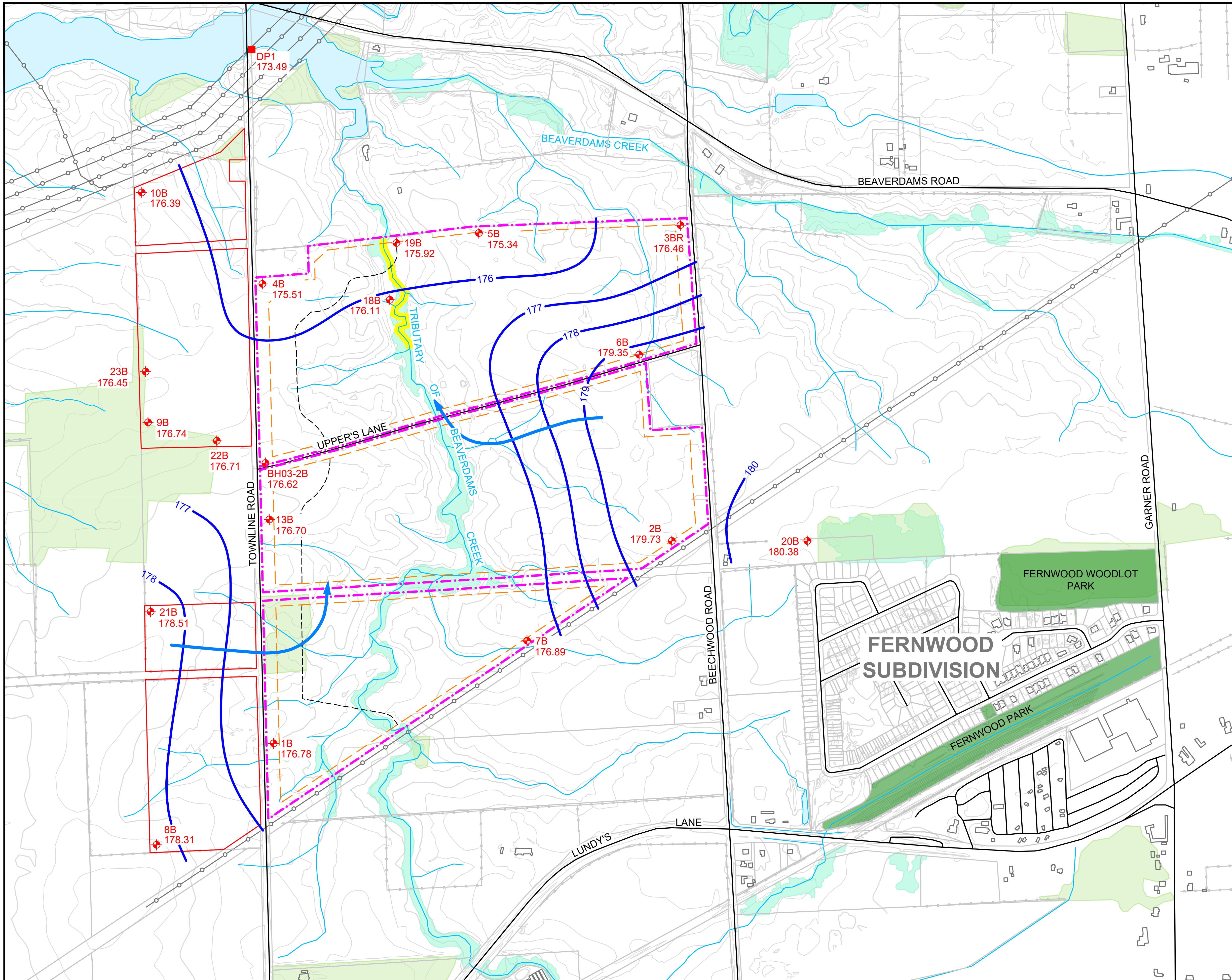
0 180 360 m

CONTACT AQUIFER POTENTIOMETRIC CONTOURS - MAY 2018

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021	wsp
PROJECT: 161-11633-00	
SCALE: 1 : 9,000	55 KING STREET, SUITE 700 ST. CATHARINES, ON L2R 3H5 T 905-687-1771 | F 905-687-1773 | www.wsp.com
DRAWN BY: JLD	FIGURE No: 17

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\0003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F17-GW.DWG



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- 1B — MONITORING WELL NEST LOCATION AND DESIGNATION
- DP1 — DRIVEPOINT LOCATION AND DESIGNATION
- 176.78 — GROUNDWATER ELEVATION, OCTOBER 1, 2017 (masl)
- 179 — INTERPOLATED POTENTIOMETRIC CONTOURS (masl)
- INFERRED GROUNDWATER FLOW DIRECTION
- AREA OF INFERRED GROUNDWATER DISCHARGE TO EXISTING WATERCOURSE

N

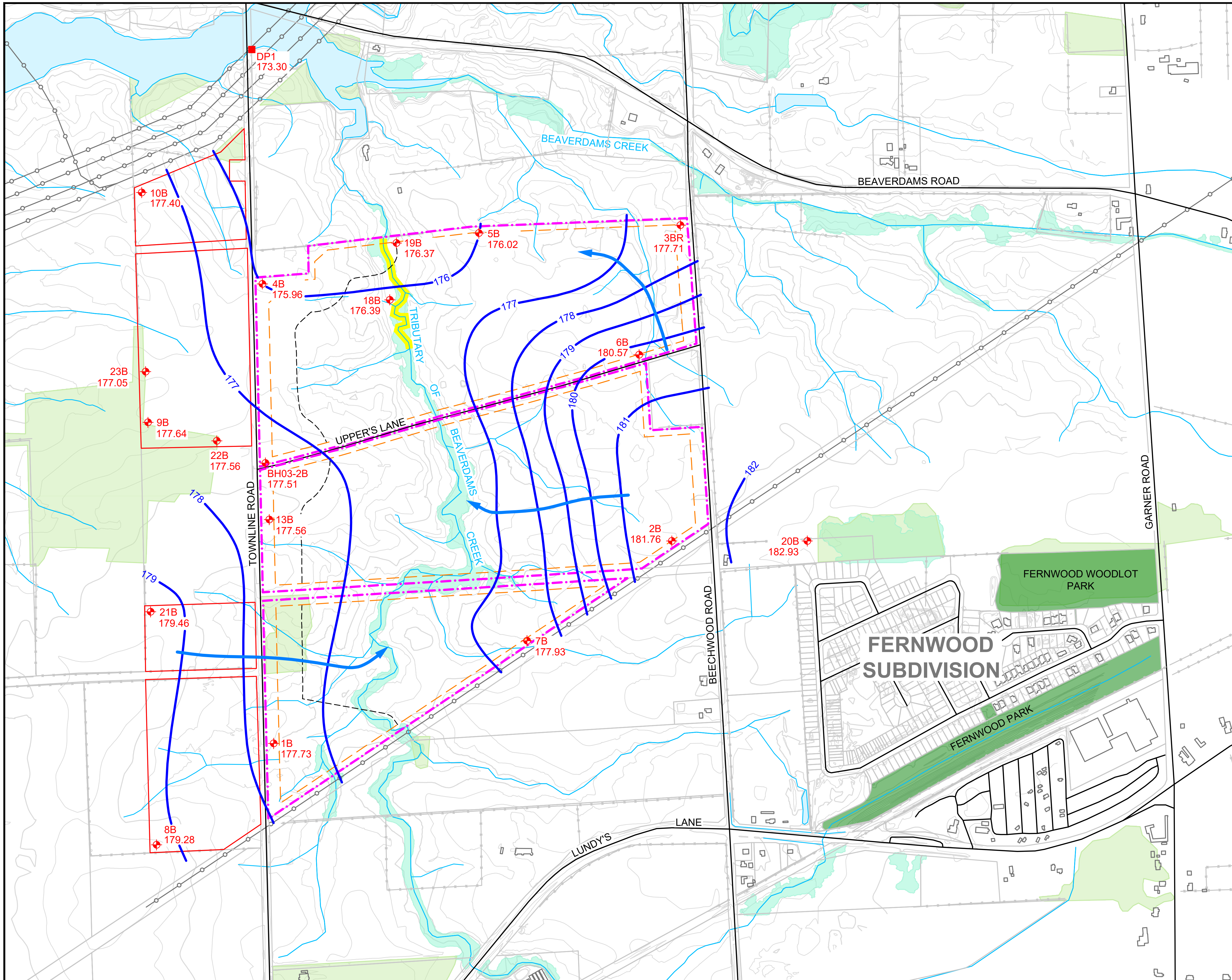
0 180 360 m

SHALLOW BEDROCK AQUIFER POTENTIOMETRIC CONTOURS - OCTOBER 2017

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 9,000
DRAWN BY:	JLD
FIGURE No:	18

55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- 1B MONITORING WELL NEST LOCATION AND DESIGNATION
- DP1 DRIVEPOINT LOCATION AND DESIGNATION
- 176.78 GROUNDWATER ELEVATION, MAY 1, 2018 (masl)
- 179 INTERPOLATED POTENTIOMETRIC CONTOURS (masl)
- INFERRED GROUNDWATER FLOW DIRECTION
- AREA OF INFERRED GROUNDWATER DISCHARGE TO EXISTING WATERCOURSE

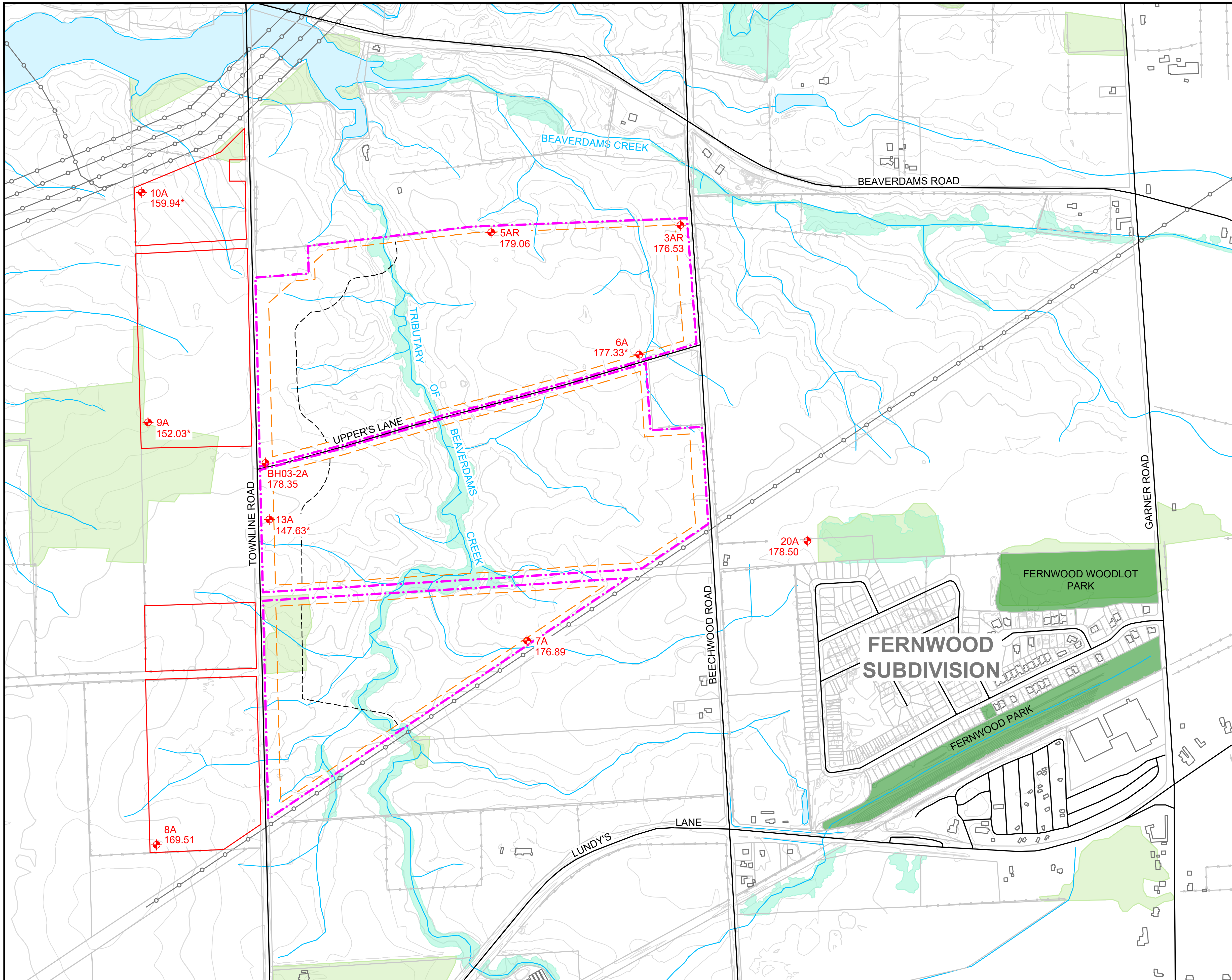
SHALLOW BEDROCK AQUIFER POTENTIOMETRIC CONTOURS - MAY 2018

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021	
PROJECT: 161-11633-00	
SCALE: 1 : 9,000	
DRAWN BY: JLD	FIGURE No: 19

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROGI\GRAPHICS\161-11633-3-F19-GW.DWG



LEGEND

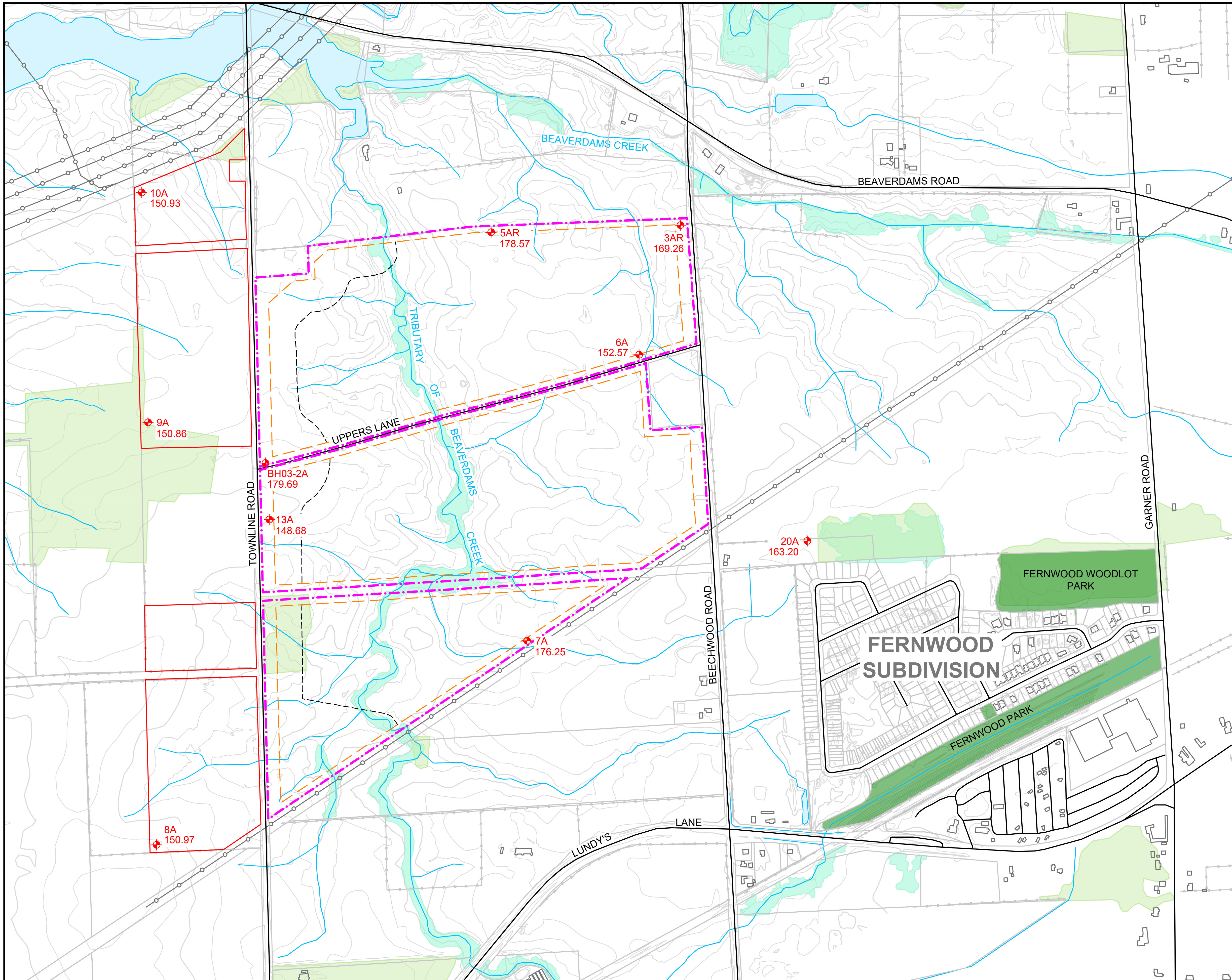
- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- 7A — MONITORING WELL NEST LOCATION AND DESIGNATION
- 176.89 — GROUNDWATER ELEVATION, OCTOBER 1, 2017 (masl)
- * — GROUNDWATER ELEVATION DATA NOT AVAILABLE FOR OCTOBER 1, 2017; DATA FROM NOVEMBER 2, 2017 SHOWN

DEEP BEDROCK AQUIFER POTENTIOMETRIC ELEVATIONS - OCTOBER 2017

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021	wsp
PROJECT: 161-11633-00	55 KING STREET, SUITE 700 ST. CATHARINES, ON L2R 3H5 T 905-687-1771 | F 905-687-1773 | www.wsp.com
SCALE: 1 : 9,000	
DRAWN BY: JLD	FIGURE No: 20

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F20-GW.DWG



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- 7A — MONITORING WELL NEST LOCATION AND DESIGNATION
- 176.89 — GROUNDWATER ELEVATION, MAY 1, 2018 (masl)

N

0 180 360 m

DEEP BEDROCK AQUIFER POTENTIOMETRIC ELEVATIONS - MAY 2018

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

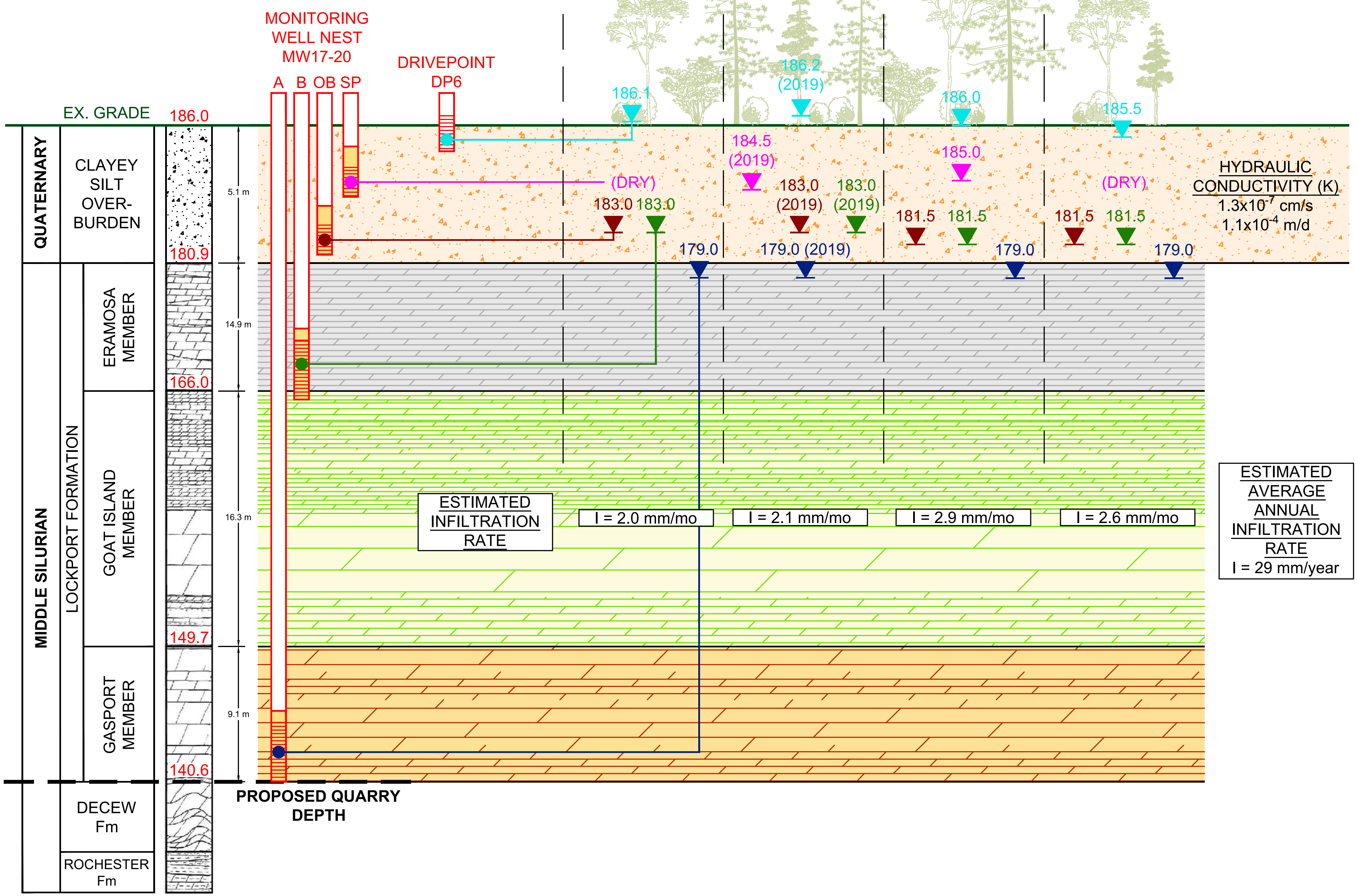
DATE: OCTOBER 2021	wsp
PROJECT: 161-11633-00	55 KING STREET, SUITE 700 ST. CATHARINES, ON L2R 3H5 T 905-687-1771 | F 905-687-1773 | www.wsp.com
SCALE: 1 : 9,000	
DRAWN BY: JLD	FIGURE No: 21

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\0003 LEVEL 2 HYDROGEOLOGY\GRAPHICS\161-11633-3-F21-GW.DWG

5584 BEECHWOOD ROAD WETLAND - BASELINE CONDITIONS

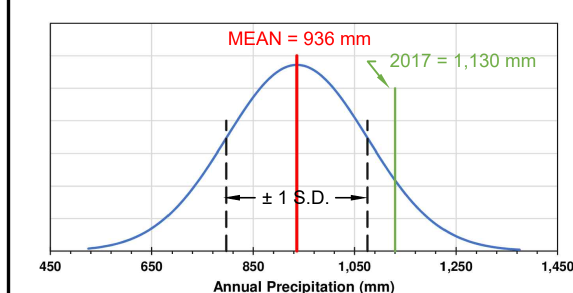
WATER BALANCE - 2017

	1964-1990 NORMAL	2017
PRECIPITATION -	953 mm	1,130 mm
EVAPOTRANSPIRATION -	644 mm	656 mm
AVAILABLE RECHARGE -	309 mm	474 mm



ANNUAL PRECIPITATION PROBABILITY CURVE

BASED ON WELLAND DATA (1931 - 2006)



5584 BEECHWOOD ROAD WETLAND - BASELINE CONDITIONS (2017)

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021		
PROJECT: 161-11633-00		
SCALE: AS SHOWN		
DRAWN BY: JLD	FIGURE No: 22A	

wsp

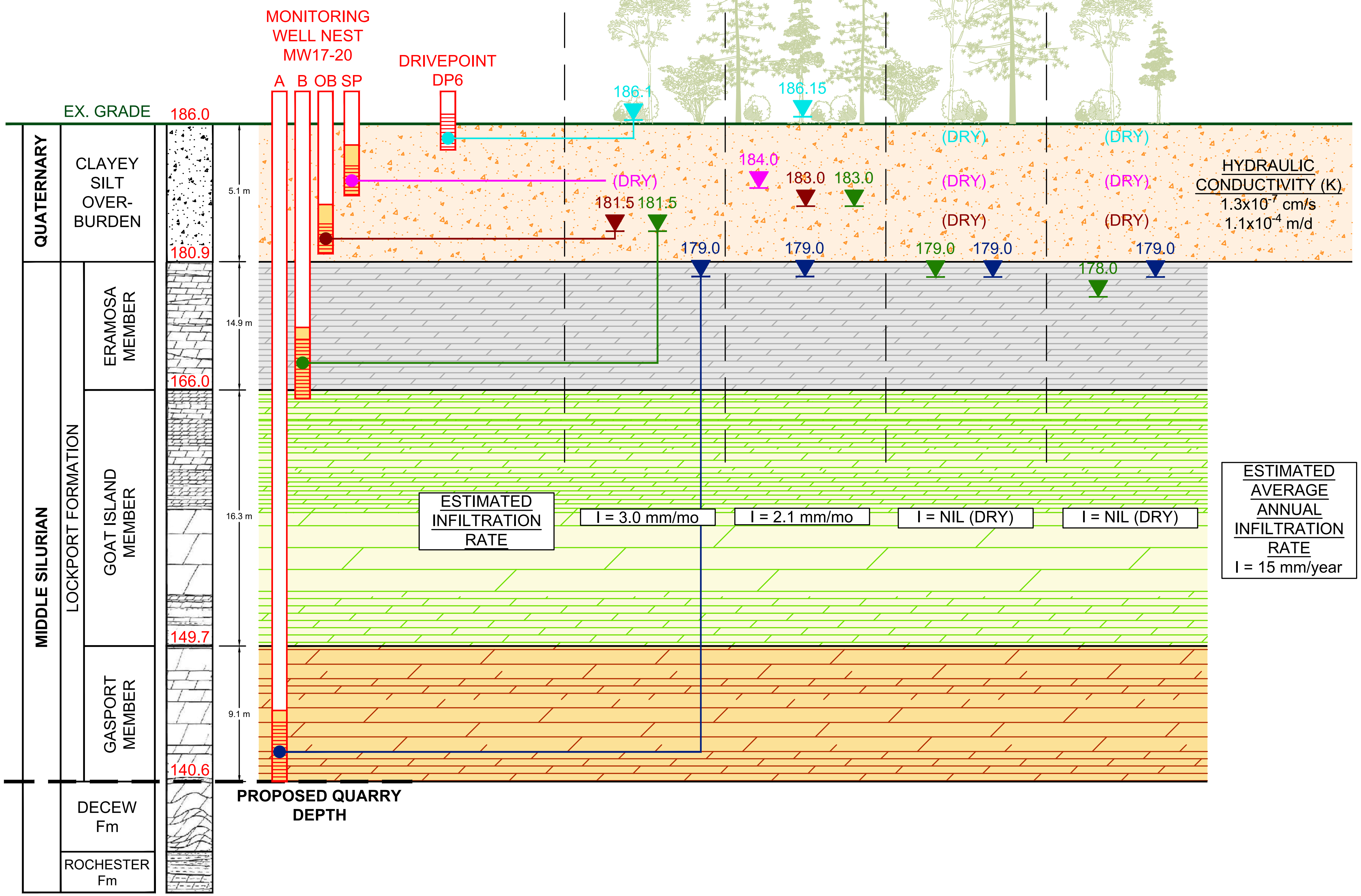
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F22-CS.DWG

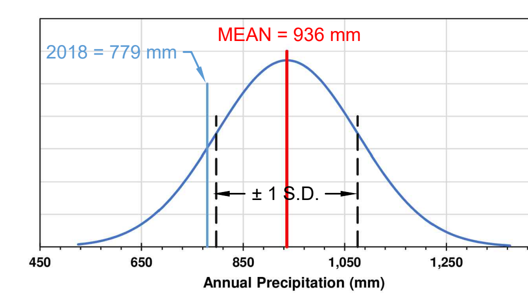
5584 BEECHWOOD ROAD WETLAND - BASELINE CONDITIONS

WATER BALANCE - 2018

	1964-1990 NORMAL	2018
PRECIPITATION -	953 mm	779 mm
EVAPOTRANSPIRATION -	644 mm	665 mm
AVAILABLE RECHARGE -	309 mm	118 mm



ANNUAL PRECIPITATION PROBABILITY CURVE
BASED ON WELLAND DATA (1931 - 2006)

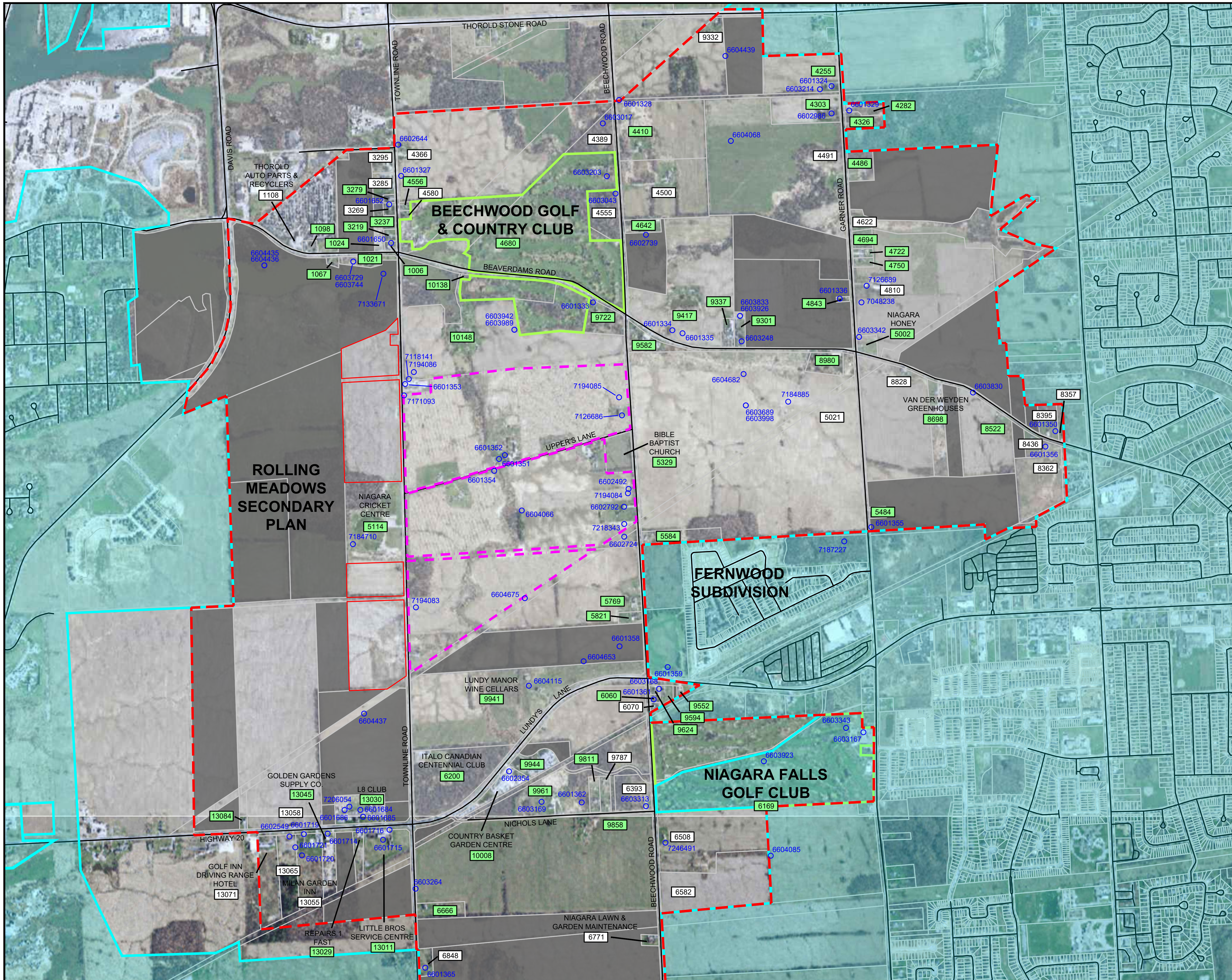


5584 BEECHWOOD ROAD WETLAND - BASELINE CONDITIONS (2018)

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021	
PROJECT: 161-11633-00	
SCALE: AS SHOWN	55 KING STREET, SUITE 700 ST. CATHARINES, ON L2R 3H5 T 905-687-1771 | F 905-687-1773 | www.wsp.com
DRAWN BY: JLD	FIGURE No: **22B**

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F22-CS.DWG



LEGEND

- SITE BOUNDARY
- ADDITIONAL LANDS OWNED BY WAI
- LAND PARCELS
- APPROXIMATE SURVEY AREA
- 5584 STREET ADDRESS (GREEN INDICATES SURVEY RETURNED)
- PARCEL WITH NO ASSOCIATED STREET ADDRESS
- 7194083 MECP WATER WELL RECORD LOCATION AND DESIGNATION
- APPROXIMATE EXISTING WATER SYSTEM (MASTER SERVICING PLAN, NIAGARA REGION, 2016)

0 350 700 m

2018 / 2019 WATER WELL SURVEY

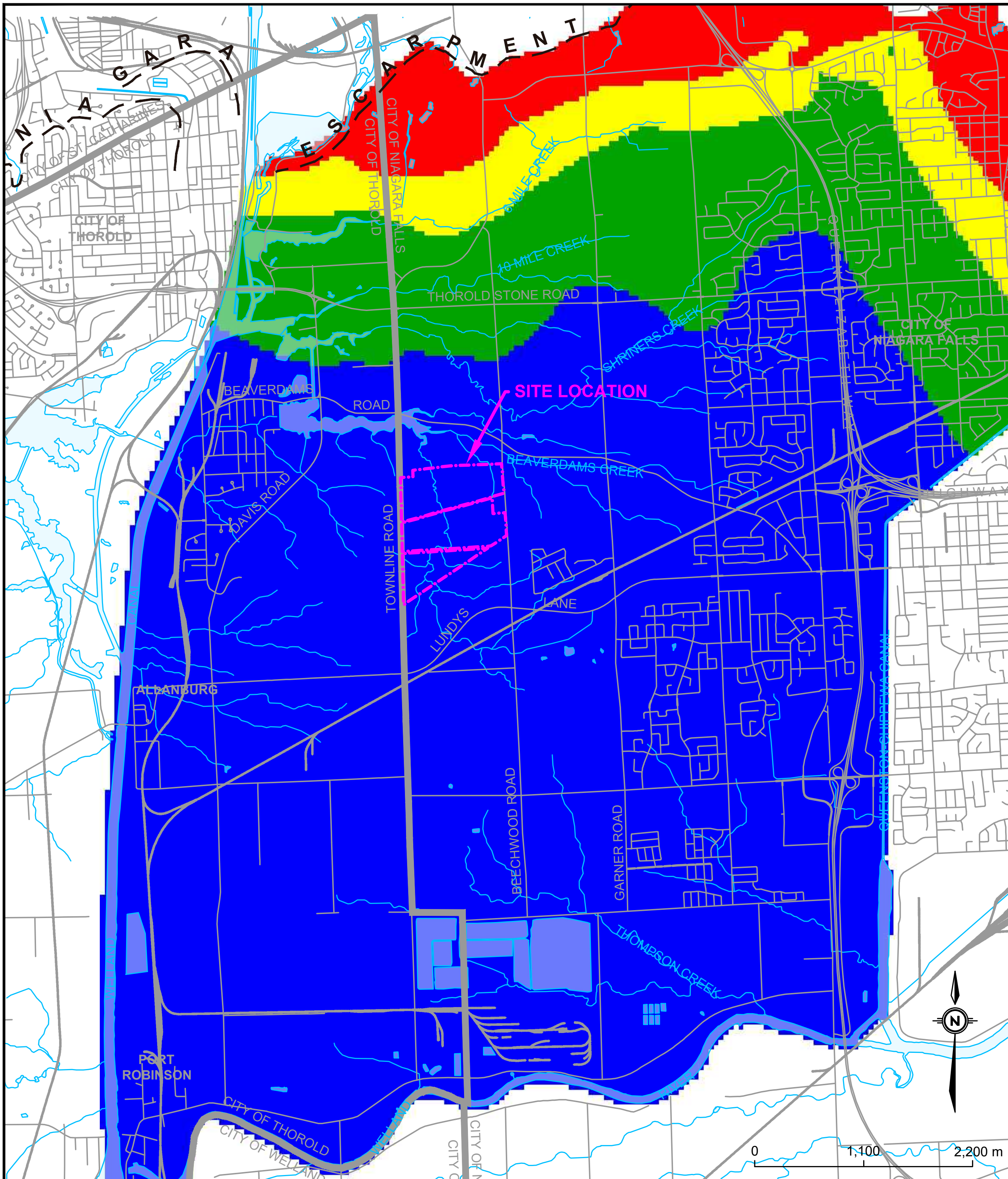
LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 17,500
DRAWN BY:	JLD
FIGURE No:	23

wsp

55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F23-SP.DWG



LEGEND

SHALLOW AND DEEP BEDROCK AQUIFER AVAILABLE DRAWDOWN (m)

- < 3
- 3 - 10
- 10 - 20
- > 20

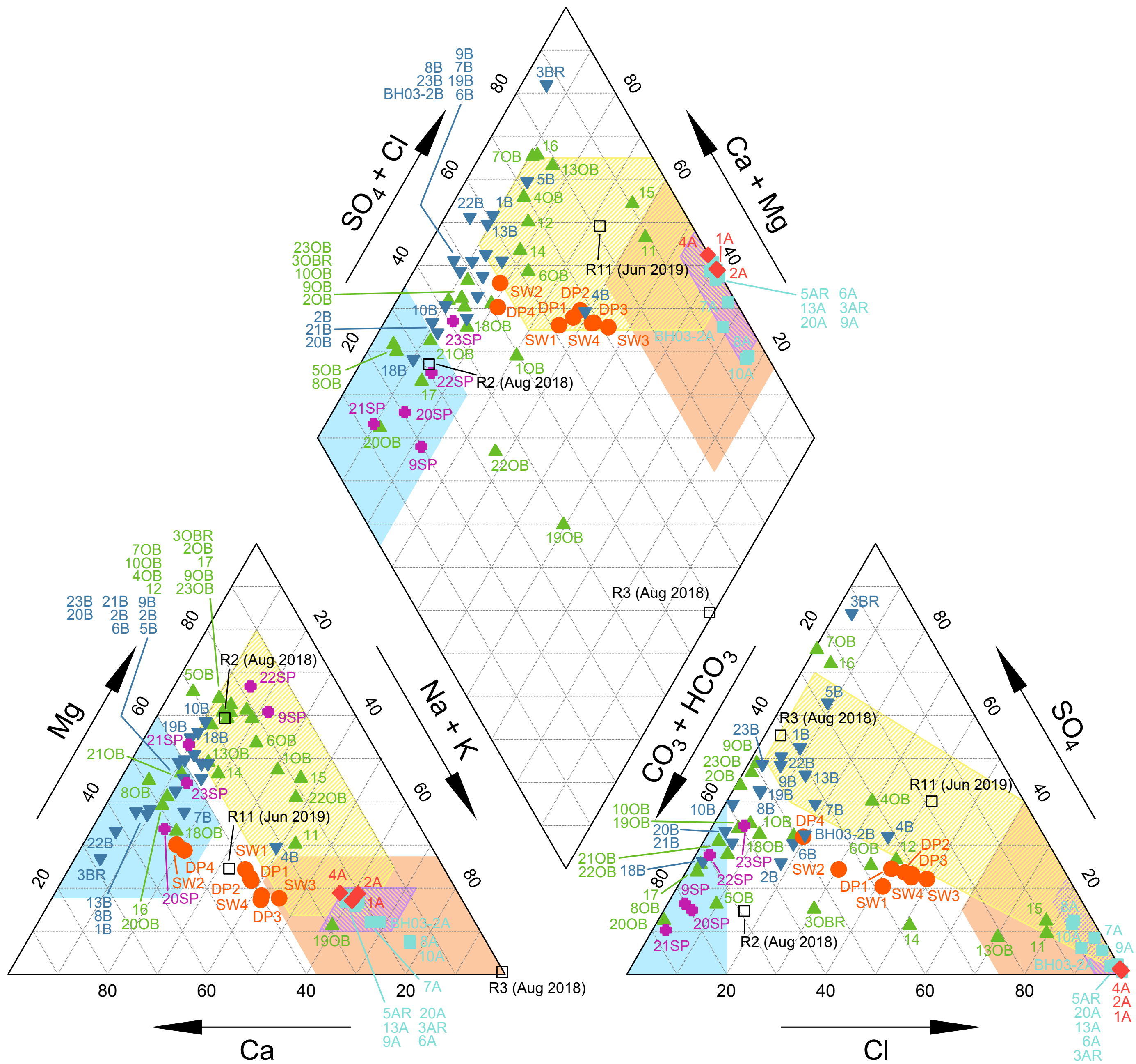
SHALLOW AND DEEP BEDROCK AQUIFER AVAILABLE DRAWDOWN - BASELINE CONDITIONS

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

wsp

SCALE:	1 : 55,000
DRAWN BY:	JLD
DATE:	OCTOBER 2021
PROJECT:	161-11633-00
FIGURE No:	24

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F24-GW.DWG



LEGEND

SW1 ● SURFACE WATER

9SP ✚ SHALLOW WEATHERED OVERBURDEN

1OB ▲ CONTACT AQUIFER

1B ▼ SHALLOW BEDROCK AQUIFER

BH03-2A ■ DEEP BEDROCK AQUIFER

1A ◆ DECEW / ROCHESTER Fm AQUITARD

R2 □ RESIDENTIAL WELL

WAI THOROLD SITE CHEMISTRY RANGES

TYPICAL METEORIC WATER

LOCKPORT DOLOSTONE

ROCHESTER SHALE

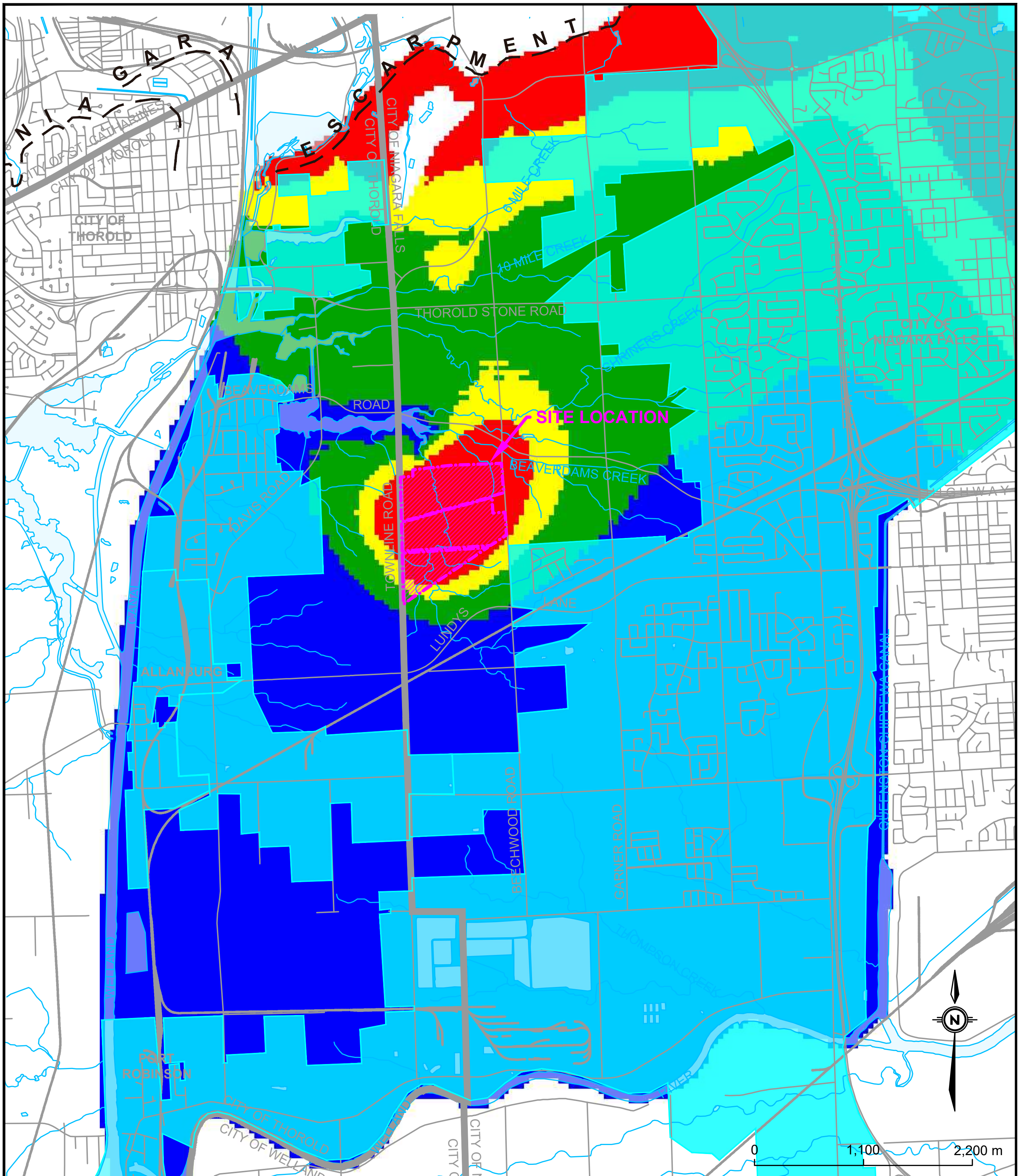
DECEW DOLOSTONE

TRILINEAR DIAGRAM - MARCH 2018

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

SCALE:	AS SHOWN
DRAWN BY:	JLD
DATE:	OCTOBER 2021
PROJECT:	161-11633-00
FIGURE No:	25

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F25-TL.DWG



LEGEND

APPROXIMATE EXISTING WATER SYSTEM (MASTER SERVICING PLAN, NIAGARA REGION, 2016)

SHALLOW AND DEEP BEDROCK AQUIFER AVAILABLE DRAWDOWN (m)

- < 3
- 3 - 10
- 10 - 20
- > 20

SHALLOW AND DEEP BEDROCK AQUIFER PREDICTED AVAILABLE DRAWDOWN - FULL QUARRY DEVELOPMENT

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

wsp

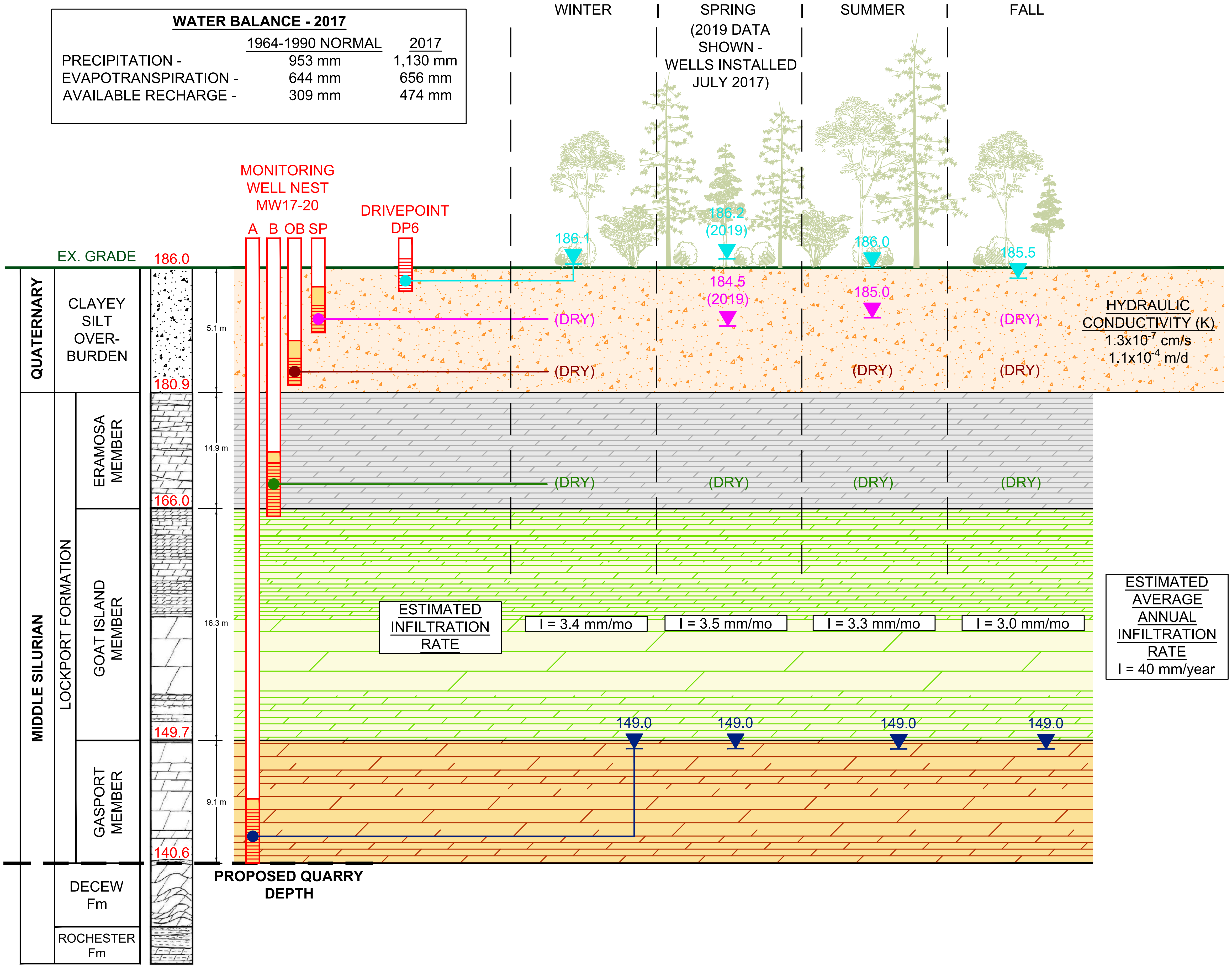
SCALE:	1 : 55,000
DRAWN BY:	JLD
DATE:	OCTOBER 2021
PROJECT:	161-11633-00
FIGURE No:	**26**

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F26-GW.DWG

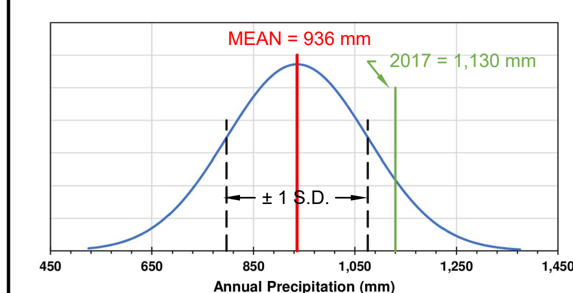
5584 BEECHWOOD ROAD WETLAND - FULL DEVELOPMENT INFILTRATION

WATER BALANCE - 2017

	1964-1990 NORMAL	2017
PRECIPITATION -	953 mm	1,130 mm
EVAPOTRANSPIRATION -	644 mm	656 mm
AVAILABLE RECHARGE -	309 mm	474 mm



ANNUAL PRECIPITATION PROBABILITY CURVE
BASED ON WELLAND DATA (1931 - 2006)



5584 BEECHWOOD ROAD WETLAND - FULL QUARRY DEVELOPMENT (WET YEAR)

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

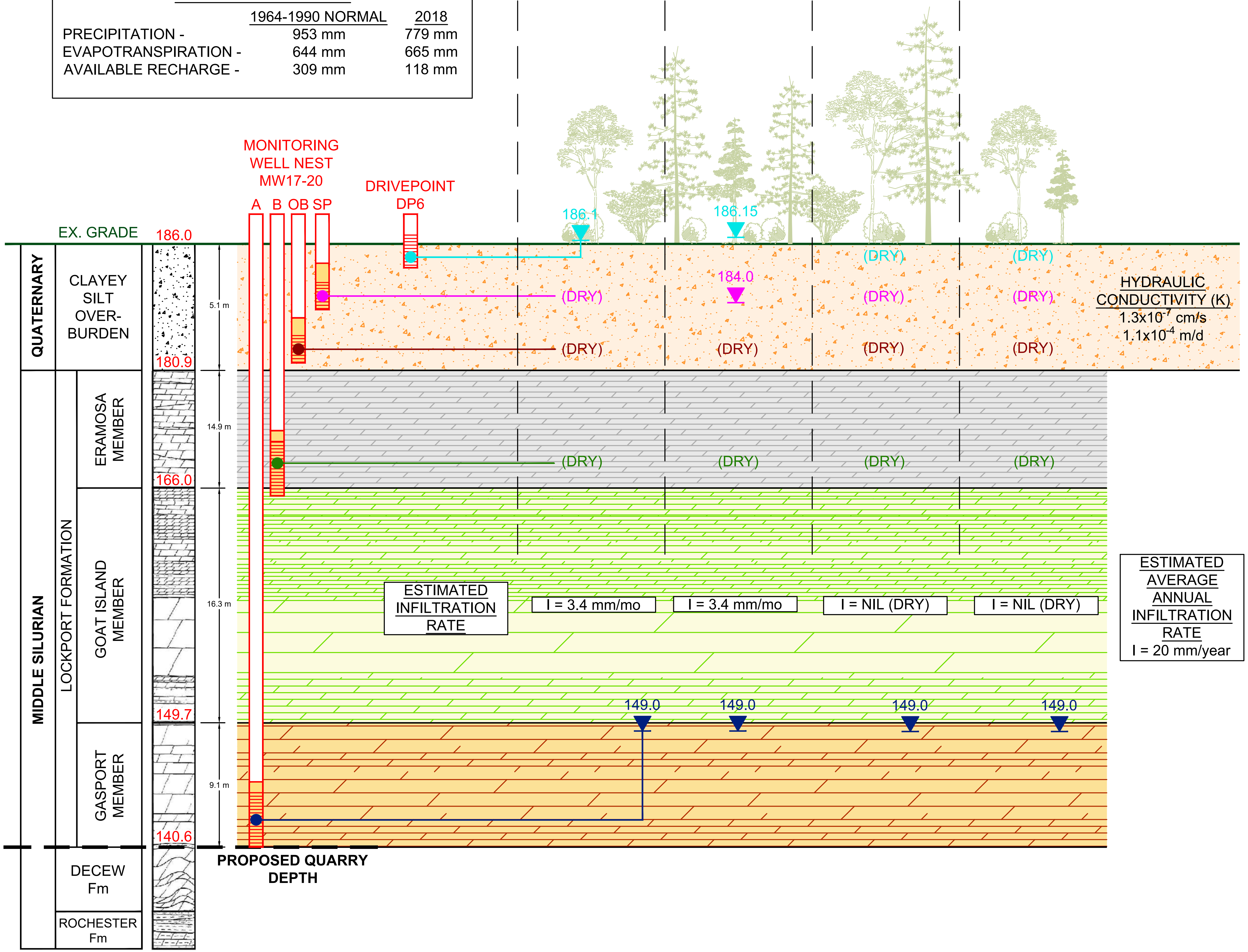
DATE: OCTOBER 2021	
PROJECT: 161-11633-00	
SCALE: AS SHOWN	
DRAWN BY: JLD	FIGURE No: 27A

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

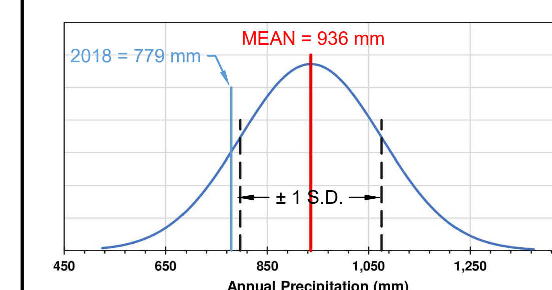
5584 BEECHWOOD ROAD WETLAND - FULL DEVELOPMENT INFILTRATION

WATER BALANCE - 2018

	1964-1990 NORMAL	2018
PRECIPITATION -	953 mm	779 mm
EVAPOTRANSPIRATION -	644 mm	665 mm
AVAILABLE RECHARGE -	309 mm	118 mm



ANNUAL PRECIPITATION PROBABILITY CURVE
BASED ON WELLAND DATA (1931 - 2006)



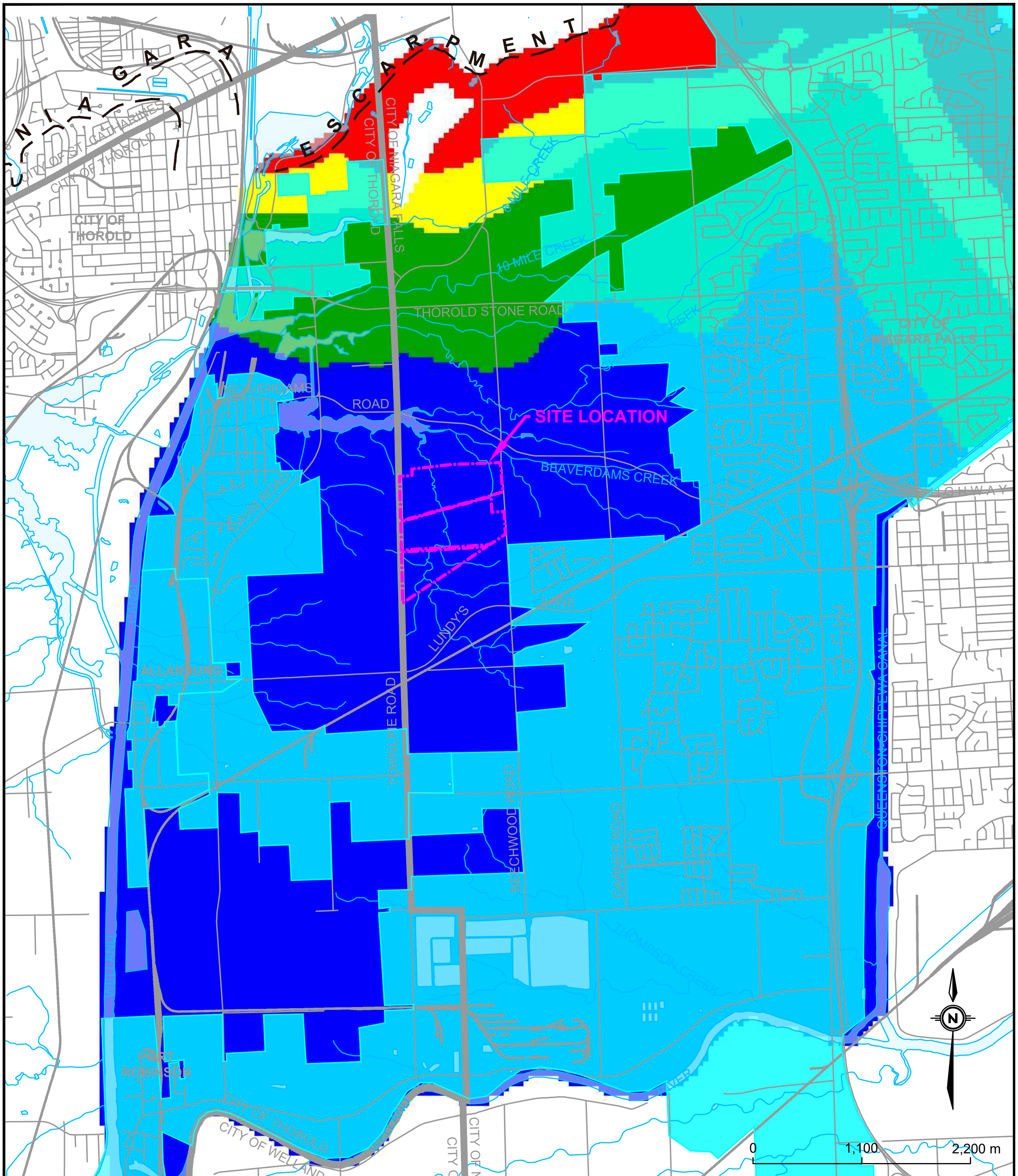
5584 BEECHWOOD ROAD WETLAND - FULL QUARRY DEVELOPMENT (DRY YEAR)

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	AS SHOWN
DRAWN BY:	JLD
FIGURE No:	27B

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F27-CS.DWG



\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F28-GW.DWG

LEGEND

APPROXIMATE EXISTING WATER SYSTEM (MASTER SERVICING PLAN, NIAGARA REGION, 2016)

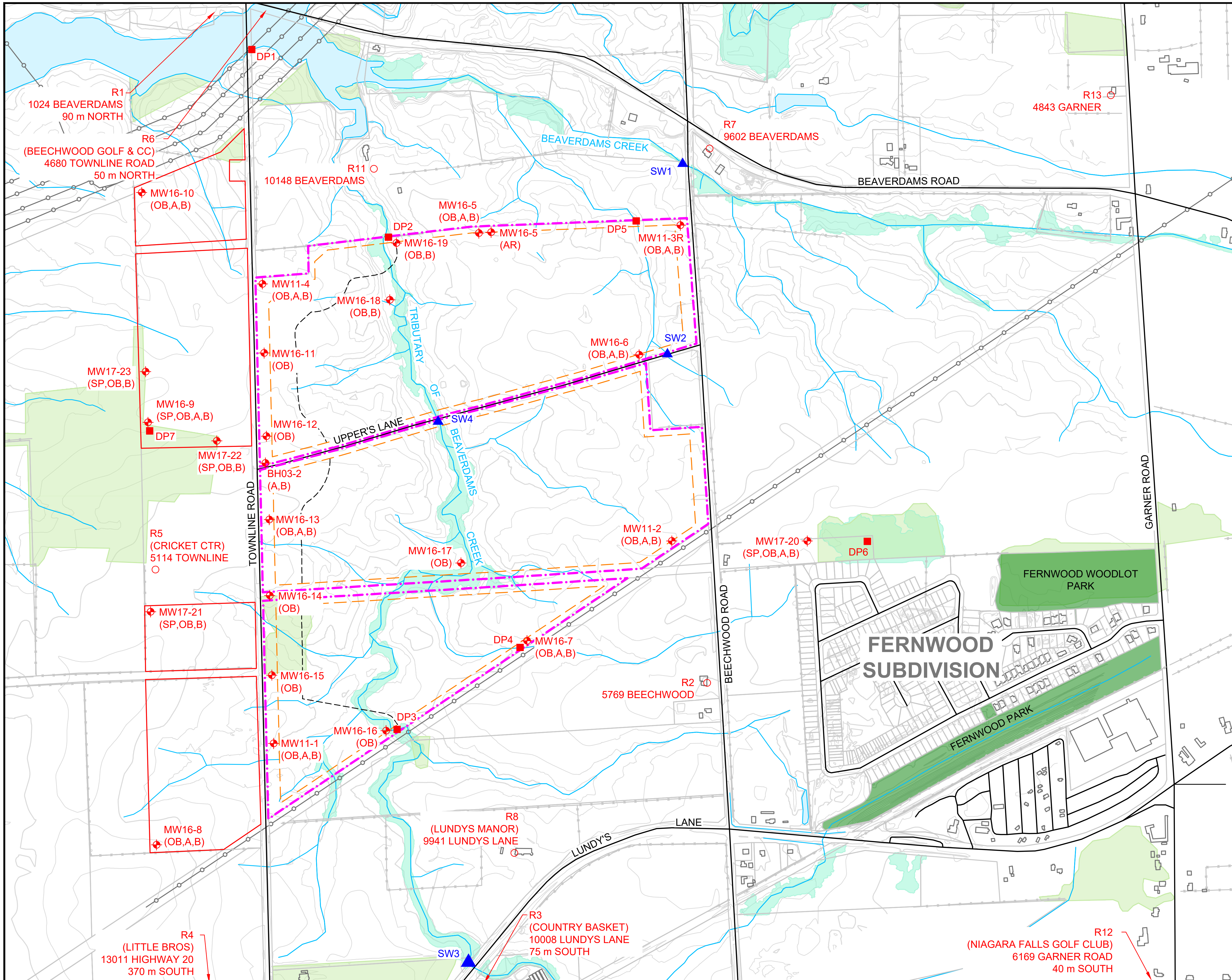
SHALLOW AND DEEP BEDROCK AQUIFER AVAILABLE DRAWDOWN (m)

- < 3
- 3 - 10
- 10 - 20
- > 20

SHALLOW AND DEEP BEDROCK AQUIFER PREDICTED AVAILABLE DRAWDOWN - FINAL REHABILITATION

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 55,000
DRAWN BY:	JLD
FIGURE No:	28



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- MW11-1 MONITORING WELL NEST LOCATION AND DESIGNATION
- R1 PRIVATE SUPPLY WELL LOCATION AND DESIGNATION
- DP1 DRIVEPOINT (STILLING WELL) SURFACE WATER STATION LOCATION AND DESIGNATION
- SW1 STAFF GAUGE SURFACE WATER STATION LOCATION AND DESIGNATION

N

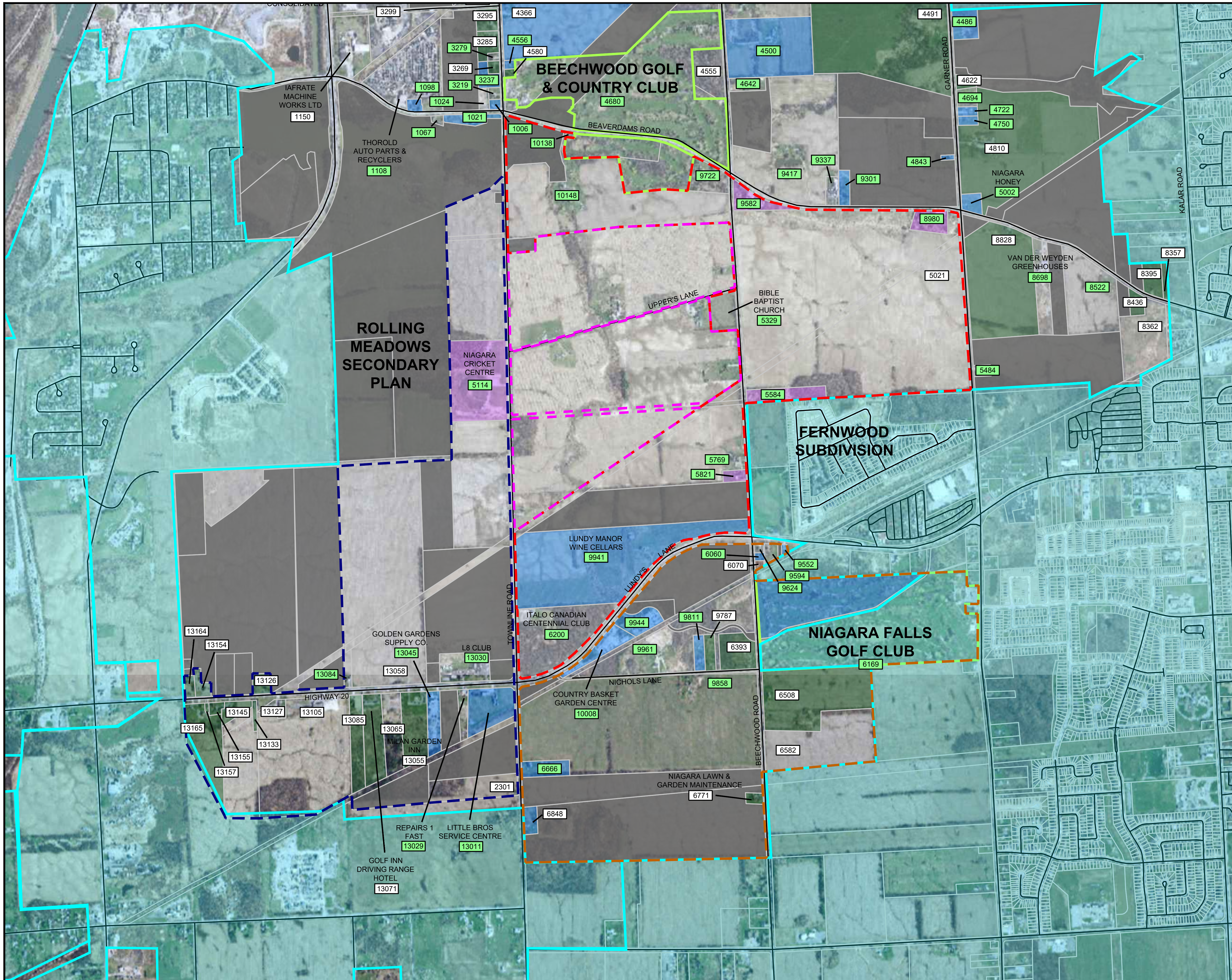
0 180 360 m

PROPOSED MONITORING PROGRAM

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021		
PROJECT:	161-11633-00		
SCALE:	1 : 9,000		55 KING STREET, SUITE 700 ST. CATHARINES, ON L2R 3H5 T 905-687-1771 | F 905-687-1773 | www.wsp.com
DRAWN BY:	JLD	FIGURE No:	29

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROGEOLOGY\GRAPHICS\161-11633-3-F29-SP.DWG



LEGEND

- SITE BOUNDARY
- LAND PARCELS
- 5584 — STREET ADDRESS, GREEN INDICATES SURVEY RETURNED
- PARCEL WITH NO ASSOCIATED STREET ADDRESS
- APPROXIMATE EXISTING WATER SYSTEM (MASTER SERVICING PLAN, NIAGARA REGION, 2016)
- WMA-1 - CLOSE PROXIMITY
- WMA-2 - CITY OF THOROLD URBAN AREA
- WMA-3 - SOUTH GROUP
- CONFIRMED WELL - DEEPENING AND TREATMENT, IF NECESSARY
- UNCONFIRMED WELL - DEEPENING AND TREATMENT, IF NECESSARY
- CONFIRMED WELL CAN BE DEEPENED AND NO TREATMENT REQUIRED
- UNCONFIRMED WELL BUT COULD BE DEEPENED IF NECESSARY AND NO TREATMENT REQUIRED

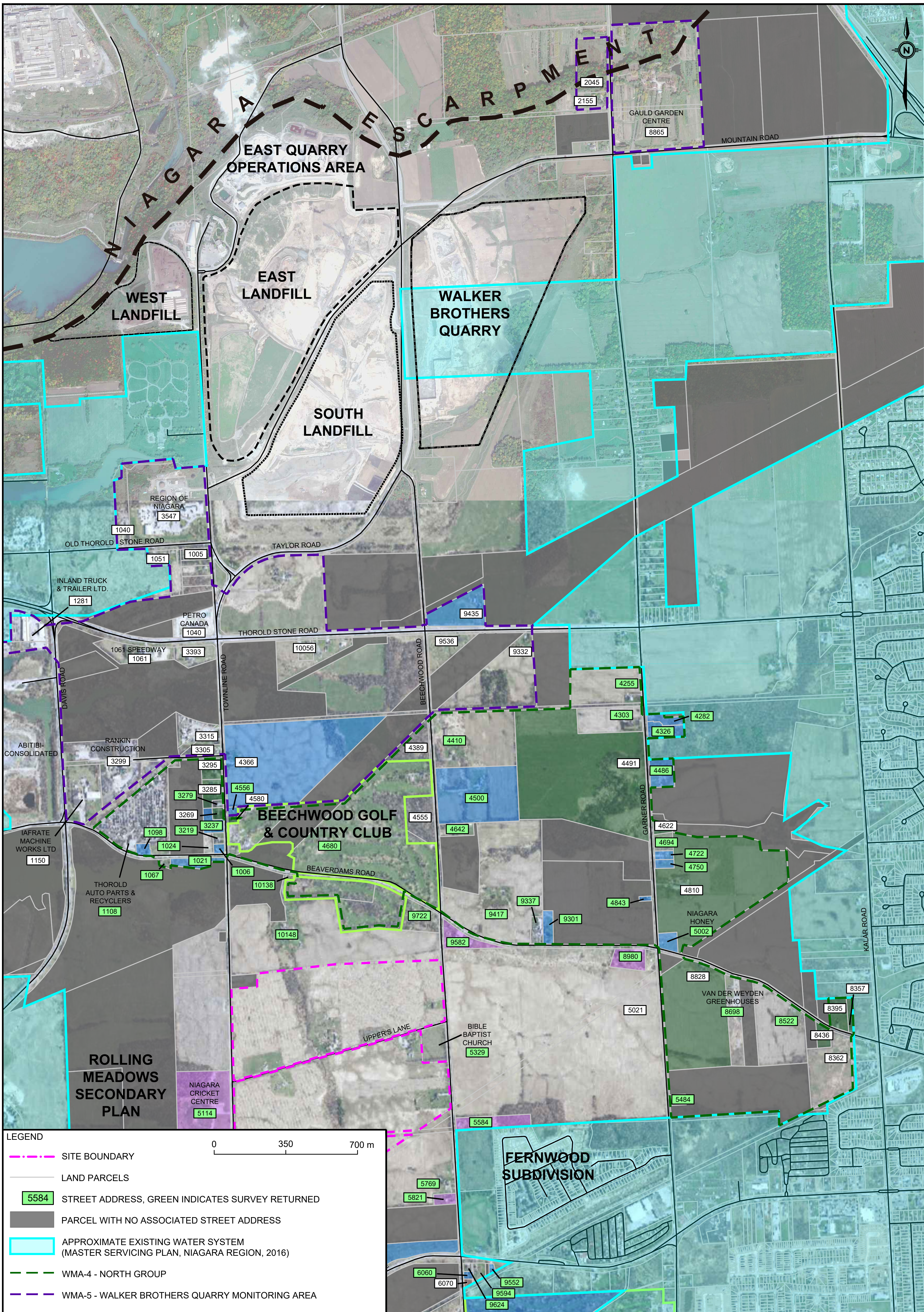
WELL MITIGATION AREA - SOUTH AREAS

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021	
PROJECT: 161-11633-00	
SCALE: 1 : 17,500	
DRAWN BY: JLD	FIGURE No: 30A

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\0003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F30-GW.DWG



LEGEND

0 350 700 m

- SITE BOUNDARY
- LAND PARCELS
- 5584 STREET ADDRESS, GREEN INDICATES SURVEY RETURNED
- PARCEL WITH NO ASSOCIATED STREET ADDRESS
- APPROXIMATE EXISTING WATER SYSTEM (MASTER SERVICING PLAN, NIAGARA REGION, 2016)
- WMA-4 - NORTH GROUP
- WMA-5 - WALKER BROTHERS QUARRY MONITORING AREA
- CONFIRMED WELL - DEEPENING AND TREATMENT, IF NECESSARY
- UNCONFIRMED WELL - DEEPENING AND TREATMENT, IF NECESSARY
- CONFIRMED WELL CAN BE DEEPENED AND NO TREATMENT REQUIRED
- UNCONFIRMED WELL BUT COULD BE DEEPENED IF NECESSARY AND NO TREATMENT REQUIRED

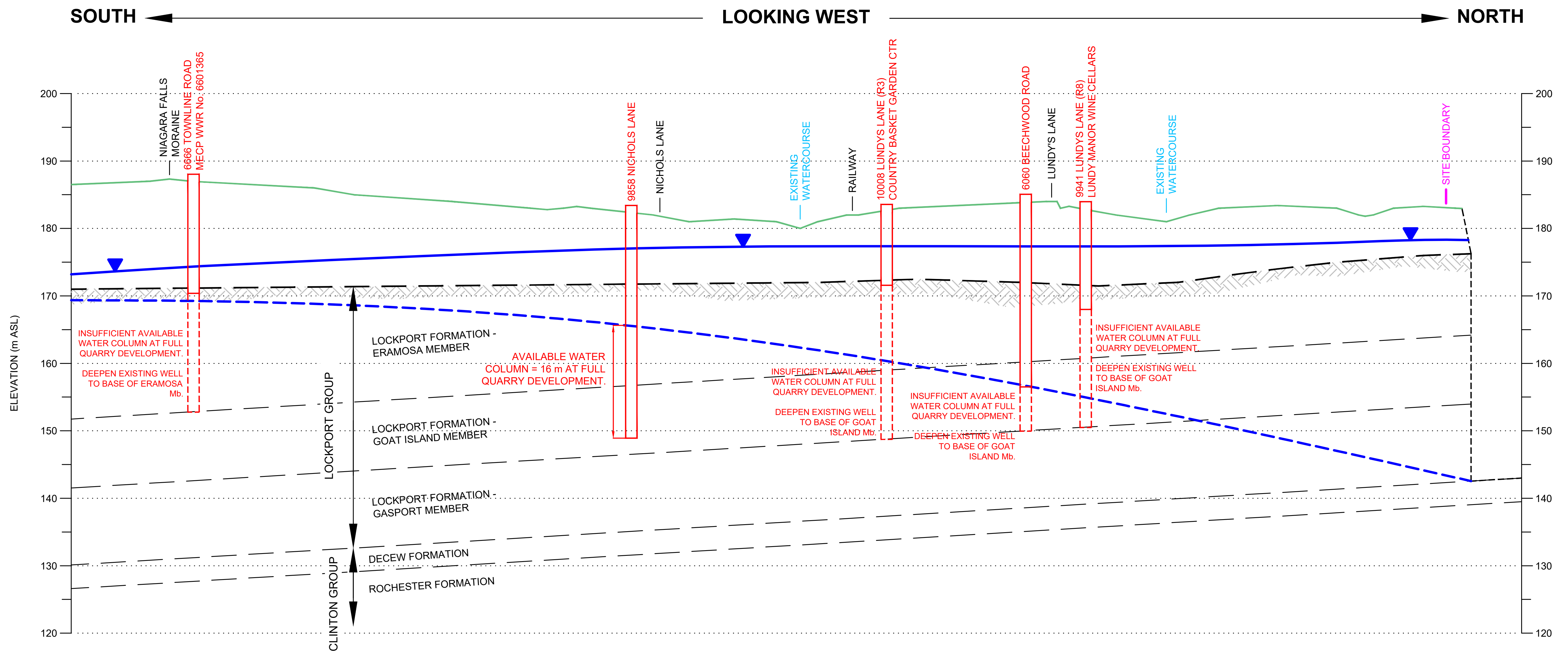
WELL MITIGATION AREA - NORTH AREAS

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 17,500
DRAWN BY:	JLD
FIGURE No:	30B

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F30-GW.DWG



HORIZONTAL SCALE:
0 120 240 m
NOTE: 10X VERTICAL EXAGGERATION

LEGEND

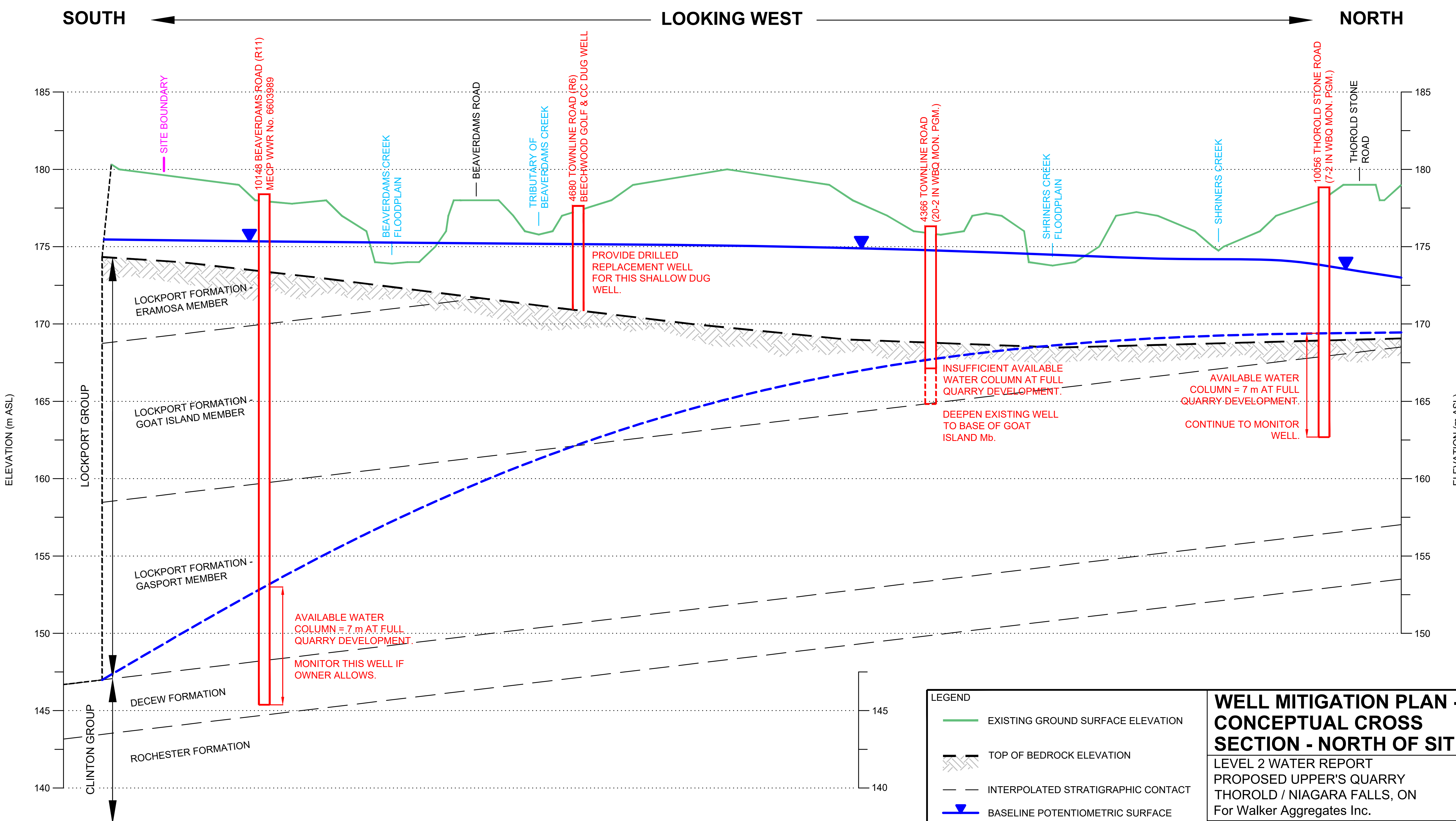
- EXISTING GROUND SURFACE ELEVATION
- TOP OF BEDROCK ELEVATION
- INTERPOLATED STRATIGRAPHIC CONTACT
- BASELINE POTENTIOMETRIC SURFACE
- PREDICTED FULL QUARRY DEVELOPMENT POTENTIOMETRIC SURFACE

WELL MITIGATION PLAN - CONCEPTUAL CROSS SECTION - SOUTH OF SITE

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021	
PROJECT: 161-11633-00	
HORIZONTAL SCALE: 1 : 6,000	55 KING STREET, SUITE 700 ST. CATHARINES, ON L2R 3H5 T 905-687-1771 | F 905-687-1773 | www.wsp.com
DRAWN BY: JLD	FIGURE No: 31A

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F31-CS.DWG



HORIZONTAL SCALE:

0 100 200 m

NOTE: 20X VERTICAL EXAGGERATION

LEGEND

- EXISTING GROUND SURFACE ELEVATION
- TOP OF BEDROCK ELEVATION
- INTERPOLATED STRATIGRAPHIC CONTACT
- BASELINE POTENTIOMETRIC SURFACE
- PREDICTED FULL QUARRY DEVELOPMENT POTENTIOMETRIC SURFACE

WELL MITIGATION PLAN - CONCEPTUAL CROSS SECTION - NORTH OF SITE

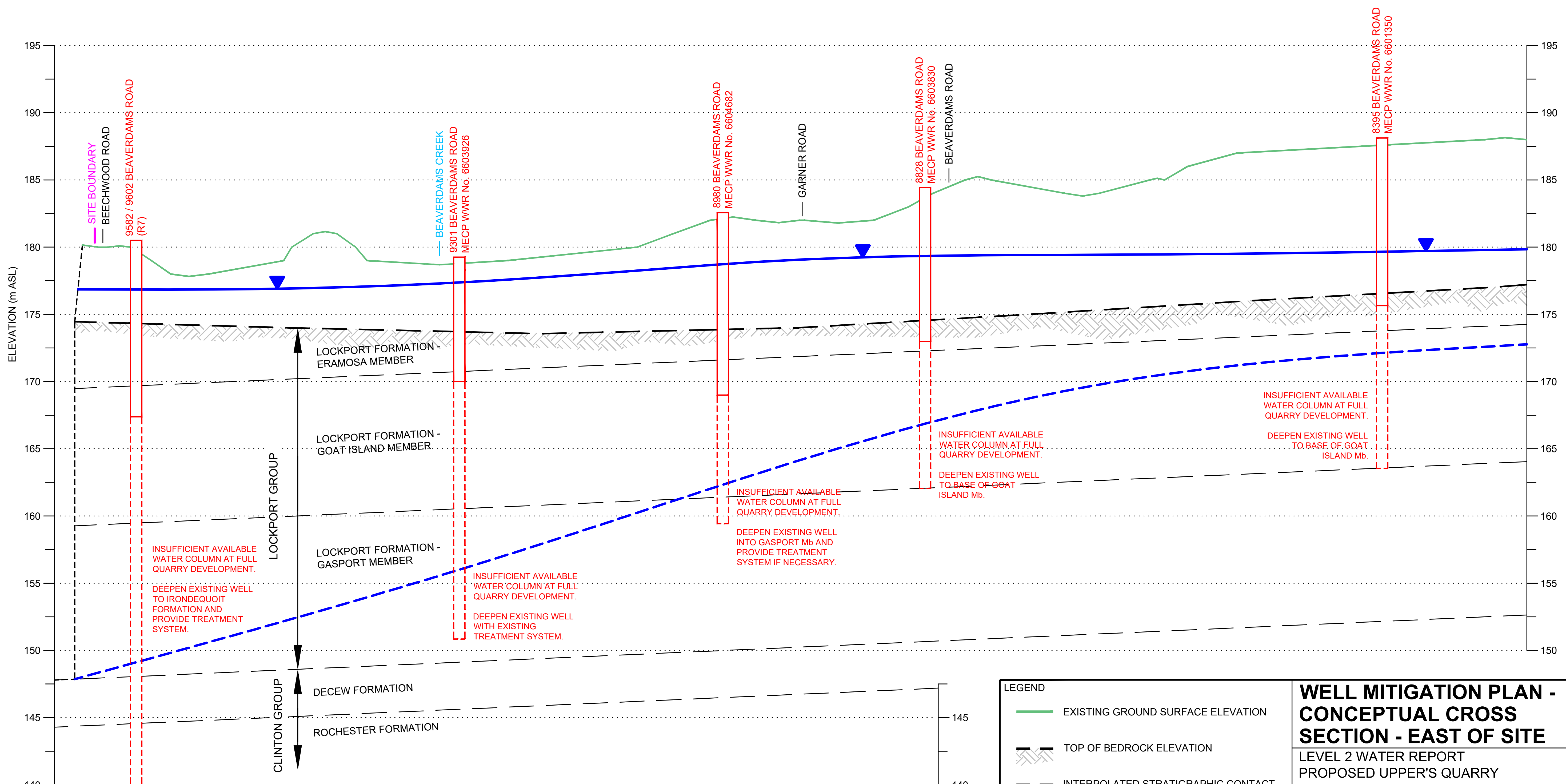
LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
HORIZONTAL SCALE:	1 : 5,000
DRAWN BY:	JLD
FIGURE No:	31B

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F31-CS.DWG

WEST ← LOOKING NORTH → EAST



HORIZONTAL SCALE:
0 120 240 m

NOTE: 20X VERTICAL EXAGGERATION

LEGEND

- EXISTING GROUND SURFACE ELEVATION
- TOP OF BEDROCK ELEVATION
- INTERPOLATED STRATIGRAPHIC CONTACT
- BASELINE POTENTIOMETRIC SURFACE
- PREDICTED FULL QUARRY DEVELOPMENT POTENTIOMETRIC SURFACE

WELL MITIGATION PLAN - CONCEPTUAL CROSS SECTION - EAST OF SITE

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
HORIZONTAL SCALE:	1 : 6,000
DRAWN BY:	JLD
FIGURE No:	31C

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00003 LEVEL 2 HYDROG\GRAPHICS\161-11633-3-F31-CS.DWG

APPENDIX

A CURRICULUM VITAE

KEVIN J. FITZPATRICK, P.Eng.

Senior Project Engineer, Environment

AREAS OF PRACTICE

Hydrogeology

Aggregate Resources

Geology & Geotechnical Engineering

Environmental Assessments & Remediation

Waste Management

PROFILE

Mr. Kevin Fitzpatrick, P. Eng. (Geological) is a Senior Project Engineer with more than 20 years of experience in geology, hydrogeology, geotechnical engineering, and water resources. His work experience encompasses project management, field investigations, analysis, interpretation, and peer review for numerous projects requiring his earth science expertise.

Mr. Fitzpatrick has developed his technical and project management expertise through his management of geological, hydrogeologic and geotechnical investigations related to groundwater quality and quantity compliance issues, aggregate resources, waste management, environmental remediation, dewatering, and civil construction. He has been a guest lecturer for geotechnical engineering course at Niagara College since 2012.

EDUCATION

B.A.Sc. Geological Engineering, University of Waterloo, ON	1993

PROFESSIONAL DEVELOPMENT

WHMIS	2013
Critical Thinking in Aquifer Test Interpretation, Christopher Neville, S.S. Papadopulos & Associates	2009
40-hour Health & Safety Training Course for Hazardous Waste Operations, OSHA, and update courses, Surface Miner Common Core Training	2005
Waterloo In-situ Groundwater Remediation Course, Toronto, ON	2000

PROFESSIONAL ASSOCIATIONS

Professional Engineers Ontario	1996
Ontario Stone, Sand and Gravel Association, Rehabilitation Committee	OSSGA
Aggregate Resource Prospecting and Evaluation Specialty, Ontario Ministry of Transportation, Registry Appraisal and Qualifications System	RAQS
Niagara College Programs Advisory Committee for Construction/ Civil Engineering Programs	2013

CAREER

Senior Project Engineer, Environment, WSP	2014 - Present
Senior Project Engineer, Environment, GENIVAR (now named WSP)	2009 - 2013
Project Engineer, Jagger Hims Limited (GENIVAR Acquisition)	1993 - 2009

PROFESSIONAL EXPERIENCE

Hydrogeology

- Assessments, Permit to Take Water Applications and Hydrogeologic Monitoring Reports (ongoing): Completed numerous studies as project manager in support of OWRA applications and Certificate of Approval for Discharge studies throughout Ontario, including in Lincoln, Waterford, Mosport, Thorold, Hamilton, Niagara Falls, Coboconk, Markham, Port Colborne, Port Dover, Wainfleet and Hagersville. The studies supported quarry applications, civil construction dewatering and industrial applications. Client: Various.
- Dewatering Assessment, Fort Erie, ON (2012): Hydrogeologic study for a pumping station within a productive, corrosive bedrock aquifer. Client: Region of Niagara.
- Hydrogeologic Assessment, Flamborough, ON (2011): Hydrogeologic assessment for a large food processing facility. Work included geotechnical design and wastewater compliance issues. Client: Earthfresh Foods Inc.
- Water Well Interference, Niagara-on-the-Lake, ON (2011): Completed a salt water intrusion contaminant assessment as part of a Ministry of Environment director's order. Design of a sulphate-resistant decommissioning program to prevent future cross-contamination. Client: Aviva Canada.
- Groundwater Interference Study, Dunnville, ON (2010): Intermittent issues at residential wells located adjacent to a dolostone and limestone quarry were evaluated for quality and quantity. The hydrogeology was complicated by the high transmissivities of the aquifer and the proximity of the Grand River and Lake Erie. Client: Dunnville Rock Products.
- Lookout Point Golf Club, Pelham, ON (2008-ongoing): Conducted a multi-year groundwater and surface water investigation that led to construction of a high capacity deep well in the Fonthill Kame for golf course irrigation. Other consultants had installed deep wells at the site; however, yields were very poor. High hydrogen sulphide concentrations and a cold-water fishery were also a concern. A thorough re-evaluation of the local hydrogeology was completed and detailed long-term pump tests were performed to satisfy Niagara Escarpment Commission and MOE concerns. Monitoring of the various system components was designed to improve data quality and lower operating costs. Client: Lookout Point Golf and Country Club.
- Groundwater Salt Impact Assessment, Lincoln, ON (ongoing): Hydrogeologic monitoring at a winter sand storage facility. The facility is located above the Niagara Escarpment on fractured bedrock upgradient of several groundwater springs. A best management plan was produced for the facility. Client: Town of Lincoln.
- Hydrogeologic Study, Port Colborne, ON (2009): Hydrogeologic study to support residential development plan. A developer needed to assess a productive shallow bedrock aquifer as part of a plan of subdivision. Client: Lester Shoaltz Limited.
- Hydrogeologic Monitoring, Caledonia, ON (2009): Hydrogeologic monitoring at a golf course in support of a Permit to Take Water. Electronic groundwater monitoring was installed to provide high quality data. Client: Numbered Ontario Company.
- Niagara Tunnel Project, Niagara Falls, ON (2008): Completed detailed core logging on deep groundwater monitors. Cores represented a complete section of Niagara Escarpment bedrock from the Guelph Formation to the Queenston Formation. Client: Strabag.
- Alternative Irrigation Sources, St. Catharines, ON (2007): Conducted hydrogeologic evaluation of a groundwater irrigation source for a golf course. The site was utilizing

a municipal supply for irrigation. Multiple low-yielding wells of poor quality complicated the assessment. Client: Urban & Environmental Management.

- Hydrogeologic Assessment, Massey, ON (2006): Hydrogeologic assessment of proposed Greenfield quarry. The site is a traprock escarpment and is located at a watershed divide. Impact assessments, a monitoring program and a closure plan were completed. Client: Pioneer Construction.

Aggregate Resources

- Completed detailed resource assessments, approvals and licensing for many major aggregate producers including Ontario Ministry of Transportation, CBM Canada, Dufferin Aggregates, Lafarge Canada, Walker Industries, Capital Materials Inc., Chefero Sand, Pioneer Construction, Waterford Sand and Gravel, Nelson Aggregates, Dimension Stone Ltd. and for several private clients.
- Conducted geologic studies in unconsolidated deposits. These sites include the Oak Ridges Moraine, Paris and Galt Moraines, and sites in Ayr, Caledon, Cambridge, London, Stratford, Brantford, North Dumfries, Orangeville, Norwood, Ommemee, and more than 60 sites in Northern Ontario.
- Conducted numerous detailed bedrock resource evaluations (dolostone, limestone, shale, granite, traprock) and licenses at sites throughout Ontario, including the Niagara Escarpment, Lake Erie shoreline, Guelph, Shelburne, Hamilton, Georgian Bay, Carden, Hudson Bay lowlands, Manitoulin Island, and Northern Ontario. Northern Ontario aggregate experience has included work within the Grenville, Southern and Superior Province locations.
- Proposed Shale Quarry Assessment, Brampton, ON (2010): Completed a resource assessment of a property zoned for a shale quarry in support of redevelopment. Client: Osmington Inc.
- Proposed Dolostone Quarry, Wainfleet, ON (2009): Peer review and witness statements at a proposed quarry for an Ontario municipal board hearing. Client: Sullivan Mahoney LLP.
- Clay Borrow Pit, Thorold, ON (2007): Completed aggregate wayside pit permit for clay borrow for 400-series highway embankments. Client: Hardrock Group.

Geology and Geotechnical Engineering

- Slope Stability Studies, Excavations and Retaining Wall Inspections (ongoing): Conducted over 60 studies in support of development approval for private clients, public agencies and consultants.
- Rock Mechanics Work (ongoing): Conducted rock wall stability assessments in Lincoln, Woodstock, Orillia, Ottawa, and Quebec for various clients in support of open excavations.
- Post-construction Investigations (ongoing): Conducted forensic examinations of failed structures and roadways related to subsurface conditions in Burlington, Niagara-on-the-Lake and Lake Simcoe for various private and professional clients.
- Foundation Inspections (ongoing): Inspections of footings for bridges, buildings, marine facilities and retaining walls for public, private and institutional clients.
- Road Construction Investigations (ongoing): Geotechnical studies completed in support of road reconstruction for municipal government agencies including project management for material inspections (concrete, asphalt and compaction testing).

- Septic System Investigations and Sewage Lagoon Assessments, various locations in Niagara Region (ongoing): Conducted geotechnical investigations for new municipal sewage lagoons, and investigations for large septic systems. Client: Niagara Region.
- Dewatering Investigation, Hamilton (2019): Dewatering investigation for earth retaining structure at a proposed waste water treatment plant. Client: Canada Centre for Inland Waters.
- Pipeline Work, Geotechnical Investigations for pipeline works across CN Rail/Welland Canal/Niagara Escarpment. (2018): Client: Walker Industries.
- Retaining Pond Design, North Dumfries ON (2017): Geotechnical work for liner installation. Client: Preston Sand and Gravel; Walker Industries
- Jerseyville Road Facility, Jerseyville, ON (2017): Water supply, geotechnical investigation and wastewater servicing peer review and project management. Client: The Green Organic Dutchman.
- Boat Ramp Investigation, Fort Erie, ON (2017): Below water geotechnical investigation within the Niagara River. Client: Niagara Parks Commission.
- Binbrook Dam Safety Review, Binbrook, ON (2016): Earth dam testing and inspection. Client: Niagara Peninsula Conservation Authority.
- East Rail Maintenance Yard, Whitby, ON (2016): Construction dewatering issues for a rail siding. Client: Bird/Kiewit Joint Venture.
- Glanbrook Landfill Collector System Evaluation, Hamilton, ON (2015): Subsurface geotechnical assessment of a failed sewer. CCTV work. Client: City of Hamilton.
- Hydrogeologic Study, Flamborough, ON (2011): Proposed Earthfresh potato processing facility hydrogeologic study. Client: Earthfresh.
- Facility Relocation and reservoir installation, Dunnville, ON (2011). Client: Intercounty Concrete.
- VivaNext, Highway 7, Markham, ON (2011): Permit to take Water for three concrete box culvert stream crossings. Client: Brennan Paving and Construction.
- Hotel Dieu Hospital, St. Catharines, ON (2004, 2010): Conducted a preliminary geotechnical investigation for a proposed general hospital on an existing site; and subsequently, geotechnical considerations for site after use. Client: Niagara Health System.
- Rail Siding Hopper, Niagara Falls, ON (2012): Conducted a geotechnical investigation for an unloading facility. Client: Redpath Sugar.
- Niagara Health System
  - Hotel Dieu Hospital, St. Catharines, ON (2004, 2010): Conducted a preliminary geotechnical investigation for a proposed general hospital on an existing site; and subsequently, geotechnical considerations for site after use. Clients: Niagara Health System and Mountainview Homes.
  - Port Colborne General Hospital (2006): Geotechnical investigation at the Port Colborne Hospital Site.
  - St. Catharines General Hospital (2005): Preliminary geotechnical investigation on a proposed greenfield general hospital site.
- Commercial Construction of an Automobile Dealership, St. Catharines, ON (2008): Geotechnical studies for construction of an automobile dealership on thick fill soils. Client: Confidential.

- Hamilton Public Housing, Stone Church Road, Burlington, ON (2005): Geotechnical Drilling Program at failed former public housing building. Client: Morrison Hershfield.
- Rolling Meadows Subdivision, St. Catharines, ON (2005): Geotechnical investigation and report at a large proposed subdivision. Client: Numbered Ontario Company.
- Arcelor Mittal, East Chicago Steel Works, Gary, IN, USA (2002): Slag granulation dewatering assessment. Provided expert testimony for a construction dewatering investigation around a sheet pile wall cofferdam. This work was in support of a dispute before the American Arbitration Association. Client: Lafarge Canada Inc.
- Caisson and Pile Inspections, St. Catharines/Thorold, ON (2002, 1999): Supervised and inspected caisson installations. Geotechnical investigation of a pile-supported outbuilding at a hospital. Clients: Walker Industries Holdings Limited; Polymax Construction.

Environmental Assessment and Remediation

- Environmental Reporting (ongoing): Numerous soil, groundwater and surface water environmental reports completed for private and public clients. Reviewed and authored numerous Phase I and Phase II Environmental Site Assessments.
- Former Public Works Yard, Lincoln, ON (ongoing): Design, operation and optimization of a pump and treat groundwater remediation system in a fractured bedrock environment. The system has operated successfully for over 15 years. Client: Town of Lincoln.
- Truck Marshalling Yard, Burlington, ON (2011): Conducted a hydrogeologic investigation at a DNALP-impacted site. Client: DML Environmental.
- Former Dry Cleaning Site, Hamilton, ON (2009): Conducted a DNAPL investigation in shallow fractured bedrock, complicated by the presence of shale. This work corrected a previous consultant’s study. Client: Confidential.
- Reported PCB-impacted Automobile Dealership Property, St. Catharines, ON (2009): Groundwater assessment program at a commercial property as part of a dispute resolution. Client: Confidential.
- Pesticide-Impacted Farm Building, St. Catharines, ON (2008): Soil assessment and remediation due to pesticide and fuel oil impacts at a former farm. Client: Confidential.
- Commercial Property Assessment, Canarctic Drive, North York, ON (2005): Soil and groundwater assessment at a former manufacturing facility prior to purchase. Client: Confidential.
- Flint Road Phase II ESA, Downsview ON (2004): The absence of groundwater and soil contamination was confirmed prior to sale of a commercial property. Client: Torkin Manes Cohen Arbus LLP.
- Fuel-impacted Soil and Groundwater, Orwell Road, Mississauga, ON (2004): Conducted a soil remediation program at a leaky underground storage tank site. Work included installation of a dewatering and treatment system for soil excavation below the water table. Client: Confidential.
- Fuel Oil Tank at a Housing Complex, Dunnville, ON (2002): Underground storage tank soil and groundwater investigation. Construction activities uncovered a UST. The tank had leaked into soil and sewer utilities. Sampling was completed and remedial options presented. Client: Hydro Vac Inc.

- Vineland Quarry Asphalt Plant, Lincoln, ON (2002): Conducted an analysis of scrubber sediment for disposal options. Client: Rankin Construction.
- Former Plating Facility, Mississauga, Ontario (2001): Environmental Assessment and remediation of soil, groundwater and installation of a remedial pumping system at a chrome and copper plating facility. Client: Chambers of Canada.
- Former General Abrasives Site, Niagara Falls, ON (2001): Extensive soil and groundwater sampling and contaminant delineation program at a large (40 ha) former industrial facility. Client: R. Ste. Pierre Excavation.
- Effluent-impacted Water Course, Beamsville, ON (2000): Investigation of a complaint led to an MOE order being rescinded regarding a leaking surface water underground storage tank. Client: Desousa Wines.

Waste Management

- Involved in numerous hydrogeologic monitoring programs at private and public landfills throughout Southern Ontario, including Niagara, Hamilton, Region of Waterloo, Simcoe County, City of North Bay, Region of Halton and in Lambton County.
- Unlicensed Landfill, Grimsby, ON (2008-ongoing): Preliminary and ongoing monitoring of a 30,000 tonne unlicensed landfill within a former quarry. Work includes a hydrogeological evaluation of the site, waste delineation and impact analysis; calculations of contaminating lifespan of the waste and financial assurance. The project involves extensive liaison with the Ministry of Environment on behalf of the client. Client: Confidential.
- Park Road Landfill, Grimsby, ON (2009, 2011): Bedrock core logging for new open-hole groundwater monitors. Interpretation of downhole geophysical logs to further define bedrock stratigraphy and fractures/flow zones. Client: Niagara Region.
- Bridge Street Landfill, Fort Erie, ON (2004, 2007, 2010): Geotechnical studies in support of L.C.S. construction. Analysis of instability of waste slopes for regarding purposes. Bedrock core logging for groundwater monitors installed through the Onondaga Escarpment. Completed leachate seep analysis and review of remedial measures, and toe drain installation. Client: Niagara Region.
- Line 5 Landfill, Niagara-on-the-Lake, ON (1994, 2004): Conducted geotechnical evaluation of base of new landfill cell to support landfill operations. Hazardous material sampling and analysis of sealed drums left at landfill site. Client: Niagara Region, Town of Niagara-on-the-Lake.
- West Quarry Landfill, Leachate Management Program, Thorold, ON (1999, 2003): Field supervision of installation of large-diameter caisson wells for controlling leachate in waste. Consultations for construction of residential compost facility on waste. Client: Niagara Waste Systems Limited.
- Glanbrook Landfill Site, Artesian Conditions Assessment, Glanbrook, ON (2000): Conducted an evaluation of deep groundwater upwellings associated with a former gas well on the landfill site. Client: Regional Municipality of Hamilton Wentworth.
- Centre Street Landfill, Pelham, ON (1998): Landfill compliance monitoring reporting as part of the site's Certificate of Approval. This landfill is located above deep unsaturated sands. Client: Town of Pelham.

PUBLICATIONS AND PRESENTATIONS

Publications

- Fitzpatrick, K and Campbell, J. 2012. Lake Erie to Lake Ontario, Spills, Mills and Landfills and GW/GS Glacial Geology; International Association of Hydrogeologists, 39th IAH Congress, September 16-21, 2012, Niagara Falls, ON, unpublished technical tour book.

J. LEIGH DAVIS, M.A.Sc., P.Eng.

Project Engineer, Environment

Areas of practice

Waste Management

Groundwater Modelling

Aggregate Resources

Geotechnical Engineering

PROFILE

Mr. Leigh Davis is a licensed Project Engineer with WSP, specializing in hydrogeology. His eleven years of experience in the environmental consulting industry include project management, preparation of hydrogeological study and annual monitoring reports, coordination and analysis of in-situ testing, field sampling (including low-flow methods), GIS/CAD figure preparation and numerical groundwater model construction and calibration, including simulation of contaminant transport in the subsurface.

Leigh holds a Bachelor of Applied Science in Environmental Engineering, as well as a Master of Applied Science in Civil Engineering, covering topics including hydrology, hydrogeology, contaminant transport mechanisms, groundwater modelling and landfill design. Leigh's Master's thesis was *Investigation of Seismic Excitation as a Method for Flow Enhancement in Porous Media.* He has a working knowledge of relevant software including ArcGIS, Microsoft Office (including Access), AutoCAD, USGS MODFLOW (including various pre/post processing software) and HELP 3.

EDUCATION

Master of Applied Science, Honours Civil Engineering, University of Waterloo	2008
Bachelor of Applied Science, Honours Environmental Engineering (Co-op), University of Waterloo	2006

PROFESSIONAL DEVELOPMENT

8-Hour Health & Safety Refresher Training Course (HAZWOPER)	2014 – Present
MODFLOW Solvers, Speed, Convergence and Robustness	2018
Introduction to Fortran Programming for MODFLOW Modelers	2018
Calibration and Uncertainty Analysis for Environmental Models	2017
Surface Miner Common Core Training	2013
Estimating Rates of Groundwater Recharge, International Association of Hydrogeologists (IAH)	2012
Reactive Transport Modelling with PHT3D, International Groundwater Modeling Centre (IGWMC)	2011
The New MODFlow Course: Theory and Hands-On Applications, NGWA	2009
Critical Thinking in Aquifer Test Interpretation, S.S.Papadopulos & Associates Inc.	2009
24-Hour Occupational Health & Safety Training Course (HAZWOPER)	2009

PROFESSIONAL ASSOCIATIONS

Professional Engineers Ontario	PEO
Halton Region Environmental and Ecological Advisory Committee (Volunteer, 2011 – 2014)	EEAC

J. LEIGH DAVIS, M.A.Sc., P.Eng.

Project Engineer, Environment

CAREER

Project Engineer, Environment, WSP	2014 – Present
Project Manager, Environment, GENIVAR (now named WSP)	2009 – 2013
Project Manager, Jagger Hims Limited (GENIVAR Acquisition)	2008 – 2009
Technical Project Assistant, Jagger Hims Limited	2005 – 2006
Engineer Assistant, St. Michael's Hospital, Toronto, ON	2004

PROFESSIONAL EXPERIENCE

Aggregate Resources

- Haliburton, ON (2019): Level 2 Hydrogeological Study in support of below water quarry application. Pumping test analysis and hydrogeological conceptual model development. Client: Confidential.
- Wainfleet, ON (2017-ongoing): Level 2 Hydrogeologicay Study in support of below water quarry extension of existing quarry. Field support, pumping test coordination and analysis, report and figure preparation and liaison with regulatory agencies. Construction and calibration of a numerical groundwater flow model to predict impacts of quarry extension on local groundwater users and sensitive features. Client: MHBC Planning.
- Thorold, ON (2016-ongoing): Level 2 Hydrogeological Study in support of below water quarry application at a greenfield site. Field support, pumping test coordination and analysis, report and figure preparation and liaison with regulatory agencies. Construction and calibration of a numerical groundwater flow model to predict impacts of quarry development on local groundwater users and sensitive features. Client: MHBC Planning.
- Walker Aggregates Inc.
  - Walker Brothers Quarry, Niagara Falls, ON (2012-ongoing): Preparation of annual compliance monitoring report for an active quarry located adjacent to one active and two closed landfill sites. Data management and QA/QC using a custom Access database. Monitoring data from all four sites are considered when characterizing and assessing the hydrogeologic setting.
  - Vineland Quarry, Interference Complaint Study, Vineland, ON (2011): Evaluation of sub-watershed hydrologic data and outflow characteristics of quarry pond to determine the cause of downstream channel erosion.
  - Duntroon Quarry Expansion, Collingwood, ON (2009): Numerical groundwater model development for a proposed quarry expansion near the Niagara Escarpment, and GIS figure preparation.
- Pioneer City Pit, Sault Ste. Marie, ON (2016-2017): Level 2 Hydrogeological Study in support of pit / quarry licence extension for below water table extraction. Data collation, report and figure preparation and liaison with regulatory agencies. Client: Pioneer Construction Ltd.
- Palmer Pit, Sault Ste. Marie, ON (2015-2016): Level 2 Hydrogeological Study in support of pit / quarry licence extension for below water table extraction. Field support, data collation, report and figure preparation and liaison with regulatory agencies. Client: Pioneer Construction Ltd.

- Erin Pit, Erin, ON (2015-2017): Level 1 Hydrogeological Study in support of pit licence extension for above water table extraction. Field support, pumping test coordination and analysis, data collation, report and figure preparation and liaison with regulatory agencies. Client: Halton Crushed Stone Inc. / MHBC Planning.
- Identify Potential New Sand and Gravel Pit, Haldimand and Norfolk Counties, ON (2015): GIS and ARIP mapping used to assess potential new sand and gravel pit locations. Client: Confidential.
- Jigs Hollow Pit, Waterloo, ON (2014-ongoing): Level 2 Hydrogeological Study in support of pit licence application. Field support, pumping test coordination and analysis, data collation, report and figure preparation and liaison with regulatory agencies. Client: Preston Sand and Gravel / IBI Group.
- Vinemount Quarry, Stoney Creek, ON (2013-2018): Level 2 Hydrogeolgical Study in support of quarry licence extension. Field support, data collation, report and figure preparation and liaison with regulatory agencies. Client: Waterford Sand and Gravel Limited / IBI Group.
- Aggregate Resource Assessment, Windsor, ON (2012): Review of borehole information and local geology to quantify remaining high-quality aggregates at two quarries near Windsor. Client: Confidential.
- Melancthon Hydrogeologic Study, Township of Melancthon, ON (2009-2010): Calibration of numerical groundwater flow model for existing site conditions and quarry scenario assessment. Client: The Highland Companies.
- Aggregate Resource Assessment, Greater Toronto Area, ON (2008): Development of aggregate resource database and GIS figure preparation to determine high quality aggregate resources in the Greater Toronto Area. Client: Confidential.

Groundwater Modelling

- Peer Review of Proposed Cumberland Quarry, County of Simcoe, ON (2018): Peer review of a Level 1 & Level 2 Hydrogeological Study report and numerical groundwater model in support of a below-water quarry application for a greenfield site. Client: Walker Aggregates Inc.
- Peer Review of Crane Mountain Landfill Groundwater Flow Model, NB (2018): Peer review of a numerical groundwater flow model used to predict landfill impacts on a drinking water aquifer in a complex bedrock setting. Client: Fundy Regional Service Commission, NB.
- Wellhead Protection Area Delineation, Pugwash, NS (2017): Construct and calibrate a numerical groundwater flow model to delineate the wellhead protection area for a municipal supply system. Client: Municipality of the County of Cumberland, NS.
- Hydrogeological Investigation/Numerical Groundwater Flow and Transport Modelling for Phosphate Mine, Kapuskasing, ON (2009-2014): Field work including drilling supervision, monitoring well installation, in-situ hydraulic conductivity tests / analysis and groundwater sampling (including low-flow sampling). Review of existing site data to construct and calibrate a groundwater flow model to be used for simulation of tailings pond leachate transport in the sub-surface in support of the mine closure plan. Hydrogeological report and figure preparation in support of a revised mine closure plan. Client: Agrium Inc.
- Groundwater Capacity Assessment, Omemee, ON (2014): Use of an existing regional numerical groundwater model to identify potential groundwater supply well locations within the community as part of a Class EA. Client: City of Kawartha Lakes.

- Detailed Water Budget Analysis, South Lake Scugog Watershed, Durham Region, ON (2011): Use of an existing regional numerical groundwater model to calculate the groundwater components of the water budget. Client: Kawartha Lakes Conservation Authority.
- Contaminant Transport Modelling for a Thermal In-Situ Heavy Oil Processing Facility, near Cold Lake, AB (2010): Review of site data to construct and calibrate a groundwater flow model to simulate chloride transport from a process water retention pond, and evaluate remediation alternatives. Client: Canadian Natural Resources Limited.
- Numerical Groundwater Modelling, Legault Subdivision Water Supply, St. Albert, ON (2010): Construct and calibrate a numerical groundwater flow model to predict the steady-state drawdown due to proposed subdivision private water supply wells, and assess the impact on nearby existing private wells. Client: The Thomson Rosemount Group, Inc.
- Wilmot Creek Watershed Tier 2 Water Budget Analysis, Durham Region, ON (2010): Calibration of an existing regional groundwater flow model within the watershed of interest to determine the water budget components. Client: Ganaraska Region Conservation Authority.
- Contaminant Transport Modelling for a Former Oil Battery Site, Calmar, AB (2009): Review of site data to construct and calibrate a groundwater flow model to simulate chloride transport and fate in the sub-surface. Client: Canadian Natural Resources Limited / Wiebe Environmental Services.
- Thermal Plume Migration Analysis, Mill Creek Aggregate Pit, Guelph, ON (2009): Use a recalibrated groundwater flow model to determine heat transfer into groundwater system from proposed final pit lake configuration, as well as assess impact on nearby cold water fish habitat. Client: Dufferin Aggregates.
- Groundwater Vulnerability Assessment, City of Kawartha Lakes, ON (2007-2009): Regional groundwater model development; capture zone modelling; GIS figure preparation; technical memo/report preparation to develop a groundwater threat inventory database for 15 municipal well systems. Client: The City of Kawartha Lakes / Trent Conservation Coalition.

Groundwater Resources

- Hydrogeological Study, St. Anns, ON (2019): Development of a hydrogeological conceptual model and water supply assessment for proposed site re-development. Client: Silverdale Gun Club / IBI Group.
- Open Space Design Development, Nova Scotia (2012-2014): Analysis of step test and pumping test data to estimate private supply well capacity as part of subdivision development applications at various sites throughout Nova Scotia. Client: Confidential.
- Earthfresh Potato Processing Facility, Hydrogeological Study, Flamborough, ON (2011): Design of drilling program and analysis of in-situ testing data. Client: Earthfresh Inc. / IBI Group.
- Viva Next H3 Project, Construction Dewatering PTTW Application, Markham, ON (2011): Hydrogeological analysis and report preparation for construction dewatering Permit to Take Water application. Client: Kiewit-EllisDon / The Miller Group.
- 3091 Appleby Line, Hydrogeological Study, Burlington, ON (2011): Design of drilling program, field groundwater sampling, data analysis, figure and report preparation for a hydrogeological study of a dense non-aqueous phase liquid (DNAPL) contaminated site. Client: 1345059 Ontario Ltd.

- Greenwich Street Sewage Pumping Station, Construction Dewatering PTTW Application, Brantford, ON (2011): Hydrogeological analysis and report preparation for construction dewatering Permit to Take Water application. Client: City of Brantford.
- Dominion Road Sewage Pumping Station, Construction Dewatering PTTW Application, Fort Erie, ON (2011): In-situ testing, hydrogeological analysis and report preparation for construction dewatering Permit to Take Water application. Client: R.V. Anderson & Associates / Niagara Region.
- Microbial Contaminant Control Plan, Halton Region, Peel Region, ON (2005, 2006): Threat inventory preparation; CAD figure preparation; field reconnaissance for development of microbial contaminant control plans for groundwater supply systems. Client: Regional Municipality of Halton, Peel Region.
- Garden City Municipal Golf Club, Evaluation of Alternative Irrigation Sources, St. Catharines, ON (2006): Report preparation, CAD figure preparation to assess the ability of a local pond to supply irrigation water requirements. Client: Urban & Environmental Management Inc.

Waste Management

- Regional Municipality of Niagara
  - Bridge Street and Quarry Road Landfill Sites and Quarry Road Constructed Wetland, Annual Monitoring Programs (2013/2014 and 2018-ongoing): Project Manager for annual compliance monitoring programs at landfills in complex fractured bedrock settings. Responsibilities include: manage field staff; liaise with client, subcontractors and laboratories; cost/budget control, collate, QA/QC, analyze and interpret technical data for leachate, groundwater, surface water and sediment samples. Evaluate and assess the condition of the monitoring well network at the Site, develop a work/cost program and implement maintenance and repair program. Performance evaluation of containment systems and perimeter leachate collection systems. Provide routine status updates to client and prepare annual report for submission to the MECP.
  - Line 5 Landfill, Niagara-on-the-Lake, ON (2013-ongoing): Project manager for annual compliance monitoring program at a closed landfill in an overburden setting. Management of field staff; liaisons with client and laboratories; cost/budget control, collation, QA/QC, analysis and interpretation of technical data for leachate, groundwater, and surface water samples; routine status updates to client; and preparation of annual compliance monitoring report. Preparation of a revised environmental monitoring program, which included assessment of site conceptual model, potential contaminant pathways and sensitive receptors.
  - Landfill Monitoring Programs, Niagara Falls, Grimsby, Pelham, Niagara-on-the-Lake, Fort Erie, ON (2005-2014): Field sampling for groundwater and surface water as part of annual monitoring programs at Mountain Road, Park Road, Niagara Road 12, Line 5, Station Road, Centre Street, Quarry Road and Bridge Street Landfills.
  - Nitrate Isotope Sampling and Assessment, Fonthill, ON (2017): Analysis of groundwater general chemistry and isotope results to determine the source of elevated nitrate concentrations at Centre Street Landfill Site.
  - Stormwater Management Pond Trigger Mechanism Plans, Line 5 Landfill and Perry Road Landfill (2014-2015): Statistical analysis of historic chemical results to determine appropriate trigger parameters and levels for operation of the stormwater management pond. Preparation of report, tables and figures.

  - Chloride Isotope Sampling and Assessment, Caistor Centre, ON (2014): Analysis of groundwater general chemistry and isotope results to determine the source of elevated chloride concentrations at Caistor Road Landfill Site.
  - Paleo-karst Investigation, Fort Erie, ON (2013): Low-flow groundwater sampling to complete a hydrogeological investigation to characterize an inferred paleo-karst zone at Bridge Street Landfill. Preparation of report and figures summarizing results, including an analysis of paleo-karst geochemistry.
  - Chloride Isotope Sampling and Assessment, Wainfleet, Fort Erie, ON (2011): Analysis of groundwater general chemistry and isotope results to determine the source of elevated chloride concentrations at Station Road and Bridge Street landfills; technical memo and figure preparation.
  - Tritium, Oxygen and Hydrogen Isotope Sampling and Assessment, Wainfleet, Fort Erie, ON (2010): Analysis of groundwater general chemistry and isotope results to determine the source of elevated chloride concentrations at Station Road and Bridge Street landfills; technical memo and figure preparation.
  - Mountain Road In-situ Hydraulic Conductivity Tests, Niagara Falls, ON (2005): In-situ hydraulic conductivity tests; slug test analysis; report preparation.
- East, South, and West Landfill Sites, City of Niagara Falls, ON (2012-ongoing): Preparation of annual compliance monitoring reports for one operating and two closed landfill sites located within one continuous footprint. Data management and QA/QC using a custom Access database. An adjacent active quarry is also monitored and monitoring data from all four sites are considered when characterizing and assessing the hydrogeologic setting. Client: Walker Environmental Group
- County of Oxford
  - Landfill Monitoring Programs, Norwich, Salford, ON (2012-2014): Preparation of annual monitoring report data tables, figures and text at Holbrook (closed) and Oxford County (operational) landfills.
  - Well Network Assessment, Norwich, ON (2013): Completion of a well network assessment at Holbrook (closed) landfill to identify monitoring program deficiencies and recommend remedial measures.
- Mohawk Street Landfill, Brantford, ON (2009-2018): Field sampling for groundwater and surface water at a large operating landfill. Data collation, technical analysis, and reporting as part of the annual monitoring program. Client: City of Brantford.
- Private Landfill Monitoring Programs, Kapuskasing, ON (2012-2013): Preparation of annual monitoring report data tables, figures and text for two private landfill sites. Client: Tembec Kapuskasing Operations.
- Potential Landfill Constraint Mapping, Eastern Ontario (2006): Constraint mapping for potential landfill sites; GIS figure preparation. Client: Confidential.

Geotechnical Engineering

- OPG Pump Generating Station Dyke Monitoring Program, Niagara Falls, ON (2012-2013): Field and technical support for the abandonment of 111 pressure relief wells and piezometers and 4 additional tunnel well nests around the PGS Dyke, including 3 Waterloo System multi-level wells. Wells were located adjacent to the Niagara Escarpment and the Buried St. Davids Gorge. Additional work included rehabilitation of 48 wells; and preparation of documentation and figures. Client: Ontario Power Generation Inc.

- Sir Adam Beck Tunnel 3, Groundwater Monitoring Program, Niagara Falls, ON (2010-2013): Installation and operation of double-valve pumps (DVPs) for low-flow groundwater sampling to monitor the effect of dewatering for tunnel construction on local groundwater resources. Client: Strabag.
- Abitibi Thorold Mill, Cogeneration Plant, Geotechnical Drilling Program, Thorold, ON (2006): Drill rig supervision; borehole logging and soil sampling as part of a geotechnical investigation of soils for a planned co-generation plant. Client: Abitibi-Consolidated.
- Whirlpool Rapids Bridge Monitoring Program, Niagara Falls, ON (2005): Groundwater sampling and erosion monitoring at a contaminated site within the Niagara River Gorge. Client: Niagara Falls Bridge Commission.

Environmental Site Assessments and Site Remediation

- Designated Substance Survey, Brantford, ON (2013): Development of an Access database for survey results and automated reporting of asbestos material location and condition. Client: City of Brantford.

J. STEPHEN ASH, P.Eng., P.Geo.

Senior Geotechnical Engineer, Environment

Areas of practice

Geotechnical Engineering

Renewable Energy

Waste Management

Mining (non-aggregate)

Dams & Hydropower

Hydrogeology

Landfill Impact Assessment and Remediation

Environmental Site Assessment, Audit & Remediation

Aggregates

PROFILE

Mr. Stephen (Steve) Ash is a CEO-designated Consulting Engineer and Professional Geoscientist and has been working in the fields of geotechnical engineering, hydrogeology, and environmental site assessment since 1994. Prior to this he worked for several years in eastern Canada as an exploration geologist to the mining industry. Steve's engineering experience includes hundreds of geotechnical investigations and assessments for structural foundations (including high rise buildings, commercial warehouses and retail stores, industrial and institutional buildings, hydropower dams and power plants, solar arrays and wind energy turbines), large municipal infrastructure projects including water treatment and pollution control plants and trunk sewer tunnels, earthworks projects including embankments, lagoons and municipal landfills, pavement design for highways, roadways and airport development, light rail transportation projects, and slope stability for embankments, open mine pits and tailings ponds.

During his career Steve has completed detailed hydrogeological evaluations for private and municipal water supplies, Permit to Take Water studies for construction dewatering and drainage for open pit mines, pits and quarries, and rural property development using large in-ground sewage disposal systems.

Steve has completed numerous Phase I and II Environmental Site Assessment studies (O. Reg. 153) for commercial and industrial land development and qualifies as a QP_{ESA}. He has also participated in several important aggregate resource evaluations for the Ontario Provincial Government, and licensing studies for large corporate and private clients. Steve has served as an expert witness at several Ontario Municipal Board (now the LPAT) hearings to provide hydrogeological and geological testimony for licensing commercial aggregate sites.

In 2002, Steve took on the responsibility of Business Unit Leader at the Peterborough offices of WSP Canada Inc. and became a Director in 2009 responsible for the Central Ontario business unit. During that period Steve oversaw the Firm's soils and concrete testing laboratories and material testing projects, including carrying out specialized and ASTM tests for construction projects. Steve joined the Centre Block Rehabilitation Project in Fall 2018 and became Geotechnical Lead for the project in 2019. Steve's project management experience includes contract administration, budget planning, client liaison, implementation of field programs, technical data analysis, numerical modeling, report preparation and offering high level presentations.

EDUCATION

Professional Engineers Ontario (PEO) license accreditation program in Geological Engineering, University of Toronto, University of Waterloo and RMC, ON	1999
B.Sc. (Hons. Geology), McMaster University, Hamilton, ON	1987

PROFESSIONAL DEVELOPMENT

WHIMIS 2015	2015 (updated 2020)
Effective Supervision and Communications in Management	1994
Building Science and Air Leakage Control Technologist	1994
Certified Concrete Field Testing Technician (ACI Grade I)	1995

Drilled Foundations Seminar (ASCE)	1998
OHSA Training Program and Refresher Courses	2001
Elements of Landfill Design and Remedial Measures	2002
Geo-Support and Soft Ground Engineering Short Course (EPIC)	2003
Nuclear Gauge Training Certification (CNSC)	2003
Creative Marketing Seminar	2004
Effective Leadership Seminar	2005
Evaluation and Rehabilitation of Pavements (EPIC)	2006
CCIL Aggregates Laboratory Testing (Levels C and D)	2007
Construction Dewatering and Groundwater Control Short Course	2008
NORCAT General Safety Induction, ZES001 Core Module	2010
Cone Penetration Testing Methods Short Course (ConeTec)	2011
Machine Foundations Design Short Course (UWO)	2012
Helical Piles Design Seminar (EBS)	2013
Geotechnical Instrumentation Seminar (GKM)	2018
RS3 Numerical Modeling Short Course (RocScience)	2019

PROFESSIONAL ASSOCIATIONS

Consulting Engineers Ontario	CEO
Professional Engineers Ontario	PEO
Association of Professional Geoscientists of Ontario	PGO
National Ground Water Association	NGWA
Ontario Stone, Sand and Gravel Association	OSSGA
Ontario Waste Management Association	OWMA

PROFESSIONAL CAREER

Consulting Engineer/Geotechnical Lead, CBR Project, Ottawa	2018 – Present
Consulting Engineer/Director, Environment, WSP	2013 – 2018
Consulting Engineer/Director, Environment, GENIVAR (now named WSP)	2009 – 2013
Project Engineer/Branch Manager, Jagger Hims Limited (GENIVAR Acquisition)	2002 – 2009
Project Engineer/Geologist, Jagger Hims Limited	1999 – 2002

Projects Coordinator, Site Investigation Services Limited
(Jagger Hims Limited Acquisition) 1994 – 1999

PROFESSIONAL EXPERIENCE

Geotechnical Engineering

Buildings

- Centre Block Rehabilitation Project, Ottawa, ON (2018-present): Geotechnical Lead for Early Works investigation projects, Seismic Liquefaction Study (Pink Road storage warehouse) and seismic upgrade analysis (Centre Block/Peace Tower), Parliament Welcome Centre (PWC) bulk excavation design, Geotechnical Data Report, Geotechnical Design Report and Geotechnical Baseline Report, hydrogeological testing and dewatering analysis, Hydrogeological Report, instrumentation development for Building and Structural Health Monitoring Programs, construction inspections (including East IT interconnect HDD tunnel, Public Washroom micropile foundations, monument relocations), Geotechnical CA lead for PWC, North Moat and CB upgrade projects. Client: PSPC
- My Place on 7 High-Rise, Vaughan, ON (2021): Geotechnical investigation report for 14-storey mixed use building with 4-storey underground parking, work plan development, technical analysis and review. Client: My Place on 7 (Ray Nicolini)
- Bayfront Yard Maintenance Station, Hamilton, ON (2020): Geotechnical investigation report, helical pile testing and supplemental foundation design report, retaining wall design reviews, construction support (QA/QC). Client: City of Hamilton
- K+S Windsor Salt, Ojibway Mine Warehouse #1 Replacement, Windsor ON (2018-2020): Geotechnical borehole and sCPT/CPTu investigations, eFSV testing, bearing capacity and settlement analysis for proposed warehouse replacement in variably loaded soft clay deposits, deep pile analysis and design. Client: K+S Windsor Salt
- Carlisle Square, St. Catharines ON (2016-2017): Geotechnical investigations, analysis and foundation design report for 12-storey building with 2-levels of underground parking; provided parameters for deep foundation design and shoring to protect immediately adjacent structures during construction. Client: Nickel Investments
- Napanee Generating Station, Napanee, ON (2013-2016): Geotechnical site investigation report for 1GW co-generation station at OPG Lennox site, shallow/deep foundations design, groundwater control and permitting, construction inspections and materials testing, rock anchor design report. Client: Kiewit Power Engineers.
- Goodfellow Road Apartment Settlement, Peterborough ON (2015): Evaluation of basement floor settlement and foundation cracking, foundation remediation design report. Client: Starlight Investments Ltd.
- Moose Cree Assisted Living Center, Moosonee ON (2014-2015): Geotechnical site investigation report, design review, construction inspection program. Client: Moose Cree First Nation.
- 555 Park Road Apartments, Brantford, ON (2015): Geotechnical and foundation design review, construction QA program. Client: Raymond Nicolini.
- 272 Charlotte Street Medical Building, Peterborough, ON (2011): Geotechnical investigations and materials testing (soil, concrete) for construction of new 4-storey medical office building in downtown Peterborough. Client: Seven Hills Development.

- DCC CFB Willow Park TEME Building, Halifax, NS (2011): Geotechnical peer reviews of caisson foundation designs. Client: Defence Construction Canada.
- Quinte Consolidated Courthouse, Belleville, ON (2010): Geotechnical and hydrogeological investigations of Brownfield site redevelopment as a courthouse. Include evaluation of geothermal heating options and design-build consultations. Client: Infrastructure Ontario / Ontario Realty Corporation.
- Eyer House, 1045 Elgin Mills East, Richmond Hill, ON (2010): Geotechnical investigation for building extension and parking lot upgrades. Client: Town of Richmond Hill.
- Oak Ridges Community Center, Oak Ridges, ON (2010): Geotechnical investigation and materials testing for new community centre, including foundations, services, paved parking and lighting systems. Client: Town of Richmond Hill.
- Minto Group vs. Billchrist Soil Settlement Claims, Toronto, ON (2010): Expert review of construction claim and input to legal action, review of excavation shoring failure and groundwater seepage control. Client: Minto Group.
- Tannery Property, Kuujjuaq, Nunavik, QC (2010): Investigation of permafrost, site survey and design layout of foundation for new structure. Client: Makivik Corporation.
- 2545 Bloor Street West, Toronto, ON (2010): Geotechnical and hydrogeological investigation of foundation leakage and driveway subsidence, including brine tracer tests. Client: Metro Toronto Condominium Corporation.
- Thorold Cogeneration Project, Thorold, ON (2009): Geotechnical design report for co-generation plant project, design consultations and construction inspections for QA program. Client: VK Mason Construction Co. / Kiewit Power Engineers
- Gale Center, Niagara Falls, ON (2006-2009): Geotechnical design report for foundations and services, and construction QA/QC inspections and testing, including subgrade, backfill and concrete. Client: City of Niagara Falls.
- Foundation and Pavement Design Reports for 9 Patrol Yards Northeastern Region, Various Locations, ON (2009): Geotechnical foundation design reports and pavement design memos for storage domes and maintenance structures. Medium Complexity RAQS. Client: Ministry of Transportation.
- Fleming College Skilled Trades Institute, Lindsay, ON (2009): Geotechnical investigations and materials testing for new Trades Institute. Client: Fleming College.
- Puvirnituq Community Center, Puvirnituq, QC (2009): Investigation of permafrost, site survey and design layout of foundation for new structure. Client: Makivik Corporation.
- Applefest Lodge Seniors Residence Addition, Brighton, ON (2009): Geotechnical design report for foundation and services. Client: Seniors Care Corp.
- Grain Storage Silo Facilities, Lindsay, ON (2008): Foundation investigations for heavily loaded silos. Client: JR Forson Equipment.
- Wutai Shan Buddhist Temple, Bethany, ON (2007, 2015): Geotechnical investigation for authentic temple design in sloping terrain, including retaining wall assessments and parking, embankment dam. Client: EcoVue Consulting Services Inc; Wutai Shan Temple.
- CFB Borden Engineering School, Angus, ON (2007): Geotechnical design report for foundation, services and pavements. Client: Defense Construction Canada.

- CFB Borden Music Building, Angus, ON (2007): Geotechnical design report for foundation, services and pavements. Client: Defense Construction Canada.
- CFB Borden Paint Shop Expansion, Angus, ON (2007): Geotechnical design report for foundation, services and pavements. Client: Defense Construction Canada.
- CFB Borden Confined Space Trainer Facility, Angus, ON (2007): Geotechnical design report for foundation, services and pavements. Client: Defense Construction Canada.
- Nephton Mine Building Expansions, Nephton, ON (2007): Geotechnical investigation for foundation and services design. Client: Unimin Canada Limited.
- Shoppers Drug Mart Development, Peterborough, ON (2007): Geotechnical investigation report for foundation design and services, and pavement design. Client: Norlon Builders London Ltd.
- Mill and Warehouse Expansions, Nephton, ON (2005): Geotechnical drilling investigations for foundation design, and construction inspections including pile inspection and compaction and concrete tests. Client: Unimin Canada Limited.
- Lakefield Speed Skating Oval, Lakefield, ON (2005): Geotechnical investigation for foundation design and construction of oval, refrigeration unit, and recreational facility. Client: Crawford Building Consultants.
- McBain Community Center, Niagara Falls, ON (2005-2007): Geotechnical design report for foundations and services, and construction QA/QC inspections and testing. Client: City of Niagara Falls.
- Peterborough Medical Clinic Foundation, Peterborough, ON (2005): Geotechnical report for foundation design and servicing. Client: The Peterborough Clinic.
- Shoppers Drug Mart Development Site, Peterborough, ON (2005): Geotechnical design report for foundations, services and pavements. Construction inspections for QA/QC including subgrade, backfill, concrete and asphalt. Client: Shoppers Drug Mart.
- Flying Colours Warehouse Building and Hangars, Peterborough Airport, Peterborough, ON (2004): Geotechnical investigation report for new jet hangar and warehouse building. Client: Cornerstone Builders.
- Sandy Lake First Nation: Geotechnical Investigation for a proposed nursing station and residence building. Helical Pile design and testing. Client: Sandy Lake Corporation

Infrastructure

- Energy Services Acquisition Project, Ottawa, ON (2019-2021): Geotechnical analysis and design reports, including bedrock slope stabilization designs, for Cliff CHCP and Tunney's Pasture CHCP. Client: PCL / Innovate Energy
- Trent Severn Lock 42 (Couchiching) Rehabilitation, Severn Township ON (2019): Geotechnical investigation and program development, geotechnical analysis and design recommendations, final design report. Client: Parks Canada
- MTO FIDR for THESL Asset Relocation (2018): Geotechnical Investigation Review, and Foundation Investigation and Design Report for tunneling (Medium Complexity RAQs), Highway 401 pipeline crossing at Neilson Road Bridge, Scarborough ON. Client: Powerline Plus Ltd.
- Front Road Trunk Watermain, Kingston ON (2017-2019): Geotechnical investigations and design for trunk sewer tunnel crossing beneath Little Cataraqui Creek; Geotechnical Design Report for Portsmouth Pumping Forcemain and

- Watermain Extension; dewatering analysis for Hydrogeological Report and Permit to Take Water (Sand Bay Lane extension and CNR crossing); geotechnical investigations and recommendations for reconstruction of Front Road. Client: Utilities Kingston
- Whitney Pumping Station and Equalization Tanks, Timmins, ON (2015): Geotechnical investigations, slope/excavation stability analysis, forensic settlement investigations and design reviews. Client: City of Timmins.
- Courtice Trunk Sewer, Clarington ON (2015): Geotechnical High Complexity RAQs (MTO) design report for trunk sewer crossing of Highway 401, including evaluation of tunneling methods and shaft designs. Client: Regional Municipality of Durham.
- West Whitby Trunk Sewer, Whitby, ON (2015): Geotechnical High Complexity RAQs (MTO) design report for trunk sewer crossing of Highway 401, including evaluation of tunneling methods and shaft designs. Client: Regional Municipality of Durham.
- Geotechnical/Hydrogeological Assessments for CPDP, Pickering, ON (2010-2013): Geotechnical investigations for over 30 km of new infrastructure, including transportation projects (bridges, roads), slope stabilization, water main and trunk sewers for Municipal Class EA project. Client: Regional Municipality of Durham.
- Whitby GO Station Expansion, Whitby, ON (2013): Geotechnical and environmental investigation, deep foundation (caisson) design report, pavement design report. Client: Metrolinx.
- Waterloo LRT, Waterloo, ON (2012-2013): Geotechnical design evaluations and reports for Waterloo LRT and King Street Grade Separation projects, addressing design of proposed 19 km of rapid transit corridors within Kitchener and Waterloo. Client: Region of Waterloo LRT.
- Port Darlington WPCP, Clarington, ON (2011): Geotechnical investigations and design report, including construction and long term dewatering initiatives for WPCP upgrades, including primary clarifiers, aeration tanks, digester, air and energy buildings, chlorination tank, and related infrastructure. Client: Regional Municipality of Durham.
- 5th Line Trunk Sewer and Watermain, Milton, ON (2010-2018): Geotechnical investigation and environmental soils and groundwater testing for trunk sewer upgrades, including rock tunnelling design under CPR corridor. Client: Region of Halton.
- Lasalle Boulevard and Notre Dame Avenue Intersection Improvement, Sudbury, ON (2011): Geotechnical and environmental assessments for roadway widening and intersection improvements. Client: City of Greater Sudbury.
- Becker/Alverna/Felix/Bonita Reconstruction, Richmond Hill, ON (2010): Geotechnical investigations, design report, dewatering design and materials testing supervision for infrastructure and roadway reconstruction. Client: Town of Richmond Hill.
- Sussex Avenue Road Reconstruction, Richmond Hill, ON (2010): Geotechnical investigation and dewatering design, infrastructure and roadway reconstruction. Client: Town of Richmond Hill.
- Bayview Avenue Widening, Richmond Hill, ON (2010): Geotechnical investigation and pavement design report for widening of Bayview Avenue. Client: Town of Richmond Hill.
- Mayfield Road Schedule C Class EA, Peel Region, ON (2010): Pavement condition rating report and geotechnical investigations for proposed roadway widening (4 to 6

lanes), Mayfield Road. Client: Region of Peel.

- Sudbury Airport Expansion, Apron 3, Phase 2, Sudbury, ON (2010): Geotechnical investigation and pavement design report for airport upgrades. Client: City of Greater Sudbury.
- Thorold Road Extension, Niagara Falls, ON (2010): Geotechnical and environmental investigation of proposed road extension into new recreational facilities. Client: AECOM.
- Highway 108 Sanitary Services Design, Elliott Lake, ON (2009): Geotechnical investigation and report for underground services and construction dewatering. Client: Tulloch Engineering.
- Milroy Park Expansion, Peterborough, ON (2009): Geotechnical investigation for design and construction of new sports fields and related infrastructure. Client: City of Peterborough.
- Otonabee River Watermain Crossing, Peterborough, ON (2009): Geotechnical investigation and barge work for design of new watermain crossing of Otonabee River and Highway 7/115. Client: D.M. Wills.
- Winchester Road and Harmony Road Extension, Oshawa, ON (2009): Geotechnical and environmental investigations for road widening and infrastructure improvements, including embankment and pavement design. Client: Regional Municipality of Durham.
- Highway 62 Improvements, Bancroft, ON (2009): Supervision of QA/QC materials testing program for highway improvements. Client: MTO.
- Ferguson Avenue Pump Station, Hamilton, ON (2009): Geotechnical investigation and design report for municipal pumping station, including slope stability assessment and caisson wall stabilization. Client: City of Hamilton.
- St. Clair Township WPCP Expansion, St. Clair Township, ON (2008): Geotechnical design report for foundations and construction dewatering considerations, preparation of permit to take water applications and monitoring requirements, materials testing of subgrade, backfill, concrete structures and asphalt. Client: AECOM/Township of St. Clair.
- Norwood WPCP Expansion, Norwood, ON (2008): Geotechnical investigation for foundation and dewatering design. Construction QA/QC. Client: Township of Asphodel Norwood and AECOM.
- Cobourg WPCP Expansion, Cobourg, ON (2008): Geotechnical investigation report for foundation and services design, construction inspections and QA/QC. Client: AECOM.
- Whitby WPCP Expansion, Whitby, ON (2008): Geotechnical investigation of plant site for foundation design report, sanitary sewer replacement along Water Street and diesel generator pad requirements. Client: AECOM.
- Highway 7 Swamp Crossing, Marmora, ON (2007): Evaluations of highway widening over soft peat soil, including subgrade, granular base and sheet pile retaining wall inspections. Client: Bare Eng. Ltd.
- Lindsay WTP Expansion, Lindsay, ON (2007): Geotechnical design report for WTP foundations and river intake structures. Construction inspections and testing and evaluation of dewatering requirements. Client: KMK Consultants Limited.
- Highway 401 Interchange at Grafton, Grafton, ON (2007): Aggregates testing and construction QA/QC for MTO project. Client: Bonnechere Excavating.

- RFP 2007-046 County Road Rehabilitation, Simcoe County, ON (2007): Geotechnical investigation and report for 25 km of road improvements. Client: County of Simcoe.
- Highway 7 Widening, Marmora, ON (2007): Aggregates testing and construction QA/QC for MTO project. Client: Bonnechere Excavating.
- CFB Borden CFAD Roads Reconstruction, Angus, ON (2007): Pavement design report for heavy duty road construction. Client: Defense Construction Canada.
- CFB Borden CFAD Roads Reconstruction, Angus, ON (2007): Pavement design report for heavy duty road construction. Client: Defense Construction Canada.
- Rideau Park WPCP Plant and Sanitary Sewer Services, Kemptville, ON (2006): Geotechnical investigation of proposed sewage treatment plant area, and sanitary sewer lines. Client: Ontario Parks.
- Highway 7 and Parkhill Road West Intersection Reconstruction, Peterborough, ON (2006): Aggregates testing and construction QA/QC for MTO project. Client: Bonnechere Excavating.
- Norland WTP and Distribution System, City of Kawartha Lakes, ON (2005): Geotechnical investigation report for foundation and services design and construction. Construction inspections of subgrade and backfill and testing of concrete. Client: Totten Sims Hubicki Associates.
- Taunton Road Widening, Whitby, ON (2005): Geotechnical and hydrogeological studies for services installation, groundwater dewatering and road reconstruction. Client: Regional Municipality of Durham.
- Anstruther Lake Road Reconstruction, Apsley, ON (2005): Geotechnical report for roadway design and reconstruction. Client: D.M. Wills Associates.
- Highway 28 Taper and Intersection Improvements, Burleigh Falls, ON (2004): Pavement design report for MTO Highway taper. Client: D.M. Wills Associates.
- Waverly Road Widening and Highway 401 Interchange, Bowmanville, ON (2004): Geotechnical and environmental investigations and preparation of soils design report for municipal road widening. Client: Regional Municipality of Durham.
- Peterborough Airport Commercial Hangars, Peterborough, ON (2004): Geotechnical investigation and testing of proposed private hangar sites and construction inspections. Client: City of Peterborough.
- Kinmount WTP and Distribution System, City of Kawartha Lakes, ON (2004): Geotechnical investigation for foundation and dewatering design, and requirements for distribution system along highway and municipal roads. Construction QA/QC. Client: Totten Sims Hubicki Associates.
- Norland WTP Expansion, City of Kawartha Lakes, ON (2004): Geotechnical investigation for foundation and dewatering design, and requirements for distribution system along highway and municipal roads. Construction QA/QC. Client: Totten Sims Hubicki Associates.
- Peterborough Airport Taxiway Development, Peterborough, ON (2004): Geotechnical investigations for taxiways and construction supervision, including subgrade soil inspections. Client: R. McPhee & Company Limited.
- Millbrook WPCP Upgrade, Millbrook, ON (2003): Geotechnical investigation for WPCP upgrade including new underground treatment tanks to 5 m depth. Client: Totten Sims Hubicki Associates.

- County Road 21, Millbrook, ON: Class EA, Design and Engineering for Culvert Replacement. Client: County of Peterborough.
- King Station, Caledon, ON: Geotechnical investigation for development site. Client: King Station.
- Woods of Jennings Creek, Lindsay, ON: Geotechnical Investigation for pipe laying in the new subdivision: Client: Dunster Investments.

Bridges

- MacDonald Cartier Bridge, Ottawa, ON (2021): Geotechnical report for structural enhancements, thrust blocks for ESAP distribution piping support. Client: PSPC / PCL Constructors.
- Royal Alexandra Bridge, Ottawa, ON (2021): Preliminary Geotechnical Study report for bridge replacement. Client: PSPC
- Sir John A. MacDonald Parkway Bridge Replacement, Ottawa, ON (2019-2020): Geotechnical investigation and foundation design report for single-span arterial roadway bridge, utilizing a deep foundation (rock socketed caisson) design. Caisson inspections and geotechnical contract administration support during construction. Client: National Capital Commission.
- Lillabelle Lake Bridge Replacement, Timmins ON (2015): Geotechnical investigation and foundation design report for single span roadway bridge. Client: Rivard Engineering.
- Emiry Road Bridge Replacement, Espanola ON (2015): Geotechnical investigation and foundation design report for two span roadway bridge. Client: Township of Sables-Spanish River.
- McCully Bridge Replacement, Sunderland ON (2012): Geotechnical investigation, foundation design report (piles) for single span roadway bridge, preloading assessment for embankment widening over marsh areas, construction monitoring. Client: Regional Municipality of Durham.
- Marlbank Bridge Replacement, Tweed ON (2010): Geotechnical investigation and design report for single span roadway bridge. Client: G.D. Jewell Engineering.
- Jackson Creek Pedestrian Bridge, Peterborough (2010): Geotechnical investigation and foundation design report for new pedestrian bridge crossing Jackson Creek for access to Crary Park. Client: City of Peterborough.
- Factory Creek Bridge Replacement, Northumberland County ON (2009): Geotechnical investigation and foundation design report, embankment stability assessment. Client: G.D. Jewell Engineering.
- Potomac River Bridge Replacement, Blind River ON (2009): Geotechnical investigation and foundation design report. Client: Tulloch Engineering.
- Gordon Lake Bridge Replacement, Johnson Township ON (2009): Geotechnical investigation and foundation design report for highway box culvert crossing. Client: Tulloch Engineering.
- Gannon’s Narrows Bridge Rehabilitation, Peterborough County (2004): Geotechnical evaluations for foundation replacement and causeway upgrades. Client: County of Peterborough.
- Lockies Bridge Replacement, Peterborough ON (2002): Geotechnical investigation and foundation design report (piles) for roadway bridge construction inspections of pile installation, embankment design. Client: City of Peterborough.
- Midlothian Road Bridge Replacement, Ryan Township, ON (2002): Geotechnical

investigation and design report for pile foundation. Client: Totten Sims Hubicki Associates.

Slopes

- Cliff Park Escarpment Stabilization Project, Ottawa, ON (2019-2021): Geotechnical investigations, rock stability assessments and inspection reports for 20m high rock cliff escarpment adjacent to Supreme Court of Canada. Client: PSPC.
- 5773 Islington Apartment Complex, Woodbridge, ON (2014-2019): Geotechnical investigations and slope stability analysis for TRCA permitting process, Slide v6.0 numerical modeling, hydrogeological assessment for dewatering. Client: Briardown Estates Inc.
- Rivers of Life Church Development, Vaughan ON (2015): Slope stability analysis using Slide 6.0 numerical modeling, TRCA permit application process. Client: Reinders + Rieder Limited.
- 951 Dundas Street West, Whitby, ON (2011): Slope stability evaluation for conservation authority of commercial development (gas station, convenience store) adjacent to protected creek and floodplain. Client: Sunray Group.
- Oakhill Drive Slope Failure, Brantford, ON (2011): Geotechnical evaluation of erosion and slope stabilization for failed slopes of Grand River along Oakhill Drive in Brantford. Project involved geotechnical design of remediation approaches, development of tender documents, assistance with contractor selection, as well as construction oversight. Client: City of Brantford.
- Town of Paris Development Site Slope Stability, Paris, ON (2010): Geotechnical investigation of closed landfill slopes adjacent to Nith River, and development of slope stabilization concept for proposed commercial redevelopment. Client: County of Brant.
- McCloskey's Containment Pond Designs and Permits, Peterborough, ON (2010): Evaluation of pond design and construction as input to Category 3 long term Permit to Take Water, including MOE consultation and pond stability review. Client: McCloskey International.
- Rock Point Provincial Park Lagoon Berms, Dunnville, ON (2009): Geotechnical investigation and assessment of berm stability to install buried force main. Client: Ontario Parks.
- Slope Stability Peer Review Services for Multiple Sites, Various Locations, ON (2006): Peer review of geotechnical reports for development properties with slope stability issues. Client: Lake Simcoe Region Conservation Authority.
- Berm Stability Assessment, Aurora, ON (2001): Evaluation of pond berm failure and rehabilitation requirements. Inspections of berm and culvert reconstruction. Client: King Cole Ducks.
- Glen Major Angling Pond Dredging Program, Uxbridge, ON (2000): Geotechnical design of pond dredging program, including equipment staging areas and material holding cells. Inspection and survey of dredging grades and berm stability, including design and inspection of reinforced equipment access pad over soft bog. Client: LGL Limited.

Renewable Energy Projects (Solar and Wind)

- Pesakastew Solar Farm, Saskatchewan (2021): Owner's technical reviewer for geotechnical report submittals, pile foundation designs, road and grading designs. Client: Natural Forces.

- Empress and Fox Coulee Solar Farms, Alberta (2021): Owner's technical reviewer for geotechnical report submittals and pile foundation designs, 110MW solar development. Client: IB Vogt.
- Claresholm Solar Farm, Alberta (2019): Geotechnical Owner's Engineer (OE) Services for pile design, 170MW solar development. Client: Capstone Power Development.
- Barlow Solar Farm, Cornwall ON (2018): Geotechnical site investigations, design of pile foundations for racking and e-houses, design validation and production pile testing and certification, electrical resistivity surveys for grounding grid, 10 MW site. Client: EDF
- PUI Solar Farm Bundle, Peterborough, ON (2016-2018): Project director and senior engineer evaluating feasibility of twenty (20) 500 kW solar farms, including EASR screenings, natural science reviews, geotechnical investigations, analysis and reporting of foundation options, civil layout and site design for tender packages. Client: Peterborough Utilities Inc.
- Queensway and Panache Lake Solar Farms, Espanola ON (2016): Geotechnical design of pile foundations for racking and e-houses, production pile testing and certification, electrical resistivity surveys for grounding grid. Client: Panasonic Energy Solutions Canada.
- Muskoka Solar Farm Bundle, Muskoka ON (2016): Electrical resistivity surveys for grounding design at four 500 kW sites, geotechnical consultation for pile design. Client: Panasonic Energy Solutions Canada.
- Canoa Solar Farm, Dominican Republic (2017): Geotechnical investigation and pile design recommendations for 10 MW remote jungle site. Client: Potentia
- Renesolar Solar Bundle (2017) – Geotechnical investigations for eighteen (18) 500 kW solar farms at various locations. Client: Client: Panasonic Energy Solutions Canada.
- Stone Mills Solar Projects (2017) – Geotechnical investigations, pile design and civil engineering layouts for six 600 kW to ~1MW sites in Stone Mills Ontario area. Client: Solar FlowThrough/Abundant Solar.
- Sunderland Solar Farm, Sunderland, ON (2013-2014): Senior engineer overseeing quality control programs for confirmation of PV pile capacities, subgrade bearing capacity, soil compaction, concrete field testing of physical properties and steel rebar placement for inverter house, substation structures, access roads and general fill placement. Client: PCL Constructors Inc.
- Orillia 1,2 and 3 Solar Farms, Orillia, ON (2013): Senior engineer overseeing quality control programs for confirmation of PV pile capacities, subgrade bearing capacity, soil compaction using nuclear densometer methods, concrete field testing of physical properties and steel rebar placement for inverter house, substation structures, access roads and general fill placement. Client: PCL Constructors Inc.
- Recurrent Energy Solar Farm Bundle, ON (2013): Geotechnical investigations, pile design recommendations, construction support for two 10 MW sites. Client: Recurrent Energy.
- Cochrane Solar Farms (Empire, Martin's Meadow, Abitibi, Long Lake), ON (2013-2015): Geotechnical investigations, materials testing and QA/QC, Engineer of Record services for four 10 MW sites (helical and micropile designs). Client: Northland Power Inc.
- Unity Solar Farm, ON (2013): Geotechnical investigations, rock micropile design and load testing for QA/QC. Client: HB White Canada Corp.

- Edwardsburg Solar Farm, ON (2013): Geotechnical investigations, pile design review, engineered fill assessment. Client: PENN Energy.
- South Glengarry Solar Farm, ON (2013): Geotechnical investigations, pile design review, engineered fill assessment. Client: PENN Energy.
- Alfred Solar Farm, ON (2013): Geotechnical assessments, pile design including frost sleeves and ground-insulated options, rehabilitation assessments related to construction deficiencies. Client: HB White Canada Corp.
- Burk's Falls Solar Farms, ON (2014) Geotechnical investigations, materials testing and QA/QC for two 10 MW sites (helical and micropile designs). Client: HB White Canada Corp/Northland Power Inc.
- Q-Cells Tundra-4 Solar Farms, ON (2014) Geotechnical investigations, frost sleeve pile design, site inspections, QA/QC, and certification for four 10 MW sites. Client: Solar FlexRack/Q-Cells
- PENN Energy Stage 2 Sites (Roseplain, Ridgefield, Brantgate), ON (2014): Geotechnical investigations and assessment, QA pile design verification program for three 10 MW sites. Completed Phase 1 ESA updates in 2017. Client: PENN Energy
- Hamilton Township Solar Farm, Hamilton Township, ON (2013-2015): Geotechnical Engineer of Record, pile design and inspections, civil works inspections, permit reviews and drainage modeling for 25 MW site. Completed Phase 1 ESA update in 2017. Client: PENN Energy, ABB/Krinner Canada.
- LP Solar Farms 1 to 17 for Mann Engineering Sites, Central Ontario (2013): Geotechnical investigations and pile design reports. Client: Solar FlexRack.
- Sculler Solar Gardens, Various Locations, ON (2014): Senior Engineer overseeing preliminary investigations and input for detailed structural design for ten (10) 500kW solar gardens in Temiskaming, West Nipissing and Frontenac areas of Ontario. Construction inspections services to confirm foundation construction also was completed. Client: Fritz Construction Services Inc.
- Fort Severn Microgrid Project, Fort Severn ON (2015): Senior geotechnical consultant for site investigation and feasibility options, drainage design, wind turbine anchorage systems. Client: Canadian Solar
- Chamberlain Solar Gardens, ON (2014): Senior Engineer overseeing preliminary investigations and input for detailed structural design multiple solar gardens in New Liskeard area of Ontario. Dual axis tracker design. Construction inspections services to confirm foundation construction also was completed. Client: Fritz Construction Services Inc.
- Capstone 5 Wind Project, City of Kawartha Lakes and Grey County, ON (2015): Geotechnical investigation and design report for 35 wind turbines located in southern central Ontario, shallow and deep foundations design, traffic route analysis and pavement design, consultations during construction. Client: Capstone Power Inc.
- Niagara Region Wind Project, Niagara, ON (2014-2015): Geotechnical investigations, in situ testing and design for 77 wind turbines, shallow/deep foundations design, construction inspections and testing program. Client: Enercon
- Romney Wind Project, Chatham-Kent ON (2016): Geotechnical investigation and foundation design report for 60 MW project. Client EDF EN
- 40 Mile Wind Project, AB (2017): Geotechnical investigations and foundation design report for 200 MW project. Client: Suncor

- Simmie Ridge and Montmatre Wind Projects, SK (2017): Geotechnical investigations and foundation design reports for two ~50 MW projects. Client: Kruger Energy
- Otter Creek Wind Project, Wallaceburg, ON (2017-2018): Geotechnical Investigations, Pile design and Load Testing Program for 35 MW project. Client: Boralex
- Henvy Inlet Wind Project (2018): Design of Pile Foundations for two turbines, L-pile and Group analysis, FEM. Client: Boralex
- McLean's Mountain Windfarm, Little Current, ON (2010): Geotechnical investigation and design report for 30 wind energy convertors, hydro corridors and marine channel crossing by HDD methods. Client: Northland Power Inc.
- Pukwis Wind Park, Georgina Island, ON (2010): Geotechnical investigation and design report for 15 wind energy convertors. Client: Windfall Energy Project.

Waste Management

- Twin Creeks Landfill, Watford, ON (2021): Geotechnical investigation and stability analysis for stockpile deficiency claims; numerical modeling of vertical landfill expansion, settlement and landfill structure impact analysis. Client: Waste Management.
- Green Lane Landfill, London, ON (2019-2020): Geotechnical analysis and design report for Flare Stack No. 4 and transformer station pads, including evaluations of engineered fill and pile foundation options, excavation design. Client: City of Toronto.
- Gerdau Landfill Cell C, Whitby ON (2018-2019): Geotechnical construction administration and QA/QC for industrial waste cell, including design support for composite geosynthetic liner, cell base and slope stability, and materials testing program. Client: Gerdau Steel Canada.
- Green Lane Landfill, London, ON (2014-2020): Geotechnical evaluations of excess soil stockpiles, CLARA/W slope stability analysis, settlement analysis and remediation plan input, construction administration and annual report for ongoing landfill expansions (cell construction). Client: City of Toronto.
- Low Level Radioactive Waste Storage Facility, Welcome ON (2017-2018): Geotechnical lead for primary and secondary liner construction oversight, material reviews and management, and weekly reporting. Client: Port Hope Area Initiative / Canadian Nuclear Safety Commission.
- Emily Landfill, Kawartha Lakes, ON (2017-2019): Hydrogeological reviews and analysis, decommissioning of leachate management systems, groundwater contaminant monitoring and analysis, input to D+O report. Client: City of Kawartha Lakes.
- Peterborough County/City Waste Management Facility, Peterborough ON (2015): Geotechnical construction QA/QC, contract administration and design support for Cell 3 liner construction (north fill area), leachate collectors, and related landfill expansions. Client: City of Peterborough.
- Oshawa Landfill (2014): Geotechnical evaluations for Oshawa Creek slope failures and remedial repairs. Client: Regional Municipality of Durham
- Harper Road Closed Landfill, Peterborough, ON (2011): Waste delineation investigation and hydrogeological design report for remediation of leachate seeps. Client: City of Peterborough.
- Twin Creeks Landfill, Watford, ON (2008-2010): Construction administration

(geotechnical lead) and QA/QC program for screening berms and clay liner construction, including geotechnical evaluations and testing of clay source materials, subgrade inspections, construction supervision and certification of landfill expansion and infrastructure projects. Client: Waste Management.

- Abitibi Landfill South Berm, Thorold, ON (2009): Geotechnical investigation and design report for perimeter berm stabilization concept of paper fibre biosolids containment cell. Client: Integrated Municipal Services.
- Gore Compost Facility, Thorold, ON (2008): Geotechnical investigation for compost pad built over waste, and construction inspections and consultations. Client: Integrated Municipal Services.
- Abitibi Thorold Mill Biosolids Landfill Expansion, Thorold, ON (2007): Evaluation of existing landfill berms, stability assessments, and design of berm reinforcement and drainage for landfill expansion. Client: Integrated Municipal Services.
- Trail Road Landfill Gas Collector and Generator Building, Ottawa, ON (2005): Geotechnical investigation and design report for foundation and structure designs. Client: Integrated Municipal Services / City of Ottawa.
- Cytec USEPA Landfill Capping Project, Thorold, ON (2004): Source material specifications and construction supervision for industrial landfill capping project to USEPA standards. Client: Integrated Municipal Services / Niagara Region.
- Line 5 Landfill Site Development and Transportation Capability Studies, Niagara-on-the-Lake, ON (2003): Geotechnical investigations for cell design, including basal uplift, slope stability and collector settlement. Study included pavement surveys for proposed transportation routes. Client: Regional Municipality of Niagara.
- Landfill Site 13 Clay Liner, Tosorontio Township, ON (2002): Clay liner source report, construction QA/QC inspections and final certification. Work included evaluations of pumping station and leachate holding tank bases. Client: County of Simcoe.
- Landfill Site 11 Clay Liner, Oro-Medonte Township, ON (2001): Evaluation of clay sources for liner, geotechnical specifications for liner construction, construction QA/QC inspections and final certification. Client: County of Simcoe.

Landfill Impact / Compliance Assessment and Remediation

- Trent Lakes Landfill Monitoring Program, Trent Lakes ON (2013-2018): Engineering oversight for sampling and monitoring of 6 closed landfill sites and transfer stations, geotechnical support for landfill remediation as required. Client: Municipality of Trent Lakes.
- Asphodel Township Landfill Monitoring Program (2013-2018): Engineering oversight for annual landfill monitoring program (5 landfills) and reporting. Client: Township of Asphodel-Norwood.
- Peterborough Waste Management Facility, Peterborough, ON (2008-2018): Annual hydrogeological compliance monitoring report and geotechnical design consultations. Client: Urban & Environmental Management, City/County of Peterborough.
- Shilo Landfill Site Impact Study, Cramahe Township, ON (2007): Site inspection and environmental impact study with public presentation of findings and evaluation of groundwater remediation alternatives. Client: Township of Cramahe.
- Landfill Site 9, Oro-Medonte Township, ON (2001): Annual monitoring and hydrogeological impact assessments of landfill contaminants. Client: County of Simcoe.

Mining (non-aggregate)

- Broken Hammer Mine Wall Stability, Sudbury ON (2015): Geotechnical review of open pit gold mine wall stability and rock fall hazards. Client: Wallbridge.
- Deloro Mine Site Clean-up, Marmora, ON (2012): Geotechnical evaluations of sediment excavations and dewatering using Geotube technology, evaluation of containment cell stability, and construction sequencing design. Client: Ontario Ministry of the Environment.
- Waste Rock Dump Stabilization, Matheson, ON (2012-2013): Geotechnical evaluations of static liquefaction, and stabilization concept for 100 m high waste rock storage piles. Client: Brigus Gold.
- Victoria Gold Mine, Timmins East, ON (2011): Evaluation of pit wall stability, and recommendations for remediation to facilitate mine expansion. Client: Victoria Gold.
- Mine Shaft Evaluation, Timmins, ON (2011): Geotechnical investigation and design options report for proposed mine access shaft in soft clayey overburden. Client: SGX Resources.
- Open Pit Stability, Access Road Design and C of A for Mine Drainage, Timmins, ON (2010): Stability assessment of open pit faces, assessment and design of access road crossing tailings area, Input to C of A for mine drainage. Client: Buffalo Ankerite.
- Hart Mine Crown Pillar, Timmins, ON (2010): Geotechnical assessment of crown pillar stability per MNR Guidelines. Client: Liberty Mines.
- Rio Tinto Talc Mine, West Timmins, ON (2010): Semi-annual inspection and stability report for solid waste storage facilities. Client: Rio Tinto Minerals.
- Sherridon Mine, Camp Lake, MB (2009): Evaluation and geotechnical design of cofferdams to create a new tailings storage facility, including construction oversight. Client: Hazco.

Dams and Hydropower

- Bala Falls Small Hydropower Project (2018-2019): Geotechnical design report, dewatering analysis, rock consolidation inspections, construction dewatering, foundation inspections. Client: Horizon Legacy.
- Talbot Canal Dam, Kirkfield ON (2016-2017): Geotechnical investigations and stability analysis for sheet pile reinforced earth embankment dam on Trent Canal. Client: Parks Canada.
- Ranney Falls Generating Station, Campbellford ON (2014-2015): Geotechnical site evaluations and preparation of GBRs for tendering and environmental permitting, groundwater sampling and water quality review for construction dewatering, design review. Client: Ontario Power Generation.
- Coniston Generating Station, Calabogie ON (2015-2016): Geotechnical investigations including borehole and packer testing program, geotechnical baseline report and concrete coring studies. Also obtained environmental work permits. Client: Ontario Power Generation Inc.
- Calabogie Generating Station, Calabogie ON (2015-2016): Geotechnical investigations including borehole and packer testing program, geotechnical baseline report and concrete coring studies. Also obtained environmental work permits. Client: Ontario Power Generation Inc.
- London Street Generating Station, Peterborough ON (2013-2014): Geotechnical and environmental site assessments for design of new powerhouse and headrace and tailrace channels, foundation design review. Client: Peterborough Utilities Inc.

- Arnold Dam Repair, Caledon ON (2014): Geotechnical investigation, seepage and stability analysis for dam safety repairs. Client: Crozier Associates.
- Stanley Adamson Generating Station, Peterborough ON (2013): Geotechnical and hydrogeological investigations and design report for power house expansion and dam upgrades, construction inspections and testing including grouting procedures. Client: Trent University/Maple Reinders.
- Camp Lake Tailings Dam, Camp Lake MB (2013): Geotechnical stability assessments and design of ~1km long rock fill dam installed over soft lake bottom. Dilatometer data analysis of settlement effects. Client: Kiewit.
- Owen Sound Harbour Fender Replacement and Structure 1 & 1A Rehabilitation, Owen Sound, ON (2012): Replacement of deteriorated fenders on Structures 7, 9, 10, 13, 14, 15, 16, 17 & 18 with Ekki/Greenheart timber fenders or horizontal steel fenders. Reconstruction of Structure 1 & 1a Harbour Wall structure, including geotechnical investigations and concept structural design options. Detailed design and construction is anticipated for 2013. Client PWGSC.
- Gull River Bundle Dam Safety Review, Haliburton, ON (2011-2012): Part of inspection team and reporting team for dam safety review of four dams in the Haliburton sector of the Trent Severn Waterway. The project involves both structural and hydraulic analyses, as well as public safety and flow tests. The structures under review include Kennisis Lake Dam, Kushog Dam, Horseshoe Lake Dam and Coboconk Dam. Client: PWSGC/Parks Canada.
- Wabagishik Generating Station, Sudbury, ON (2011): Geotechnical evaluation of foundation and bedrock stability for dam and generating station upgrades. Client: Vale Canada Inc.
- Dam Safety Inspection at Black Fox Mill Site, Matheson, ON (2011-2012): Annual inspections and report for tailings dams and polishing pond dyke. Client: Brigus Gold.
- Poonamalie Dam DSR, Smiths Falls, ON (2010): Geotechnical inspections and stability assessments for dam safety review according to Parks Canada Directive and CDA Guidelines. Client: Parks Canada.
- Nairn Generating Station, Sudbury, ON (2010): Geotechnical evaluation of foundation and bedrock stability for dam and generating station upgrades. Client: Vale Canada Inc.
- Tailings Dam Assessments, Nephton, ON (2004): Dam stability inspection and geotechnical materials testing and slope stability assessments for tailings pond reconstruction. Client: Unimin Canada Limited.
- Trent Rapids Power Generation Project, Peterborough, ON (2008): Materials testing services for hydro-electric plant on Otonabee River. Client: CRT Construction.

Hydrogeology

Dewatering

- Elice Street Water Plant, Fenelon Falls ON (2015): Permit to Take Water for construction dewatering, 10 m deep excavation. Client: City of Kawartha Lakes.
- East Rail Maintenance Facility, Whitby ON (2015): Evaluation of dewatering system performance and discharge options, water quality analysis. Client: Bird Kiewit JV.
- Lakeland Crescent PTTW and Infiltration Assessment, Richmond Hill ON (2015): Assessment of construction dewatering (well point) requirements, PTTW application (Category 3), infiltration assessment and subdrainage design for storm water and high water table management. Client: Town of Richmond Hill.

- Bath Road Pumping Station, Kingston, ON (2011): Hydrogeological investigation for dewatering and Permit to Take Water, stability assessment of railway corridor adjacent to excavation. Client: Utilities Kingston.

  Long Point Provincial Park, Rowan, ON (2011): Hydrogeological investigation and assessment for Category 3 Permit to Take Water for installation of large sewage holding tanks in sandy soils located below the groundwater table. A Permit for 1ML/day was approved for a perimeter well point dewatering system. Client: Ontario Parks.
- CCIW Wastewater Forcemain Replacement, Burlington, ON (2010): Geotechnical, hydrogeological and environmental assessments for new force main design, including dewatering and MTO encroachment permits and geotechnical design of tunnelling under MTO ROW, adjacent to Burlington Skyway Bridge. Client: Public Works and Government Services Canada.
- Haig Road Watermain Extension, Belleville, ON (2010): Geotechnical evaluation for watermain extension, including bedrock tunnel below CNR corridor and dewatering requirements for launch/receiving pits. Client: City of Belleville.
- PTTW Application JCB SPS, Kingston, ON (2010): Hydrogeological investigation for dewatering of sanitary sewer pumping station excavation to 10 m depth in varved silty clay and clayey silt deposits. Applications for Permit to Take Water, including options for handling contaminated groundwater. Client: Kingston Utilities.
- Courtice TSS for Class EA, Courtice, ON (2009): Hydrogeological investigations to evaluate dewatering requirements for trunk sewer alignments, including public meetings. Client: Regional Municipality of Durham.
- Gardiner Crescent, Richmond Hill, ON (2009): Evaluation of dewatering requirements and control of long term seepage, infrastructure improvements. Client: Town of Richmond Hill.
- Glen Darling Road Servicing, Toronto, ON (2008): Hydrogeological impact assessment and Technical Study for Category 3 Permit to Take Water for construction dewatering. Client: LVL-JEGEL and City of Toronto.
- St. Clair Avenue West, Toronto, ON (2008): Hydrogeological impact assessment and Technical Study for Category 3 Permit to Take Water for construction dewatering. Client: LVL-JEGEL and City of Toronto.
- Lakeside Subdivision Development, Odessa, ON (2006): Assessment of drainage problems in karstic limestone and mitigation of heavy flows into residential basements and service trenches. Client: Loyalist Township.
- Glen Acres Servicing and Dewatering, Uxbridge, ON (2005): Hydrogeological assessment for construction dewatering and depressurization, to facilitate installation of deep services. Client: Regional Municipality of Durham.

Site Servicing

- Campbell Farms Flooding Claim, Beckwith, ON (2021): Hydrogeological review of tributary flooding due to adjacent land development. Client: John Campbell
- Bloomington Subdivision (2019): Geotechnical and Hydrogeological analysis and design report, storm water management pond design and construction considerations, responses to TRCA commentaries. Client: 2382215 Ontario Ltd.
- Highway 7 and Highway 35 Hydrogeological Capacity Study, Lindsay, ON (2011): Geotechnical and hydrogeological assessments for severance and convenience center development, including water supply and sewage system evaluations. Client: R. and W. Gupta.

- Woodland Hills Development, Bethany, ON (2004-ongoing): Geotechnical design report for residential foundations and services, construction inspections and design consultations for drainage and engineered fills. Client: Woodland Hills Development Inc.
- Terra Rock Water Supply Expansion, New Tecumseth, ON (2011): Hydrogeological evaluations for commercial water supply development, including pumping test analysis. Client: Terra Rock Holdings.
- Hughes Development Site, Buckhorn, ON (2011): Rural servicing study, including well installation and testing program, and soil investigations for private sewage systems in this residential development. Client: Jodi Hughes.
- Four Winds Estates Development, Janetville, ON (2008-2017): Hydrogeological studies and well certification program for Phases I and II, including long term nitrate impact monitoring. Ontario Municipal Board hearing (prepared evidence), well testing program for building permits. Client: Four Winds Estates/Schickendanz Homes.
- Terra Rock Concrete Manufacturing Plant, New Tecumseth, ON (2008-2011): Hydrogeological investigations of water supply and groundwater interference, including attendance of public meetings and community groups to discuss site development alternatives. Client: Terra Rock Holdings.
- Subsurface Sewage Disposal, Timmins, ON (2010): Hydrogeological investigation for commercial sewage system design and permitting. Client: Hobo Camp.
- Havelock Family Drive-in Development, Havelock, ON (2009): Evaluation of water supply for development approval. Client: EcoVue Consulting Services Ltd.
- Adult Lifestyle Community, Apsley ON (2009): Hydrogeological investigation for water supply and sewage system. Client: Township of North Kawartha.
- Grafton Heights Subdivision, Alnwick-Haldimand Township, ON (2009): Geotechnical and hydrogeological assessments for residential townhouse development. Client: Richard Schumacher.
- Ardoch Lake Subdivision, Township of North Frontenac, ON (2008-2011): Hydrogeological evaluations for rural servicing study and draft plan approval, including borehole investigations and well testing program. Client: Colin Scott.
- Challenger Golf Course, Woodview, ON (2008): Pumping tests to evaluate proposed golf course irrigation supply, include impacts to local wetlands. Client: Eric Challenger.
- St. Martins Catholic School Sewage System Expansion, Ennismore, ON (2008): Groundwater Reasonable Use Evaluation and nitrate impact assessment for expansion of a large in ground sewage system; annual monitoring program. Client: PVNC Catholic School Board.
- Dunford Residential Subdivision, Stewart Hall, ON (2007): Hydrogeological investigation for approval of communal well supply and individual sewage systems, including evaluations of potential interference with existing municipal water supply. Client: Allen Dunford.
- Wutai Shan Buddhist Temple, Bethany, ON (2007): Hydrogeological impact assessments for sewage system design and water supply testing. Client: EcoVue Consulting Services Ltd.
- Golden Beach Trailer Park Expansion, Roseneath ON (2007): Hydrogeological studies for Permit to Take Water and expansion of onsite sewage systems. Client: Golden Beach Resort.

- Woodville WTP, City of Kawartha Lakes, ON (2007): Water supply evaluations for municipal system. Client: KMK Consultants Limited.
- Chemong Public School Sewage System and Water Supply, Bridgenorth ON (2006): Hydrogeological assessments for site rezoning, including evaluation of water supply and evaluation of large inground sewage system. Client: Township of Smith Ennismore Lakefield.
- Stewart Homes Development, Peterborough, ON (2006): Hydrogeological study for approval of youth nursing home, including water supply evaluations. Client: EcoVue Consulting Services Ltd.
- Hardy Island Subdivision, Campbellford, ON (2005): Rural servicing study for sensitive island development. Client: DeFreitas Engineering.
- Islandview Drive Subdivision, Ennismore, ON (2005): Well and soil testing program for County approval of rural development. Client: Neil Hayward
- Jack Lake Development, Apsley, ON (2005): Rural servicing study for condominium development, and well certification program. Client: Tom Robinson Associates.
- Black Diamond Golf Course, City of Kawartha Lakes, ON (2004): Hydrogeological assessments of irrigation water supply for Permit to Take Water and evaluation of sewage disposal system for MOE approval. Client: Black Diamond Golf Club Inc.

Environmental Site Assessment, Audit and Remediation

- Sir Sandford Fleming College, Peterborough (2014-2015): Assessment and remediation of VOC tank leakage below McRae Campus building, monitoring of clean up, sampling and reporting for RSC input. Client: Sir Sandford Fleming College.
- Blyth Ultramar, Blyth ON (2015): Environmental investigations, contaminated soil and groundwater sampling and removal, site remediation including backfill operations. Client: Sunray Group.
- Proposed McDonald’s Site Remediation, Brighton ON (2013): Environmental sampling and investigations, contaminated soil and water removal, site remediation including backfill operations. Client: Sunray Group.
- Residential Housing Units, CFB Kingston, ON (2009): Supervision of 3R demolition and contaminated soil sampling, excavation of contaminated soil and backfilling of removed oil tank excavations. CME (federal) standards approach. Client: Defense Construction Canada.
- Oil Tank Spill, Carrying Placer Receiver, Carrying Place, ON (2008): Phase II investigation of oil spill, including soil and groundwater testing. Client: Defense Construction Canada.
- Phase II ESA of former St. Josephs Hospital Site, Peterborough, ON (2008): Phase I and Phase II ESA of potential redevelopment property. Client: Americorp Enterprises.
- 4 Aces Auto Center Phase II ESA, Peterborough, ON (2008): Phase II ESA. Client: 4 Aces Auto Center.
- St. Thomas and Ingersoll Comfort Inn & Suites Phase I ESA, Oxford County, ON (2008): Phase I ESA’s for hotel sites. Client: Eastons Group.
- CFB Borden Paint Shop Phase II ESA, Barrie, ON (2007): Borehole investigation of paint shop area and soil and groundwater testing for related contaminants. Client: Defense Construction Canada.
- FisherCast Global Plant, Environmental Compliance Audit, Peterborough, ON

- (2007): Environmental Compliance Audit for financial lending institution. Client: Business Development Bank.
- 965-981 Chemong Road Property Phase II ESAs, Peterborough, ON (2007): Phase II ESAs of development sites. Client: Millennium Acquisitions.
- Vision Glass Commercial Property, ESA and Remediation, Peterborough, ON (2007): Borehole and test pit sampling investigations, reporting, and supervision of soil remediation. Client: Vision Glass Ltd.
- 1031 Highway 7E ESA and Remediation, Peterborough, ON (2007): Phase II ESA and Phase III site remediation to remove contaminated soil, monitoring of pump and treat system. Client: Peterborough Natural Gas Vehicle Center.
- Northeast Industrial Park ESA, Belleville, ON (2007): Phase I and II ESA's of proposed industrial development site including soil and groundwater sampling. Client: Development Services Department.
- Trent Severn Waterway Property ESA, Peterborough, ON (2006): Phase II ESA of waterway property. Client: Trent Severn Waterway.
- Peterborough Golf and Country Club DSS, Peterborough, ON (2006): Designated substances survey of clubhouse to be demolished and rebuilt. Client: Peterborough Golf Club.
- Cambro Lasertek Fabrication Plant ESA and Audit, Campbellford, ON (2006): Phase I ESA and Environmental Audit report for refinancing. Client: Cambro Lasertek.
- Trent Severn Reserve Lands ESA, Trenton, ON (2005): Phase II ESA including soil and groundwater sampling and geophysical surveys of buried debris, evaluation of site rehabilitation options. Client: Parks Canada.
- Baseline Road Apartments ESA and Fuel Tank Removal, Ottawa, ON (2005): Environmental evaluations of fuel tank area, including drilling investigations and soil and groundwater sampling. Client: ATC Associates Inc.
- Brooksy's Stop & Go Automotive Phase II ESA, Peterborough, ON (2005): Phase II ESA of petroleum hydrocarbon impacts. Client: Todd Brooks.
- Fife's Bay Marina ESA and Remediation, Peterborough, ON (2004): Phase I and II ESA of marina property with underground tanks and equipment repair shop. Client: Fife's Bay Marina.
- ESAs of 13 MTO Patrol Yards, Eastern Region, ON (2004): Groundwater sampling investigations and reporting. Client: Ministry of Transportation.
- Eldon Road Commercial Property Phase II ESA, Little Britain, ON (2004): Phase I and II ESAs. Client: Kawartha Community Futures.

Aggregates

- Technical Advisory Report Task 122 (2018): Technical review of aggregates recycling program and cost-benefit analysis, GTA properties. Client: Metrolinx
- Rockridge Quarry, Harvey Township, ON (2016-2021): Hydrogeological assessments and bedrock physical properties testing for quarry licensing and detailed design. Client: Stonescape Ontario Limited.
- Havelock Quarry, Norwood ON (2016-2021): Hydrogeological assessments for proposed quarry expansions encroaching on Provincially Significant Wetland area, including packer test studies and mitigation approaches. Client: Drain Bros. Excavating
- Dewdney Mountain Farms, Harvey Township, ON (2011-2014): Hydrogeological

- assessment for MNR licensing of proposed quarry, including public meetings, expert testimony given at OMB. Client: Paul Ritchie.
- Stonescape I and II Quarries, Harvey Township, ON (2005-ongoing): Hydrogeological assessments and bedrock physical properties testing for quarry approval and design, including drainage evaluation to capture water for aggregate processing, annual monitoring reports. Client: Stonescape Ontario Limited.
- Omemee Pit PTTW and Impact Assessments and Monitoring, Omemee, ON (2003-ongoing): Studies for Permit to Take Water for aggregate processing, and Permit to Discharge process water into onsite recirculation pond. Ongoing annual monitoring of site. Client: Robert Young Construction Ltd.
- Telephone Road Gravel Pit Expansion, Colborne, ON (2008): Evaluation of the groundwater table for licensing of pit expansion. Client: 2084059 Ontario Ltd.
- Sevell Pit Licensing Studies, Peterborough County, ON (2008): Hydrogeological assessment for design of above water pit and licensing study. Client: Drain Bros. Excavating Ltd.
- Kawartha Rock Quarry Assessments, Harvey Township, ON (2008): Evaluation of bedrock resource potential and site development constraints. Client: Kawartha Rock Quarry.
- Rigbe's Quarry Assessments, Harvey Township, ON (2007): Borehole drilling to evaluate bedrock quality and groundwater conditions as input to quarry development. Client: M. Tomlinson.
- Craig Quarry PTTW and Expansion, Belleville, ON (2007): Groundwater pumping tests to evaluate bedrock hydraulic conductivity as input to licensing and a Permit To Take Water application for the site. Work including preparation of a groundwater numerical model (MODFLOW). Client: MHBC Kingston.
- Haliburton Aggregates Pit, Haliburton, ON (2007): Aggregate resources assessment. Client: Oxnard Developments Inc.
- Norwood Pit Expansion, Peterborough County, ON (2006): Hydrogeological assessment for pit expansion lands. Client: Drain Bros. Excavating Ltd.
- Mount Pleasant Pit Expansion, Mount Pleasant, ON (2005): Hydrogeological investigation of the groundwater table and evaluation of potential impacts to local surface water tributaries. Work included a Becker drilling program to obtain aggregate samples for quality testing. Client: Drain Bros. Excavating Ltd.
- Pluard Quarry Licensing and Monitoring Studies, Harvey Township, ON (2004-present): Evaluation of the groundwater table for quarry design and quarry runoff and drainage characteristics. Long term groundwater and surface water monitoring conducted as a condition of the license. Client: Drain Bros. Excavating Ltd.
- Manvers Pit Resource Assessment, Manvers Township, ON (2004): Becker drilling investigation and evaluation of aggregate resources. Client: CDR Young Aggregates.
- Whitton Gravel Pit Assessment, City of Kawartha Lakes (2003): Test pit investigation to evaluate sand and gravel resources above the groundwater table. Client: Woellmann Development Services.
- Aggregate Resources Inventory, Lake Superior North Shore, ON (2001): Evaluation of bedrock resources around the entire north shore, within 5 km of shoreline, and preparation of Open File Report. Client: Ministry of Northern Development and Mines.
- Aggregate Resources Inventory, Highway 11 North, Various Locations, ON (2000):

- Evaluation of aggregate and bedrock resources for MTO source list. Client: Ministry of Transportation.

PUBLICATIONS AND PRESENTATIONS

Publications

- Jagger, D.E. and J.S. Ash. Geotechnical Considerations at Landfill Sites, presented at 55th Canadian Geotechnical Conference, October 2002, Niagara Falls, Ontario.

Presentations

- Ash, J.S. “Geotechnical Practice for Special Site Conditions in Ontario.” Ontario Building Officials Association, Kingston, ON. October 2008.

PETER HAYES, B.Sc., P.Geo., P.Geol.

Senior Geoscientist / Environmental Specialist

Areas of practice

Environmental Monitoring

Environmental Management & Inspection

Groundwater Resources

Pit and quarry hydrogeologic studies and permitting

Source Water Protection Evaluations

Environmental Impact Assessments

Permitting

Contaminated Sites Monitoring

Contaminated Sites Remediation

Geomorphology assessments & monitoring

Watercourse crossing design

Creek stabilization design

PROFILE

Peter Hayes has over 35 years of experience as an environmental consultant, specifically in environmental monitoring, management, and inspection; groundwater resources;Pit and Quarry permitting ,source water protection evaluations; fluvial geomorphology land development and construction dewatering; environmental impact assessments; permitting; and contaminated sites monitoring and remediation. As part of regional land development servicing and infrastructure projects, Mr. Hayes provided regional aquifer assessments and evaluation expertise, individual claims investigations, and conflict dispute resolutions involving the general public, intervener groups, and agencies. This work has included procurement of Ontario Ministry of the Environment Permits-To-Take-Water (PTTW) for construction dewatering, construction period environmental monitoring, and mitigation as relates to private groundwater supplies, erosion and sediment control, and protection of terrestrial and aquatic environments.

EDUCATION

Bachelor of Science, Applied Earth Sciences with Geography Minor, University of Waterloo, ON	1985

PROFESSIONAL DEVELOPMENT

MOE Short Course Cleanup of Contaminated Sites Guidelines, Best Practices and Pitfalls to Avoid and regulatory updates	2010 2000
Applications of Geophysics in Environmental and Engineering Investigations Short Course	1996
OSHA 29 CFR 1910.120, 40 Hour Health and Safety Training and subsequent eight-hour annual refresher courses	1994
Principles of Groundwater, Association of Groundwater Scientists and Engineers	1989
Oil Spill Containment and Recovery, Petroleum Industry Training Service	1985

PROFESSIONAL ASSOCIATIONS

Association of Professional Geoscientists of Ontario	APGO
Association of Professional Engineers and Geoscientists of Alberta	APEGA
Engineers and Geoscientists British Columbia	EGBC
Engineers and Geoscientists of Manitoba	EGM

CAREER

Senior Project Manager, Senior Geoscientist / Environmental Specialist, WSP	2016 – Present
Senior Project Manager, Senior Hydrogeologist / Environmental Specialist, MMM Group Limited, Kitchener, ON (WSP Acquisition),	2005 – 2016

Hydrogeologist and Associate, Conestoga Rovers and Associates, Waterloo, ON	1986 – 2005
Project Geologist / Principal, Canadian Environmental Services Limited, Calgary, AB	1985 – 1986

PROFESSIONAL EXPERIENCE

Management Systems

Mr. Hayes is competent with respect to the practice and implementation requirements for ISO 9000, ISO 14000, quality and environmental management systems, as well as corporate Environmental Health and Safety Procedures. He is also knowledgeable in the environmental, economic, and social requirements for Sustainability Management Systems.

Environmental Management

Geomorphology, Erosion and Sedimentation Control Plans and Inspection

- Lead author, in collaboration with our firm and MTO highway design staff, of two Approach 3 type submittals for both the Highway 7 and 407 expansion / extension in the Municipality of Durham. Both of these high-profile projects are being completed in environmentally sensitive cold-water fisheries areas. These plans were extensively reviewed and accepted by both the MOE as part of the PTTW Process and the MNR Species at Risk (SAR) permitting process. We received very favourable comments from these agencies and it greatly fast-tracked the approval and permitting for these two projects.
- Leads a team of Certified Inspector of Sediment and Erosion Control (CISEC) professionals. Over the last seven years this team has successfully provided bridge, road, and highway field inspections for these projects.
- Leads Fluvial Geomorphology staff in creek construction supervision, watercourse crossing design and baseline geomorphic assessments. Example projects include:
  - Bronte Street Bridge Replacement, Town of Milton, Milton, ON, Canada (Ongoing): Supervising detailed design of channel works associated with a bridge replacement on Bronte Street.
  - Highway 401 at the Grand River, MTO, Kitchener, ON, Canada (ongoing): Supervising the preliminary and detailed design of habitat compensation works including overwintering pools for SAR.
  - Sixteen Mile Creek bank stabilization, Town of Oakville, Oakville, ON, Canada (Ongoing): Overseeing bank stabilization study and design of remedial stabilization works near the Rebecca Street Bridge crossing of Sixteen Mile Creek.
  - Argyle Street Bridge Replacement, Ministry of Transportation (MTO), Caledonia, ON, Canada (Ongoing): Supervising detailed design of riverbank restoration sites, as part of DFO habitat compensation works for replacement bridge over the Grand River in Caledonia, ON.
  - Tremaine Road Reconstruction, No. 3 Sideroad to Steeles Avenue, Halton Region, Milton, ON, Canada (Ongoing). Supervised the geomorphic inspection of two structural culverts and one new crossing of Sixteen Mile Creek as part of the new road construction. Challenging aspects of this project included working with steep escarpment sites, former brickworks excavation areas, wetlands and

beaver dam issues. Mr. Hayes also supervised the groundwater monitoring and Erosion and Sediment Control components of this large and complex project.

- Queen Street Reconstruction, Peel Region, Brampton, ON, Canada (ongoing). Supervising the geomorphic inspection for the construction of five watercourse crossings and realignments. Channel works are part of Redside dace habitat compensation works, requiring attention to detail and liaison with agencies.
- Gordonville Bridge Replacement, Wellington County, Gordonville, ON, Canada (2018). Supervised the detailed design and construction of channel restoration works at a rural bridge replacement, including input to bridge sizing, location, and channel details.
- Spring Creek scour protection, Wellington County, Minto, ON, Canada (2018). Construction of emergency scour protection works at an existing rural bridge.
- Bayview Avenue Widening Detailed Design, York Region, ON, Canada (2017): Led long-term downstream creek erosion monitoring program during- and post-construction of channel realignment on an ecologically sensitive Tributary to the Rouge River.
- Highway 404 environmental assessment (2017): Supervised the baseline geomorphology assessment, meander belt assessment and input to preliminary design options for a new crossing of the Rouge River near Elgin Mills Road and Highway 404, Richmond Hill. The site involved evaluating effects of past channel modifications and liaising with fisheries biologists to meet stringent Species at Risk regulations for this crossing of this sensitive cold-water watercourse.

Ground Water Resource Evaluation and Development

Mr. Hayes has been involved in a number of groundwater resource evaluation and development projects for aggregate industries, municipalities, and subdivision developments throughout Canada. This work has included extensive liaison with regulators, regional water resource evaluations, groundwater protection, GUDI assessments, and wellhead capture zone analyses. Duties included aquifer and flow system delineation, water quality evaluation, design of test drilling programs, aquifer testing, and production well design. The following is a selection of projects for which Mr. Hayes has contributed.

- Category 3 permitting for ground water and surface water takings as part of MTO Highway and municipal construction projects throughout Ontario in varied overburden and bedrock settings including Regional Aquifer Evaluation, York Region Infrastructure Projects on the flanks of the Oak Ridges Moraine, Have undertaken water resource evaluation and impact assessment in support of several large infrastructure (trunk sewer) construction overburden and bedrock dewatering projects in York Region (16th Ave , **2nd Concession**, 9th Line, **Upper Centennial Parkway)**, involving large volumes, one project on the order of 15,000 L/min over a four-year period.
- Strategic development of long-term **uplift controls for the Major Mackenzie** grade separation in Richmond Hill Ontario.

- Municipal groundwater supply resource evaluation and utilization in Hanover, Lakeside, Dorchester, Linwood, King City, and Innerkip, ON.
- Investigation of the feasibility of recreational sulphur spring utilization in Preston, ON.
- Detailed design of remedial extraction well networks.
- Construction dewatering ecological and hydrogeological assessments to secure water taking permitting in support of subdivision, bridge, sewer and roadway construction work in varied bedrock and overburden environments throughout Ontario.
- Category 3 permitting for ground water and surface water takings as part of the Highway 401 widening construction projects, City of Kingston, Kingston, ON.
- Regional Aquifer Evaluation, York Region Infrastructure Projects on the flanks of the Oak Ridges Moraine, York Region, ON: Have undertaken water resource evaluation and impact assessment in support of several large infrastructure (trunk sewer) construction dewatering projects in York Region involving large volumes, one project on the order of 15,000 L/min over a four-year period.
- Regional aquifer assessment and evaluation, individual claims investigation, and conflict dispute resolution involving the general public, intervener groups, and agencies. This work has involved the compilation and assessment of all hydrogeological information within the Rouge River watershed including the geology, hydrogeology, water takings, and MOE water well record database information.
- **Hydrogeological consultant for numerous quarry operations throughout Ontario. These projects included the securement of permitting for the expansion of existing and development of greenfield quarry sites.; along with the successful closure and redevelopment of spent quarry sites.**
- **Past clients included, Lafarge (Woodstock) , Carmeuse (Beachville and Guelph) , St Marys Cement, Federal White Cement , Milton Limestone and Canada Brick.**
- Project Manager, Region of Waterloo Groundwater Level Monitoring Program, Region of Waterloo, ON: The Groundwater Level Monitoring Program included water level monitoring and capture zone assessment for the 127 supply wells and 110 observation wells on a monthly basis and reporting and assessment on an annual basis. The monitoring included the recording of both manually and electronically collected data.
- Reporting and assessments relating to zone of capture, well interference issues and compliance with conditions on Permits To Take Water.
- Hydrometric and meteorological monitoring and analysis of a small river basin in support of the hydrological characterization for radioactive waste disposal research conducted at sites near Atikokan, ON.
- **Highway 400 Bridge Reconstruction and Rehabilitation**, Port Severn, Ontario, MTO (2013-2016): conducted a detailed hydrogeological assessment in the vicinity of Highway 400 and four highway bridges over the Severn River and Severn Boat Channel, in Port Severn, Ontario, in advance of reconstruction of two Highway 400 Northbound Lanes bridges, and rehabilitation of two Highway 400 Southbound Lanes bridges, and procured a Permit-to-Take-Water from the Ontario Ministry of

the Environment and Climate Change for construction dewatering as required for this work. The hydrogeological assessment included inventory of nearby surface water users and groundwater users, private water well surveys, surface and ground water sampling and characterization, in an area where both groundwater and Severn River water is used as a source of drinking water.

Expert Witness / Peer Review

— Expert Witness Manitoba Red River Floodway Expansion, Manitoba Floodway Authority, Manitoba (2004-2005): Mr. Hayes has undertaken a peer review of this regional watershed project and provided expert testimony in regard to the incremental environmental impacts associated with this $600M project. Key watershed effects include incremental downstream flooding, groundwater under the direct influence of surface water (GUDI) effects during floodway operation, especially as it relates to the potential of pathogen migration to nearby municipal supplies. Key requirements include the need to implement both a watershed well head protection and water quality security surveillance and proactive mitigation plan. A key aspect of this project was the public consultation and integration of the concerns of multi-stakeholder groups.

— Expert Witness and Professional Advice for Ontario Municipal Board (OMB) Hearings, Operational Permit Procurement, and Ongoing Environmental Compliance Monitoring, Orica Canada Inc., Grand Valley, ON (2008-ongoing): Included regional groundwater resource investigations, detailed Site-specific soil, surface water and groundwater investigations, with emphasis on both quantity and quality, all as necessary to support an application for a operational permit and permanent zoning approval for an industrial bulk storage facility in West-Central Ontario. As part of the approval process, Mr. Hayes and members of the project team provided expert witness services for an OMB hearing, which included a public consultation. In addition, a detailed environmental Site assessment, spills response plan, and risk management plan was prepared for Orica, recommending measures to be implemented to safeguard surrounding natural environments, including provincially significant wetland areas, and groundwater users. An ongoing groundwater and surface water compliance monitoring program is being conducted at the facility.

— Expert OMB witness in regards to the former Steetley quarry reuse and Federal White Cement Quarry Expansion

— Expert OMB witness in regards to Land development within a sensitive karst limestone bedrock setting adjacent to a brown trout fishery

— Small Landfills Environmental Performance Review, Ontario Ministry of Natural Resources: Mr. Hayes and other members of this project team conducted operational and environmental performance reviews of a total of 199 small waste disposal sites operated by the Ministry of Natural Resources throughout northern and central Ontario utilizing Site characterization and environmental performance reports provided by the MNR. Our team developed a risk assessment checklist screening tool to clearly and rapidly identify priority sites where further action was necessary to ensure Site environmental compliance, and recommend appropriate Site monitoring programs and follow-up actions for all sites, in accordance to applicable legislation.

Landfill Approvals, Investigations, and Performance Monitoring

Mr. Hayes has been a key individual in the implementation and subsequent representation of EPA Level investigations over the last 35 years in support of locating a new landfill or expansion of an existing site. These investigations required extensive public and regulatory liaison. When required, Mr. Hayes has provided expert testimony with respect to his opinion on the suitability of the proposed undertakings.

- Project Manager / Hydrogeologist responsible for the coordination of long-term monitoring programs and subsequent reporting and representation at over 30 industrial and municipal landfill sites throughout Ontario.
- Provided expert hydrogeologic testimony with respect to the Consolidated Hearing (EA and EPA) application by Steetley Quarries Ltd. for the proposed utilization of the South Quarry for landfilling purposes.
- Conducted and represented the results of EA and EPA Level hydrogeologic investigations and boundary impact assessments in order to define potential areas for the location or expansion of a landfill site in Sudbury, Massey, Tavistock, Northumberland County, St. Marys, Brantford, Wellington County, Sarnia, Parry Sound, Petrolia, Region of Waterloo, Kearney / Perry Township, and McMurich Township in Ontario as well as Red Deer, Alberta, and Victoria, British Columbia.
- Geologic and hydrogeologic assessment and construction inspection during the installation of a leachate collection system in the Region of Waterloo Erb Street Landfill.
- Geological and hydrogeological assessment of an abandoned landfill site in Wauconda, Illinois.
- Investigation and evaluation of the suitable disposal or recycling of industrial wastes.
- Investigation and remediation of leaking underground gasoline and crude oil storage tanks in the Towns of High Level and Hanna, Alberta and the Towns of Perth and Petrolia, Six Nations on the Grand ,and Oakville Ontario.

Site Investigations and Remedial / Feasibility Studies

Mr. Hayes has been responsible for the execution of numerous Phase II Site Investigations and Remedial / Feasibility Studies in Canada. The duties included the scoping of the activities, design of hydrogeologic investigations, interpretation of hydrogeologic and chemistry data, determination of contaminant fate and transport, evaluation of risk, the design and evaluation of remedial alternatives, and the design / interpretation of monitoring programs. These studies also included extensive liaison with public and government regulators.

Primary contaminants of concern in groundwater and surface water included dioxins and furans, nitrate , road salt, petroleum hydrocarbons, spike, creosote, BTEX, PCBs, pentachlorophenol, acetone, TCE, 1-DCE, vinyl chloride, coal tar, and heavy metals (copper ,arsenic, lead, chromium, iron, manganese ,cadmium, and zinc).

- Supervision of various soils, percussion, and diamond drill rigs throughout Ontario, Manitoba, and Alberta.
- Construction, installation and sampling of piezometers at various locations and in varied overburden and bedrock environments.

Mineral and Oil and Gas Exploration

- Mineral exploration, which included prospecting, grid construction, radon testing of soils, regional geochemical sampling and evaluation, V.L.F., scintilometer and proton magnetometer surveys in ,Saskatchewan, Manitoba and the Northwest Territories

- Developed the conceptual model for the determination of paleo fluvial stratigraphic controls on hydrocarbon occurrence, within the deep Sunburst Sandstone, Manyberries Alberta

JAVEED KHAN, M.Eng., P.Eng., PMP

Senior Project Manager, Water Resources

Areas of practice

Design-Build / Alternative Finance and Procurement (AFP)

Highway Drainage

Roadway Municipal Drainage

Mining / Quarries

Stormwater Management

Dams / Watershed Hydrology

Hydrologic & Hydraulic Modelling

Water Balance

Flood Management

PROFILE

Javeed Khan is a Senior Project Manager with over 30 years of experience in civil / water resources engineering. Javeed holds a Bachelor's degree in Civil Engineering and Post Graduate degree in water resources engineering. Javeed's experience includes project management, work plan preparation, design coordination, hydrologic / hydraulic modelling, water balance and flood impact analysis studies, water quality and quantity monitoring, planning and design of stormwater management (SWM) and conveyance systems, detention facilities and hydraulic structures for a wide variety of transportation corridors, industrial, commercial, residential and mining / aggregate quarries developments.

Javeed has hydrologic and hydraulic computer modelling expertise in Visual OTTHYMO, SWMHYMO, GAWSER, SWAT, EPA-SWMM, PCSWMM, HEC-RAS, HEC-HMS, CulvertMaster and FlowMaster. In addition, Javeed has experience in project management, cost estimation / budgeting and construction monitoring of civil works.

EDUCATION

M.Eng., Water Resources Engineering, University of Guelph, ON, Canada	2004
B.Sc., Civil Engineering, University of Engineering and Technology, Peshawar	1989

PROFESSIONAL DEVELOPMENT

PCSWMM, Computational Hydraulics International (CHI)	2017
Project Management, University of Toronto	2012
Urban Drainage Design Workshop, Global Innovative Campus	2011
Integrated Watershed Modelling (MIKE SHE), DHI	2011
Water Quality Data Management, Schlumberger	2006
Hydrologic and Hydraulic Analysis Using ArcGIS, ESRI	2006
ArcHydro GIS for Water Resources, ESRI	2006
HEC-RAS Modelling, BOSS International	2005
Highway Drainage, Ministry of Transportation	2004
Professional Design Engineering (Civil), Maple Leaf College of Business and Technology	2002
Construction Estimation, Humber College	2001

PROFESSIONAL ASSOCIATIONS

Professional Engineers Ontario, since 2005	PEO
Project Management Institute, USA, since 2014	PMI
Pakistan Engineering Council, since 1989	PEC

JAVEED KHAN, M.Eng., P.Eng., PMP

Senior Project Manager, Water Resources

CAREER

Senior Project Manager, Water Resources, WSP	2020 – Present
Project Manager, Water Resources, WSP	2019 – 2020
Senior Project Engineer, Water Resources, WSP	2018 – 2019
Water Resources Engineer, AECOM, Mississauga, ON, Canada	2013 – 2018
Water Resources Engineer, Golder Associates, Mississauga, ON, Canada	2008 – 2013
Project Engineer, MMM Group Limited , Toronto, ON, Canada (WSP Acquisition)	2006 – 2008
Water Resources Engineer, Golder Associates, Sudbury, ON, Canada	2004 – 2006
Civil Engineer, Water and Power Development Authority, Tarbela / Attock, Pakistan	1991 – 2001
Design Engineer, NESPAK, Lahore, Pakistan	1989 – 1991

PROFESSIONAL EXPERIENCE

Design-Build / Alternative Finance and Procurement (AFP) Projects

— Design-Build Highway 104 Sutherlands River to Antigonish Twinning Project (2020 – ongoing): Drainage Technical Lead. This project involves the detailed design of Highway 104 in Nova Scotia - a 38 km four-lane divided highway corridor spanning from the end of the existing divided highway east of New Glasgow (near Exit 27) at Sutherlands River to the existing divided highway west of Addington Forks Interchange (Exit 31) at Antigonish. Proposed works include twinning of the start and end segments of the existing highway corridor (~28 km), implementation of a new 4-lane divided highway central segment (~10 km), and installation of the associated drainage system. The proposed highway drainage system consists of 71 mainline culverts, 28 non-mainline culverts, 6 major river bridge crossings, and storm sewer systems at major interchanges. Responsible for design coordination with highway and environmental design teams, supervision and review of hydrologic and hydraulic modelling of culverts, bridges, and storm sewer systems, drainage and hydrology reports of various culvert package and major river crossings, stormwater management reports and detailed engineering design drawings. Client: Nova Scotia Department of Transportation and Infrastructure Renewal / Dexter Nova Alliance (DNA).

— Highway 7 from Guelph to Kitchener, GWP 3060-16-00, ON (2020-ongoing): Project Manager, Water Resources. Currently working on the drainage design of Grand River Bridges and associated roadways as part of the proposed New Highway 7 project. The project involves three contracts, Detailed Design for the Grand River Bridges, Detailed Design of Advance Works and Concept Design of the18 km New Highway 7 and associated ramps and crossings from Kitchener to Guelph for the design-build contract. Responsible for the hydrologic and hydraulic assessment, design of bridge deck drainage system, ditches, culvert crossings, erosion and sediment control plans and SWM facility design to provide quality and quantity control for the proposed works. Client Ministry of Transportation Ontario, Western Region

- Highway 401 West Expansion (P3 Pursuit) - Regional Road 25 to the Credit River, Mississauga / Milton, ON (2018): Drainage Lead. The project involved widening a 19 km stretch of Highway 401 from Regional Road 25 (Milton) to Credit River (Mississauga). The drainage infrastructure involved replacement of two bridges (Credit River and Sixteen Mile Creek), rehabilitation and replacement of 30 mainline culverts, over 35 ramp / entrance culverts, two new stormwater management ponds, retrofit of existing 407 ponds, design of ditches and new sewers system in the median and north and south widening lanes. Main activities include review of the PA requirements, coordinate and oversee a PA compliant drainage design including hydrologic and hydraulic assessment of watercourse crossings, stormwater management facilities and preparation of concept drawings, staging plans for cost estimation of the design-build pursuit. Client: Link 401
- Gordie Howe International Bridge (P3 Pursuit), Windsor, ON (2017-2018):* Drainage Lead. Successfully coordinated the preliminary drainage design for the three main components of the Gordie Howe International Bridge Design-Build Pursuit: (i) The Bridge consisting of a clear span of 850 m with no piers in Detroit River and one approach bridge on each side of the crossing to connect Ports of Entry in Canada and the US. (ii) The Canadian Port of Entry (53 ha), consisting of inbound / outbound inspection, toll collection and maintenance facilities. (iii) The US Port of Entry (68 ha), consisting of inbound / outbound inspection, toll collection, commercial exit control and maintenance facilities. Main activities include review of PA requirements, request clarifications, design coordination, review and oversee hydrologic and hydraulic assessment, preliminary design of stormwater management system consisting of storm sewers, bridge deck drainage system, eight detention ponds, conveyance culverts, ditches and bioswales. Client: Bridging North America (BNA)
- Finch West Light Rail Transit (LRT), Toronto, ON (2016):* Water Resources Engineer. Worked on behalf of Owner's Engineer. Conducted hydrologic and hydraulic assessment and prepared the Reference Concept Design (RCD) Stormwater Management Report for the AFP Project. Client: Metrolinx

Highway / Roadway Drainage

- County Road 22 Corridor Study, Lakeshore, ON (2019-ongoing): Drainage Lead. The project involves a transportation corridor study for County Road 22 in the Township of Lakeshore. The scope of work includes existing conditions assessment of the drainage system, field investigations, hydrologic and hydraulic assessment and preliminary drainage design. Responsible for preparation of work plans and providing overall direction and review of the drainage aspects of the project. Contact: County of Essex
- Concord GO Traffic Master Plan and Schedule "C" Environmental Assessment Road Project in the Concord GO Centre Secondary Plan Area, Vaughan, ON (2019-ongoing): Drainage Lead. This project involves an environmental assessment for the proposed extension of Ortona Court to connect Rivermede Road and Highway 7. The scope of work includes conducting a drainage and stormwater management assessment to evaluate improvement alternatives and potential impacts on the receiving stormwater system, a quantity and quality assessment, a hydrologic and hydraulic analysis of the existing conditions and proposed works and impacts assessment of the proposed works on the floodplain of the adjacent Don River. Responsible for preparation of work plans, coordination with regulatory agencies and other disciplines. Reviewing design / reports and providing overall direction for the drainage component of the project. Client: City of Vaughan

- Detail Design Services for the Rehabilitation of Highway 35 at Carnarvon and Four Bridge Rehabilitations on Highway 35, Assignment No. 5018-E-0024, GWP 5288-14-00, Carnarvon, ON (2019-ongoing): Project Manager, Water Resources. The project involves the pavement rehabilitation of Highway 35, the rehabilitation of four bridges along Highway 35, and the assessment of the existing drainage system along Highway 35. The scope of work includes field investigations, hydrologic and hydraulic analyses, detailed drainage design for culvert replacements, storm sewer assessment and design, drainage improvement works associated with public properties with existing flooding issues. Responsible for planning and directing the field investigation, reviewing the culvert inspection reports, hydrologic and hydraulic assessment of culverts and proposed mitigation measures for the areas with drainage issues. Client: Ministry of Transportation Ontario, Northeastern Region
- Large Value Retainer: Highway 40 and Churchill Road Industrial Area Drainage Assessment, Assignment No. 3017-E-0006-09, GWP N/A, Work Item 09, Sarnia, ON (2019-ongoing): Project Manager, Water Resources. The project involves the assessment of the existing drainage system in the southeast quadrant of Highway 40 and Churchill Road. Responsible for preparing the overall work plan, conducting site reconnaissance with MTO and First Nations representative, assessing the existing drainage issues and preparing conceptual plans to resolve drainage issues. Client: Ministry of Transportation Ontario, Western Region
- Woodlawn Road East – Culvert Replacement and Flooding Issues, Guelph, ON (2019-2020): Project Manager. This project involves site investigations, hydrologic and hydraulic assessment to determine flood elevations and recommend culvert replacement to avoid road overtopping for safe passage of traffic. Responsible for overall direction and coordination of the project and coordinated with other disciplines for the proposed replacement works. Client: City of Guelph
- Waterloo LRT Stage 2 from Kitchener to Cambridge, ON (2019-2020): Drainage Lead. The project involves route selection and impact assessment of an 18 km long Light Rail Transit (LRT) system from Kitchener to Cambridge. Responsible for the overall direction, managing budget / staff, overseeing and reviewing the drainage design and assessment which involves two new major bridge crossings over the Grand River and Speed River, floodplain assessment along the floodplains of the Speed River, Groff Mill Creek, Mill Creek and Grand River, assessment of 9 km long existing storm sewer system for the on-street alignment, 60 m long Galt Box Culvert (6 m x 3 m) and preparation of drainage concept for the proposed 18 km long LRT providing stormwater quantity, quality and erosion controls. Client: Region of Waterloo
- Large Value Retainer: Rehabilitation of Highway 403 from Highway 401 easterly to 0.8 km east of Bishopsgate Road, Assignment No. 3017-E-0006, GWP 3003-19-00, Work Item 05, ON (2019-2020): Water Resources Engineer. The project involves filed investigations to inspect culverts and ditches in the 24 km highway stretch and provide recommendations for culverts and ditches rehabilitation works. Responsible for preparation of work plans, direction of the field investigations and reviewing the culvert and ditch inspection reports. Client: Ministry of Transportation Ontario, Western Region
- Highway 6 Caledonia Bypass, GWP, 3076-12-00, ON (2018-2019): Drainage Lead. The project involves detailed design and environmental assessment for the reconstruction of 7.3 km Highway 6 Caledonia Bypass. Responsible for the overall direction, coordinating with other design disciplines, managing drainage budget / staff and overseeing the field investigations (culvert inspection, CCTV inspection,

soil and water sampling), hydrologic and hydraulic assessment, gravity pipe design and preparation of a drainage and hydrology report to support the detailed design. Client: Ministry of Transportation Ontario, Western Region

- Highway 401 / County Road 41 Interchange and Palace Road Interchange Improvements, GWP 4459-04-00, Napanee, ON (2016-2018):* Water Resources Engineer. Responsible for conducting field investigations to assess the existing drainage issues and proposing mitigation measures. Client: Ministry of Transportation Ontario, Eastern Region
- QEW Widening / Rehabilitation, GWP 2432-13-00, Mississauga / Toronto, ON (2016-2018):* Water Resources Engineer. Responsible for conducting site investigations, hydrologic and hydraulic assessment, preparing drainage design for the proposed QEW widening / rehabilitation works and replacement of Etobicoke Creek Bridge. Client: Ministry of Transportation Ontario, Central Region
- Highway 401 / County Road 30 Interchange Design, GWP 4018-13-01, Brighton, ON (2017):* Water Resource Engineer. Responsible for carrying out site investigations, hydrologic and hydraulic assessment, preparing detailed drainage design for interchange improvement works including culvert replacements and channel realignment. Client: Ministry of Transportation Ontario, Eastern Region
- Stouffville Road Widening Environmental Assessment, Stouffville, ON (2017):* Water Resources Engineer. Carried out site investigations, hydrologic and hydraulic assessment, prepared preliminary design for road, culvert crossings and stormwater management plan for the proposed widening of Stouffville Road. Client: Region of York
- Herb Gray Parkway Bridge B-1 Project, GWP 3028-14-00, Windsor, ON (2016):* Water Resource Engineer. Conducted hydrologic and hydraulic assessment, prepared detailed drainage design and contract package for the proposed bridge at Highway 401. Client: Ministry of Transportation Ontario, Western Region
- Highway 404 / Major Mackenzie Dive Commuter Car Pool Lot (CCL), GWP 2227-09-00, Richmond Hill, ON (2016):* Water Resources Engineer. Conducted site investigations, hydrologic and hydraulic assessments, prepared a stormwater management plan including bioretention facility and detailed design contract package for the proposed CCL. Client: Ministry of Transportation Ontario, Central Region
- Gore Road Widening EA, Brampton, ON (2016):* Water Resources Engineer. Conducted site investigations, hydrologic and hydraulic assessments, prepared preliminary design, and stormwater management plan including low impact design for the proposed road widening / complete street design. Client: Region of Peel
- Major Mackenzie Drive Widening, Vaughan, ON (2016):* Water Resources Engineer. Conducted site investigations, hydrologic and hydraulic assessments, prepared preliminary design and a stormwater management plan for the proposed road widening. Client: Region of York
- Thamesville Bridge Hydraulic Assessment, Thamesville, ON (2016):* Water Resources Engineer. Conducted hydraulic modelling for Thamesville Bridge to assess its conveyance capacity and conformance to the applicable hydraulic design criteria. Client: Municipality of Chatham-Kent
- Torbram and Rena Road Floodplain Mapping, Mississauga, ON (2014):* Water Resources Engineer. Conducted hydrologic and hydraulic assessment for Torbram

Road Grade Separation works, optimized the design of Rena Road Culvert and prepared floodplain maps. Client: City of Mississauga

— Design of Stream Crossing for Miller Park Avenue, Bradford, ON (2007): Project Engineer. Carried out hydraulic design of river crossing for Miller Park Avenue, which involved hydraulic modelling, optimized the sizing of proposed bridge and impact analysis on flood elevations. Client: Brookfield Homes

Stormwater Management / Municipal Drainage

— Stormwater Assessment and MECP ECA Application for Waterloo Landfill Operations Centre SWM Facility, Kitchener, ON (2021-ongoing): Project Manager. This project involves stormwater assessment of the Region's landfill operation site, impact assessment of the proposed future expansion of the southern landfill area on the existing stormwater management (SWM) facility, concept design of a stormwater management pond, and preparation and submission of an MECP Environmental Compliance Approval (ECA) for the site. Responsible for work plan preparation, topographic survey, preparing an existing and proposed drainage mosaic, conducting an existing and proposed hydrologic assessment, identifying quality, quantity and erosion control requirements for the site, preparing a conceptual design and stormwater management report for the proposed SWM system, compiling and submission of an ECA application package. Client: Region of Waterloo

— Rosedale Functional Design Update, Hamilton, ON (2018-ongoing). Project Manager. The project involves functional and detailed design of stormwater management measures to provide flood relief for the Rosedale residential neighborhood. The scope of work includes detailed design of SWM Facility, Scoped Environmental Impact Study, Archeological Assessment, Berm Stability Assessment and environmental permits. Responsible for work plans and coordinating the overall works carried out by environment, archaeology, geotechnical and ecology disciplines for the completion of design works. City of Hamilton

— Storm Sewer Analysis 5 Locations, Hamilton, ON (2019-2020): Project Manager. This project involves assessment of the existing storm sewer system to determine whether upgrading or rehabilitation of the storm sewer system is required for the Wilmar Court and Sleepy Hollow Court Neighbour. These services are in support of the road rehabilitation works that are proposed for the area - any required storm sewer works can be conducted simultaneously. The scope of work includes field investigations, hydrologic and hydraulic assessment of the existing storm sewer system, recommendations for capacity upgrades, and storm sewer outfall concept design. Responsible for preparing work plans, coordinating with regulatory agencies, reviewing the design and providing overall direction. Client: City of Hamilton

— CN Brampton Intermodal Terminal Ditch Enclosure, Brampton, ON (2015):* Water Resources Engineer. Conducted filed investigations, hydrologic and hydraulic modelling for the Brampton Intermodal Terminal and adjacent areas, optimized the design of 700 m long culvert to enclose an existing channel. Client: CN

— CN Milton Logistics Hub, Stormwater Management Strategy, Milton, ON (2015):* Technical Lead. Carried out hydrologic and hydraulic modelling for the proposed railway yard (100 ha), designed the stormwater management system consisting of two large wet detention facilities, rainwater harvesting system, diversion channels and culverts. Client: CN

— CN Milton Logistics Hub, Indian Creek Realignment and Tributary A Enhancements Flood Impact Assessment, Milton, ON (2015):* Water Resources Engineer. Conducted hydraulic assessment for the realignment of Indian Creek and a Tributary of Indian Creek, optimized the design of culverts to convey stormwater across the railway tracks and prepared floodplain maps. Client: CN

- Metrolinx Go Weston Station Stormwater Management, Toronto, ON (2015):* Water Resources Engineer. Prepared stormwater management plan for the parking lot of Go Weston Station, which involved hydrologic modelling, design of storm sewers and an underground detention basin to provide quality and quantity controls for storm runoff. Client: Metrolinx
- Collett Road Flood Study, Mississauga, ON (2014):* Water Resources Engineer. Conducted hydrologic and hydraulic modelling for a residential subdivision site and prepared floodplain maps for a tributary of Mimico Creek. Client: Design Fine Limited
- Drainage Assessment for John Deere Properties, Woodstock, ON (2008-2013):* Water Resources Engineer. Conducted drainage assessment of industrial properties which involved site inspection, storm sewer capacity estimation and prepared a drainage plan to support the severance application. Client: John Deere
- Stormwater Management and Floodplain Impact Study for Long & McQuade Store, Pickering, ON (2008-2013):* Water Resources Engineer. To support a development / alteration application, carried out drainage assessment and floodplain impact study and prepared a SWM Plan. Client: Long & McQuade
- Stormwater Control Study for Cameco Corporation, Port Hope, ON (2008-2013):* Water Resources Engineer / Technical Lead. Responsible for the stormwater control study which involved water quality and quantity monitoring during rainfall events, water balance and pollutant loadings computations and preparation of assessment report. Client: Cameco Corporation
- Hydrologic and Hydraulic Analysis of 9th Line Trunk Sewer, Markham, ON (2008): Project Engineer – Water Resources. Conducted hydrologic and hydraulic analysis for the 9th Line Trunk Sewer in Markham. Client: 605918 Ontario Limited
- Design of SWM System for Residential Subdivisions of Bradford, Bram East (Brampton), and Picov (Ajax), ON (2006-2008): Project Engineer. Designed the SWM systems for residential subdivisions which include hydrologic and hydraulic modelling, design of detention facilities, open channels and hydraulic structures. Client: Various
- Preparation of SWM Plans for various Residential, Commercial and Institutional Developments, Various Locations in ON (2006-2008): Project Engineer - Water Resources. Prepared SWM Plans for Brampton Cassie Campbell Recreation Center, Bolton High School, Toronto West Windermere Village, Costco Richmond Hill and Toronto Forest Hill Jewish Centre. The activities include hydrologic and hydraulic modelling, design of detention facilities, open channels and hydraulic structures. Client: Various
- Flood Reduction Study for CNR, Vaughan, ON (2006-2008): Project Engineer-Water Resources. Carried out a flood reduction study which involved site assessment, hydraulic modelling and evaluation / utilization of available storages to reduce the flooding impact on the CNR facility. Client: CN

Dams / Watershed Hydrology

- Preparation of Conceptual Water Budget for Nickel District Conservation Authority, Sudbury, ON (2006):* Water Resources Engineer. Collected and analyzed the climate, water quality and quantity data and prepared a conceptual water budget for

Wanapitei River watershed (3,600 km²), Vermilion River watershed (4,800 km²) and Whitefish watershed (900 km²), as part of the Source Water Protection Program. Client: Nickel District Conservation Authority (now Conservation Sudbury)

- Hydrologic and Hydraulic Modelling for various Mining Dams, Sudbury, ON (2004-2006):* Water Resources Engineer. Carried out hydrologic and hydraulic modelling for various mining dams / reservoirs to assess its safety during various design storm events. Client: Various
- Hydrologic Modelling for Kidd Metsite, Timmins, ON (2004-2006):* Water Resources Engineer. Undertook hydrologic study for the Kidd mining site, which involved development of a continuous simulation hydrologic model (using GAWSER) calibration, validation and application of model to assess the existing capacities of reservoirs and evaluate future expansion of reservoirs. Client: Falconbridge
- Hydrologic Modelling for Placer Dome Mine, Timmins, ON (2004-2006):* Water Resources Engineer. Carried out hydrologic study for the Placer Dome mining site, which involved development of a continuous simulation hydrologic model (using GAWSER) to assess the existing capacity of reservoirs / overflow spillways and provide water level elevations for raising dam heights and spillway sizes. Client: Placer Dome

Water Resources Management of Mining and Quarries

- Carden Plain Cumulative Impact Assessment Study, Kawartha Lakes, ON (2009-2012):* Surface Water Task Lead. Organized water quality and quantity monitoring program and carried out analysis and assessment of cumulative impacts of quarry water discharges on the surface water systems. Client: Ontario Stone, Sand and Gravel Association
- Flood Line Assessment for the Proposed Norval Quarry, Brampton, ON (2008-2013):* Water Resources Engineer. Conducted hydrologic / hydraulic modelling and flood line mapping to assess the impacts of proposed quarry development. Client: Brampton Bricks
- SWM Plans and Environmental Compliance Approvals, various locations ON (2008-2013):* Water Resources Engineer. Carried out hydrologic modelling, water quality and quantity monitoring, prepared SWM Plans and compiled Environmental Compliance Approval (ECA) applications for industrial sewage works under Section 53 of the Ontario Water Resources Act (OWRA) for Lafarge Milton Concrete Plant and Dundas Quarry. Client: Lafarge Canada Inc.
- SWM System Design for Tomlinson Brechin Quarry, Brechin, ON (2008-2013):* Water Resources Engineer. Carried out stormwater management and flood impact assessment, designed detention facility to provide quality and quality control and compiled ECA application for the quarry. Client: Tomlinson
- Surface Water Assessment to support Permit To Take Water (PTTW) applications, various locations ON (2008-2013):* Water Resources Engineer. Carried out surface water assessment which included water quality and quantity analysis and water balance computations to support PTTW applications under Section 34 of the OWRA for Hanson Tansley Quarry, Hanson Niagara Quarry and Dufferin Cayuga Quarry. Client: Various
- Preparation of Annual Performance Reports, Various Locations, ON (2008-2013):* Water Resources Engineer. Carried out water quality / quantity monitoring and prepared annual performance reports for Lafarge Dundas Quarry, Hanson Niagara

Quarry, Lafarge Coldwater Quarry, Lafarge Cornwall Quarry and Innocon Ready Mix Concrete Plant. Client: Various

- SWM Plans and Environmental Compliance Approvals], various locations ON (2008-2013):* Water Resources Engineer. Carried out hydrologic modelling, water quality and quantity monitoring, prepared SWM plans and compiled ECA applications for Holcim Breslau Aggregate Plant, Milton Concrete Plant and Cayuga Quarry. Client: Holcim Canada
- Design of SWM System for Lafarge Caledon Asphalt Plant, Caledon, ON (2008):* Water Resources Engineer. Prepared Stormwater Management Plan for the proposed Asphalt Plant, which involved hydrologic modelling, design of detention facility to provide the required quality and quantity controls as per applicable design guidelines. Client: Lafarge

International Experience

- Ghazi Barotha Hydro Power Project, Attock, Pakistan, (1995-2001):*, Client: Wapda Employee. Civil Engineer. Working on a mega hydropower project, carried out various civil engineering assignments which included:
  - Impact analysis of flood water on the adjacent communities due to re-routing of natural waterways affected by the construction of power conveyance canal
  - Assessment of powerhouse dewatering impacts on the irrigation / domestic water supply and arrangement of alternate water supply system for Barotha village
  - Project resettlement activities involving cost estimation of infrastructure affected by the project and construction of resettlement villages
  - Construction monitoring of residential units of Power Complex Colony and Barotha Village Road.
- Tarbela Dam Project, Tarbela, Pakistan, (1991-1995):* Client: Wapda (Employee). Maintenance Engineer. carried out various civil engineering assignments which included:
  - Collection, processing and analysis of dam instrumentation data to assess the impacts of fluctuating water levels in reservoir
  - Managing maintenance of residential buildings and roads
  - Design, construction and maintenance of sewer system
  - Design, construction and maintenance of roadside drains, culverts and causeways
- Design of Irrigation Projects, Baluchistan, Pakistan, (1989-1991):*, Client: Various Design Engineer. Working as Design Engineer in the Water Resources sector of a multi-disciplinary consulting firm, successfully completed the following assignments:
  - Planning of irrigation / water supply schemes in consultation with farmers / residents, in the remote areas of Baluchistan
  - Design of channel systems (earthen and lined)
  - Design of hydraulic structures like weirs, outlets, culverts and drop structures
  - Prepared drawings, cost estimates and tender documents for various irrigation projects

* denotes projects completed with previous employers

APPENDIX

B

MECP WATER WELL RECORDS AND WATER WELL SURVEY

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	EASTING	NORTHING	ACCURACY	Date Completed	Contractor	COUNTY	TWP	Final Status	1st Use	2nd Use	Drilling Method
6601650	1006 Beaverdams Rd		648443	4774055	unknown UTM	10-May-49	W A Lounsbury & Sons	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Domestic		Cable Tool
6601652	3269 Townline Rd		648434	4774233	unknown UTM	28-Aug-56	W A Lounsbury & Sons	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Domestic		Cable Tool
6601684	13030 Highway 20	L8 Club	648301	4771446	unknown UTM	6-Apr-55	Raymond Schooley	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Commercial		Cable Tool
6601685	13030 Highway 20	L8 Club	648314	4771414	unknown UTM	23-Oct-57	W A Lounsbury & Sons	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Commercial	Domestic	Cable Tool
6601686	13030 Highway 20	L8 Club	648229	4771445	100 m - 300 m	13-Mar-62	W A Lounsbury & Sons	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Commercial		Cable Tool
6601714	13045 Highway 20		648151	4771336	unknown UTM	27-May-48	W A Lounsbury & Sons	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Domestic		Cable Tool
6601715	13011 Highway 20	Little Bros Service Centre	648406	4771308	unknown UTM	7-Jun-51	W A Lounsbury & Sons	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Domestic		Cable Tool
6601716	13011 Highway 20	Little Bros Service Centre	648435	4771354	unknown UTM	1-Oct-53	Walter Winger	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Domestic		Cable Tool
6601719	13055 Highway 20	Milan Garden Inn	648041	4771334	100 m - 300 m	13-Sep-63	W A Lounsbury & Sons	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Commercial		Cable Tool
6601720	13055 Highway 20	Milan Garden Inn	648032	4771236	100 m - 300 m	25-May-64	W A Lounsbury & Sons	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Commercial		Cable Tool
6601721	13065 Highway 20	Vacant lot	648002	4771273	100 m - 300 m	29-May-64	W A Lounsbury & Sons	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Commercial		Cable Tool
6602549	13065 Highway 20	Vacant lot	647975	4771323	30 m - 100 m	22-Aug-70	Donald Merritt	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Public		Cable Tool
6603729	1021 Beaverdams Rd		648268	4773970	Lot centroid	7-Oct-85	W R Field	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Domestic		Rotary (Air)
6603744		Plotted incorrectly	648268	4773970	Lot centroid	26-May-86	W R Field	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Domestic		Rotary (Air)
6604435		Plotted incorrectly	647860	4773952	Lot centroid	9-May-00	Field Well Drilling	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Industrial		Rotary (Air)

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	Screen Depth (m BGS)				Water Depth (m)		Pumping Test Data					Formation Depth (m BGS)					
			Top	Bottom	Type	Dia (in)	Depth	TYPE	Static WL (m)	Final WL (m)	Duration	Rate (GPM)	Recommended Rate (GPM)	Layer	Top	Bottom	Description		
6601650	1006 Beaverdams Rd		10.7	11.9	OPEN HOLE	6	11.6	SULPHUR	4.6	7.6	1 : 00	5	5	1	0.0	3.0		CLAY	
														2	3.0	10.7	BLUE	CLAY	
														3	10.7	11.9		LIMESTONE	
6601652	3269 Townline Rd		10.7	11.3	OPEN HOLE	6	11.0	SULPHUR	4.6	9.1	2 : 00	10		1	0.0	3.0	BROWN	CLAY	
														2	3.0	10.4	BLUE	CLAY	
														3	10.4	10.7		FINE SAND	GRAVEL
														4	10.7	11.3		LIMESTONE	
6601684	13030 Highway 20	L8 Club	13.4	14.9	OPEN HOLE	6	14.6	FRESH	6.7	6.7	0 : 30	3		1	0.0	5.5	BROWN	CLAY	
														2	5.5	13.4		MEDIUM SAND	
														3	13.4	14.9		LIMESTONE	
6601685	13030 Highway 20	L8 Club	15.2	21.0	OPEN HOLE	7	18.6	SULPHUR	8.5	19.8	24 : 00	5		1	0.0	2.1		CLAY	STONES
														2	2.1	11.3		CLAY	
														3	11.3	15.2		HARDPAN	STONES
														4	15.2	21.0		LIMESTONE	
6601686	13030 Highway 20	L8 Club	13.4	18.3	OPEN HOLE	6	18.3	SULPHUR		18.3	2 : 00	2	2	1	0.0	11.3		CLAY	
														2	11.3	13.4		CLAY	STONES
														3	13.4	18.3		LIMESTONE	
6601714	13045 Highway 20		11.3	12.2	OPEN HOLE	6	11.9	FRESH	6.1	7.0	2 : 00	4		1	0.0	1.8		CLAY	
														2	1.8	11.3	BLUE	CLAY	
														3	11.3	12.2		LIMESTONE	
6601715	13011 Highway 20	Little Bros Service Centre	12.2	13.1	OPEN HOLE	6	13.1	FRESH	7.0	10.7	2 : 00	15		1	0.0	3.0		CLAY	
														2	3.0	12.2	BLUE	CLAY	
														3	12.2	13.1		LIMESTONE	
6601716	13011 Highway 20	Little Bros Service Centre	8.8	12.2	OPEN HOLE	6	11.6	FRESH	5.5	5.5	0 : 30	20		1	0.0	2.1	YELLOW	CLAY	
														2	2.1	8.8	BLUE	CLAY	
														3	8.8	12.2		LIMESTONE	
6601719	13055 Highway 20	Milan Garden Inn	10.4	16.5	OPEN HOLE	6	15.8	SULPHUR	11.0	16.5	1 : 00	10	10	1	0.0	7.9	BROWN	CLAY	
														2	7.9	10.4		HARDPAN	
														3	10.4	16.5		LIMESTONE	
6601720	13055 Highway 20	Milan Garden Inn	10.1	16.5	OPEN HOLE	7	16.5	FRESH	10.1	16.5	2 : 00	17	17	1	0.0	8.5	BROWN	CLAY	
														2	8.5	10.1		HARDPAN	
														3	10.1	16.5		LIMESTONE	
6601721	13065 Highway 20	Vacant lot	9.4	16.5	OPEN HOLE	6	16.5	FRESH	9.1	16.5	2 : 00	17	17	1	0.0	7.6	BROWN	CLAY	
														2	7.6	9.4		HARDPAN	
														3	9.4	16.5		LIMESTONE	
6602549	13065 Highway 20	Vacant lot	10.4	23.2	OPEN HOLE	6	19.5	SULPHUR	13.1	21.3	1 : 00	6	5	1	0.0	6.1	BROWN	CLAY	
														2	6.1	8.8	GREY	CLAY	
														3	8.8	10.4	BROWN	CLAY	GRAVEL
														4	10.4	23.2	GREY	LIMESTONE	
6603729	1021 Beaverdams Rd		0.0	12.2	STEEL	6	11.6	FRESH	3.0	10.7	1 : 00	10	5	1	0.0	2.4	BROWN	CLAY	
														2	2.4	6.1	GREY	CLAY	
														3	6.1	10.7	GREY	CLAY	GRAVEL
														4	10.7	12.2	GREY	ROCK	
6603744		Plotted incorrectly	0.0	12.2	STEEL	6	11.3	FRESH	5.5	10.7	1 : 00	12	8	1	0.0	2.4	BROWN	UNKNOWN TYPE	
														2	2.4	6.1	GREY	UNKNOWN TYPE	
														3	6.1	10.7	GREY	CLAY	GRAVEL
														4	10.7	12.2	RED	ROCK	
6604435		Plotted incorrectly	0.0	13.7	STEEL	6	12.5	FRESH			1 : 00	20	10	1	0.0	0.6	BROWN	CLAY	
														2	0.6	7.9	GREY	CLAY	
														3	7.9	10.4	RED	CLAY	
														4	10.4	13.7		ROCK	LIMESTONE

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	EASTING	NORTHING	ACCURACY	Date Completed	Contractor	COUNTY	TWP	Final Status	1st Use	2nd Use	Drilling Method
6604436		Hydro ROW	647860	4773952	Lot centroid	9-May-00	Field Well Drilling	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Abandoned-Quality	Commercial		Rotary (Air)
6604437		Plotted incorrectly	648318	4771889	Lot centroid	11-May-00	Field Well Drilling	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Public		Rotary (Air)
7133671		Plotted incorrectly	648407	4773914	on WWR	17-Oct-09	Circle Eddys Drilling	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Domestic		Cable Tool
7184710	5114 Townline Rd	Niagara Cricket Centre / DMZ Paintball	648267	4772669	on WWR	20-Jul-12	Ted Vander Zalm Well Drilling	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)	Water Supply	Irrigation		Air Percussion
7206054	13030 Highway 20	L8 Club	648251	4771461	on WWR	31-Jul-13	Ted Vander Zalm Well Drilling	NIAGARA (WELLAND)	THOROLD TOWN (THOROLD)				Air Percussion

wsp

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	Screen Depth (m BGS)				Water Depth (m)		Pumping Test Data					Formation Depth (m BGS)						
			Top	Bottom	Type	Dia (in)	Depth	TYPE	Static WL (m)	Final WL (m)	Duration	Rate (GPM)	Recommended Rate (GPM)	Layer	Top	Bottom	Description			
6604436		Hydro ROW												1	0.0	0.9	BROWN	CLAY		
														2	0.9	8.8	GREY	CLAY		
														3	8.8	11.0	GREY	CLAY	BOULDERS	
														4	11.0	19.2		ROCK	LIMESTONE	
6604437		Plotted incorrectly	0.0	14.6	STEEL	6	13.1	FRESH			1 : 00	35	10	1	0.0	0.3	BROWN	CLAY		
														2	0.3	4.6	GREY	CLAY		
														3	4.6	7.9	RED	CLAY		
														4	7.9	10.4	RED	CLAY	BOULDERS	
														5	10.4	14.6		ROCK	LIMESTONE	
7133671		Plotted incorrectly	9.8	11.9	OPEN HOLE	6	11.3	FRESH	5.3	10.0	2 : 00	10	10	1	0.0	0.6	BROWN	CLAY	GRAVEL	
														2	0.6	3.0	BROWN	CLAY	STONES	
														3	3.0	6.0	GREY	CLAY	GRAVEL	
														4	6.0	9.8	GREY	CLAY	SILT	SOFT
														5	9.8	11.9	GREY	LIMESTONE		
7184710	5114 Townline Rd	Niagara Cricket Centre / DMZ Paintball	5.5	19.8	OPEN HOLE	6.25	9.1	Untested	7.0	7.6	1 : 00	10	15	1	0.0	5.5	BROWN	CLAY		DENSE
														2	5.5	19.8	GREY	ROCK		FRACTURED
7206054	13030 Highway 20	L8 Club	11.3	25.3	OPEN HOLE	6.25	13.1	Untested	13.1	15.8	1 : 00	10	30	1	0.0	11.3	BROWN	CLAY	STONES	
							18.6	Untested						2	11.3	25.3	BLACK	ROCK		FRACTURED
							23.8	Untested												

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	EASTING	NORTHING	ACCURACY	Date Completed	Contractor	COUNTY	TWP	Final Status	1st Use	2nd Use	Drilling Method
6601324	4255 Garner Rd		650468	4774778	unknown UTM	30-Jul-49	W.A. Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601327	4366 Townline Rd		648489	4774364	unknown UTM	28-May-52	W A Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601328	9332 Thorold Stone Rd		649491	4774713	unknown UTM	7-Dec-56	W.A. Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601329	4282 Garner Rd		650550	4774665	100 m - 300 m	30-Jun-65	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Commerical		Cable Tool
6601333	9722 Beaverdams Rd		649371	4773782	100 m - 300 m	17-Nov-67	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601334	9417 Beaverdams Rd		649736	4773654	unknown UTM	25-Aug-56	W A Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601335	9417 Beaverdams Rd		649783	4773640	unknown UTM	7-Feb-57	W A Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601336	4843 Garner Rd		650506	4773799	100 m - 300 m	7-Oct-61	W.A. Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601350	8395 Beaverdams Rd		651498	4773189	unknown UTM	25-Aug-55	W.A. Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601351	10033 Uppers Ln	WAI owned	648939	4773061	100 m - 300 m	22-Aug-59	D A Young	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601352	10033 Uppers Ln	WAI owned	648966	4773079	100 m - 300 m	8-Apr-63	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601353		Enbridge Station	648507	4773406	100 m - 300 m	10-Apr-63	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601354	10200 Uppers Ln	WAI owned	648917	4773006	100 m - 300 m	6-Apr-63	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601355			650651	4772748	unknown UTM	25-Jul-52	Lloyd M. Smith	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601356	8362 Beaverdams Rd		651452	4773118	unknown UTM	7-Jul-54	W.A. Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601358			649493	4772199	unknown UTM	7-Dec-53	W A Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Livestock	Domestic	Cable Tool

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	Screen Depth (m BGS)				Water Depth (m)		Pumping Test Data					Formation Depth (m BGS)						
			Top	Bottom	Type	Dia (in)	Depth	TYPE	Static WL (m)	Final WL (m)	Duration	Rate (GPM)	Recommended Rate (GPM)	Layer	Top	Bottom	Description			
6601324	4255 Garner Rd		11.3	11.6	OPEN HOLE	6	11.3	FRESH	4.6	9.8	1 : 00	10	20	1	0.0	3.0		CLAY		
														2	3.0	11.3		FINE SAND		
														3	11.3	11.6		LIMESTONE		
6601327	4366 Townline Rd		10.4	11.9	OPEN HOLE	6	11.6	SULPHUR	5.2	7.0	2 : 00	2		1	0.0	10.4		CLAY		
														2	10.4	11.9		LIMESTONE		
6601328	9332 Thorold Stone Rd		10.7	13.4	OPEN HOLE	6	13.1	SULPHUR	4.3	9.1	3 : 00	8		1	0.0	1.5		TOPSOIL	MEDIUM SAND	
														2	1.5	6.1	BLUE	CLAY		
														3	6.1	10.1		CLAY	MEDIUM SAND	
														4	10.1	10.7		CLAY	MEDIUM SAND	STONES
														5	10.7	13.4		LIMESTONE		
6601329	4282 Garner Rd		10.4	14.0	OPEN HOLE	6	13.7	SULPHUR	4.6	7.6	1 : 00	10	10	1	0.0	10.1	BROWN	CLAY		
														2	10.1	14.0	GREY	LIMESTONE		
6601333	9722 Beaverdams Rd		7.0	8.8	OPEN HOLE	6	8.5	SULPHUR	3.0	7.6	1 : 00	4	3	1	0.0	6.1	BROWN	CLAY		
														2	6.1	6.7	BLUE	CLAY		
														3	6.7	8.8	GREY	LIMESTONE		
6601334	9417 Beaverdams Rd		10.7	11.6	OPEN HOLE	6	11.0	FRESH	2.7	7.9	3 : 00	6		1	0.0	3.0	BROWN	CLAY		
														2	3.0	8.5	BLUE	CLAY		
														3	8.5	9.8		CLAY	MEDIUM SAND	
														4	9.8	10.7		CLAY	MEDIUM SAND	STONES
														5	10.7	11.6		LIMESTONE		
6601335	9417 Beaverdams Rd		9.8	12.5	OPEN HOLE	6	12.2	SULPHUR	1.8	7.0	3 : 00	5		1	0.0	3.0	BLUE	CLAY		
														2	3.0	9.1	BLUE	CLAY	MEDIUM SAND	
														3	9.1	9.8		FINE SAND		
														4	9.8	12.5		LIMESTONE		
6601336	4843 Garner Rd		12.5	13.1	OPEN HOLE	6	12.2	FRESH	5.2	13.1	2 : 00	4	4	1	0.0	0.6		TOPSOIL	MEDIUM SAND	
														2	0.6	5.5	BROWN	CLAY		
														3	5.5	11.9	BLUE	CLAY		
														4	11.9	12.2		GRAVEL		
														5	12.2	13.1		LIMESTONE		
6601350	8395 Beaverdams Rd		8.8	9.8	OPEN HOLE	6	9.4	FRESH	2.7	7.6	2 : 00	4		1	0.0	2.4		CLAY		
														2	2.4	7.6	BLUE	CLAY		
														3	7.6	8.5		STONES		
														4	8.5	8.8		FINE SAND		
														5	8.8	9.8		LIMESTONE		
6601351	10033 Uppers Ln	WAI owned	5.8	7.6	OPEN HOLE	6	7.3	FRESH	6.1	7.3	1 : 00	3	3	1	0.0	5.8	BROWN	CLAY		
														2	5.8	7.6		LIMESTONE		
6601352	10033 Uppers Ln	WAI owned	7.3	9.1	OPEN HOLE	6	9.1	FRESH	4.6	6.1	1 : 00	8	4	1	0.0	7.0	BROWN	CLAY		
														2	7.0	9.1		LIMESTONE		
6601353		Enbridge Station	5.5	9.1	OPEN HOLE	6	9.1	FRESH	5.5	6.1	1 : 00	8	4	1	0.0	4.9	BROWN	CLAY		
														2	4.9	9.1		LIMESTONE		
6601354	10200 Uppers Ln	WAI owned	5.5	9.1	OPEN HOLE	6	9.1	FRESH	4.9	6.1	1 : 00	8	4	1	0.0	4.9	BROWN	CLAY		
														2	4.9	9.1		LIMESTONE		
6601355				12.2	STEEL	6	12.2	FRESH	4.6					1	0.0	3.0	RED	CLAY		
														2	3.0	10.7		CLAY	SILT	
														3	10.7	12.2		GRAVEL		
6601356	8362 Beaverdams Rd		12.2	15.5	OPEN HOLE	6	15.2	FRESH	4.6	15.2	2 : 00	2		1	0.0	5.5		CLAY		
														2	5.5	12.5	BLUE	CLAY		
														3	12.5	15.5		LIMESTONE		
6601358			8.2	9.1	OPEN HOLE	6	8.8	FRESH	5.8	6.4	1 : 00	10		1	0.0	3.0		CLAY		
														2	3.0	6.7	BLUE	CLAY		
														3	6.7	8.2		FINE SAND		
														4	8.2	9.1		LIMESTONE		

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	EASTING	NORTHING	ACCURACY	Date Completed	Contractor	COUNTY	TWP	Final Status	1st Use	2nd Use	Drilling Method
6601359	9579 Lundys Ln	Lundy's Lane Golf Driving Range	649715	4772103	unknown UTM	13-Oct-51	Elson Schweyer	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601361	6060 Beechwood Rd		649650	4771954	unknown UTM	16-May-55	Walter Winger & Son	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601362	9961 Nichols Ln		649319	4771480	unknown UTM	25-Aug-58	W A Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6601365	6848 Townline Rd		648600	4770719	100 m - 300 m	25-Aug-61	W.A. Lounsbury & Sons	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6602354	10008 Highway 20	Country Basket Garden Centre	648985	4771623	100 m - 300 m	15-Oct-68	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6602492	5417 Beechwood Rd	WAI owned	649535	4772923	30 m - 100 m	29-Oct-69	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6602644	4366 Townline Rd		648475	4774508	30 m - 100 m	30-Nov-71	W.L. Field & Son	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Livestock	Domestic	Cable Tool
6602724		Hydro ROW	649515	4772703	30 m - 100 m	20-Oct-72	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6602739			649615	4774093	30 m - 100 m	6-Mar-69	S W Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6602792	5497 Beechwood Rd	WAI owned	649514	4772841	30 m - 100 m	27-Sep-73	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6602986	4303 Garner Rd		650468	4774652	30 m - 100 m	30-Aug-74	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603017	4389 Beechwood Rd		649416	4774606	30 m - 100 m	28-Aug-74	W.L. Field & Son	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603043	4555 Beechwood Rd		649475	4774283	30 m - 100 m	1-Sep-74	W R Field	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603167	6169 Garner Rd	Niagara Falls Golf Club	650615	4771803	30 m - 100 m	19-Jul-76	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Irrigation		Cable Tool
6603168	6060 Beechwood Rd		649675	4772003	30 m - 100 m	14-Jul-76	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603169	9961 Nichols Ln		649135	4771483	30 m - 100 m	12-Jul-76	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	Screen Depth (m BGS)				Water Depth (m)		Pumping Test Data					Formation Depth (m BGS)						
			Top	Bottom	Type	Dia (in)	Depth	TYPE	Static WL (m)	Final WL (m)	Duration	Rate (GPM)	Recommended Rate (GPM)	Layer	Top	Bottom	Description			
6601359	9579 Lundys Ln	Lundy's Lane Golf	6.1	10.1	OPEN HOLE	6	10.1	FRESH	3.7					1	0.0	6.1		CLAY		
		Driving Range												2	6.1	10.1		LIMESTONE		
6601361	6060 Beechwood Rd		8.8	11.3	OPEN HOLE	6	10.7	FRESH	2.1	2.4	0 : 30	15		1	0.0	0.3		CLAY	MEDIUM SAND	STONES
														2	0.3	5.5	BROWN	CLAY		
														3	5.5	6.7	RED	MEDIUM SAND		
														4	6.7	8.5		STONES	CLAY	
														5	8.5	11.3		LIMESTONE		
6601362	9961 Nichols Ln		11.0	13.1	OPEN HOLE	6	12.8	FRESH	7.0	12.2		3		1	0.0	6.1	GREY	CLAY		
														2	6.1	11.0	RED	CLAY	MEDIUM SAND	
														3	11.0	13.1		LIMESTONE		
6601365	6848 Townline Rd		15.8	16.5	OPEN HOLE	6	16.5	FRESH	10.7	15.2	2 : 00	10	5	1	0.0	4.6	BROWN	CLAY		
														2	4.6	15.8	BLUE	CLAY	STONES	
														3	15.8	16.5		LIMESTONE		
6602354	10008 Highway 20	Country Basket	0.0	10.1	STEEL	6	9.8	FRESH	3.7	6.1	1 : 00	10	5	1	0.0	6.7	BROWN	CLAY		
		Garden Centre												2	6.7	9.4	BLUE	CLAY		
														3	9.4	10.1	GREY	SHALE		
6602492	5417 Beechwood Rd	WAI owned	7.0	9.8	OPEN HOLE	6	7.6	FRESH	6.1	7.6	2 : 15	8	5	1	0.0	4.6	BROWN	CLAY		
														2	4.6	6.4	RED	CLAY		
														3	6.4	7.0	GREY	SHALE		
														4	7.0	9.8	GREY	LIMESTONE		
6602644	4366 Townline Rd		11.6	13.4	OPEN HOLE	6	12.2	FRESH	4.3	11.0	2 : 00	10	8	1	0.0	1.8	BROWN	TOPSOIL		
														2	1.8	11.0	BLUE	CLAY		
														3	11.0	11.6		MEDIUM SAND	GRAVEL	
														4	11.6	13.4		ROCK		
6602724		Hydro ROW	7.0	9.8	OPEN HOLE	6	9.1	FRESH	4.6	7.6	2 : 00	5	4	1	0.0	5.5	BROWN	CLAY		
														2	5.5	9.8	GREY	LIMESTONE		
6602739			8.8	11.6	OPEN HOLE	6	10.7	FRESH	4.3	6.1	1 : 30	16	10	1	0.0	7.3		CLAY		
														2	7.3	8.5		GRAVEL	CLAY	
														3	8.5	11.6		ROCK		
6602792	5497 Beechwood Rd	WAI owned	6.7	10.4	OPEN HOLE	6	9.8	FRESH	4.9	6.1	2 : 15	10	8	1	0.0	6.1	BROWN	CLAY		
														2	6.1	10.4	GREY	LIMESTONE		
6602986	4303 Garner Rd		15.5	18.3	OPEN HOLE	6	18.0	SULPHUR	6.1	13.7	2 : 00	8	6	1	0.0	5.5	BROWN	CLAY		
														2	5.5	13.7	GREY	CLAY		
														3	13.7	15.5	RED	CLAY	GRAVEL	
														4	15.5	18.3	GREY	LIMESTONE		
6603017	4389 Beechwood Rd		11.6	12.2	OPEN HOLE	6	12.2	FRESH	3.7	4.6	1 : 30	8	6	1	0.0	6.4	BROWN	CLAY		
														2	6.4	11.6	GREY	CLAY		
														3	11.6	12.2		ROCK		
6603043	4555 Beechwood Rd		10.4	11.9	OPEN HOLE	6	11.3	SULPHUR	2.7	10.7	2 : 00	6	5	1	0.0	3.7	BROWN	CLAY		
														2	3.7	10.4	GREY	CLAY		
														3	10.4	11.9		ROCK		
6603167	6169 Garner Rd	Niagara Falls	12.8	18.3	OPEN HOLE	6	17.7	SULPHUR	3.7	4.9	1 : 00	20	15	1	0.0	6.7	BROWN	CLAY	PACKED	
		Golf Club												2	6.7	12.5	GREY	CLAY	SOFT	
														3	12.5	18.3	GREY	LIMESTONE	LAYERED	
6603168	6060 Beechwood Rd		9.8	13.7	OPEN HOLE	6	13.1	MINERAL	4.9	12.2	2 : 00	3	3	1	0.0	5.5	BROWN	CLAY	PACKED	
														2	5.5	9.4	GREY	CLAY	SOFT	
														3	9.4	13.7	GREY	LIMESTONE	LAYERED	
6603169	9961 Nichols Ln		11.6	13.4	OPEN HOLE	6	13.1	MINERAL	6.1	9.1	2 : 00	10	8	1	0.0	6.1	BROWN	CLAY	PACKED	
														2	6.1	11.3	GREY	CLAY	SOFT	
														3	11.3	13.4	GREY	LIMESTONE	LAYERED	

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	EASTING	NORTHING	ACCURACY	Date Completed	Contractor	COUNTY	TWP	Final Status	1st Use	2nd Use	Drilling Method
6603203	4680 Townline Rd		649435	4774363	30 m - 100 m	8-Dec-76	Frank Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603214	4255 Garner Rd		650415	4774763	30 m - 100 m	8-Apr-77	S.W. Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603248	9301 Beaverdams Rd		650055	4773603	30 m - 100 m	28-Sep-77	W R Field	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603264	9958 Nichols Ln		648555	4771083	30 m - 100 m	11-May-78	Donald Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603313	6393 Beechwood Rd		649615	4771463	30 m - 100 m	30-Nov-78	S.W. Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603342	5002 Garner Rd		650595	4773623	30 m - 100 m	14-May-79	S.W. Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603343	6169 Garner Rd	Niagara Falls Golf Club	650535	4771823	30 m - 100 m	2-Jun-79	S.W. Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Irrigation		Cable Tool
6603689		Plotted incorrectly	650074	4773308	Lot centroid	8-Apr-85	W R Field	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603830	8522 Beaverdams Rd		651119	4773367	Lot centroid	3-Nov-88	Donald Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603833		Plotted incorrectly	650047	4773720	Lot centroid	12-Jan-89	Donald Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603923	6169 Garner Rd	Niagara Falls Golf Club	650157	4771670	Lot centroid	12-Dec-89	Donald Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Commerical		Cable Tool
6603926	9301 Beaverdams Rd		650047	4773720	Lot centroid	2-Feb-90	Field Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Rotary (Air)
6603942	10148 Beaverdams Rd		649009	4773656	Lot centroid	22-May-90	Ken Schooley	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6603989	10148 Beaverdams Rd		649009	4773656	Lot centroid	13-Jun-90	Field Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Livestock		Rotary (Air)

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	Screen Depth (m BGS) Top	Bottom	Type	Dia (in)	Water Depth (m) Depth	TYPE	Pumping Test Data Static WL (m)	Final WL (m)	Duration	Rate (GPM)	Recommended Rate (GPM)	Formation Depth (m BGS) Layer	Top	Bottom	Description			
6603203	4680 Townline Rd		11.3	11.6	OPEN HOLE	6	11.3	MINERAL	4.6	5.5	2 : 00	10	10	1	0.0	5.5	BROWN	CLAY	PACKED	
														2	5.5	11.0	RED	CLAY	SAND	SOFT
														3	11.0	11.6	GREY	LIMESTONE	LAYERED	
6603214	4255 Garner Rd			13.1		6	18.3	MINERAL	4.9	11.6	2 : 00		10	1	0.0	6.7		CLAY		
														2	6.7	13.1		STONES	CLAY	
														3	13.1	18.3		STONES		
6603248	9301 Beaverdams Rd		10.7	11.3	OPEN HOLE	7	11.0	FRESH	6.4	9.1	2 : 00	6	5	1	0.0	3.7	BROWN	CLAY		
														2	3.7	9.1		CLAY		
														3	9.1	10.7	RED	CLAY	GRAVEL	
														4	10.7	11.3	RED	CLAY	GRAVELLY	ROCK
6603264	9958 Nichols Ln		15.8	18.3	OPEN HOLE	6	17.1	MINERAL	12.8	12.8	2 : 00	14	10	1	0.0	10.7	BROWN	CLAY	STONES	PACKED
														2	10.7	14.6	GREY	CLAY	PACKED	
														3	14.6	15.5	GREY	SHALE	LAYERED	
														4	15.5	18.3	GREY	LIMESTONE	LAYERED	
6603313	6393 Beechwood Rd			11.3	STEEL	6	12.2	FRESH	4.3	15.2	2 : 00			1	0.0	11.0	GREY	CLAY		
														2	11.0	15.2		ROCK		
6603342	5002 Garner Rd			12.2		6	13.4	Not stated	3.0	7.6	2 : 00	8	6	1	0.0	8.2	GREY	CLAY		
														2	8.2	11.3		STONES	GRAVEL	
														3	11.3	14.0		STONES		
6603343	6169 Garner Rd	Niagara Falls Golf Club		12.8	STEEL	6	14.6	FRESH	4.9	6.1	1 : 30	35	50	1	0.0	12.2	GREY	CLAY		
							18.3	SULPHUR						2	12.2	21.9		STONES		
6603689		Plotted incorrectly				6					2 : 00	8	6	1	0.0	3.7	BROWN	CLAY		
														2	3.7	7.3	GREY	CLAY		
														3	7.3	8.2	GREY	CLAY	FILL	
														4	8.2	13.4	GREY	ROCK	LIMESTONE	
6603830	8522 Beaverdams Rd		12.2	13.7	OPEN HOLE	6	13.4	MINERAL	6.4	9.1			12	1	0.0	7.6	BROWN	CLAY	PACKED	
														2	7.6	10.7	RED	CLAY	PACKED	
														3	10.7	11.9	BROWN	GRAVEL	SILT	PACKED
														4	11.9	12.2	BROWN	SAND	GRAVEL	LOOSE
														5	12.2	12.5	GREY	SHALE	LAYERED	
														6	12.5	13.7	GREY	LIMESTONE	LAYERED	
6603833		Plotted incorrectly	10.4	13.7	OPEN HOLE	6	12.8	SULPHUR	6.1	12.8	1 : 00	4	3	1	0.0	8.8	BROWN	CLAY	PACKED	
														2	8.8	10.4	BROWN	GRAVEL	CLAY	PACKED
														3	10.4	13.7	GREY	LIMESTONE	LAYERED	
6603923	6169 Garner Rd	Niagara Falls Golf Club	13.1	16.5	OPEN HOLE	6	15.2	SULPHUR	6.7	7.6	2 : 15	16	15	1	0.0	0.9	GREY	GRAVEL	PACKED	
														2	0.9	6.1	BROWN	CLAY	PACKED	
														3	6.1	10.7	BROWN	CLAY	SOFT	
														4	10.7	12.8	BROWN	CLAY	STONES	PACKED
														5	12.8	13.4	BROWN	SHALE	LAYERED	
														6	13.4	16.5	GREY	LIMESTONE		
6603926	9301 Beaverdams Rd		0.0	14.9	STEEL	6	14.3	SULPHUR	4.9	14.6	1 : 00	15	8	1	0.0	0.9	BROWN	CLAY	TOPSOIL	
														2	0.9	4.6	GREY	CLAY		
														3	4.6	11.3	GREY	CLAY	GRAVEL	
														4	11.3	14.9		LIMESTONE		
6603942	10148 Beaverdams Rd		6.1	7.0	OPEN HOLE	5	7.0	FRESH	4.6	4.6	1 : 30	16		1	0.0	3.0	BROWN	CLAY	PACKED	
														2	3.0	3.4	GREY	SHALE	LOOSE	
														3	3.4	7.0	GREY	SHALE	LAYERED	
6603989	10148 Beaverdams Rd		0.0	32.6	STEEL	6	18.3	Not stated	6.1		1 : 30	40	30	1	0.0	0.6	BROWN	CLAY		
							29.0	SULPHUR						2	0.6	1.8	GREY	CLAY		
														3	1.8	4.6	GREY	CLAY	BOULDERS	
														4	4.6	32.6		LIMESTONE		

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	EASTING	NORTHING	ACCURACY	Date Completed	Contractor	COUNTY	TWP	Final Status	1st Use	2nd Use	Drilling Method
6603998	5021 Garner Rd		650074	4773308	Lot centroid	1-Apr-91	Ken Schooley	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6604066		Plotted incorrectly	649043	4772824	Lot centroid	18-Oct-91	Field Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic	Livestock	Rotary (Air)
6604068	4491 Garner Rd		650005	4774525	Lot centroid	28-Nov-91	Field Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Rotary (Air)
6604085			650189	4771235	Lot centroid	27-May-92	Field Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Rotary (Air)
6604115	9941 Highway 20	Lundy Manor Wine Cellars	649076	4772017	Lot centroid	8-Apr-92	Field Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Rotary (Air)
6604439	9332 Thorold Stone Rd		649980	4774916	Lot centroid	8-May-00	Field Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Rotary (Air)
6604653		Plotted incorrectly	649328	4772130		8-May-02	Donald Merritt	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6604675	5769 Beechwood Rd		649058	4772420	Lot centroid	31-Aug-02	Ted Vander Zalm Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
6604682	5021 Garner Rd		650064	4773452	from gis	4-Oct-02	Ted Vander Zalm	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Water Supply	Domestic		Cable Tool
7048238	4810 Garner Rd		650606	4773782	on WWR	19-Jul-07	Circle Eddy's Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY (STAMFORD)	Water Supply	Domestic		Cable Tool
7118141		Plotted incorrectly	648524	4773429	from gis		Field Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY (STAMFORD)	Abandoned-Other			
7126686		Plotted incorrectly	649504	4773262	on WWR	26-Jun-09	Field Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY (STAMFORD)	Abandoned-Quality			
7126689	4810 Garner Rd		650630	4773858	on WWR	1-Jan-09	Field Well Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY (STAMFORD)	Abandoned-Other			
7171093		WAI owned, site wells Plotted incorrectly	648502	4773354	on WWR	1-Oct-11	Aardvark Drilling Inc	NIAGARA (WELLAND)	NIAGARA FALLS CITY				
7184885	5021 Garner Rd	Decom 5 wells	650269	4773325	from gis	17-Jul-12	Elite Drilling Services	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Abandoned-Other			

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	Screen Depth (m BGS)				Water Depth (m)		Pumping Test Data					Formation Depth (m BGS)						
			Top	Bottom	Type	Dia (in)	Depth	TYPE	Static WL (m)	Final WL (m)	Duration	Rate (GPM)	Recommended Rate (GPM)	Layer	Top	Bottom	Description			
6603998	5021 Garner Rd		11.6	11.9	OPEN HOLE	6	11.9	FRESH	2.4	5.8	1 : 30			1	0.0	5.5	BROWN	CLAY	FINE GRAVEL	PACKED
														2	5.5	6.4	BROWN	CLAY	FINE SAND	LOOSE
														3	6.4	7.3	BROWN	CLAY	STONES	PACKED
														4	7.3	8.2	BROWN	CLAY	FINE SAND	PACKED
														5	8.2	10.1	BROWN	CLAY	FINE SAND	FINE GRAVEL
														6	10.1	11.9	GREY	FINE GRAVEL		
6604066		Plotted incorrectly	0.0	11.6		6	11.3	FRESH	6.7	10.7	1 : 00	6	6	1	0.0	1.2	BROWN	CLAY	TOPSOIL	
														2	1.2	6.7	GREY	CLAY		
														3	6.7	8.2	GREY	CLAY	GRAVEL	
														4	8.2	11.6	GREY	LIMESTONE		
6604068	4491 Garner Rd			14.6	STEEL	6	14.6	FRESH	7.0	16.5	1 : 00	5	3	1	0.0	0.9	BROWN	CLAY		
														2	0.9	8.2	GREY	CLAY		
														3	8.2	16.5	GREY	CLAY	GRAVEL	
														4	16.5	16.5		LIMESTONE		
6604085				18.3		6	16.8	FRESH	5.5	16.8	1 : 00	8	6	1	0.0	1.2	BROWN	CLAY		
														2	1.2	9.8	GREY	CLAY		
														3	9.8	13.7	GREY	GRAVEL		
														4	13.7	18.3		LIMESTONE		
6604115	9941 Highway 20	Lundy Manor Wine Cellars	0.0	13.4	STEEL	6	12.2	FRESH	2.4	12.2	1 : 00	10	5	1	0.0	0.9	BROWN	CLAY		
														2	0.9	4.9	GREY	CLAY		
														3	4.9	9.1	GREY	CLAY	BOULDERS	
														4	9.1	13.4		LIMESTONE		
6604439	9332 Thorold Stone Rd			19.2	STEEL	6	11.6	FRESH	4.0		1 : 00	20	15	1	0.0	0.3	BROWN	CLAY		
							16.8	SULPHUR						2	0.3	8.8	GREY	CLAY		
														3	8.8	10.1	GREY	CLAY	GRAVEL	
														4	10.1	19.2		ROCK	LIMESTONE	
6604653		Plotted incorrectly			OPEN HOLE	6	11.9	Not stated	4.6	7.6	1 : 20	15	14	1	0.0	6.1	BROWN	CLAY	PACKED	
							12.5	Not stated						2	6.1	8.5	RED	CLAY	DENSE	
							13.4	SULPHUR						3	8.5	9.1	BROWN	STONES	CLAY	PACKED
														4	9.1	10.4	BROWN	GRAVEL	CLAY	PACKED
														5	10.4	13.7	GREY	LIMESTONE	LAYERED	
6604675	5769 Beechwood Rd				OPEN HOLE	6	15.5	FRESH	6.1	12.2	1 : 00	20	15	1	0.0	0.6	GREY	TOPSOIL		
														2	0.6	7.6	GREY	CLAY	GRAVEL	
														3	7.6	15.5	GREY	CLAY	GRAVEL	HARD
														4	15.5	16.2	GREY	GRAVEL		
6604682	5021 Garner Rd				OPEN HOLE	6	12.8	FRESH	7.6	10.7	1 : 00	10	10	1	0.0	0.6	GREY	TOPSOIL		
														2	0.6	6.1	GREY	CLAY	BOULDERS	
														3	6.1	9.1	GREY	CLAY		
														4	9.1	12.2	GREY	CLAY		
														5	12.2	14.0	GREY	CLAY		
7048238	4810 Garner Rd		11.8	12.5	OPEN HOLE	6	12.0	SULPHUR	4.9	11.2	1 : 00	15	3	1	0.0	0.6	BROWN	TOPSOIL		
														2	0.6	3.0	GREY	CLAY	HARD	
														3	3.0	9.1	GREY	CLAY	SOFT	
														4	9.1	12.5	GREY	LIMESTONE		
7118141		Plotted incorrectly																		
7126686		Plotted incorrectly																		
7126689	4810 Garner Rd								2.4		1 : 00									
7171093		WAI owned, site wells Plotted incorrectly																		
7184885	5021 Garner Rd	Decom 5 wells																		

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	EASTING	NORTHING	ACCURACY	Date Completed	Contractor	COUNTY	TWP	Final Status	1st Use	2nd Use	Drilling Method
7187227	5635 Garner Rd	Cytec Inc. Soil investigation, 14 BHs Fernwood Woodlot Park	650527	4772682	on WWR	26-Apr-12	Determination Drilling	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Observation Wells	Monitoring		Boring
7194083		WAI owned MW11-01	648557	4772378	on WWR	30-Nov-12	Aardvark Drilling Inc	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Monitoring and Test Hole	Test Hole		Diamond
7194084		WAI owned MW11-02	649532	4772903	on WWR	30-Nov-12	Aardvark Drilling Inc	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Monitoring and Test Hole	Monitoring and Test Hole		Diamond
7194085	9903 Uppers Ln	WAI owned MW11-03	649491	4773345	on WWR	30-Nov-12	Aardvark Drilling Inc	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Monitoring and Test Hole	Monitoring and Test Hole		Diamond
7194086		WAI owned MW11-04	648547	4773461	on WWR	30-Nov-12	Aardvark Drilling Inc	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Monitoring and Test Hole	Monitoring and Test Hole		Diamond
7218343	5545 Beechwood Rd	WAI owned	649515	4772762	on WWR	11-Dec-13	All Halton Water Service	NIAGARA (WELLAND)	NIAGARA FALLS CITY	Abandoned-Other			
7246491	6508 Beechwood Rd		649704	4771295	on WWR	6-Jul-15	Ted Van Der Zalm & Family	NIAGARA (WELLAND)	NIAGARA FALLS CITY				

Table B-1 MECP WWIS Report

MECP WWR No.	ADDRESS	COMMENTS	Screen Depth (m BGS)				Water Depth (m)		Pumping Test Data					Formation Depth (m BGS)			
			Top	Bottom	Type	Dia (in)	Depth	TYPE	Static WL (m)	Final WL (m)	Duration	Rate (GPM)	Recommended Rate (GPM)	Layer	Top	Bottom	Description
7187227	5635 Garner Rd	Cytec Inc.	8.0	18.0	PLASTIC	0.75								1	0.0	18.0	RED CLAY DENSE
		Soil investigation, 14 BH															
		Fernwood Woodlot Park															
7194083		WAI owned	16.9	19.9	PLASTIC	1.75											
		MW11-01	41.0	43.8	PLASTIC												
7194084		WAI owned	10.1	13.1	PLASTIC	1.75											
		MW11-02	40.5	43.6	PLASTIC												
7194085	9903 Uppers Ln	WAI owned	6.9	9.9	PLASTIC	1.75											
		MW11-03	26.4	29.4	PLASTIC												
7194086		WAI owned	14.2	17.2	PLASTIC	1.75											
		MW11-04	37.8	40.8	PLASTIC												
7218343	5545 Beechwood Rd	WAI owned															
7246491	6508 Beechwood Rd																

Table B-2 2018 / 2019 Water Well Survey

Address	Water Well Plots on Property	MECP WWR No.		Building on Property	Comments	Source	Responded to Survey	Owner Name	Supply	Use
		Well 1	Well 2							
1. 1006 Beaverdams Road	Yes	6601650		Yes	Residence	Door-to-Door Survey	✓	Descoteaux	Cistern / Well	Domestic (Cistern) / Garden (Well)
2. 1021 Beaverdams Road	Multiple			Yes	Residence and farm field	Door-to-Door Survey	✓	Cupolo	Cistern / Well	Garden (Rooftop Cistern) / Domestic (Well)
3. 1024 Beaverdams Road	No			Yes	Residence, farm field	Door-to-Door Survey	✓	Gatti	Well	Domestic / Garden
4. 1067 Beaverdams Road	No			Yes	Residence	Door-to-Door Survey	✓	Memath	Cistern / Well	Domestic (Cistern) / Not in use (Well)
5. 1098 Beaverdams Road	No			Yes	Residence	Door-to-Door Survey	✓	Morrow	Cistern / Well	Domestic / Garden
6. 1108 Beaverdams Road	No			Yes	Thorold Auto Parts & Recyclers	Door-to-Door Survey	(in person)		Cistern	Domestic/ Business
7. 8357 Beaverdams Road	No			Yes	Residence	Door-to-Door Survey				
8362 Beaverdams Road	Yes			No	House appears to have been demolished	Door-to-Door Survey	(no mailbox)			
8. 8395 Beaverdams Road	Yes			Yes	Residence	Door-to-Door Survey				
9. 8436 Beaverdams Road	No			Yes	Residence	Door-to-Door Survey				
10. 8522 Beaverdams Road	Yes			Yes	Residence and farm field	Door-to-Door Survey	(in person)		Cistern	Domestic
11. 8698 Beaverdams Road	No			Yes	Van Der Weyden Greenhouses	Door-to-Door Survey	(in person)		Well	Dug well not in use
12. 8828 Beaverdams Road	No			Yes	Residence and farm field	Door-to-Door Survey				
13. 8980 Beaverdams Road	No			Yes	Residence	Door-to-Door Survey	✓		Well	Likely Domestic
14. 9301 Beaverdams Road	Multiple			Yes	Residence	Door-to-Door Survey	✓	McMaster	Well	Domestic / Livestock / Garden
15. 9337 Beaverdams Road	No			Yes	Residence and vehicle lot, storage	Door-to-Door Survey	✓	Picciariello	Cistern / Well	Domestic (Cistern) / Not in use (Well)
16. 9417 Beaverdams Road	Multiple			Yes	Residence, farm field, pond, creek, forested area	Door-to-Door Survey	✓	Muir	Cistern / Well	Domestic (Cistern and Well) / Garden (Well)
17. 9582 Beaverdams Road	No			Yes	Rural office and rental home	Door-to-Door Survey	✓	Panoramic Properties	Well	Domestic
18. 9722 Beaverdams Road	Yes	6601333		Yes	Residence and forested area	Door-to-Door Survey	✓		Cistern	Domestic / Garden
19. 10138 Beaverdams Road	No			Yes	Residence	Door-to-Door Survey	✓	Micieli	Cistern / Well	Domestic (Cistern) / Garden (Well)
20. 10148 Beaverdams Road	Multiple			Yes	Residence and farm field, creek	Door-to-Door Survey	✓	Folkes	Cistern / Well	Domestic (Cistern) / Irrigation (Well)
21. 9332 Thorold Stone Road	Yes			Yes	Residence and farm field, part of Walker Bros Quarry monitoring program	Door-to-Door Survey		Colavecchia	Well	Domestic
22. 3219 Townline Road	No			Yes	Residence	Door-to-Door Survey	✓	Malenfant	Cistern / Well	Domestic (Cistern) / Not in use (Well)
23. 3237 Townline Road	No			Yes	Residence, forested area	Door-to-Door Survey	✓	Visca	Cistern / Well	Domestic (Cistern) / Garden (Well)
24. 3269 Townline Road	Yes	6601652		Yes	Residence	Door-to-Door Survey				
25. 3279 Townline Road	No			Yes	Residence	Door-to-Door Survey	✓	Wright	Cistern / Well	Domestic (Cistern) / Garden (Well)
26. 3285 Townline Road	No			Yes	Residence	Door-to-Door Survey				
27. 3295 Townline Road	No			Yes	Residence	Door-to-Door Survey				
28. 4366 Townline Road	Yes	6601327		Yes	Residence, part of Walker Bros Quarry monitoring program	Door-to-Door Survey		Mirynech	Well	Domestic
29. 4556 Townline Road	No			Yes	Residence	Door-to-Door Survey	✓	Gould	Well	Domestic
30. 4580 Townline Road	No			Yes	Residence	Door-to-Door Survey				
31. 4680 Townline Road	No			Yes	Beechwood Golf & Country Club	Door-to-Door Survey	✓		Cistern / Well	Domestic (Cistern) / Cart Washing (Well)

Table B-2 2018 / 2019 Water Well Survey

Address	Water Well Plots on Property	MECP WWR No.		Building on Property	Comments	Source	Responded to Survey	Owner Name	Supply	Use
		Well 1	Well 2							
32. 5114 Townline Road	Yes			No	Niagara Cricket Centre	Door-to-Door Survey	✓		Well	Domestic / Irrigation
33. 6200 Townline Road	No			Yes	Italo Canadian Centennial Club, forested area	Door-to-Door Survey	✓		Cistern	Domestic
34. 6666 Townline Road	No			Yes	Residence	Door-to-Door Survey	(in person)		Well	Well use not specified
35. 6848 Townline Road	Yes			Yes	Residence	Door-to-Door Survey	(in person)		Well	Well use not specified
4389 Beechwood Road	Yes			Yes	Residence, forested area, creek	Door-to-Door Survey	(no mailbox)			
36. 4410 Beechwood Road	No			Yes	Residence, farm field	Door-to-Door Survey	✓	Masterson	Cistern / Well	Domestic (Cistern) / Well use not specified
37. 4500 Beechwood Road	No			Yes	Residence, farm field	Door-to-Door Survey	✓	Brown	Well	Domestic / Garden
4555 Beechwood Road	Yes	6603043		No	Forested area, house appears abandoned	Door-to-Door Survey	(no mailbox)			
38. 4642 Beechwood Road	No			Yes	Residence, farm field	Door-to-Door Survey	✓	Young	Cistern / Well	Domestic
39. 5329 Beechwood Road	No			Yes	Bible Baptist Church, recently severed	Door-to-Door Survey	✓		Cistern	Domestic
40. 5584 Beechwood Road	No			Yes	Residence, forested area, hobby farm	Door-to-Door Survey	✓	Hong	Well	Domestic / Livestock / Garden
41. 5769 Beechwood Road	Yes	6604675		Yes	Residence, farm field, creek	Door-to-Door Survey	✓	Gortson	Cistern / Well	Domestic (Cistern) / Not in use (Well)
42. 5821 Beechwood Road	No			Yes	Residence	Door-to-Door Survey	✓	Matyas	Well	Domestic
43. 6060 Beechwood Road	Yes	6601361		Yes	Residence	Door-to-Door Survey	✓		Well	Well use not specified
44. 6070 Beechwood Road	No			Yes	Residence	Door-to-Door Survey				
45. 6393 Beechwood Road	Yes			Yes	Residence, forested area	Door-to-Door Survey				
46. 6508 Beechwood Road	Yes			Yes	Residence and farm field	Door-to-Door Survey				
6582 Beechwood Road	No			No	Farm	Door-to-Door Survey	(no mailbox)			
47. 6771 Beechwood Road	No			Yes	Niagara Lawn & Garden Maintenance	Door-to-Door Survey				
48. 4255 Garner Road	Multiple			Yes	Residence and farm field	Door-to-Door Survey	✓	Bradley	Cistern / Well	Domestic (Cistern) / Not in use (Well)
49. 4282 Garner Road	Yes			Yes	Residence	Door-to-Door Survey	(in person)		Well	Well use not specified
50. 4303 Garner Road	Yes			Yes	Residence and farm field	Door-to-Door Survey	✓	Liefl	Cistern / Well	Domestic (Cistern) / Garden (Well)
51. 4326 Garner Road	No			Yes	Residence	Door-to-Door Survey	(in person)		Well	Well use not specified
52. 4486 Garner Road	No			Yes	Residence	Door-to-Door Survey	✓	DeGiuli	Cistern / Well	Domestic (Cistern) / Garden (Well)
53. 4491 Garner Road	Yes			Yes	Residence, farm field, creek	Door-to-Door Survey				
54. 4622 Garner Road	No			Yes	Residence	Door-to-Door Survey				
55. 4694 Garner Road	No			Yes	Residence	Door-to-Door Survey	✓	Campbell	Cistern / Well	Domestic (Cistern) / Garden (Well)
56. 4722 Garner Road	No			Yes	Residence	Door-to-Door Survey	(in person)		Well	Well use not specified
57. 4750 Garner Road	No			Yes	Residence	Door-to-Door Survey	(in person)		Well	Well use not specified
58. 4810 Garner Road	Multiple			Yes	Residence and farm field	Door-to-Door Survey				
59. 4843 Garner Road	Yes			Yes	Residence	Door-to-Door Survey	✓	Grandoni	Well	Domestic
60. 5002 Garner Road	Yes			Yes	Niagara Honey	Door-to-Door Survey	✓	Bradley	Well	Domestic / Livestock / Garden
5021 Garner Road	Multiple			No	Farm field, creek, wetland	Door-to-Door Survey	(no mailbox)			
61. 5484 Garner Road	No			Yes	Residence	Door-to-Door Survey	✓	Vanderweyden	Cistern	Domestic

Table B-2 2018 / 2019 Water Well Survey

Address	Water Well Plots on Property	MECP WWR No.		Building on Property	Comments	Source	Responded to Survey	Owner Name	Supply	Use
		Well 1	Well 2							
62. 6169 Garner Road	Multiple			Yes	Niagara Falls Golf Club	Door-to-Door Survey	✓	Grawey (Superintendent)	Municipal Service / Well	Domestic (Municipal Service) / Irrigation (Well)
63. 13011 Highway 20	Multiple			Yes	Little Bros Service Centre	Door-to-Door Survey	✓		Well	Domestic
64. 13029 Highway 20	No			Yes	Repairs 1 Fast	Door-to-Door Survey	✓		Cistern	Domestic
65. 13030 Highway 20	Multiple			Yes	L8 Club & Express Inn, recent ownership change	Door-to-Door Survey	✓	Rudan	Cistern / Well	Domestic
66. 13045 Highway 20	Yes	6601714		Yes	Golden Gardens Supply Co.	Door-to-Door Survey	✓	Gendron	Well	Domestic / Garden
67. 13055 Highway 20	Multiple			Yes	Milan Garden Inn	Door-to-Door Survey				
68. 13058 Highway 20	No			No	Farm field	Door-to-Door Survey				
13065 Highway 20	Multiple			No	Vacant lot	Door-to-Door Survey	(no mailbox)			
69. 13071 Highway 20	No			Yes	Golf Inn Driving Range Hotel	Door-to-Door Survey				
70. 13084 Highway 20	No			Yes	Residence, farm field	Door-to-Door Survey	✓	Charles	Cistern	Domestic
71. 9552 Lundys Lane	No			Yes	Residence	Door-to-Door Survey	✓	Martin	Cistern / Well	Domestic (Cistern) / Garden (Well)
72. 9594 Lundys Lane	No			Yes	Residence	Door-to-Door Survey	✓	Ellison	Cistern	Domestic
73. 9624 Lundys Lane	Yes	6603168		Yes	Residence	Door-to-Door Survey	✓	Kim	Cistern	Livestock
74. 9941 Lundys Lane	Yes	6604115		Yes	Lundy Manor Wine Cellars	Door-to-Door Survey	✓	Kern	Well	Domestic / Irrigation
75. 9944 Lundys Lane	No			Yes	Residence, pond, greenhouses	Door-to-Door Survey	✓	Bongers	Well	Domestic / Garden
76. 10008 Lundys Lane	Yes	6602354		Yes	Country Basket Garden Centre	Door-to-Door Survey	✓	Bongers	Well	Domestic / Livestock / Garden
77. 9787 Nichols Lane	No			Yes	Residence	Door-to-Door Survey				
78. 9811 Nichols Lane	No			Yes	Residence	Door-to-Door Survey	✓	Norris	Well	Likely Domestic
79. 9858 Nichols Lane	Yes	6603264		Yes	Residence, farm field	Door-to-Door Survey	✓		Well	Likely Domestic
80. 9961 Nichols Lane	Multiple			Yes	Residence, forested area, farm, pond, creek	Door-to-Door Survey	✓	Fyfe	Cistern	Domestic / Livestock

APPENDIX

C

BOREHOLE LOGS AND WELL CONSTRUCTION DETAILS

Table C-1 Monitoring Well Details

Well ID	Monitor Installation Date	Well Pipe Diameter mm	Ground Elevation	Top of Pipe Elevation	Screened Interval	Filter Pack	Seal	Surface Seal	Hydrostratigraphic Unit
1. BH03-2A	2003	26	184.33	185.01	143.5 - 146.5	143.5 - 147.1	147.1 - 184.3		Deep bedrock aquifer
2. BH03-2B	2003	26	184.33	184.98	164.5 - 167.6	164.5 - 169.7	169.7 - 184.3		Shallow bedrock aquifer
3. MW11-1A	2011	32	181.04	182.03	137.2 - 140.0	137.2 - 141.6	141.6 - 161.0		DeCew / Rochester aquitard
4. MW11-1B	2011	32	181.04	181.95	161.1 - 164.2	161.0 - 171.0	171.0 - 181.0		Shallow bedrock aquifer
5. MW11-1OB	2011	51	181.02	181.86	173.4 - 176.4				Contact Aquifer
6. MW11-2A	2011	32	184.22	185.10	140.6 - 143.7	140.6 - 147.0	147.0 - 170.8		DeCew / Rochester aquitard
7. MW11-2B	2011	32	184.22	185.06	171.1 - 174.2	170.8 - 174.6	174.6 - 184.2		Shallow bedrock aquifer
8. MW11-2OB	2011	51	184.22	185.13	179.6 - 181.2				Contact Aquifer
MW11-3A [d]	2011	32							
MW11-3B [d]	2011	32							
MW11-3OB [d]	2011	51							
9. MW11-3AR	2016	51	178.65	179.74	149.5 - 152.6	149.4 - 153.0	153.0 - 177.4	177.4 - 178.6	Deep bedrock aquifer
10. MW11-3BR	2016	51	178.69	179.76	167.9 - 171.0	167.8 - 172.0	172.0 - 178.1	178.1 - 178.7	Shallow bedrock aquifer
11. MW11-3OBR	2016	51	178.64	179.79	174.4 - 177.4	174.2 - 177.7	177.7 - 178.3	178.3 - 178.6	Contact Aquifer
12. MW11-4A	2011	32	181.64	182.46	140.8 - 143.8	140.8 - 147.8	147.8 - 164.1		DeCew / Rochester aquitard
13. MW11-4B	2011	32	181.64	182.45	164.4 - 167.5	164.1 - 174.6	174.6 - 181.6		Shallow bedrock aquifer
14. MW11-4OB	2011	51	181.63	182.56	177.1 - 180.1				Contact Aquifer
PW1	2016	203	184.08	184.78	138.7 - 178.0		178.0 - 184.1		Shallow / Deep bedrock aquifers
15. MW16-5A	2016	51	179.53	180.54	148.0 - 151.0	147.8 - 151.5	151.5 - 179.2	179.2 - 179.5	Deep bedrock aquifer
16. MW16-5AR	2017	51	179.73	180.77	148.2 - 151.3	148.2 - 151.1	151.1 - 179.2	179.2 - 179.5	Deep bedrock aquifer
17. MW16-5B	2016	51	179.58	180.65	169.0 - 172.0	168.8 - 172.9	172.9 - 179.0	179.0 - 179.6	Shallow bedrock aquifer
18. MW16-5OB	2016	51	179.52	180.56	174.5 - 177.5	174.3 - 178.0	178.0 - 178.9	178.9 - 179.5	Contact Aquifer
19. MW16-6A	2016	51	181.46	182.50	151.1 - 154.2	151.0 - 154.6	154.6 - 180.9	180.9 - 181.5	Deep bedrock aquifer
20. MW16-6B	2016	51	181.51	182.60	171.3 - 174.3	171.1 - 174.8	174.8 - 180.9	180.9 - 181.5	Shallow bedrock aquifer
21. MW16-6OB	2016	51	181.56	182.68	177.3 - 180.3	177.1 - 180.8	180.8 - 181.3	181.3 - 181.6	Contact Aquifer

Notes:
- Elevations provided in metres above sea level (mASL)
- Survey for ground surface / top of pipe elevations completed in 2016.
- Blank indicates that data is not available

Table C-1 Monitoring Well Details

Well ID	Monitor Installation Date	Well Pipe Diameter mm	Ground Elevation	Top of Pipe Elevation	Screened Interval	Filter Pack	Seal	Surface Seal	Hydrostratigraphic Unit
22. MW16-7A	2016	51	180.30	181.32	141.7 - 144.8	141.6 - 145.2	145.2 - 179.7	179.7 - 180.3	Deep bedrock aquifer
23. MW16-7B	2016	51	180.36	181.34	161.0 - 164.1	160.9 - 166.0	166.0 - 179.8	179.8 - 180.4	Shallow bedrock aquifer
24. MW16-7OB	2016	51	180.36	181.36	174.5 - 177.6	174.4 - 178.2	178.2 - 180.1	180.1 - 180.4	Contact Aquifer
25. MW16-8A	2016	51	185.98	186.84	138.0 - 141.0	137.8 - 141.6	141.6 - 185.1	185.1 - 186.0	Deep bedrock aquifer
26. MW16-8B	2016	51	185.96	186.99	160.0 - 163.1	159.9 - 163.6	163.6 - 185.0	185.0 - 186.0	Shallow bedrock aquifer
27. MW16-8OB	2016	51	185.97	186.87	175.4 - 178.4	175.2 - 179.2	179.2 - 185.4	185.4 - 186.0	Contact Aquifer
28. MW16-9A	2016	51	181.97	183.10	143.0 - 146.1	142.9 - 146.7	146.7 - 181.1	181.1 - 182.0	Deep bedrock aquifer
29. MW16-9B	2016	51	182.06	183.15	164.5 - 167.6	164.4 - 169.9	169.9 - 181.1	181.1 - 182.1	Shallow bedrock aquifer
30. MW16-9OB	2016	51	182.08	183.10	174.6 - 177.7	174.5 - 178.1	178.1 - 181.5	181.5 - 182.1	Contact Aquifer
31. MW16-9SP	2017	51	182.16	183.27	179.4 - 181.1	179.4 - 181.2		181.2 - 182.2	Shallow weathered overburden
32. MW16-10A	2016	51	181.81	183.01	148.0 - 151.0	147.8 - 151.6	151.6 - 180.3	180.3 - 181.8	Deep bedrock aquifer
33. MW16-10B	2016	51	181.91	182.96	171.3 - 174.3	171.1 - 174.9	174.9 - 181.3	181.3 - 181.9	Shallow bedrock aquifer
34. MW16-10OB	2016	51	181.80	182.96	176.5 - 179.5	176.3 - 180.3	180.3 - 181.2	181.2 - 181.8	Contact Aquifer
35. MW16-11	2016	51	182.85	183.72	176.1 - 179.2	176.0 - 179.8	179.8 - 182.2	182.2 - 182.9	Contact Aquifer
36. MW16-12	2016	51	183.64	184.75	179.7 - 182.7	179.5 - 183.0	183.0 - 183.3	183.3 - 183.6	Contact Aquifer
37. MW16-13A	2016	51	185.23	186.27	143.2 - 146.2	143.0 - 146.8	146.8 - 184.3	184.3 - 185.2	Deep bedrock aquifer
38. MW16-13B	2016	51	185.23	186.18	165.5 - 168.6	165.4 - 170.0	170.0 - 184.3	184.3 - 185.2	Shallow bedrock aquifer
39. MW16-13OB	2016	26	185.22	186.25	180.6 - 184.2	180.4 - 184.0	184.0 - 184.6	184.6 - 185.2	Contact Aquifer
40. MW16-14	2016	51	184.00	184.99	179.5 - 182.6	179.4 - 183.1	183.1 - 183.7	183.7 - 184.0	Contact Aquifer
41. MW16-15	2016	51	182.24	183.05	177.0 - 180.0	176.8 - 180.4	180.4 - 181.6	181.6 - 182.2	Contact Aquifer
42. MW16-16	2016	51	178.78	179.71	171.5 - 174.5	171.3 - 175.0	175.0 - 178.2	178.2 - 178.8	Contact Aquifer
43. MW16-17	2016	51	177.42	178.30	172.0 - 175.1	171.9 - 175.6	175.6 - 176.8	176.8 - 177.4	Contact Aquifer
44. MW16-18B	2016	51	176.23	177.17	172.0 - 173.6	171.8 - 174.1	174.1 - 175.6	175.6 - 176.2	Shallow bedrock aquifer
45. MW16-18OB	2016	51	176.36	177.24	175.1 - 175.7	175.1 - 175.9		175.9 - 176.4	Contact Aquifer
46. MW16-19B	2016	51	176.39	177.45	172.3 - 173.8	172.1 - 174.4	174.4 - 175.8	175.8 - 176.4	Shallow bedrock aquifer
47. MW16-19OB	2016	51	176.39	177.38	175.2 - 175.8	175.2 - 175.9		175.9 - 176.4	Contact Aquifer

Notes: • Elevations provided in metres above sea level (mASL)
• Survey for ground surface / top of pipe elevations completed in 2016.
• Blank indicates that data is not available

Table C-1 Monitoring Well Details

Well ID	Monitor Installation Date	Well Pipe Diameter mm	Ground Elevation	Top of Pipe Elevation	Screened Interval	Filter Pack	Seal	Surface Seal	Hydrostratigraphic Unit
48. MW17-20A	2017	51	186.04	186.91	140.6 - 143.6	140.6 - 144.3	144.3 - 185.5	185.5 - 186.0	Deep bedrock aquifer
49. MW17-20B	2017	51	186.03	187.08	166.9 - 170.0	166.9 - 170.6	170.6 - 185.5	185.5 - 186.0	Shallow bedrock aquifer
50. MW17-20OB	2017	51	186.02	187.22	181.3 - 182.8	181.3 - 183.1	183.1 - 185.5	185.5 - 186.0	Contact Aquifer
51. MW17-20SP	2017	51	185.98	187.16	183.5 - 184.7	183.5 - 185.1		185.1 - 186.0	Shallow weathered overburden
52. MW17-21B	2017	51	185.69	186.67	164.4 - 167.4	164.4 - 168.0	168.0 - 185.2	185.2 - 185.7	Shallow bedrock aquifer
53. MW17-21OB	2017	51	185.73	186.77	181.1 - 182.6	181.1 - 182.8	182.8 - 185.2	185.2 - 185.7	Contact Aquifer
54. MW17-21SP	2017	51	185.70	186.90	183.3 - 184.5	183.3 - 184.6		184.6 - 185.7	Shallow weathered overburden
55. MW17-22B	2017	51	183.50	184.46	166.1 - 169.2	165.8 - 169.9	169.9 - 183.0	183.0 - 183.5	Shallow bedrock aquifer
56. MW17-22OB	2017	51	183.49	184.53	180.4 - 181.4	180.4 - 181.5	181.5 - 183.0	183.0 - 183.5	Contact Aquifer
57. MW17-22SP	2017	51	183.51	184.62	181.7 - 182.6	181.7 - 182.7		182.7 - 183.5	Shallow weathered overburden
58. MW17-23B	2017	51	181.89	182.99	165.2 - 168.3	165.0 - 168.8	168.8 - 181.4	181.4 - 181.9	Shallow bedrock aquifer
59. MW17-23OB	2017	51	181.88	183.02	175.6 - 177.2	175.5 - 177.6	177.6 - 181.4	181.4 - 181.9	Contact Aquifer
60. MW17-23SP	2017	51	181.92	183.11	179.3 - 180.9	179.2 - 181.0		181.0 - 181.9	Shallow weathered overburden

Notes: • Elevations provided in metres above sea level (mASL)
• Survey for ground surface / top of pipe elevations completed in 2016.
• Blank indicates that data is not available

Table C-1 Monitoring Well Details

Residential Well Address	Alias	Installation Date	Well Pipe Diameter mm	Ground Elevation	Top of Pipe Elevation	Screened Interval	MECP WWR
1. 1024 Beaverdams Road	R1	2009	150	177.66	177.96	164.6 - 168.3	7278404
2. 5769 Beechwood Road	R2		150	185.62	183.85	173.6 -	
3. 10008 Lundys Lane	R3	1968	150	181.73	180.82	171.6 -	6602354
4. 13011 Highway 20	R4		150	185.62	185.92	165.7 -	
5. 5114 Townline Road	R5	2012	150	185.49	186.60	165.7 - 180.0	7184710
6. 4680 Townline Road	R6		914	176.27	176.41	174.1 -	
7. 9602 Beaverdams Road	R7		150	180.33	180.60	167.3 -	
8. 9941 Lundys Lane	R8	2002	150	183.91	184.14	171.1 -	6604653
9. 5205 Beechwood Road	R9		150	183.14	183.69	172.3 -	
10. 9903 Uppers Lane	R10		150	182.69	183.11	172.1 -	
11. 10148 Beaverdams Road	R11	1990	150				6603989
12. 6169 Garner Road	R12	1989	159	187.83	188.11	173.6 -	6603923
13. 4843 Garner Road	R13	1961	168		185.45		6601336

Notes: • Elevations provided in metres above sea level (mASL)
• Survey for ground surface / top of pipe elevations completed in 2018.
• Blank indicates that data is not available

Table C-1 Monitoring Well Details

Drivepoint / Staff Gauge ID	Installation Date	Pipe Diameter mm	Ground Elevation	Top of Pipe Elevation
1. DP1	2016	26	173.18	173.68
2. DP2	2016	26	175.08	175.34
3. DP3	2016	26	177.69	177.89
4. DP4	2016	26	179.68	179.82
5. DP5	2016	26	178.13	178.55
6. DP6	2017	38	185.92	187.09
7. DP7	2017	38	182.24	183.39
8. SW1	2016	26	175.28	175.90
9. SW2	2016	26	181.20	181.54
10. SW3	2016	26	178.91	180.21
11. SW4	2016	26	175.43	175.58

Notes:
- Elevations provided in metres above sea level (mASL)
- Survey for ground surface / top of pipe elevations completed in 2016.

Table C-2 Off-Site Well Details

Well ID	Site Name	UTM Coordinates		Monitor Installation Date	Ground Elevation	Bedrock Elevation	Bedrock Subcrop	Stratigraphic Contact Summary (masl)							Water Level Data		
		Easting	Northing					Guelph Formation	Lockport Eramosa Member	Lockport Goat Island Member	Lockport Gasport Member	DeCew Formation	Rochester Formation	Irondequoit Formation			
		m	m		masl										Date	masl	Formation
BH6	Abitibi Co-Gen Plant	646640	4774257	2006	176.52	163.12	(unspecified)	-	-	-	-	-	-	-	11-May-06	167.42	Overburden
BH14	Abitibi Co-Gen Plant	646579	4774238	2006	179.60	162.40	(unspecified)	-	-	-	-	-	-	-	09-May-06	164.46	Overburden
BH19	Abitibi Co-Gen Plant	646580	4774177	2006	178.13	163.93	(unspecified)	-	-	-	-	-	-	-	04-May-06	171.43	Overburden
MW1-I	Brown Road Landfill Site	648684	4768944	1984	181.07	165.83	Guelph Formation	-	-	-	-	-	-	-	18-Sep-84	176.31	Guelph Fm
MW2-I	Brown Road Landfill Site	650424	4768922	1984	180.16	162.35	Guelph Formation	-	-	-	-	-	-	-	18-Sep-84	175.88	Guelph Fm
MW3-I	Brown Road Landfill Site	649594	4768316	1984	178.56	160.02	Guelph Formation	-	-	-	-	-	-	-	18-Sep-84	175.61	Guelph Fm
MW4-I	Brown Road Landfill Site	649261	4767243	1984	176.62	156.38	Guelph Formation	-	-	-	-	-	-	-	18-Sep-84	174.42	Guelph Fm
MW5-I	Brown Road Landfill Site	650344	4767373	1984	175.95	155.93	Guelph Formation	-	-	-	-	-	-	-	18-Sep-84	174.11	Guelph Fm
OW12	Mountain Road Landfill Site	653331	4778385	1985	175.29	169.90	Lockport Gasport Member	-	-	-	-	-	-	-	12-Apr-16	172.73	Gasport Mb
OW54(23)	Mountain Road Landfill Site	652517	4777526	2012	195.42	195.42	Lockport Goat Island Member	-	-	-	174.82	169.12	-	-	14-Oct-16	178.42	Overburden
CMT3	Mountain Road Landfill Site	652741	4777578	2007	202.00	178.60	Lockport Gasport Member	-	-	-	-	168.70	167.60	-	14-Oct-16	182.2	Gasport Mb
CMT5	Mountain Road Landfill Site	652386	4778554	2007	174.30	170.60	Lockport Gasport Member	-	-	-	-	165.60	164.30	-	14-Oct-16	168.9	Gasport Mb
CRA-11D-09	Niagara Recycling Centre	652979	4773755	2009	193.60	183.24	Lockport Eramosa Member	-	-	-	-	-	-	-	10-Oct-14	184.90	Eramosa Mb
IW6	Niagara Recycling Centre	652985	4773843	2006	193.16	182.36	(unspecified)	-	-	-	-	-	-	-	10-Oct-14	184.21	(bedrock)
OW13D	Niagara Recycling Centre	652871	4773896	2003	193.20	182.20	(unspecified)	-	-	-	-	-	-	-	10-Oct-14	184.53	(bedrock)
MW10 (NF-30)	Niagara Tunnel Project	656361	4777364	1991	181.06	164.59	Lockport Gasport Member	-	-	-	-	157.61	155.21	136.96			
MW14	Niagara Tunnel Project	656540	4769926	2005	184.04	154.17	Lockport Eramosa Member	-	-	-	-	118.08	115.42	97.54	23-Oct-13	169.80	Eramosa Mb
NF-28	Niagara Tunnel Project	655800	4773685	1991	185.06	169.36	Lockport Goat Island Member	-	-	-	163.06	151.89	149.14	131.49			
BadenPowell (BH31)	NPCA Monitoring Well	652903	4767379	2014	176.63	150.13	Salina Formation	-	-	-	-	-	-	-			
YoungMatthews (BH11)	NPCA Monitoring Well	649479	4763858	2014	181.92	155.82	Guelph Formation	-	-	-	-	-	-	-			
BH03-1	Rolling Meadows	647685	4772408	2003	182.50	176.50	Lockport Eramosa Member	-	-	161.00	149.80	-	-	-			
BH03-3	Rolling Meadows	648112	4771708	2003	186.50	175.90	Guelph Formation	-	173.60	154.80	143.60	134.00	131.10	-			
BH03-4	Rolling Meadows	647569	4771341	2003	183.00	172.70	Guelph Formation	-	170.70	152.90	141.60	132.00	-	-			
4-I	Walker Brothers Quarry	647829	4776539	1976	180.09	168.96	(unspecified)	-	-	-	-	-	-	-	03-Aug-17	169.08	Lockport
19-1R2	Walker Brothers Quarry	649320	4777011	2015	183.90	177.10	Lockport (undifferentiated)	-	-	-	-	169.00	166.40	-	07-Sep-17	172.70	Rochester Fm
40-1r	Walker Brothers Quarry	649322	4776674	2016	184.30	177.60	Lockport Gasport Member	-	-	-	-	167.10	165.60	146.90	07-Sep-17	160.01	Irondequoit Fm
51-I	Walker Brothers Quarry	650399	4776396	1988	184.70	178.90	Lockport (undifferentiated)	-	-	-	-	165.30	163.90	-	07-Sep-17	180.58	Lockport
55-I	Walker Brothers Quarry	648943	4775340	1990	177.87	170.67	Lockport Goat Island Member	-	-	-	162.77	156.27	154.27	-	07-Sep-17	170.31	Lockport

Notes: • Elevations provided in metres above sea level (masl)

Table C-2 Off-Site Well Details

Well ID	Site Name	UTM Coordinates Easting (m)	UTM Coordinates Northing (m)	Monitor Installation Date	Ground Elevation (masl)	Bedrock Elevation (masl)	Bedrock Subcrop	Stratigraphic Contact Summary (masl): Guelph Formation	Lockport Eramosa Member	Lockport Goat Island Member	Lockport Gasport Member	DeCew Formation	Rochester Formation	Irondequoit Formation	Water Level Data: Date	masl	Formation
C-2	(Bolton, 1957)	656099	4775820	1949	181.14	166.63	Lockport Goat Island Member	-	-	-	164.81	158.07	154.63	137.37			
D-1	(Bolton, 1957)	655977	4775611	1949	180.53	169.01	Lockport Goat Island Member	-	-	-	164.74	158.04	155.27	137.56			
D-3	(Bolton, 1957)	655740	4775042	1949	184.43	168.13	Lockport Goat Island Member	-	-	-	163.01	155.66	153.16	135.64			
E-2	(Bolton, 1957)	655715	4773202	1949	185.93	166.48	Lockport Eramosa Member	-	-	164.13	159.17	146.09	143.26	126.31			
E-8	(Bolton, 1957)	656949	4770385	1949	167.18	165.08	Guelph Formation	-	146.73	138.84	128.90	123.50	120.94	102.17			
E-18	(Bolton, 1957)	655761	4774468	1950	194.52	172.91	Lockport Goat Island Member	-	-	-	162.15	156.76	153.89	136.18			
E-19	(Bolton, 1957)	656470	4770645	1950	163.80	152.83	Guelph Formation	-	143.74	141.61	131.22	124.60	122.35	104.55			
E-29	(Bolton, 1957)	655737	4771671	1951	195.86	174.92	Guelph Formation	-	159.04	156.39	141.12	135.67	132.77	115.06			
E-32	(Bolton, 1957)	655726	4772390	1951	193.94	172.61	Guelph Formation	-	167.06	162.52	146.70	141.43	137.40	120.18			
F-1	(Bolton, 1957)	658038	4777687	1950	175.05	173.19	Lockport Goat Island Member	-	-	-	164.53	154.44	150.66	134.02			
F-2	(Bolton, 1957)	657176	4777077	1950	178.92	168.46	Lockport Goat Island Member	-	-	-	159.65	152.92	150.82	132.65			
K-1	(Bolton, 1957)	656169	4776923	1950	179.92	165.05	Lockport Goat Island Member	-	-	-	161.91	154.44	151.61	134.02			
N-14	(Bolton, 1957)	657241	4770090	1951	182.76	162.34	Guelph Formation	-	151.46	141.06	127.16	119.27	116.62	97.96			
O-1	(Bolton, 1957)	658218	4770205	1949	174.35	166.70	Guelph Formation	-	138.38	134.29	124.27	117.47	114.91	96.26			
F013366	Oil, Gas and Salt Resources Library	641918	4768816	1947	183.30	154.04	(unspecified)	-	-	-	-	-	-	-			
F013943	Oil, Gas and Salt Resources Library	652452	4772579	1950	194.95	182.45	Guelph Formation	-	-	-	-	-	141.91	125.15			
F014098	Oil, Gas and Salt Resources Library	647220	4764979	1953	179.11	147.41	Guelph Formation	-	-	-	-	-	78.83	59.01			
F014123	Oil, Gas and Salt Resources Library	644275	4764547	1946	183.79	155.75	Salina Formation	131.37	-	-	-	-	72.85	58.22			
N002812	Oil, Gas and Salt Resources Library	652892	4770040	1908	179.83	166.13	(unspecified)	-	-	-	-	-	-	107.89			
N002815	Oil, Gas and Salt Resources Library	646765	4776643		158.10	145.29	(unspecified)	-	-	-	-	-	-	-			
T007932	Oil, Gas and Salt Resources Library	655602	4776811	1992	182.22	165.34	Lockport Gasport Member	-	-	-	-	-	152.51	135.11			
T010011	Oil, Gas and Salt Resources Library	650379	4766538	1926	174.96	145.82	Guelph Formation	-	-	-	-	-	-	145.86			
T012327	Oil, Gas and Salt Resources Library	650359	4766843		174.98	149.10	Guelph Formation	-	-	-	-	-	96.36	78.07			
T012542	Oil, Gas and Salt Resources Library	646587	4775276	2017	179.00	171.60	Lockport Goat Island Member	-	-	-	162.90	-	153.00	-			

Notes: • Elevations provided in metres above sea level (masl)

Table C-3 Site Well Stratigraphic Summary

Well ID	Ground Elevation	Bedrock Elevation	Bedrock Subcrop	Stratigraphic Contact Depth / Elevation					
				Lockport Goat Island Member		Lockport Gasport Member		DeCew Formation	
	masl			mbgs	masl	mbgs	masl	mbgs	masl
BH03-2	184.33	179.93	Lockport Formation, Eramosa Member	20.1	164.2	31.5	152.8	41.2	143.1
MW11-1	181.04	174.03	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW11-2	184.22	178.91	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW11-3R	178.65	174.23	Lockport Formation, Eramosa Member	11.0	167.7	19.4	159.3	29.4	149.2
MW11-4	181.64	176.76	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW16-5	179.53	174.65	Lockport Formation, Eramosa Member	11.0	168.6	21.6	157.9	31.9	147.6
MW16-6	181.46	177.04	Lockport Formation, Eramosa Member	10.4	171.1	23.2	158.2	32.9	148.5
MW16-7	180.30	174.31	Lockport Formation, Eramosa Member	19.7	160.6	29.9	150.4	39.2	141.1
MW16-8	185.98	175.24	Lockport Formation, Eramosa Member	28.0	158.0	40.0	146.0	48.3	137.7
MW16-9	181.97	174.35	Lockport Formation, Eramosa Member	17.8	164.1	29.3	152.7	39.6	142.4
MW16-10	181.81	176.32	Lockport Formation, Eramosa Member	16.3	165.6	25.9	155.9	34.6	147.2
MW16-11	182.85	175.69	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW16-12	183.64	179.37	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW16-13	185.23	180.35	Lockport Formation, Eramosa Member	21.6	163.6	32.9	152.3	42.5	142.7
MW16-14	184.00	179.12	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW16-15	182.24	176.83	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW16-16	178.78	170.88	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW16-17	177.42	171.76	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW16-18	176.23	174.91	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW16-19	176.39	175.17	Lockport Formation, Eramosa Member	-	-	-	-	-	-
MW17-20	186.04	180.99	Lockport Formation, Eramosa Member	20.0	166.0	36.3	149.7	45.4	140.6
MW17-21	185.69	180.89	Lockport Formation, Eramosa Member	21.3	164.4	-	-	-	-
MW17-22	183.50	179.54	Lockport Formation, Eramosa Member	17.5	166.0	-	-	-	-
MW17-23	181.89	175.49	Lockport Formation, Eramosa Member	17.0	164.9	-	-	-	-

Notes: • Elevations provided in metres above sea level (masl)
• Depths provided in metres below ground surface (mbgs)

APPENDIX

C-1 SITE BOREHOLE LOGS

BOREHOLE NO. 03-2

PROJECT NAME: ROLLING MEADOWS **PROJECT NO.:** 981023.02

CLIENT: WALKER INDUSTRIES HOLDING LIMITED **DATE:** JULY 7-8, 2003

BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE **SUPERVISOR:** SCL

GROUND ELEVATION: 186.0 mASL (Estimated) **REVIEWER:** PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	REMARKS
0 – 4.4	CLAYEY SILT: REDDISH BROWN CLAYEY SILT. DOLOSTONE BOULDERS AT 3.4 m.		H.W. (114.3 mm) CASING (to 7.2 m)	AUGER CUTTINGS
4.4 – 20	DOLOSTONE HARD, FRESH, BROWNISH-GREY TO GREY, MEDIUM GRAINED DOLOSTONE WITH SACCHAROIDAL TEXTURE, WITH A PETROLIFEROUS ODOUR WHEN BROKEN. THIN TO MEDIUM HORIZONTAL BEDS WITH OCCASIONAL 2 mm THICK SHALE LAYERS. RARE STYLOLITES AND NODULES OF GYPSUM AND OTHER MINERALS. APPROXIMATELY 3% VUG CONTENT. - VUGS 1-25 mm, TO 1%, LARGE ONES AT 6.2 m, 6.8 m, 7.5 m, 8.1 m AND 8.4 m. SOME ENCRUSTED WITH DOLOMITE, CALCITE, SIDERITE AND SPHALERITE. - GYPSUM NODULES AT 12.4 m AND 13.7 m, UP TO 100 mm, LESS THAN 1% BY VOLUME. - VUGGY ZONE, 14.7 m TO 14.8 m, 2 mm TO 50 mm, APPROXIMATELY 13% BY VOLUME. - VUGGY ZONE, 17.1 m TO 17.6 m, 2 mm TO 45 mm, APPROXIMATELY 10% BY VOLUME - COARSE GRAINED LAYER, 18.6 m TO 20.1 m.	ERAMOSA MEMBER, LOCKPORT FORMATION		

SAMPLE

Approx. Depth (m)	TYPE	'N' VALUE	% WATER	% RECOVERY	RQD (%)	RATE OF DRILL PENETRATION (m / min)	WATER CONTENT % (10 20 30; W_P W_L)
4.2	1RC			100	44		
5.4	2RC			100	100		
5.9	3RC			100	58		
7.9	4RC			100	97		
9.5	5RC			100	95		
10.7	6RC			100	93		
12.3	7RC			100	100		
13.9	8RC			100	47		
15.5	9RC			100	77		
17.1	10RC			100	43		
18.3	11RC			100	93		
19.9	12RC			100	92		

BOREHOLE NO. 03-2

PROJECT NAME: ROLLING MEADOWS
PROJECT NO.: 981023.02
CLIENT: WALKER INDUSTRIES HOLDING LIMITED
DATE: JULY 7-8, 2003
BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE
SUPERVISOR: SCL
GROUND ELEVATION: 186.0 mASL (Estimated)
REVIEWER: PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE TYPE	'N' VALUE	% WATER	% RECOVERY	RQD (%)	RATE OF DRILL PENETRATION m / min	WATER CONTENT % (10 20 30; WP WL)	REMARKS
20.1	DOLOSTONE: HARD, GREY, FINE GRAINED, FRESH DOLOSTONE WITH OCCASIONAL GYPSUM AND CHERT NODULES. WEAK PETROLIFEROUS ODOUR WHEN BROKEN. RARE FOSSIL FRAGMENTS, MINOR CALCITE AND GYPSUM VEINS. OCCASIONAL TO COMMON STYLOLITES AND SHALE PARTINGS 2 mm THICK. FRACTURE SURFACES CLEAN. MEDIUM BEDDED. – OCCASIONAL CHERT, GYPSUM AND OTHER NODULES, 20.1 m TO 26.5 m, 2–3% BY VOLUME. – FOSSILIFEROUS AND STYLOLITIC LAYER, 26.5 m TO 26.8 m. – RARE CHERT AND GYPSUM NODULES 26.5 m TO 31.5 m	GOAT ISLAND MEMBER, LOCKPORT FORMATION		13RC			100	93			
				14RC			100	97			
				15RC			100	100			
				16RC			100	100			
				17RC			100	92			
				18RC			100	100			
				19RC			100	98			
31.5	DOLOSTONE: HARD, FRESH, GREY TO DARK GREY, FINE TO MEDIUM GRAINED FOSSILIFEROUS DOLOSTONE WITH SACCHAROIDAL TEXTURE. MEDIUM BEDDED WITH FOSSIL FRAGMENTS UP TO 6%. OCCASIONAL STYLOLITES. RARE GYPSUM NODULES, LESS THAN 1 % BY VOLUME. – DARK GREY FOSSILIFEROUS DOLOMITIC LIMESTONE FROM 36.2 m TO 39.8 m. – FREQUENT SHALE PARTINGS BELOW 37.0 m, TO 10 mm THICK.	GASPORT MEMBER, LOCKPORT FORMATION		20RC			100	97			TEST DATA: SAMPLE 10 (31.5 m – 36.2 m) PN (CONC.) 117 M.D.C. 12.4% M.D.F. 24.5% A.M.B. IN PROGRESS ABSORPTION 1.242% $MgSO_4$ LOSS 11.6% F.T. 8.8%
				21RC			100	98			
				22RC			100	97			
				23RC			100	45			TEST DATA: SAMPLE 11 (36.2 m – 39.8 m) PN (CONC.) 168 M.D.C. 18.8% M.D.F. 25.4%* A.M.B. IN PROGRESS ABSORPTION 1.139% $MgSO_4$ LOSS 13.7% F.T. 8.6%
				24RC			100	100			
40				25RC			100	90			

BOREHOLE NO. 03-2

PROJECT NAME: ROLLING MEADOWS

PROJECT NO.: 981023.02

CLIENT: WALKER INDUSTRIES HOLDING LIMITED

DATE: JULY 7-8, 2003

BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE

SUPERVISOR: SCL

GROUND ELEVATION: 186.0 mASL (Estimated)

REVIEWER: PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE TYPE	'N' VALUE	% WATER	% RECOVERY	RQD (%)	RATE OF DRILL PENETRATION m / min	WATER CONTENT % (10 20 30; WP WL)	REMARKS
40 – 41.2	DOLOSTONE: CONTINUED - FOSSILIFEROUS CONGLOMERATIC LAYER FROM 41.0 m TO 41.2 m MARKS LOWER CONTACT.										
41.2 – 45.3	DOLOSTONE: MEDIUM HARD, DARK GREY, FINE GRAINED, FRESH ARGILLACEOUS DOLOSTONE WITH OCCASIONAL SHALE PARTINGS 3 mm THICK.	DECEW FORMATION		26RC			100	97			
				27RC			100	83			
				28RC			100	100			
45.3 – 50.3	SHALE: VERY DARK GREY TO BLACK, DOLOMITIC TO CALCAREOUS SHALE. INCREASE IN CALCAREOUS CONTENT BELOW 45.9 m - FREQUENTLY SPLITS HORIZONTALLY ALONG BEDDING PLANES. - CONCHOIDAL FRACTURES. - FOSSILIFEROUS LAYERS BELOW 49.7 m	ROCHESTER FORMATION		29RC			100	100			
				30RC			100	100			
				31RC			100	100			
50.3	BOREHOLE TERMINATED AT 50.3 m IN SHALE.										

Depth scale: 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60

LOG OF BOREHOLE BH03-2 Retrofit

wsp

DRAFT

project |	Proposed Uppers Lane Quarry			**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75	**date started |**	2016/11/08
location |	Thorold / Niagara Falls, ON	**method |**		**supervisor |**	SK
position |	E: 648519 N: 4772919 (17T, Geodetic)	**coring |**	*n/a*	**reviewer |**	KJF

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE — STRATIGRAPHY	Elevation Scale (mASL)	Lab Data and Comments
0	184.3	**GROUND SURFACE**		
0–4.4		**CLAYEY SILT**, reddish brown, dolostone boulders at 3.4 m	184–180	Stratigraphy inferred from BH03-2 borehole log completed by Jagger Hims Limited in 2003.
4.4	179.9 / 4.4	*at 4.4m below grade*	180	
4.4–20.1		**ERAMOSA FORMATION**, hard, fresh, brownish-grey to grey, medium grained dolostone with saccharoidal texture, with a petroliferous odour when broken. Thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare stylolites and nodules of gypsum and other minerals. Approximately 3% vug content. ...Vugs 1-25 mm, to 1%, large ones at 6.2 m, 6.8 m, 7.5 m, 8.1 m and 8.4m. Some encrusted with dolomite, calcite, siderite and sphalerite. ...Gypsum nodules at 12.4 m and 13.7 m, up to 100 mm, less than 1% by volume. ...Vuggy zone, 14.7 m to 14.8 m, 2 mm to 50 mm, approximately 13% by volume. ...Vuggy zone, 17.1 m to 17.6 m, 2 mm to 45 mm, approximately 10% by volume. ...Coarse grained layer, 18.6 m to 20.1 m.	179–165	
20.1	164.2 / 20.1	**GOAT ISLAND FORMATION**, hard, grey, fine grained, fresh dolostone with occasional gypsum and chert nodules. Weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum veins. Occasional to common stylolites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded. ...Occasional chert, gypsum and other nodules, 20.1 m to 26.5 m, 2-3% by volume.	164–158	

Column headings: SAMPLE (Graphic Plot, Number, Type, SPT N-Value, Core Recovery); Penetration Test Values (Blows / 0.3m): Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa): Unconfined, Field Vane, Pocket Penetrometer, Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; Fracture Frequency; PID Readings; Well Details; GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

(continued on next page)

LOG OF BOREHOLE BH03-2 Retrofit

wsp

DRAFT

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 648519 N: 4772919 (17T, Geodetic)

rig type | CME 75
method |
coring | *n/a*

project no. | 161-11633-00
date started | 2016/11/08
supervisor | SK
reviewer | KJF

Column headings: Depth Scale (m); SUBSURFACE PROFILE: Elev Depth (m), STRATIGRAPHY *(continued)*, Graphic Plot; SAMPLE: Number, Type, SPT N-Value, Core Recovery; Elevation Scale (mASL); Penetration Test Values (Blows / 0.3m): × Dynamic Cone, 10, 20, 30, 40; Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane, 40, 80, 120, 160; Water Content (%) & Plasticity: PL, MC, LL, 10, 20, 30; PID Readings; Well Details; Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

Elev / Depth (m)	Stratigraphy
	...Fossiliferous and stylolitic layer, 26.5 m to 26.8 m. Rare chert and gypsum nodules 26.5 m to 31.5 m. **GOAT ISLAND FORMATION**, hard, grey, fine grained, fresh dolostone with occasional gypsum and chert nodules. Weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum veins. Occasional to common stylolites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded. *(continued)*
152.8 / 31.5	**GASPORT FORMATION**, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Occasional stylolites. Rare gypsum nodules, less than 1% by volume. ...Dark grey fossiliferous dolomitic limestone from 36.2 m to 39.8 m. ...Frequent shale partings below 37.0 m, up to 10 mm thick.
143.1 / 41.2	...Fossiliferous conglomeratic layer from 41.0 m to 41.2 m marks lower contact.
	DECEW FORMATION, medium hard, dark grey, fine grained. Fresh argillaceous dolostone with occasional shale partings 3 mm thick.
139.0 / 45.3	**ROCHESTER FORMATION**, very dark grey to black, dolomitic to calcareous shale. Increase in calcareous content below 45.9 m. ...Frequently splits horizontally along bedding planes. Conchoidal fractures. ...Fossiliferous layers below 49.7 m.
134.0 / 50.3	**END OF BOREHOLE**

Depth scale (m): 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50

Elevation scale (mASL): 157, 156, 155, 154, 153, 152, 151, 150, 149, 148, 147, 146, 145, 144, 143, 142, 141, 140, 139, 138, 137, 136, 135

END OF BOREHOLE

Borehole was dry and open upon completion.

25 mm monitoring well installed.
No. 10 screen installed.

WELL 1 WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 10, 2016	8.5	175.9

WELL 2 WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 10, 2016	8.6	175.8

BOREHOLE LOG OF: MW11-01

PROJECT: 11-1152-0098(1200)

LOCATION: SW corner

DRILLING DATE: Aug. 30 - Sep. 1, 2011

DRILL RIG: CME 75 trackmount

DRILLING CONTRACTOR: Aardvark

DATUM:

DEPTH SCALE METRES	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	OGS CODE	GEOPHYSICAL RECORD: GAMMA (cps) 20 40 60 80	GEOPHYSICAL RECORD: CONDUCTIVITY (mS/m) 3 6 9 12	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE						
0	For Soil Details see Record of Borehole MW11-01 o/b		0.00				Oct. 6, 2011 3.22
7	Fresh to slightly weathered, medium to dark brownish grey to medium grey, fine to medium grained, sacharroidal crystalline, faintly porous, thin to medium bedded DOLOSTONE, faintly petroliferous with occasional weakly to strong developed stylolites, occasional coral fossils, sphalerite nodules and vugs with dolomite crystals (Eramosa Member)		7.01				
20	Fresh, light to medium brownish grey to medium grey, fine to medium grained, non-porous, thin to medium bedded DOLOSTONE with brown chert nodules and black, wavy argillaceous bedding partings 0.1 mm to 2 mm thick (Goat Island Member)		20.40				
23	Fresh, light to medium brown-grey to medium grey, fine grained, thickly bedded cherty DOLOSTONE, with chert nodules 2 to 7 cm in size, sphalerite crystals and occasional weak to strong stylolites (Goat Island Member)		23.10				
27	Fresh, light to medium grey, fine grained, thinly to thickly bedded DOLOSTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings (Gasport Member)		27.20				

Depth scale marks: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 150

Golder Associates

LOGGED: MB

CHECKED:

GTA-HYD 009 11-1152-0098.GPJ GAL-MISS.GDT 11/3/11

PROJECT: 11-1152-0098(1200)

BOREHOLE LOG OF: MW11-01

LOCATION: SW corner

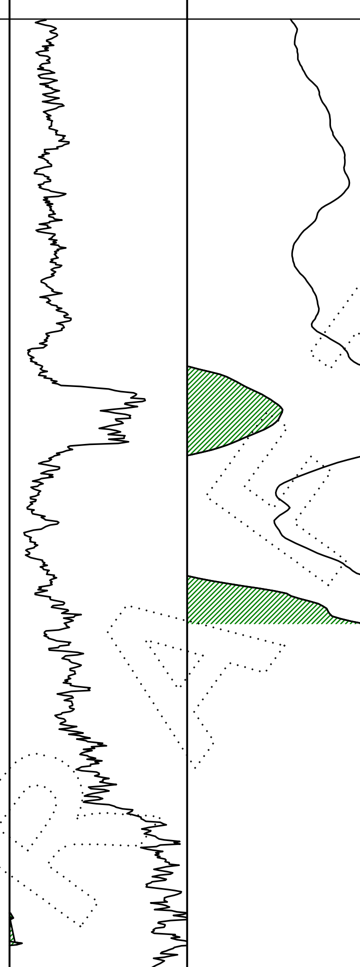
DRILLING DATE: Aug. 30 - Sep. 1, 2011
DRILL RIG: CME 75 trackmount
DRILLING CONTRACTOR: Aardvark

DATUM:

--- CONTINUED FROM PREVIOUS PAGE ---

DEPTH SCALE METRES	DESCRIPTION	ELEV. / DEPTH (m)	OGS CODE
30	Fresh, light to medium grey, fine grained, thinly to thickly bedded DOLOSTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings (Gasport Member)		
37.50	Fresh, dark grey, fine grained, thin to medium bedded shaly DOLOSTONE, fossiliferous with numerous small fossil shells, some thin black shale beds (Gasport Member)	37.50	
38.70	Fresh, light to medium grey, fine grained, thinly to thickly bedded DOLOSTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings (Gasport Member)	38.70	
39.20	Fresh, light to medium grey, fine grained, thinly to thickly bedded LIMESTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings, occasional interbeds of medium to coarse grained bioclastic limestone (Gasport Member)	39.20	
42.70	Fresh, medium grey, fine grained, massive textured, thin to medium bedded DOLOSTONE with occasional black argillaceous partings 1 to 4 mm thick (Decew Formation)	42.70	
45.80	Fresh, dark grey, very fine grained to fine grained, laminated to thinly bedded SHALE with occasional bioclastic and calcareous beds (Rochester Formation)	45.80	
52.12	END OF BOREHOLE	52.12	

GEOPHYSICAL RECORD



PIEZOMETER OR STANDPIPE INSTALLATION

PROJECT: 11-1152-0098(1200)

BOREHOLE LOG OF: MW11-02

LOCATION: SE corner

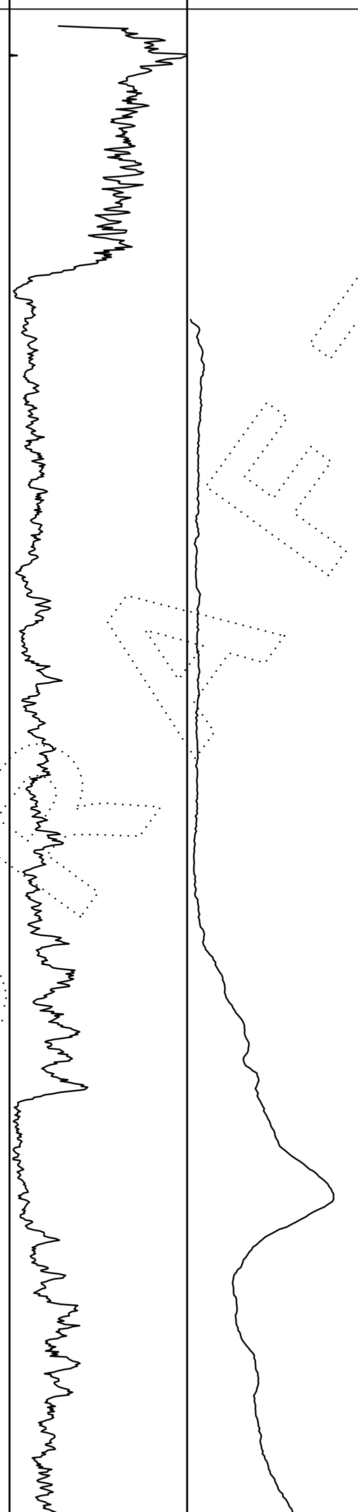
DRILLING DATE: Sep. 29 - Oct. 3, 2011

DRILL RIG: CME 75 track mount

DRILLING CONTRACTOR: Aardvark

DATUM:

DEPTH SCALE METRES	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	OGS CODE	GEOPHYSICAL RECORD: GAMMA (cps) 20 40 60 80 / CONDUCTIVITY (mS/m) 3 6 9 12	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE					
0	For Soil Details see Record of Borehole MW11-02 o/b		0.00			
5.31	Fresh to slightly weathered, medium to dark brownish grey to medium grey, fine to medium grained, sacharroidal crystalline, faintly porous, thin to medium bedded DOLOSTONE, faintly petroliferous with occasional weakly to strong developed stylolites, occasional coral fossils, sphalerite nodules and vugs with dolomite crystals (Eramosa Member)		5.31			Oct. 6, 2011 5.53
19.20	Fresh, medium grey, fine to medium grained, non-porous, thin to medium bedded DOLOSTONE with brown chert nodules and black, wavy argillaceous bedding partings 0.1 mm to 2 mm thick (Goat Island Member)		19.20			
21.50	Fresh, light to medium brown-grey to medium grey, fine grained, thickly bedded cherty DOLOSTONE, with chert nodules 2 to 7 cm in size, sphalerite crystals and occasional weak to strong stylolites (Goat Island Member)		21.50			
25.30	Fresh, light to medium grey, fine grained, thinly to thickly bedded DOLOSTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings (Gasport Member)		25.30			



Depth scale: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 150

Golder Associates

LOGGED: MB

CHECKED:

PROJECT: 11-1152-0098(1200)

BOREHOLE LOG OF: MW11-02

LOCATION: SE corner

DRILLING DATE: Sep. 29 - Oct. 3, 2011

DRILL RIG: CME 75 track mount

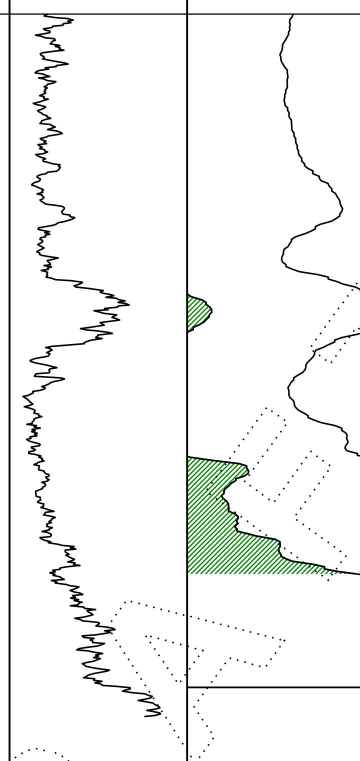
DRILLING CONTRACTOR: Aardvark

DATUM:

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

DEPTH SCALE METRES	DESCRIPTION	ELEV. / DEPTH (m)
30	Fresh, light to medium grey, fine grained, thinly to thickly bedded DOLOSTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings (Gasport Member)	
	Fresh, light to medium grey, fine grained, thinly to thickly bedded LIMESTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings, occasional interbeds of medium to coarse grained bioclastic limestone (Gasport Member)	34.60 35.40
	Fresh, dark grey, fine grained, thin to medium bedded shaly dolomitic LIMESTONE, fossiliferous with numerous small fossil shells, some thin black shale beds (Gasport Member)	36.60
	Fresh, light to medium grey, fine grained, thinly to thickly bedded LIMESTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings, occasional interbeds of medium to coarse grained bioclastic limestone (Gasport Member)	
	Fresh, medium grey, fine grained, massive textured, thin to medium bedded DOLOSTONE with occasional black argillaceous partings 1 to 4 mm thick (Decew Formation)	40.70
	Fresh, dark grey, very fine grained to fine grained, laminated to thinly bedded SHALE with occasional bioclastic and calcareous beds (Rochester Formation)	43.30
	END OF BOREHOLE	44.45

GEOPHYSICAL RECORD



PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE

1 : 150

Golder Associates

LOGGED: MB

CHECKED:

PROJECT: 11-1152-0098(1200)

BOREHOLE LOG OF: MW11-03

LOCATION: NE corner

DRILLING DATE: Sep. 22 - 23, 2011

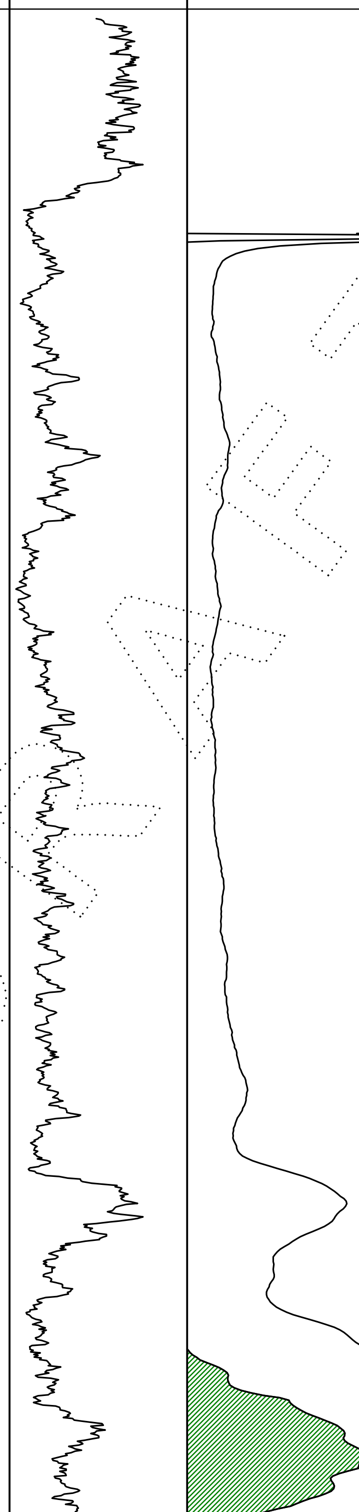
DRILL RIG: CME 75 track mount

DRILLING CONTRACTOR: Aardvark

DATUM:

DEPTH SCALE METRES	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	OGS CODE
	GROUND SURFACE			
0	For Soil Details see Record of Borehole MW11-03 o/b		0.00	
4	Fresh to slightly weathered, medium to dark brownish grey to medium grey, fine to medium grained, sacharroidal crystalline, faintly porous, thin to medium bedded DOLOSTONE, faintly petroliferous with occasional weakly to strong developed stylolites, occasional coral fossils, sphalerite nodules and vugs with dolomite crystals (Eramosa Member)		3.89	
8	Fresh, medium grey, fine to medium grained, non-porous, thin to medium bedded DOLOSTONE with brown chert nodules and black, wavy argillaceous bedding partings 0.1 mm to 2 mm thick (Goat Island Member)		7.50	
10	Fresh, light to medium brown-grey to medium grey, fine grained, thickly bedded cherty DOLOSTONE, with chert nodules 2 to 7 cm in size, sphalerite crystals and occasional weak to strong stylolites (Goat Island Member)		10.10	
14	Fresh, light to medium grey, fine grained, thinly to thickly bedded DOLOSTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings (Gasport Member)		13.70	
22	Fresh, light to medium grey, fine grained, thinly to thickly bedded LIMESTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings, occasional interbeds of medium to coarse grained bioclastic limestone (Gasport Member)		22.10	
			23.30	
24	Fresh, dark grey, fine grained, thin to medium bedded shaly dolomitic LIMESTONE, fossiliferous with numerous small fossil shells, some thin black shale beds (Gasport Member)		24.70	
26	Fresh, light to medium grey, fine grained, thinly to thickly bedded LIMESTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings, occasional interbeds of medium to coarse grained bioclastic limestone (Gasport Member)			
28			29.00	
30				

GEOPHYSICAL RECORD



PIEZOMETER OR STANDPIPE INSTALLATION

Oct. 6, 2011
1.79

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 150

Golder Associates

LOGGED: MB
CHECKED:

PROJECT: 11-1152-0098(1200)

BOREHOLE LOG OF: MW11-03

SHEET 2 OF 2

LOCATION: NE corner

DRILLING DATE: Sep. 22 - 23, 2011

DRILL RIG: CME 75 track mount

DRILLING CONTRACTOR: Aardvark

DATUM:

DEPTH SCALE METRES	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	OGS CODE	GEOPHYSICAL RECORD: GAMMA (cps) 20 40 60 80	GEOPHYSICAL RECORD: CONDUCTIVITY (mS/m) 3 6 9 12	PIEZOMETER OR STANDPIPE INSTALLATION
	--- CONTINUED FROM PREVIOUS PAGE ---						
30	Fresh, medium grey, fine grained, massive textured, thin to medium bedded DOLOSTONE with occasional black argillaceous partings 1 to 4 mm thick (Decew Formation)		30.70				
	END OF BOREHOLE						

Depth scale marks: 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60

DEPTH SCALE

1 : 150

Golder Associates

LOGGED: MB

CHECKED:

LOG OF BOREHOLE 11-3A/B Decom

DRAFT

wsp

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/10/25	
location | Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK	
position |	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF	

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE: STRATIGRAPHY	Graphic Plot	SAMPLE: Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m) × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) ○ Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160	Water Content (%) & Plasticity PL MC LL 10 20 30	PID Readings	Well Details	Lab Data and Comments GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL
0		**GROUND SURFACE**										
0–30.7		Bentonite grout										Monitoring well overdrilled to 30.7 m. PVC risers and screens removed.

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30

END OF BOREHOLE

Borehole was dry and open upon completion.

library: genivar - library.glb report: gen log v1 file: uppers lane 2016.gpj

LOG OF BOREHOLE 11-3OB Decom

DRAFT

wsp

project |	Proposed Uppers Lane Quarry	project no. |	161-11633-00
client |	Walker Aggregates Inc.	date started |	2016/10/25
rig type |	CME 75	supervisor |	SK
location |	Thorold / Niagara Falls, ON	reviewer |	KJF
method |			
position |		coring |	*n/a*

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE: STRATIGRAPHY	Graphic Plot	SAMPLE: Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m) × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) ○ Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160	Water Content (%) & Plasticity PL MC LL 10 20 30	PID Readings	Well Details	Lab Data and Comments GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL
0		GROUND SURFACE										
0–3.2		Granular bentonite										PVC riser and screen pulled from borehole. Borehole backfilled with granular bentonite.

END OF BOREHOLE

Borehole was dry and open upon completion.

library: genivar - library.glb report: gen log v1 file: uppers lane 2016.gpj

LOG OF BOREHOLE 11-3BR

DRAFT

wsp

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/10/27	
location | Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK	
position | E: 649515 N: 4773487 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF	

Column headings: Depth Scale (m) | SUBSURFACE PROFILE: Elev Depth (m), STRATIGRAPHY, Graphic Plot | SAMPLE: Number, Type, SPT N-Value / Core Recovery | Elevation Scale (mASL) | Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane 40 80 120 160 | Water Content (%) & Plasticity: PL MC LL 10 20 30 | PID Readings | Well Details | Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Elev / Depth (m)	Stratigraphy
178.7	**GROUND SURFACE**
	CLAYEY SILT For stratigraphic descriptions, refer to 11-3OBR.
174.1 / 4.6	*at 4.6m below grade* For stratigraphic descriptions, refer to 11-3AR.
167.8 / 10.9	**END OF BOREHOLE**

Fracture Frequency

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 25, 2016	3.2	175.5

LOG OF BOREHOLE 11-3AR

wsp

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/10/26
location |	Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK
position |	E: 649515 N: 4773489 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF

DRAFT

SUBSURFACE PROFILE

Elev Depth (m)	STRATIGRAPHY
178.6	**GROUND SURFACE**
	CLAYEY SILT For stratigraphic descriptions, refer to 11-3OBR.
174.0	*at 4.6m below grade*
4.6	**ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare styolites and gypsum nodules. Approximately 3% vug content.
167.6 11.0	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded.
159.4 19.4	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Stylolites shaley partings up to 3 mm, 2 per 1.5 m. Rare gypsum nodules, less than 1% by volume.

SAMPLE

Elev / Depth (m)	Number	Type	SPT N-Value / Core Recovery
174.0 / 4.6	1	R1	TCR = **100%** RQD = **59%**
172.5 / 6.1	2	R2	TCR = **100%** RQD = **73%**
171.0 / 7.6	3	R3	TCR = **100%** RQD = **72%**
169.5 / 9.1	4	R4	TCR = **100%** RQD = **76%**
168.0 / 10.6	5	R5	TCR = **100%** RQD = **97%**
166.4 / 12.2	6	R6	TCR = **100%** RQD = **95%**
165.0 / 13.6	7	R7	TCR = **100%** RQD = **100%**
163.4 / 15.2	8	R8	TCR = **100%** RQD = **100%**
161.8 / 16.8	9	R9	TCR = **100%** RQD = **100%**
160.3 / 18.3	10	R10	TCR = **98%** RQD = **91%**
159.2 / 19.7	11	R11	TCR = **97%** RQD = **90%**
157.3 / 21.3	12	R12	TCR = **98%** RQD = **98%**
155.8 / 22.8	13	R13	TCR = **97%** RQD = **97%**
154.2 / 24.4	14	R14	
152.7			

Depth Scale (m): 0–24

Elevation Scale (mASL): 178–154

Penetration Test Values (Blows / 0.3m)
× Dynamic Cone 10 20 30 40
Undrained Shear Strength (kPa)
○ Unconfined + Field Vane
● Pocket Penetrometer ■ Lab Vane
40 80 120 160

Water Content (%) & Plasticity
PL MC LL
10 20 30

Fracture Frequency

PID Readings

Well Details

Lab Data and Comments
GRAIN SIZE DISTRIBUTION (%) (MIT)
GR SA SI CL

Artesian conditions encountered

(continued next page)

LOG OF BOREHOLE 11-3AR

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/10/26
location |	Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK
position |	E: 649515 N: 4773489 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF

Depth Scale (m)	Elev / Depth (m)	STRATIGRAPHY *(continued)*	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Well Details	Lab Data and Comments
25	152.7 / 25.9; 151.2 / 27.4; 149.7 / 28.9	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Stylolites shaley partings up to 3 mm, 2 per 1.5 m. Rare gypsum nodules, less than 1% by volume. *(continued)*	14	R14	TCR = **100%** RQD = **100%**	153		Artesian conditions encountered
26–27			15	R15	TCR = **100%** RQD = **100%**	152, 151		
28			16	R16	TCR = **100%** RQD = **97%**	150		
29–30	149.2 / 29.4; 148.1 / 30.5	**DECEW FORMATION**, dolostone, medium hard, dark grey, fine grained, fresh, argillaceous with occasional shale partings, 3 mm thick.	17	R17	TCR = **85%** RQD = **82%**	149		

Column headings also include: Penetration Test Values (Blows / 0.3m) – Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) – Unconfined, Field Vane, Pocket Penetrometer, Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; PID Readings; GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL.

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 25, 2016	-0.4	179.0

library: genivar - library.glb report: gen log v1 file: uppers lane 2016.gpj

LOG OF BOREHOLE 11-3OBR

DRAFT

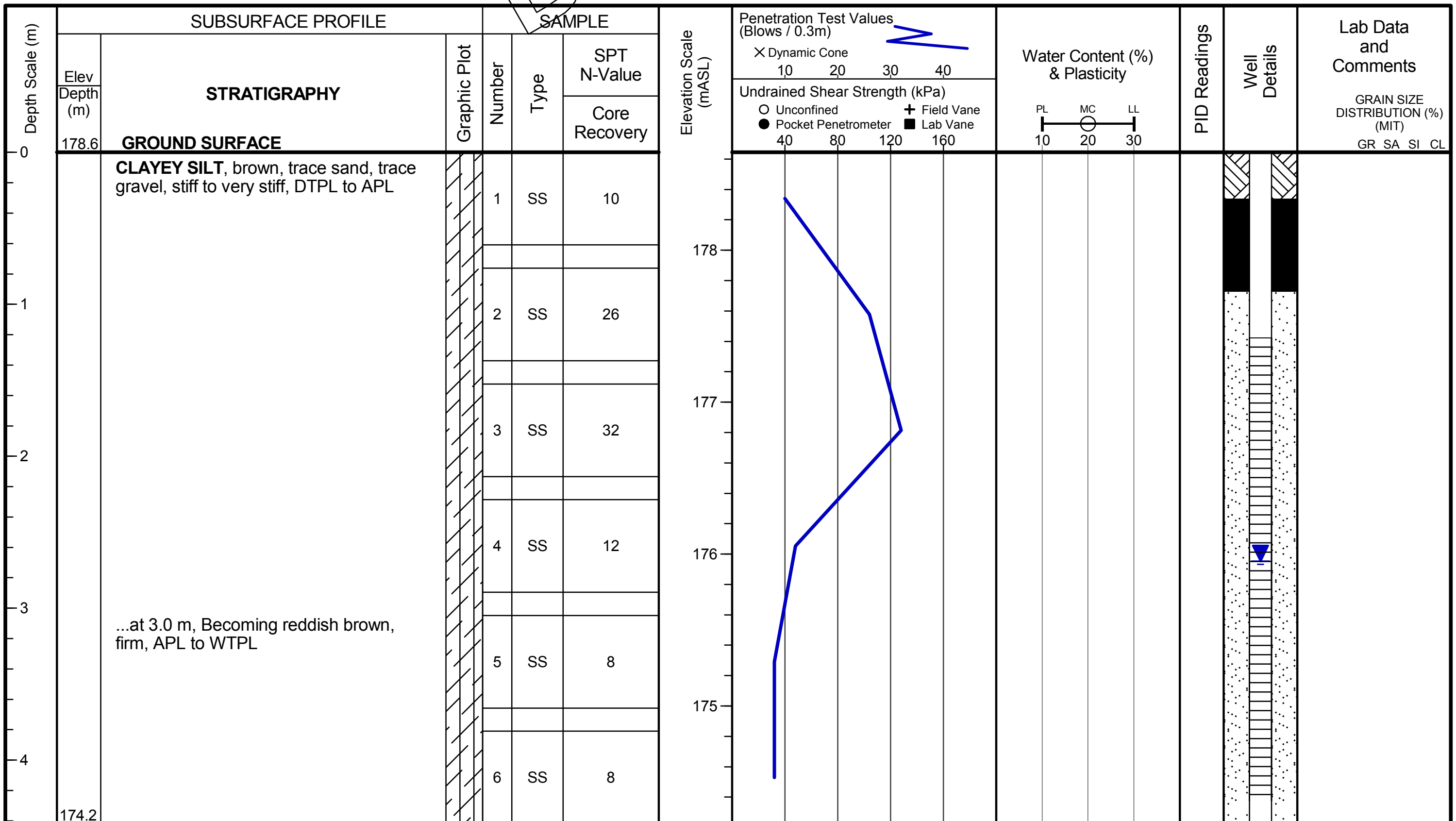
wsp

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 649515 N: 4773486 (17T, Geodetic)

rig type | CME 75
method | Hollow stem augers, 215 mm dia.
coring | n/a

project no. | 161-11633-00
date started | 2016/10/27
supervisor | SK
reviewer | KJF

Elev / Depth (m)	Stratigraphy	Sample Number	Type	SPT N-Value
178.6	**GROUND SURFACE**			
0	**CLAYEY SILT**, brown, trace sand, trace gravel, stiff to very stiff, DTPL to APL	1	SS	10
		2	SS	26
		3	SS	32
		4	SS	12
	...at 3.0 m, Becoming reddish brown, firm, APL to WTPL	5	SS	8
		6	SS	8
174.2 / 4.4	**END OF BOREHOLE**			



Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 5, 2016	2.7	176.0

PROJECT: 11-1152-0098(1200)

BOREHOLE LOG OF: MW11-04

LOCATION: NW corner

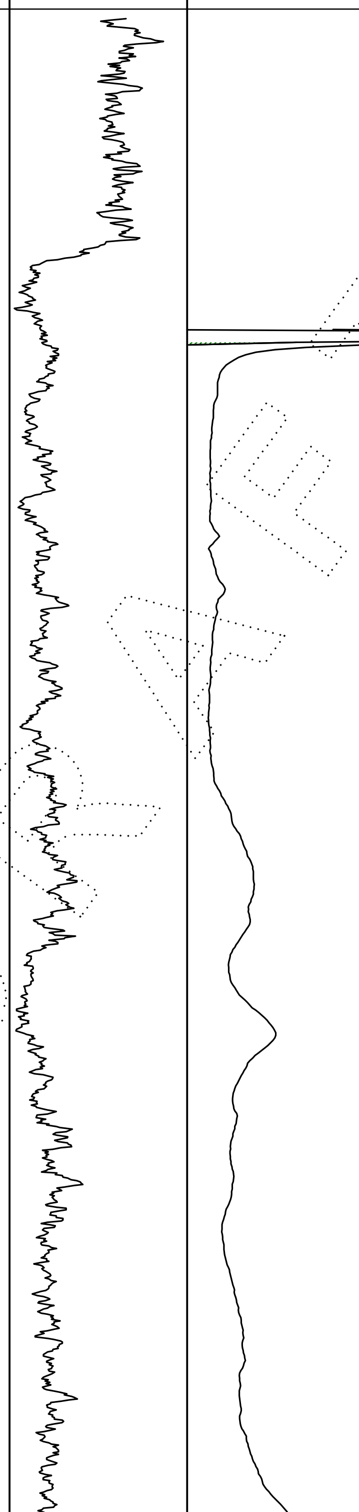
DRILLING DATE: Sep. 14 - 15, 2011

DRILL RIG: CME 75 track mount

DRILLING CONTRACTOR: Aardvark

DATUM:

DEPTH SCALE METRES	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	OGS CODE	GEOPHYSICAL RECORD: GAMMA (cps) 20 40 60 80 / CONDUCTIVITY (mS/m) 3 6 9 12	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE					
0	For Soil Details see Record of Borehole MW11-04 o/b		0.00			
4.88	Fresh to slightly weathered, medium to dark brownish grey to medium grey, fine to medium grained, sacharroidal crystalline, faintly porous, thin to medium bedded DOLOSTONE, faintly petroliferous with occasional weakly to strong developed stylolites, occasional coral fossils, sphalerite nodules and vugs with dolomite crystals (Eramosa Member)		4.88			Sep. 22, 2011 5.94
15.70	Fresh, medium grey, fine to medium grained, non-porous, thin to medium bedded DOLOSTONE with brown chert nodules and black, wavy argillaceous bedding partings 0.1 mm to 2 mm thick (Goat Island Member)		15.70			
18.60	Fresh, light to medium brown-grey to medium grey, fine grained, thickly bedded cherty DOLOSTONE, with chert nodules 2 to 7 cm in size, sphalerite crystals and occasional weak to strong stylolites (Goat Island Member)		18.60			
20.90	Fresh, light to medium grey, fine grained, thinly to thickly bedded DOLOSTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings (Gasport Member)		20.90			



Depth scale: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 150

Golder Associates

LOGGED: MB

CHECKED:

PROJECT: 11-1152-0098(1200)

BOREHOLE LOG OF: MW11-04

LOCATION: NW corner

DRILLING DATE: Sep. 14 - 15, 2011
DRILL RIG: CME 75 track mount
DRILLING CONTRACTOR: Aardvark

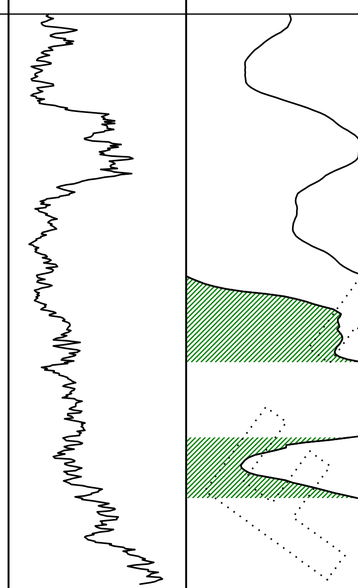
DATUM:

--- CONTINUED FROM PREVIOUS PAGE ---

DEPTH SCALE METRES	DESCRIPTION	ELEV. / DEPTH (m)	OGS CODE	PIEZOMETER OR STANDPIPE INSTALLATION
30				
	Fresh, light to medium grey, fine grained, thinly to thickly bedded LIMESTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings, occasional interbeds of medium to coarse grained bioclastic limestone (Gasport Member)	30.80		
32	Fresh, dark grey, fine grained, thin to medium bedded shaly dolomitic LIMESTONE, fossiliferous with numerous small fossil shells, some thin black shale beds (Gasport Member)	32.00		
34	Fresh, light to medium grey, fine grained, thinly to thickly bedded LIMESTONE, often argillaceous, with occasional stylolites and black argillaceous bedding partings, occasional interbeds of medium to coarse grained bioclastic limestone (Gasport Member)	33.50		
36–38	Fresh, medium grey, fine grained, massive textured, thin to medium bedded DOLOSTONE with occasional black argillaceous partings 1 to 4 mm thick (Decew Formation)	37.10		
40	Fresh, dark grey, very fine grained to fine grained, laminated to thinly bedded SHALE with occasional bioclastic and calcareous beds (Rochester Formation)	40.40		
42	END OF BOREHOLE	41.45		

Depth scale: 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60

GEOPHYSICAL RECORD



DEPTH SCALE
1 : 150

LOGGED: MB
CHECKED:

Ontario

Ministry of the Environment and Climate Change

Measurements recorded in: ☐ Metric ☑ Imperial

Well Tag No. *(Place Sticker and/or Print Below)* A191572

Well Record

Regulation 903 Ontario Water Resources Act

Well Owner's Information

First Name	Last Name / Organization	E-mail Address	☐ Well Constructed by Well Owner
	WALKER AGGREGATES		

Mailing Address (Street Number/Name)	Municipality	Province	Postal Code	Telephone No. *(inc. area code)*

Well Location

Address of Well Location (Street Number/Name)	Township	Lot	Concession
	STAMFORD	120	

County/District/Municipality	City/Town/Village	Province	Postal Code
WELLAND		Ontario	

UTM Coordinates	Zone	Easting	Northing	Municipal Plan and Sublot Number	Other
NAD 83	17	648513	4772937		

Overburden and Bedrock Materials/Abandonment Sealing Record *(see instructions on the back of this form)*

General Colour	Most Common Material	Other Materials	General Description	Depth *(m/ft)* From	To
BROWN	SILT	CLAYEY		0	13
GREY	LIMESTONE		FRACTURED / BROKEN	13	15
GREY	LIMESTONE			15	149

Annular Space

Depth Set at (m/ft) From	To	Type of Sealant Used (Material and Type)	Volume Placed (m^3/ft^3)
0	20	BENTONITE SLURRY	7

Method of Construction

- [x] Cable Tool
- [ ] Rotary (Conventional)
- [ ] Rotary (Reverse)
- [ ] Boring
- [ ] Air percussion
- [ ] Other, *specify*
- [ ] Diamond
- [ ] Jetting
- [ ] Driving
- [ ] Digging

Well Use

- [ ] Public
- [ ] Domestic
- [ ] Livestock
- [ ] Irrigation
- [ ] Industrial
- [ ] Other, *specify*
- [x] Commercial
- [ ] Municipal
- [ ] Test Hole
- [ ] Cooling & Air Conditioning
- [ ] Not used
- [ ] Dewatering
- [ ] Monitoring

Construction Record - Casing

Inside Diameter (cm/in)	Open Hole OR Material (Galvanized, Fibreglass, Concrete, Plastic, Steel)	Wall Thickness (cm/in)	Depth (m/ft) From	To
8 1/8	STEEL	0.188	2.5 AGS.	20

Construction Record - Screen

Outside Diameter (cm/in)	Material (Plastic, Galvanized, Steel)	Slot No.	Depth (m/ft) From	To
8	OPEN HOLE	—	20	149

Status of Well

- [ ] Water Supply
- [ ] Replacement Well
- [x] Test Hole
- [ ] Recharge Well
- [ ] Dewatering Well
- [ ] Observation and/or Monitoring Hole
- [ ] Alteration (Construction)
- [ ] Abandoned, Insufficient Supply
- [ ] Abandoned, Poor Water Quality
- [ ] Abandoned, other, *specify*
- [ ] Other, *specify*

Water Details

Water found at Depth	Kind of Water
35 (m/ft) [ ] Gas	[ ] Fresh [x] Untested [ ] Other, *specify*
(m/ft) [ ] Gas	[ ] Fresh [ ] Untested [ ] Other, *specify*
(m/ft) [ ] Gas	[ ] Fresh [ ] Untested [ ] Other, *specify*

Hole Diameter

Depth (m/ft) From	To	Diameter (cm/in)
0	20	10
20	149	8

Well Contractor and Well Technician Information

Business Name of Well Contractor: COUNTRY WATER SYSTEMS	Well Contractor's Licence No.: 7088
Business Address (Street Number/Name): 6995 SIMCOE RD 56	Municipality: UTOPIA
Province: ON	Postal Code: L0M1T0
Business E-mail Address:	
Bus.Telephone No. (*inc. area code*): 8773339355	Name of Well Technician (Last Name, First Name): SCOTT, PETE
Well Technician's Licence No.: 1667	Signature of Technician and/or Contractor: [signature]
Date Submitted: Y Y Y Y M M D D	

Results of Well Yield Testing

After test of well yield, water was:
- [x] Clear and sand free
- [ ] Other, *specify*

If pumping discontinued, give reason: —

Pump intake set at (m/ft): 100

Pumping rate (l/min / GPM): 40

Duration of pumping: 1 hrs + 0 min

Final water level end of pumping (m/ft): 29.3

If flowing give rate (l/min / GPM): —

Recommended pump depth (m/ft): 100

Recommended pump rate (l/min / GPM): 40

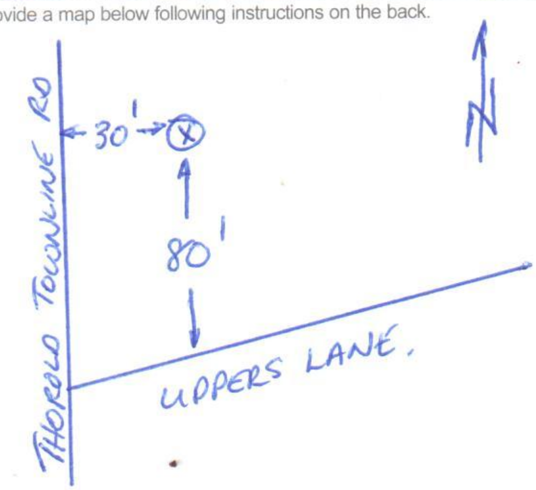
Well production (l/min / GPM): —

Disinfected? [x] Yes [ ] No

Draw Down Time (min)	Water Level (m/ft)	Recovery Time (min)	Water Level (m/ft)
Static Level	29.3		
1	29.4	1	30.1
2	29.5	2	30.0
3	29.5	3	30.0
4	29.6	4	30.0
5	29.6	5	29.9
10	29.7	10	29.8
15	29.8	15	29.8
20	29.9	20	29.7
25	30.0	25	29.6
30	30.0	30	29.6
40	30.1	40	29.4
50	30.2	50	29.4
60	30.3	60	29.3

Map of Well Location

Please provide a map below following instructions on the back.



Comments:

Well owner's information package delivered	Date Package Delivered	Ministry Use Only
[x] Yes [x] No	Y Y Y Y M M D D	Audit No. Z218939
	Date Work Completed: 20161026	Received

0506E (2014/11)

Ministry's Copy

LOG OF BOREHOLE 16-5A

wsp

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75
		date started |	2016/10/28
location |	Thorold / Niagara Falls, ON	**method |**	Rock coring
		supervisor |	SK
position |	E: 649017 N: 4773470 (17T, Geodetic)	**coring |**	HQ core, OD=96mm, ID=64mm
		reviewer |	KJF

Column headings: Depth Scale (m) | SUBSURFACE PROFILE: Elev Depth (m), STRATIGRAPHY, Graphic Plot | SAMPLE: Number, Type, SPT N-Value / Core Recovery | Elevation Scale (mASL) | Penetration Test Values (Blows / 0.3m) ✕ Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) ○ Unconfined ✚ Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160 | Water Content (%) & Plasticity PL MC LL 10 20 30; Fracture Frequency | PID Readings | Well Details | Lab Data and Comments, GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Subsurface Profile

Elev / Depth (m)	Stratigraphy
179.5	**GROUND SURFACE**
	CLAYEY SILT For stratigraphic details, refer to 16-5OB. *at 5.2m below grade*
174.3 / 5.2	**ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare styolites and gypsum nodules. Approximately 3% vug content. ...Coarsely broken core recovery from 5.49 m to 6.10 m. ...Trace vugs below 7.16 m as 2-3 mm blebs, some encrusted. ...Thin calcite or fracture surface at 7.39 m. ...Trace 4 cm gypsum nodules below 9.70 m. ...Trace sharp lower contact of change in colour and texture.
168.6 / 11.0	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded. ...Chert as 5 cm to 10 cm nodules from 14.47 m to 16.18 m, 2 to 3 % of core. ...Lower contact at 21.7 m at change is colour and increase in shale partings.
157.8 / 21.7	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Stylolites shaley partings up to 3 mm, 2 per 1.5 m. Rare gypsum nodules, less than 1% by volume. ...2 cm very fine grained (graphite like) shale layer.

Samples

Elev (m)	Depth (m)	Number	Type	Core Recovery
174.3	5.2	1	R1	TCR = 95%, RQD = 10%
173.3	6.2	2	R2	TCR = 100%, RQD = 9%
171.8	7.7	3	R3	TCR = 87%, RQD = 63%
170.3	9.2	4	R4	TCR = 98%, RQD = 83%
168.7 / 168.6	10.8 / 11.0	5	R5	TCR = 100%, RQD = 72%
167.2	12.3	6	R6	TCR = 100%, RQD = 94%
165.6	13.9	7	R7	TCR = 98%, RQD = 85%
164.1	15.4	8	R8	TCR = 98%, RQD = 88%
162.7	16.8	9	R9	TCR = 98%, RQD = 98%
161.3	18.2	10	R10	TCR = 97%, RQD = 97%
159.7	19.8	11	R11	TCR = 100%, RQD = 100%
158.1 / 157.8	21.7	12	R12	TCR = 100%, RQD = 85%
156.5	23.0	13	R13	TCR = 100%, RQD = 100%
155.0 / 153.4	24.5	14	R14	

Elevation Scale (mASL): 179, 178, 177, 176, 175, 174, 173, 172, 171, 170, 169, 168, 167, 166, 165, 164, 163, 162, 161, 160, 159, 158, 157, 156, 155

Depth Scale (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24

(continued next page)

LOG OF BOREHOLE 16-5A

DRAFT

wsp

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 649017 N: 4773470 (17T, Geodetic)

rig type | CME 75
method | Rock coring
coring | HQ core, OD=96mm, ID=64mm

project no. | 161-11633-00
date started | 2016/10/28
supervisor | SK
reviewer | KJF

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY *(continued)*	Number	Type	Core Recovery	Elevation Scale (mASL)
25		...2.5 cm chert nodule. ...Chert nodule, slighty chalky at 24.79 m.	14	R14	TCR = 98% RQD = 98%	154
26	153.4 / 26.1	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Stylolites shaley partings up to 3 mm, 2 per 1.5 m. Rare gypsum nodules, less than 1% by volume. *(continued)*	15	R15	TCR = 102% RQD = 95%	153
27, 28	151.9 / 27.6	...Noticably darker and more fossiliferous below 26.59 m.	16	R16	TCR = 100% RQD = 100%	152, 151
29, 30	150.4 / 29.1		17	R17	TCR = 94% RQD = 87%	150
31	148.9 / 30.6	...Sharp lower contact at 31.83 m on conglomeratic fossil bed.	18	R18	TCR = 102% RQD = 89%	149, 148
32, 33	147.7 / 147.4 / 31.8 / 32.1	**DECEW FORMATION**, dolostone, medium hard, dark grey, fine grained, fresh, argillaceous with occasional shale partings, 3 mm thick. ...Trace fossils below rhythmite bed at 33.02 m.	19	R19	TCR = 100% RQD = 100%	147, 146
	145.8 / 33.7					

Column headings also include: SUBSURFACE PROFILE; Graphic Plot; SAMPLE; SPT N-Value; Penetration Test Values (Blows / 0.3m) – Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) – Unconfined, Field Vane, Pocket Penetrometer, Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; PID Readings; Well Details; Lab Data and Comments – GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 17, 2016	6.0	173.6

library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2016.gpj

LOG OF BOREHOLE 16-5AR

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 649040 N: 4773471 (17T, Geodetic)

rig type | CME 75, track-mounted
method | Solid stem augers, 150 mm dia.
coring | HQ core, OD=96mm, ID=64mm

project no. | 161-11633-00
date started | 2017/07/10
supervisor | SCL/SM
reviewer | KJF

Column headings: Depth Scale (m) | SUBSURFACE PROFILE: Elev / Depth (m), STRATIGRAPHY, Graphic Plot | SAMPLE: Number, Type, SPT N-Value / Core Recovery | Elevation Scale (mASL) | Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane 40 80 120 160 | Water Content (%) & Plasticity: PL MC LL 10 20 30 | PID Readings | Well Details | Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Elev / Depth (m)	STRATIGRAPHY
179.7	**GROUND SURFACE**
	CLAYEY SILT For stratigraphic details, refer to 16-5OB.
173.6 6.1	*at 6.1m below grade* **ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare styolites and gypsum nodules. Approximately 3% vug content.
168.9 10.8	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded.
162.8 16.9	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Stylolites shaley partings up to 3 mm, 2 per 1.5 m. Rare gypsum nodules, less than 1% by volume.

Elev / Depth (m)	Type	Core Recovery
173.6 / 6.1	R1	TCR = 84% RQD = 27%
172.0 / 7.7	R2	TCR = 92% RQD = 50%
170.5 / 9.2	R3	TCR = 100% RQD = 98%
168.9 / 10.8	R4	TCR = 100% RQD = 68%
167.4 / 12.3	R5	TCR = 100% RQD = 92%
165.9 / 13.8	R6	TCR = 100% RQD = 95%
164.3 / 15.4	R7	TCR = 100% RQD = 95%
162.8 / 16.9	R8	TCR = 100% RQD = 98%
161.3 / 18.4	R9	TCR = 100% RQD = 100%
159.8 / 19.9	R10	TCR = 98% RQD = 100%
158.3 / 21.4	R11	TCR = 100% RQD = 85%
156.7 / 23.0	R12	TCR = 100% RQD = 100%
155.2 / 24.5	R13	
153.7		

Fracture Frequency

(continued next page)

LOG OF BOREHOLE 16-5AR

wsp

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |** CME 75, track-mounted	**date started |** 2017/07/10
location |	Thorold / Niagara Falls, ON	**method |** Solid stem augers, 150 mm dia.	**supervisor |** SCL/SM
position |	E: 649040 N: 4773471 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF

SUBSURFACE PROFILE (continued)

Elev / Depth (m)	STRATIGRAPHY	Sample Number	Type	Core Recovery	Elevation Scale (mASL)
	GASPORT FORMATION, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Stylolites shaley partings up to 3 mm, 2 per 1.5 m. Rare gypsum nodules, less than 1% by volume. *(continued)*		R13	TCR = **100%** RQD = **100%**	154
153.7 / 26.0			R14	TCR = **99%** RQD = **99%**	153
152.2 / 27.5			R15	TCR = **100%** RQD = **100%**	152
150.7 / 29.0			R16	TCR = **97%** RQD = **90%**	151, 150
149.1 / 30.6			R17	TCR = **103%** RQD = **85%**	149
147.9 / 31.8	**DECEW FORMATION**, dolostone, medium hard, dark grey, fine grained, fresh, argillaceous with occasional shale partings, 3 mm thick.				148
147.6 / 32.1					

Depth Scale (m): 25, 26, 27, 28, 29, 30, 31, 32

Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40

Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane 40 80 120 160

Water Content (%) & Plasticity: PL MC LL 10 20 30

PID Readings | Well Details | Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 14, 2017	5.2	174.5

LOG OF BOREHOLE 16-5B

DRAFT

wsp

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/11/03	
location | Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK	
position | E: 649015 N: 4773470 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF	

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE — STRATIGRAPHY	Graphic Plot	SAMPLE — Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m) ✕ Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) O Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160	Water Content (%) & Plasticity PL MC LL 10 20 30	PID Readings	Well Details	Lab Data and Comments GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL
0	179.6	**GROUND SURFACE**										
		CLAYEY SILT For stratigraphic descriptions, refer to 16-5OB.					179 – 175					
5	174.4 5.2	*at 5.2m below grade* For stratigraphic descriptions, refer to 16-5A.					174 – 169		Fracture Frequency		▼	
10	168.8 10.8											

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

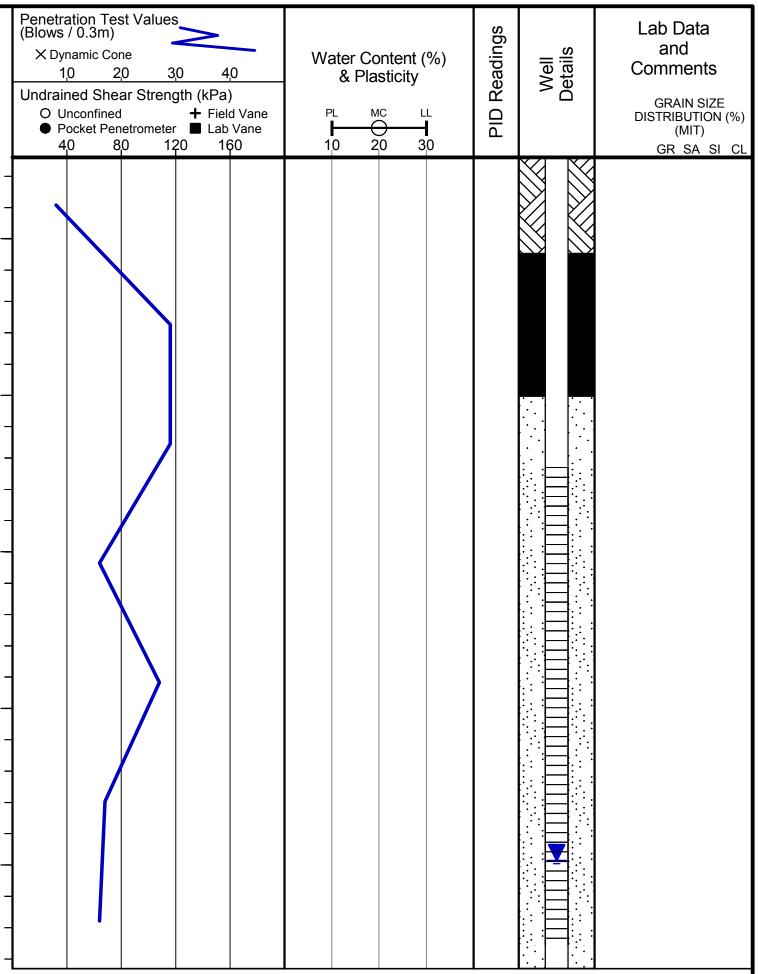
WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 17, 2016	5.0	174.6

LOG OF BOREHOLE 16-5OB

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**date started |**	2016/11/03
location |	Thorold / Niagara Falls, ON	**supervisor |**	SK
position |	E: 649014 N: 4773469 (17T, Geodetic)	**reviewer |**	KJF
rig type |	CME 75		
method |	Hollow stem augers, 215 mm dia.		
coring |	HQ core, OD=96mm, ID=64mm		

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY	Graphic Plot	SAMPLE Number	SAMPLE Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
	179.5	**GROUND SURFACE**					
0		**CLAYEY SILT**, reddish brown, trace sand, stiff to very stiff, DTPL to APL		1	SS	8	179
1				2	SS	29	178
		...at 1.5 m, 0.60 m layer of yellow silt					
2				3	SS	29	177
3				4	SS	16	176
				5	SS	27	
		...at 3.6 m, Becoming grey, stiff, APL to WTPL, dilatent					
4				6	SS	17	175
5				7	SS	16	
	174.3 5.2	**END OF BOREHOLE**					



Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 5, 2016	4.5	175.0

LOG OF BOREHOLE 16-6A

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/10/19	
location | Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK	
position | E: 649415 N: 4773168 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF	

Column headings: Depth Scale (m) | SUBSURFACE PROFILE: Elev / Depth (m), STRATIGRAPHY, Graphic Plot | SAMPLE: Number, Type, SPT N-Value / Core Recovery | Elevation Scale (mASL) | Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane 40 80 120 160 | Water Content (%) & Plasticity: PL MC LL 10 20 30; Fracture Frequency | PID Readings | Well Details | Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Elev / Depth (m)	Stratigraphy	Number	Type	Core Recovery
181.5	**GROUND SURFACE**			
	CLAYEY SILT For stratigraphic descriptions, refer to 16-6OB.			
177.1 / 4.4	*at 4.4m below grade* **ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare stylolites and gypsum nodules. Approximately 3% vug content.	1	R1	TCR = 78%, RQD = 42%
175.4 / 6.1		2	R2	TCR = 100%, RQD = 45%
174.0 / 7.5		3	R3	TCR = 94%, RQD = 63%
172.4 / 9.1		4	R4	TCR = 100%, RQD = 63%
171.1 / 170.8 / 10.4 / 10.7	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded.	5	R5	TCR = 100%, RQD = 89%
169.3 / 12.2		6	R6	TCR = 100%, RQD = 100%
167.9 / 13.6		7	R7	TCR = 98%, RQD = 82%
166.4 / 15.1		8	R8	TCR = 100%, RQD = 100%
164.7 / 16.8		9	R9	TCR = 100%, RQD = 83%
163.2 / 18.3		10	R10	TCR = 100%, RQD = 100%
161.8 / 19.7		11	R11	TCR = 100%, RQD = 100%
160.2 / 21.3		12	R12	TCR = 100%, RQD = 95%
158.6 / 158.3 / 22.9 / 23.2	*(continued on next page)*	13	R13	TCR = 98%, RQD = 92%
157.1 / 24.4 / 155.6		14	R14	

(continued next page)

LOG OF BOREHOLE 16-6A

project | Proposed Uppers Lane Quarry
project no. | 161-11633-00
client | Walker Aggregates Inc.
rig type | CME 75
date started | 2016/10/19
location | Thorold / Niagara Falls, ON
method | Rock coring
supervisor | SK
position | E: 649415 N: 4773168 (17T, Geodetic)
coring | HQ core, OD=96mm, ID=64mm
reviewer | KJF

Elev / Depth (m)	STRATIGRAPHY *(continued)*	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
155.6 / 25.9; 154.0 / 27.5; 152.6 / 28.9; 151.1 / 30.4; 149.6 / 31.9	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Stylolites shaley partings up to 3 mm, 2 per 1.5 m. Rare gypsum nodules, less than 1% by volume. *(continued)*	14	R14	TCR = **100%** RQD = **95%**	156
		15	R15	TCR = **95%** RQD = **95%**	155
		16	R16	TCR = **100%** RQD = **100%**	153
		17	R17	TCR = **100%** RQD = **100%**	152
		18	R18	TCR = **100%** RQD = **100%**	150

Depth Scale (m): 25, 26, 27, 28, 29, 30, 31

Penetration Test Values (Blows / 0.3m) — × Dynamic Cone: 10, 20, 30, 40
Undrained Shear Strength (kPa) — ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane: 40, 80, 120, 160
Water Content (%) & Plasticity — PL, MC, LL: 10, 20, 30
PID Readings
Well Details
Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

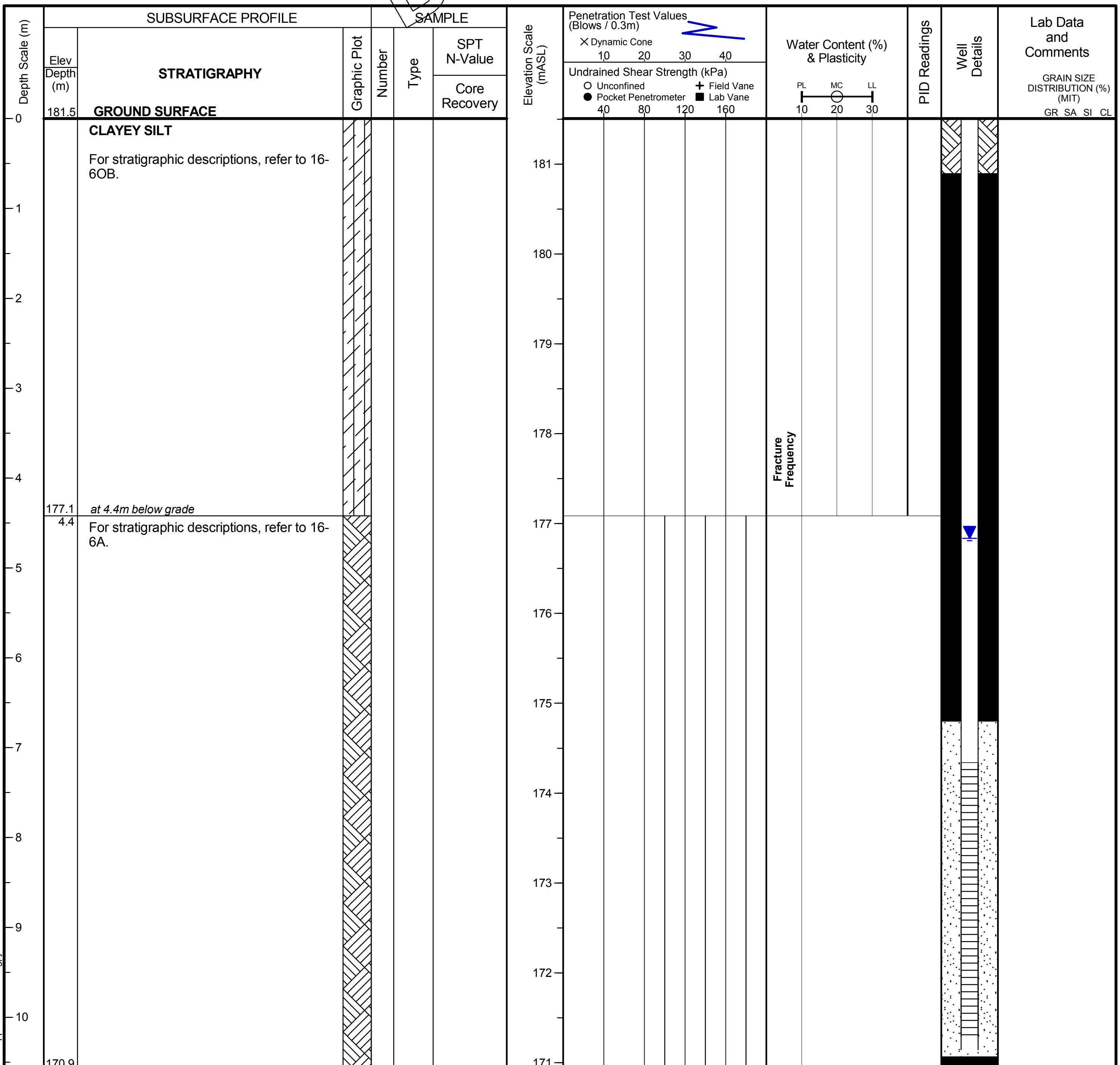
Date	Depth (m)	Elevation (m)
Nov 10, 2016	4.1	177.4

LOG OF BOREHOLE 16-6B

DRAFT

project |	Proposed Uppers Lane Quarry	project no. |	161-11633-00
client |	Walker Aggregates Inc.	rig type | CME 75	date started | 2016/10/24
location |	Thorold / Niagara Falls, ON	method | Rock coring	supervisor | SK
position |	E: 649413 N: 4773167 (17T, Geodetic)	coring | HQ core, OD=96mm, ID=64mm	reviewer | KJF

Elev / Depth (m)	STRATIGRAPHY
181.5	GROUND SURFACE
	CLAYEY SILT For stratigraphic descriptions, refer to 16-6OB.
177.1 / 4.4	*at 4.4m below grade* For stratigraphic descriptions, refer to 16-6A.
170.9 / 10.6	



END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

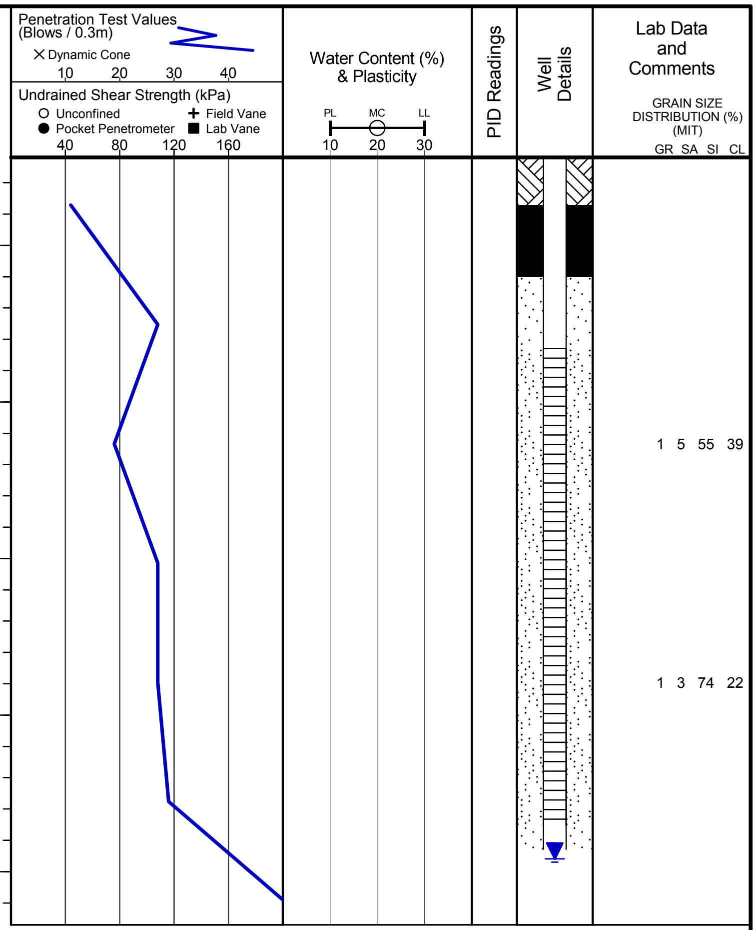
Date	Depth (m)	Elevation (m)
Nov 10, 2016	4.7	176.8

LOG OF BOREHOLE 16-6OB

DRAFT

project |	Proposed Uppers Lane Quarry			**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75	**date started |**	2016/10/24
location |	Thorold / Niagara Falls, ON	**method |**	Hollow stem augers, 215 mm dia.	**supervisor |**	SK
position |	E: 649412 N: 4773167 (17T, Geodetic)	**coring |**	*n/a*	**reviewer |**	KJF

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY	Graphic Plot	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m)	Water Content (%) & Plasticity	PID Readings	Well Details	Lab Data and Comments (GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL)
0	181.6	**GROUND SURFACE**										
		CLAYEY SILT, reddish brown, trace sand, trace gravel, stiff to very stiff, DTPL to APL		1	SS	11	181					
1				2	SS	27						
2				3	SS	19	180					1 5 55 39
				4	SS	27	179					
3				5	SS	27	178					1 3 74 22
4				6	SS	29						
	176.7 / 4.9			7	SS	70 / 175mm	177					



END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 5, 2016	4.5	177.1

library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2016.gpj

LOG OF BOREHOLE 16-7A

wsp

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 649147 N: 4772486 (17T, Geodetic)

rig type | CME 75
method | Rock coring
coring | HQ core, OD=96mm, ID=64mm

project no. | 161-11633-00
date started | 2016/10/18
supervisor | SK
reviewer | KJF

Column headings: Depth Scale (m) | SUBSURFACE PROFILE: Elev Depth (m), STRATIGRAPHY, Graphic Plot | SAMPLE: Number, Type, SPT N-Value / Core Recovery | Elevation Scale (mASL) | Penetration Test Values (Blows / 0.3m) — × Dynamic Cone (10, 20, 30, 40); Undrained Shear Strength (kPa) — ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane (40, 80, 120, 160) | Water Content (%) & Plasticity — PL, MC, LL (10, 20, 30); Fracture Frequency | PID Readings | Well Details | Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

Elev (m)	Depth (m)	Stratigraphy
180.3		**GROUND SURFACE**
	0	**SILTY CLAY TO CLAYEY SILT** For stratigraphic details, refer to 16-7OB.
174.3	6.0	*at 6.0m below grade*
		ERAMOSA FORMATION, brownish-grey to grey dolostone, hard, fresh, medium grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare stylolites and gypsum nodules. Approximately 3% vug content. ...Noticably porous and vuggy between 6.40 m and 9.45 m. ...Noticably porous and vuggy between 10.67 m and 14.02 m. ...2 cm calcite vein at 16.1 m. ...5 cm of dark shale at 19.7 m. ...7.5 cm wide calcite filled vugs (corals) from 19.96 m to 22.76 m.
160.3	20.0	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum veins. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded. ...Chert present from 21.31 m to 22.76 m.

Elevation/depth markers in column: 174.3/6.0; 172.7/7.6; 171.1/9.2; 169.6/10.7; 168.1/12.2; 166.6/13.7; 165.1/15.2; 163.6/16.7; 162.0/18.3; 160.5; 160.3/20.0; 159.0/21.3; 157.4/22.9; 155.9/24.4; 154.4

Number	Type	Core Recovery
1	R1	TCR = 88% RQD = 31%
2	R2	TCR = 95% RQD = 51%
3	R3	TCR = 102% RQD = 85%
4	R4	TCR = 98% RQD = 46%
5	R5	TCR = 100% RQD = 56%
6	R6	TCR = 98% RQD = 32%
7	R7	TCR = 98% RQD = 87%
8	R8	TCR = 100% RQD = 62%
9	R9	TCR = 100% RQD = 95%
10	R10	TCR = 100% RQD = 100%
11	R11	TCR = 100% RQD = 100%
12	R12	
13	R13	

(continued next page)

LOG OF BOREHOLE 16-7A

DRAFT

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 649147 N: 4772486 (17T, Geodetic)

rig type | CME 75
method | Rock coring
coring | HQ core, OD=96mm, ID=64mm

project no. | 161-11633-00
date started | 2016/10/18
supervisor | SK
reviewer | KJF

SUBSURFACE PROFILE *(continued)*

Elev / Depth (m)	STRATIGRAPHY
	GOAT ISLAND FORMATION, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum veins. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded. *(continued)*
150.9 / 29.4	...Gradational contact.
	GASPORT FORMATION, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Occasional stylolites. Rare gypsum nodules, less than 1% by volume. ...1 cm "graphite" layer at 30.02 m, marker bed. ...Chalky chert nodule at 31.47 m. ...Lower contact on conglomerate fossil bed.
140.7 / 39.3	**DECEW FORMATION**, dolostone, medium hard, dark grey, fine grained, fresh, argillaceous with occasional shale partings, 3 mm thick.
138.3 / 42.0	**ROCHESTER FORMATION**, shale, very dark grey to black, dolomitic to calcareous shale.
137.6 / 42.7	**END OF BOREHOLE**

SAMPLE

Number	Type	Elev / Depth (m) (top of run)	Core Recovery
13	R13	154.4 / 25.9	TCR = 100%, RQD = 100%
14	R14	152.8 / 27.5	TCR = 100%, RQD = 100%
15	R15	151.4 / 28.9	TCR = 100%, RQD = 100%
16	R16	149.8 / 30.5	TCR = 97%, RQD = 100%
17	R17	148.4 / 31.9	TCR = 102%, RQD = 102%
18	R18	146.8 / 33.5	TCR = 100%, RQD = 100%
19	R19	145.2 / 35.1	TCR = 100%, RQD = 100%
20	R20	143.7 / 36.6	TCR = 100%, RQD = 100%
21	R21	142.2 / 38.1	TCR = 100%, RQD = 86%
22	R22	141.0 / 39.3	TCR = 100%, RQD = 92%
23	R23	139.2 / 39.6 (41.1)	TCR = 100%, RQD = 93%
24	R24	138.3 / 41.1	TCR = 100%, RQD = 97%

Column headings: Depth Scale (m); Elev Depth (m); STRATIGRAPHY; Graphic Plot; Number; Type; SPT N-Value / Core Recovery; Elevation Scale (mASL); Penetration Test Values (Blows / 0.3m) × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) O Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; PID Readings; Well Details; Lab Data and Comments GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Depth scale: 25 – 42 m. Elevation scale: 155 – 138 mASL.

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 8, 2016	14.5	165.8

LOG OF BOREHOLE 16-7B

wsp

project | Proposed Uppers Lane Quarry		**project no. |**	161-11633-00
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |**	2016/10/18
location | Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |**	SK
position | E: 649148 N: 4772487 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |**	KJF

Column headings: Depth Scale (m) | SUBSURFACE PROFILE: Elev Depth (m), STRATIGRAPHY, Graphic Plot | SAMPLE: Number, Type, SPT N-Value, Core Recovery | Elevation Scale (mASL) | Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane 40 80 120 160 | Water Content (%) & Plasticity: PL MC LL 10 20 30 | Fracture Frequency | PID Readings | Well Details | Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Elev / Depth (m)	Stratigraphy
180.4	**GROUND SURFACE**
	SILTY CLAY TO CLAYEY SILT For stratigraphic descriptions, refer to 16-7OB.
174.4 / 6.0	*at 6.0m below grade* For stratigraphic descriptions, refer to 16-7A.
159.1 / 21.3	**END OF BOREHOLE**

Borehole was dry and open upon completion.

50 mm monitoring well installed. No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 8, 2016	4.3	176.1

LOG OF BOREHOLE 16-7OB

DRAFT

wsp

project |	Proposed Uppers Lane Quarry			**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75	**date started |**	2016/10/18
location |	Thorold / Niagara Falls, ON	**method |**	Hollow stem augers, 215 mm dia.	**supervisor |**	SK
position |	E: 649150 N: 4772488 (17T, Geodetic)	**coring |**	*n/a*	**reviewer |**	KJF

SUBSURFACE PROFILE

Depth Scale (m)	Elev / Depth (m)	STRATIGRAPHY	Number	Type	SPT N-Value / Core Recovery
0	180.4	**GROUND SURFACE**			
		SILTY CLAY TO CLAYEY SILT, yellowish brown, trace sand, trace gravel, hard to firm, APL	1	SS	14
1			2	SS	40
		...at 1.5 m, Becoming reddish brown	3	SS	18
2			4	SS	9
3			5	SS	7
		...at 3.8 m, Becoming dilatent	6	SS	6
4			7	SS	5
5			8	SS	36
6	174.4 / 6.0		9	SS	56 / 200mm
	6.5	**END OF BOREHOLE**			

Elevation Scale (mASL): 180, 179, 178, 177, 176, 175, 174

Penetration Test Values (Blows / 0.3m): × Dynamic Cone; 10, 20, 30, 40

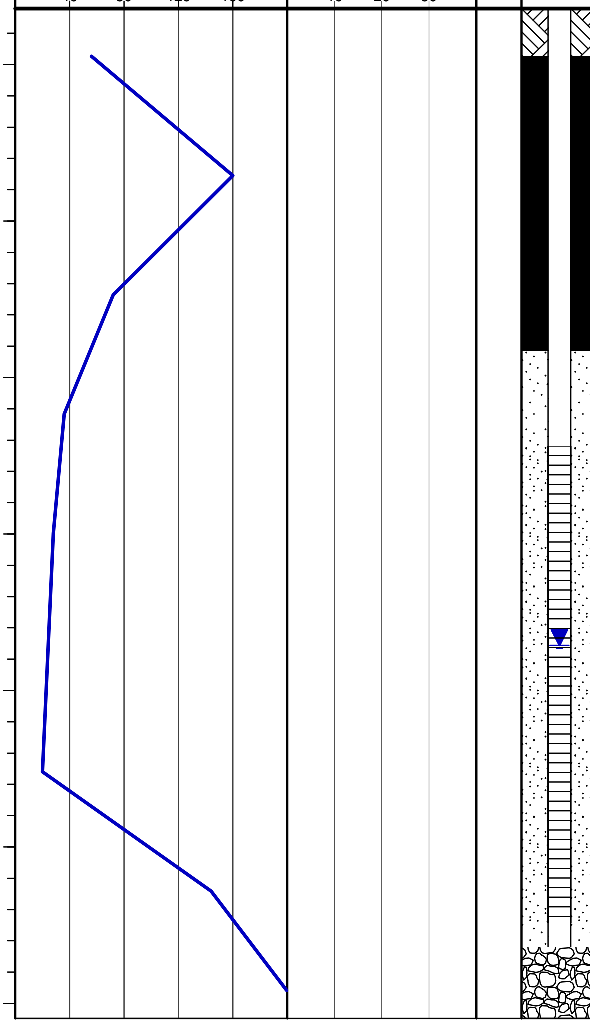
Undrained Shear Strength (kPa): ○ Unconfined; + Field Vane; ● Pocket Penetrometer; ■ Lab Vane; 40, 80, 120, 160

Water Content (%) & Plasticity: PL, MC, LL; 10, 20, 30

PID Readings

Well Details

Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL



Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 8, 2016	4.1	176.3

LOG OF BOREHOLE 16-8A

wsp

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75
		date started |	2016/10/04
location |	Thorold / Niagara Falls, ON	**method |**	Rock coring
		supervisor |	SK
position |	E: 648272 N: 4772003 (17T, Geodetic)	**coring |**	HQ core, OD=96mm, ID=64mm
		reviewer |	KJF

SUBSURFACE PROFILE / SAMPLE

Depth Scale (m); Elevation Scale (mASL); Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; Fracture Frequency; PID Readings; Well Details; Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Elev / Depth (m)	STRATIGRAPHY	Number	Type	SPT N-Value / Core Recovery
186.0	**GROUND SURFACE**			
	CLAYEY SILT For stratigraphic descriptions, refer to 16-8OB.			
175.3	*at 10.7m below grade*			
10.7	**ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare styolites and gypsum nodules. Approximately 3% vug content.	15	R1	TCR = **60%** RQD = **6%**
173.7 / 12.3		16	R2	TCR = **96%** RQD = **68%**
172.3 / 13.7		17	R3	TCR = **100%** RQD = **96%**
170.9 / 15.1		18	R4	TCR = **100%** RQD = **94%**
169.3 / 16.7		19	R5	TCR = **92%** RQD = **58%**
167.7 / 18.3		20	R6	TCR = **113%** RQD = **50%**
166.3 / 19.7		21	R7	TCR = **89%** RQD = **39%**
164.7 / 21.3		22	R8	TCR = **109%** RQD = **87%**
163.3 / 22.7		23	R9	TCR = **100%** RQD = **70%**
161.6 / 24.4	...Pinkish white calcite filled vugs from 25.25 m for 5 cm and from 27.5 m to 27.81 m.	24	R10	TCR = **88%** RQD = **39%**
160.1 / 25.9		25	R11	TCR = **90%** RQD = **90%**
158.5				

(continued next page)

LOG OF BOREHOLE 16-8A

DRAFT

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/10/04	
location | Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK	
position | E: 648272 N: 4772003 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF	

SUBSURFACE PROFILE (continued)

Elev / Depth (m)	STRATIGRAPHY
158.5 / 27.5	...2 to 4 mm shaley partings from 28.01 m to 30.78 m.
158.0 / 28.0	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded. ...Calcite fossils from 30.18 m to 31.95 m. ...Minor chert as 1 to 2 cm blebs from 32 m to 32.92 m. ...2 cm chalky calcite bleb at 40.03 m.
157.1 / 28.9	
155.5 / 30.5	
153.9 / 32.1	
152.4 / 33.6	
150.9 / 35.1	
149.3 / 36.7	
147.8 / 38.2	
146.3 / 39.7	
146.0 / 40.0	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Stylolites shaley partings up to 3 mm, 2 per 1.5 m. Rare gypsum nodules, less than 1% by volume. ...1 cm "Graphite like" marker bed at 40.54 m. ...6 cm chalky calcite bleb at 43.66 m. ...Lower gasport contact at 48.29 m on conglomerate bed.
144.7 / 41.3	
143.3 / 42.7	
141.8 / 44.2	
140.2 / 45.8	
138.9 / 47.1	
137.7 / 48.3	**DECEW FORMATION**, dolostone, medium hard, dark grey, fine grained, fresh, arenaceous. 1 cm calcite bleb at 48.46 m.
137.4 / 48.6	**END OF BOREHOLE** Borehole was dry and open upon completion. 50 mm monitoring well installed. No. 10 screen installed.

SAMPLE

Number	Type	SPT N-Value / Core Recovery
25	R11	
26	R12	TCR = 111%, RQD = 111%
27	R13	TCR = 95%, RQD = 95%
28	R14	TCR = 100%, RQD = 100%
29	R15	TCR = 100%, RQD = 100%
30	R16	TCR = 102%, RQD = 102%
31	R17	TCR = 100%, RQD = 100%
32	R18	TCR = 100%, RQD = 100%
33	R19	TCR = 97%, RQD = 92%
34	R20	TCR = 100%, RQD = 100%
35	R21	TCR = 100%, RQD = 95%
36	R22	TCR = 100%, RQD = 100%
37	R23	TCR = 98%, RQD = 98%
38	R24	TCR = 100%, RQD = 100%
39	R25	

Column headings: Depth Scale (m); Graphic Plot; Elevation Scale (mASL); Penetration Test Values (Blows / 0.3m) — Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) — Unconfined, Field Vane, Pocket Penetrometer, Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; PID Readings; Well Details; Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 8, 2016	7.9	178.1

LOG OF BOREHOLE 16-8B

DRAFT

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/10/11
location |	Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK
position |	E: 648270 N: 4772003 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF

SUBSURFACE PROFILE / SAMPLE / Penetration Test Values (Blows / 0.3m) — × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) — ○ Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; PID Readings; Well Details; Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY	Graphic Plot	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	186.0	**GROUND SURFACE**					
0		**CLAYEY SILT**					
1		For stratigraphic descriptions, refer to 16-8OB.					185
10.7	175.3 / 10.7	*at 10.7m below grade*					175
11		For stratigraphic descriptions, refer to 16-8A.					
26.1	159.9 / 26.1						160

Fracture Frequency

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 8, 2016	9.5	176.5

LOG OF BOREHOLE 16-8OB

wsp

project | Proposed Uppers Lane Quarry — **project no. |** 161-11633-00
client | Walker Aggregates Inc. — **rig type |** CME 75 — **date started |** 2016/10/04
location | Thorold / Niagara Falls, ON — **method |** Hollow stem augers, 215 mm dia. — **supervisor |** SK
position | E: 648269 N: 4772003 (17T, Geodetic) — **coring |** *n/a* — **reviewer |** KJF

Elev / Depth (m)	Stratigraphy	Sample Number	Type	SPT N-Value / Core Recovery	Lab Data: Grain Size Distribution (%) (MIT) GR SA SI CL
186.0	GROUND SURFACE				
	CLAYEY SILT, brown, trace sand, trace gravel, hard, DTPL.	1	SS	31	
		2	SS	37	4 15 64 17
		3	SS	50 / 125mm	
183.0 / 3.1	**SANDY SILT**, dark brown to brown grey, saccharoidal, trace gravel, hard/very dense, moist to wet, dilatent. Mosy recovery is in 2.5 cm to 10 cm pieces.	4	SS	50 / 100mm	
		5	SS	50 / 100mm	4 25 56 15
		6	SS	50 / 125mm	
		7	SS	50 / 100mm	
		8	SS	50 / 125mm	
		9	SS	50 / 0mm	
		10	SS	50 / 75mm	1 30 56 13
		11	SS	50 / 75mm	
		12	SS	50 / 100mm	
		13	SS	50 / 25mm	
		14	SS	50 / 75mm	
174.7 / 11.3	**END OF BOREHOLE**				

Column headings: Depth Scale (m); Graphic Plot; Elevation Scale (mASL); Penetration Test Values (Blows / 0.3m) — Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) — Unconfined, Field Vane, Pocket Penetrometer, Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; PID Readings; Well Details; Lab Data and Comments.

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 8, 2016	6.8	179.1

LOG OF BOREHOLE 16-9A

wsp

project | Proposed Uppers Lane Quarry
project no. | 161-11633-00
client | Walker Aggregates Inc.
rig type | CME 75
date started | 2016/11/18
location | Thorold / Niagara Falls, ON
method | Rock coring
supervisor | SK
position | E: 648258 N: 4773007 (17T, Geodetic)
coring | HQ core, OD=96mm, ID=64mm
reviewer | KJF

Depth Scale (m)	Elev / Depth (m)	STRATIGRAPHY	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	182.0	**GROUND SURFACE**				
		CLAYEY SILT For stratigraphic descriptions, refer to 16-9OB.				
7	174.8	*at 7.2m below grade*				175
	7.2	**ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare styolites and gypsum nodules. Approximately 3% vug content.	1	R1	TCR = 100% RQD = 0%	
8	7.7		2	R2	TCR = 98% RQD = 74%	174
9	172.8 / 9.2		3	R3	TCR = 100% RQD = 82%	173
11	171.2 / 10.8		4	R4	TCR = 95% RQD = 44%	171
12	169.7 / 12.3		5	R5	TCR = 100% RQD = 22%	169
14	168.2 / 13.8		6	R6	TCR = 100% RQD = 89%	168
15	166.6 / 15.4		7	R7	TCR = 98% RQD = 89%	166
17	165.1 / 16.9		8	R8	TCR = 100% RQD = 81%	165
18	164.2 / 17.8	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite as 1.25 cm to 3.8 cm nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded.				164
	163.6 / 18.4		9	R9	TCR = 100% RQD = 100%	163
20	162.0 / 20.0		10	R10	TCR = 97% RQD = 97%	162
21	160.5 / 21.5		11	R11	TCR = 100% RQD = 100%	160
23	159.1 / 22.9	...Three 1-3 cm nodules at 23.48 m to 22.53 m.	12	R12	TCR = 100% RQD = 88%	159
24	157.5 / 24.5		13	R13		158
	156.0					

Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40
Undrained Shear Strength (kPa): O Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane; 40 80 120 160
Water Content (%) & Plasticity: PL MC LL; 10 20 30
Fracture Frequency
PID Readings
Well Details
Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

(continued next page)

LOG OF BOREHOLE 16-9A

wsp

project | Proposed Uppers Lane Quarry
project no. | 161-11633-00

client | Walker Aggregates Inc.
rig type | CME 75
date started | 2016/11/18

location | Thorold / Niagara Falls, ON
method | Rock coring
supervisor | SK

position | E: 648258 N: 4773007 (17T, Geodetic)
coring | HQ core, OD=96mm, ID=64mm
reviewer | KJF

Depth Scale (m)	Elev / Depth (m)	SUBSURFACE PROFILE – STRATIGRAPHY *(continued)*	Sample Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
25		**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite as 1.25 cm to 3.8 cm nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded. *(continued)*	13	R13	TCR = **100%** RQD = **100%**	
26	156.0 / 26.0		14	R14	TCR = **100%** RQD = **100%**	156
27	154.4 / 27.6		15	R15	TCR = **102%** RQD = **102%**	155
28	153.0 / 29.0					154
29	152.7 / 29.3	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Stylolites shaley partings up to 3 mm, 2 per 1.5 m. Rare gypsum nodules, less than 1% by volume. ...at 29.4 m, 1 cm "graphite" marker bed is at 29.97 m.	16	R16	TCR = **100%** RQD = **100%**	153
30	151.4 / 30.6		17	R17	TCR = **100%** RQD = **100%**	152
31–32	149.8 / 32.2		18	R18	TCR = **100%** RQD = **100%**	151, 150
33	148.3 / 33.7		19	R19	TCR = **100%** RQD = **100%**	149, 148
34–35	146.8 / 35.2		20	R20	TCR = **100%** RQD = **100%**	147, 146
36	145.3 / 36.7		21	R21	TCR = **100%** RQD = **100%**	145
37–38	143.8 / 38.2		22	R22	TCR = **100%** RQD = **100%**	144, 143
39	142.4 / 39.6; 142.2 / 39.8	**DECEW FORMATION**, dolostone, medium hard, dark grey, fine grained, fresh, argillaceous with occasional shale partings, 3 mm thick.	23	R23	TCR = **100%** RQD = **95%**	142
40–41	140.7 / 41.3	**END OF BOREHOLE**				141

Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40
Undrained Shear Strength (kPa): ○ Unconfined; + Field Vane; ● Pocket Penetrometer; ■ Lab Vane — 40 80 120 160
Water Content (%) & Plasticity: PL MC LL — 10 20 30
PID Readings | Well Details
Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 25, 2016	5.3	176.7

LOG OF BOREHOLE 16-9B

wsp

DRAFT

project |	Proposed Uppers Lane Quarry			**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75	**date started |**	2016/11/22
location |	Thorold / Niagara Falls, ON	**method |**	Rock coring	**supervisor |**	SK
position |	E: 648259 N: 4773006 (17T, Geodetic)	**coring |**	HQ core, OD=96mm, ID=64mm	**reviewer |**	KJF

SUBSURFACE PROFILE | SAMPLE | Penetration Test Values (Blows / 0.3m) × Dynamic Cone 10 20 30 40 | Undrained Shear Strength (kPa) O Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160 | Water Content (%) & Plasticity PL MC LL 10 20 30 | PID Readings | Well Details | Lab Data and Comments GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY	Graphic Plot	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	182.1	**GROUND SURFACE**					182
		CLAYEY SILT For stratigraphic descriptions, refer to 16-9OB.					
7	174.9 / 7.2	*at 7.2m below grade* For stratigraphic descriptions, refer to 16-9A.					175
17.7	164.4 / 17.7						

Fracture Frequency

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

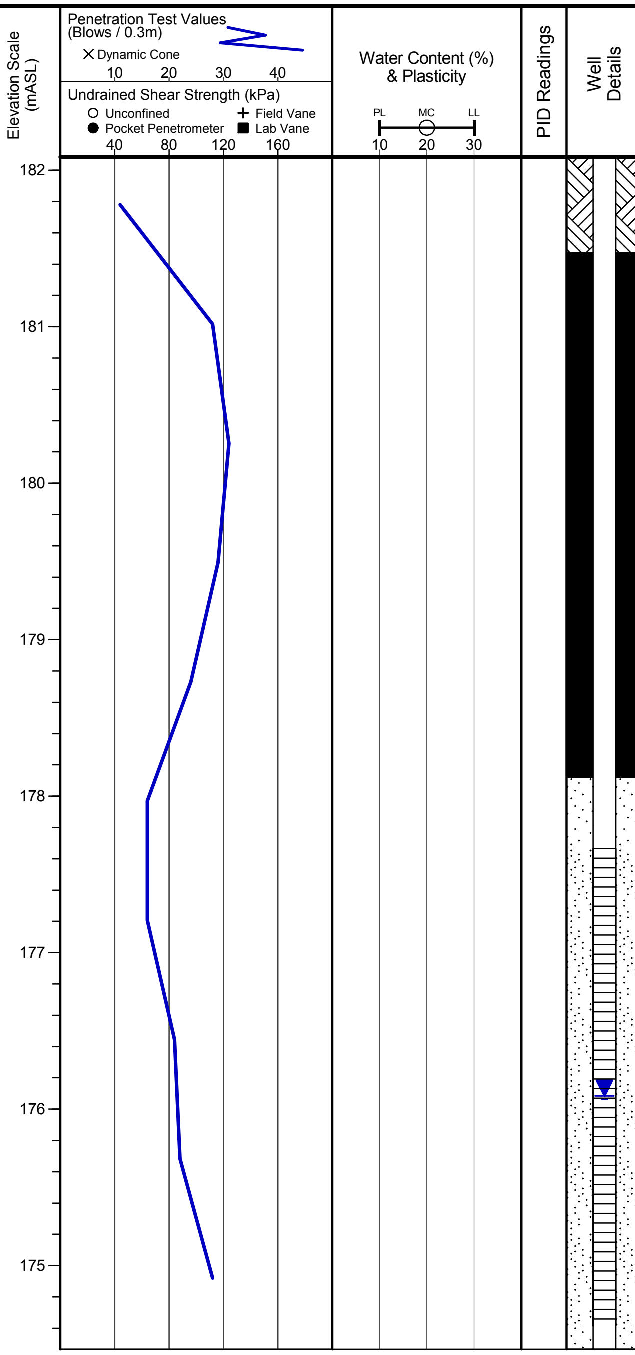
Date	Depth (m)	Elevation (m)
Nov 25, 2016	6.3	175.7

LOG OF BOREHOLE 16-9OB

DRAFT

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/11/23	
location | Thorold / Niagara Falls, ON	**method |** Hollow stem augers, 215 mm dia.	**supervisor |** SK	
position | E: 648261 N: 4773005 (17T, Geodetic)	**coring |** *n/a*	**reviewer |** KJF	

Elev / Depth (m)	Stratigraphy	Sample Number	Type	SPT N-Value	Lab Data and Comments (Grain Size Distribution (%) (MIT): GR SA SI CL)
182.1	**GROUND SURFACE**				
0.0	**CLAYEY SILT**, brown, trace silt, trace sand, trace gravel, very stiff, DTPL to APL	1	SS	11	
		2	SS	28	
		3	SS	31	2 12 33 53
		4	SS	29	
		5	SS	24	
		6	SS	16	1 3 40 56
		7	SS	16	
176.8 / 5.3	**SILT AND CLAY**, grey to reddish grey, trace sand, trace gravel, very stiff, APL to WTPL, dilatent	8	SS	21	
		9	SS	22	32 20 35 13
		10	SS	28	
174.5 / 7.6	**END OF BOREHOLE**				



Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 7, 2016	6.0	176.1

LOG OF BOREHOLE 16-9SP

DRAFT

wsp

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75, track-mounted	**date started |** 2017/07/26	
location | Thorold / Niagara Falls, ON	**method |** Hollow stem augers, 215 mm dia.	**supervisor |** SCL	
position | E: 648263 N: 4773003 (17T, Geodetic)	**coring |** *n/a*	**reviewer |** KJF	

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE – STRATIGRAPHY	Graphic Plot	SAMPLE Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m) × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) ○ Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160	Water Content (%) & Plasticity PL MC LL 10 20 30	PID Readings	Well Details	Lab Data and Comments GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL
0.0	182.2	**GROUND SURFACE**										
		CLAYEY SILT For stratigraphic descriptions, refer to 16-9OB.					182.0					
0.5							181.5					
1.0							181.0					
1.5							180.5					
2.0							180.0					
2.5							179.5					
	179.5 2.7	**END OF BOREHOLE**										

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 28, 2017	1.1	181.1

LOG OF BOREHOLE 16-10A

DRAFT

wsp

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/11/24	
location | Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK	
position | E: 648212 N: 4773549 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF	

Depth Scale (m)	Elev / Depth (m)	STRATIGRAPHY	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	181.8	**GROUND SURFACE**				
		CLAYEY SILT For stratigraphic descriptions, refer to 16-10OB.				181
5.5	176.3 / 5.5	*at 5.5m below grade* **ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium grained with saccharoidal texture, slightly vuggy, fossiliferous, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare stylites and gypsum nodules.	1	R1	TCR = 100% RQD = 38%	176
	6.1		2	R2	TCR = 100% RQD = 67%	175
	174.2 / 7.6		3	R3	TCR = 100% RQD = 71%	174
	172.6 / 9.2		4	R4	TCR = 98% RQD = 58%	172
	171.1 / 10.7	...Gradational core recovered as 5 cm to 10 cm pieces from 10.05 m to 13.82 m. ...Thin bedded from 10.36 m to 13.61 m.	5	R5	TCR = 100% RQD = 27%	170
	169.5 / 12.3		6	R6	TCR = 100% RQD = 72%	169
	168.0 / 13.8		7	R7	TCR = 100% RQD = 87%	167
	166.5 / 15.3	...Calcite filled parting at 15.60 m. ...1 cm chert nodule at 16.18 m.	8	R8	TCR = 100% RQD = 92%	166
	165.6 / 16.2	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum veins. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded. ...1 cm shale layer at 18.00 m.				
	165.0 / 16.8		9	R9	TCR = 97% RQD = 92%	164
	163.4 / 18.4		10	R10	TCR = 100% RQD = 100%	163
	161.9 / 19.9	...Chert nodules up to 7.62 cm wide, 4% of core from 19.76 m to 20.42 m.	11	R11	TCR = 100% RQD = 100%	161
	160.4 / 21.4		12	R12	TCR = 100% RQD = 100%	160
	158.8 / 23.0		13	R13	TCR = 100% RQD = 100%	158
	157.3 / 24.5		14	R14		157
	155.8					

Column headings: SUBSURFACE PROFILE; SAMPLE; Graphic Plot; Penetration Test Values (Blows / 0.3m) × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) O Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; Fracture Frequency; PID Readings; Well Details; Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

(continued next page)

LOG OF BOREHOLE 16-10A

DRAFT

wsp

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 648212 N: 4773549 (17T, Geodetic)
rig type | CME 75
method | Rock coring
coring | HQ core, OD=96mm, ID=64mm
project no. | 161-11633-00
date started | 2016/11/24
supervisor | SK
reviewer | KJF

Elev / Depth (m)	STRATIGRAPHY *(continued)*	Sample Number	Type	TCR / RQD
155.9 / 25.9		14	R14	TCR = 100%, RQD = 100%
155.8 / 26.0	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Occasional stylolites. Rare gypsum nodules, less than 1% by volume. ...1 cm "graphite" layer at 26.92 m, marker bed. ...Chalky chert nodules from 28.88 m to 29.10 m.	15	R15	TCR = 98%, RQD = 97%
154.3 / 27.5		16	R16	TCR = 100%, RQD = 90%
152.7 / 29.1		17	R17	TCR = 100%, RQD = 97%
151.2 / 30.6		18	R18	TCR = 100%, RQD = 100%
149.7 / 32.1		19	R19	TCR = 100%, RQD = 100%
148.2 / 33.6		20	R20	TCR = 100%, RQD = 95%
147.2 / 34.6	**DECEW FORMATION**, dolostone, medium hard, dark grey, fine grained, fresh, argillaceous with occasional shale partings, 3 mm thick. Slightly arenaceous, rhythmites present.			
146.7 / 35.1				

Column headings: Depth Scale (m); SUBSURFACE PROFILE; Graphic Plot; SAMPLE; SPT N-Value; Core Recovery; Elevation Scale (mASL); Penetration Test Values (Blows / 0.3m) — Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) — Unconfined, Field Vane, Pocket Penetrometer, Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; PID Readings; Well Details; Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Depth scale: 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35
Elevation scale: 156, 155, 154, 153, 152, 151, 150, 149, 148, 147

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 30, 2016	4.8	177.0

LOG OF BOREHOLE 16-10B

wsp

DRAFT

project |	Proposed Uppers Lane Quarry			**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75	**date started |**	2016/11/28
location |	Thorold / Niagara Falls, ON	**method |**	Rock coring	**supervisor |**	SK
position |	E: 648212 N: 4773547 (17T, Geodetic)	**coring |**	HQ core, OD=96mm, ID=64mm	**reviewer |**	KJF

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE: STRATIGRAPHY	Graphic Plot	SAMPLE: Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m) / Undrained Shear Strength (kPa)	Water Content (%) & Plasticity	PID Readings	Well Details	Lab Data and Comments
	181.9	**GROUND SURFACE**										
0		**CLAYEY SILT** For stratigraphic descriptions, refer to 16-10OB.										
5.5	176.4 5.5	*at 5.5m below grade* For stratigraphic descriptions, refer to 16-10A.							Fracture Frequency			
10.8	171.1 10.8	**END OF BOREHOLE**										

Column scales: Dynamic Cone 10, 20, 30, 40; Unconfined, Field Vane, Pocket Penetrometer, Lab Vane 40, 80, 120, 160; PL, MC, LL 10, 20, 30; GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL.

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Elevation scale: 181, 180, 179, 178, 177, 176, 175, 174, 173, 172.

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 30, 2016	6.4	175.5

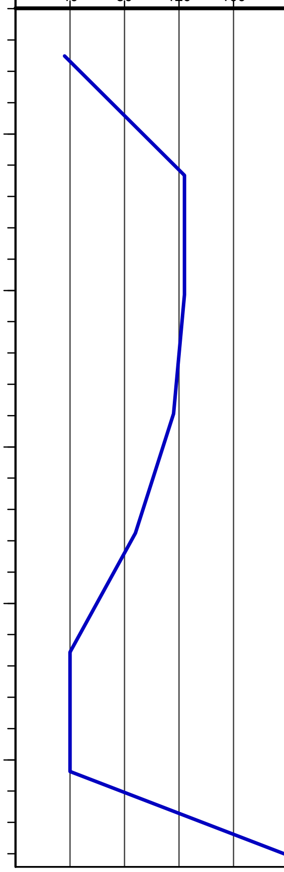
LOG OF BOREHOLE 16-10OB

wsp

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 648212 N: 4773550 (17T, Geodetic)
rig type | CME 75
method | Hollow stem augers, 215 mm dia.
coring | *n/a*
project no. | 161-11633-00
date started | 2016/11/23
supervisor | SK
reviewer | KJF

Depth Scale (m)	Elev / Depth (m)	Stratigraphy	Sample Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	181.8	**GROUND SURFACE**				
		CLAYEY SILT, brown, trace silt, trace sand, stiff to hard, DTPL to APL	1	SS	9	
1			2	SS	31	181
2			3	SS	31	180
3			4	SS	29	179
			5	SS	22	178
4			6	SS	10	
5		...at 4.6 m, Becoming reddish brown, trace gravel, stiff, APL to WTPL , dilatent	7	SS	10	177
	176.3 / 5.5		8	SS	50 / 0mm	

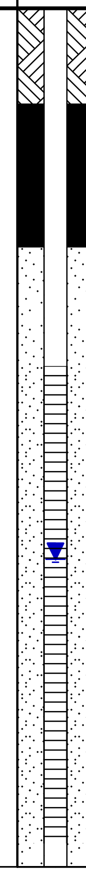
Penetration Test Values (Blows / 0.3m): × Dynamic Cone — 10, 20, 30, 40
Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane — 40, 80, 120, 160



Water Content (%) & Plasticity: PL, MC, LL — 10, 20, 30

PID Readings

Well Details



Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 7, 2016	3.5	178.3

library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2016.gpj

LOG OF BOREHOLE 16-11

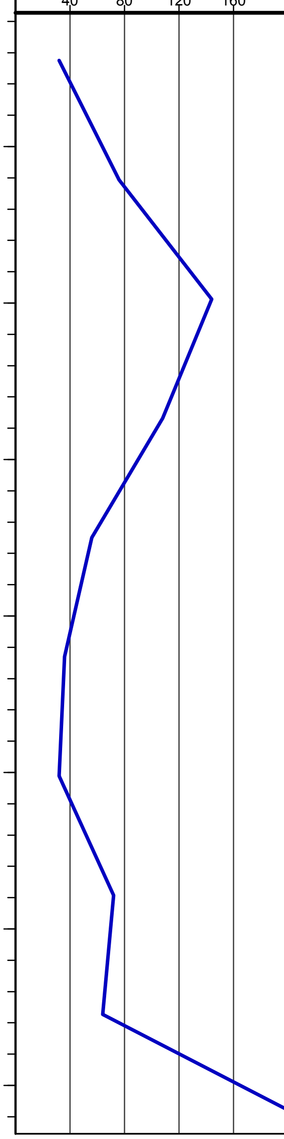
DRAFT

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75
		date started |	2016/11/08
location |	Thorold / Niagara Falls, ON	**method |**	Hollow stem augers, 215 mm dia.
		supervisor |	SK
position |	E: 648503 N: 4773178 (17T, Geodetic)	**coring |**	*n/a*
		reviewer |	KJF

SUBSURFACE PROFILE

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY	Graphic Plot	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	182.9	**GROUND SURFACE**					
		CLAYEY SILT TO SILTY CLAY, yellowish brown, trace sand, trace gravel, stiff to hard, DTPL to APL		1	SS	8	
1				2	SS	19	182
2				3	SS	36	181
				4	SS	27	
3				5	SS	14	180
4				6	SS	9	179
5		...at 4.6 m, Becoming greyish, stiff, APL, dilatent		7	SS	8	178
6				8	SS	18	177
				9	SS	16	176
7	175.7 7.2			10	SS	58 / 150mm	

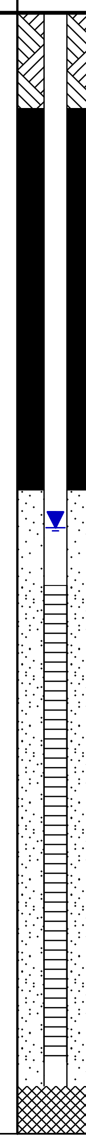
Penetration Test Values (Blows / 0.3m) — X Dynamic Cone: 10, 20, 30, 40
Undrained Shear Strength (kPa) — O Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane: 40, 80, 120, 160



Water Content (%) & Plasticity — PL, MC, LL: 10, 20, 30

PID Readings

Well Details



Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 10, 2016	3.3	179.6

library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2016.gpj

LOG OF BOREHOLE 16-12

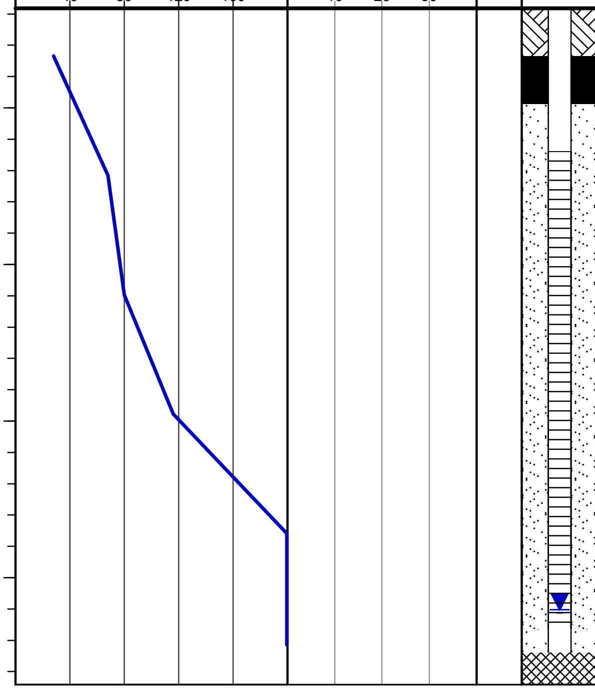
project |	Proposed Uppers Lane Quarry			**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75	**date started |**	2016/11/08
location |	Thorold / Niagara Falls, ON	**method |**	Hollow stem augers, 215 mm dia.	**supervisor |**	SK
position |	E: 648507 N: 4772982 (17T, Geodetic)	**coring |**	*n/a*	**reviewer |**	KJF

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE – STRATIGRAPHY	Graphic Plot	SAMPLE Number	Type	SPT N-Value / Core Recovery
	183.6	**GROUND SURFACE**				
0		**CLAYEY SILT**, brown, trace sand, blocky, very stiff to hard, DTPL		1	SS	7
1				2	SS	17
2				3	SS	20
				4	SS	29
3				5	SS	53
	179.8 / 3.8	**SILT**, reddish brown, trace sand, trace gravel, hard, DTPL				
4				6	SS	53
	179.3 / 4.3	**END OF BOREHOLE**				

Elevation Scale (mASL): 183, 182, 181, 180

Penetration Test Values (Blows / 0.3m): × Dynamic Cone; 10, 20, 30, 40

Undrained Shear Strength (kPa): ○ Unconfined; + Field Vane; ● Pocket Penetrometer; ■ Lab Vane; 40, 80, 120, 160



Water Content (%) & Plasticity: PL, MC, LL; 10, 20, 30

PID Readings

Well Details

Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 10, 2016	3.8	179.8

LOG OF BOREHOLE 16-13A

wsp

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/11/11	
location | Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK	
position | E: 648513 N: 4772784 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF	

SUBSURFACE PROFILE / SAMPLE

Elev / Depth (m)	STRATIGRAPHY	Number	Type	SPT N-Value / Core Recovery
185.2	**GROUND SURFACE**			
	CLAYEY SILT For stratigraphic descriptions, refer to 16-13OB.			
180.6 / 4.6	*at 4.6m below grade*			
	ERAMOSA FORMATION, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare stylites and gypsum nodules. Approximately 3% vug content.	1	R1	TCR = 77% RQD = 27%
179.0 / 6.2		2	R2	TCR = 100% RQD = 90%
177.5 / 7.7		3	R3	TCR = 98% RQD = 90%
176.0 / 9.2		4	R4	TCR = 100% RQD = 92%
174.4 / 10.8	..."Void" at 10.26 m to 10.36 m.	5	R5	TCR = 100% RQD = 75%
172.9 / 12.3		6	R6	TCR = 98% RQD = 71%
171.4 / 13.8	...Grey muddy infill at 14.78 m for 10 cm.	7	R7	TCR = 100% RQD = 87%
169.9 / 15.3	...Eramosa as 10 cm to 15 cm pieces from 15.04 m to 19.81 m.	8	R8	TCR = 90% RQD = 58%
168.3 / 16.9	...Vuggy, up to 3 mm, 30 % of core from 17.01 m to 17.08 m.	9	R9	TCR = 95% RQD = 69%
166.8 / 18.4	...Vuggy, up to 3 mm, 30 % of core from 18.49 m to 18.72 m. ...Calcite blebs up to 3 cm from 19.81 m to 20.14 m.	10	R10	TCR = 100% RQD = 86%
165.3 / 19.9		11	R11	TCR = 95% RQD = 95%
163.7 / 163.6 / 21.6	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded.	12	R12	TCR = 100% RQD = 100%
162.3 / 22.9		13	R13	TCR = 98% RQD = 90%
160.7 / 24.5 / 159.2	*(continued on next page)*	14	R14	

Depth Scale (m): 0–24; Elevation Scale (mASL): 185–161

Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40
Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane; 40 80 120 160

Water Content (%) & Plasticity: PL MC LL; 10 20 30

Fracture Frequency

PID Readings

Well Details

Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

(continued next page)

LOG OF BOREHOLE 16-13A

DRAFT

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 648513 N: 4772784 (17T, Geodetic)

rig type | CME 75
method | Rock coring
coring | HQ core, OD=96mm, ID=64mm

project no. | 161-11633-00
date started | 2016/11/11
supervisor | SK
reviewer | KJF

SUBSURFACE PROFILE *(continued)*

Elev / Depth (m)	STRATIGRAPHY
159.2 / 26.0	...2.5 cm thick black shale bed at 24.26 m. ...Chert at 25.02 m to 26.75 m.
	GOAT ISLAND FORMATION, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded. *(continued)*
157.6 / 27.6	
156.1 / 29.1	
154.6 / 30.6	
153.0 / 32.2	
152.3 / 32.9	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Stylolites shaley partings up to 3 mm, 2 per 1.5 m. Rare gypsum nodules, less than 1% by volume. ...1 cm graphite 'marker' bed at 34 m.
151.6 / 33.6	
150.0 / 35.2	
148.5 / 36.7	
146.9 / 38.3	
145.4 / 39.8	
143.9 / 41.3	
142.7 / 42.5	**DECEW FORMATION**, dolostone, medium hard, dark grey, fine grained, fresh, argillaceous with occasional shale partings, 3 mm thick.
142.4 / 42.8	

SAMPLE

Number	Type	TCR	RQD
14	R14	100%	95%
15	R15	98%	98%
16	R16	100%	100%
17	R17	100%	100%
18	R18	100%	100%
19	R19	100%	98%
20	R20	98%	98%
21	R21	100%	100%
22	R22	100%	100%
23	R23	100%	100%
24	R24	100%	100%
25	R25	100%	90%

Depth Scale (m): 25–42. Elevation Scale (mASL): 160–143.

Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane 40 80 120 160. Water Content (%) & Plasticity: PL MC LL 10 20 30. PID Readings. Well Details. Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL.

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 21, 2016	7.8	177.4

LOG OF BOREHOLE 16-13B

DRAFT

wsp

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/11/16	
location | Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK	
position | E: 648513 N: 4772783 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF	

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE: STRATIGRAPHY	Graphic Plot	SAMPLE: Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m) × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) ○ Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160	Water Content (%) & Plasticity PL MC LL 10 20 30	PID Readings	Well Details	Lab Data and Comments GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL
0	185.2	**GROUND SURFACE**					185					
0–4.6		**CLAYEY SILT** For stratigraphic descriptions, refer to 16-13OB.					184–181		Fracture Frequency			
4.6	180.6 4.6	*at 4.6m below grade* For stratigraphic descriptions, refer to 16-13A.					180–166				▼ (9.3 m)	
19.9	165.3 19.9											

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 21, 2016	9.3	175.9

library: genivar - library.glb report: gen log v1 file: uppers lane 2016.gpj

LOG OF BOREHOLE 16-13OB

wsp

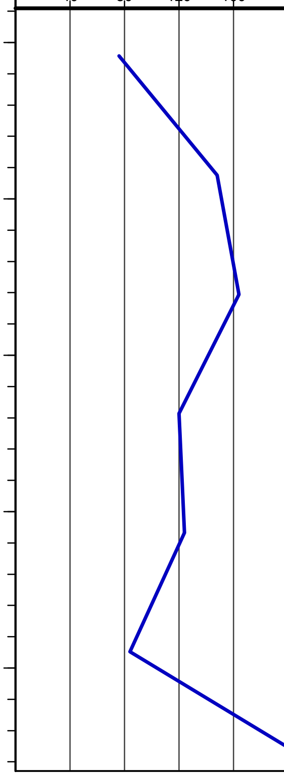
project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 648513 N: 4772782 (17T, Geodetic)

rig type | CME 75
method | Hollow stem augers, 215 mm dia.
coring | *n/a*

project no. | 161-11633-00
date started | 2016/11/17
supervisor | SK
reviewer | KJF

Depth Scale (m)	Elev / Depth (m)	Stratigraphy	Sample Number	Type	SPT N-Value / Core Recovery
0	185.2	**GROUND SURFACE**			
		CLAYEY SILT, brown becoming reddish brown, trace sand, trace gravel, very stiff to hard, DTPL to APL	1	SS	19
1			2	SS	37
2			3	SS	41
			4	SS	30
3			5	SS	31
4			6	SS	21
	180.3 / 4.9		7	SS	58 / 150mm

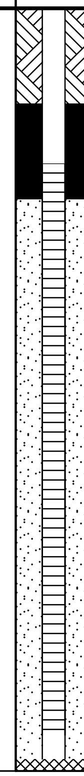
Penetration Test Values (Blows / 0.3m): Dynamic Cone; scale 10, 20, 30, 40
Undrained Shear Strength (kPa): Unconfined; Field Vane; Pocket Penetrometer; Lab Vane; scale 40, 80, 120, 160
Elevation Scale (mASL): 185, 184, 183, 182, 181



Water Content (%) & Plasticity: PL, MC, LL; scale 10, 20, 30

PID Readings

Well Details



Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 5, 2016	dry	n/a

library: genivar - library.glb report: gen log v1 file: uppers lane 2016.gpj

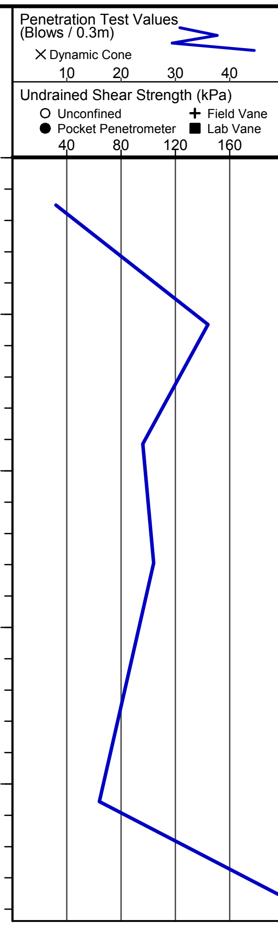
LOG OF BOREHOLE 16-14

wsp

DRAFT

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/11/10	
location | Thorold / Niagara Falls, ON	**method |** Hollow stem augers, 215 mm dia.	**supervisor |** SK	
position | E: 648520 N: 4772609 (17T, Geodetic)	**coring |** *n/a*	**reviewer |** KJF	

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE: STRATIGRAPHY	Graphic Plot	SAMPLE Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
	184.0	**GROUND SURFACE**					
0		**CLAYEY SILT**, brown, trace sand, trace gravel, very stiff to hard, DTPL		1	SS	8	184
1				2	SS	36	183
2				3	SS	24	182
				4	SS	26	
3		...at 3.0 m, Becoming reddish brown, very stiff, DTPL to APL		5	SS	21	181
4				6	SS	16	180
	179.1 4.9			7	SS	60 / 150mm	



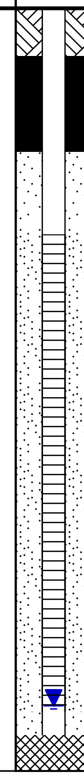
Water Content (%) & Plasticity

PL MC LL

10 20 30

PID Readings

Well Details



Lab Data and Comments

GRAIN SIZE DISTRIBUTION (%) (MIT)

GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 6, 2016	4.5	179.5

LOG OF BOREHOLE 16-15

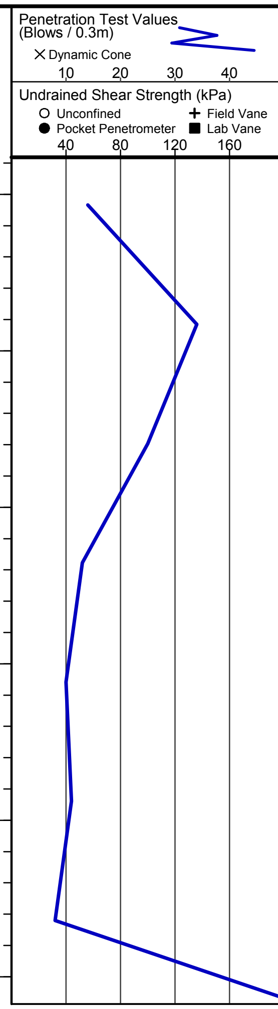
DRAFT

wsp

project	Proposed Uppers Lane Quarry			**project no.**	161-11633-00
client	Walker Aggregates Inc.	**rig type**	CME 75	**date started**	2016/10/13
location	Thorold / Niagara Falls, ON	**method**	Hollow stem augers, 215 mm dia.	**supervisor**	SK
position	E: 648524 N: 4772420 (17T, Geodetic)	**coring**	*n/a*	**reviewer**	KJF

SUBSURFACE PROFILE / SAMPLE

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY	Graphic Plot	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	182.2	**GROUND SURFACE**					
		CLAYEY SILT, yellowish brown, trace sand, hard to stiff, DTPL		1	SS	14	182
1				2	SS	34	181
2				3	SS	25	180
				4	SS	13	
3		...at 2.7 m, Becoming reddish brown, firm to stiff, APL to WTPL, dilatent		5	SS	10	179
4				6	SS	11	178
5				7	SS	8	177
	176.8 5.4			8	SS	50 / 75mm	



Water Content (%) & Plasticity

PL MC LL

10 20 30

PID Readings

Well Details

Lab Data and Comments

GRAIN SIZE DISTRIBUTION (%) (MIT)

GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 6, 2016	dry	n/a

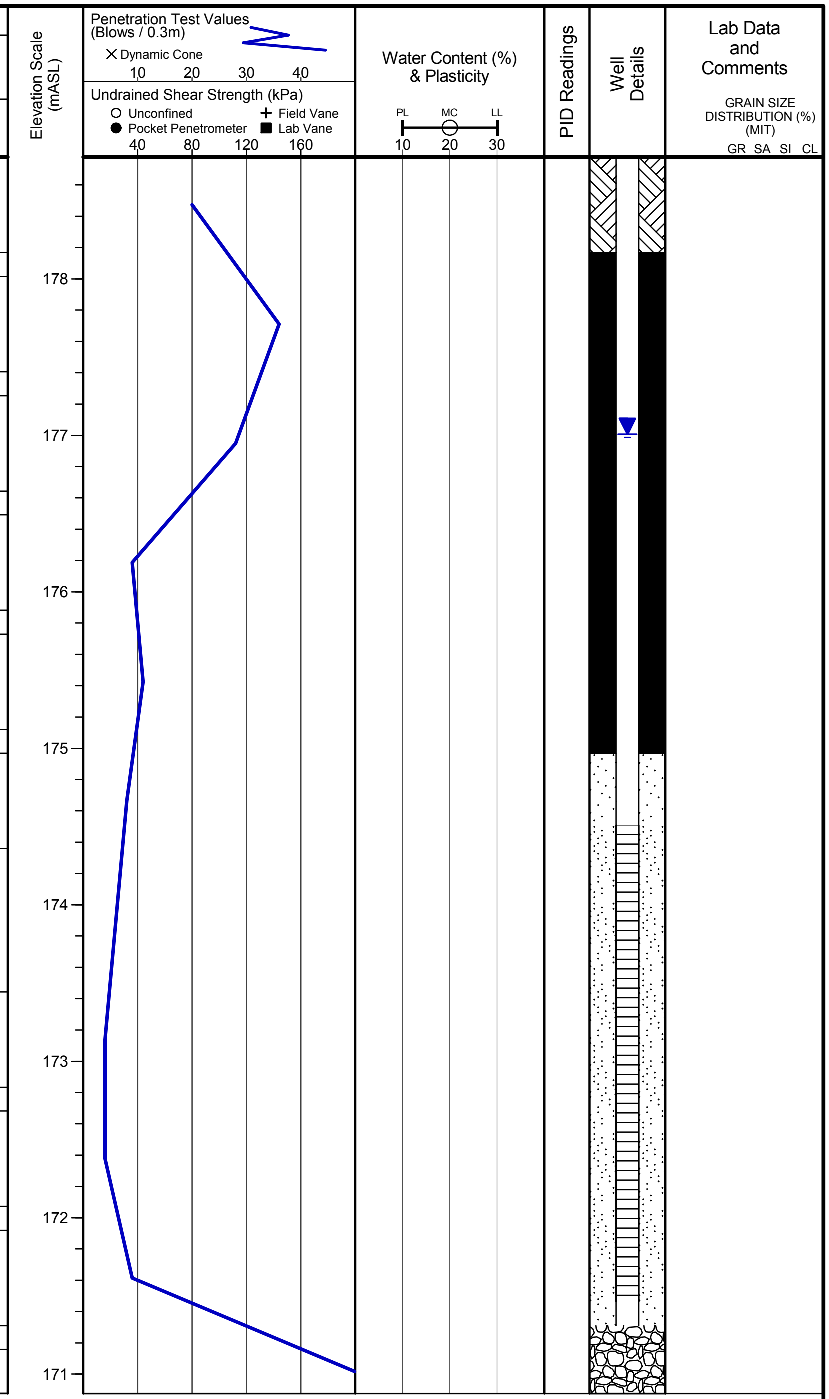
library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2016.gpj

LOG OF BOREHOLE 16-16

DRAFT

project	Proposed Uppers Lane Quarry	**project no.**	161-11633-00
client	Walker Aggregates Inc.	**date started**	2016/10/13
location	Thorold / Niagara Falls, ON	**supervisor**	SK
position	E: 648806 N: 4772274 (17T, Geodetic)	**reviewer**	KJF
rig type	CME 75		
method	Hollow stem augers, 215 mm dia.		
coring	*n/a*		

Depth Scale (m)	Elev / Depth (m)	STRATIGRAPHY	Sample Number	Type	SPT N-Value / Core Recovery
0	178.8	**GROUND SURFACE**			
		CLAYEY SILT TO SILTY CLAY, brown, trace sand, hard to firm, DTPL to APL	1	SS	20
1			2	SS	36
2			3	SS	28
			4	SS	9
3			5	SS	11
4			6	SS	8
5			7	ST	
		...at 5.3 m, Becoming red, soft to firm, WTPL	8	SS	4
6			9	SS	4
7	171.6 / 7.2	**SILTY SAND AND GRAVEL**, grey, compact, wet	10	SS	9
	170.9 / 7.9		11	SS	50 / 125mm



END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 8, 2016	1.8	177.0

library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2016.gpj

LOG OF BOREHOLE 16-17

wsp

DRAFT

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**date started |**	2016/11/10
location |	Thorold / Niagara Falls, ON	**supervisor |**	SK
position |	E: 648996 N: 4772677 (17T, Geodetic)	**reviewer |**	KJF
rig type |	CME 75		
method |	Hollow stem augers, 215 mm dia.		
coring |	*n/a*		

SUBSURFACE PROFILE / SAMPLE

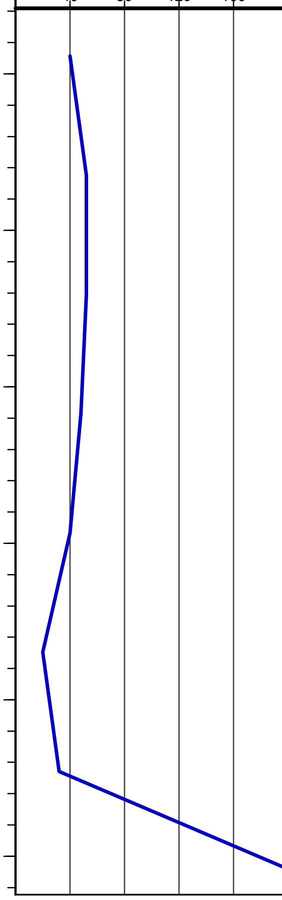
Penetration Test Values (Blows / 0.3m): × Dynamic Cone; 10, 20, 30, 40

Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane; 40, 80, 120, 160

Water Content (%) & Plasticity: PL, MC, LL; 10, 20, 30

PID Readings; Well Details; Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

Depth Scale (m)	Elev / Depth (m)	Stratigraphy	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	GR SA SI CL
0	177.4	**GROUND SURFACE**					
		SILTY CLAY TO CLAYEY SILT, brown, trace sand, stiff, DTPL to APL	1	SS	10	177	
1			2	SS	13	176	
			3	SS	13		1 4 29 66
2	175.3 / 2.1	**CLAYEY SILT**, reddish brown, trace sand, trace gravel, firm to stiff, APL to WTPL, dilatent					
			4	SS	12	175	
3			5	SS	10	174	0 4 72 24
4			6	SS	5	173	
5			7	SS	8		3 13 70 14
	171.7 / 5.7		8	SS	54 / 175mm	172	



END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 21, 2016	1.5	176.0

library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2016.gpj

LOG OF BOREHOLE 16-18B

DRAFT

wsp

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 648816 N: 4773300 (17T, Geodetic)
rig type | CME 75
method | Rock coring
coring | HQ core, OD=96mm, ID=64mm
project no. | 161-11633-00
date started | 2016/11/07
supervisor | SK
reviewer | KJF

Depth Scale (m)	Elev / Depth (m)	STRATIGRAPHY	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	176.2	**GROUND SURFACE**				
		CLAYEY SILT For stratigraphic descriptions, refer to 16-18OB.				176
1	174.9 1.3	*at 1.3m below grade*				175
		ERAMOSA FORMATION, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare styolites and gypsum nodules. Approximately 3% vug content.	1	R1	TCR = **40%** RQD = **0%**	
2	1.7	...Broken recovery to 2.08 m.	2	R2	TCR = **98%** RQD = **62%**	174
3		...Vuggy, 1 to 3 mm, from 2.69 m to 2.77 m.				173
	172.9 3.3	...Vuggy, 1 to 3 mm, from 3.81 m to 4.06 m.	3	R3	TCR = **100%** RQD = **67%**	
4		...30 % of core as 2.5 cm to 5 cm pieces.				172
	171.8 4.4	**END OF BOREHOLE**				

Graphic Plot

Penetration Test Values (Blows / 0.3m)
× Dynamic Cone
10 20 30 40
Undrained Shear Strength (kPa)
O Unconfined + Field Vane
● Pocket Penetrometer ■ Lab Vane
40 80 120 160

Water Content (%) & Plasticity
PL MC LL
10 20 30

Fracture Frequency

PID Readings

Well Details

Lab Data and Comments
GRAIN SIZE DISTRIBUTION (%) (MIT)
GR SA SI CL

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 17, 2016	0.7	175.5

LOG OF BOREHOLE 16-18OB

DRAFT

project	Proposed Uppers Lane Quarry	**project no.**	161-11633-00
client	Walker Aggregates Inc.	**date started**	2016/11/07
location	Thorold / Niagara Falls, ON	**supervisor**	SK
position	E: 648815 N: 4773302 (17T, Geodetic)	**reviewer**	KJF
rig type	CME 75		
method	Hollow stem augers, 215 mm dia.		
coring	*n/a*		

Depth Scale (m)	Elev / Depth (m)	SUBSURFACE PROFILE – STRATIGRAPHY	SAMPLE Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0.0	176.4	**GROUND SURFACE**				
		CLAYEY SILT, reddish brown, trace sand, firm to stiff, DTPL.	1	SS	6	176.0
0.5		...Red brown infilling in top 0.91 m.				
						175.5
1.0			2	SS	14	
	175.1 / 1.3	**END OF BOREHOLE**				

Penetration Test Values (Blows / 0.3m): × Dynamic Cone; 10, 20, 30, 40
Undrained Shear Strength (kPa): ○ Unconfined; + Field Vane; ● Pocket Penetrometer; ■ Lab Vane; 40, 80, 120, 160
Water Content (%) & Plasticity: PL, MC, LL; 10, 20, 30
PID Readings
Well Details
Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 5, 2016	0.7	175.7

LOG OF BOREHOLE 16-19B

wsp

DRAFT

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75	**date started |** 2016/11/04	
location | Thorold / Niagara Falls, ON	**method |** Rock coring	**supervisor |** SK	
position | E: 648826 N: 4773443 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF	

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	176.4	**GROUND SURFACE**				
		CLAYEY SILT For stratigraphic descriptions, refer to 16-19OB.				176
1	175.2 1.2	*at 1.2m below grade*				
		ERAMOSA FORMATION, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare styolites and gypsum nodules. Approximately 3% vug content.		R1	TCR = **88%** RQD = **0%**	175
2	1.7	...Vugs up to 5 mm at 1.82 m for 5 cm.		R2	TCR = **95%** RQD = **21%**	174
3	173.2 3.2	...Vugs up to 3 mm at 3 m for 2.5 cm. ...Most pieces of core are 2.5 to 7.5 cm.		R3		173
4	172.2 4.2	**END OF BOREHOLE**				

Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40
Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane 40 80 120 160
Water Content (%) & Plasticity: PL MC LL 10 20 30
Fracture Frequency
PID Readings
Well Details
Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Nov 17, 2016	1.3	175.1

library: genivar - library.glb report: gen log v1 file: uppers lane 2016.gpj

LOG OF BOREHOLE 16-19OB

DRAFT

wsp

project |	Proposed Uppers Lane Quarry			**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75	**date started |**	2016/11/03
location |	Thorold / Niagara Falls, ON	**method |**	Hollow stem augers, 215 mm dia.	**supervisor |**	SK
position |	E: 648826 N: 4773444 (17T, Geodetic)	**coring |**	*n/a*	**reviewer |**	KJF

Depth Scale (m)	Elev / Depth (m)	STRATIGRAPHY	Graphic Plot	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m) / Undrained Shear Strength (kPa)	Water Content (%) & Plasticity	PID Readings	Well Details	Lab Data and Comments (GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL)
0.0	176.4	**GROUND SURFACE**										
		CLAYEY SILT, brown becoming reddish brown, trace sand, stiff to very stiff, DTPL		1	SS	11	176.0					
0.5												
1.0				2	SS	30	175.5					
	175.2 / 1.2	**END OF BOREHOLE**										

Penetration Test Values legend: × Dynamic Cone; scale 10, 20, 30, 40. Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane; scale 40, 80, 120, 160. Water Content: PL, MC, LL; scale 10, 20, 30.

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 5, 2016	dry	n/a

library: genivar - library.glb report: gen log v1 file: uppers lane 2016.gpj

LOG OF BOREHOLE 17-20A

wsp

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**date started |**	2017/06/29
location |	Thorold / Niagara Falls, ON	**supervisor |**	SM
position |	E: 649805 N: 4772733 (17T, Geodetic)	**reviewer |**	KJF
rig type |	CME 75, track-mounted		
method |	Solid stem augers, 150 mm dia.		
coring |	HQ core, OD=96mm, ID=64mm		

Column headings: Depth Scale (m) | SUBSURFACE PROFILE: Elev Depth (m), STRATIGRAPHY, Graphic Plot | SAMPLE: Number, Type, SPT N-Value / Core Recovery | Elevation Scale (mASL) | Penetration Test Values (Blows / 0.3m): × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane 40 80 120 160 | Water Content (%) & Plasticity: PL MC LL 10 20 30; Fracture Frequency | PID Readings | Well Details | Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Elev / Depth (m)	Stratigraphy	Sample	Core Recovery
186.0	**GROUND SURFACE**		
	CLAYEY SILT For stratigraphic descriptions, refer to 17-20OB.		
180.9 / 5.1	*at 5.1m below grade* **ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare styolites and gypsum nodules. Approximately 3% vug content.	R1	TCR = 65%, RQD = 32%
179.7 / 6.3		R2	TCR = 95%, RQD = 29%
178.2 / 7.8		R3	TCR = 97%, RQD = 43%
176.7 / 9.3		R4	TCR = 100%, RQD = 29%
175.2 / 10.8		R5	TCR = 94%, RQD = 55%
173.6 / 12.4		R6	TCR = 106%, RQD = 40%
172.0 / 14.0	...at 13.7 m, grey clay seam to 13.9 m	R7	TCR = 107%, RQD = 29%
170.5 / 15.5		R8	TCR = 100%, RQD = 43%
169.0 / 17.0		R9	TCR = 100%, RQD = 76%
167.5 / 18.5		R10	TCR = 100%, RQD = 70%
166.0 / 20.0	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum veins. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded.	R11	TCR = 100%, RQD = 56%
164.4 / 21.6		R12	TCR = 98%, RQD = 98%
162.9 / 23.1		R13	TCR = 100%, RQD = 100%
161.4 / 24.6		R14	

Elevation scale (mASL): 186 – 162

Well Details: groundwater level symbol at approx. 7.8 m depth.

Lab Data and Comments: Augered straight to bedrock

(continued next page)

library: genivar - library.glb report: gen log v1 file: uppers lane 2017 supplemental drilling.gpj

LOG OF BOREHOLE 17-20A

DRAFT

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |** CME 75, track-mounted	**date started |** 2017/06/29
location |	Thorold / Niagara Falls, ON	**method |** Solid stem augers, 150 mm dia.	**supervisor |** SM
position |	E: 649805 N: 4772733 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF

SUBSURFACE PROFILE (continued)

Depth Scale (m)	Elev / Depth (m)	STRATIGRAPHY	Sample Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
25		**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite and gypsum veins. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded. *(continued)*		R14	TCR = 98% RQD = 98%	161
26	159.9 / 26.1			R15	TCR = 100% RQD = 99%	160
27	158.3 / 27.7			R16	TCR = 102% RQD = 100%	159
28–29	156.8 / 29.2			R17	TCR = 100% RQD = 98%	158–157
30	155.3 / 30.7			R18	TCR = 100% RQD = 93%	156
31–32	153.7 / 32.3			R19	TCR = 100% RQD = 99%	155–154
33	152.2 / 33.8			R20	TCR = 100% RQD = 99%	153
34–35	150.6 / 35.4			R21	TCR = 100% RQD = 97%	152–151
36	149.7 / 36.3	**GASPORT FORMATION**, dolostone, hard, fresh, grey to dark grey, fine to medium grained fossiliferous dolostone with saccharoidal texture. Medium bedded with fossil fragments up to 6%. Occasional stylolites. Rare gypsum nodules, less than 1% by volume.				150
37	149.2 / 36.8			R22	TCR = 100% RQD = 98%	149
38	147.6 / 38.4			R23	TCR = 101% RQD = 100%	148
39–40	146.1 / 39.9			R24	TCR = 100% RQD = 87%	147–146
41	144.5 / 41.5			R25	TCR = 100% RQD = 100%	145
42–43	143.0 / 43.0			R26	TCR = 100% RQD = 85%	144–143
44	141.5 / 44.5			R27	TCR = 100% RQD = 99%	142
45	140.6 / 45.4	**DECEW FORMATION**, dolostone, medium hard, dark grey, fine grained, fresh, argillaceous with occasional shale partings, 3 mm thick.				141
46	140.0 / 46.0			R28		140
47	138.5 / 47.5	**END OF BOREHOLE**				139

Penetration Test Values (Blows / 0.3m): × Dynamic Cone; 10, 20, 30, 40

Undrained Shear Strength (kPa): ○ Unconfined; + Field Vane; ● Pocket Penetrometer; ■ Lab Vane; 40, 80, 120, 160

Water Content (%) & Plasticity: PL, MC, LL; 10, 20, 30

PID Readings

Well Details

Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 7, 2017	7.9	178.1

library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2017 supplemental drilling.gpj

LOG OF BOREHOLE 17-20B

DRAFT

project |	Proposed Uppers Lane Quarry	project no. |	161-11633-00
client |	Walker Aggregates Inc.	rig type |	CME 75, track-mounted
date started |	2017/07/06	location |	Thorold / Niagara Falls, ON
method |	Solid stem augers, 150 mm dia.	supervisor |	SM
position |	E: 649805 N: 4772731 (17T, Geodetic)	coring |	HQ core, OD=96mm, ID=64mm
reviewer |	KJF		

Depth Scale (m)	Elev / Depth (m)	SUBSURFACE PROFILE – STRATIGRAPHY	Graphic Plot	SAMPLE Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m)	Water Content (%) & Plasticity	PID Readings	Well Details	Lab Data and Comments
0	186.0	GROUND SURFACE					186					
0–5.1		**CLAYEY SILT** For stratigraphic descriptions, refer to 17-20OB.					186–181		Fracture Frequency			
5.1	180.9 / 5.1	*at 5.1m below grade* For stratigraphic descriptions, refer to 17-20A.					181				Water level 4.8 m	
19.3	166.7 / 19.3						167					

Penetration Test Values (Blows / 0.3m): × Dynamic Cone — 10, 20, 30, 40
Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane — 40, 80, 120, 160
Water Content: PL, MC, LL — 10, 20, 30
Lab Data: GRAIN SIZE DISTRIBUTION (%) (MIT) — GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

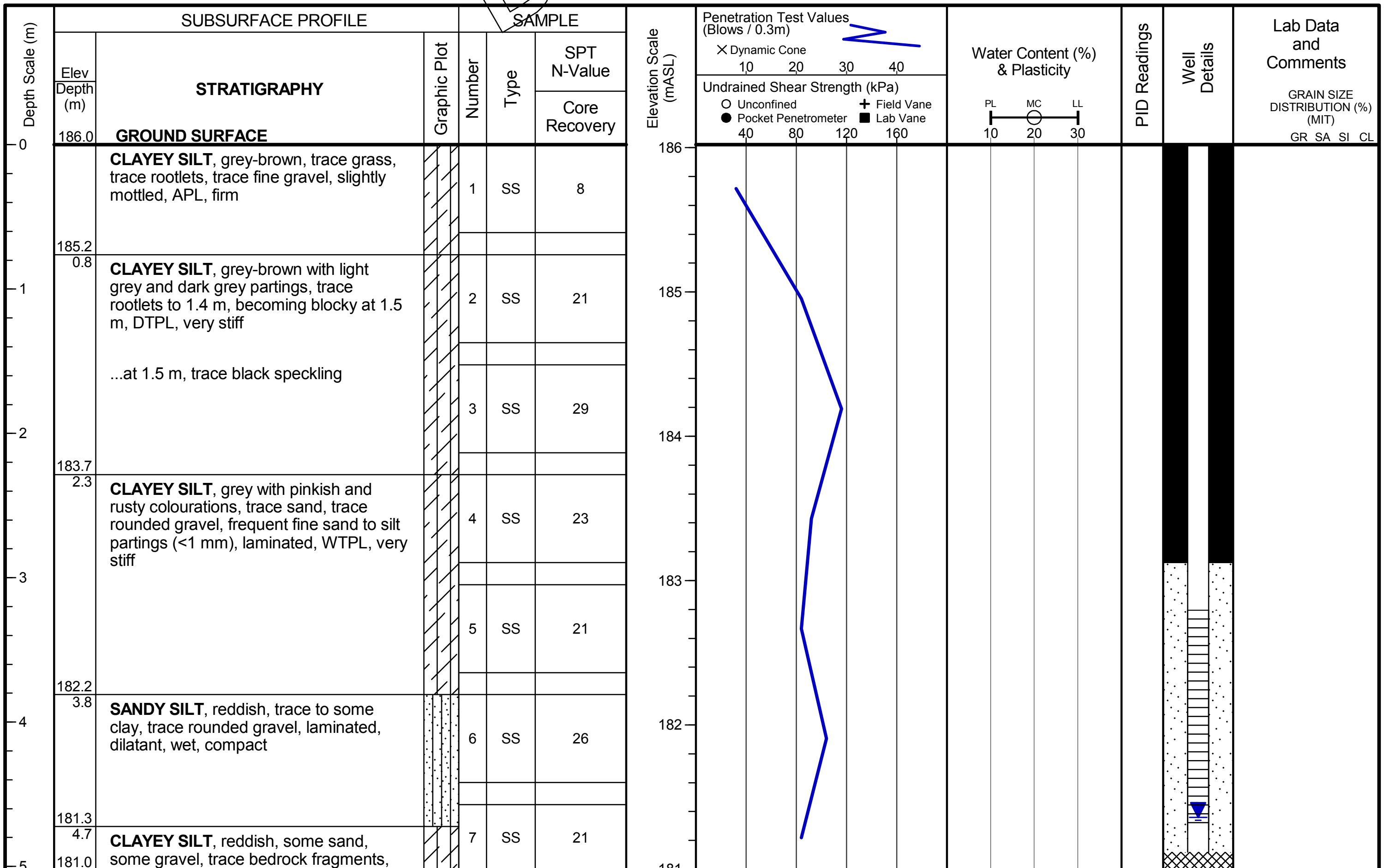
Date	Depth (m)	Elevation (m)
Jul 6, 2017	4.8	181.3

LOG OF BOREHOLE 17-20OB

wsp

project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 649804 N: 4772730 (17T, Geodetic)
rig type | CME 75, track-mounted
method | Hollow stem augers, 215 mm dia.
coring | *n/a*
project no. | 161-11633-00
date started | 2017/07/07
supervisor | SCL
reviewer | KJF

Elev / Depth (m)	STRATIGRAPHY	Sample Number	Type	SPT N-Value / Core Recovery
186.0	**GROUND SURFACE**			
	CLAYEY SILT, grey-brown, trace grass, trace rootlets, trace fine gravel, slightly mottled, APL, firm	1	SS	8
185.2 / 0.8	**CLAYEY SILT**, grey-brown with light grey and dark grey partings, trace rootlets to 1.4 m, becoming blocky at 1.5 m, DTPL, very stiff	2	SS	21
	...at 1.5 m, trace black speckling	3	SS	29
183.7 / 2.3	**CLAYEY SILT**, grey with pinkish and rusty colourations, trace sand, trace rounded gravel, frequent fine sand to silt partings (<1 mm), laminated, WTPL, very stiff	4	SS	23
		5	SS	21
182.2 / 3.8	**SANDY SILT**, reddish, trace to some clay, trace rounded gravel, laminated, dilatant, wet, compact	6	SS	26
181.3 / 4.7	**CLAYEY SILT**, reddish, some sand, some gravel, trace bedrock fragments, WTPL, very stiff	7	SS	21
181.0 / 5.0				



END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 7, 2017	4.7	181.4

library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2017 supplemental drilling.gpj

LOG OF BOREHOLE 17-20SP

DRAFT

wsp

project | Proposed Uppers Lane Quarry		**project no. |**	161-11633-00
client | Walker Aggregates Inc.	**rig type |** CME 75, track-mounted	**date started |**	2017/07/07
location | Thorold / Niagara Falls, ON	**method |** Hollow stem augers, 215 mm dia.	**supervisor |**	SCL
position | E: 649803 N: 4772728 (17T, Geodetic)	**coring |** *n/a*	**reviewer |**	KJF

Depth Scale (m)	Elev / Depth (m)	SUBSURFACE PROFILE – STRATIGRAPHY	Graphic Plot	SAMPLE Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m) × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) ○ Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160	Water Content (%) & Plasticity PL MC LL 10 20 30	PID Readings	Well Details	Lab Data and Comments GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL
0.0	186.0	**GROUND SURFACE**										
		CLAYEY SILT For stratigraphic descriptions, refer to 17-20OB.										
0.5							185.5					
1.0							185.0					
1.5							184.5					
2.0							184.0					
	183.5 2.5											

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 7, 2017	1.0	184.9

library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2017 supplemental drilling.gpj

LOG OF BOREHOLE 17-21B

wsp

DRAFT

project	Proposed Uppers Lane Quarry	**project no.**	161-11633-00
client	Walker Aggregates Inc.	**rig type**	CME 75, track-mounted
date started	2017/07/18	**location**	Thorold / Niagara Falls, ON
method	Hollow stem augers, 215 mm dia.	**supervisor**	SM
position	E: 648250 N: 4772587 (17T, Geodetic)	**coring**	HQ core, OD=96mm, ID=64mm
reviewer	KJF		

Elev / Depth (m)	Stratigraphy	Sample Number	Type	SPT N-Value / Core Recovery
185.7	GROUND SURFACE			
	SILT For stratigraphic descriptions, refer to 17-21OB.			
181.1 / 4.6	*at 4.6m below grade*			
4.8	**ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare stylites and gypsum nodules. Approximately 3% vug content.	R1		TCR = 98% RQD = 30%
179.4 / 6.3		R2		TCR = 109% RQD = 89%
177.9 / 7.8		R3		TCR = 107% RQD = 33%
176.4 / 9.3		R4		TCR = 98% RQD = 10%
174.9 / 10.8		R5		TCR = 95% RQD = 29%
173.3 / 12.4		R6		TCR = 102% RQD = 78%
171.8 / 13.9		R7		TCR = 100% RQD = 63%
170.3 / 15.4		R8		TCR = 100% RQD = 51%
168.7 / 17.0		R9		TCR = 100% RQD = 32%
167.2 / 18.5		R10		TCR = 105% RQD = 28%
165.7 / 20.0		R11		TCR = 100% RQD = 35%
164.4 / 21.3				
164.1 / 21.6	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite as 1.25 cm to 3.8 cm nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded.			

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed. No. 10 screen installed.

Column headings: Depth Scale (m); Graphic Plot; Elevation Scale (mASL); Penetration Test Values (Blows / 0.3m) — Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) — Unconfined, Field Vane, Pocket Penetrometer, Lab Vane 40 80 120 160; Water Content (%) & Plasticity PL MC LL 10 20 30; Fracture Frequency; PID Readings; Well Details; Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 19, 2017	6.8	178.9

LOG OF BOREHOLE 17-21OB

DRAFT

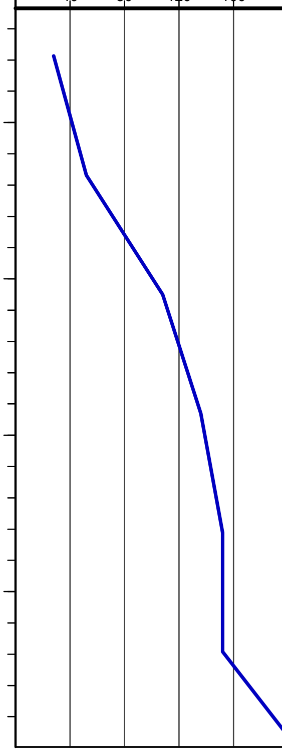
project | Proposed Uppers Lane Quarry
client | Walker Aggregates Inc.
location | Thorold / Niagara Falls, ON
position | E: 648247 N: 4772587 (17T, Geodetic)

rig type | CME 75, track-mounted
method | Hollow stem augers, 215 mm dia.
coring | *n/a*

project no. | 161-11633-00
date started | 2017/07/14
supervisor | SM
reviewer | KJF

Depth Scale (m)	Elev / Depth (m)	STRATIGRAPHY	Sample Number	Type	SPT N-Value / Core Recovery
0	185.7	**GROUND SURFACE**			
	185.6 / 0.1	**TOPSOIL**			
		SILT, brownish-grey, some clay, APL, firm	1	SS	7
		...at 0.8 m, grey mottling, becoming stiff			
1			2	SS	13
	184.2 / 1.5	**SILT**, brown, trace clay, occasional red and grey silty partings, APL, very stiff	3	SS	27
2		...at 2.3 m, becoming hard	4	SS	34
3			5	SS	38
4		...at 3.8 m, becoming reddish-brown, trace gravel from 4.1 m to 4.4 m	6	SS	38
	181.0 / 4.7		7	SS	20 / 0mm

Penetration Test Values (Blows / 0.3m): X Dynamic Cone — 10, 20, 30, 40
Undrained Shear Strength (kPa): O Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane — 40, 80, 120, 160
Elevation Scale (mASL): 185, 184, 183, 182
Water Content (%) & Plasticity: PL, MC, LL — 10, 20, 30
PID Readings
Well Details
Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL



END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 14, 2017	0.3	185.4

LOG OF BOREHOLE 17-21SP

DRAFT

wsp

project	Proposed Uppers Lane Quarry	**project no.**	161-11633-00
client	Walker Aggregates Inc.	**rig type**	CME 75, track-mounted
date started	2017/07/14	**location**	Thorold / Niagara Falls, ON
method	Hollow stem augers, 215 mm dia.	**supervisor**	SM
position	E: 648249 N: 4772587 (17T, Geodetic)	**coring**	*n/a*
reviewer	KJF		

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE – STRATIGRAPHY	Graphic Plot	SAMPLE Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m) / Undrained Shear Strength (kPa)	Water Content (%) & Plasticity	PID Readings	Well Details	Lab Data and Comments
0.0	185.7	**GROUND SURFACE**										
		SILT For stratigraphic descriptions, refer to 17-21OB.										
	183.3 2.4	**END OF BOREHOLE**										

Penetration Test Values legend: × Dynamic Cone (10, 20, 30, 40); Undrained Shear Strength (kPa): O Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane (40, 80, 120, 160). Water Content: PL, MC, LL (10, 20, 30). GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL.

Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0. Elevation scale: 185.5, 185.0, 184.5, 184.0, 183.5.

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 14, 2017	2.3	183.4

library: genivar - library.glb report: gen log v1 file: uppers lane 2017 supplemental drilling.gpj

LOG OF BOREHOLE 17-22B

DRAFT

wsp

project |	Proposed Uppers Lane Quarry			**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75, track-mounted	**date started |**	2017/07/20
location |	Thorold / Niagara Falls, ON	**method |**	Hollow stem augers, 215 mm dia.	**supervisor |**	SCL
position |	E: 648409 N: 4772965 (17T, Geodetic)	**coring |**	HQ core, OD=96mm, ID=64mm	**reviewer |**	KJF

SUBSURFACE PROFILE / SAMPLE

Column headings: Depth Scale (m); Elev / Depth (m); STRATIGRAPHY; Graphic Plot; Number; Type; SPT N-Value / Core Recovery; Elevation Scale (mASL); Penetration Test Values (Blows / 0.3m) — × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) — O Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane, 40 80 120 160; Water Content (%) & Plasticity — PL MC LL, 10 20 30; PID Readings; Well Details; Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Elev / Depth (m)	Stratigraphy	Type	Number	Core Recovery
183.5	**GROUND SURFACE**			
	SILT AND CLAY For stratigraphic descriptions, refer to 17-22OB. *at 4.0m below grade*			
179.5 / 4.0	**ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare stylites and gypsum nodules. Approximately 3% vug content.	C	R1	TCR = **100%** RQD = **32%**
178.8 / 4.7		C	R2	TCR = **100%** RQD = **75%**
177.3 / 6.2		C	R3	TCR = **100%** RQD = **62%**
175.8 / 7.7		C	R4	TCR = **100%** RQD = **75%**
174.2 / 9.3		C	R5	TCR = **100%** RQD = **67%**
172.8 / 10.7		C	R6	TCR = **100%** RQD = **97%**
171.2 / 12.3		C	R7	TCR = **100%** RQD = **78%**
169.7 / 13.8		C	R8	TCR = **102%** RQD = **46%**
168.2 / 15.3		C	R9	TCR = **95%** RQD = **70%**
166.6 / 16.9		C	R10	TCR = **100%** RQD = **73%**
166.0 / 17.5	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite as 1.25 cm to 3.8 cm nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded.			
165.1 / 18.4				

Fracture Frequency

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 21, 2017	6.5	177.0

library: genivar - library.glb **report:** gen log v1 **file:** uppers lane 2017 supplemental drilling.gpj

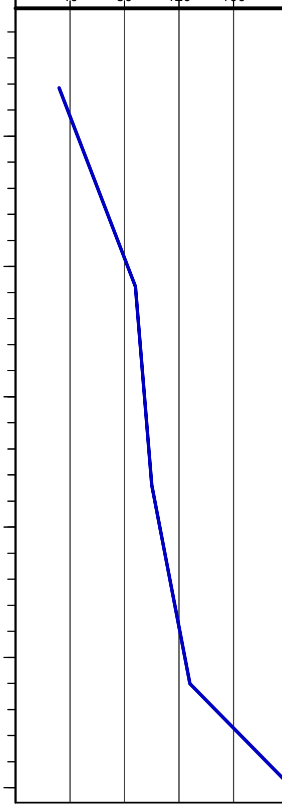
LOG OF BOREHOLE 17-22OB

DRAFT

project	Proposed Uppers Lane Quarry	**project no.**	161-11633-00
client	Walker Aggregates Inc.	**rig type**	CME 75, track-mounted
date started	2017/07/24	**location**	Thorold / Niagara Falls, ON
method	Hollow stem augers, 215 mm dia.	**supervisor**	BC
position	E: 648411 N: 4772964 (17T, Geodetic)	**coring**	*n/a*
reviewer	KJF		

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE – STRATIGRAPHY	Sample Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0.0	183.5	**GROUND SURFACE**				
		TOPSOIL				
		SILT AND CLAY, brown-grey, trace organics, occasional black, red-brown and light grey partings, DTPL, stiff to very stiff	1	SS	8	
0.5						183.0
1.0			2	SS	22	182.5
1.5						182.0
			3	SS	25	
2.0						181.5
	181.2 / 2.3	**SILT**, brown, occasional black, grey and red partings, trace clay, DTPL, hard				
2.5			4	SS	32	181.0
		...at 2.7 m, becoming brownish-red in colour				
		...at 2.9 m, some angular to subrounded bedrock fragments to 3.0 m	5	SS	27 / 0mm	
3.0	180.5 / 3.1					180.5

Penetration Test Values (Blows / 0.3m): × Dynamic Cone; 10, 20, 30, 40
Undrained Shear Strength (kPa): ○ Unconfined; + Field Vane; ● Pocket Penetrometer; ■ Lab Vane; 40, 80, 120, 160

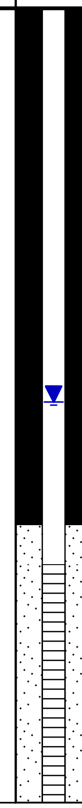


Water Content (%) & Plasticity: PL, MC, LL; 10, 20, 30

PID Readings

Well Details

Lab Data and Comments: GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL



END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 24, 2017	1.5	182.0

LOG OF BOREHOLE 17-22SP

wsp

project | Proposed Uppers Lane Quarry
project no. | 161-11633-00
client | Walker Aggregates Inc.
rig type | CME 75, track-mounted
date started | 2017/07/24
location | Thorold / Niagara Falls, ON
method | Hollow stem augers, 215 mm dia.
supervisor | BC
position | E: 648412 N: 4772963 (17T, Geodetic)
coring | *n/a*
reviewer | KJF

Depth Scale (m)	Elev / Depth (m)	Stratigraphy (Subsurface Profile)	Elevation Scale (mASL)
0.0	183.5	**GROUND SURFACE**	183.5
		SILT AND CLAY For stratigraphic descriptions, refer to 17-22OB.	
0.5			183.0
1.0			182.5
1.5			182.0
	181.7 / 1.8	**END OF BOREHOLE**	

Column headings: SUBSURFACE PROFILE (Elev Depth (m), STRATIGRAPHY, Graphic Plot); SAMPLE (Number, Type, SPT N-Value, Core Recovery); Elevation Scale (mASL); Penetration Test Values (Blows / 0.3m) – × Dynamic Cone 10 20 30 40; Undrained Shear Strength (kPa) – ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane 40 80 120 160; Water Content (%) & Plasticity – PL MC LL 10 20 30; PID Readings; Well Details; Lab Data and Comments – GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed. No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 24, 2017	1.3	182.2

LOG OF BOREHOLE 17-23B

wsp

DRAFT

project | Proposed Uppers Lane Quarry		**project no. |** 161-11633-00	
client | Walker Aggregates Inc.	**rig type |** CME 75, track-mounted	**date started |** 2017/07/25	
location | Thorold / Niagara Falls, ON	**method |** Hollow stem augers, 215 mm dia.	**supervisor |** SCL	
position | E: 648239 N: 4773134 (17T, Geodetic)	**coring |** HQ core, OD=96mm, ID=64mm	**reviewer |** KJF	

SUBSURFACE PROFILE | SAMPLE | Penetration Test Values (Blows / 0.3m) × Dynamic Cone 10 20 30 40 | Undrained Shear Strength (kPa) ○ Unconfined + Field Vane ● Pocket Penetrometer ■ Lab Vane 40 80 120 160 | Water Content (%) & Plasticity PL MC LL 10 20 30 | PID Readings | Well Details | Lab Data and Comments GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY	Graphic Plot	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	181.9	**GROUND SURFACE**					
		CLAYEY SILT For stratigraphic descriptions, refer to 17-23OB.					181–176
	175.5	*at 6.4m below grade*					
	6.4	**ERAMOSA FORMATION**, brownish-grey to grey dolostone, hard, fresh, medium to thin grained with saccharoidal texture, petroliferous odour when broken, thin to medium horizontal beds with occasional 2 mm thick shale layers. Rare stylolites and gypsum nodules. Approximately 3% vug content.			R1	TCR = **102%** RQD = **30%**	175
	174.2 / 7.7				R2	TCR = **98%** RQD = **79%**	174
	172.7 / 9.2				R3	TCR = **95%** RQD = **63%**	172
	171.1 / 10.8				R4	TCR = **104%** RQD = **79%**	171
	169.6 / 12.3				R5	TCR = **95%** RQD = **62%**	169
	168.0 / 13.9				R6	TCR = **103%** RQD = **71%**	167
	166.5 / 15.4				R7	TCR = **97%** RQD = **100%**	166
	165.0 / 164.9 / 16.9 / 17.0	**GOAT ISLAND FORMATION**, dolostone, hard, grey, fine grained, fresh, occasional gypsum and chert nodules, weak petroliferous odour when broken. Rare fossil fragments, minor calcite as 1.25 cm to 3.8 cm nodules. Occasional to common stylites and shale partings 2 mm thick. Fracture surfaces clean. Medium bedded.			R8	TCR = **98%** RQD = **77%**	164
	163.4 / 18.5						

Fracture Frequency

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 25, 2017	5.0	176.9

LOG OF BOREHOLE 17-23OB

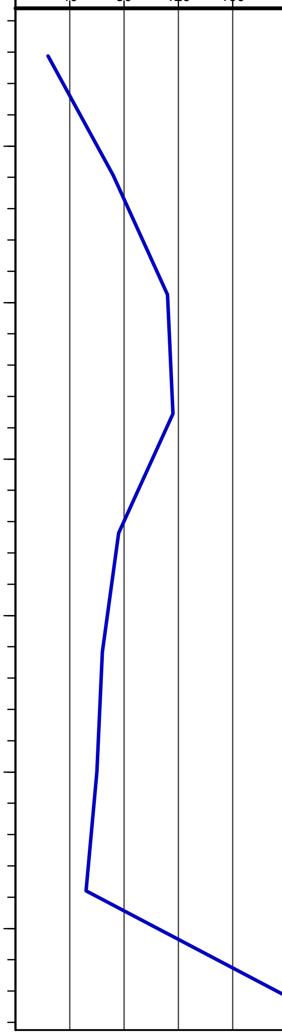
DRAFT

project |	Proposed Uppers Lane Quarry	**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**date started |**	2017/07/26
location |	Thorold / Niagara Falls, ON	**supervisor |**	SCL
position |	E: 648239 N: 4773132 (17T, Geodetic)	**reviewer |**	KJF

rig type | CME 75, track-mounted
method | Hollow stem augers, 215 mm dia.
coring | *n/a*

SUBSURFACE PROFILE

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY	Sample Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)
0	181.9	**GROUND SURFACE**				
		TOPSOIL				
		CLAYEY SILT, brown-grey, some rusty colouring, occasional grey partings, trace sand, trace rootlets, DTPL, firm	1	SS	6	
		...at 0.8 m, becoming very stiff				181
1			2	SS	18	
	180.4 / 1.5	**CLAYEY SILT**, brown-grey, trace grey and reddish partings, trace gravel, DTPL, very stiff	3	SS	28	180
2			4	SS	29	179
3		...at 3.0 m, becoming APL	5	SS	19	
		...at 3.5 m, presence of grey clay seams with rootlets to 4.9 m				178
4			6	SS	16	
5			7	SS	15	177
		...at 5.3 m, becoming WTPL				
	176.3 / 5.6	**CLAYEY SILT**, red-grey, WTPL, stiff	8	SS	13	176
6		...at 6.1 m, some fine rounded to subangular gravel, trace fine sand laminations to 6.5 m	9	SS	60 / 275mm	
	175.4 / 6.5					



Water Content (%) & Plasticity: PL MC LL — 10 20 30

PID Readings

Well Details

Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT) — GR SA SI CL

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 26, 2017	3.6	178.3

LOG OF BOREHOLE 17-23SP

DRAFT

project |	Proposed Uppers Lane Quarry			**project no. |**	161-11633-00
client |	Walker Aggregates Inc.	**rig type |**	CME 75, track-mounted	**date started |**	2017/07/26
location |	Thorold / Niagara Falls, ON	**method |**	Hollow stem augers, 215 mm dia.	**supervisor |**	SCL
position |	E: 648239 N: 4773130 (17T, Geodetic)	**coring |**	*n/a*	**reviewer |**	KJF

Depth Scale (m)	Elev Depth (m)	SUBSURFACE PROFILE: STRATIGRAPHY	Graphic Plot	SAMPLE: Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Penetration Test Values (Blows / 0.3m) / Undrained Shear Strength (kPa)	Water Content (%) & Plasticity	PID Readings	Well Details	Lab Data and Comments / GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL
0.0	181.9	**GROUND SURFACE**										
		CLAYEY SILT For stratigraphic descriptions, refer to 17-23OB.										
2.7	179.2											

Penetration Test Values legend: × Dynamic Cone (10, 20, 30, 40). Undrained Shear Strength (kPa): ○ Unconfined, + Field Vane, ● Pocket Penetrometer, ■ Lab Vane (40, 80, 120, 160). Water Content: PL, MC, LL (10, 20, 30).

Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5. Elevation scale: 181.5, 181.0, 180.5, 180.0, 179.5.

END OF BOREHOLE

Borehole was dry and open upon completion.

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Jul 26, 2017	1.2	180.7

library: genivar - library.glb report: gen log v1 file: uppers lane 2017 supplemental drilling.gpj

Staff Gauge SW1 Log

Project Name:	Proposed Uppers Lane Quarry	**Date:**	December 21, 2016
Client:	Walker Aggregates Inc.	**Supervisor:**	SK
Project Number:	161-11633-00	**Scale:**	NTS

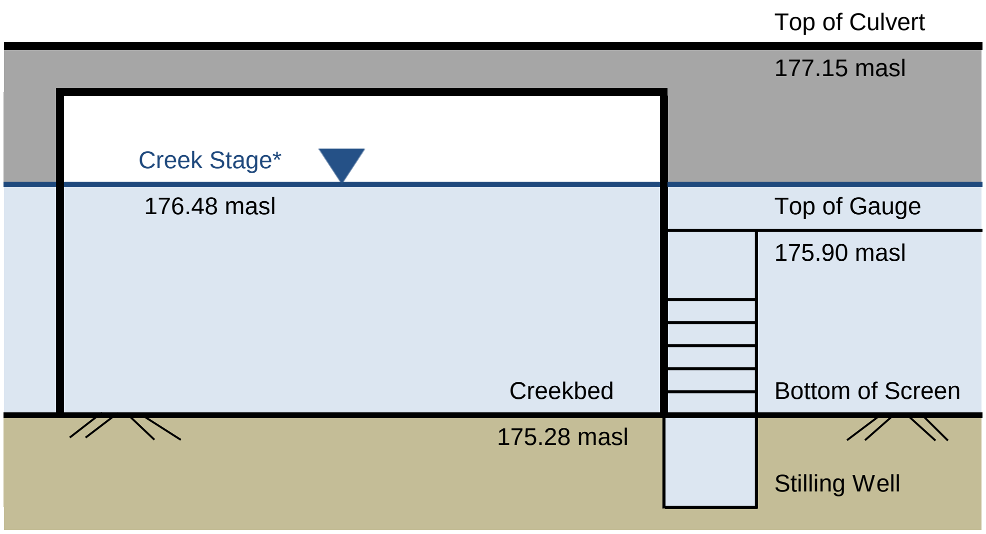


Photo taken on March 7, 2017 (looking upstream to the east).

Notes:

Located where Beaverdams Creek intersects Beechwood Road, northeast of Site.

GPS Coordinates 649,518 E 4,773,623 N (NAD 83 Zone 17).

*Creek stage measured at 176.48 masl on December 21, 2016.

Staff Gauge SW2 Log

Project Name:	Proposed Uppers Lane Quarry	**Date:**	October 25, 2016
Client:	Walker Aggregates Inc.	**Supervisor:**	SK
Project Number:	161-11633-00	**Scale:**	NTS

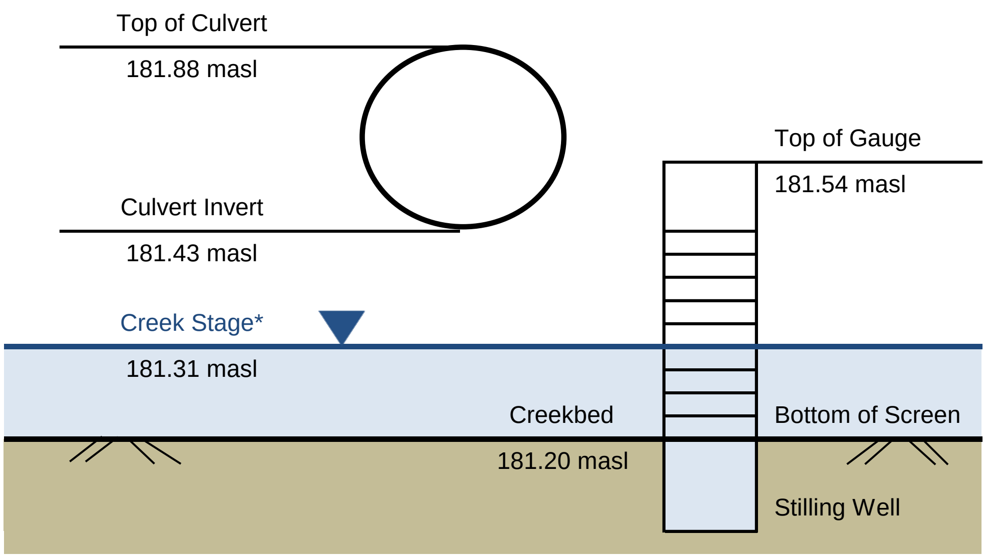


Photo taken on March 7, 2017 (looking upstream to the south).

Notes:

Located where Beaverdams Creek tributary intersects Uppers Lane, east part of Site.

GPS Coordinates 649,471 E 4,773,179 N (NAD 83 Zone 17).

*Creek stage measured at 181.31 masl on April 4, 2017.

Staff Gauge SW3 Log

Project Name:	Proposed Uppers Lane Quarry	**Date:**	December 21, 2016
Client:	Walker Aggregates Inc.	**Supervisor:**	SK
Project Number:	161-11633-00	**Scale:**	NTS

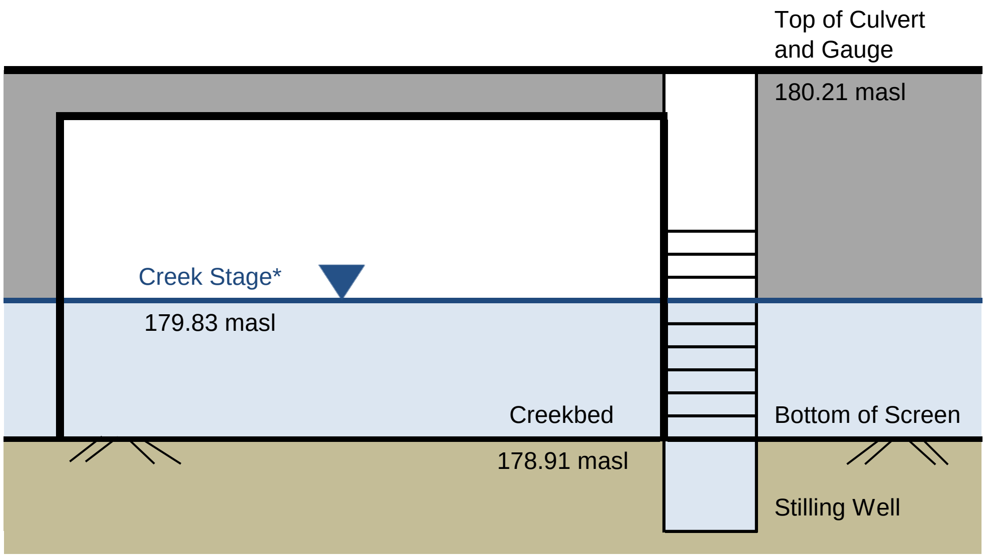


Photo taken on March 7, 2017 (looking downstream to the north).

Notes:

Located where Uppers Lane Creek intersects Lundy's Lane, south of Site.

GPS Coordinates 649,009 E 4,771,733 N (NAD 83 Zone 17).

*Creek stage measured at 179.83 masl on December 21, 2016.

Staff Gauge SW4 Log			
Project Name:	Proposed Uppers Lane Quarry	**Date:**	November 7, 2016
Client:	Walker Aggregates Inc.	**Supervisor:**	SK
Project Number:	161-11633-00	**Scale:**	NTS

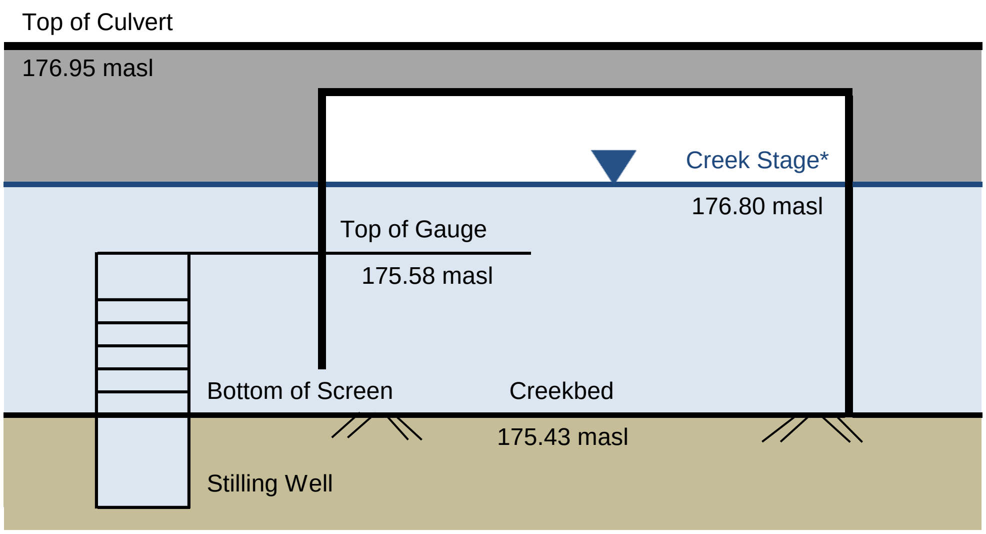


Photo taken on March 7, 2017 (looking downstream to the southeast).

Notes:

Located where Uppers Lane Creek intersects Uppers Lane, centre of Site.

GPS Coordinates 648,933 E 4,773,015 N (NAD 83 Zone 17).

*Creek stage measured at 176.80 masl on April 4, 2017.

Drivepoint DP1 Log

Project Name:	Proposed Uppers Lane Quarry	**Date:**	December 21, 2016
Client:	Walker Aggregates Inc.	**Supervisor:**	SK
Project Number:	161-11633-00	**Scale:**	NTS

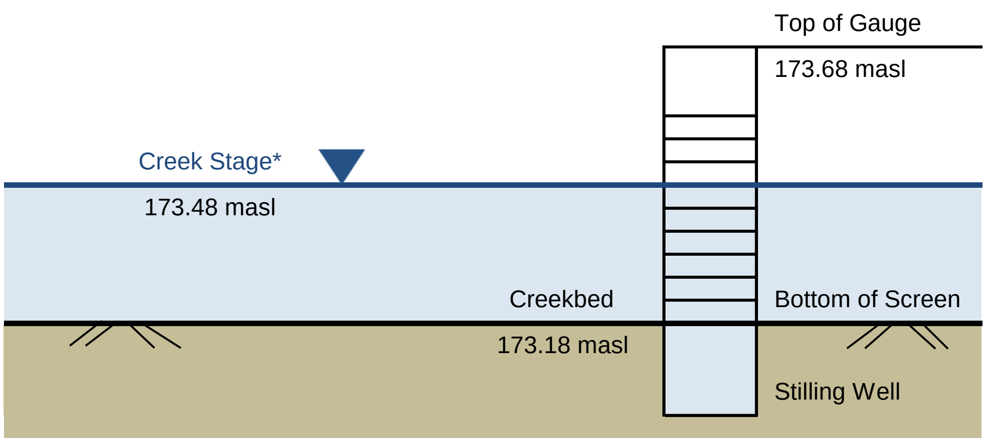


Photo taken on January 13, 2017 (looking downstream to the northeast).

Notes:

Located where Beaverdams Creek intersects Townline Road, northwest of Site.

GPS Coordinates 648,488 E 4,773,917 N (NAD 83 Zone 17).

*Creek stage measured at 173.48 masl on December 21, 2016.

Drivepoint DP2 Log

Project Name:	Proposed Uppers Lane Quarry	**Date:**	November 7, 2016
Client:	Walker Aggregates Inc.	**Supervisor:**	SK
Project Number:	161-11633-00	**Scale:**	NTS

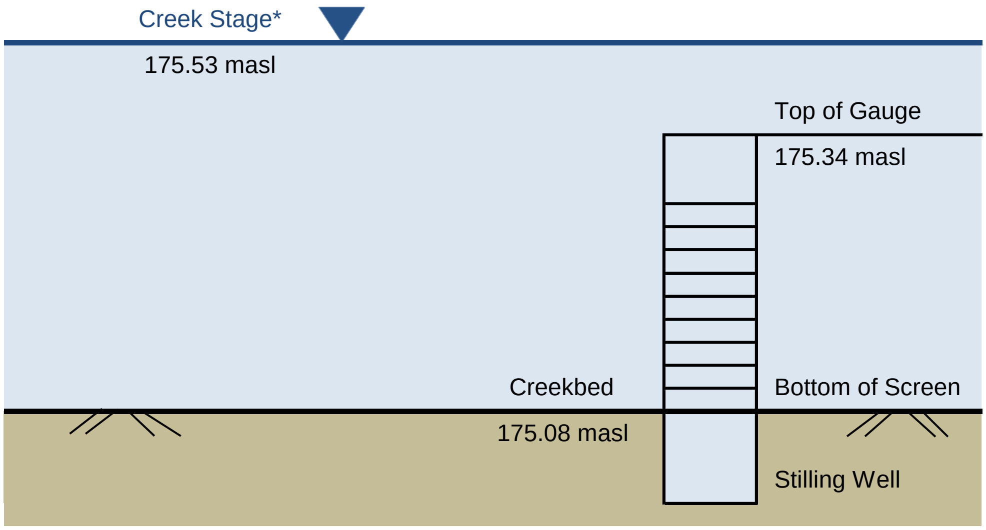


Photo taken on August 3, 2017.

Notes:

Located where Uppers Lane Creek intersects northern Site boundary.

GPS Coordinates 648,812 E 4,773,450 N (NAD 83 Zone 17).

*Creek stage measured at 175.53 masl on April 4, 2017.

Drivepoint DP3 Log

Project Name:	Proposed Uppers Lane Quarry	**Date:**	November 7, 2016
Client:	Walker Aggregates Inc.	**Supervisor:**	SK
Project Number:	161-11633-00	**Scale:**	NTS

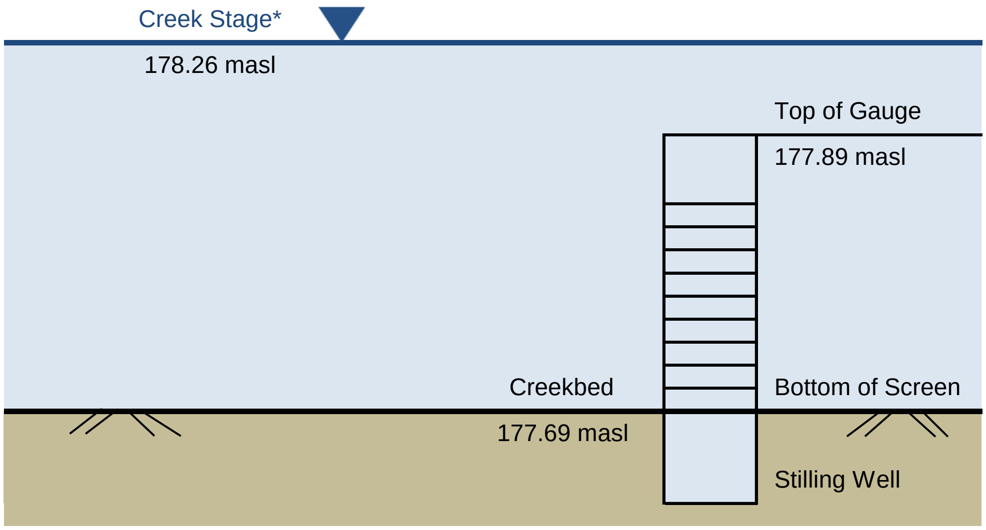


Photo taken on August 3, 2017.

Notes:

Located where Uppers Lane Creek intersects southern Site boundary.

GPS Coordinates 648,815 E 4,772,283 N (NAD 83 Zone 17).

*Creek stage measured at 178.26 masl on April 4, 2017.

Drivepoint DP4 Log

Project Name:	Proposed Uppers Lane Quarry	**Date:**	October 19, 2016
Client:	Walker Aggregates Inc.	**Supervisor:**	SK
Project Number:	161-11633-00	**Scale:**	NTS

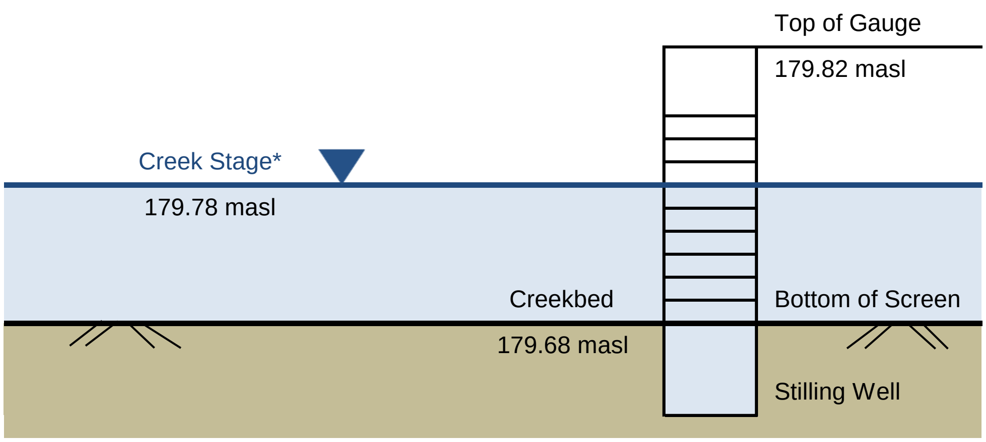


Photo taken on April 4, 2017 (looking downstream to the northwest).

Notes:

Located where Uppers Lane Creek tributary intersects southern Site boundary.

GPS Coordinates 649,133 E 4,772,475 N (NAD 83 Zone 17).

*Creek stage measured at 179.78 masl on April 4, 2017.

Drivepoint DP5 Log

Project Name:	Proposed Uppers Lane Quarry	**Date:**	October 28, 2016
Client:	Walker Aggregates Inc.	**Supervisor:**	SK
Project Number:	161-11633-00	**Scale:**	NTS

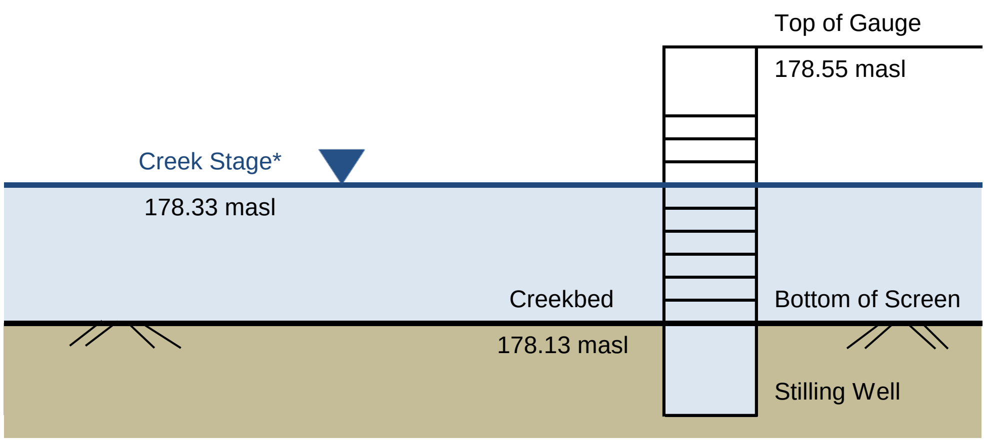


Photo taken on April 4, 2017 (looking downstream to the north).

Notes:

Located where Uppers Lane Creek tributary intersects northern Site boundary.

GPS Coordinates 649,401 E 4,773,487 N (NAD 83 Zone 17).

*Creek stage measured at 178.33 masl on April 4, 2017.

Drivepoint DP6 Log

Project Name:	Proposed Uppers Lane Quarry	**Date:**	July 4, 2017
Client:	Walker Aggregates Inc.	**Supervisor:**	SCM
Project Number:	161-11633-00	**Scale:**	NTS

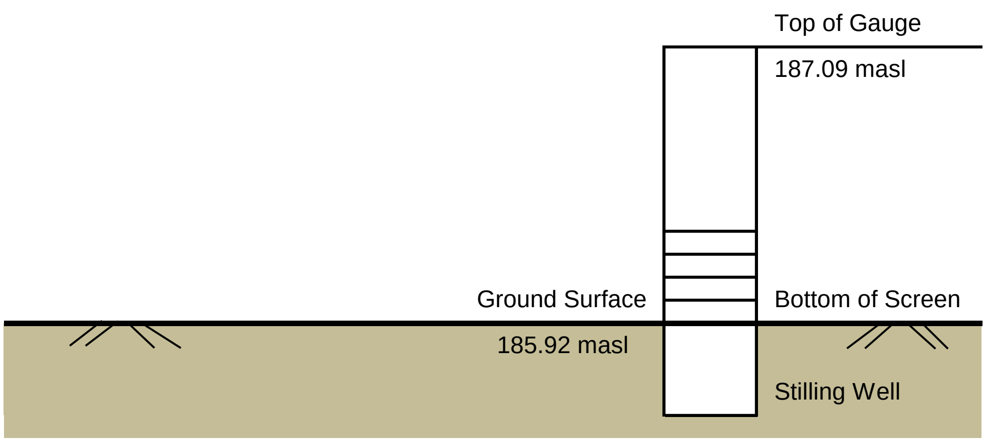


Photo taken on September 29, 2017.

Notes:

Located within mapped wetland at 5584 Beechwood Road, east of Site.

*Dry upon completion on July 4, 2017.

Drivepoint DP7 Log

Project Name:	Proposed Uppers Lane Quarry	**Date:**	July 4, 2017
Client:	Walker Aggregates Inc.	**Supervisor:**	SCM
Project Number:	161-11633-00	**Scale:**	NTS

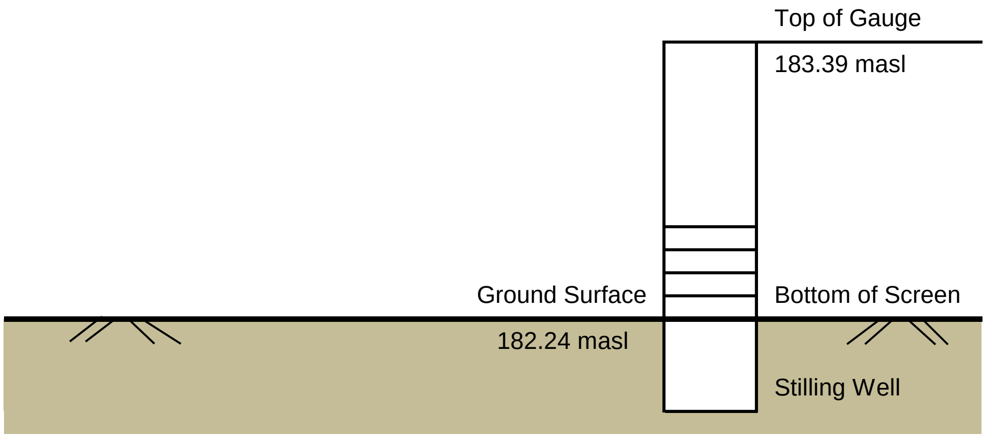


Photo taken on September 29, 2017.

Notes:

Located within woodlot near well nest MW16-9, west of Site.

*Dry upon completion on July 4, 2017.

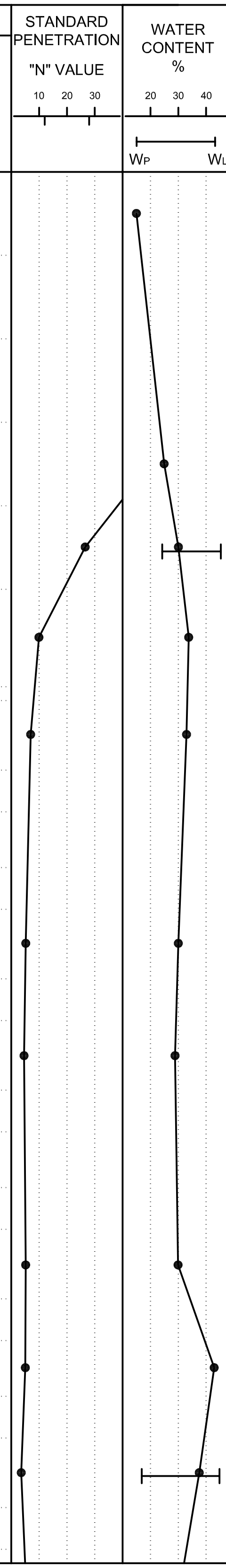
APPENDIX

C-2 OFF-SITE MONITOR DETAILS

BOREHOLE NO. 6

PROJECT: Abitibi Thorold Mill - Cogeneration Plant	Project No: 1040244.01	Contractor: Lantech Drilling Services Inc.
CLIENT: Abitibi - Consolidated Company of Canada	Date Drilled: May 11, 2006	Drill Type: CME 75
SITE: Abitibi Thorold Mill Site	Date of Backfilling: May 11, 2006	Auger: 210 mm (O.D.) Hollow Stem Auger
SUPERVISOR: RFK	Ground Elevation: 176.52 m ASL	Sampler: 51 mm (O.D.) Split Spoon
REVIEWER: JSA	UTM Coordinates: N/A	

DEPTH (m) / ELEV (m ASL)	STRATIGRAPHIC DESCRIPTION	MONITOR DETAILS	SAMPLE DATA: DEPTH (m)	SAMPLE No. / TYPE	SPT PER 6"	"N" VALUE	POCKET PENETROMETER (kg/cm^2)	% RECOVERY	% WATER	REMARKS
0	SAND, RUBBLE (FILL) Grey sand, gravel. Intermittent concrete.	No Monitor Installed	0.0–0.6	SS1	7, 50 - 6"	>50	-	13	15	Water level estimated at 9.1 mbgs upon completion. Geophysics probe installed upon completion.
1			0.6–1.2	SS2	-	-	-	-	-	
			1.2–1.8	SS3	-	-	-	-	-	
1.8 / 174.72	CLAY AND SILT Brown, grey mottling clay and silt to silty clay, APL to WTPL, hard to firm, tough, high dry strength.		1.8–2.4	SS4	11, 28, 40, 42	>50	4.5	75	25	
			2.4–3.0	SS5	10, 11, 16, 16	27	3.5	92	30	SS5 Particle Size 60% Clay, 38% Silt, 2% Sand. UCS Symbol: CL
3			3.0–3.7	SS6	4, 4, 6, 14	10	2.5	88	33	SS5 Atterberg Limit WL = 44% WP = 24% PI = 20%
4	Becoming grey, WTPL.		3.8–4.3	SS7	3, 4, 4	8	1.0	100	32	
5			4.6–5.0	ST8	-	-	-	-	-	Shelby Tube Sample.
			5.3–5.8	SS9	2, 2, 3	5	0.5	100	30	
6	Silt nodules.		6.1–6.6	SS10	3, 2, 3	5	0	100	29	
7			6.9–7.3	ST11	-	-	-	-	-	Shelby Tube Sample.
8			7.6–8.1	SS12	1, 2, 4	6	0	100	30	
			8.4–8.8	SS13	2, 3, 3	6	-	100	43	SS14 Particle Size 67% Clay, 31% Silt, 2% Sand. UCS Symbol: CL
9			9.1–9.6	SS14	2, 1, 2	3	-	100	38	SS14 Atterberg Limit WL = 45% WP = 17% PI = 28%
10			9.9							



BOREHOLE NO. 6

PROJECT: Abitibi Thorold Mill - Cogeneration Plant
Project No: 1040244.01
Contractor: Lantech Drilling Services Inc.

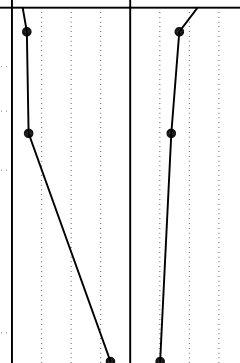
CLIENT: Abitibi - Consolidated Company of Canada
Date Drilled: May 11, 2006
Drill Type: CME 75

SITE: Abitibi Thorold Mill Site
Date of Backfilling: May 11, 2006
Auger: 210 mm (O.D.) Hollow Stem Auger

SUPERVISOR: RFK
Ground Elevation: 176.52 m ASL
Sampler: 51 mm (O.D.) Split Spoon

REVIEWER: JSA
UTM Coordinates: N/A

DEPTH (m) / ELEV (m ASL)	STRATIGRAPHIC DESCRIPTION	MONITOR DETAILS	SAMPLE DATA: DEPTH (m)	SAMPLE No. / TYPE	SPT PER 6"	"N" VALUE	POCKET PENETROMETER (kg/cm^2)	% RECOVERY	% WATER	STANDARD PENETRATION "N" VALUE (10, 20, 30)	WATER CONTENT % (20, 30, 40) Wp WL	REMARKS
10	CLAY AND SILT (cont.)	No Monitor Installed	10.4	SS15	2, 3, 3	6	-	100	28			
10.7 / 165.82			10.7									
11	CLAYEY SILT Reddish grey to reddish brown clayey silt, trace sand (possible fill), WTPL, firm to hard.		11.1	SS16	2, 3, 4	7	0	100	23			
12			12.2									
	Broken angular gravel.		12.6	SS17	7, 12, 20	32	0.5	100	20			
13												
13.4 / 163.12	Refusal at 13.4 m on presumed bedrock.											
14												
15												
16												
17												
18												
19												
20												

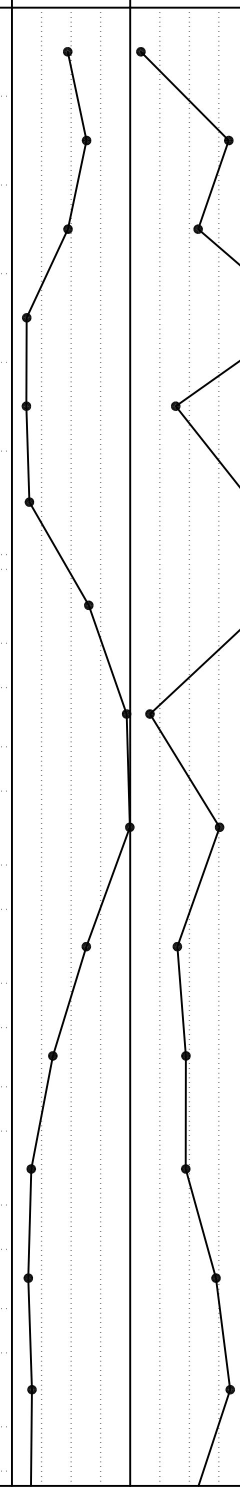


BOREHOLE NO. 14

PROJECT: Abitibi Thorold Mill - Cogeneration Plant
Project No: 1040244.01
Contractor: Lantech Drilling Services Inc.
CLIENT: Abitibi - Consolidated Company of Canada
Date Drilled: May 8-9, 2006
Drill Type: CME 75
SITE: Abitibi Thorold Mill Site
Date of Backfilling: May 9, 2006
Auger: 210 mm (O.D.) Hollow Stem Auger
SUPERVISOR: RFK
Ground Elevation: 179.60 m ASL
Sampler: 51 mm (O.D.) Split Spoon
REVIEWER: JSA
UTM Coordinates: 646579E / 4774237N

DEPTH (m) / ELEV (m ASL)	STRATIGRAPHIC DESCRIPTION	MONITOR DETAILS	SAMPLE DATA: DEPTH (m)	SAMPLE No. / TYPE	SPT PER 6"	"N" VALUE	(kg/cm^2) POCKET PENETROMETER	% RECOVERY	% WATER	REMARKS
0	FILL Black, grey, brown sandy gravel becoming silty clay to clayey silt fill, with black coal dust, possible cinders, brick debris, trace wood, moist or APL, compact to loose.	No Monitor Installed	0.0–0.6	SS1	11, 9, 10, 11	19	-	25	14	Water level at 15.14 mbgs upon completion.
1			0.6–1.2	SS2	15, 15, 11, 8	26	-	38	43	
			1.2–1.8	SS3	7, 15, 4	19	0	29	32	
2			1.8–2.4	SS4	2, 2, 3, 2	5	0	25	67	
3			2.4–3.0	SS5	2, 2, 6	4	0	42	26	
			3.0–3.7	SS6	3, 3, 4, 5	7	0.5	50	51	
4 4.1 175.50	CLAY AND SILT TO SILTY CLAY Brown, grey mottling, clay and silt to silty clay, DTPL to APL, hard.		3.8–4.3	SS7	9, 12, 15	27	>4.5	67	56	
5			4.6–5.0	SS8	10, 14, 25	39	>4.5	100	17	
6			5.3–5.8	SS9	10, 19, 21	40	>4.5	100	40	
	Trace orange mottling.		6.1–6.6	SS10	7, 12, 14	26	>4.5	100	27	
7	Reddish brown silt nodules.		6.9–7.3	SS11	5, 6, 6	12	4.0	100	29	
8	Becoming grey, stiff, WTPL.		7.6–8.1	SS12	4, 3, 5	8	1.0	100	29	
9			8.4–8.8	SS13	3, 3, 3	6	0	100	39	
10			9.1–9.6	SS14	3, 4, 4	8	0	100	43	
			9.9							

STANDARD PENETRATION "N" VALUE (10 20 30) / WATER CONTENT % (20 30 40), WP WL



BOREHOLE NO. 14

PROJECT: Abitibi Thorold Mill - Cogeneration Plant	Project No: 1040244.01	Contractor: Lantech Drilling Services Inc.
CLIENT: Abitibi - Consolidated Company of Canada	Date Drilled: May 8-9, 2006	Drill Type: CME 75
SITE: Abitibi Thorold Mill Site	Date of Backfilling: May 9, 2006	Auger: 210 mm (O.D.) Hollow Stem Auger
SUPERVISOR: RFK	Ground Elevation: 179.60 m ASL	Sampler: 51 mm (O.D.) Split Spoon
REVIEWER: JSA	UTM Coordinates: N/A	

DEPTH (m) / ELEV (m ASL)	STRATIGRAPHIC DESCRIPTION	MONITOR DETAILS	SAMPLE DATA: DEPTH (m)	SAMPLE No. / TYPE	SPT PER 6"	"N" VALUE	(kg/cm^2) POCKET PENETROMETER	% RECOVERY	% WATER	STANDARD PENETRATION "N" VALUE (10 20 30)	WATER CONTENT % (20 30 40) WP WL	REMARKS
10	CLAY AND SILT TO SILTY CLAY (cont.)	No Monitor Installed	10.4	SS15	2, 3, 2	5	0	100	28			
	Stiff becoming firm.		10.7 – 11.1	SS16	2, 3, 2	5	1.0	100	25			
11 / 12			12.2 – 12.6	SS17	1, 2, 2	4	0	100	39			
13 / 13.7 / 165.90	CLAYEY SILT (TILL) Brown, reddish brown clayey silt, trace gravel, till-like, APL to WTPL, very stiff becoming hard.		13.7 – 14.2	SS18	4, 2, 3	5	0	100	30			
14 / 15			15.2 – 15.7	SS19	5, 7, 11	18	2.5	50	13			
16	Weathered rock zone.		16.8 – 17.2	SS20	50 - 2"	>50	1.0	11	14			
17.2 / 162.40	Borehole terminated at 17.2 m in dense weathered rock and clayey silt (presumed bedrock).											
18 / 19 / 20												

BOREHOLE NO. 19

PROJECT: Abitibi Thorold Mill - Cogeneration Plant
Project No: 1040244.01
Contractor: Lantech Drilling Services Inc.

CLIENT: Abitibi - Consolidated Company of Canada
Date Drilled: May 3-4, 2006
Drill Type: CME 75

SITE: Abitibi Thorold Mill Site
Date of Backfilling: May 4, 2006
Auger: 210 mm (O.D.) Hollow Stem Auger

SUPERVISOR: RFK
Ground Elevation: 178.13 m ASL
Sampler: 51 mm (O.D.) Split Spoon

REVIEWER: JSA
UTM Coordinates: 646577N / 4774174E

Stratigraphic Description

DEPTH (m) / ELEV (m ASL)	STRATIGRAPHIC DESCRIPTION	MONITOR DETAILS
0	FILL Black sand, coal dust, some angular gravel, rootlets, moist, loose to compact. Coal and brick debris, trace silt and clay. Wet, gravelly. Grey, weathered contact.	No Monitor Installed
2.7 / 175.43	SILTY CLAY TO CLAY AND SILT Brown to grey silt, clay to clayey silt, APL, very stiff. Light brown silt nodules. Becoming mainly grey, WTPL.	

Sample Data

DEPTH (m)	SAMPLE No. / TYPE	SPT PER 6"	"N" VALUE	(kg/cm^2) POCKET PENETROMETER	% RECOVERY	% WATER
0.0 – 0.6	SS1	3, refusal	-	-	33	11
0.6 – 1.2	SS2	4, 5, 3, 3	8	-	42	24
1.2 – 1.8	SS3	0, 0, 4, 5	4	-	17	14
1.8 – 2.4	SS4	12, 11, 5, 2	16	-	33	16
2.4 – 3.0	SS5	3, 5, 12, 17	17	>4.5	79	19
3.0 – 3.7	SS6	3, 5, 8, 14	13	>4.5	46	20
3.8 – 4.3	SS7	5, 7, 14, 20	21	4.5	100	23
4.6 – 5.0	SS8	3, 9, 13, 19	22	1.0	100	24
5.3 – 5.8	SS9	3, 5, 7	12	0.75	100	30
6.1 – 6.6	SS10	6, 5, 7	12	2.5	100	25
6.9 – 7.3	SS11	5, 5, 9	14	0	100	24
7.6 – 8.1	SS12	3, 4, 4	8	0.75	100	27
8.4 – 8.8	SS13	5, 5, 7	12	1.0	100	13
9.1 – 9.6	SS14	5, 7, 7	14	1.25	100	22
9.9						

STANDARD PENETRATION "N" VALUE (10, 20, 30) — WATER CONTENT % (20, 30, 40), W_P — W_L

REMARKS

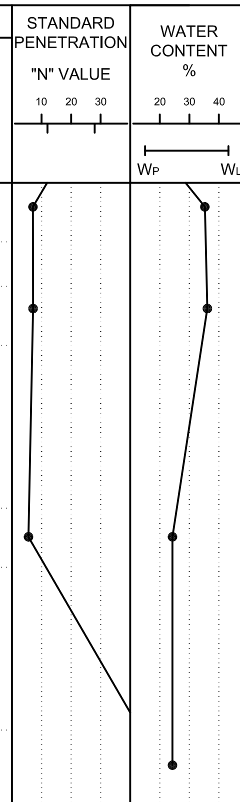
Water level estimated at 6.7 mbgs upon completion.

Geophysics probe installed upon completion.

BOREHOLE NO. 19

PROJECT: Abitibi Thorold Mill - Cogeneration Plant
Project No: 1040244.01
Contractor: Lantech Drilling Services Inc.
CLIENT: Abitibi - Consolidated Company of Canada
Date Drilled: May 3-4, 2006
Drill Type: CME 75
SITE: Abitibi Thorold Mill Site
Date of Backfilling: May 4, 2006
Auger: 210 mm (O.D.) Hollow Stem Auger
SUPERVISOR: RFK
Ground Elevation: 178.13 m ASL
Sampler: 51 mm (O.D.) Split Spoon
REVIEWER: JSA
UTM Coordinates: 646577N / 4774174E

DEPTH (m) / ELEV (m ASL)	STRATIGRAPHIC DESCRIPTION	MONITOR DETAILS	SAMPLE DATA: DEPTH (m)	SAMPLE No. / TYPE	SPT PER 6"	"N" VALUE	(kg/cm^2) POCKET PENETROMETER	% RECOVERY	% WATER	REMARKS
10	SILTY CLAY TO CLAYEY SILT (cont.)	No Monitor Installed		SS15	3, 4, 4	8	0	100	36	
			10.4							
	Becoming stiff.		10.7							
11				SS16	3, 4, 4	8	0	100	37	
			11.1							
12			12.2							
				SS17	2, 2, 3	5	0	100	24	
			12.6							
12.7 / 165.43	SILT TO CLAYEY SILT (TILL) Dark brown to brown silt, some gravel, to orange mottled silt, till-like, moist, dense/hard.									
13			13.7							
14				SS18	1, 7, 50 - 0"	>50	-	44	23	
14.2 / 163.93	Refusal at 14.2 m on presumed bedrock.		14.2							
15–20										



BOREHOLE NO. 1-I,II,III

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc. DATE July 18, 19/84

BOREHOLE TYPE 83 mm Hollow Stem Auger GEOLOGIST G.A.M.

GROUND ELEVATION 181.07 m PROJECT NO. 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	TYPE	'N' VALUE	% WATER	PENETRATION RESISTANCE BLOWS/0.3m (30 60 90)	WATER CONTENT % / COMMENTS (Wp 10 20 30 WL)
0	<u>Lacustrine clayey SILT to silty Clay</u> Medium brown becoming grey brown. Fractured in upper 4.1±m with occasional laminations of sandy silt and clayey silt. A.P.L. becoming W.T.P.L. below 4.1 m. Stiff to very stiff becoming very soft to firm below 4.1m±. Occasional fine grit present between 4.1 m to 8.1 m±			1	SS	7	24		
				2	SS	8			
				3	SS	19	22		
				4	SS	9			
				5	SS	9	22		
				6	ST				
				7	SS	6	28		
5				8	SS	4			
			III	9	SS	4	27		
				10	SS	4	26		
				11	SS	2	29		
10			I, II	12	ST				

Gartner Lee Associates Limited

BOREHOLE NO. 1-I,II,III CONFIDENTIAL

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc. DATE July 18,19/84

BOREHOLE TYPE 83 mm Hollow Stem Auger GEOLOGIST G.A.M.

GROUND ELEVATION 181.07 m PROJECT NO. 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	SAMPLE NO.	TYPE	'N' VALUE	% WATER
10	Lacustrine clayey SILT to silty CLAY (Continued)	13	SS	3	31
		14	SS	2	28
13.72	Sandy SILT TILL Red brown to brown, very dense, saturated.	15	SS	5	20
		16	SS	65	6
15.24	Dolomitic LIMESTONE Medium grey, slightly weathered, medium hard very fine grained, moderately vuggy and containes occasional fractures in the upper 2m. Fractures are about 30-100 mm apart, most fracture surfaces show secondary calcite deposition.				
18.29	Borehole terminated in limestone at ±18.29 m.				
20					

Monitor details: II (screen approx. 13.7–14.6 m); I (screen approx. 16.6–17.8 m)

Penetration resistance blows/0.3m: 30 60 90. Water content %: 10 20 30 (Wp — WL)

BOREHOLE NO. 2-I,II,III

CONFIDENTIAL

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1,

CLIENT Cyanamid of Canada Inc. **DATE** July 11, 12/84

BOREHOLE TYPE 83 mm Hollow Stem Auger **GEOLOGIST** G.A.M.

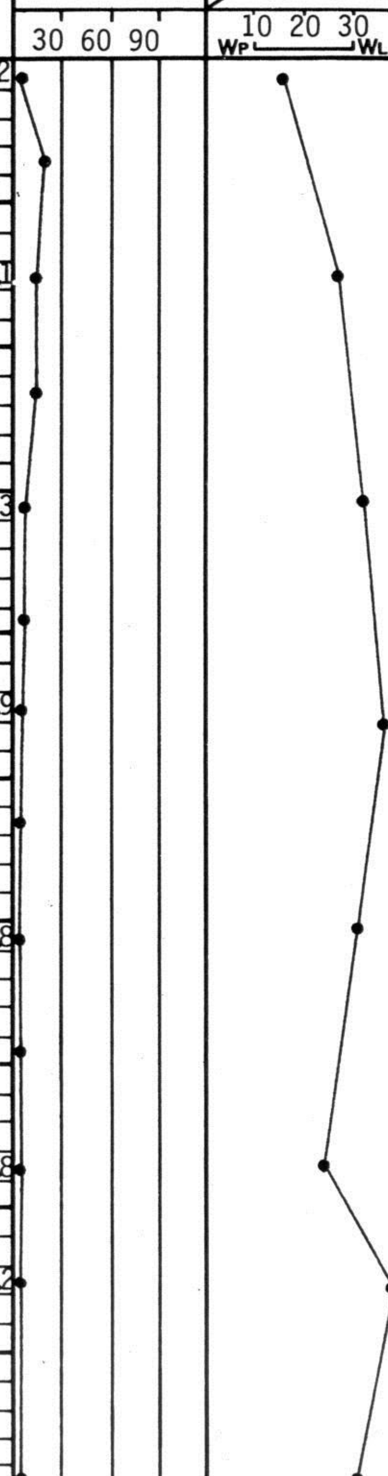
GROUND ELEVATION 180.16 m **PROJECT NO.** 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION
0	Topsoil
	Lacastrine clayey SILT to silty CLAY Medium brown becoming grey brown. Fractured in upper 3.1 m with occasional laminations of sandy silt and clayey silt. A.P.L. becoming W.T.P.L. below 3.1m Stiff to very stiff becoming very soft to firm below 4.1 m± Occasional fine grit present between 6.9 m to 10.4 m±
5	
10	

MONITOR DETAILS AND NUMBER: I, II, III

SAMPLE NO.	TYPE	'N' VALUE	% WATER
1	SS	7	15.2
2	SS	20	
3	SS	16	26.1
4	SS	16	
5	SS	8	31.3
6	SS	5	
7	SS	4	35.9
8	SS	4	
9	SS	4	30.8
10	SS	3	
11	SS	4	23.8
12	ST		
13	SS	4	38.2
14	SS	4	

PENETRATION RESISTANCE BLOWS/0.3m — WATER CONTENT % / COMMENTS



Gartner Lee Associates Limited

CONFIDENTIAL

BOREHOLE NO. 2-I,II,III

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc. **DATE** July 11,12/84

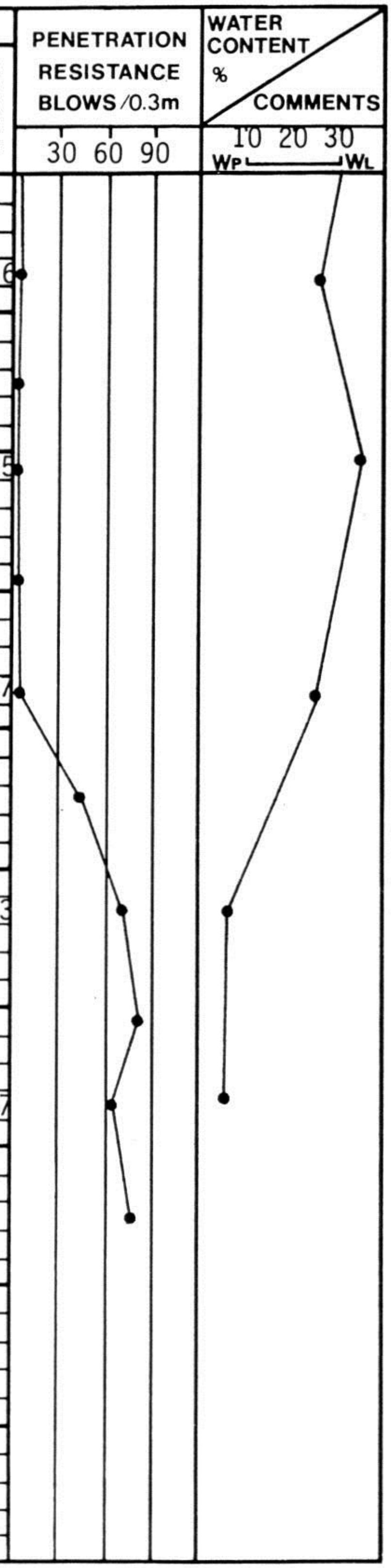
BOREHOLE TYPE 83 mm Hollow Stem Auger **GEOLOGIST** G.A.M.

GROUND ELEVATION 180.16 m **PROJECT NO.** 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION
	Lacustrine clayey SILT to silty CLAY (continued)
	Becomes more silty at depth. With layers of silty fine sand.
14.48	
14.68	Silty very fine SAND, medium brown
	Sandy SILT TILL Red brown to brown Very dense Saturated
17.53	Medium to coarse grained SAND
17.81	Grey brown, silty, mixed with some rock fragments.
	Dolomitic LIMESTONE medium grey slightly weathered limestone, medium hard, very fine grained, contains several small vugs and some near verticle solution cracks contains occasional horizontal fractures.
20	Fractures spaced about 30-100 mm apart. Some fracture surfaces show secondary calcite deposition.

MONITOR DETAILS AND NUMBER: II (at approx. 16.1 m), I (at approx. 20 m)

SAMPLE NO.	TYPE	'N' VALUE	% WATER
15	SS	3	25.6
16	SS	3	
17	SS	3	34.5
18	SS	2	
19	SS	5	25.7
20	SS	45	
21	SS	72	6.3
22	SS	84	
23	SS	62	6.7
24	SS	74	



Gartner Lee Associates Limited

000193

BOREHOLE NO. 2-I,II,III

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc, DATE July 11, 12/84

BOREHOLE TYPE 83 mm Hollow Stem Auger GEOLOGIST G.A.M.

GROUND ELEVATION PROJECT NO. 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (30 60 90)	WATER CONTENT % (10 20 30, Wp–WL) / COMMENTS
	Dolomitic LIMESTONE (cont'd)								
20.97			I						
	Borehole terminated in dolomitic limestone at ±20.97m.								

BOREHOLE NO. 3-I,II,III

CONFIDENTIAL

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc,

DATE July 27/84

BOREHOLE TYPE 83 mm Hollow Stem Auger

GEOLOGIST G.A.M.

GROUND ELEVATION 178.56 m

PROJECT NO. 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	TYPE	'N' VALUE	% WATER	PENETRATION RESISTANCE BLOWS/0.3m (30 60 90)	WATER CONTENT % (Wp 10 20 30 WL) COMMENTS
0	Lacustrine clayey SILT to silty CLAY Medium brown becoming grey brown Fractured in upper 4.0 ±m with occasional laminations of sandy silt and clayey silt A.P.L. becoming W.T.P.L. below 5.3m Stiff becoming very soft to firm below 3.1m Occasional fine grit present between 3.1 to 6.6 ±m			1	SS	10	17.3		
				2	SS	11			
				3	SS	15	26.6		
				4	SS	12			
				5	SS	7	22.1		
				6	ST				
				7	SS	5			
5									
				8	SS	4	23.6		
			III	9	SS	3	30.1		
				10	SS	6	27.1		
				11	ST				
				12	SS	4	30.0		
10			I, II						

Gartner Lee Associates Limited

000195

BOREHOLE NO 3-I,II,III

CONFIDENTIAL

PROJECT NAME: Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT: Cyanamid of Canada Inc. DATE: July 27/84

BOREHOLE TYPE: 83 mm Hollow Stem Auger GEOLOGIST: G.A.M.

GROUND ELEVATION: 178.56 m PROJECT NO. 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	TYPE	'N' VALUE	% WATER	PENETRATION RESISTANCE BLOWS/0.3m (30 60 90)	WATER CONTENT % (10 20 30, Wp–WL) COMMENTS
10	Lacustrine clayey SILT to silt CLAY (continued)			13	SS	5	33.3		
11.66	Clayey SILT Till red-brown firm A.P.L.			14	SS	5	13.6		
13.19	Fine grained SAND medium brown, saturated, very loose			15	SS	2	20.6		
14.17	Sandy SILT TILL red-brown, very dense, saturated			16	SS	77	18.5		
			II	17	SS	80	7.0		
				18	SS	88	4.5		
				19	SS	67	10.0		
18.54	Dolomitic LIMESTONE light grey slightly to medium weathered, medium hard contains occasional vugs and near horizontal cracks, closely, fractured, some discontinuities are infilled with		I						
20									

secondary calcite, discontinuities are generally restricted to the upper 2 m

Gartner Lee Associates Limited

000196

BOREHOLE NO. 3-I,II,III

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc. **DATE** July 27/84

BOREHOLE TYPE 83 mm Hollow Stem Auger **GEOLOGIST** G.A.M.

GROUND ELEVATION 178.56 m **PROJECT NO.** 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (30 60 90)	WATER CONTENT % (10 20 30, Wp – Wl) / COMMENTS
20	LIMESTONE (cont'd)		I						
23.07	Borehole terminated in limestone at ±23.07 m								

BOREHOLE NO. 4-I,II,III

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc. DATE July 23, 24/ 84

BOREHOLE TYPE 83 mm Hollow Stem Auger GEOLOGIST G.A.M.

GROUND ELEVATION 176.62 m PROJECT NO. 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	SAMPLE NO.	TYPE	'N' VALUE	% WATER
0	Lacustrine clayey SILT to silty CLAY Medium brown becoming grey brown Fractured in upper 5.3 m± with occasional laminations of sandy silt and clayey silt, A.P.L. becoming W.T.P.L. below 5.3 m. Stiff to very stiff becoming soft to firm below 5.3±m.	1	SS	9	19.1
		2	SS	18	
		3	SS	12	26.3
		4	SS	15	
		5	SS	9	25.0
		6	ST		
		7	SS	6	29.7
5		8	SS	3	
		9	SS	2	26.3
		10	SS	3	23.8
		11	ST		
8.66	Clayey SILT TILL - red brown, soft to firm, A.P.L. Contains occasional stone free lacustrine sequences 30-40 mm thick	12	SS	5	11.6
9.90	Sandy SILT TILL				

MONITOR DETAILS AND NUMBER: I, II, III

PENETRATION RESISTANCE BLOWS/0.3m: 30 60 90

WATER CONTENT % / COMMENTS: 10 20 30 (Wp — WL)

BOREHOLE NO. 4-I,II,III

CONFIDENTIAL

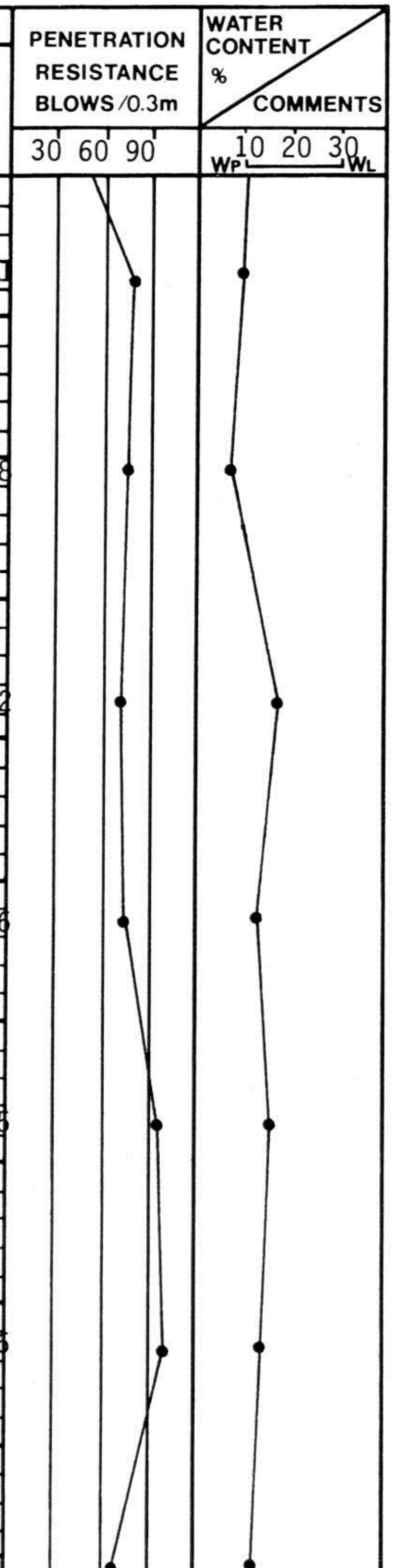
PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc. **DATE** July 23, 24/84

BOREHOLE TYPE 83 mm Hollow Stem Auger **GEOLOGIST** G.A.M.

GROUND ELEVATION 176.62 m **PROJECT NO.** 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	SAMPLE NO.	TYPE	'N' VALUE	% WATER
10	Sandy SILT TILL (cont'd) Grey-brown, very dense, saturated. Contains occasional silty fine sand seams, 20-40 mm thick, silty fraction generally increases with depth.	13	SS	81	10.1
		14	SS	75	7.8
		15	SS	70	18.2
		16	SS	74	11.6
		17	SS	92	16.5
		18	SS	99	13.6
19.81	Silty fine grained SAND - grey brown, contains occasional sandy silt seams 20-30 mm thick, very dense, saturated.	19	SS	67	11.1



BOREHOLE NO. 4-I,II,III,

PROJECT NAME: Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT: Cyanamid of Canada Inc. | DATE: July 23,24/84

BOREHOLE TYPE: 83 mm Hollow Stem Auger | GEOLOGIST: G.A.M.

GROUND ELEVATION: 176.62 m | PROJECT NO. 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (30 60 90)	WATER CONTENT % (Wp 10 20 30 WL) / COMMENTS
20.24	SAND (cont'd)								
	Dolomitic LIMESTONE light grey, slightly to medium weathered, medium hard, contains small vugs and solution cracks from ±20.2m to ±21.4 m								
22.56			I						
	Borehole terminated in limestone at ±22.56 m								

CONFIDENTIAL

BOREHOLE NO. 5-I,II,III,

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc. **DATE** July 27/84

BOREHOLE TYPE 83 Hollow Stem Auger **GEOLOGIST** G.A.M.

GROUND ELEVATION I-175.95, II-176.31, III-176.21, IV-176.17 m **PROJECT NO.** 84-26

DEPTH (m): 0 – 10

STRATIGRAPHIC DESCRIPTION

Lacustrine clayey SILT to silty CLAY
Medium brown becoming grey brown. Fractured in upper 4.6 m with occasional laminations of sandy silt and clayey silt. A.P.L. becoming W.T.P.L. at 7.62±m. Stiff to very stiff becoming very soft to firm below 6.6 ±m. Occasional fine grit present between 3.4 to 5.0 ±m.

MONITOR DETAILS AND NUMBER: III, IV, I, II

SAMPLE NO.	TYPE	'N' VALUE	% WATER
1	SS	11	21.2
2	SS	23	
3	SS	12	29.3
4	SS	8	
5	ST		
6	SS	8	22.8
7	SS	8	26.1
8	SS	12	
9	SS	6	30.6
10	SS	4	28.5
11	ST		
12	SS	3	25.3

PENETRATION RESISTANCE BLOWS/0.3m: 30 60 90

WATER CONTENT % / COMMENTS: 10 20 30, Wp — WL

BOREHOLE NO. 5-I,II,III,IV

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc. **DATE** July 27/84

BOREHOLE TYPE 83 mm Hollow Stem Auger **GEOLOGIST** G.A.M.

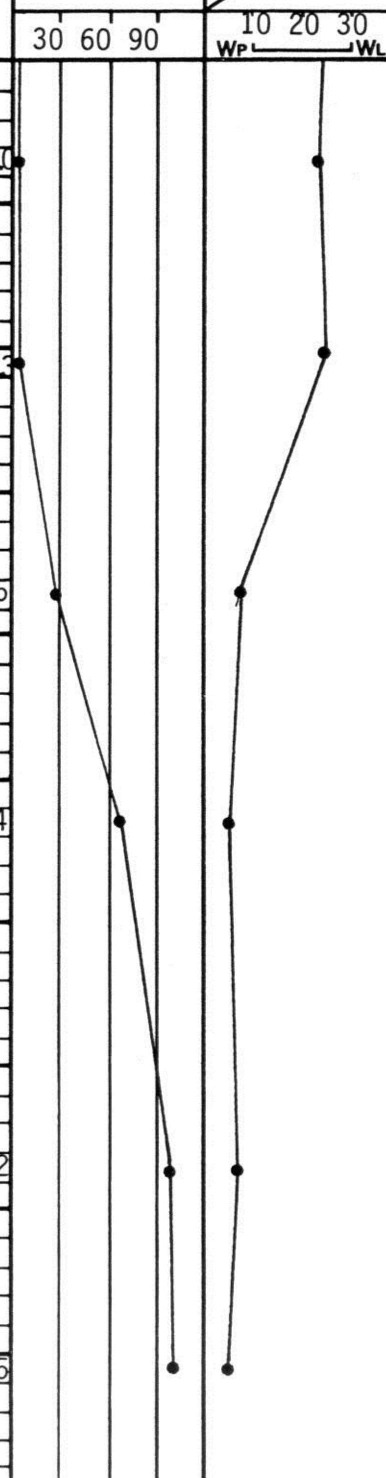
GROUND ELEVATION I-175.95, II-176.31, III-176.21, IV-176.17m **PROJECT NO.** 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION
10	Lacustrine clayey SILT to silty CLAY (continued)
12.12	Clayey SILT TILL Red brown, very stiff to hard, A.P.L.
14.7	Sandy SILT TILL Red brown, very dense. Saturated. Silt fraction is predominant from 15.2 to 15.7±m but decreases with depth.
20	

Monitor details and number: II, I

SAMPLE NO.	TYPE	'N' VALUE	% WATER
13	SS	3	23.[illegible]
14	SS	4	24.[illegible]
15	SS	30	7.5
16	SS	71	5.4
17	SS	99	8.2
18	SS	107	5.5

PENETRATION RESISTANCE BLOWS/0.3m — WATER CONTENT % / COMMENTS



BOREHOLE NO. 5-I,II,III

CONFIDENTIAL

PROJECT NAME Cyanamid Hydrogeological Study, Welland Plant, Phase 1

CLIENT Cyanamid of Canada Inc. DATE July 27/84

BOREHOLE TYPE 83 mm Hollow Stem Auger GEOLOGIST G.A.M.

GROUND ELEVATION I-175.95, II-176.31, III-176.21, IV-176.17m PROJECT NO. 84-26

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (30 60 90)	WATER CONTENT % (10 20 30, Wp — WL) / COMMENTS
20.02	Sandy SILT TILL (cont'd)								
	Dolomitic LIMESTONE light grey, slightly to medium weathered, medium hard, rock is vuggy from ±20.02 to ±23.07 m and contains occasional solution cracks. Some vugs and cracks are infilled with secondary calcite, contains occasional fractures 30-100 mm apart but these are generally restricted to the upper 2 m.								
23.16			I						
	Borehole terminated in limestone at ±23.16 m								

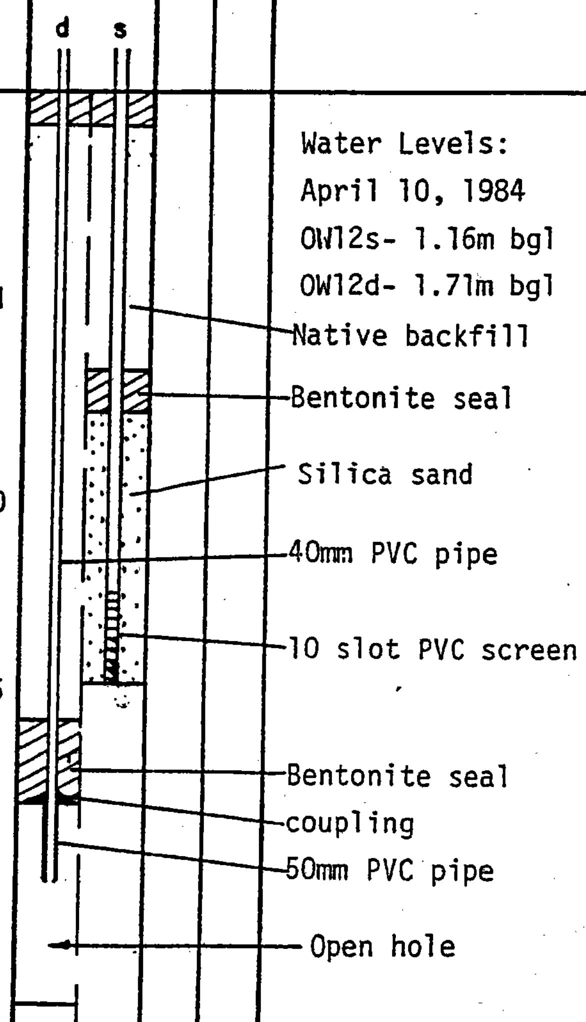
morrison beatty
Consulting Engineers and Hydrogeologists

OW12s-84
OW12d-84

CLIENT: City of Niagara Falls   FILE NO. 345-832
PROJECT: LOCATION: Mountain Road Landfill
GEOLOGIST/ENGINEER: J.R.   DATE COMPLETED: April 10, 1985

DESCRIPTION	DEPTH metres	DEPTH feet	SAMPLE no.	SAMPLE type	SAMPLE "N"	REMARKS
CLAY: with fine sand, reddish brown blocky, moist	1	5	1	SS	11	Water Levels: April 10, 1984 OW12s- 1.16m bgl OW12d- 1.71m bgl
	2					
SILT: with fine sand reddish brown with pebbles, saturated	3	10	2	SS	20	
	4	15	3	SS	36	
	5					
DOLOSTONE	6	20				
	7	25				
	8					
	9	30				
	10					

WELL DETAIL



BLOWS PER FOOT: 10 20 30 40 50 60 70 80 90

GS- GRAB SAMPLE   SS- SPLIT SPOON   ST- SHELBY TUBE   "N" BLOWS PER FOOT   WATER LEVEL ▽

WL-040481

BOREHOLE NO. OW54(23)

PROJECT NAME: MOUNTAIN ROAD LANDFILL SITE

PROJECT NO.: 111-53076-00 132-00

CLIENT: THE REGIONAL MUNICIPALITY OF NIAGARA

DATE COMPLETED: Apr 04, 2012

BOREHOLE TYPE: 110 mm HOLLOW STEM AUGER / HQ CORE

SUPERVISOR: RLB

GROUND ELEVATION: 195.4 mASL

REVIEWER: KJF

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE TYPE	N VALUE	% WATER	% RECOVERY	RQD (%)	CONE PENETRATION "N" VALUE (10 20 30) / SHEAR STRENGTH	WATER CONTENT % (10 20 30) Wp WL	REMARKS
0.0	SILT: BROWN SILT, TRACE CLAY, TRACE SAND, TRACE TO SOME GRAVEL, LOOSE, WET, WEAKLY DILATENT.			SS1	7		71				
1.0				SS2	8		75				
2.0				SS3	5		58				
				SS4	5		71				
3.0				SS5	4		54				
4.0				SS6	4		96				
5.0				SS7	14		79				
				SS8	73		96		73		
6.0	6.0 SILT: BROWN SILT, WET, DILATENT, VERY DENSE.			SS9	86		75		86		
7.0											
8.0				SS10	96		83		96		
9.0				SS11	80		108		80		
10.0											
11.0				SS12	89		71		89		
12.0				SS13	35		104				
13.0											
14.0				SS14	36		100				
15.0											

BOREHOLE NO. OW54(23)

PROJECT NAME: MOUNTAIN ROAD LANDFILL SITE **PROJECT NO.:** 111-53076-00 132-00

CLIENT: THE REGIONAL MUNICIPALITY OF NIAGARA **DATE COMPLETED:** Apr 04, 2012

BOREHOLE TYPE: 110 mm HOLLOW STEM AUGER / HQ CORE **SUPERVISOR:** RLB

GROUND ELEVATION: 195.4 mASL **REVIEWER:** KJF

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	REMARKS
15.0 – 18.4		
18.4	SAND AND GRAVEL: ANGULAR AND ROUNDED ROCK FRAGMENTS, SAND AND SILT.	
19.2	LOCKPORT FORMATION (GOAT ISLAND MEMBER): NIAGARA FALLS FACIES DARK GREY DOLOSTONE, FINE GRAINED CRYSTALLINE, MEDIUM BEDDED WITH THIN STYLOLYTIC PARTINGS (TYPICALLY 1 PER 0.3 m), STRONG SMOOTH CORE, SLIGHTLY SCRATCHED BY A KNIFE, POOR TO FAIR RQD, FOSSILIFEROUS. GRADATIONAL LOWER CONTACT ON CHANGE IN COLOUR AND TEXTURE.	BROKEN RECOVERY, WITH REDDISH BROWN MUD INFILLING FROM 19.2 m TO 19.3 m AND 19.5 m TO 19.8 m.
20.6	LOCKPORT FORMATION (GASPORT MEMBER): BLUEISH GREY DOLOSTONE, CRINOIDAL GRAINSTONE, LESS FREQUENTLY A PACKSTONE, FINE TO MEDIUM GRAINED CRYSTALLINE WITH OCCASIONAL STYLOLYTE PARTINGS (TYPICALLY 1 TO 2 PER 0.3 m), SLIGHTLY PITTED CORE WITH A SMOOTH TO SLIGHTLY SANDY TEXTURE, EXCELLENT TO GOOD RQD.	2 cm SHALE BED AT 21.4 m, WITH A BRECCIATED APPEARANCE. SHARP LOWER CONTACT ON COLOUR AND TEXTURE CHANGE.
26.3	DECEW FORMATION: DARK GREY, VERY FINE GRAINED DOLOSTONE, WAVY BEDDING FEATURES WITH SHALEY LAMINAE, BARREN APPEARANCE - NO FOSSILS NOTED, EXCELLENT RQD.	
27.6	BOREHOLE TERMINATED AT 27.6 m DEPTH IN DOLOSTONE.	

Column headings of the log: DEPTH (m) · STRATIGRAPHIC DESCRIPTION · STRATIGRAPHY · MONITOR DETAILS · SAMPLE (TYPE, N VALUE, % WATER, % RECOVERY, RQD (%)) · CONE PENETRATION ("N" VALUE 10 20 30, SHEAR STRENGTH) · WATER CONTENT % (10 20 30, W_P W_L) · REMARKS

Depth scale: 15.0, 16.0, 17.0, 18.0, 19.0, 20.0, 21.0, 22.0, 23.0, 24.0, 25.0, 26.0, 27.0, 28.0, 29.0, 30.0

TYPE	N VALUE	% WATER	% RECOVERY	RQD (%)
SS15	19		25	
SS16	43		92	
SS17	38		54	
RC18			100	42
RC19			89	67
RC20			86	82
RC21			98	105
RC22			100	100
RC23			101	76
RC24			100	100

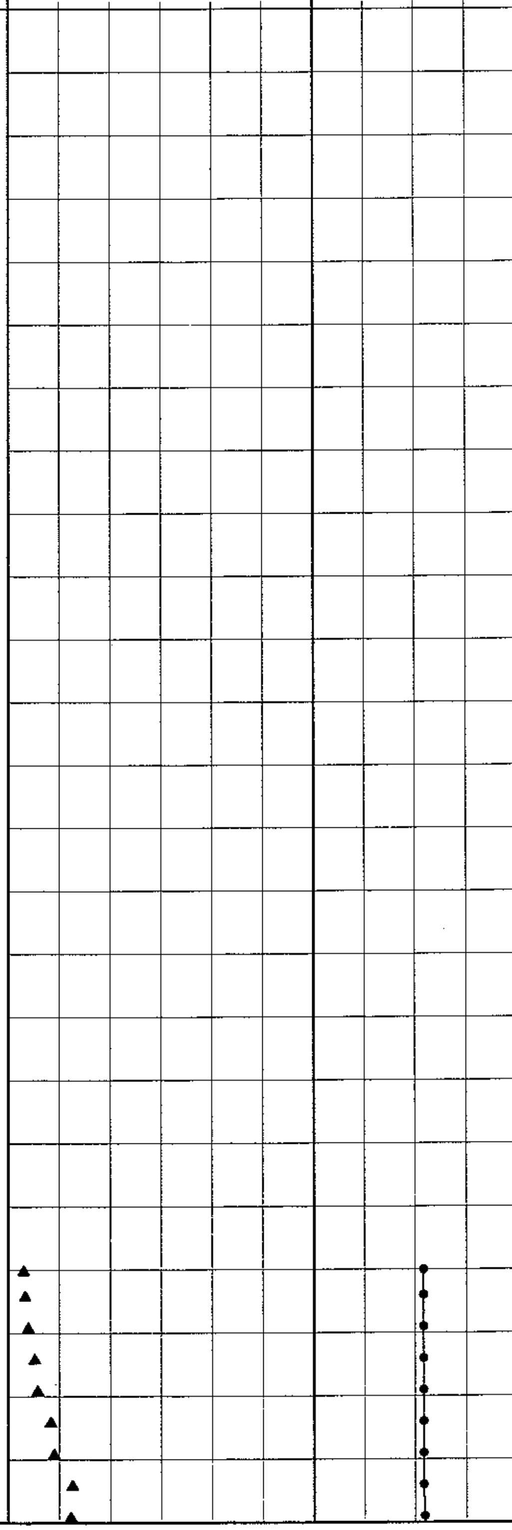
Cone penetration "N" value plot annotation: 43

RECORD OF BOREHOLE No CMT 3

PROJECT	Mountain Road Landfill	LOCATION	(refer to Borehole Location Plan)
CLIENT	RMON		Aardvark: Track-mount CME 75
JOB NO.	TG71108	DATE	11.6.07 - 11.12.07
			Core Size: PQ

ORIGINATED BY RVH
COMPILED BY RVH
CHECKED BY RS

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	RUN (SAMPLES)	RQD (%)	RECOVERY (%)	GROUND WATER CONDITIONS	DEPTH (m)	GROUNDWATER ELECTRICAL CONDUCTIVITY (µS/cm) 1000 2000 3000 4000 5000	GROUNDWATER TEMPERATURE (C) 5 10 15	OBSERVATIONS & REMARKS
202.0 / 0.0	Unsampled overburden.						0–23			
178.7										Run 1 : Steady water return
~~178.6~~ / 23.4	**GLACIAL TILL**, with cobbles.		1	78	100					



Continued Next Page

amec

RECORD OF BOREHOLE No CMT 3

PROJECT Mountain Road Landfill | LOCATION (refer to Borehole Location Plan) | ORIGINATED BY RVH

CLIENT RMON | Aardvark: Track-mount CME 75 | COMPILED BY RVH

JOB NO. TG71108 | DATE 11.6.07 - 11.12.07 | Core Size: PQ | CHECKED BY RS

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	RUN	RQD (%)	RECOVERY (%)	DEPTH (m)	OBSERVATIONS & REMARKS
	LOCKPORT FORMATION, GASPORT MEMBER, GREY LIMESTONE, chert nodules, stylolites, vugs, crinoidal fossils.	2	97	100	25	Run 2 : No water return.
		3	83	100	26–27	Run 3 : No water return.
	(NOTE: Silt in lower part of open hole prevented conductivity and temperature profiling in CMT 3)	4	92	100	28	Run 4 : No water return.
		5	100	100	29–30	Run 5 : No water return.
		6	77	100	31	Run 6 : No water return.
168.7 / 33.3		7	90	100	32–33	Run 7 : No water return
167.6 / 34.4	**DECEW FORMATION**, GREY DOLOSTONE, with ocassional shale partings.	8	100	100	34	Run 8 : No water return
	ROCHESTER FORMATION, Dark grey SHALE. ocassional fossils, dolostone layers.	9	100	100	35–36	Run 9 : No water return.
163.8 / 38.3		10	97	100	37–38	Run 10 : No water return.
38.3	**BOREHOLE TERMINATED**					

GROUNDWATER ELECTRICAL CONDUCTIVITY (µS/cm): 1000 2000 3000 4000 5000

GROUNDWATER TEMPERATURE (C): 5 10 15

RECORD OF BOREHOLE No CMT 5

PROJECT	Mountain Road Landfill	LOCATION	(refer to Borehole Location Plan)
CLIENT	RMON		Aardvark: Track-mount CME 75
JOB NO.	TG71108	DATE	10.18.07 - 10.22.07
			Core Size: PQ

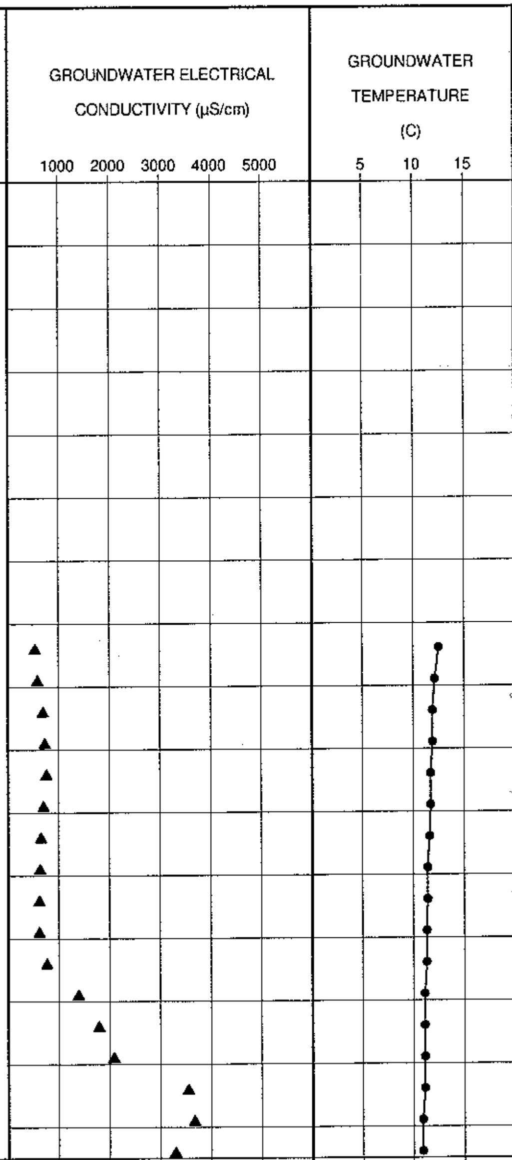
ORIGINATED BY RVH
COMPILED BY RVH
CHECKED BY RS

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
174.3 / 0.0	Unsampled overburden
170.8 / 3.5	**LOCKPORT FORMATION, GASPORT MEMBER**, GREY LIMESTONE, with occasional shale partings, small vugs, crinoidal fossils, stylolites, gypsum filled vugs, vertical break from 6.1 to 6.4 mbgs
165.6 / 8.7	**DECEW FORMATION**, GREY LIMESTONE with ocassional shale partings, gypsum vugs,
164.3 / 10.0	**ROCHESTER FORMATION**, Dark grey SHALE WITH DOLOSTONE LAYERS occasional fossils, fine grained.
158.8 / 15.5	**BOREHOLE TERMINATED.**

SAMPLES

RUN	RQD (%)	RECOVERY (%)	OBSERVATIONS & REMARKS
1	73	92	Run 1 : Steady water return
2	93	98	Run 2 : Steady water return
3	75	100	Run 3 : Steady water return
4	89	100	Run 4 : Steady water return
5	94	100	Run 5 : Steady water return
6	99	96	Run 6 : Steady water return
7	96	94	Run 7 : Steady water return
8	98	100	Run 8 : Steady water return



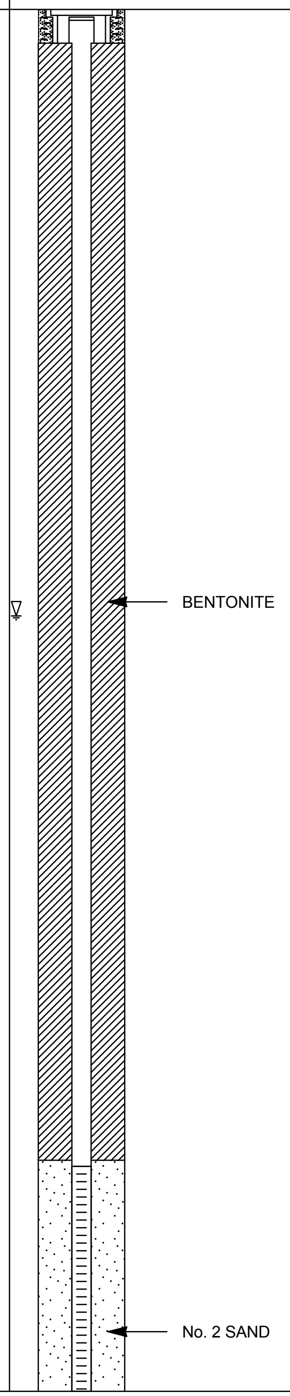
STRATIGRAPHIC AND INSTRUMENTATION LOG
(OVERBURDEN)

PROJECT NAME: NIAGARA RECYCLING CENTRE
PROJECT NUMBER: 54284
CLIENT: NIAGARA REGION
LOCATION: NIAGARA FALLS, ONTARIO

HOLE DESIGNATION: CRA-11D-09 (PART 1)
DATE COMPLETED: February 18, 2009
DRILLING METHOD: HSA
FIELD PERSONNEL: E. STAHL

STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH m BGS
ASPHALT	0.15
SAND AND GRAVEL (FILL), fine to medium grained, light grey, very dense, well graded	1.22
SILTY CLAY, very stiff, low plasticity, reddish brown - increasing silt, stiff at 1.37m BGS	1.83
SILT, very stiff, low plasticity, reddish brown - hard at 2.44m BGS - moist at 3.05m BGS - slightly moist at 3.66m BGS	5.18
SILTY CLAY, very stiff, medium plasticity, reddish brown, wet	5.79
SILT, hard, medium plasticity, reddish brown, moist to wet - very stiff, medium to low plasticity at 6.10m BGS - hard at 6.71m BGS - trace fine sands at 7.32m BGS	7.92
SAND with silt, compact, fine grained, poorly graded, reddish brown, wet	8.53
SILT with trace fine sands, very stiff, high plasticity, wet	9.14
SAND, very dense, fine grained, poorly graded, grey with trace silt, wet	9.45
SILT(TILL), with trace gravel, hard, low plasticity, reddish brown, moist to wet - slight odor at 9.75m BGS - refusal of augers at 10.33m BGS	10.36
BEDROCK - refer to bedrock log for details	

HSA



SAMPLE NUMBER	REC (%)	'N' VALUE	PID (ppm)
1	100	101	1.5
2	50	30	0.5
3	100	9	0.1
4	100	22	0.1
5	100	30	0.1
6	100	37	0.1
7	100	35	0.2
8	100	30	0.2
9	100	22	0.0
10	100	38	0.0
11	100	24	0.5
12	100	35	0.6
13	100	19	0.4
14	100	12	0.6
15	100	17	0.1

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ⊽

STRATIGRAPHIC AND INSTRUMENTATION LOG (OVERBURDEN)

PROJECT NAME: NIAGARA RECYCLING CENTRE
PROJECT NUMBER: 54284
CLIENT: NIAGARA REGION
LOCATION: NIAGARA FALLS, ONTARIO

HOLE DESIGNATION: CRA-11D-09 (PART 1)
DATE COMPLETED: February 18, 2009
DRILLING METHOD: HSA
FIELD PERSONNEL: E. STAHL

DEPTH m BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH m BGS	HSA	SAMPLE NUMBER	SAMPLE INTERVAL	SAMPLE REC (%)	SAMPLE 'N' VALUE	SAMPLE PID (ppm)
13								
14	END OF BOREHOLE @ 13.82m BGS	13.82	WELL DETAILS Screened interval: 10.46 to 13.51m BGS Length: 3.05m Diameter: 50.8mm Slot Size: 10 Material: PVC Seal: 0.30 to 10.41m BGS Material: BENTONITE Sand Pack: 10.41 to 13.51m BGS Material: No. 2 SAND					
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE
WATER FOUND ⊻

STRATIGRAPHIC LOG
(BEDROCK)

PROJECT NAME: NIAGARA RECYCLING CENTRE
PROJECT NUMBER: 54284
CLIENT: NIAGARA REGION
LOCATION: NIAGARA FALLS, ONTARIO

HOLE DESIGNATION: CRA-11D-09 (PART 2)
DATE COMPLETED: February 20, 2009
DRILLING METHOD: HQ
FIELD PERSONNEL: E. STAHL

DEPTH m BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH m BGS	RUN NUMBER	CORE RECOVERY %	RQD %
0–10.36	REFER TO BOREHOLE LOG CRA-10D-09 (PART 1)		1	75	
			2	100	60
			3	95	
10.36–	ERAMOSA FORMATION, dolostone, dark grey, massive to thick bedded, finely crystalline, occasional vugs and styloites - styloite (multiple for approx. 5.08cm) at 10.52m BGS - vuggy for approx. 5.08cm at 10.67m BGS - vuggy lined with small crystals at 10.80m BGS - vertical fracture, very close, rough, tight, slightly weathered, silt infilling at 10.97m BGS - vug 2cm x 1cm lined with small crystals at 11.02m BGS - fragmental dolostone with silt and clay infilling with smaller gravel	10.36	4	100	150

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

STRATIGRAPHIC LOG (BEDROCK)

PROJECT NAME: NIAGARA RECYCLING CENTRE

PROJECT NUMBER: 54284

CLIENT: NIAGARA REGION

LOCATION: NIAGARA FALLS, ONTARIO

HOLE DESIGNATION: CRA-11D-09 (PART 2)

DATE COMPLETED: February 20, 2009

DRILLING METHOD: HQ

FIELD PERSONNEL: E. STAHL

DEPTH m BGS	STRATIGRAPHIC DESCRIPTION & REMARKS	DEPTH m BGS	RUN NUMBER	CORE RECOVERY %	RQD %
13	(weathered), cobbles, medium to course grained, reddish brown at 11.07m BGS - natural horizontal fracture, very close, rough, tight, slight lateral along black shale parting, petroliferous odor at 11.33m BGS - vuggy at 11.51m BGS - vuggy at 11.66m BGS	13.82	5	100	240
14	- horizontal fracture along styloite, horizontal and vertical about 10 cm, rough, tight, slightly weathered, clay infilling at 11.80m BGS - vuggy at 11.91m BGS - horizontal fractures along styloites for 5.08 cm at 11.96m BGS				
15	- horizontal fracture along black shale party, tight, slightly weathered, petroliferous odor at 11.99m BGS - horizontal fracture, slightly weathered, clay infilling at 12.22m BGS - natural horizontal fracture along black shale party, tight, petroliferous odor at 12.36m BGS				
16	- mechanical fracture at 12.60m BGS - natural horizontal fracture, tight, slightly weathered at 12.67m BGS - styloite at 12.70m BGS - natural horizontal fracture along styloite, tight, crystalline infilling with trace clays, slightly weathered at 12.73m BGS				
17	- vertical fracture along horizontal plane fracture, slightly weathered, clay infilling at 12.75m BGS - natural horizontal fracture, tight, rough, slightly weathered, gypsum infilling at 12.80m BGS				
18	- natural horizontal fracture along black shale party, tight, petroliferous odor at 12.85m BGS - syloite with gypsum/calcite infilling at 12.93m BGS - natural horizontal fracture, tight, rough, slightly weathered, clay infilling at 13.18m BGS				
19	- vuggy with crystalline infilling at 13.26m BGS - natural horizontal fracture along black shale parting, tight, trace gypsum infilling at 13.31m BGS - natural horizontal fracture, slight vertical fracture, tight, rough, slightly weathered, clay infilling, fractured along stylite at 13.36m BGS				
20	- vugs 7.62 cm at 13.41m BGS - vuggy with gypsum/calcite, infilling in cavityupes and along planes 10.16 cm thick at 13.59m BGS				
21	- vuggy (2.54cm), vertical stylite with calcite (white), infilling approximately 7.62cm tall at 13.66m BGS END OF BOREHOLE @ 13.82m BGS				
22					
23					
24					

NOTES: MEASURING POINT ELEVATIONS MAY CHANGE; REFER TO CURRENT ELEVATION TABLE

XCG Consultants Ltd.

Project #: 5-586-18-04

Project: Subsurface Investigation
Client: Regional Municipality of Niagara
Location: 5030 Montrose Rd, Niagara Falls, Ont.

Privileged and Confidential
LOG OF WELL: IW-6

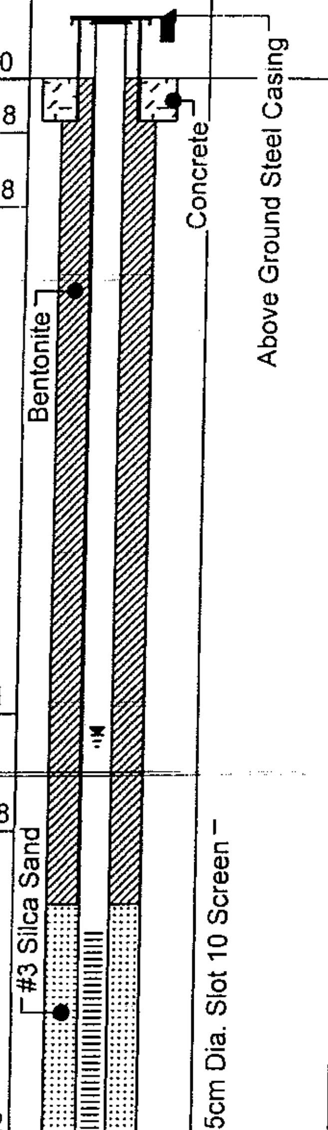
Driller: Geo-Environmental Drilling Inc
Drill Method: Hollow Stem Auger / continuous core
Sample Method: Standard Splitspoon

Borehole Diameter: 20 cm
Start Date: Sept 1, 2006
Completed: Sept 1, 2006

Checked By: TW
Logged By: MU

Geology has been inferred from previous Boreholes

Depth (m)	Sample No.	N-Value	Recovery (%)	Vapour Reading	Geology Description	Depth/Elev (m)
					Ground Surface	0.0
0–0.8					***GRAVEL FILL*** Some silty sand, grey brown, dry, no odour or staining.	-0.8
0.8–1.8					***SILT FILL*** Red brown, moist, no odour or staining.	-1.8
1.8–9.1	1	22	80	13 ppm	***SANDY SILT*** Red brown, some sand, trace clay, moist, no odour or staining.	
	2	21	80	11 ppm		
	3	29	80	8 ppm	becoming wet, no odour or staining	-9.1
9.1–10.8	4	32	80	10 ppm	***SILT TILL*** Red brown, some fine gravel, moist, no odour or staining	-10.8
10.8–15.2					***BEDROCK*** Grey dolostone, some weathering and horizontal fractures, no evidence of impacts, staining or odours becoming competant with less fracturing	-15.2
					End of Borehole	



Groundwater Elevation: 184.276 m (Sept 14, 2006)
T.O.P Elevation: 193.936 m
Ground Surface Elevation: 193.129 m

Screening Tool: PID 2020

Monitoring Well Log
For Environmental Purposes Only

Sheet: 1 of 1

BOREHOLE LOG

BOREHOLE LOG	**PROJECT:** 23-423	**BOREHOLE:** OW13D 1 of 1
Niagara Enviro-Centre Niagara Falls, Ontario **FOR:** The Regional Municipality of Niagara		**DATE:** 25 June 2003 **GEOLOGIST** RFK **ELEVATION** 193.2 m ASL

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	SAMPLE NUMBER	TYPE	N VALUE	% WATER	% REC	% RQD	COMMENTS
0.1	**ROAD BASE (FILL)** Grey, medium grained sand and gravel, trace rootlets, moist, loose.	1	CS			13		**PID READINGS *** Auger Head Space=0.0 ppm Soil Sample = 0.0 ppm
1.3	**SILTY CLAY TO CLAYEY SILT (FILL)** Brown to reddish brown silty clay to clayey silt, some gravel, rootlets, APL, soft.	2	CS			82		Auger Head Space=0.0 ppm Soil Sample = 0.0 ppm
	SILT (NATIVE) Reddish brown silt, trace fine grained sand, trace fine gravel, layered, moist, very loose. - Alternating layers of light brown very fine grained sand ~ 1 mm thickness, between 2.6 m to 3.0 m.	3	CS			82		Auger Head Space=0.0 ppm Soil Sample = 0.0 ppm
		4	CS			67		Auger Head Space=0.0 ppm Soil Sample = 0.0 ppm
	- Becoming wet below 5.3 m depth	5	CS			100		Auger Head Space=0.0 ppm Soil Sample = 0.0 ppm
6.7	**SANDY SILT TO SILTY SAND (NATIVE)** Brown to reddish brown sandy silt to silty sand, trace clay, fine to medium rounded gravel, wet to saturated, very loose to loose.	6	CS			55		Auger Head Space=0.0 ppm Soil Sample = 0.0 ppm
8.5	**SILT TILL (NATIVE)** Reddish brown silt till, rounded gravel, angular dolostone gravel, moderate hydrocarbon odour, saturated, very loose.	7	CS			65		Auger Head Space=0.0 ppm Soil Sample = 0.0 ppm
		8	CS			40		Auger Head Space=0.0 ppm Soil Sample = 0.0 ppm
11.0	**DOLOSTONE** Light grey dolostone, aphanitic to fine crystalline, medium hard, very broken to blocky, slightly weathered, trace calcite infilling, mud on fracture faces.	9	HQ			83	22	
	- Becoming vuggy below ~ 13 m depth	10	HQ			92	58	
14.0	Borehole terminated at 14 m depth in dolostone.							* PID relative response to Isobutylene calibration gas.

Printed: 18 Nov 03

Gartner Lee Limited

HOLE NF-30

(MW10)

GRAPHICAL BOREHOLE DATA

ACRES

CLIENT Ontario Hydro
PROJECT Niagara River
Hydroelectric Development
SITE Niagara Falls - near St. Davids Gorge
CONTRACTOR Longyear Canada Inc.
LOCATION: COORDINATES N7827.9 W2536.4
INITIAL DIP 90 deg
BEARING -

DRILLING METHOD:
-SOIL Wash Boring
-ROCK Rotary Diamond, Triple Tube
CASING NW
CORE HQ-3
ELEVATIONS: DATUM Geodetic
-PLATFORM - GROUND 181.01
-END OF HOLE -44.43 GWT m

JOB P09552
SHEET 1 OF 17
DATE February, 1991

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD Is_{50} A/D (MPa)	REMARKS
		Ground surface. Overburden. Not Sampled. Installed NW casing to 17.83 m.										
2												
4												
6												
8												
10												

GRAPHICAL BOREHOLE DATA

HOLE NF-30

(MW10)

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	RUN DEPTH	REC / RQD	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec)	REMARKS
12							
14							
16	164.59 / 16.42	**LOCKPORT FORMATION** DOLOSTONE, subdivided into three members, only one member occurs in this borehole as described below. Discontinuities include bedding joints at 75 to 90 deg to core axis, inclined joints at 40 to 60 deg to core axis, and subvertical joints at 20 deg to core axis. Bedding joints dominate, they are rough and irregular with hard joint surfaces, occasionally silt coated and generally closely to moderately spaced. The inclined and subvertical joints are rough and irregular and occur sporadically.	16.42	100/83	5		
18		16.42 to 23.20 m: Gasport Member, unit 1. Fresh, light gray, fine to medium grained, medium to thickly bedded DOLOSTONE, stylolitic, some shaly partings, faintly porous, vuggy with calcite growth. Sharp contact with the DeCew Formation.	17.95	100/92	3		
		16.42 to 63.90 m: Full water return.			0	5.2E-05	
20		16.64 to 16.76 m: Fragmented zone due to drill action on faintly weathered rock.	19.49	100/100	0		
		18.00 to 23.20 m: Crinoidal.	21.02		1		
22		18.13 to 18.14 m: Fragmented zone, reddish silt coating on joint surfaces.		100/92	3		MP Packer
		18.96 to 21.42 m: Massive, few bedding joints.	22.59				Measurement Port [Closed]
	157.81 / 23.20	20.67 to 20.68 m: Fragmented zone due to drill action on shaly partings.		100/83	5		[Closed] Pumping Port
24		22.05 to 22.09 m: Fragmented zone, angular pieces with silt coating.					

Column headings also include: LOG; RECOVERY % / RQD % (20 40 60 80); HYDRAULIC CONDUCTIVITY 10^{-6} 10^{-4} 10^{-2}; WTR LEV; PIEZOMR; POINT LOAD I_{s50} A/D (MPa).

GRAPHICAL BOREHOLE DATA

ACRES

HOLE NF-30

(MW10)

REF. DEPTH	ELEV. DEPTH	DESCRIPTION
		DECEW FORMATION. Fresh, brownish-gray, fine to medium grained, medium bedded DOLOSTONE, argillaceous. Transitional contact with the Rochester Formation. 24.14 to 24.16 m: Fragmented zone due to drill action on a shaly seam. 24.61 to 24.65 m: Fragmented zone due to drill action on closely jointed rock.
26	155.21 / 25.80	**ROCHESTER FORMATION** Fresh, dark gray, fine grained, laminated to very thinly bedded SHALE with light gray dolostone beds, slightly fissile, occasional gypsum nodules. Gradational contact with the Irondequoit Formation. Discontinuities include bedding joints at 80 to 90 deg to core axis and inclined joints at 35 to 50 deg to core axis. Bedding joints are rough, irregular, gypsum infilled, rarely silt coated, generally closely to widely spaced and locally very closely spaced. Inclined joints occur sporadically and are rough and irregular. 26.10 to 26.14 m: Fragmented zone, flat, angular pieces with silt coating.
28		
30		
32		
34		
36		
38		

RUN DEPTH	REC / RQD
24.14	100/79
25.67	100/80
27.19	100/96
28.74	100/100
30.33	100/94
31.83	100/99
33.40	98/98
34.95	100/100
36.17	100/100
37.47	

RECOVERY % / RQD % (20 40 60 80)

JOINTS PER M: 5, 1, 9, 0, 1, 1, 1, 1, 0, 4, 3, 4, 3, 1

HYDRAULIC CONDUCTIVITY (cm/sec) (10^{-6} 10^{-4} 10^{-2}): 3.6E-06; 1E-06; 1E-07

WTR LEV

PIEZOMR

POINT LOAD I_{s50} A/D (MPa)

REMARKS:
- MP Packer
- Measurement Port [Closed]
- [Closed] Pumping Port
- MP Packer

GRAPHICAL BOREHOLE DATA

ACRES

HOLE NF-30

(MW10)

SHEET 4 OF 17

REF. DEPTH	ELEV. DEPTH	DESCRIPTION
40		39.50 to 40.30 m: Rock is light gray with increased dolostone content.
42		
		42.85 to 44.05 m: Crinoidal.
44	136.96 / 44.05	IRONDEQUOIT FORMATION Fresh, light gray, medium to coarse grained, thickly bedded LIMESTONE, stylolityic, faintly porous, crinoidal. Sharp contact with the Reynales Formation.
46	136.39 / 46.62	REYNALES FORMATION DOLOSTONE, subdivided into two units as described below. The only discontinuities are bedding joints at 80 to 90 deg to core axis. These are generally rough or rarely slickensided on shaly partings, irregular with hard joint surfaces, rarely infilled with gypsum and generally moderately to widely spaced. 46.62 to 49.65 m: Reynales Formation, unit 2. Fresh, light to medium brownish-gray, very fine grained, thin to medium bedded DOLOSTONE, argillaceous with gray shaly partings. Sharp contact with unit 1. 49.65 to 50.30 m: Reynales Formation, unit 1. Fresh, light gray, fine to medium grained, thinly to medium bedded LIMESTONE, occasional shaly partings, crinoidal. Sharp contact with the Neahga Formation.
48		
50	130.71 / 50.30	NEAHGA FORMATION Fresh, dark gray, very fine grained thinly laminated SHALE, fissile, distinct waxy appearance. Sharp
52	129.01	

RUN DEPTH	REC / RQD
	100/100
38.71	99/99
39.97	99/99
41.22	100/100
42.42	99/99
43.99	100/100
45.55	100/84
47.07	100/94
48.55	100/92
50.10	100/73
51.65	

JOINTS PER M: 3, 6, 4, 3, 2, 6, 1, 0, 2, 1, 2, 3, 3, 8

RECOVERY % / RQD % (20 40 60 80)

HYDRAULIC CONDUCTIVITY (cm/sec) (10^{-6} 10^{-4} 10^{-2}): 2E-07

WTR LEV

PIEZOMR

POINT LOAD I_{s50} A/D (MPa)

REMARKS:
- NP Packer
- Measurement Port [Closed]
- [Closed] Pumping Port
- NP Packer

GRAPHICAL BOREHOLE DATA

REF. DEPTH	ELEV. DEPTH	DESCRIPTION
	52.00	contact with the Thorold Formation. Most discontinuities are apperently caused by drill action on the fissile. rock. Two such discontinuities had a silt coating.
		THOROLD FORMATION Fresh, light greenish-gray, fine to medium grained, medium to thickly bedded SANDSTONE, irregular greenish-gray shaly partings. Sharp contact with the Grimsby Formation. The only discontinuities are bedding joints at 90 deg to core axis. They are rough and irregular with hard joint surfaces, sometimes infilled with gypsum and are closely to moderately spaced. 53.04 to 53.05 m: Fragmented zone due to drill action on shaly zone.
54	126.79 / 54.22	**GRIMSBY FORMATION** Fresh, reddish-brown with intermittent green bands, fine to medium grained, thinly to medium bedded SANDSTONE, SILTSTONE and SHALE, shaly beds. are fissile, medium to thickly bedded and widely spaced. Sharp contact with the Power Glen Formation. Discontinuities include bedding joints at 80 to 90 deg to core axis and inclined joints at 40 deg to core axis. Bedding joints dominate and are rough or rarely slickensided and planar with hard joint surfaces, commonly infilled with gypsum and rarely a silt or clay coating. Joint spacings are described below. Only one inclined joint was encountered it was slickensided and planar. 54.25 to 65.19 m: Bedding joints generally moderately to widely spaced. 57.03 to 57.04 m: Fragmented zone due to drill action on a shaly zone.
56		
58		
60		
62		
		63.40 to 63.90 m: No water return.
64		63.90 to 225.44 m: Water return. 64.21 to 64.22 m: Fragmented zone due to drill action on shaly partings.
		65.19 to 70.80 m: Extremely closely to moderately spaced bedding joints. 65.25 to 65.37 m: Fragmented zone, pieces coated with red clay, possibly clay seam.
66		

RUN DEPTH	REC / RQD
– 53.20	100/79
53.20 – 54.75	100/86
54.75 – 56.30	100/82
56.30 – 57.81	100/100
57.81 – 59.36	100/100
59.36 – 60.85	100/100
60.85 – 62.37	100/95
62.37 – 63.89	95/76
63.89 – 65.43	100/80

JOINTS PER M (top to bottom): 3, 3, 5, 3, 3, 0, 3, 0, 2, 1, 6, 3, 3, 21

HYDRAULIC CONDUCTIVITY (cm/sec), scale 10^{-6} 10^{-4} 10^{-2}: 8E-07; 1.4E-06

Other columns: LOG, RECOVERY % / RQD % (20 40 60 80), WTR LEV, PIEZOMR, POINT LOAD Is_{50} A/D (MPa), REMARKS

GRAPHICAL BOREHOLE DATA

ACRES

HOLE NF-30

(MW10)

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	RUN DEPTH	REC/RQD	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec)	REMARKS
				100/72	6		
	113.86 / 67.15	**POWER GLEN FORMATION** SHALE and SANDSTONE, subdivided into two units as described below. The only discontinuities are bedding joints at 80 to 90 deg to core axis. They are rough and irregular with hard joint surfaces, infilled with gypsum and generally closely to moderately spaced.	66.94	100/76	8		
68		67.15 to 70.75 m: Power Glen Formation, unit 2. Fresh, light gray, fine grained, thinly to medium bedded SANDSTONE with interbedded and interlaminated siltstone and minor gray shale. Sharp contact with unit 1.			9	1.4E-06	
			68.43	100/89	5		Measurement Port [Closed]
70			69.99	99/95	3		
		70.75 to 79.93 m: Power Glen Formation, unit 1 (Cabot Head). Fresh, medium to dark gray, very fine grained, laminated to thinly bedded SHALE with thin to medium interbeds of light gray siltstone and sandstone, fissile. Transitional contact with the Whirlpool Formation.			3		
72			71.56	100/100	1		[Closed] Pumping Port; MP Packer
			73.04	100/92	1		
74					2	2.6E-06	
			74.59	100/95	0		
76		76.33 to 79.93 m: Transitional contact. Shale interbedded with coarser grained siltstone and sandstone.	76.14	100/95	1		
					6		
78			77.65	100/79	8		MP Packer
			79.13		1		
80	101.08						

LOG; RECOVERY % / RQD % (20 40 60 80); HYDRAULIC CONDUCTIVITY scale 10^{-6} 10^{-4} 10^{-2}; WTR LEV; PIEZOMR; POINT LOAD I_{s50} A/D (MPa).

GRAPHICAL BOREHOLE DATA

ACRES

HOLE NF-30

(MW10)

REF. DEPTH	ELEV. DEPTH	DESCRIPTION
	79.93	**WHIRLPOOL FORMATION** SANDSTONE, cross bedded, some shale partings. Sharp contact with the Queenston Formation. The only discontinuities are bedding joints at a high angle to the core axis. They are rough, planar or irregular with hard joint surfaces, no infill and are widely to very widely spaced.
82		
84	96.35 84.66	**QUEENSTON FORMATION** Fresh, reddish-brown with occasional greenish-gray reduction bands, fine grained, indistinctly bedded MUDSTONE, gypsum nodules scattered throughout. The green reduction bands are up to 170 mm thick, 0.3 to 0.5m apart. Discontinuities include bedding joints at 80 to 90 deg to the core axis, inclined joints at 45 to 75 deg to the core axis, and subvertical joints at 5 to 30 deg to the core axis. Bedding joints dominate, they are generally rough or rarely slickensided, irregular with hard joint surfaces and often infilled with gypsum. The inclined joints are rough or occasionally slickensided, irregular and usually gypsum infilled. Subvertical joints occur rarely and are usually infilled with gypsum and tight. The overall joint spacing is described below. 84.65 to 85.23 m: Core loss, very weak contact. 85.23 to 144.14 m: Very closely to moderately spaced joints.
86		
88		
90		
92		91.68 to 91.70 m: Fragmented zone, pieces are slickensided.
94		

RUN DEPTH	REC / RQD
	100/100
80.68	100/100
82.19	100/100
83.73	62/52
85.23	85/46
85.53	100/87
87.08	100/68
88.30	100/90
89.83	100/100
91.33	100/93
92.86	100/93

RECOVERY % / RQD % (20 40 60 80)

JOINTS PER M: 1, 1, 0, 0, 3, 1, 5, 7, 2, 4, 2, 5, 5, 7

HYDRAULIC CONDUCTIVITY (cm/sec) (10^{-6} 10^{-4} 10^{-2}): 1.8E-06; 2.2E-06

WTR LEV

PIEZOMR

POINT LOAD Is_{50} A/D (MPa)

REMARKS:
- Measurement Port [Closed]
- [Closed] Pumping Port
- MP Packer

GRAPHICAL BOREHOLE DATA

HOLE NF-30

(MW10)

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD Is_{50} A/D (MPa)	REMARKS
				94.37	100/98		4, 4					
96				95.92	100/99		3, 3					
98				97.40	100/81		5	2.2E-06				
				98.78	100/98		5					
100							8					
				100.34	100/93		6					
102				101.85	100/95		5, 5					Measurement Port [Closed]
104				103.35	97/87		3	1.7E-06				[Closed] Pumping Port
				104.95	100/100		5, 6					MP Packer
106				106.48	100/91		6					
108		107.89 to 107.94 m: Fragmented zone, possibly due to										

ACRES

GRAPHICAL BOREHOLE DATA

HOLE NF-30

(MW10)

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD Is_{50} A/D (MPa)	REMARKS
		drill action.		108.03	100/94							
110				109.56	100/90			2E-06				
				111.04	100/94							
112				112.57	100/92							MP Packer
114				114.11	100/97							
116				115.65	100/89			1.4E-06				
118				117.18	100/100							
				118.72	100/100							
120				120.24	100/100							
122												

Joints per m (top to bottom):

6	8	5	6	8	9	6	6	5	5	4	3	5	8

GRAPHICAL BOREHOLE DATA

ACRES

HOLE NF-30

(MW10)

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD I_{s50} A/D (MPa)	REMARKS
				121.78	100/97		9, 3	2E-06				
124				123.39	100/100		5					
				124.83	100/95		6, 4					
126				126.38	100/93		3					
128				127.89	100/100		1, 4	2.3E-06				
130				129.41	100/94		11					
				130.94	100/87		9, 6					
132				132.47	100/96		8					
134				134.00	100/97		6, 3	2E-06				
				135.53								
136												

GRAPHICAL BOREHOLE DATA

HOLE NF-30

(MW10)

Columns: REF. DEPTH | ELEV./DEPTH | DESCRIPTION | LOG | RUN DEPTH | REC/RQD | RECOVERY % / RQD % (20 40 60 80) | JOINTS PER M | HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2} | WTR LEV | PIEZOMR | POINT LOAD Is_{50} A/D (MPa) | REMARKS

REF. DEPTH	DESCRIPTION
138	
140	140.15 to 140.48 m: Fragmented zone due to drill action.
142	
144	144.14 to 225.44 m: Widely to very widely spaced joints.
146	
148	
150	

RUN DEPTH	REC/RQD
	100/96
137.05	100/100
138.58	100/100
140.09	100/29
140.67	100/83
141.88	100/100
143.14	100/100
144.69	100/100
146.19	100/100
147.74	100/85
149.24	

JOINTS PER M	6, 2, 4, 3, 3, 6, 2, 4, 1, 0, 1, 1, 0, 0

HYDRAULIC CONDUCTIVITY (cm/sec)	1.5E-06; 9E-07

GRAPHICAL BOREHOLE DATA

AGRES

HOLE NF-30

(MW10)

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD I_{s50} A/D (MPa)	REMARKS
					100/91		0					
				150.77			1					
					100/100							
152							2					
				152.27								
					100/100		0	1.6E-05				
154				153.84			0					
					100/95		0					
				155.33								
156					100/98		1					
				156.86			0					
					100/100							
158							3					
				158.38								
					100/99		0	4E-07				
160				159.90			0					
					100/98		0					
				161.44								
162					100/100		0					
				162.98			0					
164		163.63 to 163.66 m: Fragmented zone due to drill action.			100/91							

GRAPHICAL BOREHOLE DATA

HOLE NF-30

(MW10)

REF. DEPTH	ELEV./DEPTH	DESCRIPTION	RUN DEPTH	REC/RQD	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec)	REMARKS
					0		
			164.49	100/71	4	4.3E-06	
166		165.49 to 165.52 m: Fragmented zone due to drill action on thinly laminated zone. 165.57 to 165.58 m: Fragmented zone due to drill action on thinly laminated zone. 165.65 to 165.66 m: Fragmented zone due to drill action on very thinly laminated zone. 166.00 to 166.07 m: Fragmented zone due to drill action on extremely closely spaced slickensided joints.	166.04	100/87	0, 1		
168			167.52	100/100	0		
			169.07	100/96	0, 0		
170			170.57	100/100	0	1E-06	
172			172.12	100/84	1, 0		
174			173.62	100/100	0		MP Packer
			175.18	100/100	0, 0		
176			176.67	100/100	0	7.8E-07	
178							

Column headings: LOG; RECOVERY % / RQD % (20 40 60 80); HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}; WTR LEV; PIEZOMR; POINT LOAD Is_{50} A/D (MPa)

ACRES

GRAPHICAL BOREHOLE DATA

HOLE	NF-30

(MW10)

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD Is_{50} A/D (MPa)	REMARKS
				178.23	100/100		0					
							0					
180				179.72	100/100		0					
							1					
182				181.29	100/100		0					
				182.76	100/100		0	4.8E-07				
184							0					
				184.33	100/96		0					
186				185.81	100100		0					
							1					
188				187.35	100/100		0					
				188.86	100/100		1	5.8E-07				
190							0					
				190.42	100/100		1					
192												

GRAPHICAL BOREHOLE DATA

HOLE NF-30
(MW10)
SHEET 15 OF 17

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec)	REMARKS
				191.91	100/100	0, 1		
194				193.47	100/100	1		
				194.96	100/100	0, 1	1.1E-06	
196				196.53	100/96	0		
198				198.00	100/100	0, 0		Mearurement Port [Open]
200				199.59	100/100	0		
				201.05	100/100	0, 1	1.4E-06	[Open] Pumping Port
202				202.60	100/100	0		MP Packer
204				204.10	100/98	4, 0		
206				205.65				

Column headings also include: RECOVERY % (20 40 60 80), RQD %, WTR LEV, PIEZOMR, POINT LOAD Is_{50} A/D (MPa). Hydraulic conductivity scale: 10^{-6} 10^{-4} 10^{-2}.

GRAPHICAL BOREHOLE DATA

HOLE	NF-30
(MW10)	
SHEET	16 OF 17

REF. DEPTH	RUN DEPTH	REC / RQD	HYDRAULIC CONDUCTIVITY (cm/sec)	REMARKS
		100/100		
	207.15		1.6E-06	End Cap
208		100/100		
	208.70	100/100		
210	210.20	100/100		
212	211.73	100/100		
	213.25		1.8E-06	
214		100/100		
	214.82	100/100		
216	216.29	100/100		
218	217.87	100/99		
	219.39			
220				

JOINTS PER M (top to bottom)
0
0
0
0
0
0
0
0
0
0
0
0
0
1
0

Column headings: REF. DEPTH · ELEV. DEPTH · DESCRIPTION · LOG · RUN DEPTH · REC / RQD · RECOVERY % / RQD % (20 40 60 80) · JOINTS PER M · HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2} · WTR LEV · PIEZOMR · POINT LOAD Is_{50} A/D (MPa) · REMARKS

GRAPHICAL BOREHOLE DATA

HOLE NF-30

(MW10)

REF. DEPTH	ELEV. / DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD Is_{50} A/D (MPa)	REMARKS
					100/100		0					
				220.89			0					
222					100/100		0					
				222.39								
					100/100		0					
224				223.93			0					
					100/100							
	-44.43 / 225.44	End of borehole.										

Notes

1. Water levels during and after drilling:

Date	Time	Depth(m)
90 09 24	1300	11.47
90 09 25	1200	10.49
90 09 26	1200	11.58
90 09 28	1300	14.96
90 10 01	0730	11.29
90 11 13	1200	11.40
90 11 22	1200	11.50
90 11 30	1200	11.37

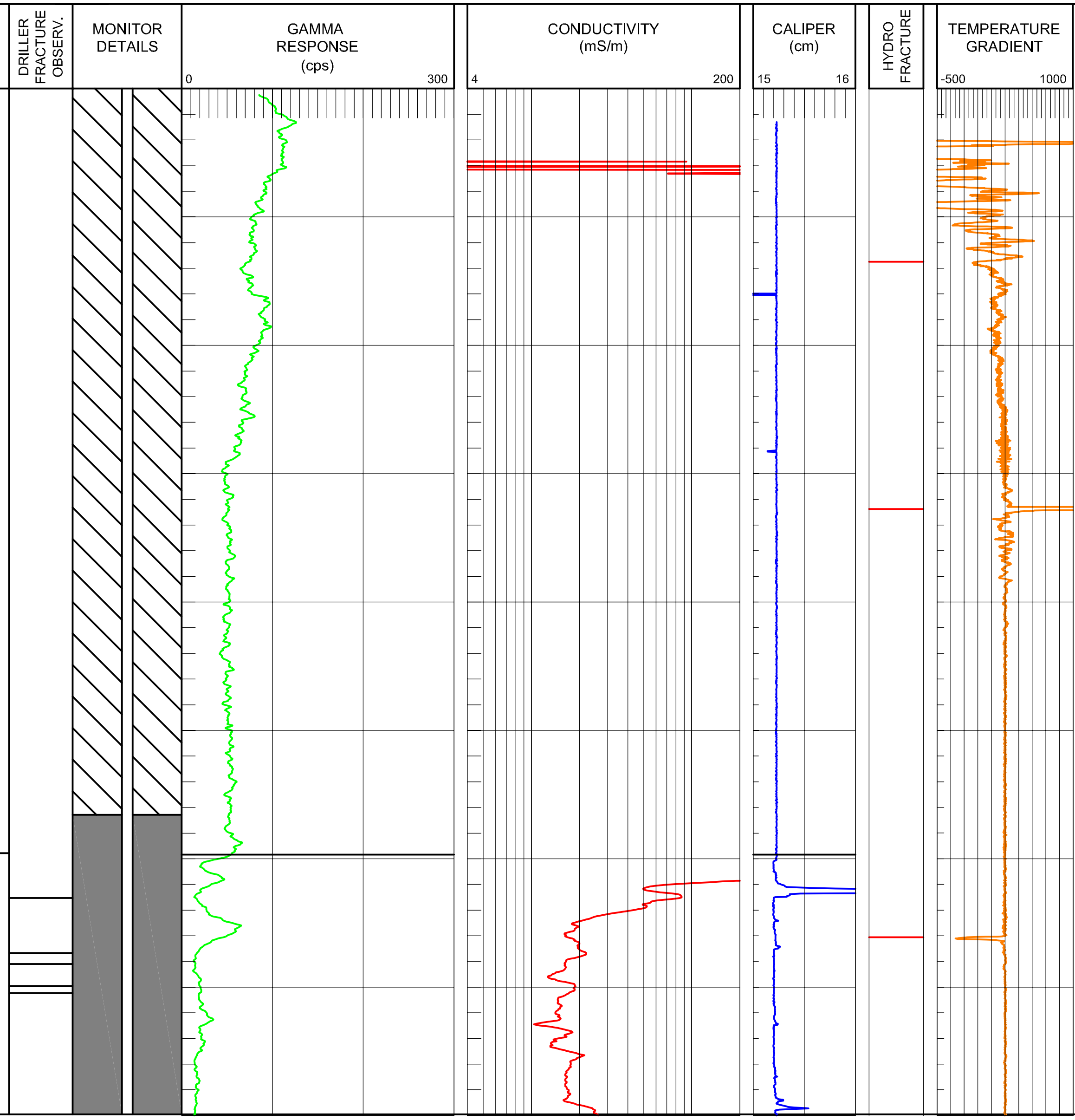
2. For borehole water pressure test results, see Table 3.3.
3. For hydrofracturing stress measurements, see Tables 3.11 and 3.13.
4. For Westbay multipoint piezometer installation details, see Table 3.4 and Appendix G.
5. For piezometer water level readings, see Table 3.6.

BOREHOLE LOG　　MW14-I　　DRAFT

PROJECT:	Niagara Tunnel Project	PROJECT NO:	1040240.03	CONTRACTOR:	Dufferin Well Drilling & Supply Inc.
CLIENT:	Ontario Power Generation	DATE DRILLED:	October 31, 2005 to November 2, 2005	DRILL TYPE:	Ingersol Rand IR-TH-60
SUPERVISOR:	R. F. Kurcz	GROUND ELEVATION:	184.04 m ASL	METHOD SOIL:	156 mm Mud Rotary, Tri-Cone
REVIEWER:	D. S. Mohr	COORDINATES:	4769926.05 N / 656539.89 E	ROCK:	156 mm Air Rotary, Tri-Cone

DEPTH (m) / ELEV (m ASL)	STRATIGRAPHIC DESCRIPTION	REMARKS
0	SILTY CLAY (Overburden) Reddish brown to brown silty clay, some gravel.	Stratigraphy based on geophysical logging and drilling observations.
29.87 154.17	DOLOSTONE (Lockport Formation) Light to dark grey, aphanitic to fine crystalline dolostone, thin shale interbeds increasing with depth.	152 mm diameter steel casing seated in bedrock at 30.5 m depth and sealed in place with bentonite grout. Water bearing fracture at 31.6 m depth.

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40

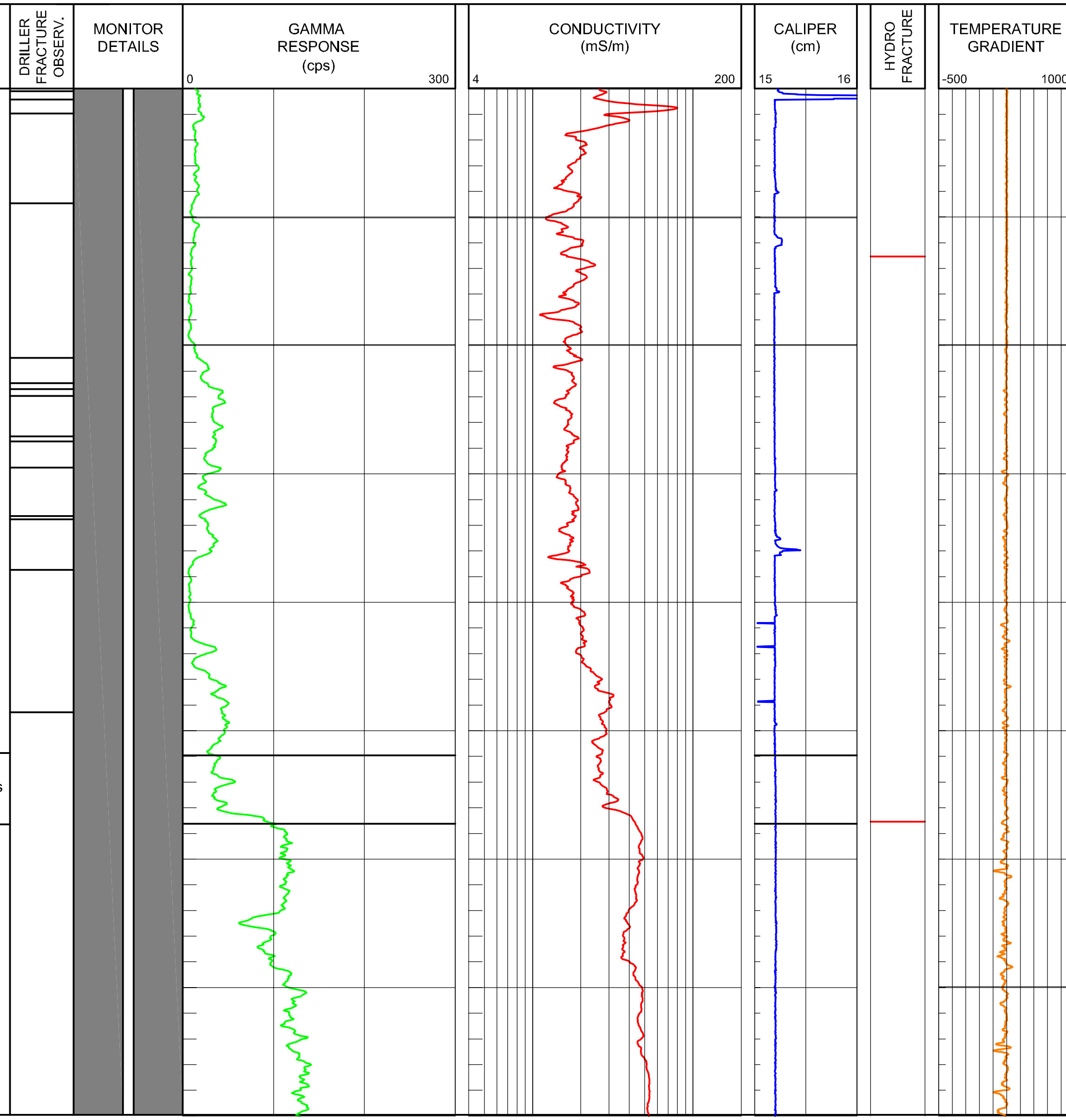


BOREHOLE LOG — MW14-I — DRAFT

PROJECT:	Niagara Tunnel Project	PROJECT NO:	1040240.03	CONTRACTOR:	Dufferin Well Drilling & Supply Inc.
CLIENT:	Ontario Power Generation	DATE DRILLED:	October 31, 2005 to November 2, 2005	DRILL TYPE:	Ingersol Rand IR-TH-60
SUPERVISOR:	R. F. Kurcz	GROUND ELEVATION:	184.04 m ASL	METHOD SOIL:	156 mm Mud Rotary, Tri-Cone
REVIEWER:	D. S. Mohr	COORDINATES:	4769926.05 N / 656539.89 E	ROCK:	156 mm Air Rotary, Tri-Cone

DEPTH (m) / ELEV (m ASL)	STRATIGRAPHIC DESCRIPTION
40 – 65.96	DOLOSTONE (cont.)
65.96 / 118.08	DOLOSTONE (Decew Formation) Dark grey, aphanitic to very fine crystalline, argillaceous dolostone.
68.62 / 115.42	SHALE (Rochester Formation) Dark grey, aphanitic shale.

Depth scale: 40, 45, 50, 55, 60, 65, 70, 75, 80



REMARKS

BOREHOLE LOG

MW14-I DRAFT

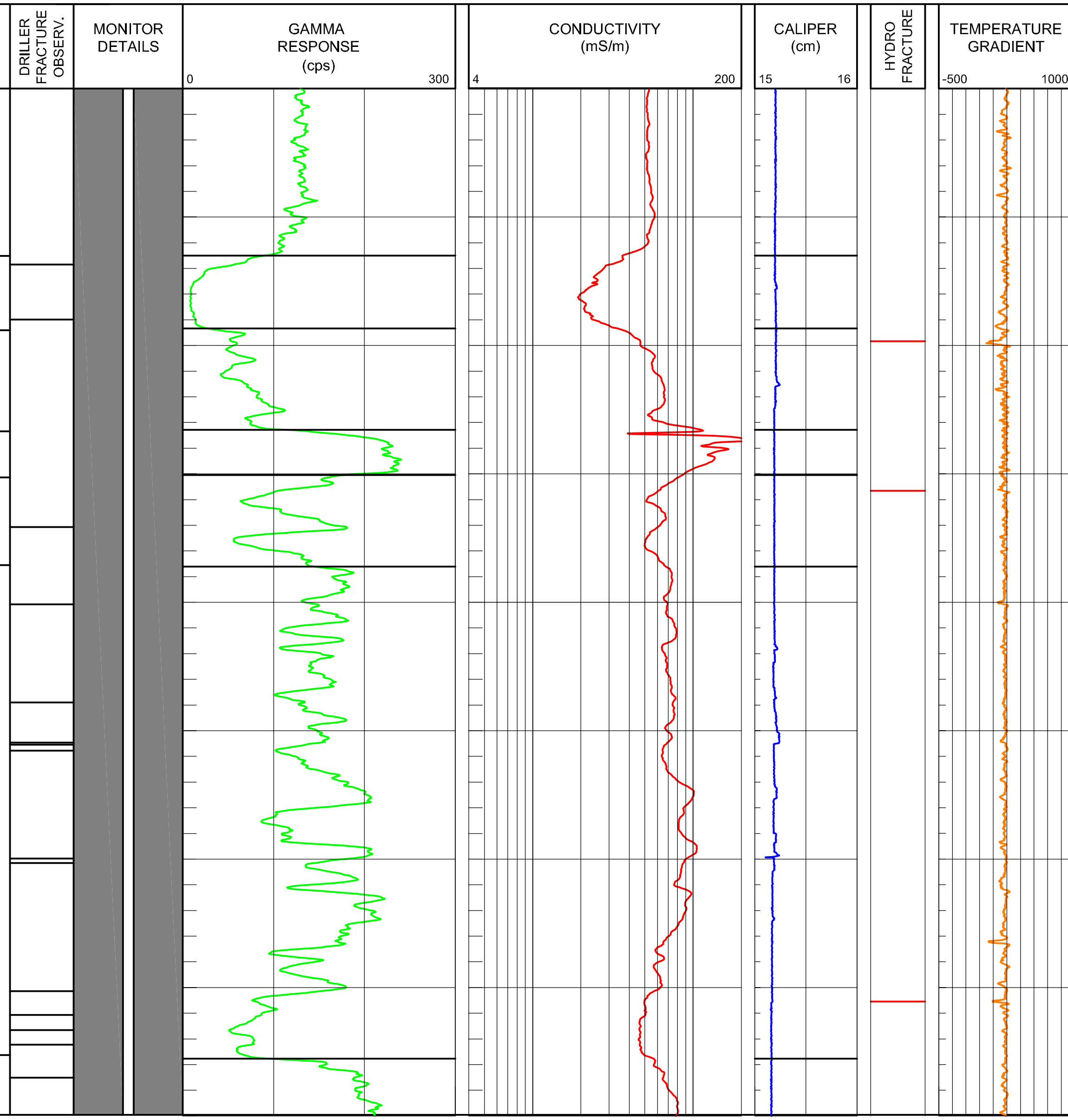
PROJECT: Niagara Tunnel Project
CLIENT: Ontario Power Generation
SUPERVISOR: R. F. Kurcz
REVIEWER: D. S. Mohr

PROJECT NO: 1040240.03
DATE DRILLED: October 31, 2005 to November 2, 2005
GROUND ELEVATION: 184.04 m ASL
COORDINATES: 4769926.05 N / 656539.89 E

CONTRACTOR: Dufferin Well Drilling & Supply Inc.
DRILL TYPE: Ingersol Rand IR-TH-60
METHOD SOIL: 156 mm Mud Rotary, Tri-Cone
ROCK: 156 mm Air Rotary, Tri-Cone

DEPTH (m)	ELEV (m ASL)	STRATIGRAPHIC DESCRIPTION
		SHALE (cont.)
86.50	97.54	LIMESTONE (Irondequoit Formation) Pinkish grey, medium to coarse crystalline limestone.
89.34	94.70	DOLOSTONE (Reynales Formation) Grey, fine crystalline dolostone.
93.28	90.76	SHALE (Neahga Formation) Medium to dark grey, aphanitic shale.
95.05	88.99	SANDSTONE (Thorold Formation) White to light grey, fine grained sandstone.
98.61	85.43	SANDSTONE & SHALE (Grimsby Formation) Reddish brown to greyish green, fine to very fine grained sandstone and shale, interbedded. Shale content increasing with depth.
117.77	66.27	SHALE & SANDSTONE (Power Glen Formation) Light grey, fine grained sandstone, becoming greyish green, very fine grained shale.

Depth scale: 80, 85, 90, 95, 100, 105, 110, 115, 120



REMARKS

BOREHOLE LOG

MW14-I DRAFT

PROJECT:	Niagara Tunnel Project	**PROJECT NO:**	1040240.03
CLIENT:	Ontario Power Generation	**DATE DRILLED:**	October 31, 2005 to November 2, 2005
SUPERVISOR:	R. F. Kurcz	**GROUND ELEVATION:**	184.04 m ASL
REVIEWER:	D. S. Mohr	**COORDINATES:**	4769926.05 N / 656539.89 E
CONTRACTOR:	Dufferin Well Drilling & Supply Inc.	**DRILL TYPE:**	Ingersol Rand IR-TH-60
METHOD SOIL:	156 mm Mud Rotary, Tri-Cone	**ROCK:**	156 mm Air Rotary, Tri-Cone

DEPTH (m) / ELEV (m ASL)	STRATIGRAPHIC DESCRIPTION
120	SHALE & SANDSTONE (cont.)
122.42 / 61.62	SANDSTONE (Whirlpool Formation) Light grey to white, fine to medium grained sandstone.
128.27 / 55.77	SHALE (Queenston Formation) Dark reddish brown, very fine grained shale.
128.80 / 55.24	Borehole terminated at 128.8 m depth in sandstone.

Depth scale: 120, 125, 130, 135, 140, 145, 150, 155, 160

Columns: DRILLER FRACTURE OBSERV. | MONITOR DETAILS | GAMMA RESPONSE (cps) | CONDUCTIVITY (mS/m) | CALIPER (cm) | HYDRO FRACTURE | TEMPERATURE GRADIENT | REMARKS

HOLE	NF-28

GRAPHICAL BOREHOLE DATA

ACRES

CLIENT Ontario Hydro
PROJECT Niagara River Hydroelectric Development
SITE Niagara Falls
CONTRACTOR Longyear Canada Inc.
LOCATION: COORDINATES N4170.0 W3200.0
INITIAL DIP 90 deg
BEARING -

DRILLING METHOD:
-SOIL Wash Boring
-ROCK Rotary Diamond, Triple Tube
CASING NW
CORE NQ-3
ELEVATIONS: DATUM Geodetic
-PLATFORM 185.39 GROUND 185.06
-END OF HOLE -30.04 GWT 170.39 m DATE February, 1991

JOB P09552
SHEET 1 OF 16

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD I_{s50} A/D (MPa)	REMARKS
	185.06	Drill platform.										
	0.33	Ground Surface. Overburden. Not Sampled. Installed NW casing to 17.16 m .										
2												
4												
6												
8												
10												

GRAPHICAL BOREHOLE DATA

ACRES

HOLE NF-28

REF. DEPTH	ELEV. / DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD Is_{50} A/D (MPa)	REMARKS
12												
14												
16	169.36 / 16.03	LOCKPORT FORMATION		16.03			3					
					100/93		3					
18				17.53	100/86		4	7E-04				
				18.52	100/96		4					
20				20.10	100/86		3					
							4					
22				21.50	100/81		2	1E-04				MP Packer
				23.05	100/69		6					
24												

LOCKPORT FORMATION
DOLOSTONE, subdivided into three members, only two members occur in this borehole as described below. Discontinuities include bedding joints associated with stylolitic partings parallel or nonparallel to bedding at 80 to 90 deg to the core axis and inclined joints at 45 to 50 deg to core axis. Bedding joints dominate, they are rough and usually planar with hard joint surfaces and are closely to widely spaced but mostly moderately spaced. The inclined joints are rough and planar with hard joint surfaces and they occur infrequently.

16.03 to 18.25 m: Goat Island Member, unit 2. Fresh, light buff brown, very fine grained, medium bedded DOLOSTONE with occasional stylolites and white chert and gypsum nodules.

18.25 to 22.00 m: Goat Island Member, unit 1. Fresh, gray, very fine grained, medium to thickly bedded DOLOSTONE with occasional gypsum nodules and vugs. Sharp contact with the Gasport Member.

20.07 m: Lost water momentarily.

21.50 to 21.52 m: Fragmented zone, start of run.

22.00 to 23.80 m: Gasport Member, unit 2. Fresh, gray, fine grained, thinly to medium bedded DOLOSTONE, argillaceous, nodular with abundant bryozoan branches. Sharp contact with unit 1.

22.23 m: Stylolitic and argillaceous.

22.52 to 22.55 m: Fragmented zone, slickensided.

GRAPHICAL BOREHOLE DATA

HOLE NF-28

SHEET 3 OF 16

REF. DEPTH	ELEV. DEPTH	DESCRIPTION
		22.92 to 22.95 m: Fragmented zone, irregular shale partings.
		23.80 to 33.50 m: Gasport Member, unit 1. Fresh, light gray with dark mottles, medium grained, medium to thick bedded DOLOSTONE, stylolitic, faintly to moderately porous, occasional crinoid fossils. Sharp contact with the DeCew Formation.
		24.40 to 25.80 m: Porous and vuggy.
26		
28		
30		
		30.45 to 31.97 m: Lost water, returned at end of run.
		30.52 to 30.54 m: Fragmented zone due to drill action on shaly partings.
		31.01 to 31.05 m: Fragmented zone due to drill action on shaly partings.
32		31.59 to 31.61 m: Fragmented zone due to drill action on shaly partings.
		31.97 to 33.47 m: Lost water at start of run, returned at end of run.
	151.89 33.50	DECEW FORMATION Fresh, brownish-gray, fine to medium grained, medium bedded, DOLOSTONE, argillaceous with slumped bedding features. Transitional contact with the Rochester Formation.
34		
36	149.14 36.25	ROCHESTER FORMATION Fresh, dark gray, fine grained, very thinly to thinly bedded SHALE, dolomitic, slightly fissile, gypsiferous bedding partings and occasional gypsum nodules. Gradational contact with the Irondequoit Formation. The only discontinuities are bedding joints generally
38		

RUN DEPTH	REC / RQD	JOINTS PER M
24.53	100/100	5, 2
26.10	100/87	5, 5
27.50	100/99	2
29.01	100/68	8, 7
30.45	100/78	5
31.97	100/81	5, 4
33.47	100/91	3
35.08	100/92	3, 3
36.50	100/100	0

Column headings: LOG; RECOVERY % / RQD % (20 40 60 80); HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-8} 10^{-4} 10^{-2}; WTR LEV; PIEZOMR; POINT LOAD I_{s50} A/D (MPa); REMARKS

Hydraulic conductivity: 2E-04; 2E-05

REMARKS:
- Measurement Port (approx. 31.8 m)
- Pumping Port (approx. 34.5 m)
- MP Packer (approx. 35.4 m)

GRAPHICAL BOREHOLE DATA

ACRES

Ref. Depth	Elev./Depth	Description	Run Depth	REC/RQD	Joints per m	Hydraulic Conductivity (cm/sec)	Remarks
		at 90 deg to core axis. These are smooth, planar, infilled with gypsum up to 3 mm thick.	38.06	100/99	1, 2	4E-05	Measurement Port
40			39.50	100/98	1		
		41.45 to 47.05 m: No water return. 41.60 to 41.90 m: Bioclastic, shaly dolostone bed.	41.03	100/92	3, 5, 4	4E-05	Pumping Port
42							MP Packer
44			44.04	100/99	3, 3, 2		
46							
48			47.05	100/96	3, 5, 3		
50		50.05 to 53.02 m: No water return.	50.05	100/99	2, 1	5E-05	MP Packer
52							

Column headings: REF. DEPTH; ELEV./DEPTH; DESCRIPTION; LOG; RUN DEPTH; REC/RQD; RECOVERY % / RQD % (20 40 60 80); JOINTS PER M; HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}; WTR LEV; PIEZOMR; POINT LOAD I_{s50} A/D (MPa); REMARKS

ACRES

GRAPHICAL BOREHOLE DATA

HOLE NF-28

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	RUN DEPTH	REC / RQD	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec)	REMARKS
54	131.49 / 53.90	53.02 to 55.96 m: Water return. **IRONDEQUOIT FORMATION** Fresh, light gray with pinkish tint, coarse grained, crystalline, medium bedded LIMESTONE, stylolitic, crinoid fossils. Sharp contact with the Reynales Formation. No natural discontinuities noted.	53.02	100/99	6, 3, 2, 2		
56	128.69 / 56.70	55.96 to 57.50 m: No water return. **REYNALES FORMATION** DOLOSTONE, subdivided into two units as described below. The only discontinuities are bedding joints at 90 deg to the core axis. These are smooth and planar and readily identified by gypsum infilling or shale partings and are closely to moderately spaced.	55.96	100/90	1, 4, 4	1E-05	Measurement Port
58, 60	124.69 / 60.70	56.70 to 59.30 m: Reynales Formation, unit 2. Fresh, greenish-gray, fine grained, thinly to medium bedded DOLOSTONE, argillaceous, occasional gypsum nodules. Sharp contact with unit 1. 57.50 to 60.70 m: Water return. 59.30 to 60.70 m: Reynales Formation, unit 1. Fresh, light gray, fine to medium grained, thinly to medium bedded, shaly LIMESTONE. Sharp contact with the Neahga Formation. 60.00 to 60.70 m: Light to dark gray limestone with dark gray shale bands.	58.95	100/74	2, 3, 15		Pumping Port MP Packer
62, 64	123.24 / 62.15	**NEAHGA FORMATION** Fresh, dark greenish-gray, fine grained, laminated SHALE, fissile, distinct waxy appearance. Sharp contact with Thorold Formation. The only discontinuities are bedding joints formed due to rock fissility. These are often slick and planar, rarely infilled and generally very closely spaced. 61.85 to 62.15 m: Light gray sandstone bed. 61.97 to 62.15 m: No water return.	61.97	97/82	5, 4, 5	2E-06	
66	119.94 / 65.45	**THOROLD FORMATION** Fresh, light greenish-white, fine grained, medium to thick bedded SANDSTONE with occasional greenish-gray siltstone beds. Transitional contact with Grimsby Formation. The only discontinuities are bedding joints at 90 deg	65.05		3		

LOG; RECOVERY % / RQD % (20 40 60 80); HYDRAULIC CONDUCTIVITY scale 10^{-6} 10^{-4} 10^{-2}; WTR LEV; PIEZOMR; POINT LOAD I_{s50} A/D (MPa).

ACRES

GRAPHICAL BOREHOLE DATA

HOLE NF-28

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD I_{s50} A/D (MPa)	REMARKS

to core axis. These are rough and planar with hard joint surfaces, infilled with gypsum and are generally closely to moderately spaced.
62.15 to 62.30 m: Siltstone bed.
63.15 to 65.05 m: Water return.
64.35 to 64.40 m: Clay gouge.
64.95 to 65.45 m: Siltstone bed.
65.05 m: No water return.
65.05 to 65.45 m: Water return.

GRIMSBY FORMATION
Fresh, dark reddish-brown, gray, green and black, fine to medium grained, thinly to medium bedded SHALE, SILTSTONE AND SANDSTONE. The shale beds range from 0.2 to 0.8 m thick and are moderately spaced. Sharp contact with the Power Glen Formation.
The only discontinuities are bedding joints at 90 deg to the core axis. These are generally rough and planar with hard joint surfaces, infilled with gypsum and generally closely to moderately spaced becoming closely spaced in the shaly beds.
68.02 to 69.50 m: No water return.
69.50 to 72.76 m: Water return.

72.76 to 77.03 m: No water return.

76.00 to 76.02 m: Fragmented zone.

106.38
79.01 **POWER GLEN FORMATION**
SHALE, SANDSTONE and SILTSTONE subdivided into two units as described below.
No natural discontinuities were identifiable.

Ref. depth marks: 68, 70, 72, 74, 76, 78, 80

Run depths: 68.02, 71.05, 72.76, 74.04, 77.03

REC/RQD: 100/93, 100/89, 100/72, 100/100, 100/93, 100/83

Joints per m: 4, 4, 6, 4, 6, 9, 5, 2, 5, 9, 3, 4, 5, 3

Hydraulic conductivity: 6E-06, 5E-05

Remarks: Measurement Port

GRAPHICAL BOREHOLE DATA

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	RUN DEPTH	REC/RQD	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec)	REMARKS
		79.01 to 83.50 m: Power Glen Formation unit 2. Fresh, light to dark gray, fine to medium grained, laminated to thickly bedded SANDSTONE with interbedded shale and siltstone. Sharp contact with unit 1.	80.02	100/65	5	8E-05	
			81.27	100/90	4		
82		82.03 to 82.04 m: Fragmented zone due to drill action on shaly partings. 82.58 to 90.00 m: No water return.			4		Pumping Port
			82.58	100/100			
		83.50 to 90.00 m: Power Glen Formation unit 1 (Cabot Head). Fresh, dark gray, fine grained, fissile SHALE with thin interbeds of sandstone and siltstone. Transitional contact with the Whirlpool Formation. 83.50 to 86.67 m: Rock is strongly fissile and susceptible to handling breakage.	83.02	100/86	1		MP Packer
84					0		
					0		
86		85.99 to 86.01 m: Clay gouge.	86.02	100/87	1		
		86.67 to 90.00 m: Rock is fissile but less susceptible to handling breakage.			2	8E-05	
88					1		
			89.04	100/95	5		MP Packer
90	95.39 90.00	WHIRLPOOL FORMATION Fresh, light gray, medium grained, crossbedded, thinly to medium bedded SANDSTONE with occasional shale partings. Sharp contact with Queenston Formation. Discontinuities include bedding joints at 70 to 90 deg to the core axis, usually along shaly partings and subvertical joints as described at. 95.40 m. The bedding joints are rough and planar with hard joint surfaces, sometimes infilled with soft gypsum. 92.02 to 96.30 m: Water return.			1		
					2		
92			92.02	100/97	3		
					3	9E-05	Measurement Port
94							

LOG; RECOVERY % / RQD % (20 40 60 80); HYDRAULIC CONDUCTIVITY scale 10^{-6} 10^{-4} 10^{-2}; WTR LEV; PIEZOMR; POINT LOAD I_{s50} A/D (MPa).

GRAPHICAL BOREHOLE DATA

ACRES

HOLE NF-28

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	RUN DEPTH	REC RQD	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	POINT LOAD I_{s50} A/D (MPa)	REMARKS
					3			
		94.95 to 94.96 m: Fragmented zone.						
		95.40 to 95.68 m: Vertical joint at 5 deg to the core axis, tight.	95.02		4			
96	89.09 96.30							
		QUEENSTON FORMATION			7			Pumping Port
		Fresh, reddish-brown with occasional greenish-gray reduction bands, fine grained, indistinctly bedded MUDSTONE, gypsum filled vugs scattered throughout. Green reduction bands up to 100 mm thick, 0.3 to 0.5 m apart.		100/68				
					0			MP Packer
98		Discontinuities include bedding joints at 90 deg to core axis, subvertical joints at 0 to 10 deg to core axis and inclined joints at 45 to 70 deg to core axis.					/1.36	
		Bedding joints are generally smooth and planar, sometimes rough, with hard joint surfaces and commonly a gypsum infilling.	98.04		5			
		The inclined joints occur sporadically and are sometimes infilled with gypsum.			2	1E-04	/0.79	
		The vertical joints occur rarely and are generally tight, filled with gypsum and are 0.1 to 0.2 m long.		100/94				
100		96.30 to 175.00 m: Bedding joints are frequent.			4			
		96.30 to 96.61 m: 45 to 70 deg joints are closely spaced.					/1.43	
		96.61 to 175.0 m: Generally closely to moderately spaced jointing.	101.03		6			
102		96.94 to 96.96 m: Fragmented zone.						
		98.04 to 100.04 m: No water return during drilling, returned at end of run.		100/95	3		1.5/	
					2		1.84/2.06	
104			104.04		2			
		105.23 to 105.30 m: Fragmented zone due to drill action on moderately weathered shale.		100/78	8	2E-04	/1.44	
106					5		1.41/0.81	
			107.02		5		1.28/0.03	
108								

HOLE NF-28

GRAPHICAL BOREHOLE DATA

SHEET 9 OF 16

Columns: REF. DEPTH | ELEV. DEPTH | DESCRIPTION | LOG | RUN DEPTH | REC/RQD | RECOVERY % / RQD % (20 40 60 80) | JOINTS PER M | HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2} | WTR LEV | PIEZOMR | POINT LOAD I_{s50} A/D (MPa) | REMARKS

Description

- 110.04 to 113.03 m: Water return.
- 113.03 to 116.03 m: No water return until end of run.
- 116.03 to 146.02 m: Water return.

Run depths and REC/RQD

Run depth (m)	REC/RQD
(above 110.04)	100/79
110.04	100/92
113.03	100/84
114.55	100/93
116.03	100/94
119.05	100/93

Joints per m (top to bottom): 2, 3, 2, 7, 5, 5, 6, 3, 6, 7, 5, 5, 1, 3

Hydraulic conductivity: 1E-04; 2E-04

Point load I_{s50} A/D (MPa) (top to bottom): 1.38/0.02, /1.18, /1.38, /0.84, /0.74, /0.94, /0.02, /1.10, /0.80, /0.04, /0.97, 1.35/1.35

Remarks: Measurement Port; Pumping Port; MP Packer

Ref. depth: 110, 112, 114, 116, 118, 120, 122

ACRES

GRAPHICAL BOREHOLE DATA

HOLE NF-28

SHEET 10 OF 16

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD I_{s50} A/D (MPa)	REMARKS
				122.03			4				/0.44	
								2E-04				
					100/97		2				/0.92	
124							2					MP Packer
				125.02			4				/0.03	
126							2				/1.03	
					100/91		2					
128				128.05			6				/1.66	
							5					
130					100/92		5					
				131.04	100/78		0				1.73/0.35	
132				131.85			4				1.76/	
					100/96		2				/0.03	
134				134.02			5				1.73/	
							4	5E-05			1.79/0.03	
136					100/93							

HOLE NF-28

ACRES

GRAPHICAL BOREHOLE DATA

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD I_{s50} A/D (MPa)	REMARKS
							3				/0.56	
				137.02			2				/0.05	
138							6				/1.49	
					100/98							
							5				1.86/	
		139.52 to 139.55 m: Fragmented zone due to drill action, some red clay.										
140		139.61 m: Core ground, some red clay.		140.02			3				/1.46	
		140.51 m: Fragmented zone, pieces ground.										
							7				/0.03	
					100/89							
142							9				1.78/0.76	
		142.35 m: Fragmented zone, pieces ground.										
				143.02			6				1.91/1.15	
144							4				1.86/1.49	
					100/96							
							5				1.67/0.70	
146		146.02 to 149.01 m: No water return.		146.02			8				1.37/	
							5				/1.46	
					100/89							
148							2				/1.31	
		149.01 to 165.26 m: Water return.		149.01			4				1.80/0.02	
150												

GRAPHICAL BOREHOLE DATA

HOLE NF-28

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	RUN DEPTH	REC / RQD	JOINTS PER M	POINT LOAD Is50 A/D (MPa)	REMARKS
					8	1.40/0.72	
		150.51 to 150.54 m: Fragmented zone, pieces ground.		100/93			
					4	/0.03	
152							
			152.03		7		
					4	2.01	
				100/100			
154							
					6		
						2.14/0.40	
		154.96 to 154.98 m: Fragmented zone.					
			155.01		2		
						/<0.03	
156							
					4	2.29/0.82	
				100/98			
					6	/0.03	
158							
			158.02		5		
					8	/0.97 /1.15	
				100/94			
160							
					3	/1.02	
			161.02		5	/<0.03	
162							
					6	/1.82	
				100/96			
							MP Packer
					4	/1.28	
164							

GRAPHICAL BOREHOLE DATA

ACRES

HOLE NF-28

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD I_{s50} A/D (MPa)	REMARKS
				164.00			7				/0.03	
					100/78							
		165.26 to 167.02 m: No water return.		165.26			5				1.86/1.53	
166												
					100/98		0				/1.85	
		167.02 to 215.43 m: Water return.		167.02			6				/0.15	
168							4					
					100/96							
							5				1.89/0.72	
170				170.02			3				/0.48	
							4				/0.03	
					100/93							
172							0				/0.72	
				173.02			4				/1.23	
174							4				2.07/0.58	
					100/94							
		175.00 to 215.06 m: Generally moderately to very widely spaced joints. If ground breaks are ignored then the core is essentially unjointed.					2				1.68/1.82	
176				176.02			1				/0.56	
							2				/0.70	
					100/99							
178												

ACRES

GRAPHICAL BOREHOLE DATA

HOLE NF-28

REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD I_{s50} A/D (MPa)	REMARKS
							0				1.43/1.53	
				179.02			1				1.66/<0.03	
180							1				/0.03	
					100/100							
							3				2.65/	
182				182.02			2				/0.03	
							2					
					100/95							
184							0				/1.64	
				185.03			2				2.14/0.03	
186							2				2.52/0.24	
					100/98							
							1				1.86/2.05	
188				188.05			1				2.88/1.07	
							2				1.86/0.03	
					100/100							
190							3				1.86/1.97	
				191.07			0				2.40/2.13	
192												

GRAPHICAL BOREHOLE DATA

ACRES

HOLE NF-28

SHEET 15 OF 16

REF. DEPTH	ELEV. / DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD I_{s50} A/D (MPa)	REMARKS
					100/100		1				2.23/	
							0				/0.03	
194				194.12			0				/1.43	
					100/100		0				/1.26	
196							0				2.83/	Measurement Port
				197.17			1				2.87/1.90	
198							0				/0.07	
					100/96		0				2.18/1.40	Pumping Port
200				200.22			1				/1.43	MP Packer
							2				/0.03	
202					100/95		0				2.68/0.03	
				203.27			0				2.50/1.58	
204							1				/1.03	End Cap
					100/98		1				2.05/0.03 2.01/	
206												

GRAPHICAL BOREHOLE DATA

HOLE NF-28

SHEET 16 OF 16

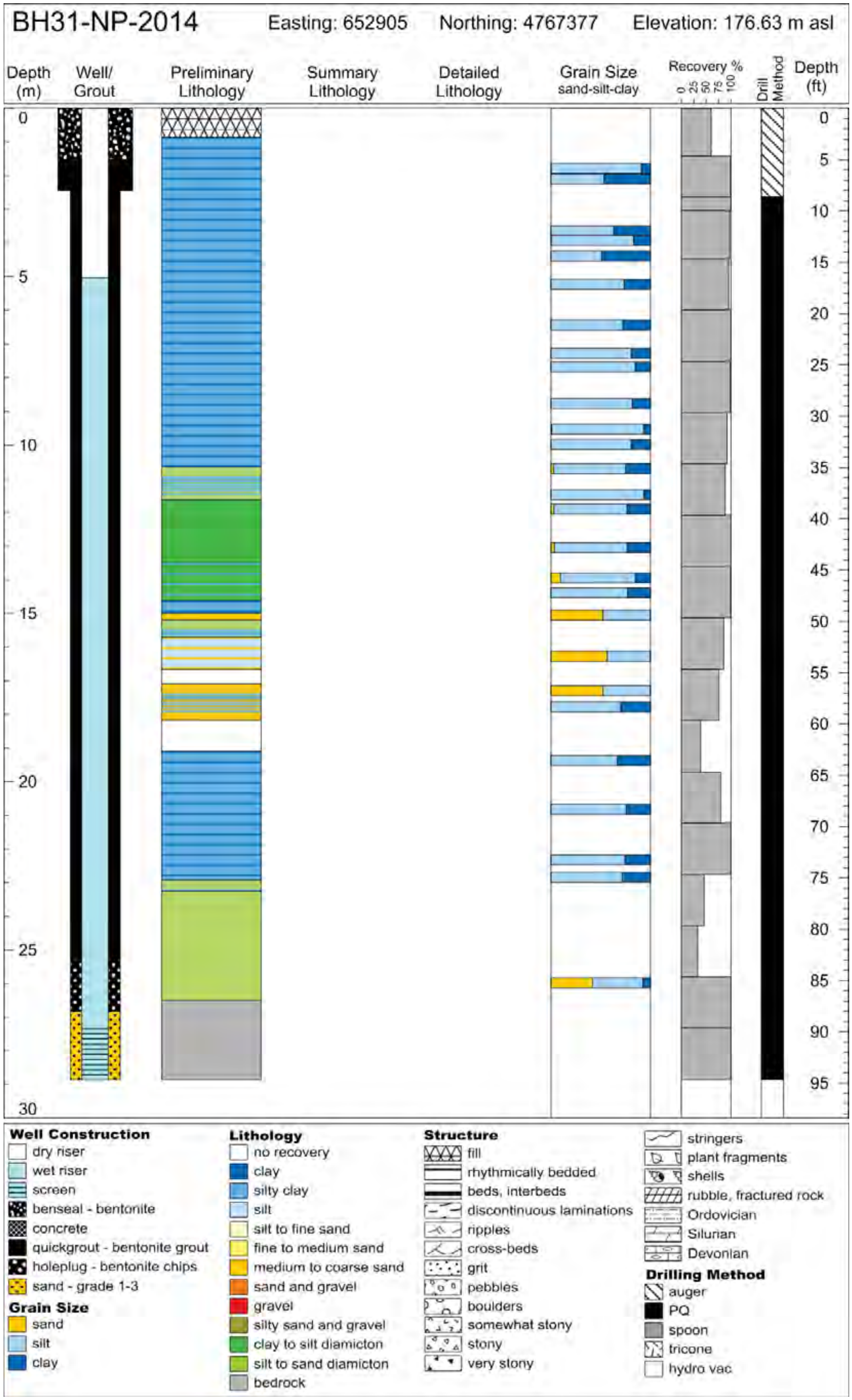
REF. DEPTH	ELEV. DEPTH	DESCRIPTION	LOG	RUN DEPTH	REC / RQD	RECOVERY % / RQD % (20 40 60 80)	JOINTS PER M	HYDRAULIC CONDUCTIVITY (cm/sec) 10^{-6} 10^{-4} 10^{-2}	WTR LEV	PIEZOMR	POINT LOAD I_{s50} A/D (MPa)	REMARKS
				206.31			0				3.31/	
							0				2.14/0.03	
208					100/100		0				/1.36	
							0				2.29/0.08	
				209.36								
210							0				/4.25	
					100/100		0				/1.58	
212							0				2.52/	
				212.32								
							1				2.53/0.03	
214					100/100		0				2.01/0.03	
											/1.00	
	-30.04 215.43	End of borehole										

Notes

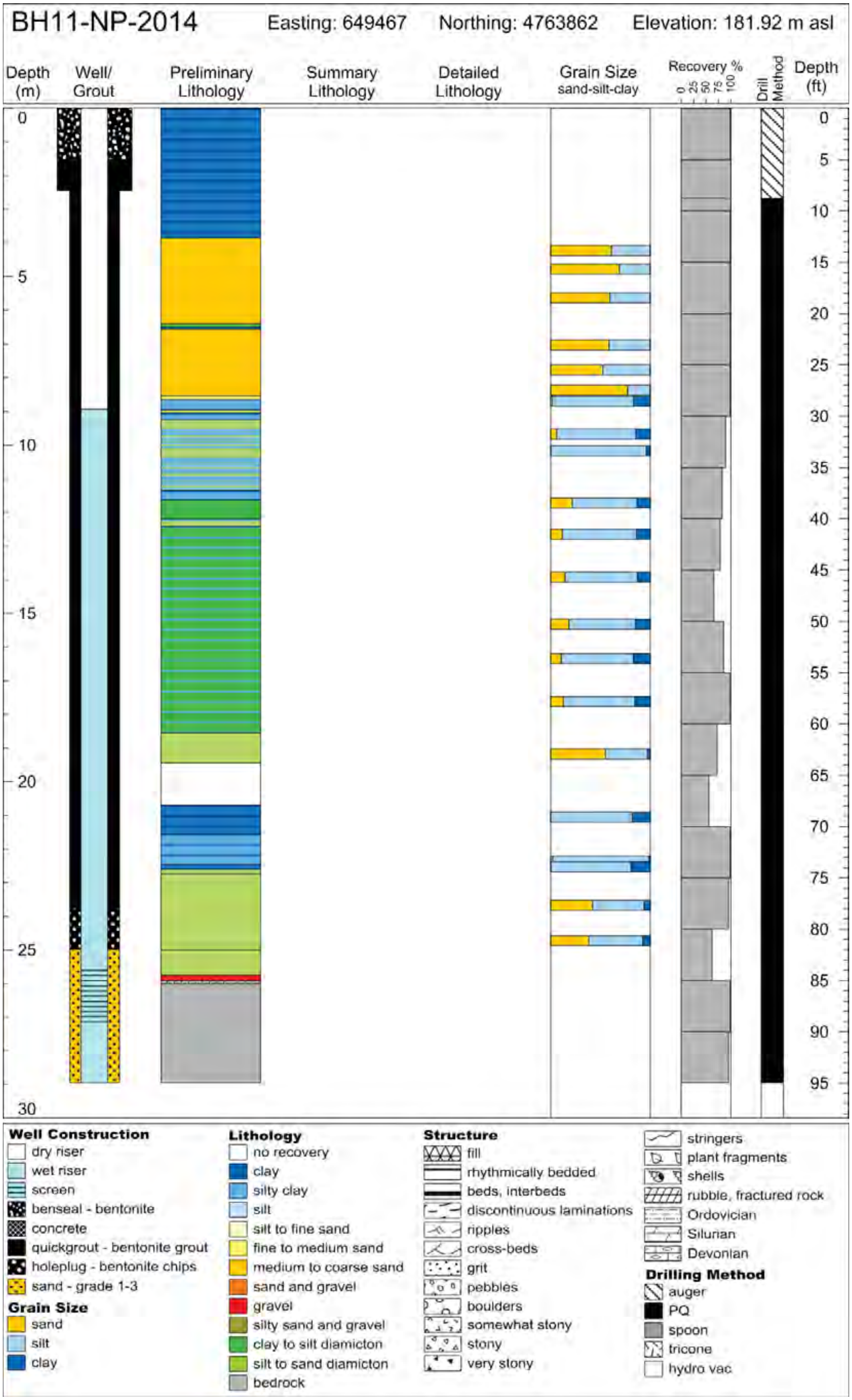
1. Water levels during and after drilling:

Date	Time	Depth(m)
90 11 13	730	8.00

2. For borehole water pressure test results see Table 3.3.
3. For point load index test results, see Table 4.12.
4. For hydrofracturing stress measurement test results see Tables 3.11 and 3.13.
5. For Westbay multipoint piezometer installation details, see Table 3.4 and Appendix G.
6. For piezometer water level readings, see Table 4.6.



BH31-NP-2014
Easting: 652905
Northing: 4767377
Elevation: 176.63 m asl
Depth (m)
Well/ Grout
Preliminary Lithology
Summary Lithology
Detailed Lithology
Grain Size sand-silt-clay
Recovery %
0 25 50 75 100
Drill Method
Depth (ft)
0
5
10
15
20
25
30
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
Well Construction
dry riser
wet riser
screen
benseal - bentonite
concrete
quickgrout - bentonite grout
holeplug - bentonite chips
sand - grade 1-3
Grain Size
sand
silt
clay
Lithology
no recovery
clay
silty clay
silt
silt to fine sand
fine to medium sand
medium to coarse sand
sand and gravel
gravel
silty sand and gravel
clay to silt diamicton
silt to sand diamicton
bedrock
Structure
fill
rhythmically bedded
beds, interbeds
discontinuous laminations
ripples
cross-beds
grit
pebbles
boulders
somewhat stony
stony
very stony
stringers
plant fragments
shells
rubble, fractured rock
Ordovician
Silurian
Devonian
Drilling Method
auger
PQ
spoon
tricone
hydro vac


BH11-NP-2014
Easting: 649467
Northing: 4763862
Elevation: 181.92 m asl
Depth (m)
Well/ Grout
Preliminary Lithology
Summary Lithology
Detailed Lithology
Grain Size sand-silt-clay
Recovery %
0 25 50 75 100
Drill Method
Depth (ft)
0
5
10
15
20
25
30
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
Well Construction
dry riser
wet riser
screen
benseal - bentonite
concrete
quickgrout - bentonite grout
holeplug - bentonite chips
sand - grade 1-3
Grain Size
sand
silt
clay
Lithology
no recovery
clay
silty clay
silt
silt to fine sand
fine to medium sand
medium to coarse sand
sand and gravel
gravel
silty sand and gravel
clay to silt diamicton
silt to sand diamicton
bedrock
Structure
fill
rhythmically bedded
beds, interbeds
discontinuous laminations
ripples
cross-beds
grit
pebbles
boulders
somewhat stony
stony
very stony
stringers
plant fragments
shells
rubble, fractured rock
Ordovician
Silurian
Devonian
Drilling Method
auger
PQ
spoon
tricone
hydro vac

BOREHOLE NO. 03-1

PROJECT NAME: ROLLING MEADOWS | PROJECT NO.: 981023.02
CLIENT: WALKER INDUSTRIES HOLDING LIMITED | DATE: APRIL 3-8, 2003
BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE | SUPERVISOR: KJF
GROUND ELEVATION: 184.0 mASL (Estimated) | REVIEWER: PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE TYPE	'N' VALUE	% WATER	% RECOVERY	RQD (%)	CONE PENETRATION "N" VALUE 10 20 30 / SHEAR STRENGTH	WATER CONTENT % 10 20 30 Wp WL	REMARKS
0 – 6.0	CLAYEY SILT, SOME GRAVEL: BROWN TO GREY.		H.W. (114.3 mm) CASING (to 7.7 m)								
6.0	DOLOSTONE HARD, FRESH, BROWNISH-GREY TO GREY, MEDIUM GRAINED DOLOSTONE WITH SACCHAROIDAL TEXTURE, WITH A PETROLIFEROUS ODOUR WHEN BROKEN. THIN TO MEDIUM BEDDED WITH OCCASIONAL SHALE LAYERS AND STYLOLITES, 1 TO 3 MM THICK. RARE NODULES OF GYPSUM AND OTHER MINERALS, LESS THAN 0.2% BY VOLUME. LESS THAN 1-2% VUG CONTENT. - FRACTURED 8.21m TO 8.36 m, SURFACES CLEAN AND FRESH. - SOME JOINTS COATED WITH CALCITE, 8.5 m TO 11.4 m.	ERAMOSA MEMBER, LOCKPORT FORMATION	7.7 m	1RC			100	75			TEST DATA: SAMPLE 1 (6.0 m – 11.9m) PN (CONC.) 108 M.D.C. 8.1% M.D.F. 19.1%* A.M.B. 0.007% DENSITY 2.706* ABSORPTION 1.11%* $MgSO_4$ LOSS 0.9%* F.T. 2.3%*
				2RC			100	30			
				3RC			100	38			
				4RC			100	0			
				5RC			100	19			
				6RC			100	83			TEST DATA: SAMPLE 2 (11.9 m – 19.4 m) PN (Conc.) 122 M.D.C. 8.7% M.D.F. 19.1%* A.M.B. 0.008% DENSITY 2.706* ABSORPTION 1.11%* $MgSO_4$ LOSS 0.9%* F.T. 2.3%*
				7RC			100	47			
14	- PARTINGS COMMON ALONG SHALE LAYERS BELOW 14 m.			8RC			100	85			
				9RC			100	28			
16	- OCCASIONAL NODULES OF GYPSUM, CHERT AND OTHER MINERALS 15.6 m TO 16.5 m, LESS THAN 0.5%.										
				10RC			100	23			
				11RC			100	24			* ROCK CORE FROM 6.0 m TO 19.4 m.
20	- MEDIUM TO COARSE GRAINED LAYER 19.5 m TO 20.3 m.			12RC			100	77			

BOREHOLE NO. 03-1

PROJECT NAME: ROLLING MEADOWS — PROJECT NO.: 981023.02

CLIENT: WALKER INDUSTRIES HOLDING LIMITED — DATE: APRIL 3-8, 2003

BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE — SUPERVISOR: KJF

GROUND ELEVATION: 184.0 mASL (Estimated) — REVIEWER: PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE TYPE	'N' VALUE	% WATER	% RECOVERY	RQD (%)	CONE PENETRATION "N" VALUE 10 20 30 / SHEAR STRENGTH	WATER CONTENT % 10 20 30 / W_P W_L	REMARKS
20–21.5	DOLOSTONE: (CONTINUED)			13RC			100	77			TEST DATA: SAMPLE 3 (19.4 m – 32.7 m) PN (Conc.) 119; M.D.C. 11.0%; M.D.F. 23.8%; DENSITY 2.725; ABSORPTION 1.25%; $MgSO_4$ LOSS 2.0%; F.T. 3.8%
21.5–32.7	DOLOSTONE: HARD, FRESH, GREY, FINE GRAINED DOLOSTONE WITH A WEAK PETROLIFEROUS ODOUR WHEN BROKEN. OCCASIONAL GREY TO WHITE CHERT AND GYPSUM NODULES, APPROXIMATELY 2 TO 3% BY VOLUME. MEDIUM BEDDED WITH OCCASIONAL SHALE LAYERS 1 MM TO 3 mm THICK. OCCASIONAL TO COMMON STYLOLITIC SHALE PARTINGS, 1 mm TO 3 mm THICK, SOMETIMES COATED WITH CALCITE. LOWER CONTACT GRADATIONAL. - CONCENTRATION OF CHERT NODULES FROM 24.4 m TO 24.7 m, TO 50% BY VOLUME. - CHERT AND GYPSUM NODULES FROM 24.4 m TO 26.8 m, TO 5–8% BY VOLUME. - FOSSILIFEROUS AND STYLOLITIC LAYER FROM 27.5 m TO 27.9 m.	GOAT ISLAND MEMBER, LOCKPORT FORMATION		14RC			100	87			
				15RC			100	89			
				16RC			100	100			
				17RC			100	78			
				18RC			100	78			
				19RC			100	100			
				20RC			100	100			
				21RC			100	100			
				22RC			100	98			
32.7–36.7	DOLOSTONE: HARD, FRESH, DARK GREY, MEDIUM GRAINED, FOSSILIFEROUS DOLOSTONE. MEDIUM BEDDED WITH OCCASIONAL SHALE PARTINGS, 1MM TO 3MM THICK. - FOSSILIFEROUS LAYER 32.7M - 34.7M. - RARE NODULES OF CHERT, 33.8M TO 34.7 m, 1 mm TO 15 mm, LESS THAN 0.2 % BY VOLUME. - NO CHERT NODULES BELOW 34.7 m	GASPORT MEMBER, LOCKPORT FORMATION		23RC			100	98			TEST DATA: SAMPLE 4 (32.7 m – 36.7 m) PN (Conc.) 107; DENSITY 2.729; M.D.C. 11.0%; ABSORPTION 1.35%; $MgSO_4$ LOSS 2.2%; F.T. 5.9%
				24RC			100	100			
36.7	BOREHOLE TERMINATED AT 36.7 m IN DOLOSTONE.			25RC			100	100			

BOREHOLE NO. 03-3

PROJECT NAME: ROLLING MEADOWS
PROJECT NO.: 981023.02
CLIENT: WALKER INDUSTRIES HOLDING LIMITED
DATE: JULY 9-10, 2003
BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE
SUPERVISOR: SCL/PAM
GROUND ELEVATION: 187.0 mASL (Estimated)
REVIEWER: PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE TYPE	'N' VALUE	% WATER	% RECOVERY	RQD (%)	RATE OF DRILL PENETRATION m / min	WATER CONTENT % (10 20 30; W_P W_L)	REMARKS
0	CLAYEY SILT: REDDISH BROWN CLAYEY SILT.		H.W. (114.3 mm) CASING								AUGER CUTTINGS DESCRIBED
	– BOULDERS AT 4.3 m										
	– BOULDERS OF GREY, MEDIUM GRAINED DOLOSTONE 10.3 m TO 10.6 m			1RC			100	0			
10.6	DOLOSTONE: HARD, FRESH, BROWNISH-GREY, VUGGY, MEDIUM GRAINED DOLOSTONE WITH SACCHAROIDAL TEXTURE AND A PETROLIFEROUS ODOUR WHEN BROKEN. WELL LAMINATED IN SOME LAYERS. VUGS FROM 1 mm TO 30 mm, APPROXIMATELY 4%.	GUELPH FORMATION		2RC			100	40			TEST DATA: SAMPLE 5 (10.6 m – 25.9 m) PN (Conc.) 109; M.D.C. 9.6%; M.D.F. 23.9%; A.M.B. 0.02; DENSITY 2.707; ABSORPTION 1.09%; $MgSO_4$ LOSS 1.5%; F.T. 1.7%
				3RC			100	71			
12.9	DOLOSTONE: HARD, FRESH, BROWNISH-GREY TO GREY, MEDIUM GRAINED DOLOSTONE WITH SACCHAROIDAL TEXTURE AND A PETROLIFEROUS ODOUR WHEN BROKEN. THIN TO MEDIUM BEDDED WITH OCCASIONAL SHALE LAYERS 1 MM TO 3 MM THICK. VUGS AND NODULES OF GYPSUM AND OTHER MINERALS, LESS THAN 0.2 %.	ERAMOSA MEMBER, LOCKPORT FORMATION	13.2 m (base of casing)	4RC			100	92			
	– NUMEROUS FRACTURES 13.2 m TO 13.5 m.			5RC			100	86			
	– OCCASIONAL STYLOLITES BELOW 13.9 m			6RC			100	75			
				7RC			100	78			
	– SHALE PARTINGS COMMON BELOW 19.3 m. SOMETIMES COATED WITH CALCITE VEINS.										
20				8RC			95	86			

BOREHOLE NO. 03-3

PROJECT NAME: ROLLING MEADOWS — PROJECT NO.: 981023.02

CLIENT: WALKER INDUSTRIES HOLDING LIMITED — DATE: JULY 9-10, 2003

BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE — SUPERVISOR: SCL/PAM

GROUND ELEVATION: 187.0 mASL (Estimated) — REVIEWER: PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE TYPE	'N' VALUE	% WATER	% RECOVERY	RQD (%)	RATE OF DRILL PENETRATION m / min	WATER CONTENT % (10 20 30; Wp WL)	REMARKS
20	DOLOSTONE; CONTINUED - RARE NODULES OF CALCITE, SPHALERITE, CHERT AND GYPSUM FROM 20.7 m TO 30.3 m.	ERAMOSA MEMBER, LOCKPORT MEMBER		9RC			100	54			
22				10RC			88	88			
24	- VUGS 24.10 m TO 24.13 m APPROXIMATELY 10%,			11RC			100	73			
26				12RC			100	67			TEST DATA: SAMPLE 6 (25.9 m – 42.9 m) PN (Conc.) 129 M.D.C. 11.4% M.D.F. 17.1% A.M.B. 0.12 DENSITY 2.717 ABSORPTION 1.18% $MgSO_4$ LOSS 4.8% F.T. 5.0%
				13RC			100	65			
28	- MEDIUM TO COARSE GRAINED FROM 27.7 m TO 29.6 m.			14RC			100	100			
30				15RC			100	97			
31.7 / 32	DOLOSTONE: HARD, FRESH, GREY, FINE GRAINED DOLOSTONE WITH A WEAK PETROLIFEROUS ODOUR WHEN BROKEN. OCCASIONAL WHITE CHERT AND WHITE GYPSUM NODULES, APPROXIMATELY 3% BY VOLUME. MEDIUM BEDDED WITH OCCASIONAL SHALE LAYERS 1 mm TO 10 mm THICK. OCCASIONAL TO COMMON STYLOLITIC SHALE PARTINGS, 1 mm TO 3 mm THICK SOMETIMES COATED WITH GYPSUM VEINS UP TO 3 mm THICK. LOWER CONTACT GRADATIONAL.	GOAT ISLAND MEMBER, LOCKPORT FORMATION		16RC			98	93			
34				17RC			100	100			
	- CHERT, DOLOMITE AND GYPSUM, 32.3 m TO 33.2 m, UP TO 20% BY VOLUME.			18RC			100	100			
36	- CHERT, DOLOMITE, GYPSUM, SIDERITE AND SPHALERITE NODULES, 33.2 m TO 36.0 m, TO 10% BY VOLUME. - FOSSILIFEROUS AND STYLOLITIC LAYERS, 36.6 m TO 36.9 m, 37.2 m AND 37.6 m.			19RC			100	100			
38	- CHERT, GYPSUM, DOLOMITE AND SPHALERITE, BELOW 38.0 m, LESS THAN 1% BY VOLUME, 1 mm TO 100 mm			20RC			100	100			
				21RC			100	100			
				22RC			100	100			
40				23RC			100	100			

BOREHOLE NO. 03-3

PROJECT NAME: ROLLING MEADOWS
PROJECT NO.: 981023.02
CLIENT: WALKER INDUSTRIES HOLDING LIMITED
DATE: JULY 9-10, 2003
BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE
SUPERVISOR: SCL/PAM
GROUND ELEVATION: 187.0 mASL (Estimated)
REVIEWER: PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE: TYPE	SAMPLE: 'N' VALUE	SAMPLE: % WATER	SAMPLE: % RECOVERY	SAMPLE: RQD (%)	RATE OF DRILL PENETRATION m / min	WATER CONTENT % (10 20 30; Wp WL)	REMARKS
40 – 42.9	DOLOSTONE (CONTINUED)	GOAT ISLAND MEMBER, LOCKPORT FORMATION		24RC			100	100			
				25RC			100	100			
42.9 – 52.5	DOLOSTONE HARD, FRESH, CREAM-GREY TO DARK GREY, FINE TO COARSE GRAINED FOSSILIFEROUS DOLOSTONE WITH SACCHAROIDAL TEXTURE. MEDIUM BEDDED WITH OCCASIONAL SHALE PARTINGS AND STYLOLITES, SOMETIMES WITH GYPSUM VEINS, UP TO 4 mm THICK. FOSSILS UP TO 5% AND CHERT NODULES LESS THAN 0.5%. - CREAM-GREY FOSSILIFEROUS DOLOMITIC LIMESTONE FROM 48.4 m TO 51.3 m. CALCAREOUS FOSSILS UP TO 50% BY VOLUME. - COARSE GRAINED, 48.4 m TO 52.5 m. - FOSSILIFEROUS CONGLOMERATIC LAYER, 52.4 m TO 52.5 m MARKS LOWER CONTACT.	GASPORT MEMBER, LOCKPORT FORMATION		26RC			100	97			TEST DATA: SAMPLE 7 (42.9 m – 52.5 m) PN (Conc.) 115 M.D.C. 15.8% M.D.F. 26.7% A.M.B. 0.13 DENSITY 2.734 ABSORPTION 1.45% $MgSO_4$ LOSS 10.7% F.T. 13.3%
				27RC			100	100			
				28RC			100	100			
				29RC			100	100			
				30RC			100	100			
				31RC			100	100			
				32RC			100	100			
				33RC			100	93			
52.5 – 55.4	DOLOSTONE: MEDIUM HARD, DARK GREY, FINE GRAINED, FRESH ARGILLACEOUS DOLOSTONE WITH OCCASIONAL SHALE PARTINGS AND RARE NODULES OF GYPSUM AND SPHALERITE.	DECEW FORMATION		34RC			100	100			
				35RC			100	100			
				36RC			100	98			
55.4 – 58.0	SHALE: VERY DARK GREY, DOLOMITIC TO CALCAREOUS SHALE. SPLITS READILY ALONG BEDDING.	ROCHESTER FORMATION		37RC			100	100			
58.0	BOREHOLE TERMINATED AT 58.0 m IN SHALE.										

BOREHOLE NO. 03-4

PROJECT NAME: ROLLING MEADOWS
PROJECT NO.: 981023.02
CLIENT: WALKER INDUSTRIES HOLDING LIMITED
DATE: JULY 11-15, 2003
BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE
SUPERVISOR: SCL
GROUND ELEVATION: 183.0 mASL (Estimated)
REVIEWER: PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE: TYPE	SAMPLE: 'N' VALUE	SAMPLE: % WATER	SAMPLE: % RECOVERY	SAMPLE: RQD (%)	RATE OF DRILL PENETRATION (m / min)	WATER CONTENT % (10 20 30; W_P W_L)	REMARKS
0	CLAYEY SILT: BROWNISH GREY CLAYEY SILT. – GREY CLAYEY SILT BELOW 6.1 m.		H.W. (114.3 mm) CASING								AUGER CUTTINGS DESCRIBED
10.3	DOLOSTONE: HARD, FRESH, BROWNISH-GREY, VUGGY, MEDIUM GRAINED DOLOSTONE WITH SACCHAROIDAL TEXTURE AND A PETROLIFEROUS ODOUR WHEN BROKEN. VUGS FROM 1 mm TO 30 mm, APPROXIMATELY 10% BY VOLUME.	GUELPH FORMATION	11.73 m	1RC			100	55			TEST DATA: SAMPLE 8 (10.3 m – 30.1 m) PN (CONC.) 104 M.D.C. 8.0% M.D.F. 21.7% A.M.B. IN PROGRESS ABSORPTION 1.070% $MgSO_4$ LOSS 3.1% F.T. 3.4%
				2RC			100	28			
12.3	DOLOSTONE: HARD, FRESH, BROWNISH-GREY, MEDIUM GRAINED DOLOSTONE WITH SACCHAROIDAL TEXTURE AND A PETROLIFEROUS ODOUR WHEN BROKEN. THIN TO MEDIUM BEDDED WITH OCCASIONAL SHALE LAYERS 1 mm TO 3 mm THICK. OCCASIONAL VUGS UP TO 70 mm AND LESS THAN 0.5% BY VOLUME. RARE NODULES OF GYPSUM AND OTHER MINERALS, LESS THAN 0.3% BY VOLUME.	ERAMOSA MEMBER, LOCKPORT FORMATION		3RC			100	89			
				4RC			100	100			
				5RC			100	100			
	– VEINS AND OCCASIONAL NODULES OF GYPSUM AND SPHALERITE 17.0 m TO 17.3 m, UP TO 6%, AND 18.2 m TO 18.6 m, UP TO 3% BY VOLUME.			6RC			100	100			
				7RC			100	100			
	– RARE ENCRUSTATIONS AND NODULES OF DOLOMITE, GYPSUM, SIDERITE AND SPHALERITE BELOW 18.0 m.			8RC			100	84			
				9RC			100	92			

BOREHOLE NO. 03-4

PROJECT NAME: ROLLING MEADOWS
PROJECT NO.: 981023.02
CLIENT: WALKER INDUSTRIES HOLDING LIMITED
DATE: JULY 11-15, 2003
BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE
SUPERVISOR: SCL
GROUND ELEVATION: 183.0 mASL (Estimated)
REVIEWER: PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE TYPE	'N' VALUE	% WATER	% RECOVERY	RQD (%)	RATE OF DRILL PENETRATION m / min	WATER CONTENT % (10 20 30; W_P W_L)	REMARKS
20–30.1	DOLOSTONE: CONTINUED - CHERT, GYPSUM, CALCITE AND SIDERITE NODULES 22.0 m TO 30.1 m, LESS THAN 1%, - VUGGY ZONE 25.6 m TO 25.9 m, UP TO 10%, OCCASIONALLY ENCRUSTED WITH CALCITE. - MEDIUM TO COARSE GRAINED FROM 27.4 m TO 28.0 m.	ERAMOSA MEMBER, LOCKPORT FORMATION		10RC			100	93			
				11RC			100	66			
				12RC			100	79			
				13RC			100	0			
				14RC			100	92			
				15RC			100	98			
				16RC			100	92			
30.1–40	DOLOSTONE: HARD, FRESH, GREY, FINE GRAINED DOLOSTONE WITH A WEAK PETROLIFEROUS ODOUR WHEN BROKEN. OCCASIONAL WHITE CHERT AND WHITE GYPSUM NODULES. MEDIUM BEDDED WITH OCCASIONAL SHALE LAYERS 1 mm TO 5 mm THICK. OCCASIONAL STYLOLITIC SHALE PARTINGS, 1 mm TO 3 mm THICK BELOW 25 m. LOWER CONTACT GRADATIONAL. - SHALE PARTINGS, UP TO 2 mm BELOW 30.1 m. - CONCENTRATIONS OF GYPSUM AND CHERT NODULES, 30.5 m TO 35.4 m, UP TO 70 mm, 5-8% CHERT, 2-5% GYPSUM. - CHERT, GYPSUM AND INFILLINGS OF DOLOMITE, LESS THAN 1% BELOW 35.4 m, - FOSSILIFEROUS LAYERS, 35.4 m TO 35.7 m AND 36.2 m TO 36.5 m.	GOAT ISLAND MEMBER, LOCKPORT FORMATION		17RC			100	71			
				18RC			100	93			
				19RC			100	96			
				20RC			100	100			
				21RC			100	100			
				22RC			100	98			
				23RC			100	100			
				24RC			100	98			

BOREHOLE NO. 03-4

PROJECT NAME: ROLLING MEADOWS
PROJECT NO.: 981023.02
CLIENT: WALKER INDUSTRIES HOLDING LIMITED
DATE: JULY 11-15, 2003
BOREHOLE TYPE: H.Q. (64 mm) DIAMOND DRILL CORE
SUPERVISOR: SCL
GROUND ELEVATION: 183.0 mASL (Estimated)
REVIEWER: PAM/AJC

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS	SAMPLE TYPE	'N' VALUE	% WATER	% RECOVERY	RQD (%)	RATE OF DRILL PENETRATION m / min	WATER CONTENT % (10 20 30; WP WL)	REMARKS
40	DOLOSTONE (CONTINUED)	GASPORT MEMBER, LOCKPORT FORMATION		25RC			100	97			
41.4	DOLOSTONE: HARD, FRESH, CREAM-GREY TO DARK GREY, FINE TO COARSE GRAINED FOSSILIFEROUS DOLOSTONE WITH SACCHAROIDAL TEXTURE. MEDIUM BEDDED WITH OCCASIONAL STYLOLITES. FOSSILS UP TO 5%. GYPSUM, DOLOMITE AND CALCITE NODULES LESS THAN 1%.			26RC			100	100			TEST DATA: SAMPLE 10 (41.4 m – 45.4m) PN (CONC.) 117; M.D.C. 12.4%; M.D.F. 24.5%; A.M.B. INPROGRESS; ABSORPTION 1.242%; $MgSO_4$ LOSS 11.6%; F.T. 8.8%
42											
44				27RC			100	100			
				28RC			100	100			
46				29RC			100	100			
48	- FOSSILS INCREASING TO 50%, 48 m TO 51 m. - BECOMING CREAMY-GREY TO LIGHT GREENISH-GREY, 48 m TO 51 m.			30RC			100	100			TEST DATA: SAMPLE 11 (48.0 m – 51.0 m) PN (CONC.) 168; M.D.C. 18.8%; M.D.F. 25.4%; A.M.B. IN PROGRESS; ABSORPTION 1.139%; $MgSO_4$ LOSS 13.7%; F.T. 8.6%
50	- FOSSILIFEROUS CONGLOMERATIC DOLOMITIC LIMESTONE LAYER WITH ELONGATED PEBBLES OF THE DECEW FORMATION FROM 50.8 m TO 51.0 m MARKS LOWER CONTACT.			31RC			100	100			
51.0	DOLOSTONE: MEDIUM HARD, DARK GREY, FINE GRAINED, FRESH ARGILLACEOUS DOLOSTONE.	DECEW FORM.		32RC			100	100			
52 / 52.0	BOREHOLE TERMINATED AT 52.0 m IN ARGILLACEOUS DOLOSTONE.										
54											
56											
58											
60											

BOREHOLE NO. 4

PROJECT NAME Walker Brothers Quarry Landfill Site (West Pit) PROJECT NO.

CLIENT Walker Brothers Quarries Limited DATE Dec. 8, 1976

BOREHOLE TYPE 3¼" I.D. Hollow Stem Augers and NX Rock Core GEOLOGIST G.W.J.

ELEVATION 591.0' asl. TECHNOLOGIST

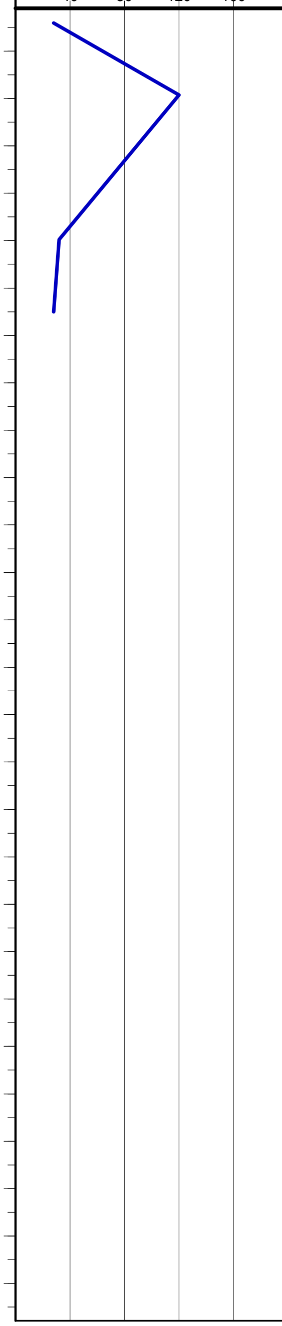
DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE TYPE	BLOWS/FT	M/C	% RECOVERY	GROUND WATER	REMARKS
0.0		Till Brown, silt till, moist	SS	55	11			
7'		Lacustrine Clayey Silt Brown clayey silt, odd grits, random very fine sand seams, fractured, rust fissures DTPL	SS	55	12			
			SS	22	12			
		Becoming grey and WTPL from 25'±						
33'		Till Brown silt till, stony, saturated.	SS	15	25		▲	Refusal to augers at 36.5'
			SS	77/9	4			
36.5		Cacitic Dolomite to Dolomite Light to dark grey; massively bedded; fossiliferous; well jointed 36.5'-40.0' and 45.5'-51.3'.	NX			94		
			NX			99		
51.3		Shale Dark grey; thinly bedded; calcareous zone 51.3'-56.0' and 78.0'-83.0'; porous 78.0'-83.0'.	NX			99	▲●	Discontinuity at 51.3'
			NX			100		
			NX			99		
			NX			98	●	
85.0		Borehole terminated at 85.0'						

LOG OF BOREHOLE 19-1R2

WSP

project | Walker Landfills
project no. | 131-22826-01
client | Walker Environmental Group
rig type | CME 75, track-mounted
date started | 2015/09/22
location | East Landfill Site
method | Hollow stem augers, 215 mm dia.
supervisor | LG
position |
coring | HQ core, OD=96mm, ID=64mm
reviewer | KJF

Elev Depth (m)	STRATIGRAPHY	Number	Type	SPT N-Value / Core Recovery	Lab Data and Comments
183.9	**GROUND SURFACE**				
	Brown with orange mottling, mottling becoming grey at 1.5m **SILT FILL**, clayey becoming trace clay at 1.5m, trace gravel, trace sand, APL becoming DTPL at 1.5m, firm becoming very stiff at 1.5m.	1	SS	7	
		2	SS	30	
181.9 / 2.0	Brown, becoming reddish brown at 4.6m, becoming reddish grey brown at 6.1m **CLAYEY SILT TILL**, occasional gravel becoming trace gravel at 3.2m, trace sand, DTPL becoming APL at 3.2m, becoming WTPL at 4.6m, stiff becoming firm at 4.6 m.	3	SS	19	
		4	SS	8	
		5	SS	7	
177.1 / 6.8	Light bluish grey fossiliferous Lockport Formation **DOLOSTONE**, with subtle grey banding, medium to coarse grained, medium to thick bedded, finely crystalline. 2% vugs up to 1 mm. Hard strong smooth core scratched with difficulty with a knife. Generally fresh appearance with broken core recovered to 7.0 m. Trace thin stylolytes, 1 to 2 per 2 metres. The core is noticeably darker in colour, less fossiliferous and finer grained below 11.6 m. Fair to excellent RQD. Sharp lower contact below greenish grey 15 cm glauconitic bed.	R1		TCR = 115%, RQD = 52%	Gasport and Goat Island members not positively distinguished from core .
		R2		TCR = 86%, RQD = 89%	Thin muddy infilling of fractures at 8.6 m, 8.9 m, 11.6 m, 12.0 m, 13.0 m
		R3		TCR = 104%, RQD = 97%	
		R4		TCR = 104%, RQD = 96%	6 mm to 8 mm vugs for 5cm at 11.6 m
		R5		TCR = 100%, RQD = 99%	
		R6		TCR = 105%, RQD = 100%	
169.0 / 14.9	Medium grey argillaceous Decew Formation **DOLOSTONE**, dull appearance, wavy bedding, excellent RQD, scratched by knife, barren, minor pyrite at 16.1 m associated with shaley parting. Gradational lower contact.	R7		TCR = 98%, RQD = 97%	2 cm calcareous nodule at 16.1 m
		R8		TCR = 102%, RQD = 100%	
166.4 / 17.5	Dark grey to black Rochester Formation **DOLOMITIC SHALE**, fine grained, thinly bedded, scratched easily with a knife. Trace fossils. Thin white gypsum partings 1 to 2 mm thick typically 1 per 0.3 m. Excellent RQD. Lighter grey fossiliferous and calcareous beds 0.1 m to 0.3 m thick below 24.7 m representing 40% to 50% of recovered core. Mud infilling of fractures at 22.8 m for 5 cm, and at 27.4 m for 3 cm.	R9		TCR = 98%, RQD = 100%	
		R10		TCR = 102%, RQD = 97%	
		R11		TCR = 100%, RQD = 95%	
		R12		TCR = 98%, RQD = 100%	
		R13		TCR = 102%, RQD = 100%	
		R14		TCR = 99%, RQD = 99%	
156.2 / 27.7	**END OF BOREHOLE**	R15		TCR = 112%, RQD = 0%	



Columns: Depth Scale (m) 0–27; Graphic Plot; Elevation Scale (mASL) 183–157; Water Content (%) & Plasticity (PL, MC, LL; 10 20 30); Water level on completion; PID Readings; Well Details; GRAIN SIZE DISTRIBUTION (%) (MIT) GR SA SI CL.

Unstabilized water level at 8.4 m below ground surface; borehole was open upon completion.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Sep 23, 2015	8.4	175.5
Sep 24, 2015	13.7	170.2

library: genivar - library.glb report: gen log v1 file: walker landfill ver1.gpj

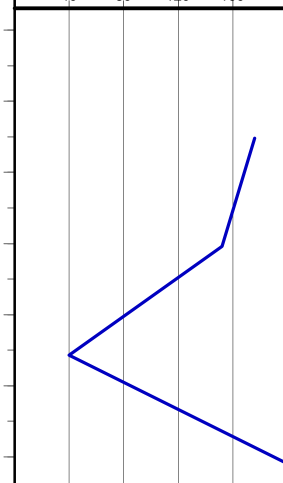
LOG OF BOREHOLE 40-1r

WSP

project |	South Landfill			**project no. |**	131-22826-01
client |	Walker Aggregates Inc.	**rig type |**	CME 75	**date started |**	2016/12/05
location |	Thorold, ON	**method |**	Rock coring	**supervisor |**	SK
position |		**coring |**	HQ core, OD=96mm, ID=64mm	**reviewer |**	KJF

SUBSURFACE PROFILE: Depth Scale (m); Elev Depth (m); STRATIGRAPHY; Graphic Plot
SAMPLE: Number; Type; SPT N-Value / Core Recovery
Elevation Scale (mASL)
Penetration Test Values (Blows / 0.3m) — Dynamic Cone: 10, 20, 30, 40
Undrained Shear Strength (kPa) — Unconfined; Field Vane; Pocket Penetrometer; Lab Vane: 40, 80, 120, 160
Water Content (%) & Plasticity — PL, MC, LL: 10, 20, 30
PID Readings
Well Details
Lab Data and Comments — GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

Elev / Depth (m)	Stratigraphy	Number	Type	SPT N-Value / Core Recovery	Lab Data and Comments
184.3	**GROUND SURFACE**				
	Brown **Fill**, silty clay to clayey silt with trace gravel, sand and wood, very hard, DTPL	S1	SS	44	
	...at 3.0 m, Reddish brown with trace red silt, firm to soft, ATPL to 3.7 m	S2	SS	38	
180.6 / 3.7	Grey **SILTY CLAY**, trace gravel, soft, ATPL	S3	SS	10	
		S4	SS	96	
177.6 / 6.7	*at 6.7m below grade*				
176.1 / 8.2; 174.6 / 9.7; 173.1 / 11.2; 171.8 / 12.5; 170.2 / 14.1; 168.6 / 15.7	Grey to light grey medium grained fossiliferous Gasport Formation **DOLOSTONE**, medium to thickly bedded. Hard core, scratched with difficulty with a knife. Light coloured crinoidal grainstone beds give the core a blotchy appearance. Reddish staining and red mud infilling to 7.9 m. Moderate RQD to 8.8 m then good to excellent RQD. Vuggy; up to 5% vugs typically 3 to 5 mm to 11.0 m. Shaley partings 2 mm to 6 mm thick, typically 5 per 1.5 m below 14.9 m.	5	R5	TCR = **100%**	
		6	R6	TCR = **100%**	
		7	R7	TCR = **100%**	Vertical fractures from 10.8 to 11.2 m
		8	R8	TCR = **100%**	
		9	R9	TCR = **100%**	Vertical fractures from 13.6 to 14.1 m
		10	R10	TCR = **100%**	
	...Sharp lower contact on change in texture	11	R11	TCR = **100%**	
167.1 / 17.2	Medium to dark grey, fine grained argillaceous Decew Formation **DOLOSTONE**, barren. The core displays wavy soft sediment deformation. ...Gradational lower contact on change in texture	12	R12	TCR = **98%**	
165.6 / 18.7; 164.1 / 20.2; 162.8 / 21.5	Dark grey, very fine grained Rochester Formation **DOLOMITIC SHALE**, with numerous, thin, lighter coloured, fine to medium grained bioclastic calcarenite beds up to 150 mm thick. Calcarenite beds represent 20% of the recovered core but increase to 50% below 35.3 m. Very poor RQD; core typically recovered at 25 mm pieces. Scratched easily with a knife.	13	R13	TCR = **100%**	
		14	R14	TCR = **100%**	
161.3		15	R15	TCR = **100%**	



(continued next page)

LOG OF BOREHOLE 40-1r

WSP

project | South Landfill **project no. |** 131-22826-01
client | Walker Aggregates Inc. **rig type |** CME 75 **date started |** 2016/12/05
location | Thorold, ON **method |** Rock coring **supervisor |** SK
position | **coring |** HQ core, OD=96mm, ID=64mm **reviewer |** KJF

Depth Scale (m)	Elev Depth (m)	STRATIGRAPHY *(continued)*	Number	Type	SPT N-Value / Core Recovery	Elevation Scale (mASL)	Well Details	Lab Data and Comments
22–23	161.3 / 23.0	Dark grey, very fine grained Rochester Formation **DOLOMITIC SHALE**, with numerous, thin, lighter coloured, fine to medium grained bioclastic calcarenite beds up to 150 mm thick. Calcarenite beds represent 20% of the recovered core but increase to 50% below 35.3 m. Very poor RQD; core typically recovered at 25 mm pieces. Scratched easily with a knife. *(continued)*	15	R15	TCR = **100%**	162		
23	23.3		16	R16	TCR = **100%**	161		
24	159.5 / 24.8		17	R17	TCR = **100%**	160		
25–26	157.9 / 26.4		18	R18	TCR = **100%**	159		
27	156.7 / 27.6		19	R19	TCR = **100%**	158, 157		
28–29	155.1 / 29.2		20	R20	TCR = **100%**	156		
30	153.5 / 30.8		21	R21	TCR = **100%**	155, 154		
31–32	151.9 / 32.4		22	R22	TCR = **100%**	153, 152		
33	150.4 / 33.9		23	R23	TCR = **100%**	151		
34–35	148.8 / 35.5		24	R24	TCR = **100%**	150, 149		
36	147.3 / 37.0		25	R25	TCR = **100%**	148		
37	146.9 / 37.4	...Sharp lower contact on change in colour and texture				147		
37–38	146.0 / 38.3	Light grey, medium to coarse grained, thickly bedded fossiliferous Irondequoit Formation **LIMESTONE**, reacts to H-Cl. Hard, strong core. Good to excellent RQD.	26	R26	TCR = **100%**	146	No. 10 sand, 50mm MW	No. 10 sand 50mm MW
38–39	145.1 / 39.2		27	R27	TCR = **100%**	145		
39	144.7 / 39.6	...Sharp lower contact on change in texture						
40	143.5 / 40.8	Light grey to light greenish grey, fine grained, thinly bedded Reynales Formation **DOLOSTONE**, poor RQD.	28	R28	TCR = **100%**	144		Light grey muddy infilling at 39.9 m

Penetration Test Values (Blows / 0.3m): × Dynamic Cone; 10, 20, 30, 40
Undrained Shear Strength (kPa): ○ Unconfined; + Field Vane; ● Pocket Penetrometer; ■ Lab Vane; 40, 80, 120, 160
Water Content (%) & Plasticity: PL, MC, LL; 10, 20, 30
PID Readings
GRAIN SIZE DISTRIBUTION (%) (MIT): GR SA SI CL

END OF BOREHOLE

50 mm monitoring well installed.
No. 10 screen installed.

WATER LEVEL MONITORING

Date	Depth (m)	Elevation (m)
Dec 6, 2016	9.0	175.4

BOREHOLE LOG

PROJECT NO. 87-347

BOREHOLE NO. 51-I

PROJECT NAME WALKER BROTHERS QUARRY EXPANSION HYDROGEOLOGICAL STUDY

CLIENT WALKER BROTHERS QUARRIES

DATE 88/02/05

GEOLOGIST D.C.F.

ELEVATION 184.7 m A.S.L.

DEPTH (m)	STRATIGRAPHIC DESCRIPTION
	CLAYEY SILT: Mottled, grey and reddish brown clayey silt with trace fine sand. Grey laminations at 1 to 5 mm intervals. D.P.T.L. becoming W.T.P.L. below 5 m. Very stiff to firm at depth.
5.8	DOLOSTONE: (Lockport Formation) Fine to medium grained dolostone. Grey, fossiliferous, medium to massive bedded, occasional fractures, minor clay seams (1-2 mm), minor vugs (1-5 mm) with calcite and gypsum infilling, vuggy (25 %) 8.8-9.1 m.

Columns: STRATIGRAPHY; MONITOR DETAILS & NUMBER: I; SAMPLE; PENETRATION RESISTANCE 'N' VALUE (BLOWS/0.3 m): 10 20 30 40; WATER CONTENT (%) W_p — W_l: 10 20 30 40

NO.	TYPE	'N' VALUE	% WATER
1	SS	13	23
2	SS	28	23
3	SS	25	25
4	SS	12	26
5	SS	6	36
6	SS	13	23
		REC	RQD
1	HQ	87	73
2	HQ	100	83
3	HQ	100	93

BOREHOLE LOG

PROJECT NO.	87-347
BOREHOLE NO.	51-I
PROJECT NAME	WALKER BROTHERS QUARRY EXPANSION HYDROGEOLOGICAL STUDY
DATE	88/02/05
GEOLOGIST	D.C.F.
CLIENT	WALKER BROTHERS QUARRIES
ELEVATION	184.7 m A.S.L.

DEPTH (m) 10	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS & NUMBER I	INTERVAL	SAMPLE NO.	TYPE	RECOVERY	RQD	PENETRATION RESISTANCE 'N' VALUE (BLOWS/0.3 m)	WATER CONTENT (%) W_p — W_l
	DOLOSTONE: (Lockport Formation) -continued									
					4	HQ	100	100		
					5	HQ	100	100		
					6	HQ	100	95		
					7	HQ	100	88		
					8	HQ	100	100		
					9	HQ	100	98		
19.4	DOLOSTONE: (Decew Formation) - description over				10	HQ	100	97		

BOREHOLE LOG

PROJECT NO. 87-347

BOREHOLE NO. 51-I

PROJECT NAME WALKER BROTHERS QUARRY EXPANSION HYDROGEOLOGICAL STUDY

DATE 88/02/05

GEOLOGIST D.C.F.

CLIENT WALKER BROTHERS QUARRIES

ELEVATION 184.7 mASL

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS & NUMBER	SAMPLE INTERVAL	SAMPLE NO.	SAMPLE TYPE	SAMPLE RECOVERY	SAMPLE RQD	PENETRATION RESISTANCE 'N' VALUE (BLOWS/0.3 m)	WATER CONTENT (%) W_p — W_l
20	Fine crystalline argillaceous dolostone. Dark grey, massive bedded, conchoidal fracture.		I							
20.8	SHALE: (Rochester Formation) Aphanitic Shale, dark grey, thinly bedded (1-10 mm) platy, calcareous interbeds of siltstone and shale (5-30 cm)				11	HQ	100	92		
					12	HQ	100	100		
					13	HQ	100	100		
	MONITOR 51-I IS CONSTRUCTED OF TEFLON									
					14	HQ	100	100		
26.8	HQ core hole terminated 26.8 m into shale.		P							

BOREHOLE LOG

PROJECT: 90-115

BOREHOLE: 55-I

Walker Brothers Quarry Expansion Study
Thorold, Ontario
FOR: Walker Brothers Quarries Limited

DATE: 31 July 1990
GEOLOGIST KTH
ELEVATION 177.87 m ASL

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	SAMPLE NUMBER	TYPE	N VALUE	% WATER	% REC	% RQD
17	Medium to dark grey, very finely to finely crystalline, medium to massive bedded dolostone. Locally highly fossiliferous, dense to weakly porous, occasional shaly stringers, styolites. Highly fossiliferous, shaly from about 15.1 m to 16.5 m.						
18–19	Laminated calcareous siltsone, possibly conglomeratic from about 18.2 m to 21.6 m.	13	HQ			97	93
20	(Gasport Member - continued)						
21.6	Contact gradational.	14	HQ			98	83
22–23	**DOLOSTONE** (Decew Formation) Dark brownish-grey, very finely crystalline, medium to massive bedded argillaceous dolostone. Dense, occasional shaly stringers, gypsum seams.						
23.6	Contact gradational.						
24–25	**SHALE** (Rochester Formation) Dark grey to black, thin to medium bedded calcareous shale to siltstone with interbeds of fossiliferous limestone. Occasional clay seam. Clean, highly fossiliferous limestone from about 24.5 m to 24.7 m.	15	HQ			100	57
26	Sulfurous gas encountered at about 26.5 m.						
28		16	HQ			100	53
29–30	Weathered zone from about 29.6 m to 30.3 m.						
30	Fossiliferous limestone, locally porous from about 30.2 m to 30.7 m.						
31.2							
	Borehole terminated at 31.16 m in shale.						

Printed: 11 SEP 90

Gartner Lee Limited

BOREHOLE LOG

PROJECT: 90-115

BOREHOLE: 55-II

Walker Brothers Quarry Expansion Study
Thorold, Ontario
FOR: Walker Brothers Quarries Limited

DATE: 1 August 1990
GEOLOGIST KTH
ELEVATION 177.89 m ASL

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	SAMPLE NUMBER	TYPE	N VALUE	% WATER	% REC	% RQD
0	**CLAYEY SILT** Medium brown clayey silt, some very fine to fine sand, weakly laminated, reddish-brown mottling, blue clay-infilled horizontal and vertical partings, DTPL, stiff to very stiff, rootlets to about 1.4 m.						
	WTPL from about 3.5 m.						
	Soft to firm from about 4.9 m						
	Reddish-brown sandy silt with greyish clayey silt from about 5.5 m.						
6.2	**SILTY SAND TILL** Reddish-brown silty sand, some fine to coarse gravel, trace clay, massive, moist to wet, loose to compact.						
7.2	**DOLOSTONE** (Lockport Formation - Goat Island Member) Medium grey, very finely crystalline, thin to thick bedded argillaceous dolostone. Dense, occasional shaly stringer, locally vuggy with gypsum and sphalerite infilling. Occasional chert nodule.	1	HQ			97	68
		2	HQ			100	63
		3	HQ			98	83
	Contact gradational.						
15.1	**DOLOSTONE** (Lockport Formation - Gasport Member)	4	HQ			100	83

Columns also include: STRATIGRAPHY; MONITOR DETAILS & NUMBER (II); INTERVAL; RECOVERY (%) (25 50 75 100); RQD (%) (25 50 75 100).

Gartner Lee Limited

Hole No. C-2

Location: 20,437·1 feet N., 9,709·3 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 546·7 feet — Depth of overburden: 47·6 feet
Total depth: 290·6 feet — Drilled: Sept., 1949
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
47·6-48·8	Core missing
48·8-53·6	Dolomite; calcareous, brownish grey, non-petroliferous, granular
	Gasport Member
53·6-57·2	Limestone; dark grey, dense, crinoidal
57·2-60	Limestone; dark grey, stylolitic, porous
60 -67·6	Limestone; light grey, slightly denser, crinoidal; gypsum
67·6-75·7	Limestone; light grey, crystalline, crinoidal
	DeCew Formation
75·7-87	Dolomite; dark grey, dense; slightly argillaceous 80-81 feet
	Rochester Formation
87 -105·8	Shale; calcareous, grey
105·8-107	Limestone; grey; minor shale; Bryozoa
107 -141·3	Shale; black, fissile; thin limestones at 107·4-107·6, 109·6-109·7, 115·5-115·8, 120·1-120·3, 137·3, 138·4, 139·5, 140 feet
141·3-143·6	Limestone; grey, thin shale partings; Bryozoa
	Irondequoit Formation
143·6-149·7	Limestone; white, light grey, crystalline; grey increasing in the upper 1·7 feet; *Parmorthis elegantula* (Dalman), *Bumastus ioxus* (Hall), *Calymene niagarensis* (Hall) at 144·4 feet
149·7-151·4	Limestone; grey, denser
	Reynales Formation
151·4-161	Limestone or dolomite; light grey, dense; upper contact sharp lithological break; grey shale partings at 155·1-155·3, 158·5, 159·7, 160·6 feet
161 -163·3	Dolomite; argillaceous; Bryozoa
	Neahga Formation
163·3-168·2	Shale; fissile, greenish black
	Thorold Formation
168·2-172·8	Sandstone; light grey to white, very fine; rare shale bands, widest at 171·9-172 feet; thin section at 172·6 feet shows finely medium-grained, dusty to clear (secondary) quartz; accessories, zircon, biotite, magnetite, carbonate, apatite, microcline, albite (?), and collophane

Hole No. C-2—*Continued*

Depth	Lithology
Feet	
	Grimsby Formation
172·8-173	Sandstone; argillaceous, green
173 -173·4	Shale; red
173·4-176	Sandstone; white to light grey, very fine grained
176 -176·4	Shale; red and green
176·4-176·7	Sandstone; greenish grey
176·7-176·9	Shale; red
176·9-177·1	Sandstone; red
177·1-177·4	Shale; red
177·4-177·5	Sandstone; red
177·5-177·9	Shale; red
177·9-180·5	Sandstone; red and greenish grey
180·5-183·4	Shale and sandstone; red
183·4-185·6	Sandstone; red
185·6-187·7	Sandstone; red; green shale fragments at 185·7 and 185·8 feet
187·7-188·1	Shale; red
188·1-191·2	Sandstone; red
191·2-191·4	Shale; red
191·4-192·7	Sandstone; red
192·7-193	Shale; red
193 -194	Sandstone; red; red shale fragments
194 -194·2	Shale; red
194·2-196	Sandstone to siltstone; red; shale partings
196 -196·3	Shale; red
196·3-199·5	Sandstone; red and green; shale pellets at 197·9 feet
199·5-199·8	Shale; red
199·8-200·1	Sandstone; red and green
200·1-200·8	Shale; red
200·8-203·1	Sandstone; red and greenish grey
203·1-204·5	Shale; red
204·5-205·1	Sandstone; red
205·1-206	Shale; red, green mottled
206 -208·2	Sandstone; red and green
208·2-209·2	Shale; red
209·2-209·6	Sandstone; red
209·6-211·6	Shale; red
211·6-213·7	Shale and sandstone; red
213·7-214·6	Shale; red
214·6-215·2	Sandstone; red, fine grained
215·2-218·5	Shale and sandstone; red and green
218·5-219·4	Interbedded sandstone and shale; red and green; a few shale pellets
	Power Glen Formation
219·4-220	Sandstone; minor shale; black shale fragments and iron stains near upper contact
220 -221·4	Sandstone; white, hard, intact
221·4-226·8	Shale and thin sandstone bands
226·8-230·1	Sandstone; calcareous; shale partings and fragments
230·1-230·6	Shale; grey
230·6-230·7	Sandstone; calcareous
230·7-232·4	Shale; grey
232·4-246	Shale; minor sandstone
246 -248·6	Sandstone; whitish grey, calcareous; many thin shale partings
248·6-251·9	Shale; minor sandstone

HOLE NO. C-2—*Continued*

Depth	Lithology
Feet	*Power Glen Formation*—Continued
251·9-252·3	Sandstone; whitish grey, fine grained, calcareous
252·3-252·7	Shale; sandy, calcareous
252·7-254·2	Sandstone; calcareous, whitish grey, fine grained
254·2-255·7	Shale; fissile, grey; minor sandstone
	Whirlpool Formation
255·7-284·1	Sandstone; whitish grey, fine grained; red sandstone at 277-278·1 feet and at various horizons down to 281 feet; grey shale pellets at 261·5, 270·6 273, 273·9-274·6, 279·5, 282·8 feet

Hole No. D-1

Location: 19,748·8 feet N., 10,109·9 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 554·5 feet — Depth of overburden: 37·8 feet

Total depth: 291·4 feet — Drilled: Sept., 1949

Core logged by T. E. Bolton, 1950.

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
37·8-51·8	Dolomite; reddish grey to grey, granular; gypsum and calcite-filled vugs; lower contact arbitrary, Gasport may extend up to 41·5 feet
	Gasport Member
51·8-73·8	Limestone; light grey, crystalline, crinoidal; denser and dolomitic in upper 3 feet
	DeCew Formation
73·8-82·9	Dolomite; dark grey to chocolate, dense; upper contact sharp lithological break
	Rochester Formation
82·9-137	Shale; dark grey; minor limestone beds; Bryozoa beds at 87·4, 89·1, 103·2-104·8, 105·2, 106·8-106·9 feet; slightly more calcareous in upper 22 feet
137 -141	Shale and limestone interbedded; shale increasing upward; limestone beds up to 0·4 foot thick, filled with Bryozoa

HOLE NO. D-1—*Continued*

Depth	Lithology
Feet	
	Irondequoit Formation
141 -149·6	Limestone; pinkish grey, finely crystalline, argillaceous in upper ½ foot; thin shale parting at 141·4 feet; *Atrypa reticularis* (Linnaeus), and *Whitfieldella intermedia* (Hall) at 141·2 feet
	Reynales Formation
149·6-161·6	Dolomite; dark grey, dense; three shale partings; Crinoidea and Bryozoa produce mottled appearance in basal 2 feet
	Neahga Formation
161·6-166·8	Shale; dark grey, fissile; basal 0·2 foot small lenticular shale fragments cemented by pyrite and sand; lower contact undulating, possible unconformity; upper contact sharp lithological break
	Thorold Formation
166·8-172·9	Sandstone; whitish grey, very fine grained; grey shale partings at 169·8, 171·3-171·5 feet
	Grimsby Formation
172·9-195·3	Sandstone; red, green mottled, fine grained; eight 0·1-foot-thick red shale partings; upper contact in sandstone marked by simple colour change, and green shale pellets
195·3-196	Shale and siltstone; red
196 -197·1	Sandstone; red and greenish grey
197·1-197·7	Siltstone; red, green mottled
197·7-201	Sandstone; red and green, finely crossbedded
201 -202·4	Shale and sandstone; red
202·4-203·5	Sandstone; reddish grey
203·5-204·4	Shale; red
204·4-205·6	Sandstone; greenish red
205·6-207·2	Sandstone and shale; red
207·2-207·5	Sandstone; finely bedded, light red, fine grained
207·5-212·1	Shale; red, green mottled; minor sandstone
212·1-212·9	Sandstone; red
212·9-213·6	Core missing
213·6-214·4	Shale; red
214·4-215	Sandstone; red
215 -217·8	Shale; red; black shale pellets
	Power Glen Formation
217·8-218·4	Sandstone; light grey; grey shale pellets concentrated in upper 0·2 foot; *Strophonella* sp. cf. *S. striata* (Hall) at 218·4 feet
218·4-219	Sandstone; dark red; red shale pellets
219 -219·5	Sandstone; light grey
219·5-220	Shale; grey
220 -220·7	Sandstone; buff, finely crossbedded

HOLE NO. D-1—*Continued*

Depth	Lithology
Feet	
	Power Glen Formation—Continued
220·7-225·3	Shale; grey; thin calcareous sandstone beds
225·3-230·6	Sandstone; whitish grey, fine grained, impure; many shale partings
230·6-244·4	Shale and sandstone; dark grey, latter increasing in upper 2½ feet; small-scale crossbedding at 231·3-231·4 feet
244·4-250·6	Shale; grey; minor calcareous sandstone beds
250·6-253	Sandstone; dark grey, very fine grained; possibly Whirlpool formation
253 -254·1	Shale and sandstone; grey
	Whirlpool Formation
254·1-282·6	Sandstone; quartzose, white to whitish grey, fine to medium grained; coarser at base; finely banded by heavy minerals; grey shale partings at 258·2-258·3, 268·6-268·7 feet; reddish tinged from 273·3-280 feet; thin section at 254·8 feet shows coarsely medium-grained, angular to subangular, compact (secondary) quartz (99%); accessories, carbonate, zircon, leucoxene, and microcline; thin section at 282·2 feet shows coarse-grained, very compact, subrounded to subangular quartz, some corroded by interstitial carbonate; accessories, pyrite, chlorite, collophane, and zircon
	Queenston Formation
282·6-292·6	Shale and siltstone; red, green mottled

Hole No. D-3

Location: 17,883·7 feet N., 10,886·2 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 551·6 feet — Depth of overburden: 53·5 feet

Total depth: 304·3 feet — Drilled: October, 1949

Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	*Lockport Formation*
	Goat Island Member
53·5-70·3	Dolomite; dark grey to brownish grey, dense to granular; rare bituminous partings in upper part; rare crinoids in basal 9 feet; chert band at 56·2 feet
	Gasport Member
70·3-94·4	Limestone; light grey to pinkish grey, crinoidal; numerous stylolites; upper contact gradual lithological change

HOLE NO. D-3—*Continued*

Depth	Lithology
Feet	
	DeCew Formation
94·4-102·6	Dolomite; dark grey to chocolate, dense; rare shale partings; upper contact sharp lithological break
	Rochester Formation
102·6-121·1	Shale and siltstone; black; rare calcareous beds in upper 2 feet; upper contact placed where shale ends
121·1-123·2	Limestone; dark grey, with Bryozoa; thin shale partings
123·2-153·6	Shale; blackish grey with minor silty to sandy partings
153·6-160·1	Shale; grey; numerous Bryozoa and Crinoidea in thin (0·2-foot) limestone beds
	Irondequoit Formation
160·1-168·5	Limestone; whitish grey, crystalline; upper 6 inches argillaceous; *Atrypa reticularis* (Linnaeus), cf. *Fardenia subplana* (Conrad) at 161·5 feet; *Favosites* sp. at 166·4-167·5 feet (reef)
	Reynales Formation
168·5-181·4	Dolomite; dark (basal 2·5 feet) to light grey, dense; some thin shale partings, particularly in basal dark, fossiliferous dolomitic limestone band; upper contact simple lithological change; thin section at 171·8 feet shows very fine-grained, euhedral to semi-euhedral, compact carbonate; rare larger euhedral carbonate surrounded by fine anhedral carbonate and associated with clumps of interstitial pyrite
	Neahga Formation
181·4-186·8	Shale; fissile, black
	Thorold Formation
186·8-197·5	Sandstone; quartzose, light grey, fine grained; basal 0·8 foot mottled by black shale; greenish grey shale partings at 190·5, 191·3-191·4, 192·2-193·1 feet; upper 0·3 foot transitional
	Grimsby Formation
197·5-198·5	Shale; red, green in upper 0·1 foot
198·5-226·5	Sandstone; massive, red, green mottled; minor silty bands at 202·2, 203·6-203·8, 206·1-206·3 feet
226·5-228·2	Shale; red; minor red sandstone
228·2-228·5	Sandstone; red to greenish grey
228·5-235·6	Shale; red; minor green mottled interbedded sandstone
235·6-236·1	Sandstone; red
236·1-238·6	Shale; red; minor sandstone
238·6-239·3	Sandstone; dark grey to red
239·3-240·3	Shale; red
240·3-243·2	Sandstone; red and grey
243·2-243·9	Siltstone; red; lower contact sharp colour change only

HOLE NO. D-3—*Continued*

Depth	Lithology
Feet	
	Power Glen Formation
243·9-244·1	Siltstone; green
244·1-246·4	Shale; grey; minor sandstone bands
246·4-252·7	Sandstone and shale interbedded; reddish mottled
252·7-253·3	Shale; grey
253·3-254·7	Sandstone and shale interbedded
254·7-256	Sandstone; white, light grey, fine grained
256 -267	Shale and siltstone
267 -270·5	Siltstone with interbedded grey, calcareous sandstone; thin section at 270·5 feet shows very fine-grained, angular to subangular quartz (90%) with varying thicknesses of interstitial carbonate (8%); accessories, chlorite (1%), pyrite, zircon, plagioclase, and leucoxene
270·5-273	Shale; grey; two limestone bands
273 -274·1	Sandstone; whitish grey, very fine grained
274·1-274·5	Siltstone; grey
274·5-275·3	Sandstone; white, very fine grained, calcareous; thin section at 275·3 feet shows fine-grained, subangular to subrounded, clear and dusty quartz (80%) with interstitial carbonate (19%) grains and patches; accessories, pyrite (in carbonate), chlorite, biotite, (rounded grains), zircon (rounded grains), andesine, rutile (rounded), magnetite, and leucoxene
275·3-276·1	Shale to siltstone; grey
276·1-279·4	Sandstone; white, fine grained
279·4-279·9	Shale; grey
	Whirlpool Formation
279·9-297·7	Sandstone; quartzose, whitish grey, fine grained; coarser at the base; shale pellet bands at 285·6-286, 289·4-289·7, 290-290·2, 291·2-291·5 feet; some thin shale partings in upper beds; upper contact where grey shale first predominates; thin section at 280·5 feet shows finely medium-grained, dusty and clear, compact (secondary) quartz (98%); rare quartz aggregates; accessories, microcline, andesine, carbonate (1%), collophane, chlorite, magnetite, leucoxene, zircon, biotite, and rutile; thin section at 287·2 feet shows finely medium-grained, subangular to subrounded, clear and dusty quartz (98%); a few quartz aggregates; accessories, zircon, albite, andesine, carbonate, chlorite, augite, apatite, collophane, magnetite, and leucoxene
	Queenston Formation
297·7-305·1	Shale; red and green; upper 0·1 foot green

Hole No. E-2

Location: 11,846·2 feet N., 10,970·3 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.) Stamford tp., Welland co.
Elevation bedrock: 546·2 feet — Depth of overburden: 63·8 feet
Total depth: 339·8 feet — Drilled: Nov., 1949
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Lockport Formation
	Eramosa Member
63·8-65	Core missing
65 -71·5	Dolomite; chocolate-brown; bituminous partings; strong petroliferous odour
	Goat Island Member
71·5-87·8	Dolomite; dark grey to chocolate-grey, dense to granular; chert at 72·6, 72·8-72·9 feet; few crinoids; some gypsum bands up to 0·1 foot thick; rare bituminous partings in upper part

HOLE NO. E-2—*Continued*

Depth	Lithology
Feet	
	Lockport Formation—Continued
	Gasport Member
87·8-130·7	Limestone; basal 5·4 feet, light grey, crystalline, crinoidal; remainder light grey, semicrystalline to dense; crinoids less abundant; calcite and gypsum; typical basal conglomerate in lower 3 feet, concentrated in basal 1 foot
	DeCew Formation
130·7-140	Dolomite; dark grey, dense; occasionally chocolate coloured; lower contact transitional; upper contact wavy
	Rochester Formation
140 -156·6	Shale; calcareous, grey
156·6-157·9	Interbedded limestone, light pinkish grey, and shale, grey
157·9-194·3	Shale and siltstone; dark grey
194·3-195·6	Interbedded limestone, light grey, fossiliferous, dense, and shale, dark grey
	Irondequoit Formation
195·6-205·6	Limestone; white to light grey, crystalline; upper contact transitional; *Eospirifer niagarensis* (Conrad) at 198 feet; *Plectodonta transversalis* (Wahlenberg) at 198·7 feet; *Atrypa reticularis* (Linnaeus) at 198, 199·9 (large), 200·3, 201·8 feet
	Reynales Formation
205·6-218·8	Dolomite; light to dark grey, dense to semicrystalline; grey shale at 206·6, 209·7-209·9 feet; upper contact slightly wavy; coarse fossiliferous limestone with three thin shale partings in basal 2½ feet
	Neahga Formation
218·8-224	Shale; fissile, dark grey
	Thorold Formation
224 -233·6	Sandstone; quartzose, white; shale bands at 225·5-226·3 (silty), 227·3-228·3 (silty), 228·6-228·8, 231·4, 231·9-232·1 feet
	Grimsby Formation
233·6-234·6	Sandstone; dark red; green shale pellets at 234·2 feet
234·6-234·9	Shale; red
234·9-242·3	Sandstone; red to greenish grey; shale partings
242·3-242·7	Shale; red
242·7-242·9	Sandstone; red
242·9-243·4	Shale; red
243·4-243·9	Sandstone; red

HOLE NO. E-2—*Continued*

Depth	Lithology
Feet	
	Grimsby Formation—Continued
243·9-244·2	Shale; red
244·2-244·6	Sandstone; red
244·6-245·1	Shale; red
245·1-245·8	Sandstone; red
245·8-246·3	Shale and sandstone interbedded; red
246·3-255·7	Sandstone; whitish grey to red; thin section at 246·7 feet shows fine-grained, anhedral, clear and dusty quartz (99%); secondary quartz forms compact sandstone; accessories, albite-oligoclase, microcline, chlorite, biotite-muscovite, zircon, and leucoxene
255·7-256·1	Shale; red
256·1-262·7	Sandstone; red; shale partings
262·7-263·1	Shale; red
263·1-265	Sandstone; red, rare shale partings
265 -266·4	Shale; red
266·4-267·3	Sandstone; red
267·3-268·5	Shale; red, 0·1 foot sandstone bed at 267·5 feet
268·5-269·4	Sandstone; red, fine grained
269·4-270·5	Shale; red
270·5-271·7	Shale and sandstone interbedded; red
271·7-272·9	Shale; red
272·9-275·5	Sandstone; argillaceous, red; lower contact simple colour change
	Power Glen Formation
275·5-284·1	Sandstone; quartzose, whitish grey, medium grained; thin grey shale partings
284·1-285·8	Shale and thin sandstones interbedded; grey
285·8-295	Sandstone; quartzose, white, fine grained; grey shale partings; upper 2½ feet coarser
295 -312·7	Shale; dark grey; a few sandstone beds with fine crossbedding; core missing 297·2-300·6 feet
312·7-316·2	Sandstone; argillaceous, calcareous, dark grey; lower contact placed where argillaceous material first appears; thin section at 315·1 feet shows medium-grained, angular to subangular, clear and dusty, quartz (95%) well separated by interstitial carbonate (4½%); accessories, chlorite, pyrite, zircon, apatite, microcline, and albite-oligoclase
	Whirlpool Formation
316·2-337·2	Sandstone; quartzose, white, fine grained, finely bedded; rare shaly partings; coarser grained in basal 5 feet; thin section at 320·9 feet shows mediumly fine- to fine-grained, subangular, dusty to clear (secondary) quartz (99%); a few small quartz aggregates; accessories, carbonate, chlorite, collophane, zircon, plagioclase, biotite, apatite, leucoxene, and tourmaline (?)
	Queenston Formation
337·2-338	Shale; red, green in upper 0·25 foot

Hole No. E-8

Location: 2,604·3 feet N., 6,922·2 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 541·6 feet — Depth of overburden: 6·9 feet

Total depth: 162·4 feet — Drilled: Nov., 1949

Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Guelph Formation
6·9-8	Core missing
8 -34·5	Dolomite; chocolate-brown, granular; *Favosites* sp. abundant in top porous 5 feet
34·5-67·1	Dolomite; chocolate-brown, granular to semicrystalline; bryozoans and *Favosites* sp. dotted throughout, *Favosites niagarensis* Hall at 46·2-46·8, 46·9 and 47·1 feet
	Lockport Formation
	Eramosa Member
67·1-93	Dolomite; chocolate-brown to brownish grey, fine grained, porous; bituminous, petroliferous odour
	Goat Island Member
93 -118·9	Dolomite; chocolate-brown, granular to dense; basal ½ foot calcite blebs
118·9-125·6	Limestone; light whitish grey, crystalline; vertical jointing

Hole No. E-8—*Continued*

Depth	Lithology
Feet	
	Gasport Member
125·6-129·3	Dolomite; brownish grey to dark grey, dense; transitional phase
129·3-143·3	Limestone; light whitish grey to grey, crystalline; rare argillaceous material and stylolites; lower contact sharp lithological break; fine conglomerate in basal 0·2 foot
	DeCew Formation
143·3-151·7	Dolomite; light grey to brown, dense
	Rochester Formation
151·7-213·3	Shale; dark grey to black and fossiliferous limestone in basal 5 feet; central part calcareous shale with numerous thin fossiliferous limestone bands or lenses; upper 10 to 20 feet sandy dolomitic shale; *Atrypa reticularis* (Linnaeus) and *Whitfieldella intermedia* (Hall) at 212·7 feet
	Irondequoit Formation
213·3-221·3	Limestone; light grey to white, crystalline; argillaceous upper 0·7 feet; lower and upper contacts sharp lithological breaks; *Eospirifer niagarensis* (Conrad) at 213·6 feet, *Plectodonta transversalis* (Wahlenberg) and *Plectatrypa nodostriata* Hall at 214·2 feet, *A. reticularis* (Linnaeus) at 213·6, 215·4, 216·1, 220·1, 220·3 feet
	Reynales Formation
221·3-231·4	Dolomite; light to dark grey, somewhat argillaceous, dense
231·4-234·3	Dolomite; dark grey, fine grained with thin shale bands of varying thickness; some pyrite; crinoid stems, *Enterolasma* sp. at 232 feet; pyritized *Fenestrellina* sp. at 233·6 feet, *Eospirifer niagarensis* (Conrad) at 234 feet
	Neahga Formation
234·3-239·3	Shale; dark blackish grey, fissile
	Thorold Formation
239·3-248·3	Sandstone; quartzose, white to light grey, fine grained; green shale bands at 240·6-240·9, 241·2, 241·8-241·9, 242-242·2, 242·8-243 feet; lower contact sharp; upper contact transitional from 239·1-239·3 feet
	Grimsby Formation
248·3-248·6	Shale; green
248·6-249·6	Sandstone; green, fine grained
249·6-263·5	Shale; red with a few 0·2-foot thick, green, very fine-grained sandstone bands

Hole No. E-18

Location: 15,998·7 feet N., 10,819·1 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 567·3 feet — Depth of overburden: 70·9 feet

Total depth: 311·2 feet — Drilled: March, 1950

Core logged by T. E. Bolton, 1951

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
70·9-74·3	Core missing
74·3-83	Dolomite; buff-grey, porous, sugary
83 -92·5	Dolomite; light buff-grey, finely crystalline
92·5-95·4	Dolomite; buff, sugary
95·4-106·2	Dolomite; buff-grey to light grey, finely crystalline; grey shale partings in basal 1 foot; rare crinoid stems
	Gasport Member
106·2-123·9	Limestone; grey, porous, crystalline; crinoidal, stylolitic; upper contact transitional; lower contact sharp with 0·1-inch-thick basal conglomerate
	DeCew Formation
123·9-133·3	Dolomite; buff to dark grey, dense; lower contact arbitrary
	Rochester Formation
133·3-188·6	Shale; calcareous, dark grey, massive in upper 6 feet; bryozoan limestone at 151·4-152, 152·2, 152·6-152·7, 153·8-154, 154·5, 155·6, 185·7, 186, 186·4-186·7, 187·9-188, 188·1-188·2 feet
188·6-191·4	Limestone with minor shale interbedded; lower contact transitional from argillaceous limestone to pure limestone; Bryozoa
	Irondequoit Formation
191·4-200·3	Limestone; whitish grey, porous, crystalline; basal 1 foot fine grained; *Parmorthis elegantula* (Dalman) at 192·6 feet, *Plectatrypa nodostriata* Hall at 192·8 feet
	Reynales Formation
200·3-210	Dolomite; dark grey to buff-grey, dense; greenish grey shale at 200·3, 201·5, 203·6, 206·2, 207·4, 208·1 feet
210 -212·3	Limestone; grey, coarsely crystalline, fossiliferous; basal 1·5 inches phosphatic; greenish grey shale at 210·7, 210·9, 211·1, 211·5, 211·7, 211·9-212 feet
	Neahga Formation
212·3-217·9	Shale; black, fissile; basal ½ foot calcareous dense limestone; lower contact sharp, slightly undulating

HOLE No. E-18—*Continued*

Depth	Lithology
Feet	
	Thorold Formation
217·9-225	Sandstone; white to greenish, fine grained; top ½ foot and bottom 1½ feet dark green argillaceous sandstone
	Grimsby Formation
225 -272·6	Sandstone; red, green to yellowish green, fine grained; red shale at 233·2-233·4, 235·5-235·9, 237-237·3, 237·5, 241·1-241·4, 241·9-242·1, 243·2, 243·3-243·4, 244-244·1, 249·1-249·3, 249·8-250, 258·2-258·3, 259·3, 259·7-260, 262·1-262·9, 264·1-264·4, 265·7-266·2, 271·8-272·5 feet
	Power Glen Formation
272·6-273	Sandstone; grey, and shale, green, interbedded
273 -278·9	Shale; grey, with sandstone at 275-275·2 feet
278·9-283·4	Sandstone; whitish grey, very fine grained; numerous grey shale partings
283·4-297·4	Limestone; grey, coarse; phosphatic blebs; *Helopora fragilis* Hall and *Lingula* cf. *cuneata* Conrad at 295·8 feet
297·4-303·7	Shale; calcareous, dark grey
303·7-306·8	Shale; grey, and sandstone interbedded
	Whirlpool Formation
306·8-317·4	Sandstone; light grey, fine grained; grey shale blebs and partings in upper 1 foot

HOLE No. E-19

Location: 3,457·5 feet N., 8,491·8 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 501·4 feet — Depth of overburden: 36·0 feet

Total depth: 162·6 feet — Drilled: March, 1950

Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Guelph Formation
36 -57·3	Dolomite; chocolate-grey, sugary with bituminous partings in lower part; some gypsum; crinoids at 53·4 feet; upper 5 feet dark chocolate-brown, very sugary, true Guelph dolomite
57·3-65·8	Dolomite; porous, chocolate to light brown, fossiliferous; selenite at 64·6 feet

HOLE NO. E-19—*Continued*

Depth	Lithology
Feet	
	Lockport Formation
	Eramosa Member
65·8-72·8	Dolomite; light brown, granular; bituminous, petroliferous odour
	Goat Island Member
72·8-97·9	Dolomite; light brown to brownish grey, granular; rare chert in lower part
97·9-106·9	Dolomite; brownish grey, sugary; some gypsum
	Gasport Member
106·9-110	Dolomite; light brown, granular; much gypsum
110 -116·2	Dolomite; dark grey to buff-grey, granular; gypsum at 110·4-110·8, 111·3, 111·6, 111·9-112, 113·5 feet; this and the above unit may belong to the Goat Island member
116·2-128·6	Limestone; dolomitic, whitish grey, crystalline; crinoidal
	DeCew Formation
128·6-136	Dolomite; dark grey to brownish grey, granular
	Rochester Formation
136 -149·9	Shale; calcareous; bryozoan beds at 149·4-149·5, 149·8-149·9 feet
149·9-190	Shale with minor thin calcareous bands
190 -194·4	Shale; grey with fossiliferous limestone beds
	Irondequoit Formation
194·4-204·7	Limestone; pinkish grey, crystalline; dolomitic pebbles at 204·4 feet; upper contact sharp; *Atrypa reticularis* (Linnaeus) at 194·7, 195·6, 199·7 feet
	Reynales Formation
204·7-218·5	Limestone; basal 3½ feet with Brachiopoda and shale partings; remainder light grey, dense dolomite; shale band at 209·5-209·6 feet; upper contact undulating
	Neahga Formation
218·5-223·2	Shale; black, fissile; shale pebbles in basal 0·2 foot
	Thorold Formation
223·2-232·5	Sandstone; light grey, very fine grained; grey shale at 224·6-224·9 feet; upper 0·5 foot calcareous sandstone, may be basal Neahga

HOLE NO. E-19—*Continued*

Depth	Lithology
Feet	
	Grimsby Formation
232·5-233·1	Shale; red; upper 0·2 foot green siltstone
233·1-239·1	Sandstone; red and green, fine grained; a few shale partings
239·1-239·8	Shale; red
239·8-241·1	Sandstone; red, fine grained
241·1-241·5	Shale; red
241·5-241·7	Sandstone; green
241·7-243·4	Shale; red
243·4-255·4	Sandstone; red, green mottled
255·4-256	Shale; red
256 -258·1	Sandstone; red and green, two shale partings
258·1-258·3	Shale; red
258·3-261·2	Sandstone; red and green
261·2-264	Shale and siltstone; red

Hole No. E-29

Location: 6,823·7 feet N., 10,898·0 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 573·9 feet — Depth of overburden: 68·7 feet
Total depth: 395·3 feet — Drilled: Jan.-Feb., 1951
Core logged by T. E. Bolton, 1951

Depth	Lithology
Feet	
	Guelph Formation
68·7-120·8	Dolomite; buff-grey to dark grey, porous, sugary; crowded with large and small colonies of *Favosites niagarensis* Hall; basal 5 feet denser and fewer corals; lower contact sharp lithological break
	Lockport Formation
	Eramosa Member
120·8-129·5	Dolomite; buff to dark grey, sugary, a few bituminous partings; strong petroliferous odour in upper 5 feet
	Goat Island Member
129·5-139·8	Dolomite; buff-grey, porous, crystalline; abundant calcite-filled vugs
139·8-179·6	Dolomite; buff-grey, dense to sugary; bituminous partings, scattered calcite seams; chert nodules at 140·8, 142·1, 142·2, 144-144·2, 146·7 feet; indeterminable Stromatoporoidea at 153·6 and 153·9 feet
	Gasport Member
179·6-186·7	Limestone; light grey, medium grained
186·7-188	Dolomite; greenish grey, very fine grained
188 -191·6	Dolomite; buff-grey, sugary; Eramosa-like
191·6-197·5	Limestone; light grey, finely crystalline; rare bituminous partings; lower contact sharp; no conglomerate noted; not typical Gasport facies
	DeCew Formation
197·5-207	Dolomite; dark buff-grey, sugary
	Rochester Formation
207 -243·9	Shale; calcareous, dark grey; limestone bands, dark grey, fine grained at 221·1-222, 223, 224·2-224·8, 226-226·5 feet
243·9-262·9	Limestone and shale; grey, interbedded; Bryozoa at 243·9 and 259·2 feet
262·9-265·1	Limestone; argillaceous, dark grey, fossiliferous; basal 6 inches transitional into underlying Irondequoit limestone; *Atrypa reticularis* (Linnaeus) at 264·6, 265, and 265·1 feet, *Stegerhynchus neglectum* (Hall) and *Fenestrellina elegans* (Hall) at 265 feet, *Hallopora* cf. *elegantula* (Hall) at base

HOLE NO. E-29—*Continued*

Depth	Lithology
Feet	
	Irondequoit Formation
265·1-274·6	Limestone; light to dark grey, coarsely crystalline, finer towards base; *Strophonella patenta* (Hall) at 265·2, 265·5, 266·9 feet, *Plectodonta transversalis* (Wahlenberg) at 266·6 and 267·4 feet; *Fardenia subplana* (Hall) at 266·1 feet, *Atrypa reticularis* (Linnaeus) at 266·4, 266·6, 268·6, 269·5, 271·2 and 271·8 feet
	Reynales Formation
274·6-284·4	Dolomite; whitish grey, dense; grey shale at 275, 276·4, 278·1-278·2, 281·4, and 281·9 feet; upper contact sharp
284·4-287·1	Limestone; grey, fine grained, fossiliferous; many grey shale partings with limestone fragments; lower contact sharp, marked with phosphatic blebs; *Plectodonta transversalis* (Wahlenberg) at 285·4 feet
	Neahga Formation
287·1-292·1	Shale; dark grey, fissile; basal contact sharp with upper 0·1 inch of the underlying Thorold irregularly argillaceous
	Thorold Formation
292·1-301·5	Sandstone; whitish grey, commonly green mottled, fine to very fine grained; green shale at 292·7, 293·3-293·5, 293·6, 299·4-299·5, 299·6-300·1, 301·1-301·2 feet; many green shale fragments 300·5-300·8 feet; lower contact sharp
	Grimsby formation
301·5-301·6	Shale; green
301·6-302·2	Sandstone; red, green mottled, fine grained, argillaceous; basal ½ inch grey with green shale fragments
302·2-303·2	Siltstone; dark red
303·2-303·6	Shale; red
303·6-312·4	Sandstone; red, very fine grained; interbedded shale; sandstone contacts undulating gently
312·4-316	Shale; red; sandstone at 313·3-313·8 feet
316 -329·6	Sandstone; red, green mottled, very fine grained; interbedded shale
329·6-330·4	Shale; red
330·4-332·5	Sandstone; red and green, fine grained
332·5-333·5	Shale; red
333·5-334	Sandstone; green and red
334 -336·2	Shale; red, and sandstone, yellowish green to red, interbedded
336·2-337·6	Shale; red; green at top
337·6-339·3	Sandstone; red; red shale fragments
339·3-341·4	Shale; red
341·4-342·5	Sandstone; red, fine grained
342·5-344·3	Shale; red; sandy at base; lower contact sharp from green to red shale

HOLE NO. E-29- *Continued*

Depth	Lithology
Feet	
	Power Glen Formation
344·3-346·7	Shale; grey; impure calcareous sandstone at 345·4-345·8 feet
346·7-363·5	Sandstone; grey, very fine grained; twenty-three grey shale partings
363·5-377·8	Shale; dark grey; numerous thin sandstone bands
	Whirlpool Formation
377·8-380·5	Sandstone; argillaceous, dark grey, very fine grained
380·5-395·8	Sandstone; quartzose, whitish grey, very fine grained; rare grey shale partings

Hole No. E-32

Location: 9,181·1 feet N., 10,934·9 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 566.3 feet — Depth of overburden: 70 feet
Total depth: 322·8 feet — Drilled: March-April, 1951
Core logged by T. E. Bolton, 1951

Depth	Lithology
Feet	
	Guelph Formation
70 -73·3	Dolomite; argillaceous, brownish grey, sugary; distinct lithological break at base
73·3-88·2	Dolomite; buff-grey, sugary; numerous bituminous partings
	Lockport Formation
	Eramosa Member
88·2-103·1	Dolomite; petroliferous, buff to dark grey, sugary; base placed arbitrarily at last petroliferous indication as underlying dolomites lithologically similar, except for disappearance of bituminous partings
	Goat Island Member
103·1-124·1	Dolomite; buff, sugary, rare bituminous partings; chert at 109·5, 113·2, 113·4, 116·8-116·9, 117·6-117·9, 118·4-118·7, 120·2 feet; *Clathrodictyon vesiculosum* Nicholson and Murie at 115·5, 115·8-116·1, 116·2-116·5 feet; rare *Favosites* in basal 2·5 feet
124·1-155	Dolomite; buff to buff-grey, sugary; basal 6·5 feet coarser, porous, transitional phase into underlying Gasport; *Clathrodictyon vesiculosum* Nicholson and Murie at 131·9, 132·4, 138 feet
	Gasport Member
155 -172·3	Limestone; light whitish grey, crystalline, crinoidal; upper 5 feet somewhat finer with rare stylolites; basal contact sharp; ¼-inch thick basal conglomerate
	DeCew Formation
172·3-185·5	Dolomite; dark grey, dense; upper foot lighter grey, sugary, with rare calcite-filled vugs
	Rochester Formation
185·5-197·9	Shale; dolomitic, dark grey
197·9-199·2	Shale; grey, and bryozoan limestone, interbedded
199·2-238·9	Shale; calcareous, dark grey, compact; rare thin grey limestone beds
238·9-242	Shale and limestone interbedded; latter increasing towards base; basal contact transitional

HOLE NO. E-32—*Continued*

Depth	Lithology
Feet	
	Irondequoit Formation
242 -250·9	Limestone; light grey to white, coarsely crystalline, crinoidal; upper foot dark due to argillaceous content, and packed with crinoids and brachiopods; lower contact sharp; *Enterolasma caliculum* (Hall) at 242·6 feet, *Eospirifer niagarensis* (Conrad) at 242·8 and 243 feet, *Atrypa reticularis* (Linnaeus) at 242·2, 242·4, 243·4, 245·9, 247 feet
	Reynales Formation
250·9-261·3	Dolomite; light grey to buff-grey, dense; upper 2 feet greenish tinged; grey shale at 254·8-255, 255·3, 258·2, 260 feet; thin conglomeratic zone at 261·1 feet
261·3-263·8	Limestone; dark grey, crystalline, fossiliferous (Crinoidea and Bryozoa); grey shale at 263-263·2, 263·6-263·7 feet
	Neahga Formation
263·8-269·4	Shale; dark grey, fissile; upper contact transitional with calcareous content increase; basal 3 inches calcareous, with a ½-inch basal conglomerate of thin flat dark grey sandy pebbles
	Thorold Formation
269·4-279·2	Sandstone; light whitish grey, fine grained; many green shale fragments scattered throughout; green shale at 270·3, 271·3-272·1, 272·3, 272·9, 277·4-277·5, 278·4-278·5 feet; lower contact sharp on red shale
	Grimsby Formation
279·2-285·1	Shale; chocolate-red; sandstone, greenish grey, fine grained at 279·5-280, 280·8, 281-281·4, 283·5-283·7 feet
285·1-309·3	Sandstone; red to greenish grey, fine grained; green shale fragments and partings at 285·5, 285·9-286, 286·5-286·6, 287·2, 287·3, 289·7-290·1, 292, 303·1-303·5, 303·6, 303·9, 304·9-305, 305·4-305·5 feet
309·3-320·5	Shale; red and green; red sandstone at 310·6-311·3 (with red shale fragments), 311·4-311·6, 312·9, 313·6-314, 314·6-314·8, 315-316·8 feet
	Power Glen Formation
320·5-323·4	Sandstone; calcareous, light grey, fine grained; numerous grey shale partings; many tiny grey shale fragments in upper 1 foot; red hematite seam at 320·6 feet

HOLE NO. F-1

Location: 26,560·0 feet N., 3,349·2 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 568·2 feet Depth of overburden: 6·1 feet
Total depth: 274·9 feet Drilled: Jan., 1950
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
6·1- 7	Core missing
7 -21·1	Dolomite; dark brownish grey, dense; some calcite and bituminous partings, but non-petroliferous
21·1-34·5	Limestone; highly porous (*Favosites* and Brachiopoda), granular, brown to brownish grey; basal ½ foot conglomeratic
	Gasport Member
34·5-56	Limestone; highly porous (*Favosites*), grey to brownish grey, semicrystalline
56 -67·6	Limestone; dark to light grey, crinoidal, crystalline
	DeCew Formation
67·6-80	Dolomite; argillaceous, dark grey, dense; upper 0·13 foot brownish grey
	Rochester Formation
80 -90·8	Shale; highly calcareous or dolomitic
90·8-101·5	Shale; calcareous, grey
101·5-105·1	Limestone with thin shale partings; Bryozoa
105·1-133	Shale; black with thin calcareous bands at 107·5-107·7 (Bryozoa), 109·8-110·4, 114·8-115, 115·4-116, 116·5, 123·8-124·6, 125·6-125·7, 127·8, 128·3, 128·6, 129·4, 130·8-131·1 feet
133 -134·6	Shale; highly calcareous; numerous Bryozoa and Brachiopoda
	Irondequoit Formation
134·6-145·5	Limestone; pinkish grey to grey, crystalline; upper 1 foot darker as argillaceous material increases, upper contact sharp; *Fardenia subplana* (Hall) at upper contact, *Strophonella* sp. at 134·7 feet, *Atrypa reticularis* (Linnaeus) at 134·8 and 135·4 feet, *Plectodonta transversalis* (Wahlenberg) at 137 feet
	Reynales Formation
145·5-158·8	Dolomite; dark grey, dense, rarely argillaceous; thickest shale bands in basal 2·8 feet; crinoidal dolomite brecciated in appearance
	Neahga Formation
158·8-164·7	Shale; fissile, dark black; basal 0·65 foot calcareous; tongues and lenses of argillaceous limestone, extending into or included in the Thorold

HOLE NO. F-1—*Continued*

Depth	Lithology
Feet	
	Thorold Formation
164·7-172·6	Sandstone; quartzose, whitish grey, fine grained; reddish tinged basal 4 feet; red shale at 168·6-168·9, 169·7-169·9, 170·7, 170·9 feet; green shale at 165·2, 166·9-167·5 feet; basal 0·2 foot large and small red and green shale pellets; thin section at 165·9 feet shows finely medium to fine grained, compact, clear and dusty quartz (95%); accessories, carbonate (4%), chlorite, biotite, zircon, albite-oligoclase, microcline, apatite, leucoxene, and collophane (?); thin section at 171 feet shows medium-grained, compact, clear and dusty quartz; pyrite, hematite, carbonate, chlorite, biotite, zircon, microcline, plagioclase, magnetite, and leucoxene
	Grimsby Formation
172·6-204·7	Sandstone; red, green mottled, fine grained; thin shale bands at 174-174·5, 181·1 (pellets), 183·9-184, 184·4-185·2, 186·1-186·4, 186·6-187·8, 188·6-189·1 feet
204·7-214·7	Shale; red, green mottled; sandstone bands at 205-205·5, 207·6-208·4, 210·4-210·8, 212·8-213, 213·1-213·5, 214·4, 214·7 feet
	Power Glen Formation
214·7-215·1	Shale; greenish grey
215·1-229	Sandstone; light grey, fine grained; shale bands at 215·4-215·5, 221·9-222·1, 224·2-225 feet; some fine crossbedding; grey shale pellets scattered throughout; upper contact marked by a seam of red oolitic-iron shale
229 -250	Shale to siltstone; dark grey; calcareous bands at 242·3-242·5, 243·5, 244·1-244·6, 249 feet
	Whirlpool Formation
250 -270·1	Sandstone; quartzose, whitish grey, fine grained; argillaceous material increasing upwards until upper 2 feet dark; upper contact transitional into siltstone; shale pellets at 261·7, 266-266·9 feet; some small-scale crossbedding; thin section at 256·7 feet shows fine-grained subangular, clear, compact (secondary) quartz (98%); a few small quartz aggregates; accessories, carbonate, chlorite, leucoxene, zircon, biotite, plagioclase, collophane, and apatite; thin section at 268·2 feet shows coarse-grained, dusty to clear, anhedral quartz (98%); some quartz aggregates; very compact through secondary quartz; accessories, carbonate (1%), chlorite, pyrite, zircon, biotite, and leucoxene.
	Queenston Formation
270·1-275·8	Shale and siltstone; red, green mottled; upper 0·3 foot green shale

Hole No. F-2

Location: 24,558·8 feet N., 6,175·0 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 552·7 feet — Depth of overburden: 34·3 feet
Total depth: 297·7 feet — Drilled: Jan.-Feb., 1950
Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
34·3-48	Dolomite; buff, sugary
48 -63·2	Dolomitic limestone; whitish grey, finely crystalline; numerous bituminous partings; a few crinoid stems and Bryozoa; upper and lower contacts gradational
	Gasport Member
63·2-80	Limestone; whitish grey, slightly porous, crystalline; stylolitic
80 -85·3	Limestone; crinoidal, grey, coarsely crystalline; numerous grey shale partings; traces of conglomerate at 85-85·2 feet
	DeCew Formation
85·3-92·2	Dolomite; buff, dense to sugary; rare shale parting
	Rochester Formation
92·2-145	Shale; calcareous, grey, fissile; Bryozoa limestone at 94-94·1, 116·5-116·9, 117·3, 119·9, 120-120·3, 120·9, 121·4, 121·6-121·9, 130·1, 138·3, 139·4-139·5, 140·2, 144·4, 144·6 feet
145 -151·8	Limestone and shale interbedded; basal 1½ feet argillaceous limestone; Bryozoa in limestone
	Irondequoit Formation
151·8-161·2	Limestone; whitish grey to pinkish grey, coarsely crystalline, finer in basal 1 foot; upper 0·4 foot highly fossiliferous, *Enterolasma caliculum* (Hall) at 152 feet, *Atrypa reticularis* (Linnaeus) at 152 and 155·4 feet
	Reynales Formation
161·2-171·3	Dolomite; buff-grey, dense; upper 1 foot transitional with numerous green shale bands; grey shale at 164·5-165, 169·4 feet
171·3-173·2	Limestone; argillaceous, grey, coarsely crystalline, fossiliferous
	Neahga Formation
173·2-179·3	Shale; grey, fissile; limestone band at 173·9-174·1 feet; basal 0·7 foot calcareous; upper contact undulating gently

HOLE NO. F-2—*Continued*

Depth	Lithology
Feet	
	Thorold Formation
179·3-182·7	Sandstone; greenish white, very fine grained; basal 1·5 feet very shaly (green); basal contact placed at a thin sandstone seam with an undulating base cutting down into green shale
	Grimsby Formation
182·7-185	Shale; red and green; interbedded sandstone
185 -187·8	Sandstone; red, fine grained; greenish tinged, white medium-grained, quartzose sandstone 185-187·8 feet with red shale 185·6-186·3 feet; basal contact with red sandstone undulating; suggestion of a conglomerate
187·8-228·2	Sandstone; red, fine grained; red shale at 190·3-190·7, 191·4-192·1, 198·7, 201·6, 202·2-202·3, 202·5, 204-204·1, 204·2, 204·5, 204·6, 207·7-209·4, 210-211, 213·4-213·8, 218-222·3, 223·2-225, 226·2-227·9 feet; white sandstone at 215-216·8 feet; lower contact in sandstone based on colour change
	Power Glen Formation
228·2-237·3	Sandstone; quartzose, whitish grey, fine grained; numerous grey shale partings; upper 5 feet commonly red tinged; many black blebs 228·7-229·8, 232·8-233·1, 233·9, 236·6-237·3 feet
237·3-239·2	Shale; arenaceous, grey
239·2-239·5	Sandstone; grey, coarse; many black blebs
239·5-244·6	Sandstone; some shale partings; Bryozoa
244·6-246·5	Shale; arenaceous, grey
246·5-247·1	Sandstone; grey, fine grained
247·1-256	Shale; grey
256 -260	Sandstone; argillaceous, dark grey, very fine grained
260 -263·2	Grey shale; sandstone 260·1-260·2, 260·6-260·9 feet
263·2-267·9	Sandstone; whitish grey, fine grained, and interbedded grey shale
	Whirlpool Formation
267·9-286·6	Sandstone; quartzose, white, fine grained; medium grained near base; grey shale at 279·9-280·8, 281·3, 281·4-281·6, 281·7, 282·1 (fragments) feet
	Queenston Formation
286·6-298·3	Sandstone and shale; red; upper 0·2 foot green shale; upper contact sharp

Hole No. K-1

Location: 24,055·2 feet N., 9,479·8 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 541·5 feet — Depth of overburden: 48·8 feet
Total depth: 304·5 feet — Drilled: June, 1950
Core logged by T. E. Bolton 1951

Depth	Lithology
Feet	
	Lockport Formation
	Goat Island Member
48·8-59·1	Limestone; dolomitic, buff to buff-grey, porous, finely crystalline; grey argillaceous partings; chert nodules at 54·5 feet; stylolites at 57·4 feet; small *Favosites* colony at 53·8 feet, *Enterolasma caliculum* (Hall) at 55·9 and 56·1 feet
	Gasport Member
59·1-83·6	Limestone; light grey, finely crystalline; crinoidal, rare argillaceous partings; dense grey band 63·9-64·2 feet; calcite 60-62 feet; basal contact sharp, 2-inch-thick basal conglomerate of tiny dolomite pebbles; *Favosites niagarensis* Hall 59·1-59·5 feet
	DeCew Formation
83·6-92·5	Dolomite; grey to buff-grey, dense
92·5-92·9	Core missing
	Rochester Formation
92·9-114·6	Shale; calcareous, dark grey to black, compact; bryozoan band 93·2-93·3 feet
114·6-115·7	Limestone; argillaceous, grey, finely crystalline; thin gypsum seams abundant; Bryozoa
115·7-117·6	Shale; calcareous, grey
117·6-118·3	Limestone; argillaceous; Bryozoa
118·3-146·8	Shale; calcareous, grey; bryozoan limestone bands at 119·2, 119·5-119·7, 120-120·3, 136·6-137·6, 141·2-141·3, 143·8 feet
146·8-150·6	Interbedded shale and limestone; grey; basal contact transitional from light grey to argillaceous limestone
	Irondequoit Formation
150·6-160·8	Limestone; whitish grey, porous, crystalline, crinoidal; upper 3·5 feet coarser; lower contact poorly defined as gradually finer with shale partings from 159 feet down; *Plectodonta transversalis* (Wahlenberg) at 152 feet
	Reynales Formation
160·8-169·3	Dolomite; whitish grey to light grey, dense to fine grained; a few shale partings
169·3-171·1	Limestone; grey, porous, crystalline; many grey shale partings; lower contact sharp

HOLE NO. K-1--*Continued*

Depth	Lithology
Feet	
	Neahga Formation
171·1-176·5	Shale; greenish grey
176·5-180·3	Shale; green; arenaceous shale to grey sandstone bands at 178·5-178·7, 178·9-179·2 feet; lower contact reasonably sharp, somewhat transitional
	Thorold Formation
180·3-185·9	Sandstone; white, fine grained; shale, green and red, at 181, 181·6-181·7, 183, 183·2-183·5, 183·8 feet
	Grimsby Formation
185·9-205·7	Sandstone; red, green mottled, fine grained
205·7-207	Shale; red
207 -208	Sandstone; red
208 -208·9	Shale; red
208·9-210·2	Sandstone; red
210·2-211·1	Shale; red
211·1-217·2	Sandstone; red; red shale partings at 212·6-212·9, 213·6-215, 216·5 feet
217·2-220·7	Shale and sandstone; red, interbedded
220·7-221·9	Sandstone; red, greenish mottled, very fine grained
221·9-226·8	Shale; red and green; numerous thin red sandstone bands
226·8-229·1	Sandstone; red and green; lower contact marked solely by colour change
	Power Glen Formation
229·1-234·2	Sandstone; calcareous, light grey, fine grained, fossiliferous; grey shale partings at 231·5-231·6, 232·2-232·4, 232·9-233·2 feet
234·2-236·5	Sandstone; calcareous, porous, medium grained, many black phosphatic particles and Bryozoa; conglomerate interbed
236·5-254·7	Shale; dark grey; interbedded sandstone
254·7-258·9	Sandstone; light grey, medium to fine grained; many grey shale partings imparting a conglomeratic appearance
258·9-260·2	Shale; sandy, grey
260·2-264	Sandstone; light grey, fine grained, and shale, grey, interbedded; shale increasing downwards; bryozoan limestone at 261·9 feet
	Whirlpool Formation
264 -283·3	Sandstone; pure, white, fine to medium grained; grey shale partings at 265·2, 265·6-265·8, 267·2, 275·3-275·7; crossbedding, 80 degrees to the core, at 267·2-275·3 feet
	Queenston Formation
283·3-305·5	Sandstone; red, fine grained; upper 1 foot green mottled

HOLE NO. N-14

Location: 1,638·1 feet N., 5,962·6 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.
Elevation bedrock: 532·6 feet
Depth of overburden: 67 feet
Total depth: 403·4 feet
Drilled: Dec.-Jan., 1950-51
Core logged by T. E. Bolton, 1951

Depth	Lithology
Feet	
	Guelph Formation
67 -95·7	Dolomite; bituminous, buff, sugary; small colonies of *Favosites niagarensis* Hall scattered throughout, producing porosity
95·7-102·7	Dolomite; lighter coloured and denser; numerous small *Favosites* colonies and Bryozoa
	Lockport Formation
	Eramosa Member
102·7-110	Dolomite; bituminous, dark buff, sugary; strong petroliferous odour
110 -118	Dolomite; buff-grey, slightly more porous; few small corals and many Bryozoa scattered throughout. (Redrilling commenced at 110 feet; this zone closely resembles the dolomite at 100 feet)
118 -136·8	Dolomite; buff, sugary; faint petroliferous odour
	Goat Island Member
136·8-155	Dolomite; buff, porous, dense to sugary; numerous calcite-filled vugs; chert nodule with *Hallopora* sp. indet. at 150·8 feet
155 -175·8	Dolomite; light grey, fine to sugary; some calcite-filled vugs and gypsum seams; numerous cherty, earthy nodules down to 160·5 feet
175·8-182·4	Dolomite; buff, fine; many large calcite-filled vugs
	Gasport Member
182·4-191·3	Dolomite; light grey, porous, finely crystalline; much calcite in basal 3 feet; this part more of a transitional zone as referable to either Gasport or Goat Island
191·3-208·3	Limestone; light grey, crystalline, finer near the top, stylolitic; few crinoid stems; lower contact sharp; minor basal conglomerate in lower 0·25 inch; other zones at 0·6 foot and 1·4 feet above the base
	DeCew Formation
208·3-217	Dolomite; buff-grey, dense, massive; calcite-filled vugs at 211·8 and 212 feet
	Rochester Formation
217 -274·1	Shale; calcareous, dark grey; bryozoan limestone at 230·2-230·5, 230·8, 235-235·4, 267, 272·2-272·9, 273·2, 273·6, 273·7, 273·8-273·9 feet
274·1-278·2	Limestone and shale interbedded; basal 1½ feet mainly argillaceous limestone, transitional into the underlying Irondequoit; *Conularia* cf. *niagarensis* Hall at 276 feet, *Strophonella* cf. *striata* (Hall) at 277·5 feet

Hole No. N-14—*Continued*

Depth	Lithology
Feet	
	Irondequoit Formation
278·2-287	Limestone; light grey to pinkish, coarsely crystalline; lower contact sharp, undulating slightly; *Fardenia subplana* (Hall) at 279·6 feet, *Atrypa reticularis* (Linnaeus) at 279·1 and 285 feet, *Eospirifer niagarensis* (Conrad) at 279·1 feet
	Reynales Formation
287 -297·1	Dolomite; dark to buff-grey, dense; green shale partings from 287·7-288·1 feet, grey shale at 290·7, 290·8-291, 294·1, 296·2 feet
297·1-299·6	Limestone; grey, coarsely crystalline; many grey shale partings; basal 0·5 inch phosphatic; Bryozoa
	Neahga Formation
299·6-304·4	Shale; black, fissile; basal ½ foot calcareous; lower contact gently undulating
	Thorold Formation
304·4-313·3	Sandstone; greenish white, very fine grained; green shale at 306·1, 306·2, 306·6, 306·7-306·8, 308·7, 309·4-309·5, 310·4-310·6 feet; lower contact sharp
	Grimsby Formation
313·3-359·7	Sandstone; red, green mottled, fine grained; red shale at top, 315, 320-320·4, 321·1, 323·2-324·8, 326-326·5, 327·8, 329·5, 331·6, 332·1-332·3, 333·8, 334·2, 337·5, 338·3, 339·2-340, 354, 356·6-356·7, 358 feet
359·7-360·5	Sandstone and shale; red, interbedded; lower contact between red sandstone and green shale
	Power Glen Formation
360·5-361·3	Shale; grey, arenaceous
361·3-371·8	Shale and sandstone; grey, fossiliferous, interbedded; red seams at top, 362·1, 363 and 364·5 feet
371·8-372·4	Sandstone; whitish grey, fine grained
372·4-372·8	Shale; grey
372·8-373·1	Limestone; grey, coarse; fossiliferous with black blebs
373·1-379·4	Shale and sandstone interbedded
379·4-386·4	Shale; grey; minor sandstone beds
386·4-390	Shale; grey
390 -394·2	Sandstone; argillaceous; numerous grey shale partings in basal 1 foot
394·2-396·6	Core missing
	Whirlpool Formation
396·6-403·4	Sandstone; quartzose, white, fine grained; rare grey shale partings

Hole No. O-1

Location: 2,013·2 feet N., 2,759·0 feet W. of "Monument Chippawa" (43° 03′ 44″.484 Lat., 79° 02′ 47″.798 Long.), Stamford tp., Welland co.

Elevation bedrock: 546·9 feet | Depth of overburden: 25·1 feet

Total depth: 270·8 feet | Drilled: Nov.-Dec., 1949

Core logged by T. E. Bolton, 1950

Depth	Lithology
Feet	
	Guelph Formation
25·1-26·6	Core missing
26·6-60	Dolomite; chocolate-brown to brownish grey, granular; rare bituminous partings; gypsum at 37·5 feet; *Enterolasma* sp. at 39 feet, scattered *Favosites* sp.
60 -66·5	Dolomite; light brown, highly porous, granular; *Favosites* cf. *niagarensis* Hall at 60·7 feet
66·5-70	Dolomite; dark brown to chocolate, granular; a few small *Favosites* sp.
70 -99·5	Dolomite; brownish grey, dense; some shaly matter particularly in the lower 5 feet producing mottled appearance; much gypsum; upper 7 feet highly porous; *Favosites* sp. scattered throughout
99·5-101·2	Dolomite; light brownish grey, granular
101·2-113·5	Dolomite; buff, dense to granular; *Favosites* sp. concentrated in 105-109 feet
113·5-118	Dolomite; light grey, granular; *Favosites* sp. abundant
	Lockport Formation
	Eramosa Member
118 -131·4	Dolomite; dark brownish grey, bituminous, dense; abundant shale partings; gypsum at 118·8 and 122·1 feet; slightly coarser with scattered *Favosites* sp. in the upper 4 feet; petroliferous odour; upper contact ill-defined
	Goat Island Member
131·4-150·3	Limestone or dolomitic limestone; light grey, highly porous, semicrystalline to crystalline; rare stylolites; *Favosites* cf. *forbesi* (Edwards and Haime) prolific
150·3-156·3	Dolomite; dark grey, dense; shale partings; upper and lower contacts transitional
156·3-164·3	Limestone; whitish grey, crystalline; *Favosites* sp. (tiny corallites) reef; lower contact sharp
	Gasport Member
164·3-175	Dolomite; dark steel-grey, dense; numerous shale partings; gradual downward transition into typical Gasport; two small gypsum masses at 167·2 feet
175 -186·6	Limestone; whitish grey, crystalline, crinoidal; nine stylolite bands; small *Favosites* sp. concentrated at 181·4-185 feet; pebble conglomerate (pebbles of dark grey, dense dolomite, maximum length 0·1 foot) in basal 0·85 foot; sharp contact with underlying DeCew

(Note: above divisions somewhat arbitrary; no typical Goat Island present; entire sequence coral-reef nature even up into stratigraphic Guelph equivalent; normal buff dolomite phases of Lockport possibly inter-reef phase for the Niagara region; Eramosa-Guelph contact far from definite)

HOLE NO. O-1—*Continued*

Depth	Lithology
Feet	
	DeCew Formation
186·6-195	Dolomite; argillaceous, dark grey, dense; base transitional; calcite stringers at 194 feet; *Eospirifer* sp. at 197·7 feet
	Rochester Formation
195 -200	Shale; highly calcareous to dolomitic
200 -248·1	Shale; black to grey, calcareous; limestone at 209-209·1, 209·2-209·5, 210, 210·7-211, 213-215·6 (streaks), 235·1-235·5 (streaks), 239·5-241 (streaks) feet
248·1-256·2	Shale; grey; bryozoan limestone beds increasing; pyrite blebs and thin calcite seams associated in basal 1 foot transitional into Irondequoit
	Irondequoit Formation
256·2-260	Limestone; light grey, crystalline, fossiliferous, crinoidal, shale partings at 256·6, 256·7, 256·9, 257·6, 258·3, 258·6, 259·5 feet; stylolitic; *Whitfieldella* sp. at 257·2 feet, *Atrypa reticularis* (Linnaeus) at 256·5, 257·9, 260 feet, *Parmorthis elegantula* (Dalman), *Plectodonta transversalis* (Wahlenberg) at 257·9 feet
260 -265·5	Limestone; whitish grey, less fossiliferous, crystalline; rare shale partings; gypsum at 264·1 and 264·9 feet; *Plectodonta transversalis* (Wahlenberg) at 261·8 feet, *Parmorthis elegantula* (Dalman) at 262·4 feet, *Atrypa reticularis* (Linnaeus) at 261·5 and 265 feet
	Reynales Formation
265·5-272·1	Limestone; argillaceous, dark grey, dense

Form No. 7

ONTARIO
PROVINCE OF ONTARIO
DEPARTMENT OF MINES

THE NATURAL GAS CONSERVATION ACT, R.S.O. Chap. 47

Form to be Filled in by Persons Prospecting or Exploring for Gas

Natural Gas Commissioner's Office
Room 1327, East Block, Parliament Buildings, Toronto

Name of Gas or Oil Company or person for whom Prospecting or Exploring is being done.
EUGENE TANKE c/o E. W. Tyrrill, Drawer 200, Fort Erie North, Ontario.
Company Well No. 1

The District where Drilling is Proposed or is in Progress:
County Welland Township Thorold Lot or Part Lot 241 Concession --
Property Owner C. W. Anderson

The Name and Address of Driller Actively Engaged:
Patterson & Culver, Dunnville, Ontario.
Farm Well No. 1

Unwashed samples of drill cuttings must be kept from about every five feet unless otherwise directed.

The Distance from the nearest Producing Well to the Location described herein and the Names and Addresses of Owners thereof: (This information to be furnished prior to the drilling of any well.)
One Thousand Feet West
Nevada Gas Syndicate

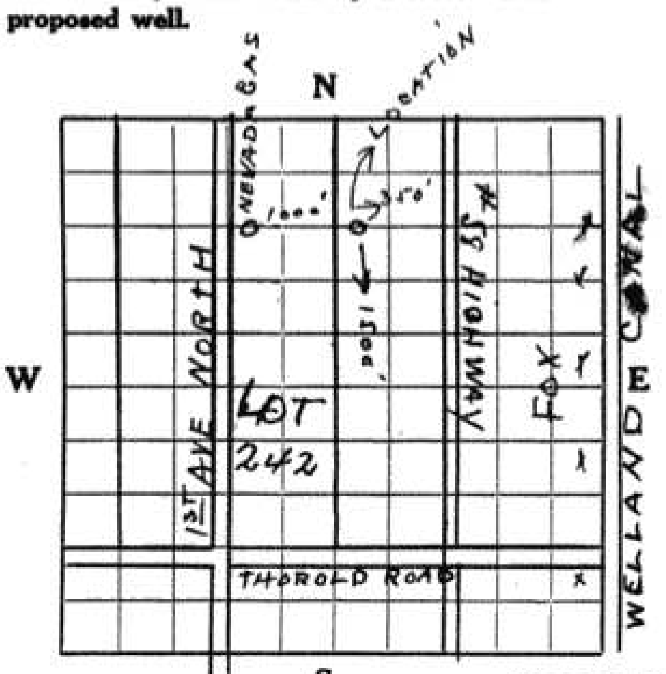
Probable date of commencing operations:
November 10th, 1947.

Proposed Depth 650'

NOTE:—One of these forms must be sent in for each well, fourteen days before commencing operations.

SKETCH

N.B.—If squares cannot be used to show lot, use blank space. Mark location of the proposed well by a circle and any other wells by a cross. Give measurements from two adjacent sides of the lot to the proposed well.



Eugene Tanke
(Signed) by E. W. Tyrrill

(Address) Drawer 200, Fort Erie N., Ontario.

Date November 14 1947 License No. 6262

Entered in book T.W.P.

Form No. 11

,7,0"

ONTARIO

THE NATURAL GAS CONSERVATION ACT, R.S.O. CHAP. 47 and WELL DRILLERS ACT, R.S.O. CHAP 48

DEPARTMENT OF MINES—PROVINCE OF ONTARIO

LOG OF GAS OR OIL WELL

To be filled in by every Well Driller and returned to the Natural Gas Commissioner Parliament Buildings, Toronto

(If desired, this information will be treated as confidential for a period of six months)

Drillers are required to describe each change of formation, its thickness, colour and hardness; and save samples of every five feet drilled.

DRILLER'S LOG

Formation	Thickness	Total
Surface ~~Clay & gravel~~	96	96
Lime & Shale	74	I70
Niagara	205	375
Shale	55	430
Clinton	35	465
RedMedina	50	515
Shale	30	545
W. Medina	24	569
Red Shale	3	572

Location of Well—County Welland

Township Thorold Concession

Lot 241 Part Lot Acres

Property Owner Anderson Farm Well No. I

Company Name E. Tanke

Address Buffalo N.y. Company Well No. 1

Drilling Contractor Patterson & Culver

Address Box 92 Dunnville

Date Drilling Begun Nov 4 1947

" " Completed Nov 27 1947

TUBING AND CASING RECORD

Length	Diameter	Weight per Ft.
96	8"	24#
394	5 5/8 "	I2#

If a dry hole, record method of plugging in above space

WATER RECORD

Depth	Kind	No. Feet that it Rises
I00	Fresh	40 level
I85	Fresh	35 "
250	Sulphur	30 "
Sulphur Gas @ 355'		

Length and Diameters of Packer

Set ft. off bottom. If shot, what explosive used No. qts. or lbs.

Shot between and from surface

Settled production after shot { Oil bbls. per day; Gas 60 M cu. ft. per day

Rock Pressure 275 lbs. after shut in I days

				N					
W									E
				S					

First Gas or Oil struck at 455 ft., Flow show cu. ft. or bbls.

Second " " 462 " " 60 M " "

Third " " " " " "

Fourth " " " " " "

Fifth " " " " " "

Sixth " " " " " "

Recorded by Patterson & Culver

Home Address Dunnville

Date Dec 29 /47 LICENSE NUMBER I572

Draw shape of farm showing its location on the lot as described above. Mark location of well by a circle giving distances to two adjacent sides of farm. Mark any other wells by a cross

Entered in book T.U.P. Comb. 6.

Name of Gas or Oil Co. Robert J. Thompson

F √ Year 1950

Address 218 Centre St. East Aurora, N. Y.

Co. Well No. 1

Location. County Welland Tp. Stamford Con. Lot 133 Pt. Lot

Driller K. Held Address Fisherville, Ont. Prop. Owner Harold E. Mashford #1

Date commenced May 22, 1950 Date completed June 2, 1950 Elev. Acres

DRILLERS LOG (Formation)	Thickness	TOTAL
Surface	42	42
Niagara	133	175
Rochester	55	230
Clinton	31	261
Red Medina	47	308
Grey shale	36	344
White Medina	25	369
Red shale	2	371

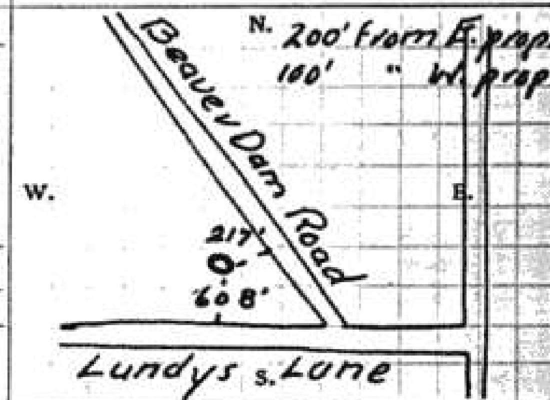
WATER RECORD

Kind	Depth	Ft. Rises
Fresh	62	18
Sulphur	160	18

CASING RECORD

Length	Diam.	Weight
Plugged at 225' & 100' Filled with clay and hard heads		

SKETCH OF LOCATION



Type Packer

Size

Set off Bottom feet

Explosive or Acid No. gals. or lbs.

Placed between and ft. from surface

Initial Oil Yield bbls./day. Initial Gas Yield M. cu. ft./day

Rock Pressure DRY HOLE lbs. After being shut in Days

		ft.	Flow	cu. ft. or bbls./day
1st Gas or Oil	232			
2nd " " "	237			
3rd " " "	260			
4th " " "				
5th " " "				
6th " " "				

No. 7
40 (R2486)

G.H.S

ONTARIO
PROVINCE OF ONTARIO
DEPARTMENT OF MINES

THE NATURAL GAS CONSERVATION ACT, R.S.O. Chap. 47

Form to be Filled in by Persons Prospecting or Exploring for Gas

Natural Gas Commissioner's Office
Room 1327, East Block, Parliament Buildings, Toronto

Name of Gas or Oil Company or person for whom Prospecting or Exploring is being done.
Robert I. Thompson
218 Center Street, East Aurora, N.Y. Company Well No. -1-

The District where Drilling is Proposed or is in Progress:
County Welland, Township Stamford Lot or Part Lot 133 Concession

Property Owner Harold E. Mashford

The Name and Address of Driller Actively Engaged:
Karl Held, Fisherville, Ont.
Farm Well No. -1-

Unwashed samples of drill cuttings must be kept from about every five feet unless otherwise directed.

The Distance from the nearest Producing Well to the Location described herein and the Names and Addresses of Owners thereof: (This information to be furnished prior to the drilling of any well.)
About 3 miles ### Falls View Syndicate, Post Office Box #200, Ft. Erie, Ont.

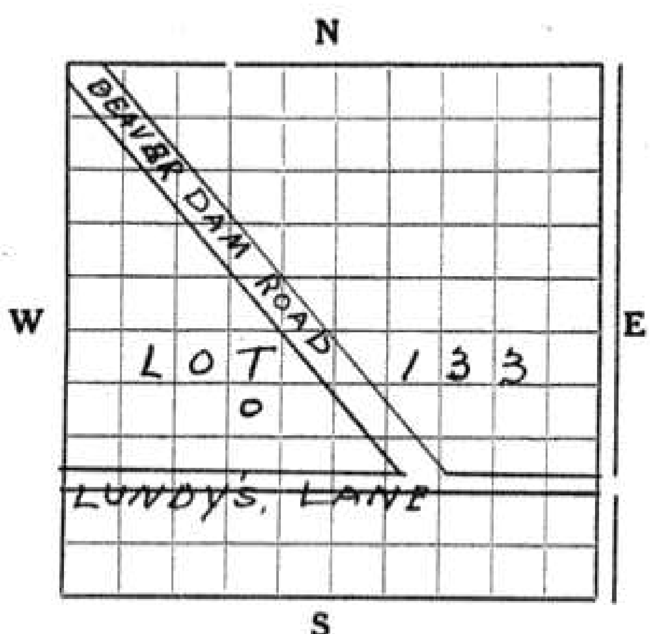
Probable date of commencing operations:
May 22, 1950.

Proposed Depth About 450 feet.

NOTE:—One of these forms must be sent in for each well, fourteen days before commencing operations.

SKETCH

N.B.—If squares cannot be used to show lot, use blank space. Mark location of the proposed well by a circle and any other wells by a cross. Give measurements from two adjacent sides of the lot to the proposed well.



200' FROM PROPERTY ON WEST.
100' " " " EAST.

(Signed)

(Address) 218 Center St. East Aurora, N.Y.

Date May 20, 1950 License No. 1835

ONTARIO

THE NATURAL GAS CONSERVATION ACT, R.S.O. CHAP. 47 and WELL DRILLERS ACT, R.S.O. CHAP 48

DEPARTMENT OF MINES—PROVINCE OF ONTARIO

LOG OF GAS OR OIL WELL

To be filled in by every Well Driller and returned to the Natural Gas Commissioner Parliament Buildings, Toronto

(If desired, this information will be treated as confidential for a period of six months)

Drillers are required to describe each change of formation, its thickness, colour and hardness; and save samples of every five feet drilled.

DRILLER'S LOG

Formation	Thickness	Total
Surface	42'	42
Niagara	133	175
Rochester	55	230
Clinton	31	261
Red Medina	47	308
Grey Shale	36	344
White Medina	25	369
Red Shale	2	371

Location of Well—County Welland

Township Stamford Concession —

Lot 133 Part Lot Acres

Property Owner Harold E. Maxford Farm Well No. 1

Company Name Robt. J. Thomson

Address 218 Centre St, East Aurora N.Y. Company Well No. 1

Drilling Contractor K. Held

Address Fisherville

Date Drilling Begun May 22 1950

" " Completed June 2 1950

TUBING AND CASING RECORD

Length	Diameter	Weight per Ft.
Plugged at 225' and 100'		
filled with clay &		
hard heads.		

If a dry hole, record method of plugging in above space

WATER RECORD

Depth	Kind	~~No. Feet that it Rises~~ level
62	Fresh	18'
160	Light Sulphur	18'

Length and Diameters of Packer

Set .... ft. off bottom. If shot, what explosive used .... No. qts. or lbs. ....

Shot between .... and .... from surface

Settled production after shot { Oil .... bbls. per day; Gas .... cu. ft. per day

Rock Pressure .... lbs. after shut in .... days

				N					
W									E
				S					

First Gas or Oil struck at 232 ft., Flow .... cu. ft. or bbls.

Second " " 237 " " Dry " "

Third " " 260 " " " "

Fourth " " " " " "

Fifth " " " " " "

Sixth " " " " " "

Recorded by

Home Address

Date LICENSE NUMBER

Draw shape of farm showing its location on the lot as described above. Mark location of well by a circle giving distances to two adjacent sides of farm. Mark any other wells by a cross

J.W.P.

2426

Name of Gas or Oil Co. Crowland Gas Syndicate ✓ Year 1954

Address R. R. #4, Welland, Ont. Co. Well No. 49

Location, County Welland Tp. Crowland Con. I Lot 14 Pt. Lot

Driller Wm. Harris and Son Address R. R.#1, Welland, Ont. Prop. Owner John Hagar #1

Date commenced November 18, 1953 Date completed January 8, 1954 Elev. 593 592 Acres 100

DRILLERS LOG (Formation)	Thickness	TOTAL
Surface	105	
Niagara	225	330
Grey shale	65	395
Clinton	25	420
Red Medina	55	475
Grey shale	20	495
White Medina	23	518
Red shale	2	520

WATER RECORD

Kind	Depth	Ft. Rises
Fresh	130	104
Black	190	164

SKETCH OF LOCATION

N. W. E. S.

360' SNLL
360' EWLL
365' N } consumers
340' E }

CASING RECORD

Length	Diam.	Weight
105	8	24
333	6	20

Clay & stone plugged 410' & 333' casing seat plugged at 160' filled clay & stone Saved for water well 8" left in

Type Packer

Size

off Bottom feet

Explosive or lbs. or lbs.

Placed between and ft. from surface

Initial Oil Yield bbls./day. Initial Gas Yield M. cu. ft./day

Rock Pressure lbs. After being shut in Days

1st Gas or Oil	435	ft.	Flow	1 M	cu. ft. or bbls./day
2nd " " "	500	"	"	1.6M	" " " "
3rd " " "	DRY HOLE	"	"		" " " "
4th " " "		"	"		" " " "
5th " " "		"	"		" " "
6th " " "		"	"		" " " "

77

'Form No. 7

9, HS

'54

ONTARIO

PROVINCE OF ONTARIO

DEPARTMENT OF MINES

THE NATURAL GAS CONSERVATION ACT, R.S.O. Chap. 47

Form to be Filled in by Persons Prospecting or Exploring for Gas

Natural Gas Commissioner's Office
Room 1327, East Block, Parliament Buildings, Toronto

Name of Gas or Oil Company or person for whom Prospecting or Exploring is being done.
R.R.4 Welland

Company Well No. 49

The District where Drilling is Proposed or is in Progress:

County Welland Township Crowland Lot or ~~Part Lot~~ 16 Concession 1

Property Owner John Hagar

The Name and Address of Driller Actively Engaged:
Wm Harris & Sons R.R.1 Welland

Farm Well No. 1

Unwashed samples of drill cuttings must be kept from about every five feet unless otherwise directed.

The Distance from the nearest Producing Well to the Location described herein and the Names and Addresses of Owners thereof: (This information to be furnished prior to the drilling of any well.)

Feet Over a mile away

Probable date of commencing operations:
Nov 18 1953

Proposed Depth 600

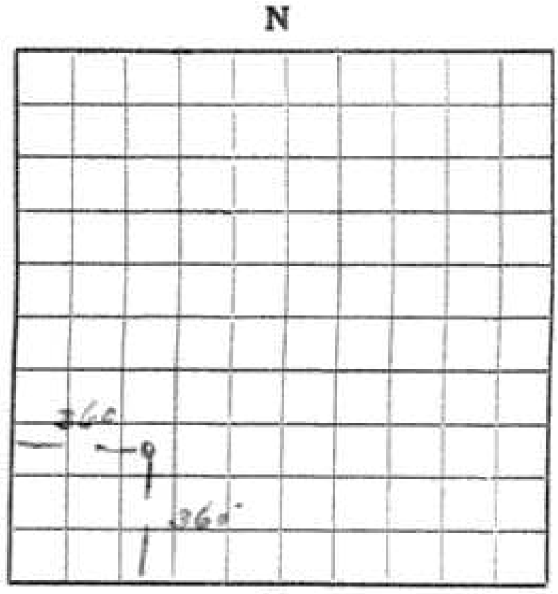
NOTE:—One of these forms must be sent in for each well, fourteen days before commencing operations.

SKETCH

N.B.—If squares cannot be used to show lot, use blank space. Mark location of the proposed well by a circle and any other wells by a cross. Give measurements from two adjacent sides of the lot to the proposed well.

N

W



E

S

(Signed) W T Pearson

(Address) R.R.4 Welland

Date Nov 2 1953 License No.

Form No. 11

16921 G.H.S.

ONTARIO

THE NATURAL GAS CONSERVATION ACT, R.S.O. CHAP. 47 and WELL DRILLERS ACT, R.S.O. CHAP 48

DEPARTMENT OF MINES—PROVINCE OF ONTARIO

LOG OF GAS OR OIL WELL

Elev 593' + 2'

To be filled in by every Well Driller and returned to the Natural Gas Commissioner Parliament Buildings, Toronto

(If desired, this information will be treated as confidential for a period of six months)

Drillers are required to describe each change of formation, its thickness, colour and hardness; and save samples of every five feet drilled.

DRILLER'S LOG

Formation	Thickness	Total
Surface	105	
Niagara	225	330
Grey Shale	65	395
Clinton	25	420
Red Medina	55	475
Grey Shale	20	495
White Medina	23	518
Red Shale	2	520

Location of Well—County Welland
Township Crowland Concession 1
Lot 14 Part Lot Acres 100
Property Owner John Heggi Farm Well No. 1
Company Name Crowland Gas Synd.
Address R R 4 Welland Company Well No. 49
Drilling Contractor Wm Harris & Son
Address R R 1 Welland
Date Drilling Begun Nov 18 1953
" " Completed Jan 8 1954

TUBING AND CASING RECORD

Length	Diameter	Weight per Ft.
105	8	28
333	6	20

Clay and stone plugged 40 & 333 casing seat plugged at 160 ft filled clay & stone at 140 Saved Welch Well 8" left in

If a dry hole, record method of plugging in above space

WATER RECORD

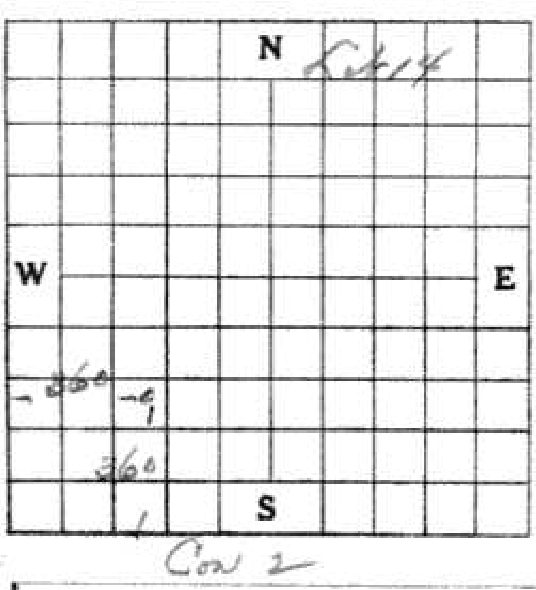
Depth	Kind	No. Feet that it Rises
130	Fresh	104
190	Black	164

Length and Diameters of Packer
Set ft. off bottom. If shot, what explosive used No. qts. or lbs.
Shot between and from surface
Settled production after shot { Oil bbls. per day; Gas cu. ft. per day
Rock Pressure lbs. after shut in days

First Gas or Oil struck at 435 ft., Flow 1000 cu. ft. or bbls.
Second " " 500 " " 1600 " "
Third " " " " " "
Fourth " " " " " "
Fifth " " " " " "
Sixth " " " " " "

Dry

Recorded by Wm Harris
Home Address R R 1 Welland
Date Jan 15 1954 LICENSE NUMBER



Draw shape of farm showing its location on the lot as described above. Mark location of well by a circle giving distances to two adjacent sides of farm. Mark any other wells by a cross

Name of Gas or Oil Co. Donald N. Young | Year 1946✓
Address Welland, Ont. Box 83 | Co. Well No. 1
Location, County Welland | Tp. Crowland | Con. II | Lot 21 | Pt. Lot
Driller H. L. Emerson | Address RR#1, Dunnville, Ont. | Prop. Owner Donald N. Young (1)
Date commenced June 4, 1946 | Date completed June 29, 1946 | Elev. | Acres

DRILLERS LOG (Formation)	Thickness	TOTAL
Surface	92	92
Shale lime	80	172
Niagara	192	364
Shale	48	412
Clinton	36	448
Red medina	40	488
Shale	41	529
White medina	13	542
Red shale	40	582

Plugged in 1947

93

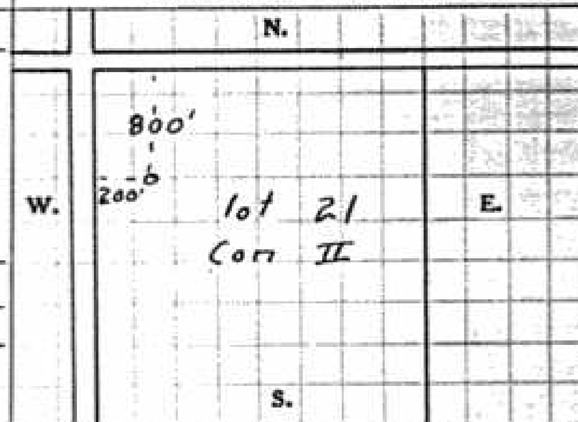
WATER RECORD

Kind	Depth	Ft. Rises
Fresh	92'	68'
"	180'	155'
Black	335'	

CASING RECORD

Length	Diam.	Weight
360	$6\frac{1}{4}$	

SKETCH OF LOCATION



Type Packer
Size
Set off Bottom feet
Explosive or Acid No. gals. or lbs.
Placed between and ft. from surface
Initial Oil Yield bbls./day. Initial Gas Yield 3 M. cu. ft./day
Rock Pressure 50 lbs. After being shut in Days
1st Gas or Oil 540. ft. Flow cu. ft. or bbls./day
2nd " " " " " " " " " "
3rd " " " " " " " " " "
4th " " " " " " " " " "
5th " " " " " " " "
6th " " " " " " " " " "

Form No. 7

ONTARIO
PROVINCE OF ONTARIO
DEPARTMENT OF MINES

DEPARTMENT OF MINES
RECEIVED
NATURAL GAS COMMISSIONERS OFFICE
TORONTO, ONT.

THE NATURAL GAS CONSERVATION ACT, R.S.O. Chap. 47

Form to be Filled in by Persons Prospecting or Exploring for Gas

Natural Gas Commissioner's Office
Room 1327, East Block, Parliament Buildings, Toronto

Name of Gas or Oil Company or person for whom Prospecting or Exploring is being done.
Donald N. Young
Company Well No. 1

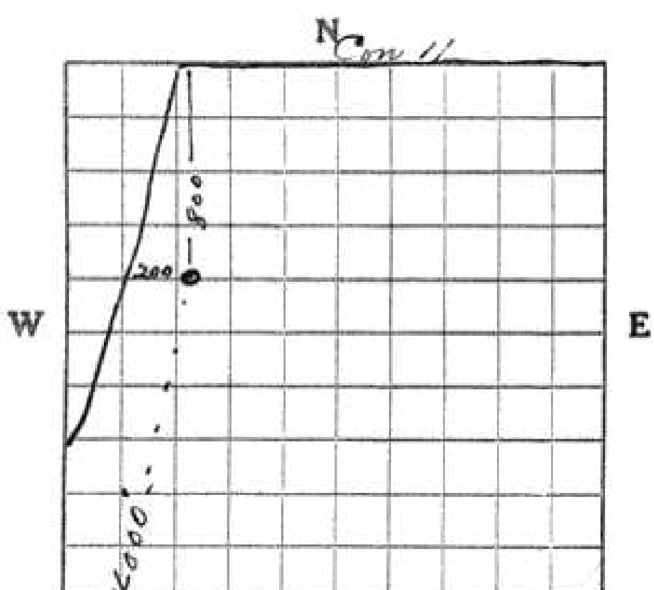
The District where Drilling is Proposed or is in Progress:
County Welland Township Crowland Lot or Part Lot 21 Concession 2
Property Owner Donald N. Young
The Name and Address of Driller Actively Engaged:
Harry L. Emerson Dunnville
Farm Well No. 1

Unwashed samples of drill cuttings must be kept from about every five feet unless otherwise directed.

The Distance from the nearest Producing Well to the Location described herein and the Names and Addresses of Owners thereof: (This information to be furnished prior to the drilling of any well.)
4000 Feet Clarence Schwenge Welland

Probable date of commencing operations:
June 3 1946
Proposed Depth 600 ft
NOTE:—One of these forms must be sent in for each well, fourteen days before commencing operations.

SKETCH
N.B.—If squares cannot be used to show lot, use blank space. Mark location of the proposed well by a circle and any other wells by a cross. Give measurements from two adjacent sides of the lot to the proposed well.



800 ft south con 11
200 ft East River road

Entered ... Book
Twp

(Signed) Donald N. Young
(Address) Box 83 Welland.

Date May 30 1946. License No.

Form No. 11
2500-Oct. 40-B2486

ONTARIO

THE NATURAL GAS CONSERVATION ACT, R.S.O. CHAP. 47 and WELL DRILLERS ACT, R.S.O. CHAP. 48

DEPARTMENT OF MINES—PROVINCE OF ONTARIO

DEPARTMENT OF MINES RECEIVED ... 1946 NATURAL GAS COMMISSIONERS OFFICE TORONTO, ONT.

LOG OF GAS OR OIL WELL

To be filled in by every Well Driller and returned to the Natural Gas Commissioner Parliament Buildings, Toronto

(If desired, this information will be treated as confidential for a period of six months)

Drillers are required to describe each change of formation, its thickness, colour and hardness; and save samples of every five feet drilled.

DRILLER'S LOG

Formation	Thickness	Total
Surface	92	92
Shale Lime	80	172
Niagara	192	364
Shale	48	412
Clinton	36	448
Red Medina	40	488
Shale	41	529
White Medina	13	542
Red shale	40	582
	582	

Location of Well—County: Welland

Township: Crowland Concession: 2

Lot: 21 Part Lot: Acres:

Property Owner: D.N. Young Farm Well No.: 1

Company Name: Private Well

Address: Company Well No.: #1

Drilling Contractor: H. L. Emerson

Address: Dunnville R.R.1

Date Drilling Begun: June 4 1946

" " Completed: June 29 1946

TUBING AND CASING RECORD

Length	Diameter	Weight per Ft.
360	6 1/4	

If a dry hole, record method of plugging in above space

WATER RECORD

Depth	Kind	No. Feet that it Rises
92	fresh	68
180	Hard	155
335	Black	

Length and Diameters of Packer

Set ft. off bottom. If shot, what explosive used No. qts. or lbs.

Shot between and from surface

Settled production after shot { Oil bbls. per day; Gas 3000 cu. ft. per day

Rock Pressure 50 lbs. after shut in days

First Gas or Oil struck at 540 ft., Flow 3 M cu. ft. or bbls.

Second " " " " " "

Third " " " " " "

Fourth " " " " " "

Fifth " " " " " "

Sixth " " " " " "

Recorded by: H. L. Emerson

Home Address: Dunnville R.R.1

Date: Nov 1/46 LICENSE NUMBER

	N	
W	800' S.N. Rd 200' E.W. Rd.	E
	S	

Draw shape of farm showing its location on the lot as described above. Mark location of well by a circle giving distances to two adjacent sides of farm. Mark any other wells by a cross

Entered in book S.W.P.

CTY: Welland	TWP: Stamford	TRACT:	LOT: 178	CON:
WELL NAME: Provincial Natural Gas No. 262			WELL ID: N002812	CLASS: NPW
OPERATOR: Provincial Gas Company, Ltd	Target: CAM		STATUS: DH - UNK	

DRILLING DATA	DATES	COORDINATES	SAMPLES
RIG TYPE: Cable	LICENCE ISSUED:	N/S BOUND: 121.00 N	TRAY:
GRND ELEV: 179.83	SPUD DATE:	E/W BOUND: 30.50 E	POOL
KB ELEV: 180.13	TD DATE: 1908-08-06	NAD 83	
TVD: 857.10 PBTD:	COMPLETE DATE:	SURF LAT: 43.06766611 SURF LONG: -79.12217667	
	WORKOVER DATE:	BOT LAT: 43.06766611 BOT LONG: -79.12217667	
	PLUG DATE:		

FORMATION	TOP	TVD	ELEV
Drift	0.30	0.30	179.84
Top of Bedrock	14.00	14.00	166.13
Irondequoit	72.24	72.24	107.89
Reynales/Fossil Hill	80.47	80.47	99.66
Grimsby	83.52	83.52	96.61
Manitoulin	96.93	96.93	83.20
Whirlpool	105.77	105.77	74.37
Queenston	111.25	111.25	68.88
Georgian Bay/Blue Mtn	377.95	377.95	-197.82
Trenton Group	623.32	623.32	-443.19
Cobourg	623.32	623.32	-443.19
Cambrian	835.46	835.46	-655.33
Precambrian	857.10	857.10	-676.97
Geology by Operator			

LOCATION COMMENTS

DATE	ACCURACY	METHOD OBTAINED
	Within 200 metres	Well Records (pre 1921)

INITIAL GAS INTERVAL	FLOW 1000 m3/dM	SIP kPag

INITIAL OIL INTERVAL	FLOW m3/d	SIP kPag

WATER RECORD INTERVAL	STATIC LEVEL	TYPE
839.72 -		Salt
855.57 -		Salt

LOGGING RECORD INTERVAL	TYPE	COMPANY

Casing O.D. (mm)	Weight (kg/m)	Setting Depth (m)	How Set
203.20		13.72	SHO
158.75		63.09	

CTY: Welland	TWP: Thorold	TRACT:	LOT: 8	CON:
WELL NAME: Consumer's Gas No. 1122 (Thorold Natural Gas) P.L.O.: G. Arilette			WELL ID: N002815	CLASS: NPW
OPERATOR: Enbridge Gas Distribution Inc.	Target: ORD		STATUS: LOC - ABD	

DRILLING DATA	DATES	COORDINATES	SAMPLES
RIG TYPE: Cable	LICENCE ISSUED:	N/S BOUND: 137.20 N	TRAY:
GRND ELEV: 158.10	SPUD DATE:	E/W BOUND: 3.40 W	POOL
KB ELEV: 158.40	TD DATE: 1888-01-01	NAD 83	
TVD: 753.77 PBTD:	COMPLETE DATE:	SURF LAT: 43.12830778 SURF LONG: -79.19565139	
	WORKOVER DATE:	BOT LAT: 43.12830778 BOT LONG: -79.19565139	
	PLUG DATE: 1963-04-22		

FORMATION	TOP	TVD	ELEV
Drift	0.30	0.30	158.10
Top of Bedrock	13.11	13.11	145.29
Geology by Operator			

LOCATION COMMENTS

DATE	ACCURACY	METHOD OBTAINED
	Within 200 metres	Well Records (pre 1921)

INITIAL GAS INTERVAL	FLOW 1000 m3/dM	SIP kPag
580.64 -	SHOW	
740.66 -	SHOW	

INITIAL OIL INTERVAL	FLOW m3/d	SIP kPag

WATER RECORD INTERVAL	STATIC LEVEL	TYPE
86.56 -		Salt

LOGGING RECORD INTERVAL	TYPE	COMPANY
-	Gamma Ray	
-	Caliper	
-	Resistivity	
-	Casing Collar Locator	
-	Neutron	

Casing O.D. (mm)	Weight (kg/m)	Setting Depth (m)	How Set
203.20			
143.00		94.18	

CTY: Welland	**TWP:** Stamford	**TRACT:**	**LOT:** 43	**CON:**
WELL NAME: 92-B			**WELL ID:** T007932	**CLASS:** STR
OPERATOR: Acres Bechtel Canada	**Target:** ORD		**STATUS:** STR - ABD	

DRILLING DATA	**DATES**	**COORDINATES**	**SAMPLES**
RIG TYPE: Rotary	**LICENCE ISSUED:**	**N/S BOUND:** X	**TRAY:**
GRND ELEV: 182.22	**SPUD DATE:**	**E/W BOUND:** X	**POOL**
KB ELEV: 182.22	**TD DATE:** 1992-06-10	**NAD 83**	
TVD: 220.43 **PBTD:**	**COMPLETE DATE:**	**SURF LAT:** 43.12805194 **SURF LONG:** -79.08701778	
	WORKOVER DATE:	**BOT LAT:** 43.12805194 **BOT LONG:** -79.08701778	
	PLUG DATE:		

FORMATION	TOP	TVD	ELEV
Drift	0.01	0.01	182.21
Top of Bedrock	16.88	16.88	165.34
Gasport	16.88	16.88	165.34
Rochester	29.71	29.71	152.51
Irondequoit	47.11	47.11	135.11
Reynales/Fossil Hill	49.79	49.79	132.43
Thorold	55.42	55.42	126.80
Grimsby	58.36	58.36	123.86
Whirlpool	81.16	81.16	101.06
Queenston	88.81	88.81	93.41
Geology by Operator			

LOCATION COMMENTS

DATE	ACCURACY	METHOD OBTAINED
	Within 20 metres	Well Records (1954 to 1997)

INITIAL GAS INTERVAL	FLOW 1000 m3/dM	SIP kPag

INITIAL OIL INTERVAL	FLOW m3/d	SIP kPag

WATER RECORD INTERVAL	STATIC LEVEL	TYPE
7.19 -	7.19	

LOGGING RECORD INTERVAL	TYPE	COMPANY

Casing O.D. (mm)	Weight (kg/m)	Setting Depth (m)	How Set
117.60		17.30	

Name of Gas or Oil Co. Pro~~vincial~~ Natural Gas Co. File No. 1926

Address Niagara Falls, Ont. (PRIVATE WELL) Well No. 502

Location, County Welland Tp. Crowland Con. Bkn. Front Lot 7

Driller Prov. Nat. Gas Co. Address Niagara Falls Prop. owner Dominick Christoforo

Date commenced Sept 25/26 Date completed Oct. 15/26 Elev. 535'

Samples cuttings rec'd Sent to Ottawa Elev 574' Lot 5 (Caley

DRILLERS LOG			CASING RECORD			WATER RECORD		
Formations	Depth	Total	Length	Diam.	Wgt.	Kind	Depth	Ft. Rises
Top of Clinton	317		Drive pipe			93'		
Top of Red Med.	347		Casing			284		
Top of White Med.	432							
~~Bott~~ Depth of do.	12							
Pocket Red Shale	~~4~~56							
~~Total~~	500							
Thickness								

* Sold to property owner DOMINIC CHRISTOFARI / Aug. 1928

SKETCH OF LOCATION: N. 1700' N. of S. rd 150' W. of E. rd — W. — E. — Lot 7 Broken Front — S.

Make of Packer 335

Size Set at

Was well torpedoed? What Explosive?

No. qts. or lbs. Shot placed between

and ft. from surface Date

Initial oil yield bbls. Initial gas yield 8,400 cu. ft.

Rock pressure 200 lbs. Shut in days

First Gas or Oil ft. Flow cu. ft. or bbls.

Second " " " " " "

Third " " " " " "

Fourth " " " " " "

Fifth " " " " " "

[illegible] well

* DOMINIC CHRISTOFARI purchased Aug 1928 PRIVATE WELL

over.

36

Plugging Record

Date plugged..........

By whom plugged..........

Address..........

Days shut in.......... Rock pressure..........

Name of Inspector.......... Was plugging approved?..........

Kind of plug	Length	Set at

588
317
271

588
245
343

Yearly Rock Pressure

Year	Date taken	Lbs. pressure	Hrs. shut in
Log from samples			
	Guelph & Lockport	150	245'
	Rochester	72	317
	Clinton	18	335
	Rd. & Gry shale	15	350
	Rd & Gry S.S.	√10	360
	Red Shale	5	365'
	Rd & Gry SS	√5	370
	Red Shale	10	380
	Grey SS.	√20	400
	Grey shale	29	429
	Whirlpool	21	450
	Queenston	50	500

Form No. 11.

THE NATURAL GAS ACT, 1919

DEPARTMENT OF MINES—PROVINCE OF ONTARIO

Natural Gas Commissioner's Office, No. 5 Queen's Park, Toronto

FORM TO BE FILLED IN BY EACH OWNER OR OPERATORS OF DRILLING RIGS.

(If desired, this Information will be treated as confidential for a period of six months.)

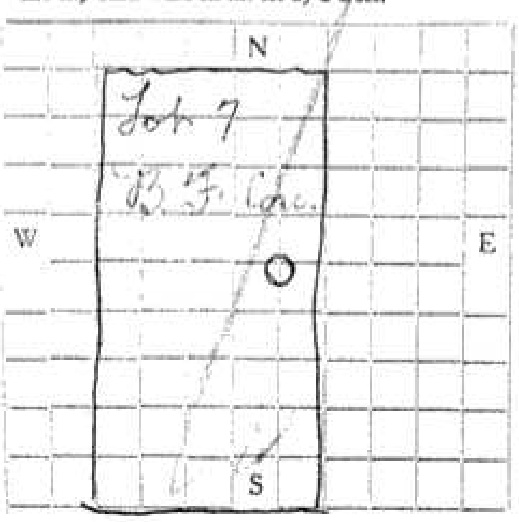
Drillers are required to record the depths of each change of formation, the name of the formation and the depths at which they encounter any minerals, oil, gas or water. In the case of water state whether salt, sulphur, alkaline or fresh and how high it rises in the well.

Samples of cuttings must be taken about every 5 feet and forwarded to the Commissioner as taken without being washed. Bags may be had at the Commissioner's Office upon request

DRILLER'S LOG

Formation	Depth	Total
D[illegible]e Pipe	93	
Casing	284	
Top of Clinton	317	
Top of Red Med	347	
Top of White Med	437	
Depth of White Med	12	
Pocket	56	
		500

Draw the shape of the lot that the well is drilled on by using four of the lines. Mark location of well by a circle and any other wells on the lot by a cross.



This well is located in Lot No. 7 Concession Broken Front

Township Crowland County Welland

Property Owner Dominick Christofor

Name and address of the person or Company for whom this well is being drilled is Provincial Natural Gas & Fuel Co. of Ontario Limited

Well No. 507

Drilling Contractor Same

Address Niagara Falls Ont

Type of drilling Rig used Star

The date this well was started Sept. 25 1926

Date completed October 15 1926 Depth of well 500

Elevation of ground above Sea Level .... feet.

TUBING AND CASING RECORD

Length	Diameter	Weight per ft.

If a dry Hole and Casing pulled, record Method of Plugging in above space.

Make of packer .... Size ....

Set .... feet above bottom of well. Was this well Torpedoed? ....

What explosive was used? .... No. of quarts or lbs. ....

Shot placed between .... ft. and .... ft. below surface.

Initial Oil yield per day .... bbls.

Initial Gas yield per day 8400 cu. ft.

Rock pressure 200 lbs. after being shut in .... days.

Gravity of Oil .... ° Beaume.

First Gas or Oil struck at .... ft., Flow .... cu. ft. or bbls.

Second " " .... " " .... " "

Third " " .... " " .... " "

Fourth " " .... " " .... " "

Fifth " " .... " " .... " "

Recorded by C. M. Glenny

Home Address Bridgeburg Ont

Date ....

LICENSE NUMBER ....

No. 7

G.H.S.

ONTARIO

PROVINCE OF ONTARIO

DEPARTMENT OF MINES

THE NATURAL GAS CONSERVATION ACT, R.S.O. Chap. 47

Form to be Filled in by Persons Prospecting or Exploring for Gas

Natural Gas Commissioner's Office
Room 1327, East Block, Parliament Buildings, Toronto

Name of Gas or Oil Company or person for whom Prospecting or Exploring is being done.

Dell-Burn Gas Limited

Box 105 Dunnville Ont. Company Well No.

The District where Drilling is Proposed or is in Progress:

County Welland Township Crowland Lot or Part Lot 6 Concession Broken front

Property Owner C. Cebrinski

The Name and Address of Driller Actively Engaged:

Dell-Burn Wright & ...

Farm Well No. 2

Unwashed samples of drill cuttings must be kept from about every five feet unless otherwise directed.

The Distance from the nearest Producing Well to the Location described herein and the Names and Addresses of Owners thereof: (This information to be furnished prior to the drilling of any well.)

600' Feet North of Cebrinski No. 1

Probable date of commencing operations:

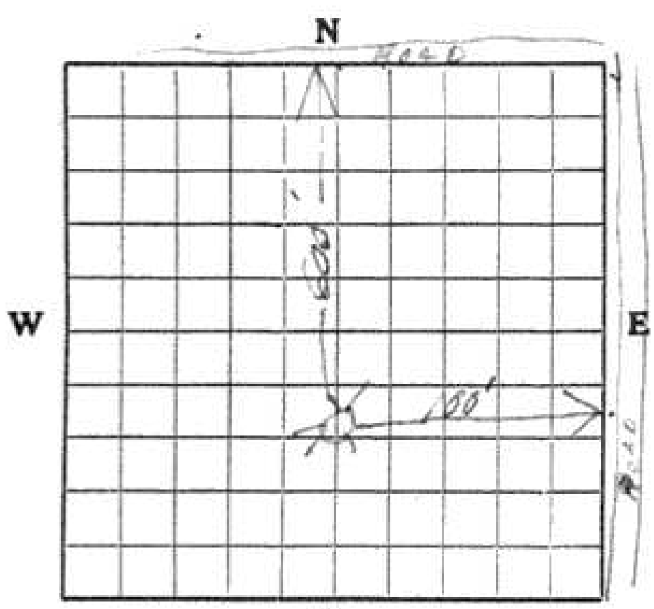
May 6 1952

Proposed Depth 550'

NOTE:—One of these forms must be sent in for each well, fourteen days before commencing operations.

SKETCH

N.B.—If squares cannot be used to show lot, use blank space. Mark location of the proposed well by a circle and any other wells by a cross. Give measurements from two adjacent sides of the lot to the proposed well.



(Signed) Dell-Burn Gas Limited

W. O. E. Wardell

(Address) Dunnville

Date May 6 1952 License No. 1974

G.H.S.

Form No. 11

16864

ONTARIO

THE NATURAL GAS CONSERVATION ACT, R.S.O. CHAP. 47 and WELL DRILLERS ACT, R.S.O. CHAP 48

DEPARTMENT OF MINES—PROVINCE OF ONTARIO

LOG OF GAS OR OIL WELL

To be filled in by every Well Driller and returned to the Natural Gas Commissioner Parliament Buildings, Toronto

(If desired, this information will be treated as confidential for a period of six months)

Drillers are required to describe each change of formation, its thickness, colour and hardness; and save samples of every five feet drilled.

DRILLER'S LOG

Formation	Thickness	Total
Surface	80	80
Sand & Gravel	6	86
Niagara	173	259
Shale	60	319
Clinton	37	356
Red Medina	58	414
Grey Shale	17	431
White Medina	24	455
Red Shale	2	457

Location of Well—County Welland

Township Crowland Concession Broken Front

Lot 6 Part Lot Acres

Property Owner ~~[illegible]~~ Cebryn[illegible] Farm Well No. 2

Company Name Dell-Burn Gas

Address Dunnville Company Well No. 1

Drilling Contractor Dell-Burn

Address Dunnville Ont

Date Drilling Begun May 6 1952

" " Completed June 5 1952

TUBING AND CASING RECORD

Length	Diameter	Weight per Ft.
86'	8'	24
270'	3"	

If a dry hole, record method of plugging in above space

WATER RECORD

Depth	Kind	No. Feet that it Rises
81'	fresh	41 ft
104'	Sulphur	69'
224'	Sulphur	208'

Length and Diameters of Packer 3 ft 6¼ Rockwell

Set .... ft. off bottom. If shot, what explosive used .... No. qts. or lbs. ....

Shot between .... and .... from surface

Settled production after shot { Oil .... bbls. per day; Gas .... cu. ft. per day

Rock Pressure 150 lbs. after shut in 2 days

				N					
W									E
				S					

First Gas or Oil struck at 361 ft., Flow .... cu. ft. or bbls.

Second " " 370 " " 8,000 " "

Third " " " " " "

Fourth " " " " " "

Fifth " " " " " "

Sixth " " " " " "

FM

Recorded by Dell-Burn Gas Limited

Home Address Dunnville

Date June 12 LICENSE NUMBER 203

Draw shape of farm showing its location on the lot as described above. Mark location of well by a circle giving distances to two adjacent sides of farm. Mark any other wells by a cross

CTY: Welland	TWP: Thorold	TRACT: 1	LOT: 29	CON:
WELL NAME: pGT17-01			WELL ID: T012542	CLASS: OBS
OPERATOR: Ministry of Transportation - Central Region (Toronto)	Target: CLI		STATUS: LIC - NDR	

DRILLING DATA	DATES	COORDINATES	SAMPLES
RIG TYPE: Rotary	LICENCE ISSUED: 2017-10-05	N/S BOUND: 165.00 S	TRAY:
GRND ELEV: 179.00	SPUD DATE:	E/W BOUND: 155.00 E	POOL
KB ELEV: 178.70	TD DATE: 2017-10-30	NAD 83	
TVD: 36.20 PBTD:	COMPLETE DATE:	SURF LAT: 43.11603889 SURF LONG: -79.19820000	
	WORKOVER DATE:	BOT LAT: 43.11606111 BOT LONG: -79.19826944	
	PLUG DATE:		

FORMATION	TOP	TVD	ELEV
Goat Island	7.10	7.10	171.60
Gasport	15.80	15.80	162.90
Rochester	25.70	25.70	153.00
Geology by Operator			

LOCATION COMMENTS

DATE	ACCURACY	METHOD OBTAINED
2017-07-07	Within 1 metre	Document Report

INITIAL GAS INTERVAL	FLOW 1000 m3/dM	SIP kPag
27.80 - 29.40	SHOW	

INITIAL OIL INTERVAL	FLOW m3/d	SIP kPag

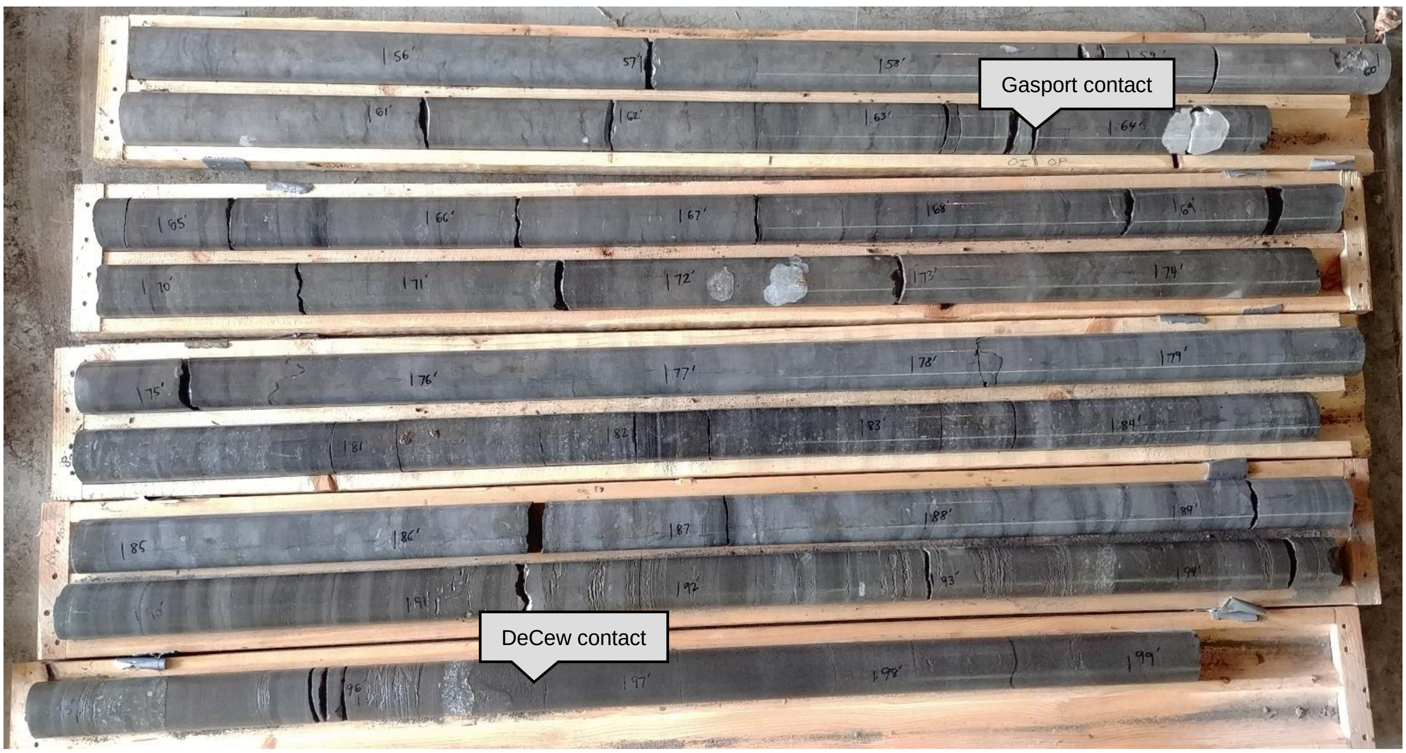
WATER RECORD INTERVAL	STATIC LEVEL	TYPE
16.10 -		
23.20 -		

LOGGING RECORD INTERVAL	TYPE	COMPANY
0.00 - 142.50	Striplog / Mudlog	Golder Associates

Casing O.D. (mm)	Weight (kg/m)	Setting Depth (m)	How Set
114.00	14.40	13.97	ROT

APPENDIX

C-3 ROCK CORE PHOTOS

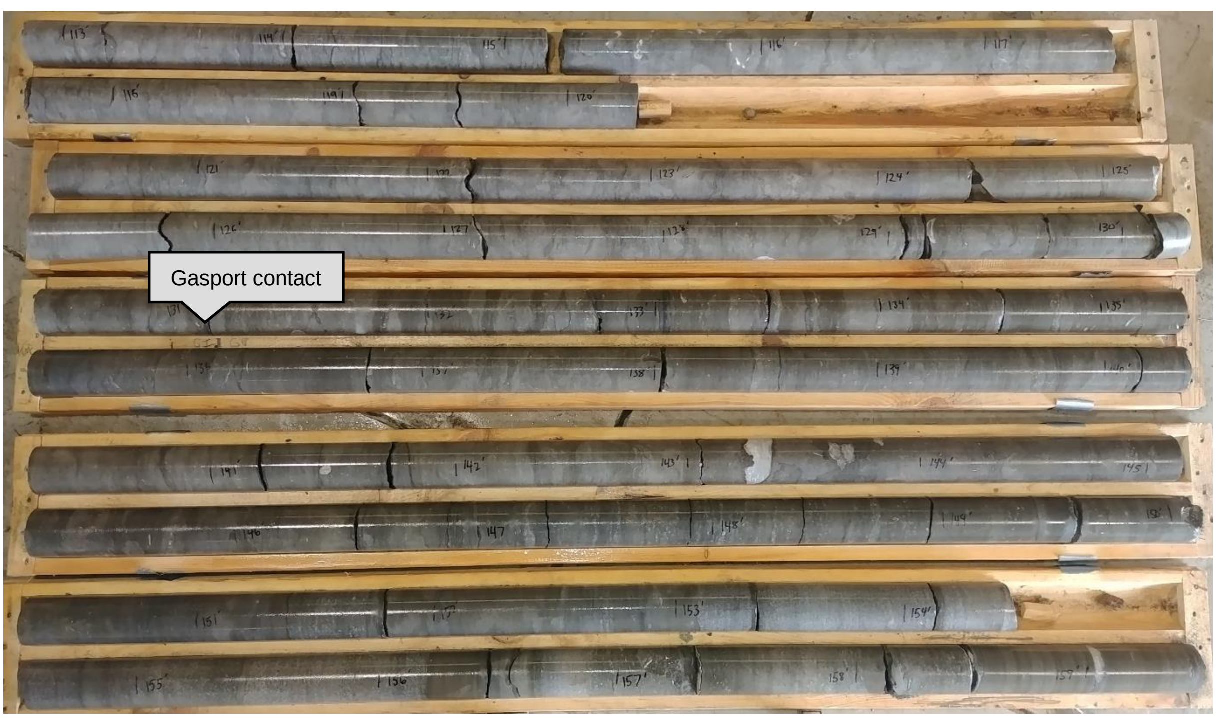
BH11-3AR, 16’ bgs to 99’ bgs

BH16-5A, 17’ bgs to 111’ bgs

BH16-5AR, 21’ bgs to 105’ bgs

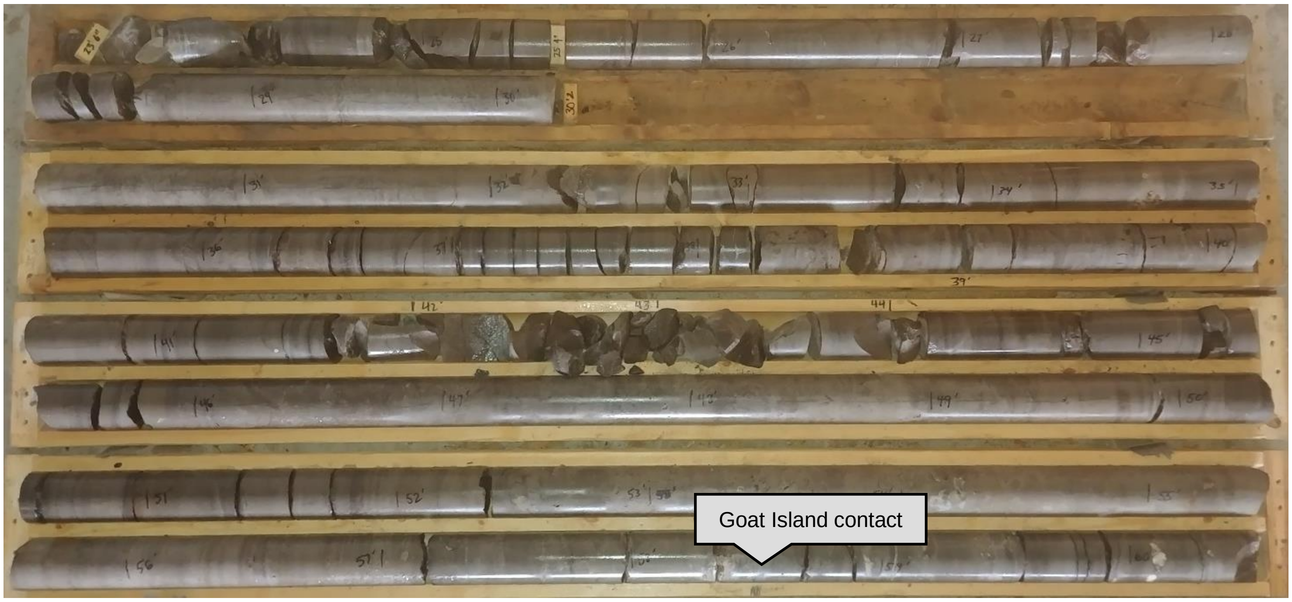
BH16-6A, 15’ bgs to 104’ bgs

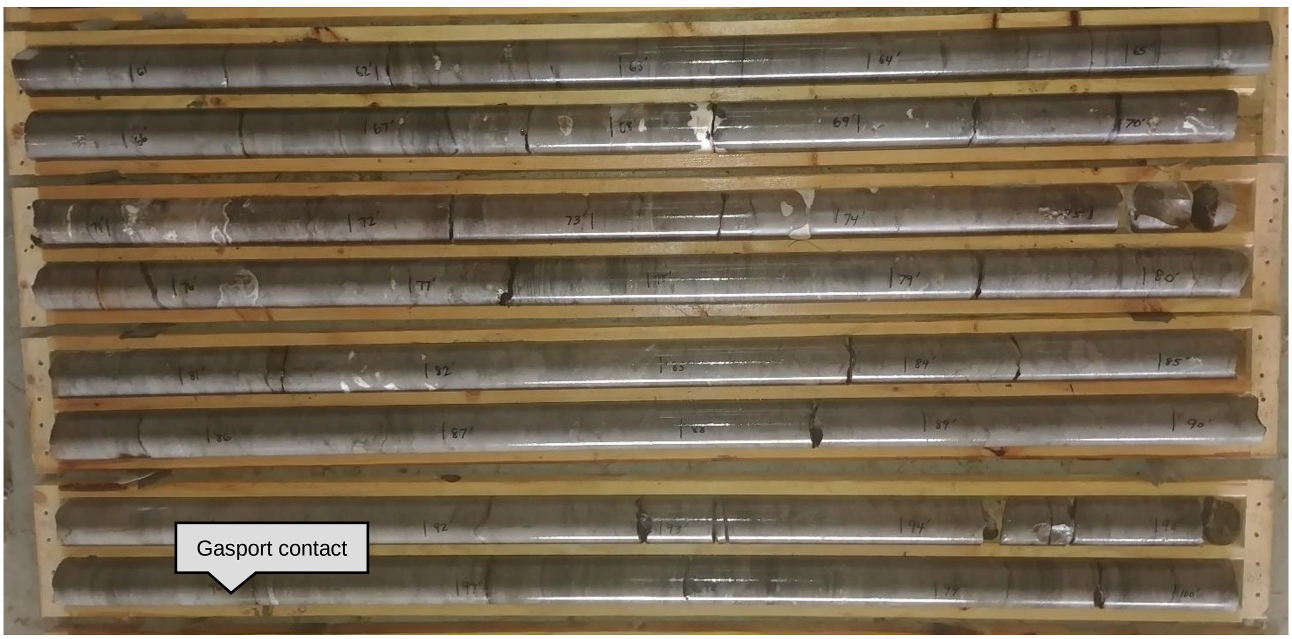
BH16-7A, 20’ bgs to 100’ bgs

BH16-8A, 35’ bgs to 159’ bgs



BH16-9A, 23’ bgs to 135’ bgs





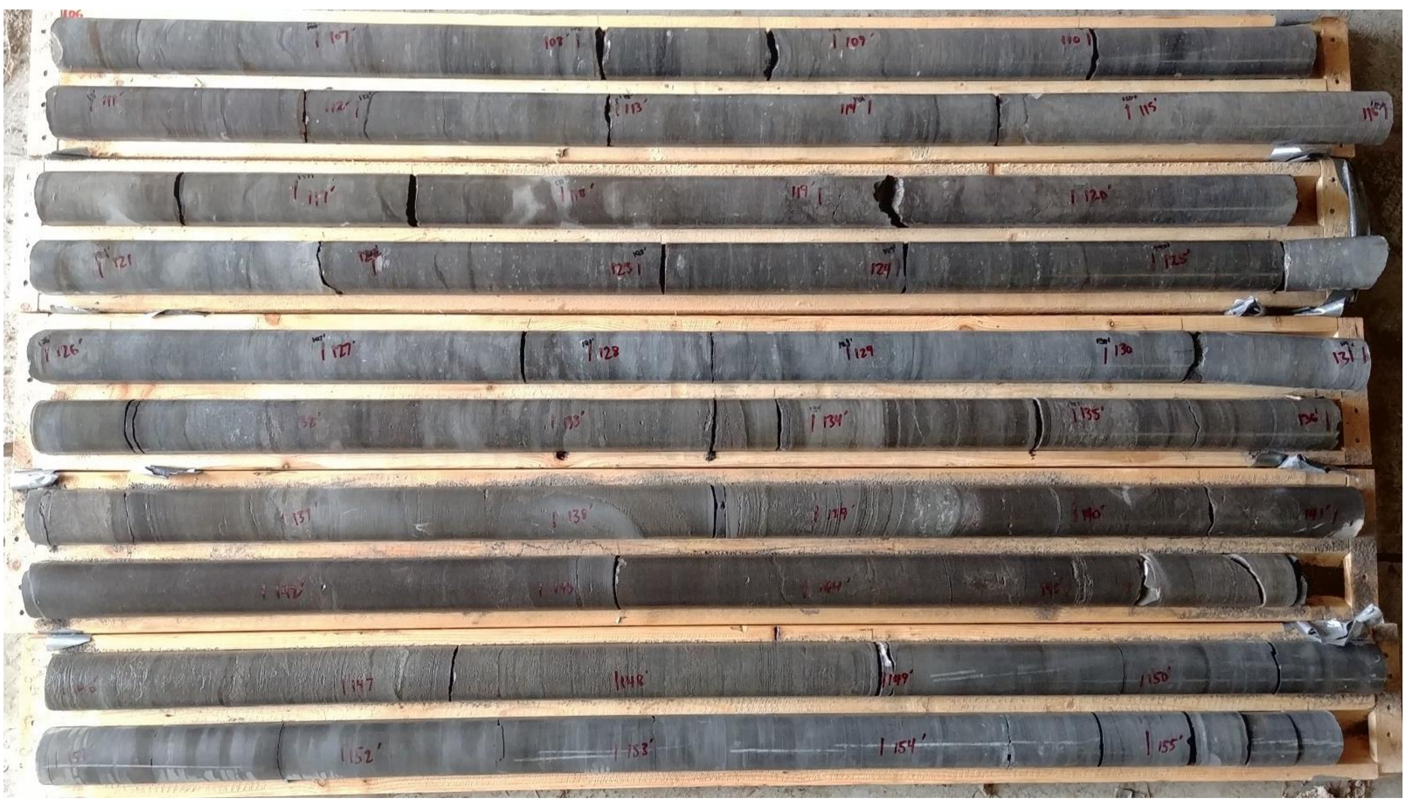
BH16-10A, 18’ bgs to 65’ bgs

BH16-13A, 18’ bgs to 95’ bgs

BH16-18B, 5’ bgs to 15’ bgs

BH16-19B, 4’ bgs to 14’ bgs

BH17-20A, 17’ bgs to 155’ bgs

BH17-20A (cont'd), 17' bgs to 155' bgs

BH17-21B, 15’ bgs to 70’ bgs

BH17-22B, 12’ bgs to 60’ bgs

BH17-23B, 22’ bgs to 61’ bgs

APPENDIX

D

HYDRAULIC CONDUCTIVITY TESTING DATA

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

D.1 INTRODUCTION

Various methods were used to perform the hydraulic conductivity testing at the Site, all of which are summarized in this Appendix. A description of the testing undertaken at the Site is provided below.

Section D.2 Packer testing completed during borehole advancement of selected wells to assess relative hydraulic conductivity of discreet bedrock intervals during the initial (2016) drilling program, undertaken between October 5, 2016 and November 28, 2016. Test data included in **Appendix D-1**.

Section D.3 Single well response testing completed to determine local in-situ hydraulic conductivity. Two testing periods: following the initial (2016) drilling program between November 8 – 30, 2016, and following the supplemental (2017) drilling program between August 8, 2017 and September 14, 2017. Test data included in **Appendix D-2**.

Section D.4 Long-term pumping test completed at pumping well PW1 in 2017 to estimate larger-scale transmissivity of the shallow (Eramosa member) bedrock aquifer. Stepped-rate test completed on February 7, 2017; long-term constant rate test completed between February 8 – 16, 2017. Test data included in **Appendix D-3**.

Section D.5 Short-term pumping tests completed following supplemental (2017) drilling program to assess hydraulic connection between shallow (Eramosa member) bedrock aquifer, shallow weathered overburden and contact aquifer. Five ~8-hr duration tests completed between September 5 – 13, 2017. Test data included in **Appendix D-4**.

Section D.6 Permeameter tests completed on the shallow weathered overburden to estimate vertical hydraulic conductivity / recharge to the groundwater system. Seven tests completed at various locations across the Site and additional lands owned by WAI. Test data included in **Appendix D-5**.

Section D.7 Additional long-term pumping tests completed at pumping well PW1 and private well at 5205 Beechwood Road to estimate larger-scale transmissivity of the shallow bedrock aquifer. Long-term constant rate test for PW1 completed between February 20 – March 1, 2019. Long-term constant rate test for 5205 Beechwood residential well completed between March 5 – 11, 2019. Stepped-rate test completed on March 15, 2019. Test data included in **Appendix D-6**.

D.2 PACKER TESTING

A total of four (4) monitoring well nests were selected for falling head packer testing during advancement of the deep ‘A’ series boreholes to assess the hydraulic conductivity along the depth of the borehole at approximately 3 m (10’) intervals. Packer testing was completed at well nests MW16-5 close to the Existing Watercourse meander valley north of the proposed quarry, MW16-6 to the east, MW16-8 to the southwest and MW16-10 to the northwest. The packer testing analyses are included in **Appendix D-1**, and summarized in **Table D.2.1** below, along with the depth interval, interpreted stratigraphy, rock quality density (RQD) and other relevant notes.

Table D.2.1 Summary of Packer Testing Analyses

Well Nest	Figure No.	Depth Interval (mbgs)	Hydraulic Conductivity (cm/s)	Stratigraphic Unit from Borehole Log	RQD (%)	Notes
MW16-5 (north)	1-5-1	7.7 – 10.8	$1.2x10^{-3}$	Eramosa Mb	63 – 83	Top of bedrock at 5.2 mbgs; ‘B’ screen interval
	1-5-2	10.8 – 13.9	$1.1x10^{-3}$	Goat Island Mb	72 – 94	Goat Island Mb contact at 11.0 mbgs
	1-5-3	13.9 – 16.8	$1.6x10^{-5}$	Goat Island Mb	85 – 88	
	1-5-4	16.8 – 19.8	$1.0x10^{-7}$	Goat Island Mb	97 – 98	
	1-5-5	19.8 – 23.0	$1.2x10^{-3}$	Goat Island / Gasport	85 – 100	Gasport Mb contact at 21.6 mbgs
	1-5-6	23.0 – 26.1	$2.2x10^{-6}$	Gasport Mb	98 – 100	
	1-5-7	26.1 – 29.1	$8.2x10^{-6}$	Gasport Mb	95 – 100	Top of sand pack at 28.0 mbgs
	1-5-8	29.1 – 32.1	$1.9x10^{-5}$	Gasport Mb	87 – 89	DeCew Fm contact at 31.9 mbgs; ‘A’ screen interval
MW16-6 (east)	1-6-1	7.6 – 9.1	$3.8x10^{-4}$	Eramosa Mb	63	Top of bedrock at 4.4 mbgs
	1-6-2	9.1 – 13.6	$8.1x10^{-5}$	Eramosa / Goat Island	63 – 100	Goat Island Mb contact at 10.4 mbgs; ‘B’ screen interval
	1-6-3	13.6 – 16.8	$6.1x10^{-7}$	Goat Island Mb	82 – 100	
	1-6-4	16.8 – 19.7	$2.3x10^{-7}$	Goat Island Mb	83 – 100	Gasport Mb contact at 19.7 mbgs
	1-6-5	19.7 – 22.9	$5.0x10^{-4}$	Gasport Mb	95 – 100	
	1-6-6	22.9 – 25.9	$1.4x10^{-5}$	Gasport Mb	92 – 95	
	1-6-7	25.9 – 28.9	$2.1x10^{-6}$	Gasport Mb	95 – 100	Top of sand pack at 26.8 mbgs
	1-6-8	28.9 – 31.9	$8.5x10^{-7}$	Gasport Mb / DeCew Fm	100	DeCew contact at 30.9 mbgs; ‘A’ screen interval

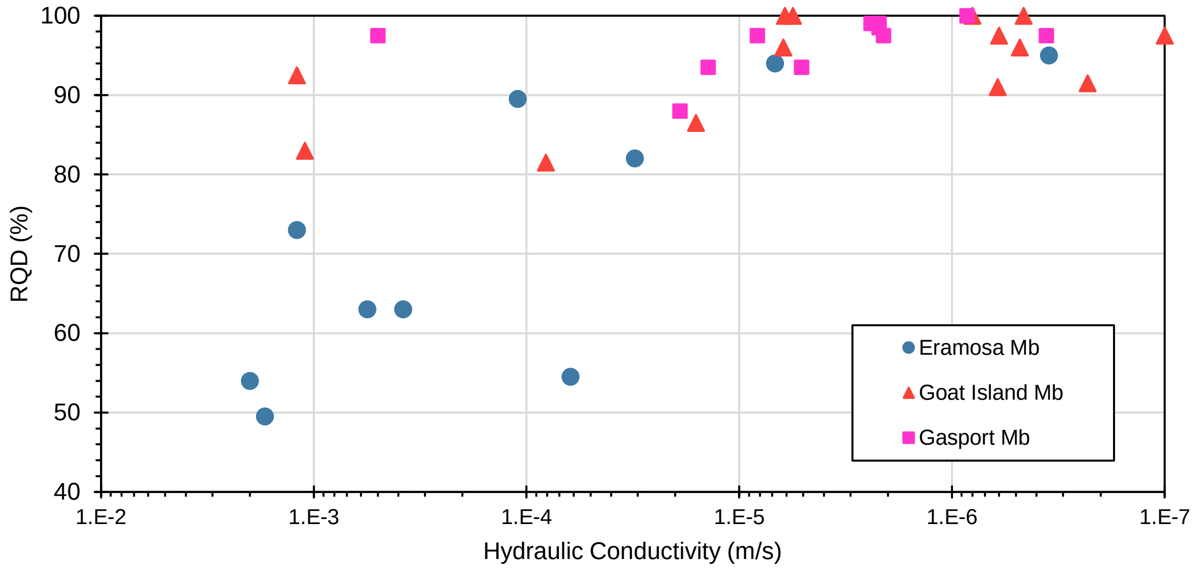
Table D.2.1 Summary of Packer Testing Analyses (cont'd)

Well Nest	Figure No.	Depth Interval (mbgs)	Hydraulic Conductivity (m/s)	Stratigraphic Unit from Borehole Log	RQD (%)	Notes
MW16-8 (southwest)	1-8-1	12.8 – 15.1	$3.1x10^{-5}$	Eramosa Mb	68 – 96	Top of bedrock at 10.7 mbgs
	1-8-2	15.1 – 16.7	$6.8x10^{-6}$	Eramosa Mb	94	
	1-8-3	16.7 – 19.7	$2.0x10^{-3}$	Eramosa Mb	50 – 58	
	1-8-4	19.7 – 22.7	$5.6x10^{-4}$	Eramosa Mb	39 – 87	
	1-8-5	22.7 – 25.9	$6.2x10^{-5}$	Eramosa Mb	39 – 70	'B' screen interval
	1-8-6	25.9 – 28.9	$3.5x10^{-7}$	Eramosa / Goat Island Mb	90 – 100	Goat Island Mb contact at 28.0 mbgs
	1-8-7	28.9 – 32.1	$6.0x10^{-7}$	Goat Island Mb	95 – 100	
	1-8-8	32.1 – 35.1	$4.6x10^{-7}$	Goat Island Mb	100	
	1-8-9	35.1 – 38.2	$8.0x10^{-7}$	Goat Island Mb	100	
	1-8-10	38.2 – 41.2	$4.8x10^{-7}$	Goat Island / Gasport Mb	92 – 100	Gasport Mb contact at 40.0 mbgs
	1-8-11	41.2 – 44.2	$3.6x10^{-7}$	Gasport Mb	95 – 100	Top of sand pack at 44.2 mbgs
	1-8-12	44.2 – 47.1	$2.4x10^{-6}$	Gasport Mb	98 – 100	'A' screen interval
MW16-10 (northwest)		7.6 – 10.7	na *	Eramosa Mb	58 – 71	Top of bedrock at 5.5 mbgs; 'B' screen interval
	1-10-2	10.7 – 13.8	$1.7x10^{-3}$	Eramosa Mb	27 – 72	
	1-10-3	13.8 – 16.8	$1.1x10^{-4}$	Eramosa / Goat Island Mb	87 – 92	Goat Island Mb contact at 16.2 mbgs
	1-10-4	16.8 – 19.9	$6.2x10^{-6}$	Goat Island Mb	92 – 100	
	1-10-5	19.9 – 23.0	$5.6x10^{-6}$	Goat Island Mb	100	
	1-10-6	23.0 – 26.0	$6.1x10^{-6}$	Goat Island Mb	100	Gasport Mb contact at 25.9 mbgs
	1-10-7	26.0 – 29.1	$5.1x10^{-6}$	Gasport Mb	90 – 97	
	1-10-8	29.1 – 32.1	$2.2x10^{-6}$	Gasport Mb	97 – 100	Top of sand pack at 30.2 mbgs; 'A' screen interval

Note: * Water level did not fall for the duration of test; hydraulic conductivity estimate not available.

It is noted that the absolute values for conductivity obtained from the packer tests are not expected to be representative of the bulk aquifer, but rather, the values obtained along the depth of each borehole provide an indication of zones of relatively high hydraulic conductivity. This qualitative information was used to enhance the conceptual understanding of the hydrogeology of the Site.

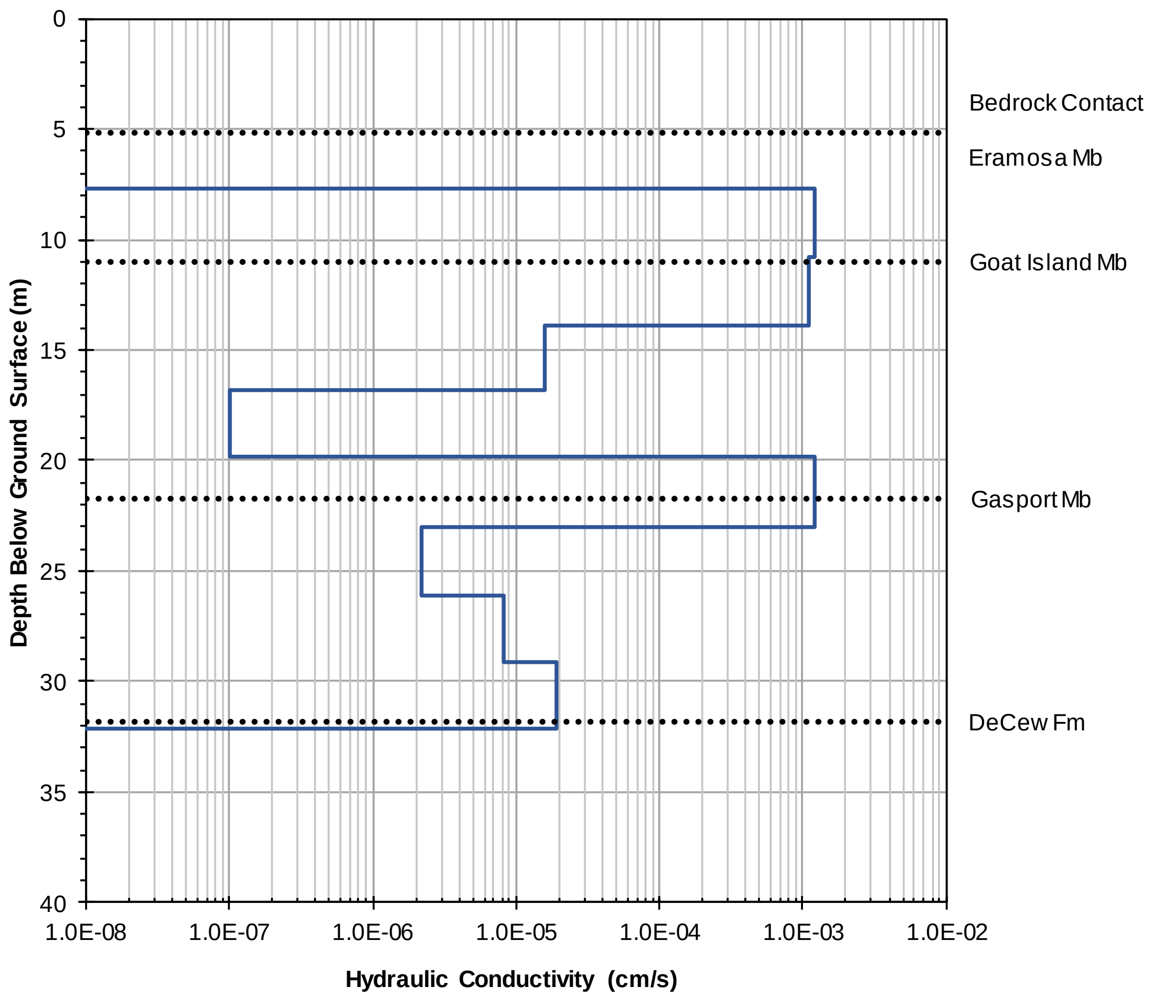
A plot of hydraulic conductivity versus RQD is provided below.



Not unexpectedly, the plot above shows that the lower hydraulic conductivities are typically associated with higher RQD (i.e. less fractured) rock. The packer test results suggest that at the Site, the Eramosa member typically consists of lower-RQD / higher hydraulic conductivity rock, while the lower Lockport members are associated with higher-RQD / lower hydraulic conductivity rock.

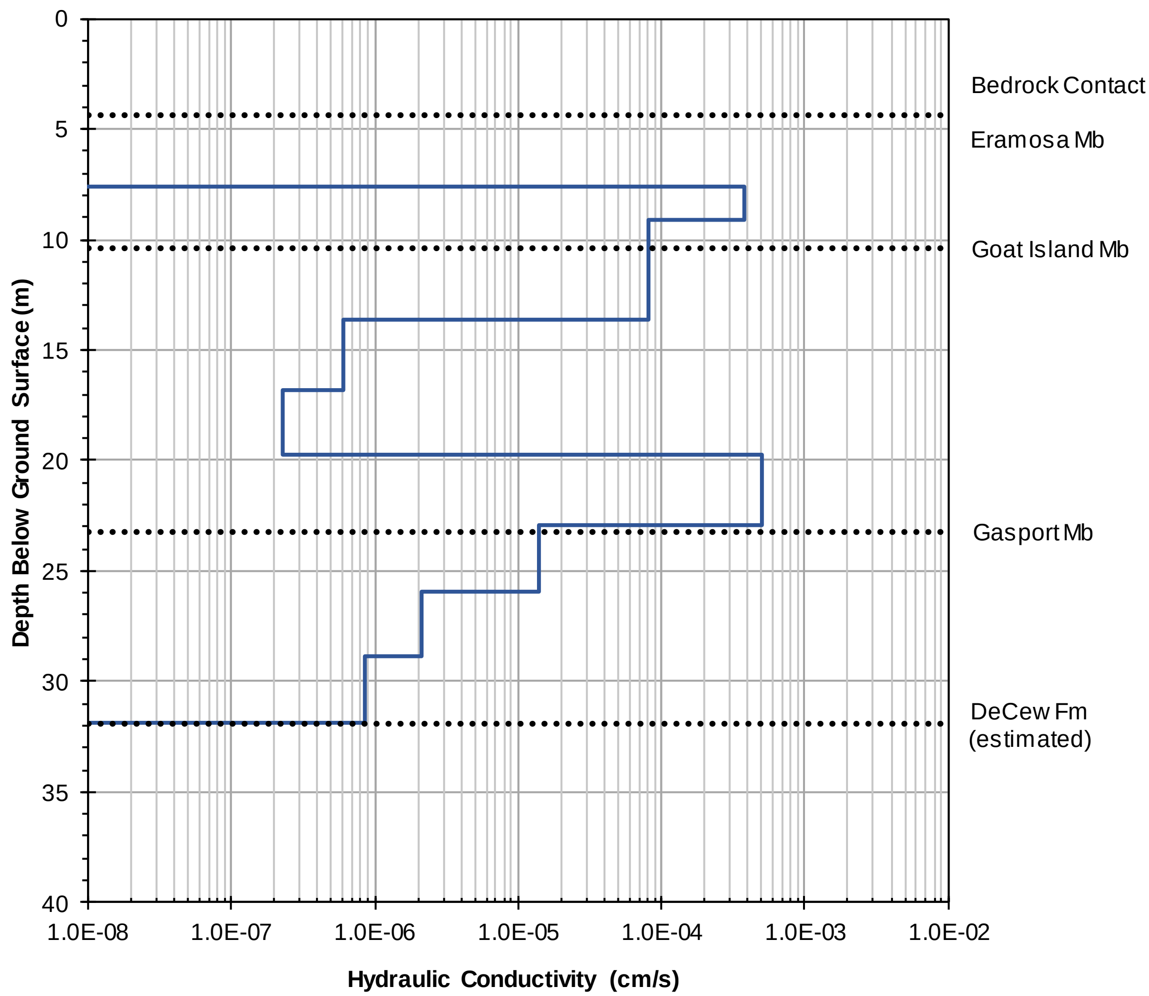
The results from **Table D.2.1** are represented graphically in the figures below for each of the four boreholes where packer testing was completed.

MW16-5 Packer Test Results



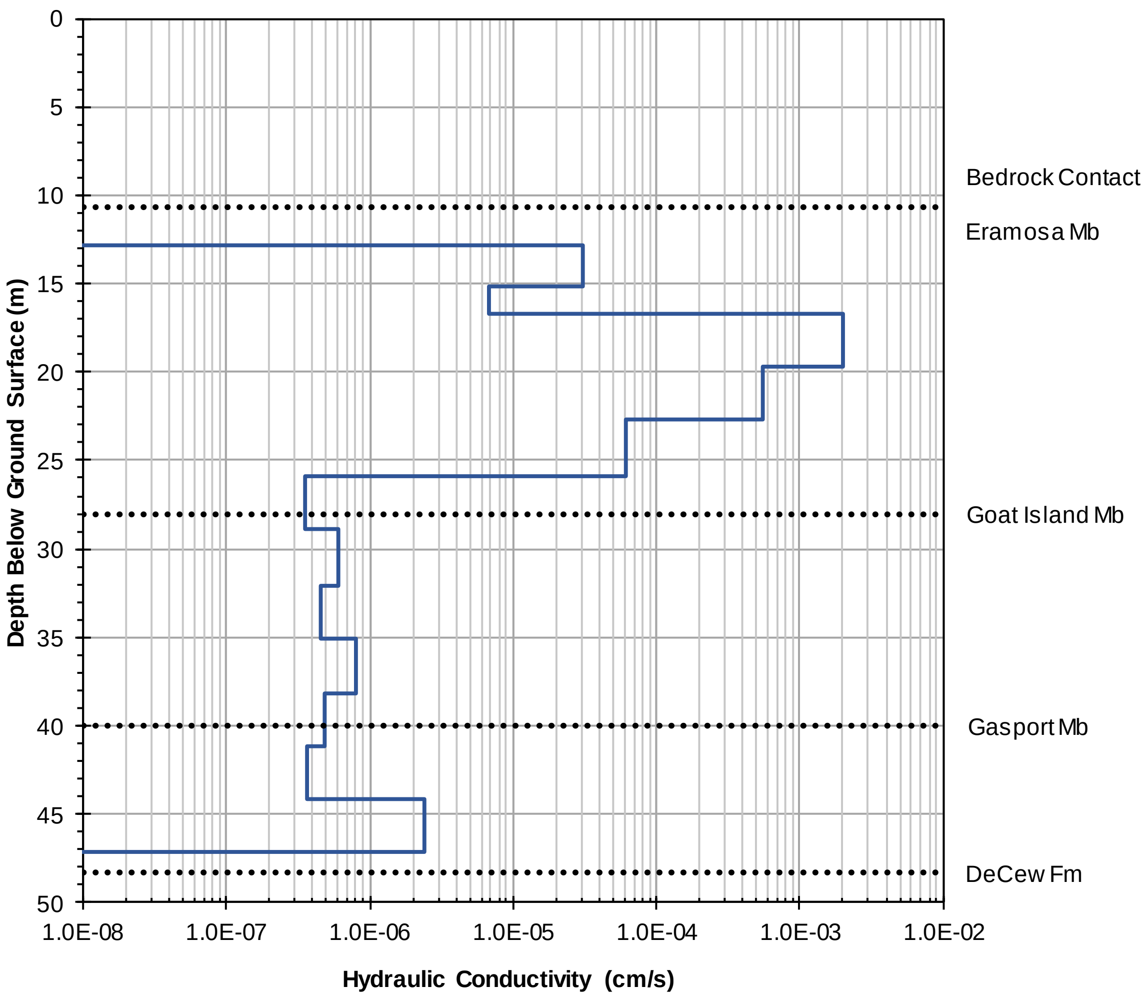
Cumulative Transmissivity = 1.1 cm²/s (9.6 m²/day)

MW16-6 Packer Test Results



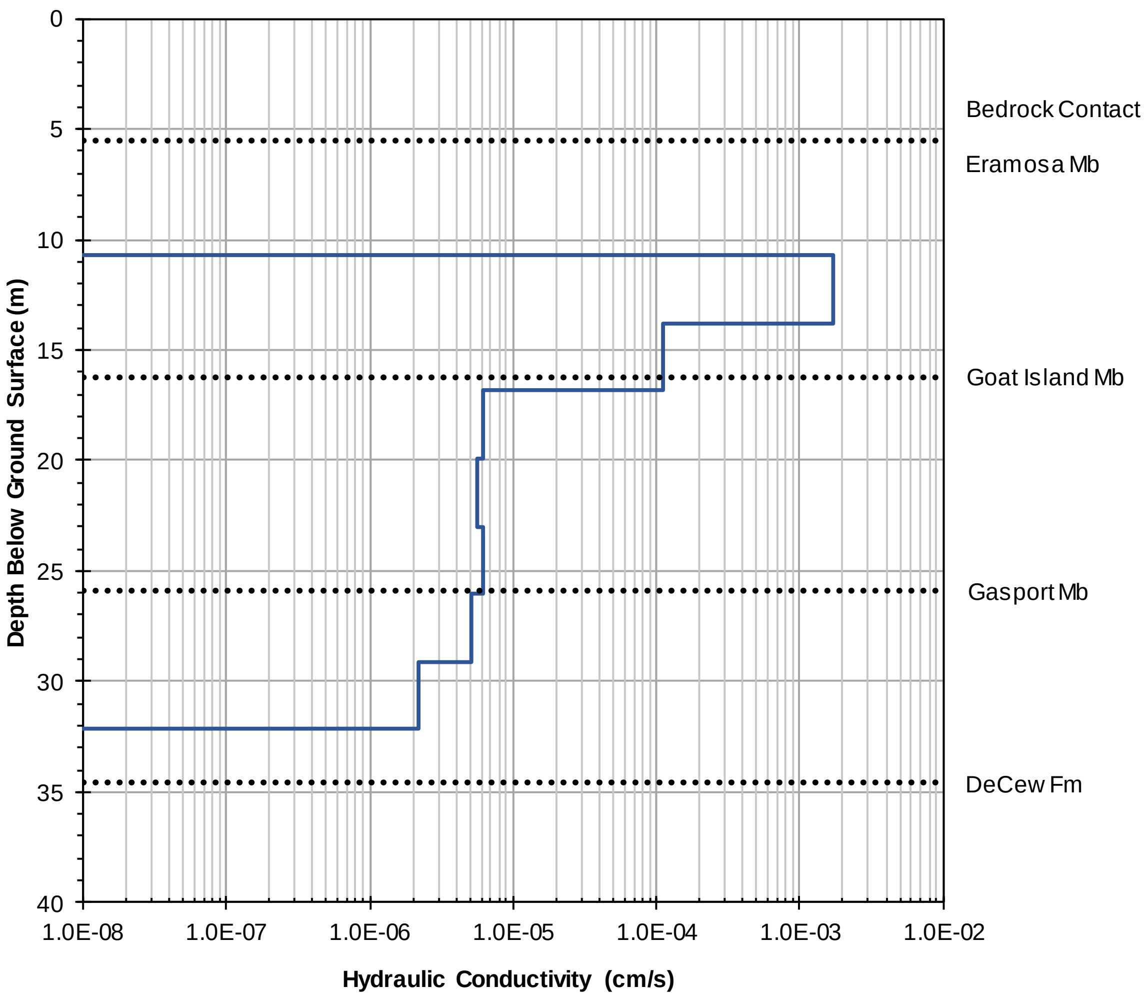
Cumulative Transmissivity = 0.26 cm^2/s (2.2 m^2/day)

MW16-8 Packer Test Results



Cumulative Transmissivity = 0.8 cm^2/s (6.9 m^2/day)

MW16-10 Packer Test Results



Cumulative Transmissivity = 0.57 cm²/s (4.9 m²/day)

D.3 SINGLE WELL RESPONSE TESTING

As part of the current hydrogeological investigation undertaken at the Site, in-situ single well response hydraulic conductivity (slug) tests have been completed at most monitoring wells. The slug testing analyses are included in **Appendix D-2**, and summarized in **Tables D.3.1 through D.3.5** below.

Table D.3.1 Hydraulic Conductivity in Overburden Wells

Well	Figure No.	Hydraulic Conductivity cm/s	Notes
MW11-1OB	2-1	3.3×10^{-6}	
MW11-2OB	2-2	1.0×10^{-7}	
MW11-3OBR	2-3	9.7×10^{-5}	
MW11-4OB	2-4	4.4×10^{-7}	
MW16-5OB	2-5	4.0×10^{-6}	
MW16-6OB		--	Insufficient volume in well to complete test
MW16-7OB	2-6	2.4×10^{-5}	
MW16-8OB	2-7	2.4×10^{-5}	
MW16-9OB	2-8	2.7×10^{-5}	
MW16-9SP	2-9	5.9×10^{-8}	
MW16-10OB	2-10	1.3×10^{-6}	
MW16-11	2-11	6.8×10^{-6}	
MW16-12		--	Insufficient volume in well to complete test
MW16-13OB		--	Insufficient volume in well to complete test
MW16-14		--	Insufficient volume in well to complete test
MW16-15		--	Insufficient volume in well to complete test
MW16-16	2-12	9.4×10^{-7}	
MW16-17	2-13	1.3×10^{-5}	
MW16-18OB	2-14	3.3×10^{-7}	
MW16-19OB	2-15	1.1×10^{-6}	
MW17-20OB	2-16	3.6×10^{-6}	
MW17-20SP	2-17	1.3×10^{-7}	
MW17-21OB	2-18	5.9×10^{-5}	

Table D.3.1 Hydraulic Conductivity in Overburden Wells (cont'd)

Well	Figure No.	Hydraulic Conductivity cm/s	Notes
MW17-21SP	2-19	1.4×10^{-7}	
MW17-22OB	2-20	2.1×10^{-7}	
MW17-22SP	2-21	1.4×10^{-8}	
MW17-23OB	2-22	3.5×10^{-4}	
MW17-23SP	2-23	1.8×10^{-8}	

Table D.3.2 Hydraulic Conductivity in Shallow Bedrock Aquifer Wells

Well	Figure No.	Hydraulic Conductivity cm/s	Notes
BH03-2B	2-24	8.0×10^{-4}	
MW11-1B			Test not completed
MW11-2B	2-25	9.3×10^{-4}	
MW11-3BR	2-26	2.5×10^{-4}	Pumped at rate of 9 L/min
MW11-4B	2-27	1.0×10^{-4}	
MW16-5B	2-28	1.3×10^{-4}	Pumped at rate of 30 L/min
MW16-6B	2-29	$3.0 \mathrm{X} 10^{-5}$	Pumped at rate of 20 L/min
MW16-7B	2-30	1.3×10^{-4}	
MW16-8B	2-31	2.9×10^{-5}	Pumped at rate of 9 L/min
MW16-9B	2-32	3.1×10^{-4}	
MW16-10B	2-33	1.4×10^{-3}	Pumped at rate of 8 L/min
MW16-13B	2-34	1.2×10^{-2}	Pumped at 30 L/min; overdamped response
MW16-18B	2-35	2.0×10^{-4}	Pumped at rate of 15 L/min
MW16-19B	2-36	1.0×10^{-4}	Pumped at rate of 6 L/min
MW17-20B	2-37	5.1×10^{-3}	Pumped at 30 L/min; overdamped response
MW17-21B	2-38	7.5×10^{-6}	Pumped at rate of 30 L/min
MW17-22B	2-39	4.5×10^{-4}	Pumped at 30 L/min; overdamped response
MW17-23B	2-40	2.8×10^{-5}	Pumped at rate of 10 L/min

Table D.3.3 Hydraulic Conductivity in Deep Bedrock Aquifer Wells

Well	Figure No.	Hydraulic Conductivity cm/s	Notes
BH03-2A	2-41	$6.0x10^{-9}$	
MW16-5A	2-42	$1.5x10^{-6}$	Gas production in well
MW16-5AR		--	Gas production in well prevents analysis
MW16-6A	2-43	--	Gas production in well prevents analysis
MW16-7A	2-44	--	Gas production in well prevents analysis
MW16-8A	2-45	$5.9x10^{-6}$	
MW16-9A	2-46	--	Gas production in well prevents analysis
MW16-10A	2-47	--	Gas production in well prevents analysis
MW16-13A	2-48	$1.7x10^{-8}$	
MW17-20A			No test completed

Table D.3.4 Hydraulic Conductivity in Lower Aquitard Wells

Well	Figure No.	Hydraulic Conductivity cm/s	Notes
MW11-1A	2-49	$1.8x10^{-10}$	Water level recovery after well installation
MW11-2A	2-50	$3.6x10^{-10}$	Water level recovery after well installation
MW11-3A	2-51	$4.2x10^{-10}$	Water level recovery after well installation
MW11-4A	2-52	$2.4x10^{-10}$	Water level recovery after well installation

Table D.3.5 Summary of Hydraulic Conductivity in Stratigraphic Units

Stratigraphic Unit	No. of Wells	Hydraulic Conductivity (cm/s)			Published Range * cm/s
		Minimum	Maximum	Geometric Mean	
Shallow Weathered Overburden	5	$1.4x10^{-8}$	$1.4x10^{-7}$	$4.9x10^{-8}$	$1x10^{-9}$ – $5x10^{-7}$
Contact Aquifer	18	$1.0x10^{-7}$	$3.5x10^{-4}$	$4.5x10^{-6}$	$1x10^{-10}$ – $2x10^{-4}$
Shallow Bedrock Aquifer	17	$7.5x10^{-6}$	$1.2x10^{-2}$	$2.3x10^{-4}$	$1x10^{-7}$ – $6x10^{-4}$ (1)
Deep Bedrock Aquifer	4	$6.0x10^{-9}$	$5.9x10^{-6}$	$1.7x10^{-7}$	
Lower Aquitard	4	$1.8x10^{-10}$	$4.2x10^{-10}$	$2.8x10^{-10}$	$1x10^{-11}$ – $2x10^{-7}$

Notes: * From Domenico and Schwartz, 1998.
(1) Sound limestone and dolomite

D.4 2017 PUMPING TEST

A ~3 day constant rate pumping test was performed on pumping well PW1 between February 8 and 11, 2017 to simulate dewatering of the proposed quarry and to determine potential effects on local groundwater users and sensitive features. The pumping test was completed under Permit-to-Take-Water (PTTW) No. 2550-AGSQ2H, issued by the MECP on December 23, 2016, and NPCA Permit No. 3872, issued on December 14, 2016.

During the test, groundwater elevations were monitored at pumping well PW1 and all available Site monitoring wells screened in the overburden and bedrock (excluding those installed after February 2017). Water levels were recorded using automated dataloggers augmented with periodic manual measurements during the pumping test.

Background groundwater elevation data were collected prior to the pumping test (refer to **Appendix E** of the Level 2 Hydrogeological Study report). The background data suggest that ambient groundwater elevation trends did not have a significant impact on water level data obtained during the pumping test.

D.4.1 PW1 STEP TEST

Prior to the constant rate test, on February 7, 2017, a step test was completed on PW1. The results of the step test were reviewed to evaluate the performance of the pumping well and estimate well efficiency.

Well efficiency (E_w) can be calculated using the following equation (Kruseman and de Ridder, 1990).

$$E_w = \left\{ \frac{B_1 Q}{(B_1 + B_2)Q + CQ^P} \right\} \times 100\%$$

Where: B_1 = linear aquifer loss coefficient

B_2 = linear well loss coefficient

$B \approx B_1 + B_2$

C = non-linear well loss coefficient

Q = well discharge

P = 2

In an ideal well (i.e., efficiency = 100%), groundwater within the aquifer is able to flow directly into the well bore and the drawdown in the well reflects the actual drawdown within the aquifer. In a fractured bedrock setting, the capacity of the water-bearing fractures is quantified by parameter B_1. Well inefficiency arises due to the alteration of the formation during drilling and the well screen not fully penetrating the aquifer (quantified by parameter B_2) and development of turbulent flow conditions in the pumping well and potentially the formation itself (quantified by parameter C).

The step test at PW1 consisted of three approximately 60 minute pumping steps at flow rates of 343 L/min (75 Igpm), 546 L/min (120 Igpm) and 750 L/min (165 Igpm). After the third step, the pump was shut off to allow monitoring of the pumping well recovery. The observed drawdown during the step test is shown in **Figure 3-1**, **Appendix D-3**.

The results of the step test analysis for PW1 are presented in **Figure 3-2**, **Appendix D-3**.

The water level in PW1 was lowered during each pumping step. The well efficiency estimated from the step test at PW1 decreased from 40% to 23% at the pumping rates used in the step test.

The recovery water level data following the step test were analyzed to provide an additional estimate of the aquifer properties, as shown in **Figure 3-3**, **Appendix D-3**. The Theis recovery analysis was used to perform the analysis. A pumping rate of 546 L/min (120 Igpm) was used for the analysis, which corresponds to the average of the three stepped rates used during the test. The estimated transmissivity from the step test recovery is approximately 62 m^2/day. Assuming an aquifer thickness of 17.4 m, the hydraulic conductivity is estimated as 3.6 m/day ($4.1x10^{-3}$ cm/s). This is within the range of reported values for the shallow bedrock aquifer in **Table D.3.5** above, and within an order of magnitude of the geometric mean of the slug test results for the shallow bedrock aquifer.

D.4.2 PW1 CONSTANT RATE TEST

On February 8, 2017, Country Water Systems, under the supervision of WSP personnel, initiated an ~80-hour (4,755 minute) constant rate pumping test at PW1. A pumping rate of 573 L/min (126 Igpm) was used during the test, with a pump depth of 30.5 m below top of pipe (mbtop), which roughly corresponds with the inferred Lockport formation, Goat Island / Gasport member contact. It is noted that pumping well PW1 was completed as an open hole in the bedrock, extending from approximately 2.1 m below the bedrock contact (6.1 mbgs) to the base of the Gasport member at approximately 45.4 mbgs. The pumping rate was maintained within 5% of this flow for the duration of the test (elapsed time of 4,755 minutes). A plot of the PW1 drawdown water level data is shown in **Figure 3-4**, **Appendix D-3**. A total drawdown of 5.73 m was observed in the pumping well. This represents approximately 16% of the available water column (approximately 33 m).

During the constant rate test, groundwater levels in most shallow bedrock aquifer ‘B’ series wells were observed to lower in response to pumping at PW1, as well as contact aquifer wells MW16-7OB and MW16-9OB, and deep bedrock aquifer well MW16-5A. Plots of the well water level data where pumping test responses were observed are shown in **Figures 3-5 through 3-10**, **Appendix D-3**. A summary of the drawdown at each well is summarized in **Table D.4.1** below. Pumping test drawdown contours in the contact aquifer, shallow bedrock aquifer, deep bedrock aquifer and lower aquitard are plotted in **Figures D-1 through D-4**.

Table D.4.1 Summary of Drawdown at Observation Wells

Direction from Pumping Well	Observation Well	Figure No.	Distance from Pumping Well (m)	Drawdown (m)
South	BH03-2B	3-5	27	5.46
	MW16-13B		161	5.43
	MW11-1B		690	4.09
North	MW11-4B	3-6	398	3.08
	MW16-18B		464	1.39
	MW16-19B		582	1.36
West	MW16-9OB *	3-7	288	1.30
	MW16-9B		288	4.03

Table D.4.1 Summary of Drawdown at Observation Wells (cont'd)

Direction from Pumping Well	Observation Well	Figure No.	Distance from Pumping Well (m)	Drawdown (m)
Northeast	MW16-5B	3-8	722	1.13
	MW16-5A †		722	3.54
Southeast	MW16-7OB *	3-9	762	1.44
	MW16-7B		762	3.73
	MW11-2B		982	1.16
Distant Wells	MW16-6B	3-10	911	0.82
	MW16-8B		966	1.19
	MW16-10B		681	3.16

Notes: * Contact Aquifer well.
† Deep Bedrock Aquifer well.

Upon completion of the constant rate test at PW1, the groundwater elevation recovery was monitored at the pumping well as well as the observation wells. On February 13, 2017, after a period of 2,240 minutes (37 hours and 20 minutes), the water level in PW1 had fully recovered to the pre-test static water level. Similar rates of recovery were noted for the observation wells.

The pumping test data were analyzed using AQTESOLV v.4.50 (HydroSOLVE Inc., 2007) software. The pumping well logger data were "thinned out" to show only representative levels on a log scale for the duration of the test. A number of different analyses were completed on the data as summarized below.

<u>**Pumping Well Cooper-Jacob Straight-Line Analysis**</u>

The Cooper-Jacob Straight-Line (CJSL) analysis was completed on both the pumping well PW1 drawdown and recovery curves to obtain an initial estimate of aquifer transmissivity, as shown on **Figures 3-11 and 3-12**, **Appendix D-3**. Using this method, the shallow bedrock aquifer transmissivity is estimated to be 50 m^2/day to 60 m^2/day. Assuming an aquifer thickness of 17.4 m, the hydraulic conductivity is estimated as 2.9 m/day to 3.4 m/day (3.4×10^{-3} cm/s to 3.9×10^{-3} cm/s). This is within the range of reported values for the shallow bedrock aquifer in **Table D.3.5** above, and within an order of magnitude of the geometric mean of the slug test results for the shallow bedrock aquifer. Of note, the storage coefficients reported by the software for these analyses are not physically realistic and are a result of the limitations of using the CJSL analysis; however, the estimated transmissivity (i.e., slope of the best-fit straight line) is not affected by the limitations of the method.

The CJSL analysis is only used to obtain an initial estimate of aquifer transmissivity, since the pumping well response deviates from an "ideal" aquifer. For an ideal aquifer:

- ➔ The aquifer is confined and has an "apparent" infinite extent;
- ➔ The aquifer is homogeneous, isotropic and of uniform thickness over the area influenced by pumping;
- ➔ The piezometric surface is horizontal prior to pumping;
- ➔ The well is pumped at a constant rate;

- ➔ The well is fully penetrating;
- ➔ Water removed from storage is discharged instantaneously with decline in head;
- ➔ The well diameter is small, so well storage is negligible; and
- ➔ The values of u are small (typically, u < 0.01), where

$$u = \frac{r^2 S}{4Tt}$$

and *r* = distance from the pumped well to a point where drawdown is measured
S = storage coefficient
T = transmissivity
t = time

Using the Cooper-Jacob methodology to analyze the test results implicitly assumes an equivalent porous medium approach, where the response of the fractured bedrock aquifer is approximated by an equivalent aquifer consisting of unconsolidated porous media. This means that the predicted drawdown in the pumping well assumes that flow to the well is radial so that the response provides an impression of depth-averaged conditions.

The derivative plot of the data is also included in both figures (green symbols). The derivative curves indicate that after approximately 1,000 minutes elapsed time, the drawdown and recovery curves deviate from the straight line and the rate of increase in the drawdown / recovery levels off. This response may either be the result of leakage from the overburden above, or the result of the pumping well being situated within a zone of higher permeability than the bulk aquifer properties outside of the zone around the pumping well. In an 'ideal' infinite aquifer, the drawdown would continue indefinitely at a rate proportional to the aquifer transmissivity, and the derivative plot would initially increase and then level off at a value of around '1'. Either of the above scenarios results in a plateau in the derivative, and then a decrease.

Pumping Well Recovery Theis Analysis

Pumping well PW1 recovery data was also analyzed using Theis recovery analysis, as shown in **Figure 3-13**, **Appendix D-3**. The plotted early recovery time is on the right and the late recovery is on the left (i.e., the timescale is inverted). In an ideal aquifer where the drawdown reaches steady-state by the time the pump is shut off, the recovery in the pumping well would be expected to mirror that of the drawdown. On the plot, the ideal aquifer response curve is shown as the red line. However, the pumping well water level recovers to pre-test static conditions faster than the drawdown time. The plot of recovery water levels versus t/t' reaches zero to the right of the graph origin. This pattern is also indicative of an increase in recharge to the shallow bedrock aquifer and lends credence to the 'leaky aquifer' hypothesis discussed above. The estimated transmissivity of the aquifer based on the Theis analysis of the recovery data is approximately 74 m^2/day. Assuming an aquifer thickness of 17.4 m, the hydraulic conductivity is estimated as 4.3 m/day (4.9×10^{-3} cm/s). These results compare favourably to the CJSL analytical results.

Pumping Well Leaky Aquifer Analysis

The pumping well PW1 drawdown and recovery data were analyzed assuming a leaky aquifer (after Moench, 1985) owing to leakage (recharge) from the overburden. This assumption corresponds to Case 3, a constant-head source aquifer supplying leakage across an overlying aquitard and a no flow boundary representing the underlying aquitard. In this case, the overlying aquitard thickness (b') is interpreted to be approximately 4.5 m, while the underlying aquitard thickness (b'') is assumed to be approximately 22 m (based on the stratigraphy from the original borehole log for BH03-2, the nearest monitoring well to pumping well PW1). The results of the leaky aquifer analyses for the drawdown and recovery of PW1 are shown in **Figures 3-14 and 3-15**, **Appendix D-3**.

Using the assumption of a leaky aquifer, the transmissivity of the shallow bedrock aquifer is calculated to be 20 m^2/day to 33 m^2/day, somewhat lower than the CJSL analysis above. Assuming an aquifer thickness of 17.4 m, the hydraulic conductivity is calculated as 1.1 m/day to 1.8 m/day (1.2×10^{-3} cm/s to 2.1×10^{-3} cm/s). This is again within the range of reported values for the shallow bedrock aquifer in **Table D.3.5** above, and within an order of magnitude of the geometric mean of the slug test results for the shallow bedrock aquifer.

The dimensionless parameters (r/B') and β' suggest that the overlying "aquitard" has hydraulic conductivity and storativity values similar to a sand and gravel aquifer. The dimensionless parameters for the underlying aquitard were insensitive to the data and are therefore not calculated. Finally, the dimensionless well skin factor (S_w) is estimated as approximately -3 to -4. Negative skin factors occur when the permeability in the aquifer around the well bore is enhanced. Assuming a thick skin model and no head loss through the skin, then the effective radius of the pumping well is estimated to be between 2 m and 6 m.

Pumping Well Non-Uniform Aquifer Analysis

The pumping well PW1 drawdown and recovery data were analyzed assuming a non-uniform aquifer (after Butler, 1988). For this conceptual aquifer model, the solution assumes that the pumping well is located at the centre of a cylinder of radius R embedded within an infinite aquifer. The hydrogeological properties of the cylinder (T_1, S_1) and the infinite aquifer (T_2, S_2) differ from each other. Using the distance-drawdown data presented below, the radius of the theoretical cylinder is estimated as approximately 200 m. The results of the non-uniform aquifer analyses for the drawdown and recovery of PW1 are shown in **Figures 3-16 and 3-17**, **Appendix D-3**.

Using the assumption of a non-uniform aquifer, the transmissivity of the shallow bedrock aquifer outside of the cylinder surrounding the pumping well (i.e., T_2) is calculated to be approximately 50 m^2/day, which is similar to the CJSL analysis above. Assuming an aquifer thickness of 17.4 m, the hydraulic conductivity is calculated as 2.9 m/day (3.3×10^{-3} cm/s). This is again within the range of reported values for the shallow bedrock aquifer in **Table D.3.5** above, and within an order of magnitude of the geometric mean of the slug test results for the shallow bedrock aquifer. The storage coefficients (i.e., S_2) are in the range of 1×10^{-5} to 1×10^{-4}.

For the cylinder surrounding the pumping well PW1, the calculated transmissivity (i.e., T_1) is notably higher, between 2,300 m^2/day to 12,000 m^2/day. Assuming an aquifer thickness of 17.4 m, the hydraulic conductivity is calculated as 130 m/day to 690 m/day (1.5×10^{-1} cm/s to 8.0×10^{-1} cm/s). These values are consistent with karst and reef limestone (Domenico & Schwartz, 1998).

Observation Well CJSL Composite Analysis

The drawdown curves for observation wells during the constant rate test were evaluated using the CJSL composite analysis. The results of this analysis are shown in **Figure 3-18**, **Appendix D-3**. The following observations are noted:

- ➔ The curves from the various observation wells do not fall along a single line; however, the slopes of most curves are similar. The slope of the best-fit line yields a shallow bedrock aquifer transmissivity of approximately 53 m^2/day, which compares favourably to the estimated values above.
- ➔ The fact that the curves for the various observation wells do not converge on a single line suggests that the shallow bedrock aquifer is not ideal, but rather heterogeneous in nature, which is not unexpected.
- ➔ On the CJSL composite plot, most of the observation wells have similar slopes for the best-fit lines. These wells include BH03-2B, MW16-13B, MW11-1B, MW11-4B, MW16-9B, MW16-7B and MW16-10B. The estimates of transmissivity for these wells are similar to that of PW1. These data also illustrate where the observed aquifer response began to deviate from the ideal aquifer response. This is an indication that the leaky aquitard boundary condition was encountered at all of these wells.
- ➔ Six of the observation wells shown on the CJSL composite plot have best-fit lines with lower slopes. These results suggest that the shallow bedrock aquifer response at wells MW16-6B, MW16-8B, MW16-18B, MW16-19B, MW16-5B and MW11-2B differs from that of the remaining observation wells. The transmissivity estimates at these six outlier wells are similar, calculated to be approximately 100 m^2/day. Interestingly, the slope of the best-fit type curve for these outlier wells is similar to the slope of the observed drawdown data for the remaining wells where the data started to diverge from the ideal aquifer response.
- ➔ Outlier wells MW16-18B and MW16-19B are situated within the inferred bedrock low associated with the Existing Watercourse where the Eramosa member bedrock unit is expected to be the thinnest, while MW16-5B is in close proximity to this feature. The remaining outlier wells are located quite far from pumping well PW1.

Observation Well Distance-Drawdown Analysis

Finally, the observation well drawdowns prior to pump shutoff during the constant rate test were analyzed using the distance-drawdown method, assuming (1) a confined ideal aquifer (Cooper-Jacob), (2) a leaky aquifer with a constant head upper boundary (Moench Case 3), and (3) a non-uniform aquifer (after Butler, 1988). The results of these analyses are shown in **Figures 3-19, 3-20 and 3-21**, **Appendix D-3**.

As shown in **Figure 3-19**, the estimated aquifer transmissivity using the Cooper-Jacob distance-drawdown method for an ideal confined aquifer is approximately 50 m^2/day with a storage coefficient of approximately $2x10^{-4}$. As shown in the figure, the best-fit line is roughly situated along the centroid of the observation well drawdown results, with the exception of BH03-2B (approximately 20 m from the pumping well) and the pumping well itself.

As shown in **Figure 3-20**, the estimated aquifer transmissivity using the leaky aquifer assumption is slightly lower, at approximately 45 m^2/day, with a storage coefficient of approximately $1x10^{-5}$. The best-fit line is also situated along the centroid of the observation well drawdown results. To fit the drawdown results at PW1, BH03-2B and MW16-13B, a dimensionless skin factor (S_w) of approximately -8 is required. It is noted that the generally accepted practical lower limit of the skin factor is -5 (Horne, 1995). The estimated skin factor of -8 results in an effective well radius of over 300 m.

As shown in **Figure 3-21**, assuming a non-uniform aquifer, the estimated transmissivity for the aquifer outside of the high-permeability zone around the pumping well is approximately 50 m^2/day, with a storage coefficient of approximately $2x10^{-4}$. The transmissivity of the zone surrounding the pumping well is estimated as approximately 5,300 m^2/day, which is consistent with karst or reef dolostone (Domenico & Schwartz, 1998).

D.4.3 PW1 DISCHARGE CHEMISTRY

Field measurements for pH, conductivity and temperature, as well as a sample of the pumping test discharge was collected during each day of pumping and submitted to Maxxam Analytics of Mississauga, Ontario, for analysis. The sample results are presented in **Table D.4.3** below. A sample was also collected from the pumping well following installation and is included for comparison. The pumping test samples collected on February 7, 8, and 9, 2017 were collected directly from the pumping well discharge pipe while the samples collected on February 10 and 11, 2017 were collected from the end of the agricultural field swale prior to discharging to the Existing Watercourse, downstream of the silt fence. Only parameters which were generally detected above the lab reported detection limit are included on the table below.

Table D.4.2 Summary of Pumping Well PW1 Discharge Chemical Results

Parameter	Sample Date					
	26-Oct-16	7-Feb-17	8-Feb-17	9-Feb-17	10-Feb-17	11-Feb-17
Field Measurements						
pH (pH units)	7.80	7.34	7.33	6.65	6.87	6.85
Conductivity (µS/cm)	1873	1467	1594	2170	3370	3410
Temperature (ºC)	11.7	11.3	11.3	11.3	0.1	5.2
Clarity	Clear	Clear	Clear	Clear to cloudy	Clear to cloudy	Clear
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Odour	None	Slight sulfur	Sulfur	Strong sulfur	None	None
General Parameters						
pH (lab) (pH units)	7.90	7.37	7.39	7.36	8.01	8.01
Hardness	940	760	860	1100	1100	1200
Total Suspended Solids	<10	10	<10	<10	46	13
Alkalinity	460	450	450	420	380	380
Sulphide	0.022				0.040	0.028
Hydrogen Sulphide (undissociated)	0.004				0.030	0.020
Nutrients						
Ammonia	0.24	0.10	0.12	0.45	0.46	0.51
Un-ionized Ammonia	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Table D.4.2 Summary of Pumping Well PW1 Discharge Chemical Results (cont'd)

Parameter	Sample Date					
	26-Oct-16	7-Feb-17	8-Feb-17	9-Feb-17	10-Feb-17	11-Feb-17
Total Metals						
Aluminum	0.029	0.028	0.015	0.0079	1	0.23
Antimony	0.0023	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Arsenic	0.016	0.001	<0.0010	<0.0010	<0.0010	<0.0010
Barium	0.42					
Boron	0.089	0.051	0.056	0.23	0.29	0.33
Cobalt	<0.00050	<0.00050	<0.00050	<0.00050	0.00066	<0.00050
Copper	<0.0010	0.0023	0.0014	<0.0010	0.0014	<0.0010
Iron	0.54	2.1	1.7	0.58	1.2	0.28
Molybdenum	0.0063	0.00086	0.0008	<0.00050	<0.00050	0.00054
Nickel	0.0021	<0.0010	<0.0010	<0.0010	0.0012	<0.0010
Lead	<0.00050	<0.00050	<0.00050	<0.00050	0.00075	<0.00050
Uranium	0.012	0.0016	0.0013	0.00056	0.0018	0.0019
Vanadium	0.0028	<0.00050	<0.00050	<0.00050	0.0021	0.00095
Zinc	0.017	0.069	0.041	0.013	0.0078	<0.0050

Notes: Concentrations in mg/L unless otherwise noted.

In general, the laboratory results from the samples collected from the pumping discharge during the pumping test were similar to the results of the sample collected from the pumping well in October 2016. The discharge from the pumping well during the pumping test was observed to be clear and colourless. A slight sulfur odour was noted during the first day of pumping and got stronger as the test progressed.

D.5 SHORT-TERM PUMPING TESTS

Following the long-term pumping test at pumping well PW1 completed in February 2017, four (4) additional monitoring wells were installed at several nested locations during the summer of 2017 to assess the hydraulic connection between the shallow weathered overburden, the contact aquifer and the shallow bedrock aquifer.

A total of five (5) short-term (~8 hr) pumping tests were completed by WSP personnel, at well nests MW16-9 (September 6, 2017), MW17-20 (September 13, 2017), MW17-21 (September 12, 2017), MW17-22 (September 5, 2017) and MW17-23 (September 7, 2017). For each test, a Grundfos Redi-Flo pump was installed within the well screen in the shallow bedrock “B” series well at each nest. The pump has a small enough diameter to allow it to fit within a typical 51 mm (2”) diameter monitoring well riser pipe. The pumping rate is adjustable, with a maximum sustained rate of approximately 30 L/min.

Groundwater levels within the “B” series wells, and nested “OB” and “SP” wells were monitored during the tests with automated data loggers augmented with periodic manual measurements. Hydrographs for the well nests are shown in **Figures 4-1 through 4-5**, **Appendix D-4**.

The recovery data from the “B” series wells were used to interpret local in-situ hydraulic conductivity of the shallow bedrock (refer to **Section D.3** above). **Section D.3** also includes the pumping rates used during each test.

D.6 PERMEAMETER TESTS

To provide an additional estimate of the vertical hydraulic conductivity of the shallow weathered overburden to calculate groundwater recharge to the aquifer, seven (7) permeameter tests were completed at various locations around the Site and additional lands owned by WAI. The permeameter test locations are shown in **Figure D-5**.

The permeameter tests were completed following the methodology created by Canadian Sewage Solutions Inc. (CSS) after Moores and Waller (1993), also referred to as the Nova Scotia method. The results of the permeameter test analyses are shown in **Figures 5-1 to 5-7**, **Appendix D-5**, and summarized in **Table D.6.1** below.

Table D.6.1 Vertical Hydraulic Conductivity in Shallow Overburden

Location	Figure No.	Vertical Hydraulic Conductivity cm/s
PERM1	5-1	$7.3x10^{-6}$
PERM2	5-2	$2.4x10^{-6}$
PERM3	5-3	$7.9x10^{-6}$
PERM4	5-4	$5.5x10^{-7}$
PERM5	5-5	$8.4x10^{-6}$
PERM6	5-6	$9.9x10^{-6}$
PERM7	5-7	$1.1x10^{-5}$

D.7 2019 PUMPING TESTS

Two additional pumping tests were completed in early 2019:

- ➔ A ~147-hour constant rate pumping test was performed on pumping well PW1 between February 20 and 26, 2019.
- ➔ A ~143-hour constant rate pumping test was performed on the private domestic supply well at 5205 Beechwood Road, within the northeast portion of the Site, between March 5 and 11, 2019.

These pumping tests were completed under PTTW No. 8530-B8QSLH, issued by the MECP on January 28, 2019, and NPCA Permit No. 201900095, issued on February 8, 2019.

The purpose of the additional test at pumping well PW1 was to include the additional Site monitoring wells installed after the previous pumping test in 2017, and to stress the shallow bedrock aquifer at a higher rate and for a longer duration. The pumping test at the 5205 Beechwood residential well was completed to provide an additional estimate of aquifer properties to the northeast of the Site, where the pumping tests at PW1 did not demonstrate an impact.

During the tests, groundwater elevations were monitored at the pumping wells and Site monitoring wells screened in the overburden and bedrock. Water levels were recorded using automated dataloggers augmented with periodic manual measurements during the pumping tests.

Background groundwater elevation data were collected prior to the pumping tests (refer to **Appendix E** of the Level 2 Hydrogeological Study report). The background data suggest that ambient groundwater elevations in the shallow bedrock aquifer were relatively stable prior to commencement of the pumping tests. During the PW1 pumping test, notable precipitation events occurred on February 20 / day 1 of pumping (3 mm), February 24 / day 4 of pumping (3 mm) and February 27 / day 2 of recovery (7 mm). The precipitation event of February 24 caused a decrease in the pumping test drawdown which is visible on most observation well hydrographs. During the 5205 Beechwood residential well pumping test, notable precipitation events occurred on March 9 / day 5 of pumping (4 mm) and March 10 / day 6 of pumping (11 mm). The precipitation event of March 10 caused a decrease in the pumping test drawdown which is visible on all observation well hydrographs.

D.7.1 PW1 CONSTANT RATE TEST

On February 20, 2019, Country Water Systems, under the supervision of WSP personnel, initiated a ~147-hour (8,830 minute) constant rate pumping test at PW1. A pump depth of 30.5 m below top of pipe (mbtop), which roughly corresponds with the inferred Lockport formation, Goat Island member / Gasport member contact. The pumping rate was initially set at approximately 885 L/min (195 Igpm); however, the rate was subsequently lowered within the first seven minutes of elapsed time to comply with the maximum permitted rate of 760 L/min. The flow rate was maintained at 750 L/min (165 Igpm) ± 5% for the duration of the test (elapsed time of 8,830 minutes). Of note, the generator supplying the pump with power ran out of fuel early in the morning of February 25 starting at approximately 12:56 AM. The generator and pump were re-started at approximately 8:02 AM; therefore, the pump was off for a total of 426 minutes (7 hours and 6 minutes). A plot of the PW1 water level data is shown in **Figure 6-1**, **Appendix D-6**. A total drawdown of 5.89 m was observed in the pumping well prior to the planned shut down of the pump on February 26, 2019. This represents approximately 16% of the available water column.

Similar to the 2017 pumping test, groundwater levels in most shallow bedrock aquifer 'B' series wells were observed to lower in response to pumping at PW1, as well as contact aquifer wells MW16-7OB and MW16-9OB, and deep bedrock aquifer well MW16-5A. Drawdown was also observed in the contact aquifer at MW17-23OB and deep bedrock aquifer wells MW16-5AR and MW16-7A during the 2019 pumping test. Plots of the well water level data where pumping test responses were observed are shown in **Figures 6-2 through 6-29**, **Appendix D-6**. A summary of the drawdown at each well is summarized in **Table D.7.1** below. Drawdown contours in the shallow bedrock aquifer from the 2019 pumping test at PW1 are plotted in **Figure D-6**.

Table D.7.1 Summary of Drawdown at Observation Wells

Direction from Pumping Well	Observation Well	Figure No.	Distance from Pumping Well (m)	Drawdown (m)
South	BH03-2B	6-2	27	5.57
	MW16-13B	6-3	161	5.51
	MW11-1B	6-4	690	4.45
North	MW11-4B	6-5	398	1.36
	MW16-18B	6-6	464	1.34
	MW16-19B	6-7	582	1.21
	MW16-10B	6-8	681	2.75
West	MW17-22B	6-9	122	5.49
	MW16-9OB *	6-10	288	1.98
	MW16-9B	6-11	288	4.33
	MW17-23OB *	6-12	342	2.43
	MW17-23B	6-13	342	3.73
	Cricket Ctr Well (5114 Townline Road)	6-14	378	2.25
	MW17-21B	6-15	468	2.17
Northeast	MW16-5B	6-16	722	1.17
	MW16-5A †	6-17	722	3.97
	MW15-5AR †	6-18	747	2.11
	MW16-6B	6-19	911	1.09
	5205 Beechwood Well	6-20	1,030	0.50
	MW11-3BR	6-21	1,117	0.23
Southeast	MW16-7OB *	6-22	762	1.95
	MW16-7B	6-23	762	4.18
	MW16-7A †	6-24	762	3.97
	MW11-2B	6-25	982	1.14
	Gortson Well (5769 Beechwood Road)	6-26	1,177	1.87

Table D.7.1 Summary of Drawdown at Observation Wells (cont'd)

Direction from Pumping Well	Observation Well	Figure No.	Distance from Pumping Well (m)	Drawdown (m)
South Distant Wells	**MW16-8B**	6-27	966	2.11
	Lundys Manor Well (9941 Lundys Lane)	6-28	1,116	1.14
	Country Basket Well (10008 Lundys Lane)	6-29	1,428	1.69

Notes: * Overburden well.
† Gasport Mb well.

Upon completion of the constant rate test at PW1, the groundwater elevation recovery was monitored at the pumping well as well as the observation wells. On March 1, 2019, after a period of 4,429 minutes (73 hours and 49 minutes), the water level in PW1 had fully recovered to the pre-test static water level. Similar rates of recovery were noted for the observation wells.

The pumping test data were analyzed using AQTESOLV v.4.50 (HydroSOLVE Inc., 2007) software. The pumping well logger data were "thinned out" to show only representative levels on a log scale for the duration of the test. As expected, the aquifer response to the 2019 pumping test was similar to the 2017 test results, and as such, the data was analyzed in a similar manner as described in **Section D.4** above.

<u>Pumping Well Cooper-Jacob Straight-Line Analysis</u>

The CJSL analyses are shown on **Figures 6-30 and 6-31**, **Appendix D-6**. Using this method, the aquifer transmissivity is estimated to be 62 m^2/day to 72 m^2/day. Assuming an aquifer thickness of 17.4 m, the hydraulic conductivity is estimated as 3.6 m/day to 4.1 m/day ($4.2x10^{-3}$ cm/s to $4.7x10^{-3}$ cm/s).

<u>Pumping Well Recovery Theis Analysis</u>

Pumping well PW1 recovery data was also analyzed using Theis recovery analysis, as shown in **Figure 6-32**, **Appendix D-6**. The estimated transmissivity of the aquifer based on the Theis analysis of the recovery data is approximately 84 m^2/day. Assuming an aquifer thickness of 17.4 m, the hydraulic conductivity is estimated as 4.8 m/day ($5.6x10^{-3}$ cm/s).

<u>Pumping Well Leaky Aquifer Analysis</u>

The results of the leaky aquifer analyses are shown in **Figures 6-33 and 6-34**, **Appendix D-6**. Using these analyses, the transmissivity of the shallow bedrock aquifer is estimated to be 18 m^2/day to 28 m^2/day. Assuming an aquifer thickness of 17.4 m, the hydraulic conductivity is estimated as 1.0 m/day to 1.6 m/day ($1.2x10^{-3}$ cm/s to $1.9x10^{-3}$ cm/s).

<u>Pumping Well Non-Uniform Aquifer Analysis</u>

The results of the non-uniform aquifer analyses are shown in **Figures 6-35 and 6-36**, **Appendix D-6**. Using these analyses, the bulk transmissivity of the aquifer outside of the high-permeability zone surrounding the pumping well is estimated to be 110 m^2/day to 150 m^2/day. Assuming an aquifer thickness of 17.4 m, the hydraulic conductivity is estimated as 6.3 m/day to 8.6 m/day ($7.3x10^{-3}$ cm/s to $1.0x10^{-2}$ cm/s). The hydraulic conductivity within the high-permeability zone is estimated to be 2,500 m^2/day to 2,700 m^2/day.

Observation Well CJSL Composite Analysis

The results of the CJSL composite analysis are shown in **Figure 6-37**, **Appendix D-6**. Similar to the 2017 pumping test results, the curves from the various observation wells do not fall along a single line; however, the slopes of most curves are similar. The slope of the best-fit line yields a shallow bedrock aquifer transmissivity of approximately 82 m^2/day. Notable outliers are MW11-4B and MW16-18B to the north and northeast of the pumping well. The transmissivity estimates for these two wells is between 150 m^2/day and 300 m^2/day.

Observation Well Distance-Drawdown Analysis

The observation well drawdowns prior to pump shutoff during the constant rate test were analyzed using the distance-drawdown method, assuming (1) a confined ideal aquifer (Cooper-Jacob), (2) a leaky aquifer with a constant head upper boundary (Moench Case 3), and (3) a non-uniform aquifer (after Butler, 1988). The results of these analyses are shown in **Figures 6-38, 6-39 and 6-40**, **Appendix D-6**.

As shown in **Figure 6-38**, the estimated aquifer transmissivity using the Cooper-Jacob distance-drawdown method is approximately 40 m^2/day with a storage coefficient of approximately $4x10^{-4}$. As shown in **Figure 6-39**, the estimated aquifer transmissivity using the leaky aquifer assumption is slightly lower, at approximately 30 m^2/day, with a storage coefficient of approximately $9x10^{-4}$. Similar to the 2017 results, the estimated skin factor of -8 results in an effective well radius of over 300 m, which is greater than the practical limit noted in the literature. As shown in **Figure 6-40**, the estimated bulk transmissivity of the aquifer outside of the high-permeability zone surrounding the pumping well is approximately 35 m^2/day, while the estimated transmissivity of the high-permeability zone is approximately 2,800 m^2/day.

D.7.2 PW1 DISCHARGE CHEMISTRY

Field measurements for pH, conductivity and temperature, as well as a sample of the pumping test discharge was collected during each day of pumping and submitted to Eurofins Environment Testing Canada Inc. of Ottawa, Ontario, for analysis. The sample results are presented in **Table D.7.2** below. The samples were collected directly from the pumping well discharge pipe. Only parameters which were generally detected above the lab reported detection limit are included on the table below.

Table D.7.2 Summary of Pumping Well PW1 Discharge Chemical Results

Parameter	Sample Date						
	20-Feb-19	21-Feb-19	22-Feb-19	23-Feb-19	24-Feb-19	25-Feb-19	26-Feb-19
Field Measurements							
pH (pH units)	7.3	7.2	7.5	7.1	7.2	6.9	7.1
Conductivity (µS/cm)	1,340	1,697	950	1,602	1,175	2,110	2,080
Temperature (ºC)	11.5	11.4	11.1	10.5	11.1	9.5	11.2
Clarity	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Odour	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur

Table D.7.2 Summary of Pumping Well PW1 Discharge Chemical Results (cont'd)

Parameter	Sample Date						
	20-Feb-19	21-Feb-19	22-Feb-19	23-Feb-19	24-Feb-19	25-Feb-19	26-Feb-19
General Parameters							
pH (lab) (pH units)	7.70	7.63	7.59	7.72	7.66	7.54	7.52
Hardness	634	803	815	824	843	837	915
Total Suspended Solids	14	3	<2	3	<2	<2	<2
Sulphide	<0.01	1.4	5.4	8.3	7.9	5.8	6.8
Hydrogen Sulphide (undissociated)	<0.01	0.7	1.7	4.5	3.8	3.9	3.7
Major Ions							
Chloride	116	126	127	150	187	196	192
Sulphate	245	452	458	348	352	349	422
Alkalinity	473	449	438	445	443	428	431
Calcium	112	178	188	185	191	190	213
Magnesium	86	87	84	88	89	88	93
Sodium	49	63	72	80	93	96	109
Potassium	3	3	3	4	4	4	4
Nutrients							
Ammonia	0.09	0.12	0.12	0.14	0.15	0.17	0.17
Un-ionized Ammonia	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total Metals							
Aluminum	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	0.03	0.09	0.13	0.15	0.16	0.18	0.17
Iron	2.09	1.13	0.87	0.73	0.68	0.64	0.56
Zinc	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01

Notes: Concentrations in mg/L unless otherwise noted.

The discharge from the pumping well during the pumping test was observed to be clear and colourless. A slight sulfur odour was noted during the first day of pumping and got stronger as the test progressed. Most parameter concentrations fluctuated during the pumping test with no discernable trends. The exceptions were concentrations of hardness, sulphide, chloride, calcium, sodium, ammonia and boron which experienced an overall increase during the test, while the iron concentrations decreased during the test.

D.7.3 5205 BEECHWOOD PRIVATE WELL CONSTANT RATE TEST

On March 5, 2019, Country Water Systems, under the supervision of WSP personnel, initiated a ~143-hour (8,589 minute) constant rate pumping test at the private supply well at 5205 Beechwood Road. This well is situated on property owned by WAI, and was selected for the pumping test to provide additional aquifer information in the northeast portion of the Site, given that the pumping tests at PW1 had little influence on this area. The private well was installed previously by others; there is no associated water well record and the installation date is unknown. The depth of the well was measured in the field as approximately 11.4 mbtop; therefore, the well is inferred to be completed as an open hole in the upper portion of the shallow bedrock aquifer (i.e., the well only partially penetrates the shallow bedrock aquifer). A pump depth of 10.8 mbtop was used for the test. Initially, the pumping rate was set at approximately 40 L/min (8.5 Igpm); however, after a few hours of pumping, the available drawdown in the pumping well decreased significantly and the pumping rate was lowered to approximately 15 L/min. This rate was maintained within ±5% for the remainder of the test. The average pumping rate for the entire test is estimated to be 14.7 L/min. A plot of the 5205 Beechwood residential well water level data is shown in **Figure 6-41**, **Appendix D-6**. A drawdown of 3.21 m was observed in the pumping well which represents approximately 51% of the available water column.

Unlike the PW1 pumping tests, only groundwater levels in the shallow bedrock ‘B’ series wells within approximately a 400 m radius of the 5205 Beechwood residential well were observed to lower in response to pumping. Plots of the well water level data where pumping test responses were observed are shown in **Figures 6-42 through 6-46**, **Appendix D-6**. A summary of the drawdown at each well is summarized in **Table D.7.3** below. Drawdown contours in the shallow bedrock aquifer from the 2019 pumping test at the 5205 Beechwood residential well are plotted in **Figure D-7**.

Table D.7.3 Summary of Drawdown at Observation Wells

Direction from Pumping Well	Observation Well	Figure No.	Distance from Pumping Well (m)	Drawdown (m)
North	MW11-3OBR *	6-42	206	0.29
	MW11-3BR	6-43	206	0.11
	9602 Beaverdams Well	6-44	394	0.08
West	MW16-6OB *	6-45	138	0.21
	MW16-6B	6-46	138	0.63

Notes: * Overburden well.

Upon completion of the constant rate test at the 5205 Beechwood residential well, the groundwater elevation recovery was monitored at the pumping well as well as the observation wells. On March 12, 2019, after a period of 1,162 minutes (19 hours and 22 minutes), the water level in the 5205 Beechwood well had fully recovered to the pre-test static water level. Similar rates of recovery were noted for the observation wells.

The pumping test data were analyzed using AQTESOLV v.4.50 (HydroSOLVE Inc., 2007) software. The pumping well logger data were “thinned out” to show only representative levels on a log scale for the duration of the test. The data was analyzed in a similar manner to the pumping tests for PW1 as described above.

Pumping Well Cooper-Jacob Straight-Line Analysis

The CJSL analysis was completed using only the recovery curve for the 5205 Beechwood well, given the initial issues with establishing a suitable pumping rate at the beginning of the test. The results are shown on **Figure 6-47**, **Appendix D-6**. Using this method, the aquifer transmissivity is estimated to be 4 m^2/day. For this pumping test, an aquifer thickness of 6.8 m was assumed, since the well is inferred to partially penetrate the shallow bedrock aquifer. Using this thickness, the hydraulic conductivity is estimated as 0.6 m/day ($6.9x10^{-4}$ cm/s). This is marginally lower than the values calculated for the pumping tests at PW1; however, it is still within the range of reported values for the shallow bedrock aquifer in **Table D.3.5** above, and similar to the geometric mean of the slug test results for the shallow bedrock aquifer.

Pumping Well Leaky Aquifer Analysis

The results of the leaky aquifer analysis are shown in **Figure 6-48**, **Appendix D-6**. Using this analysis, the transmissivity of the shallow bedrock aquifer is estimated to be 2 m^2/day, somewhat lower than the CJSL analysis above. It is also noted that the transmissivity estimate from this analysis is lower than the transmissivity estimate from the leaky aquifer analysis for the 2019 pumping test at PW1 (18 m^2/day to 28 m^2/day); however, this is not unexpected since the 5205 Beechwood well is inferred to only partially penetrate the shallow bedrock aquifer. Assuming an aquifer thickness of 6.8 m, the hydraulic conductivity is estimated as 0.3 m/day ($3.5x10^{-4}$ cm/s). This is again within the range of reported values for the shallow bedrock aquifer in **Table D.3.5** above, and similar to the geometric mean of the slug test results for the shallow bedrock aquifer.

The dimensionless parameters (r/B') and β' suggest the overlying "aquitard" has hydraulic conductivity and storativity values similar to a coarse to medium sandy aquifer. The dimensionless parameters for the underlying aquitard were insensitive to the data and are therefore not calculated. Finally, the dimensionless well skin factor (S_w) is estimated as approximately -1, which is notably different from the results of the pumping tests at PW1. Assuming a thick skin model and no head loss through the skin, then the effective radius of the pumping well is estimated to be approximately 0.2 m.

Observation Well CJSL Composite Analysis

The drawdown curves for observation wells during the constant rate test were evaluated using the CJSL composite analysis. The results of this analysis are shown in **Figure 6-49**, **Appendix D-6**. The most significant response to pumping was at MW16-6B. The slope of the best-fit line to this curve yields a shallow bedrock aquifer transmissivity of 9 m^2/day. The transmissivity estimate from this analysis is lower than the transmissivity estimate from the leaky aquifer analysis for the 2019 pumping test at PW1 (18 m^2/day to 28 m^2/day); however, as noted above, this is not unexpected since the 5205 Beechwood well is inferred to partially penetrate the shallow bedrock aquifer. Further away from the pumping well at MW11-3BR, the slope of the best-fit line yields a transmissivity of 17 m^2/day. The data suggest that the private well at 9602 Beaverdams Road was impacted by the test; however, the drawdown curve is quite noisy due to its active use to provide domestic water supply.

Observation Well Distance-Drawdown Analysis

The observation well drawdowns prior to pump shutoff during the constant rate test were analyzed using the distance-drawdown method, assuming a confined ideal aquifer (Cooper-Jacob) as shown in **Figure 6-50**, **Appendix D-6**. The estimated aquifer transmissivity using the Cooper-Jacob distance-drawdown method is approximately 4.5 m^2/day with a storage coefficient of approximately $6x10^{-4}$.

D.7.4 5205 BEECHWOOD PRIVATE WELL DISCHARGE CHEMISTRY

Field measurements for pH, conductivity and temperature, as well as a sample of the pumping test discharge was collected during each day of pumping and submitted to Eurofins Environment Testing Canada Inc. of Ottawa, Ontario, for analysis. The sample results are presented in **Table D.7.4** below. The samples were collected directly from the pumping well discharge pipe. Only parameters which were generally detected above the lab reported detection limit are included on the table below.

Table D.7.4 Summary of 5205 Beechwood Well Discharge Chemical Results

Parameter	Sample Date						
	5-Mar-19	6-Mar-19	7-Mar-19	8-Mar-19	9-Mar-19	10-Mar-19	11-Mar-19
Field Measurements							
pH (pH units)	7.8	7.3	7.4	7.2	7.2	7.5	7.0
Conductivity (µS/cm)	1,922	1,235	1,185	1,132	999	1,119	1,344
Temperature (ºC)	10.4	8.0	9.6	9.4	11.4	11.0	11.4
Clarity	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Colour	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
Odour	Sulphur	None	None	None	None	Sulphur	Sulphur
General Parameters							
pH (lab) (pH units)	7.56	7.61	7.57	7.76	7.59	7.59	7.57
Hardness	626	628	615	622	622	622	618
Total Suspended Solids	16	<2	6	<2	<2	<2	<2
Sulphide	<0.05	0.04	<0.02	0.05	0.08	0.17	0.21
Hydrogen Sulphide (undissociated)	<0.01	0.02	<0.008	0.02	0.04	0.05	0.13
Major Ions							
Chloride	39	42	42	42	42	43	44
Sulphate	248	250	265	252	256	267	260
Alkalinity	458	455	461	458	470	458	465
Calcium	127	126	121	122	127	127	127
Magnesium	75	76	76	77	74	74	73
Sodium	40	40	40	40	42	42	42
Potassium	3	3	3	3	3	3	3

Table D.7.4 Summary of 5205 Beechwood Well Discharge Chemical Results (cont'd)

Parameter	Sample Date						
	5-Mar-19	6-Mar-19	7-Mar-19	8-Mar-19	9-Mar-19	10-Mar-19	11-Mar-19
Nutrients							
Ammonia	0.06	0.05	0.06	0.06	0.09	0.09	0.09
Un-ionized Ammonia	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total Metals							
Aluminum	0.33	0.01	0.06	0.02	0.01	0.01	0.01
Boron	0.1	0.09	0.08	0.09	0.08	0.08	0.09
Iron	1.16	0.83	0.79	0.75	0.7	0.69	0.7
Zinc	0.08	0.03	0.03	0.03	0.02	0.02	0.01

Notes: Concentrations in mg/L unless otherwise noted.

The discharge from the pumping well during the pumping test was observed to be clear and colourless. A slight sulfur odour was noted during the first day of pumping and again towards the end of the test. The parameter concentrations fluctuated during the pumping test with no discernable trends.

D.7.5 5205 BEECHWOOD WELL STEP TEST

Following recovery of the water level after the constant rate test, on March 15, 2019, a step test was completed on the 5205 Beechwood well. The results of the step test were reviewed to evaluate the performance of the pumping well and estimate well efficiency.

The step test at the 5205 Beechwood well consisted of three 30 minute pumping steps at flow rates of 9 L/min (2 Igpm), 18L/min (4 Igpm) and 27 L/min (6 Igpm). After the third step, the pump was shut off to allow monitoring of the pumping well recovery. The step test water level data are shown in **Figure 6-51**, **Appendix D-6**.

The results of the step test analysis for the 5205 Beechwood well are presented in **Figure 6-52**, **Appendix D-6**.

The water level in the 5205 Beechwood residential well was lowered during each pumping step. The rate that the water level was lowered was similar during each step. The well efficiency estimated from the step test at the 5205 Beechwood residential well decreased from 95% to 86% at the pumping rates used in the step test. The B and C constants from the step test analysis suggest that turbulent flow is much less predominant at this well in comparison to PW1, where significant turbulent flow was inferred to result in a much lower apparent well efficiency.

REFERENCES

Butler, J.J. Jr., 1988. *Pumping Tests in Non-Uniform Aquifers – The Radially Symmetric Case*. Journal of Hydrology, Vol. 101, pp. 15-30.

Domenico, P.A., and Schwartz, F.W., 1998. *Physical and Chemical Hydrogeology*. John Wiley & Sons, New York, 506 p.

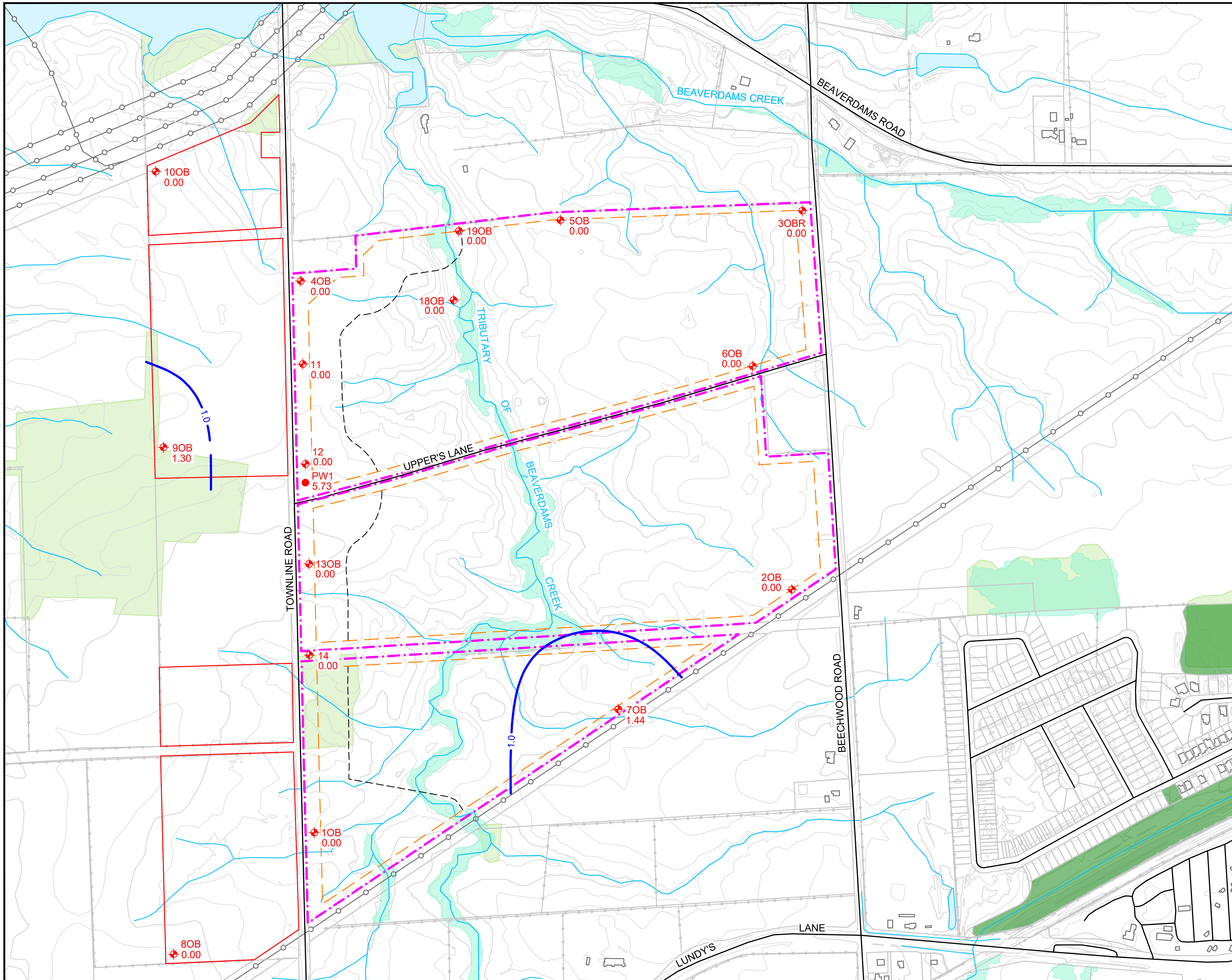
Horne, R.N., 1995. *Modern Well Test Analysis*. Petroway Inc., 1995.

Kruseman, G.P. and de Ridder, N.A., 1990. *Analysis and Evaluation of Pumping Test Data, 2nd Edition*.

Moench, A.F., 1985. *Transient Flow to a Large-Diameter Well in an Aquifer with Storative Semi-Confining Layers*. Water Resources Research, Vol. 21, No. 8, pp. 1121-1131.

Moores, J.D. and Waller, D.H., 1993. *On-Site Wastewater Disposal in Nova Scotia, Final Report: On-Site Wastewater Research Program, Phase II, 1990-1993*.

FIGURES



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- PW1 ● PUMPING WELL LOCATION AND DESIGNATION
- 1OB MONITORING WELL LOCATION AND DESIGNATION
- 5.73 MAXIMUM OBSERVED DRAWDOWN DURING PUMPING TEST, FEBRUARY 11, 2017 (m)
- 1.0 DRAWDOWN CONTOUR (m)

0 150 300 m

2017 PW1 PUMPING TEST DRAWDOWN - CONTACT AQUIFER

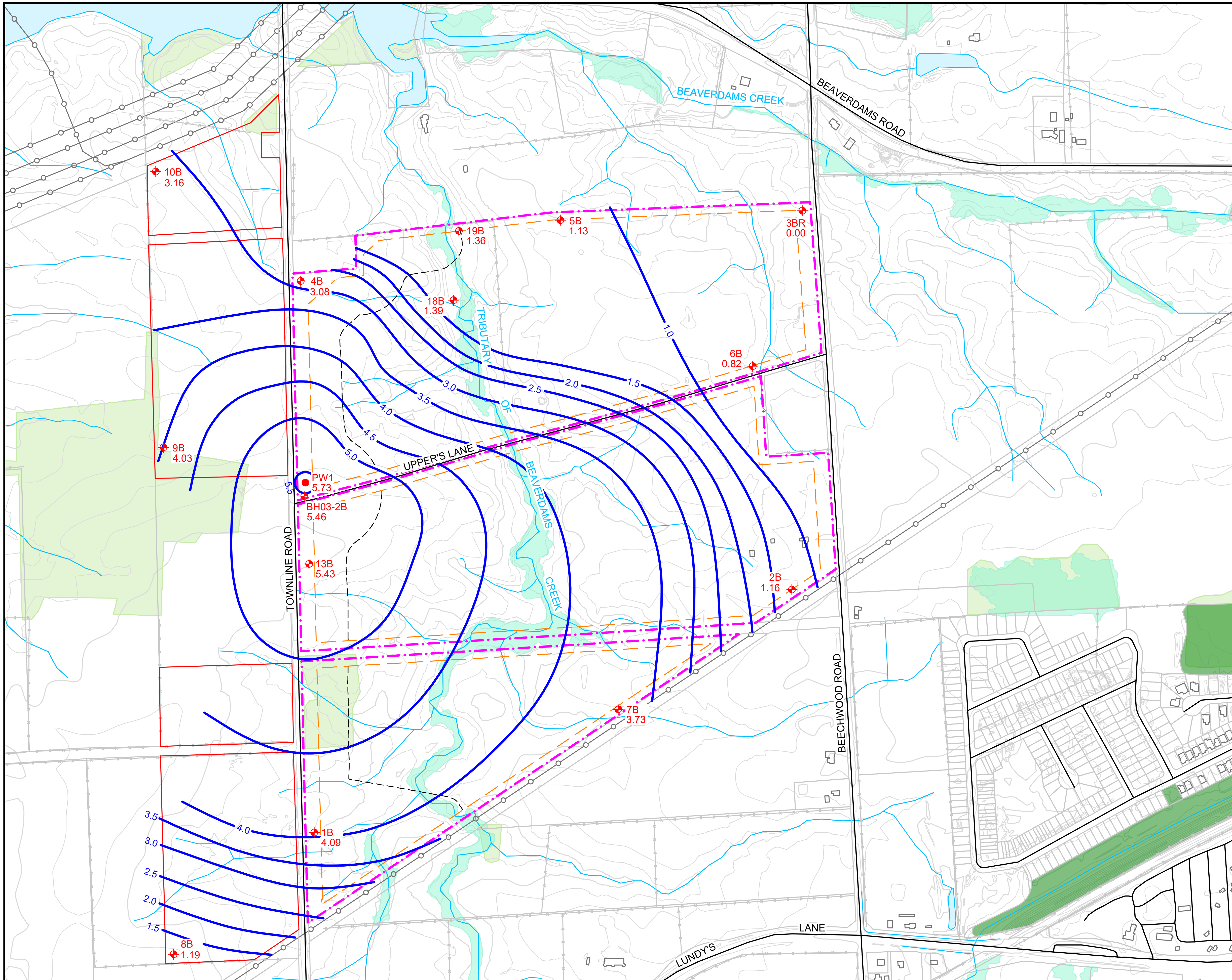
LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 7,500
DRAWN BY:	JLD
FIGURE No:	D-1

wsp

55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\0003 LEVEL 2 HYDROGIGRAPHICS\APPENDIX D\161-11633-3-FD1-SP.DWG



LEGEND

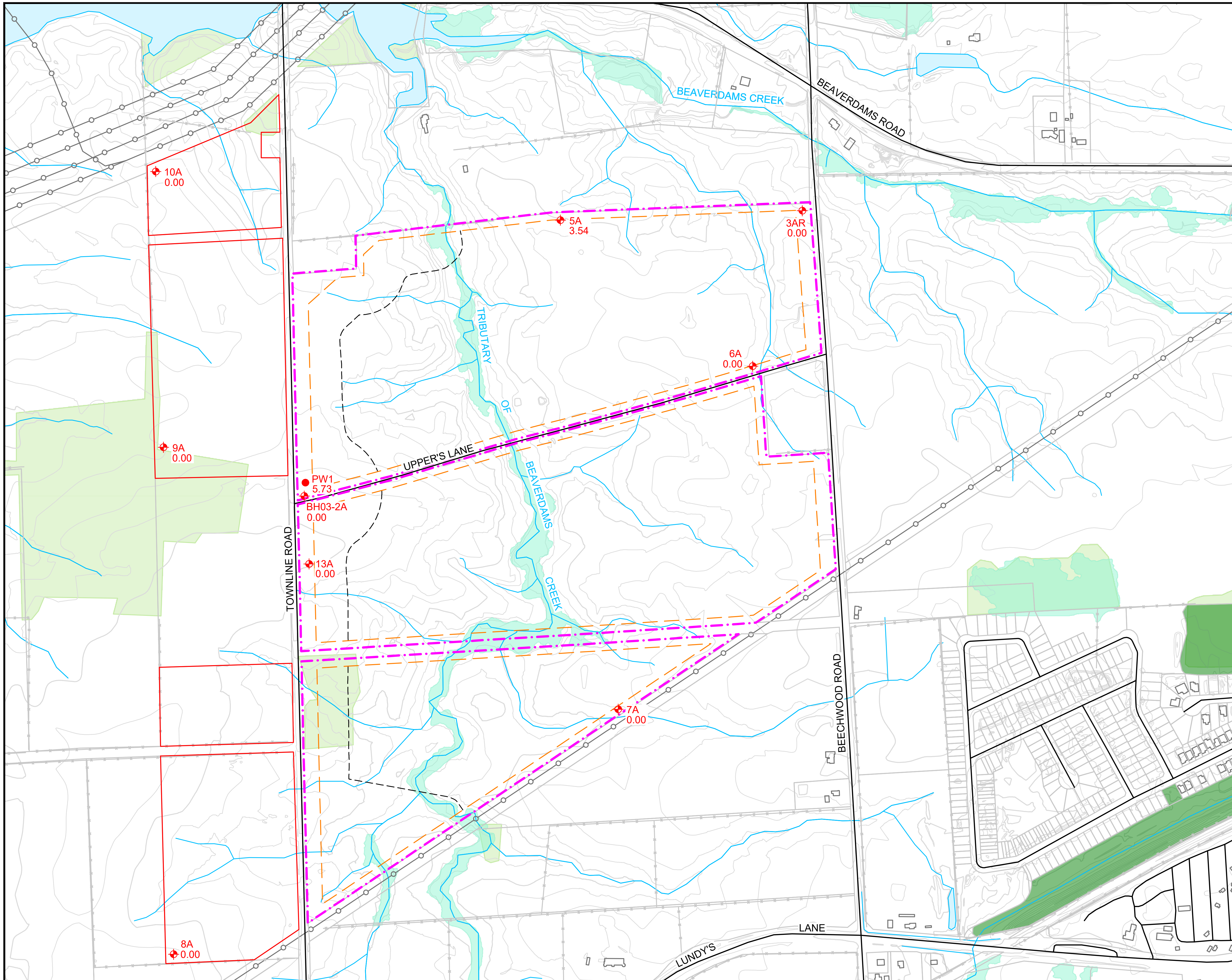
- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- PW1 PUMPING WELL LOCATION AND DESIGNATION
- 1B MONITORING WELL LOCATION AND DESIGNATION
- 5.73 MAXIMUM OBSERVED DRAWDOWN DURING PUMPING TEST, FEBRUARY 11, 2017 (m)
- 1.0 DRAWDOWN CONTOUR (m)

2017 PW1 PUMPING TEST DRAWDOWN - SHALLOW BEDROCK AQUIFER

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021	wsp
PROJECT: 161-11633-00	
SCALE: 1 : 7,500	55 KING STREET, SUITE 700 ST. CATHARINES, ON L2R 3H5 T 905-687-1771 | F 905-687-1773 | www.wsp.com
DRAWN BY: JLD	FIGURE No: D-2

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\APPENDIX D\161-11633-3-FD2-SP.DWG



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- PW1 ● PUMPING WELL LOCATION AND DESIGNATION
- 1A MONITORING WELL LOCATION AND DESIGNATION
- 5.73 MAXIMUM OBSERVED DRAWDOWN DURING PUMPING TEST, FEBRUARY 11, 2017 (m)
- 1.0 DRAWDOWN CONTOUR (m)

N

0 150 300 m

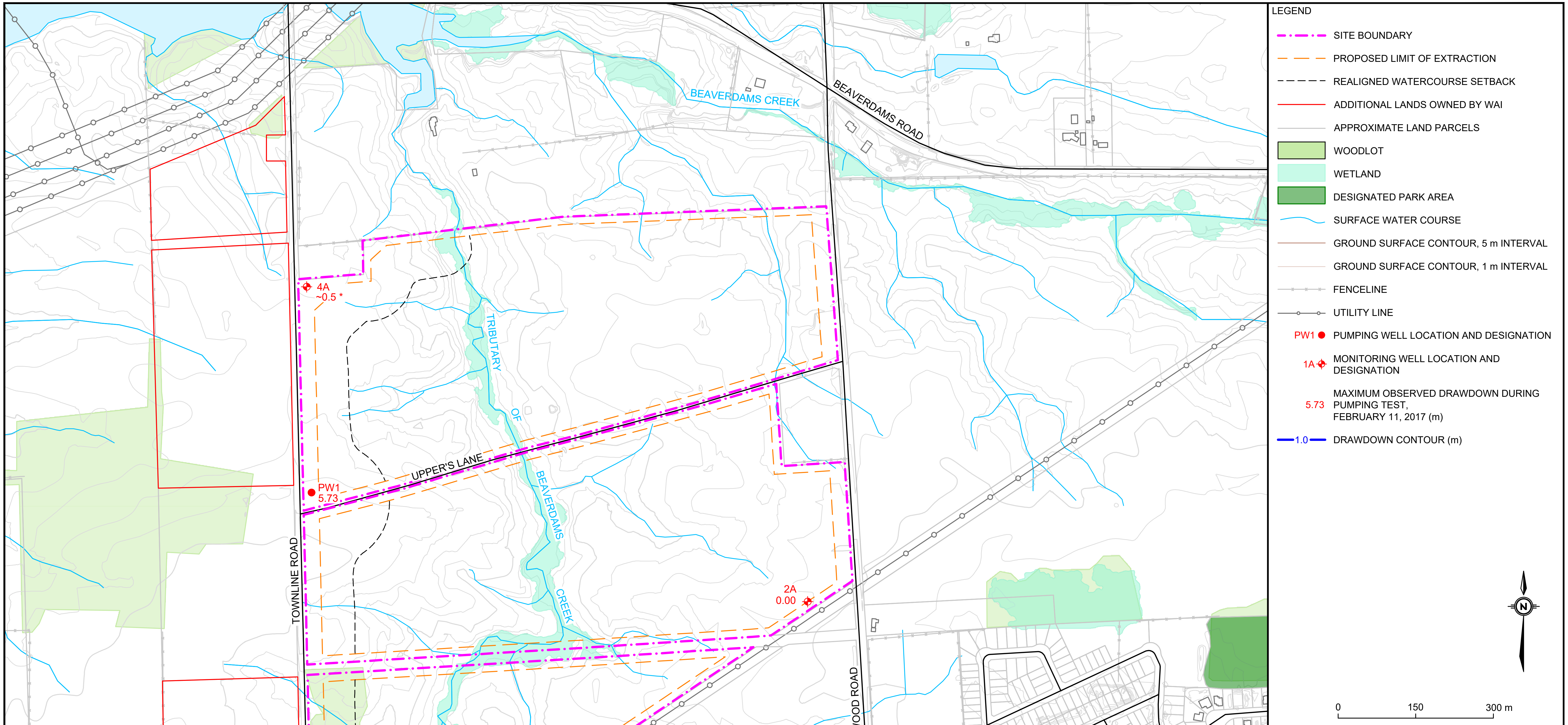
2017 PW1 PUMPING TEST DRAWDOWN - DEEP BEDROCK AQUIFER

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 7,500
DRAWN BY:	JLD
FIGURE No:	D-3

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\APPENDIX D\161-11633-3-FD3-SP.DWG



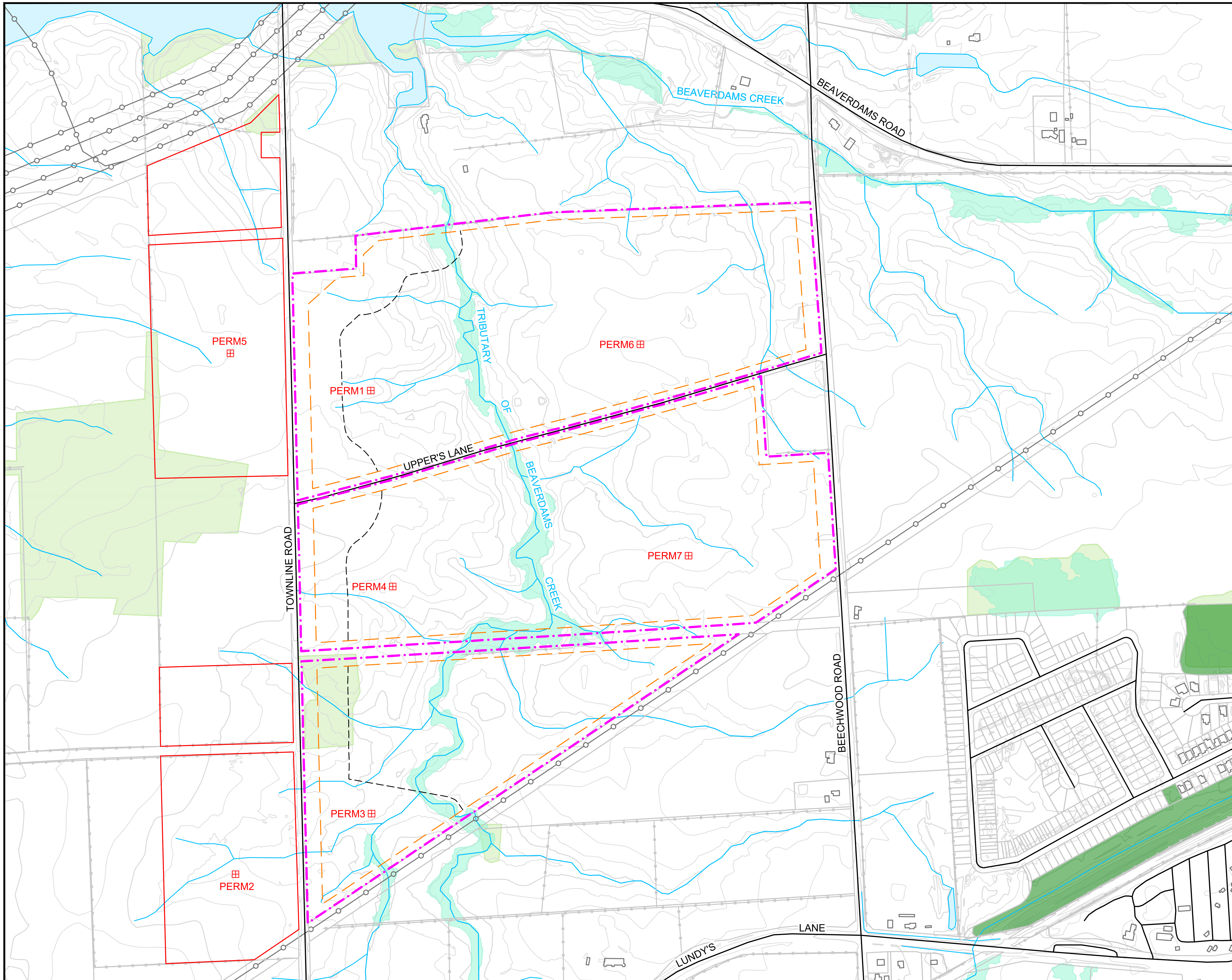
2017 PW1 PUMPING TEST
DRAWDOWN - LOWER AQUITARD

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 7,500
DRAWN BY:	JLD
FIGURE No:	D-4

WSP
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\APPENDIX D\161-11633-3-FD4-SP.DWG



LEGEND

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WOODLOT
- WETLAND
- DESIGNATED PARK AREA
- SURFACE WATER COURSE
- GROUND SURFACE CONTOUR, 5 m INTERVAL
- GROUND SURFACE CONTOUR, 1 m INTERVAL
- FENCELINE
- UTILITY LINE
- PERM1 ⊞ PERMEAMETER TEST LOCATION AND DESIGNATION

N

0 150 300 m

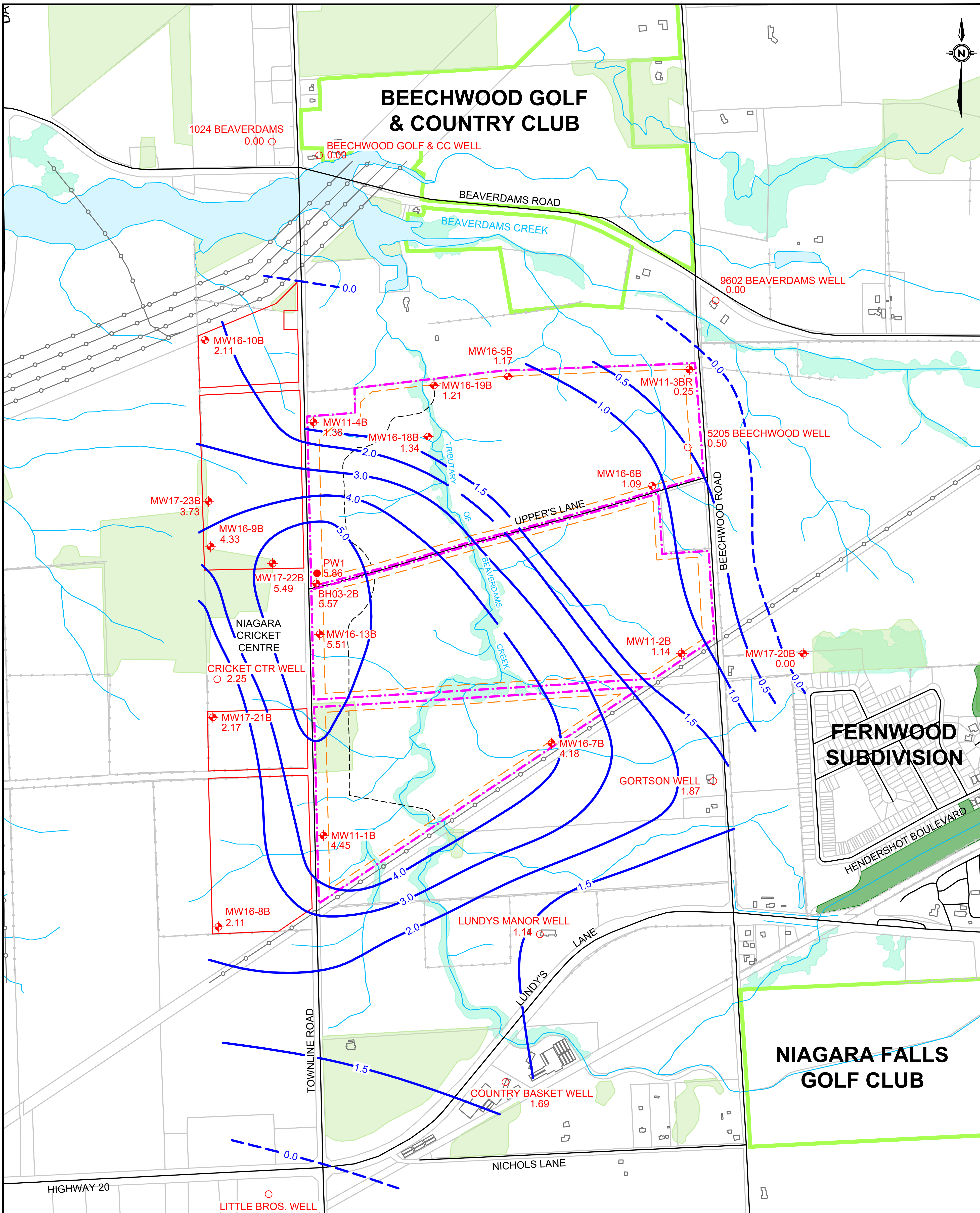
PERMEAMETER TEST LOCATIONS

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 7,500
DRAWN BY:	JLD
FIGURE No:	D-5

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\APPENDIX D\161-11633-3-FD5-SP.DWG



LEGEND

0 200 400 m

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WETLAND
- SURFACE WATER COURSE
- MW16-8B MONITORING WELL LOCATION AND DESIGNATION
- PW1 PUMPING WELL LOCATION AND DESIGNATION
- PRIVATE SUPPLY WELL LOCATION AND DESIGNATION
- 2.11 MAXIMUM OBSERVED DRAWDOWN DURING PUMPING TEST,FEBRUARY 26, 2019 (m)
- 5.0 DRAWDOWN CONTOUR (m)

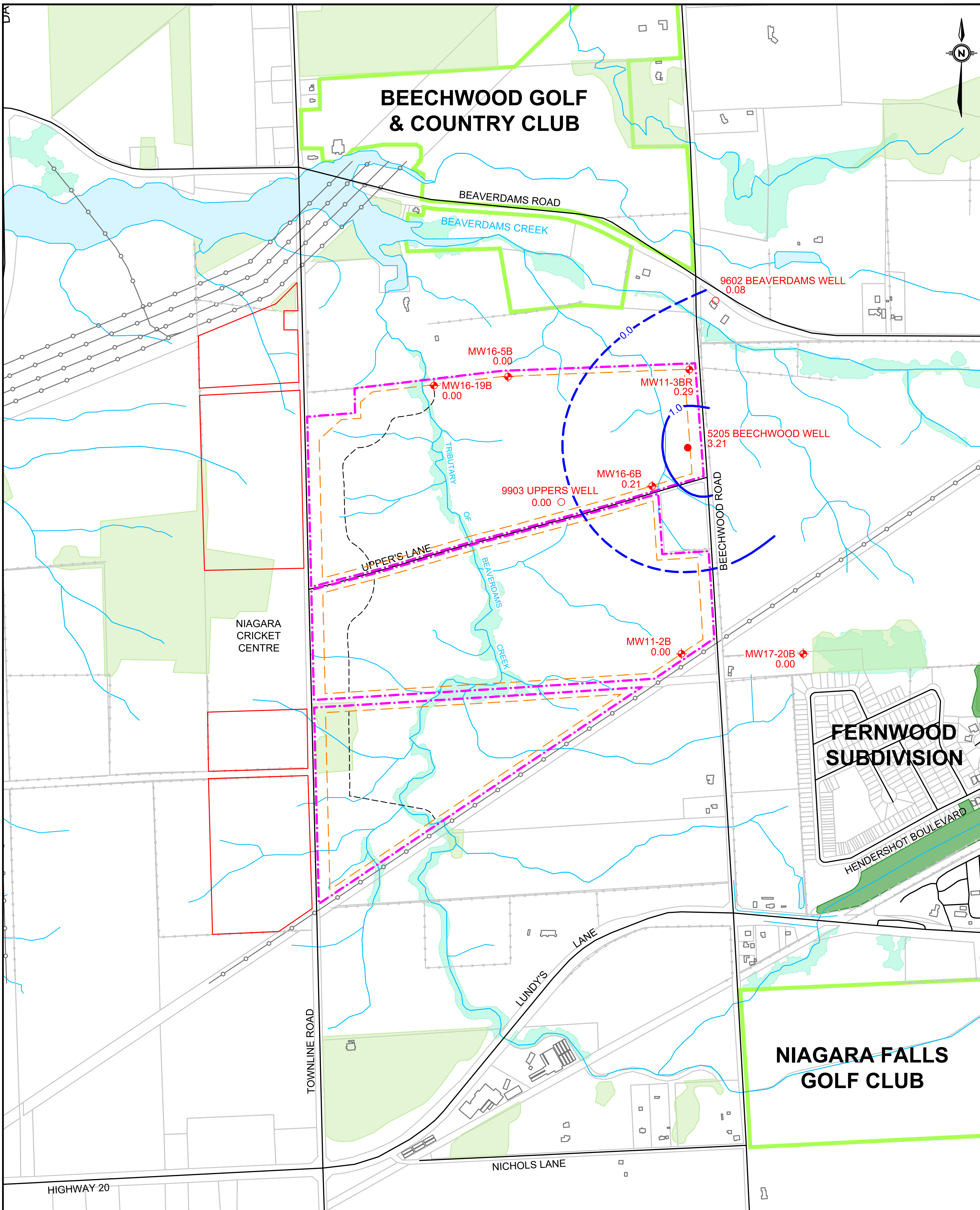
2019 PW1 PUMPING TEST DRAWDOWN - SHALLOW BEDROCK AQUIFER

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 10,000
DRAWN BY:	JLD
FIGURE No:	D-6

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\APPENDIX D\161-11633-3-FD6-GW.DWG



LEGEND

0 200 400 m

- SITE BOUNDARY
- PROPOSED LIMIT OF EXTRACTION
- REALIGNED WATERCOURSE SETBACK
- ADDITIONAL LANDS OWNED BY WAI
- APPROXIMATE LAND PARCELS
- WETLAND
- SURFACE WATER COURSE
- MW16-8B MONITORING WELL LOCATION AND DESIGNATION
- PUMPING WELL LOCATION AND DESIGNATION
- PRIVATE SUPPLY WELL LOCATION AND DESIGNATION
- 2.11 MAXIMUM OBSERVED DRAWDOWN DURING PUMPING TEST, FEBRUARY 26, 2019 (m)
- 5.0 DRAWDOWN CONTOUR (m)

2019 5205 BEECHWOOD PRIVATE WELL PUMPING TEST DRAWDOWN - SHALLOW BEDROCK AQUIFER

LEVEL 2 WATER REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 10,000
DRAWN BY:	JLD
FIGURE No:	D-7

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\03 LEVEL 2 HYDROG\GRAPHICS\APPENDIX D\161-11633-3-FD7-GW.DWG

APPENDIX

D-1 PACKER TEST ANALYSES

Figure 1-5-1

MW16-5 (7.7m - 10.8m)

Falling Head Packer Test Analysis

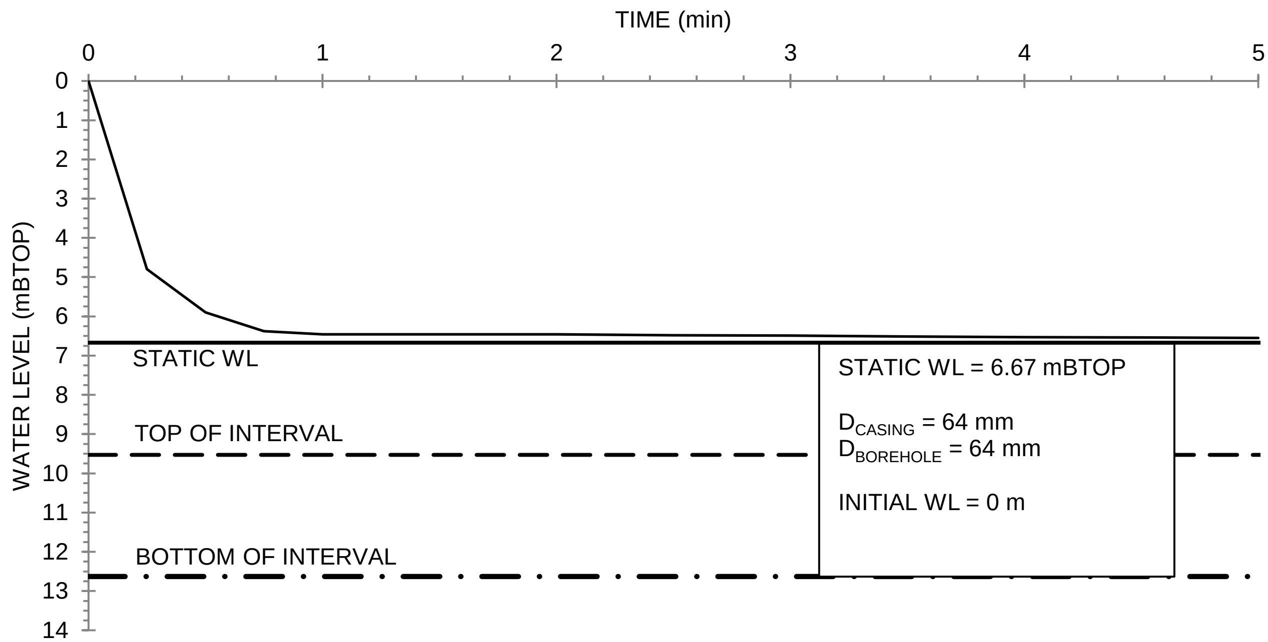
Hvorslev Method

Proposed Upper's Quarry

wsp

Date: November 1-2, 2016

Performed by: SK / BC



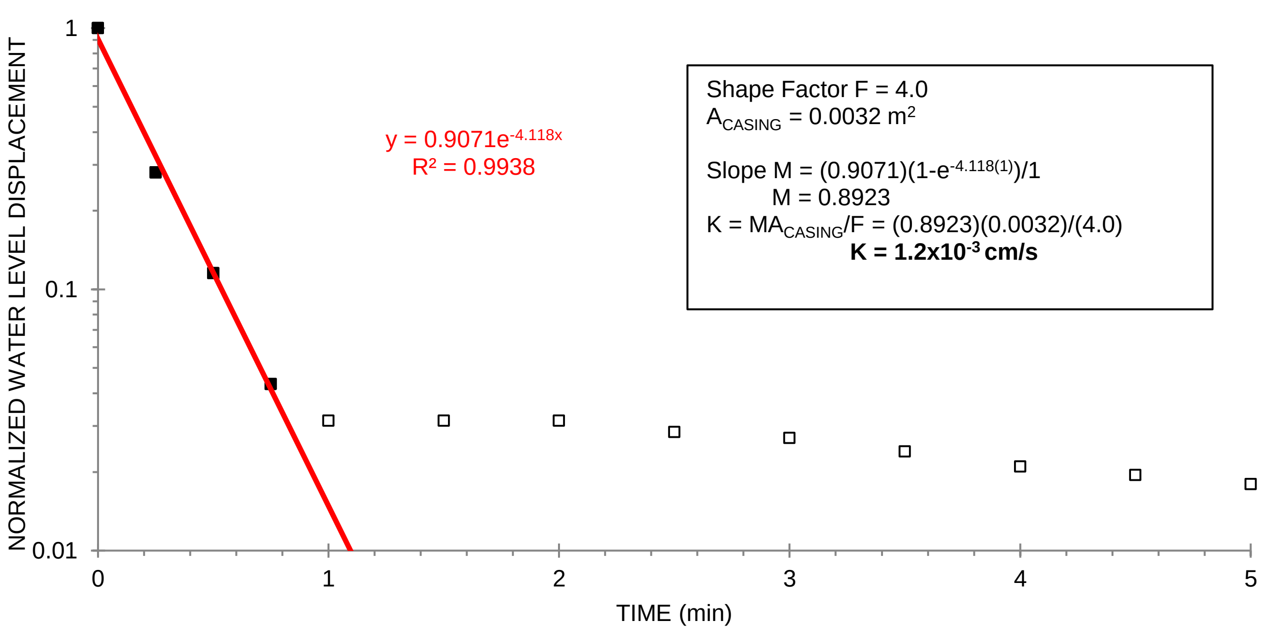


Figure 1-5-2

MW16-5 (10.8m - 13.9m)

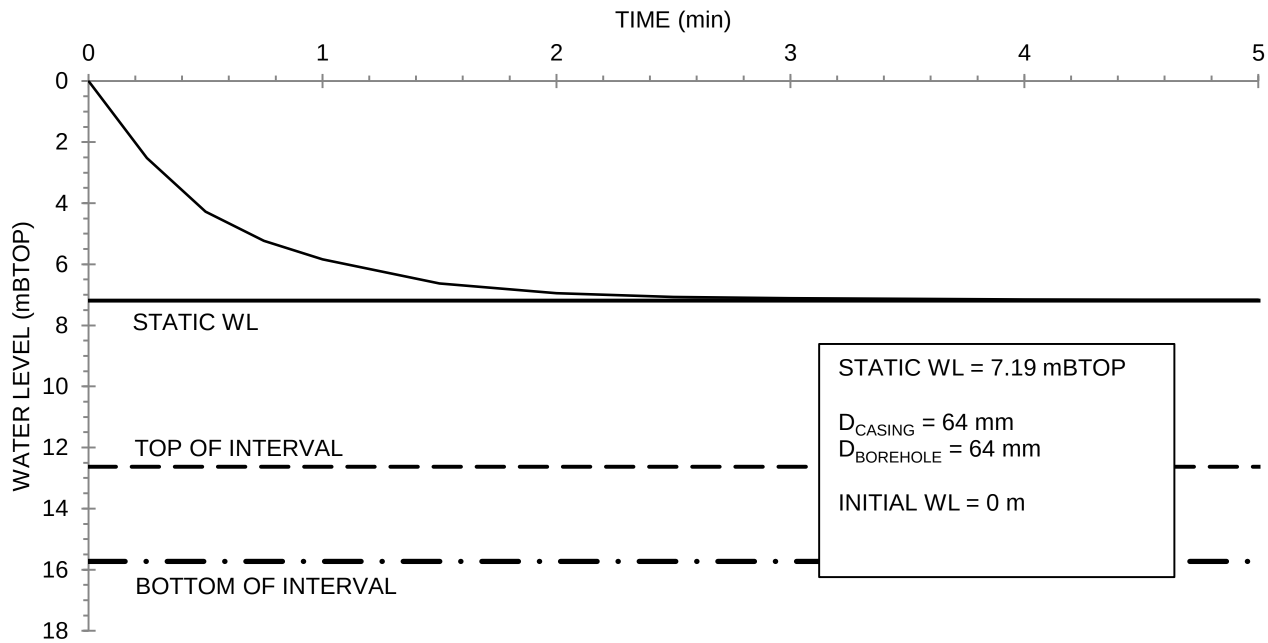
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 1-2, 2016

Performed by: SK / BC



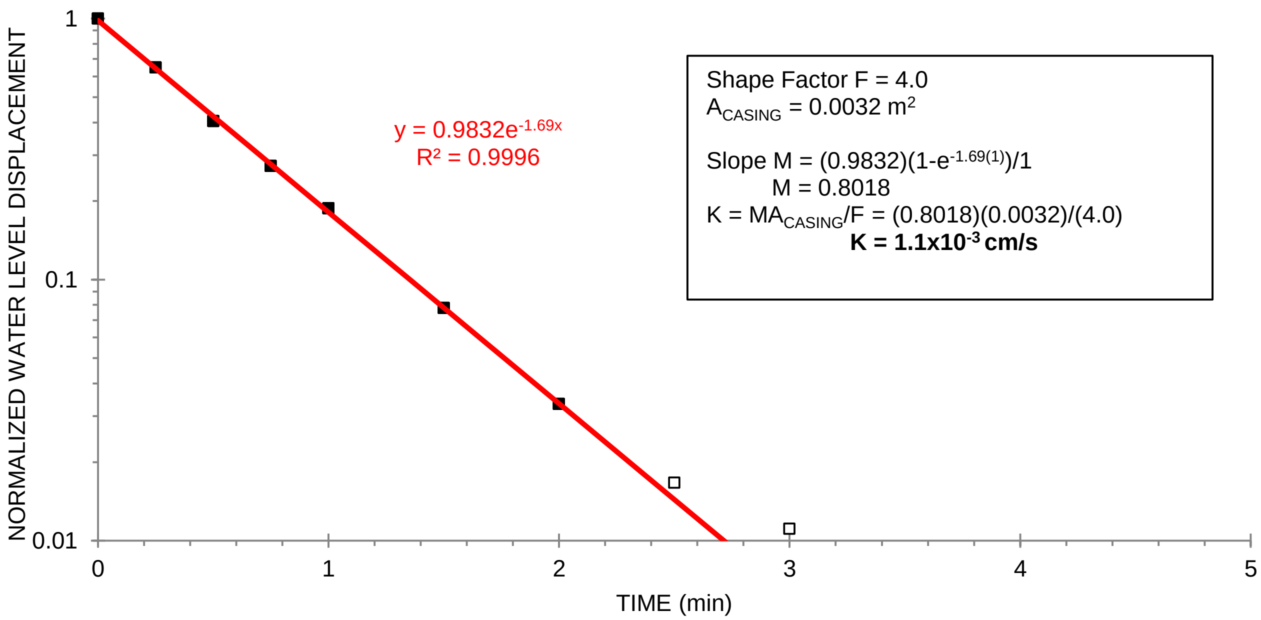


Figure 1-5-3

MW16-5 (13.9m - 16.8m)

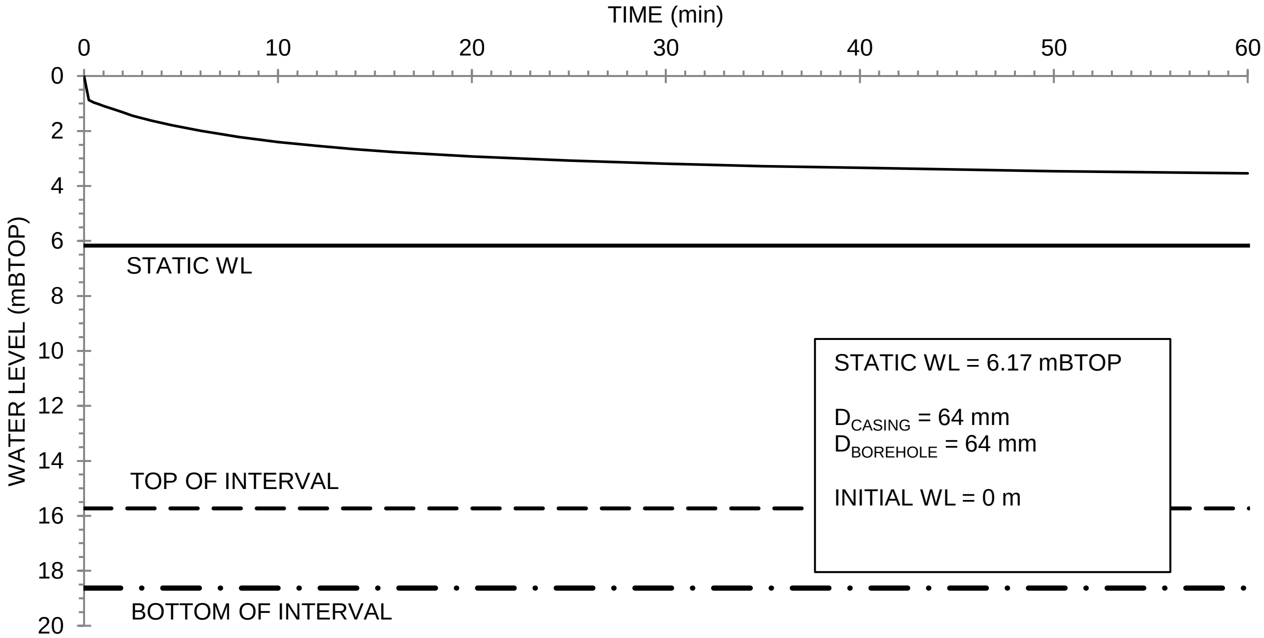
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 1-2, 2016

Performed by: SK / BC



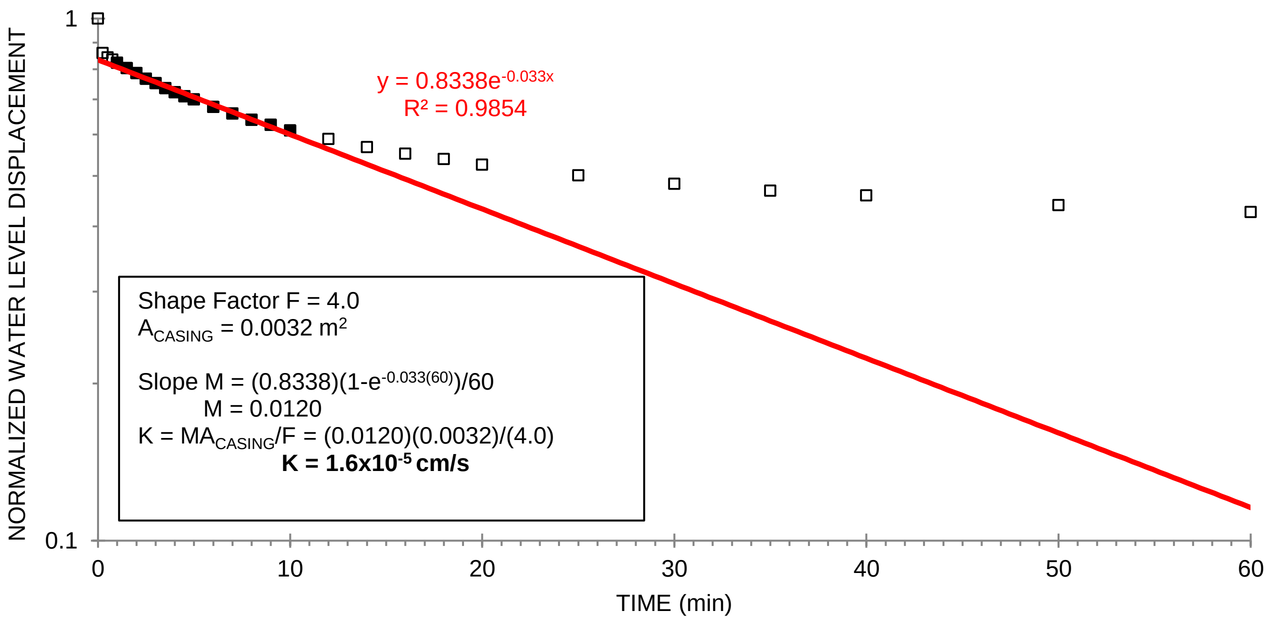


Figure 1-5-4

MW16-5 (16.8m - 19.8m)

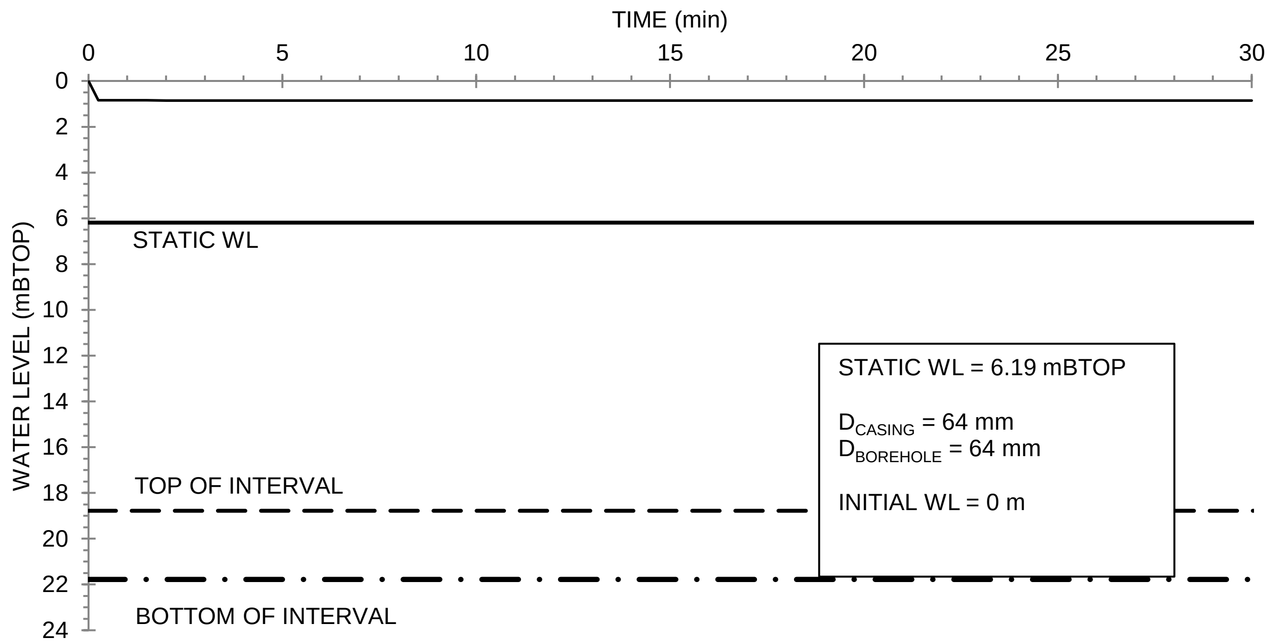
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 1-2, 2016

Performed by: SK / BC



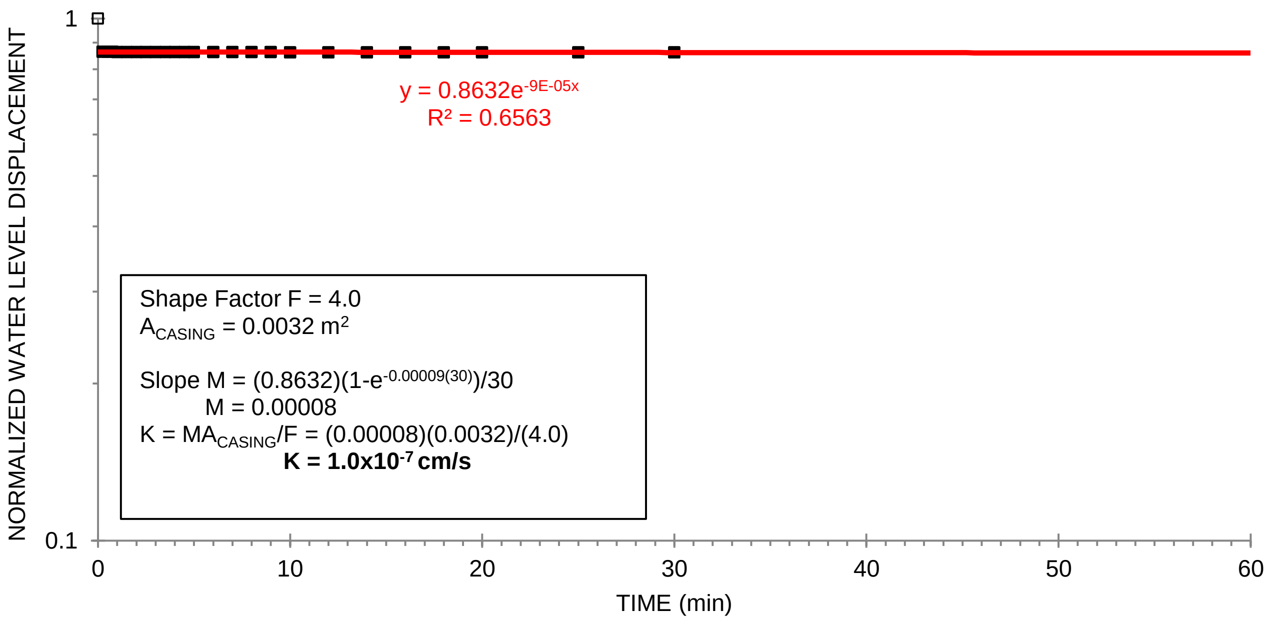


Figure 1-5-5

MW16-5 (19.8m - 23.0m)

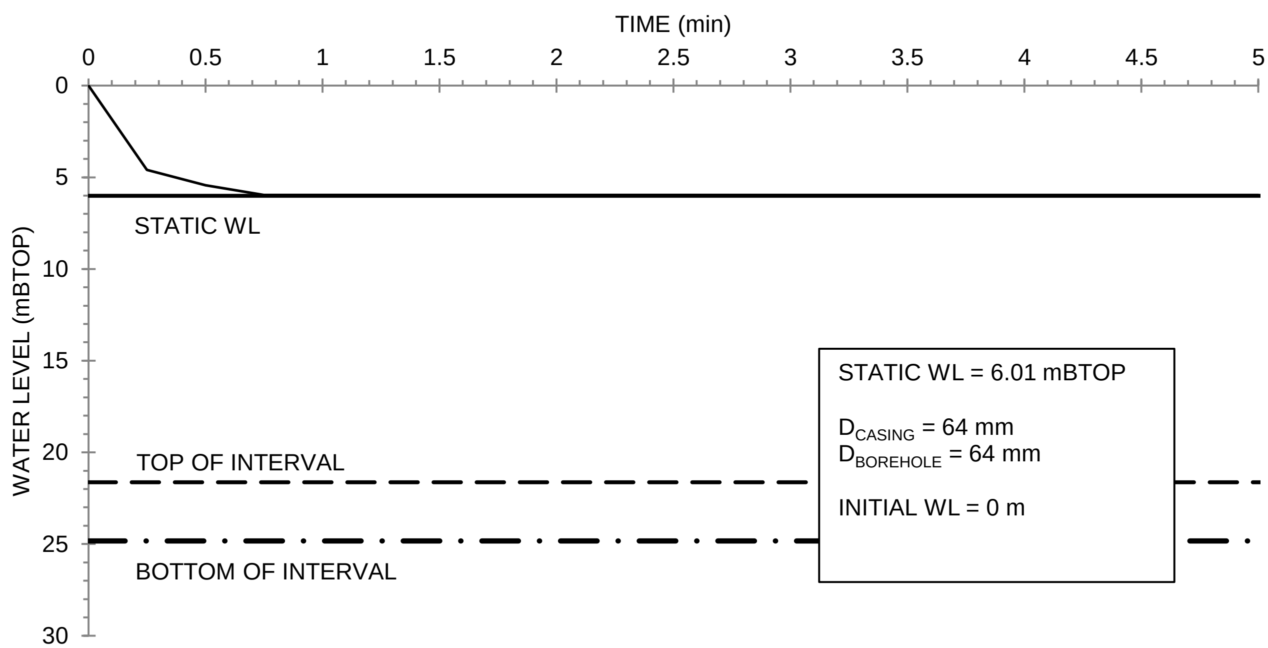
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 1-2, 2016

Performed by: SK / BC



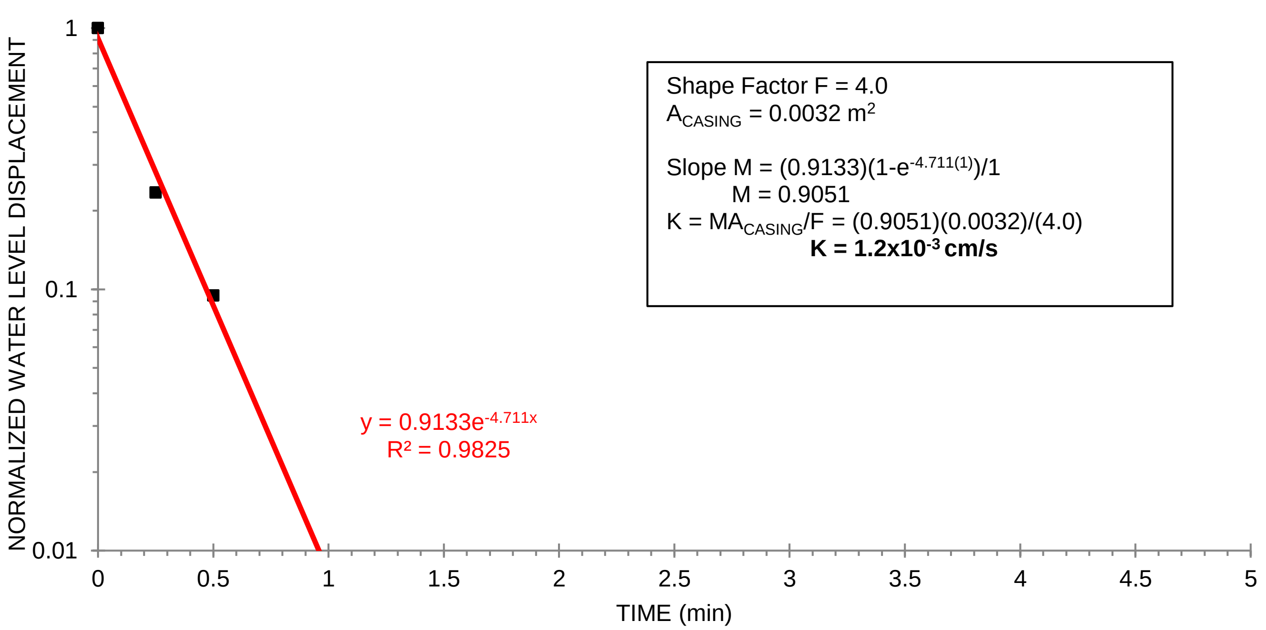


Figure 1-5-6

MW16-5 (23.0m - 26.1m)

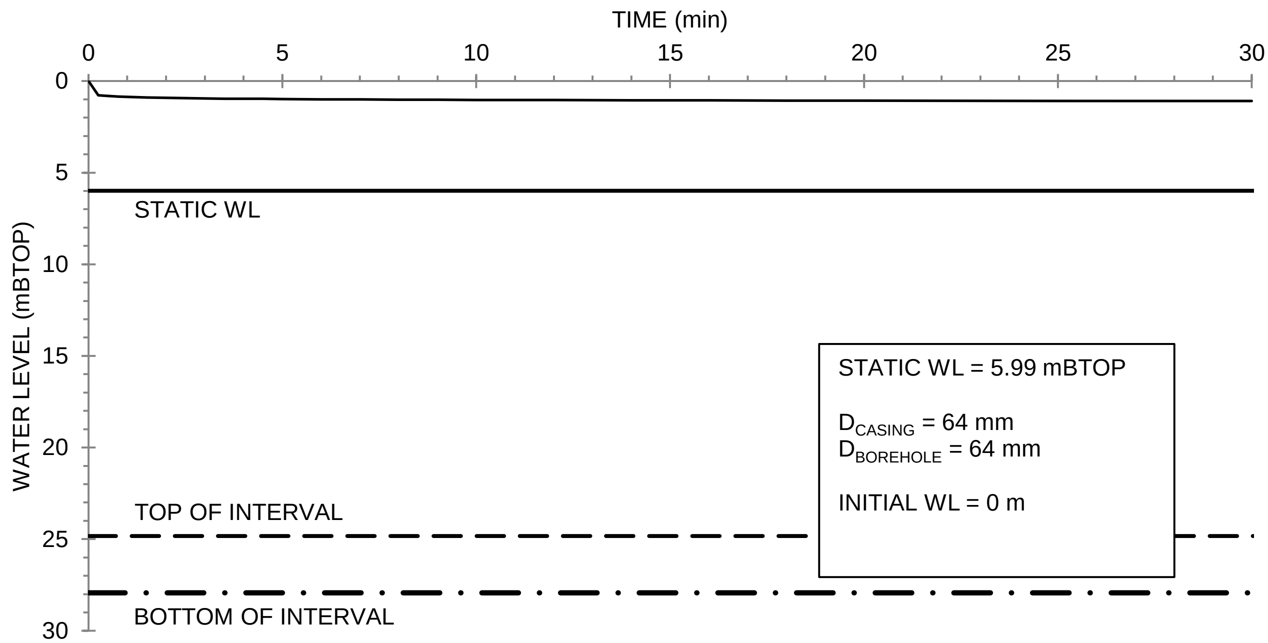
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 1-2, 2016

Performed by: SK / BC



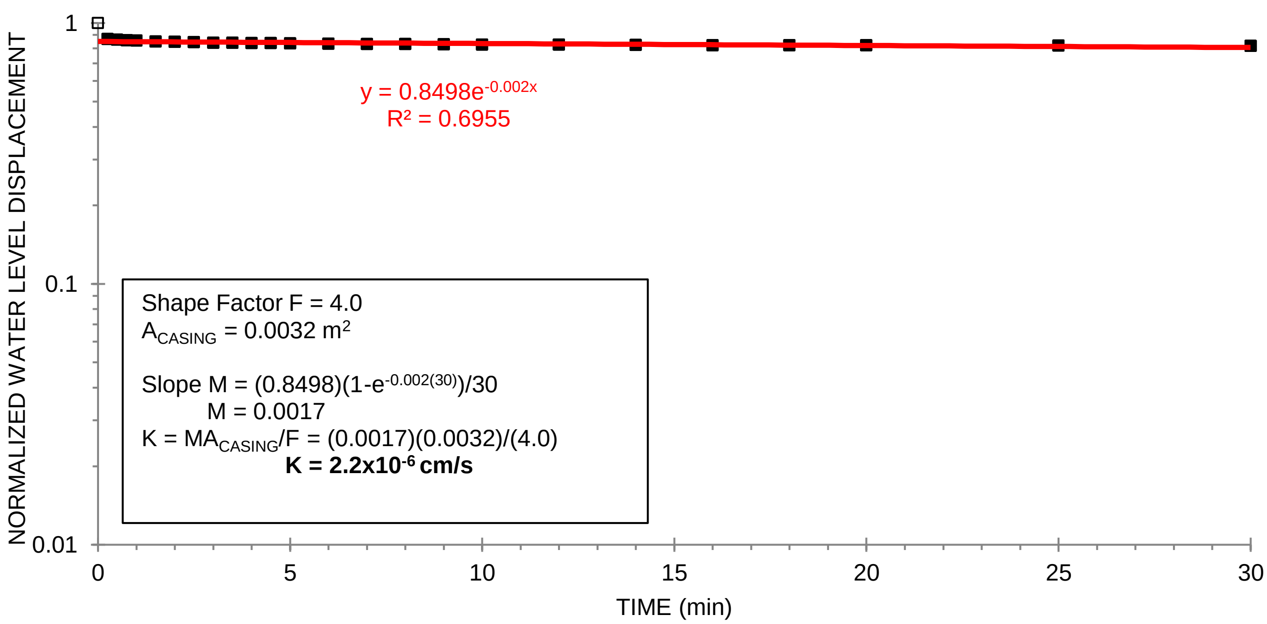


Figure 1-5-7

MW16-5 (26.1m - 29.1m)

Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 1-2, 2016

Performed by: SK / BC

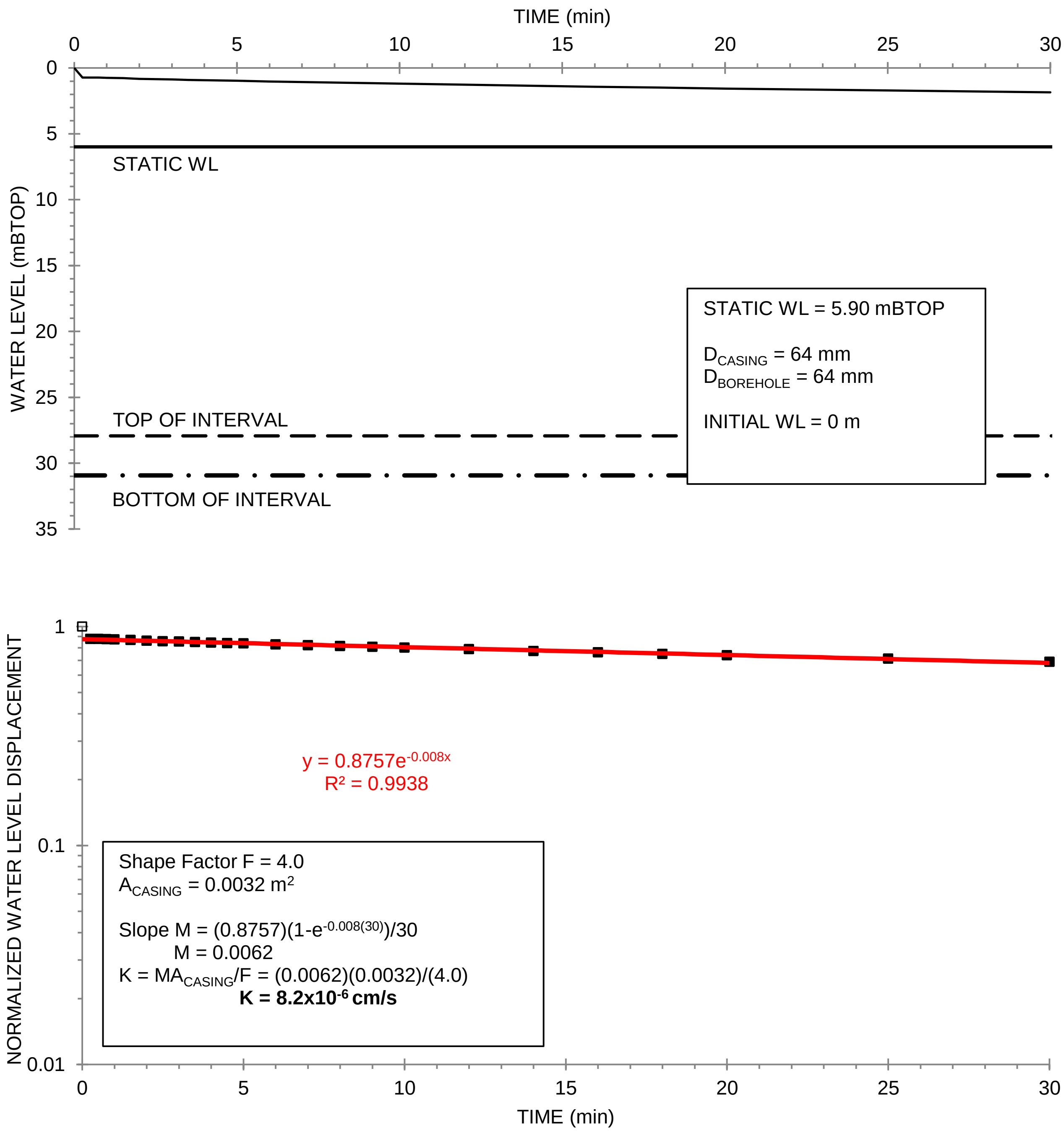


Figure 1-5-8

MW16-5 (29.1m - 32.1m)

Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 1-2, 2016

Performed by: SK / BC

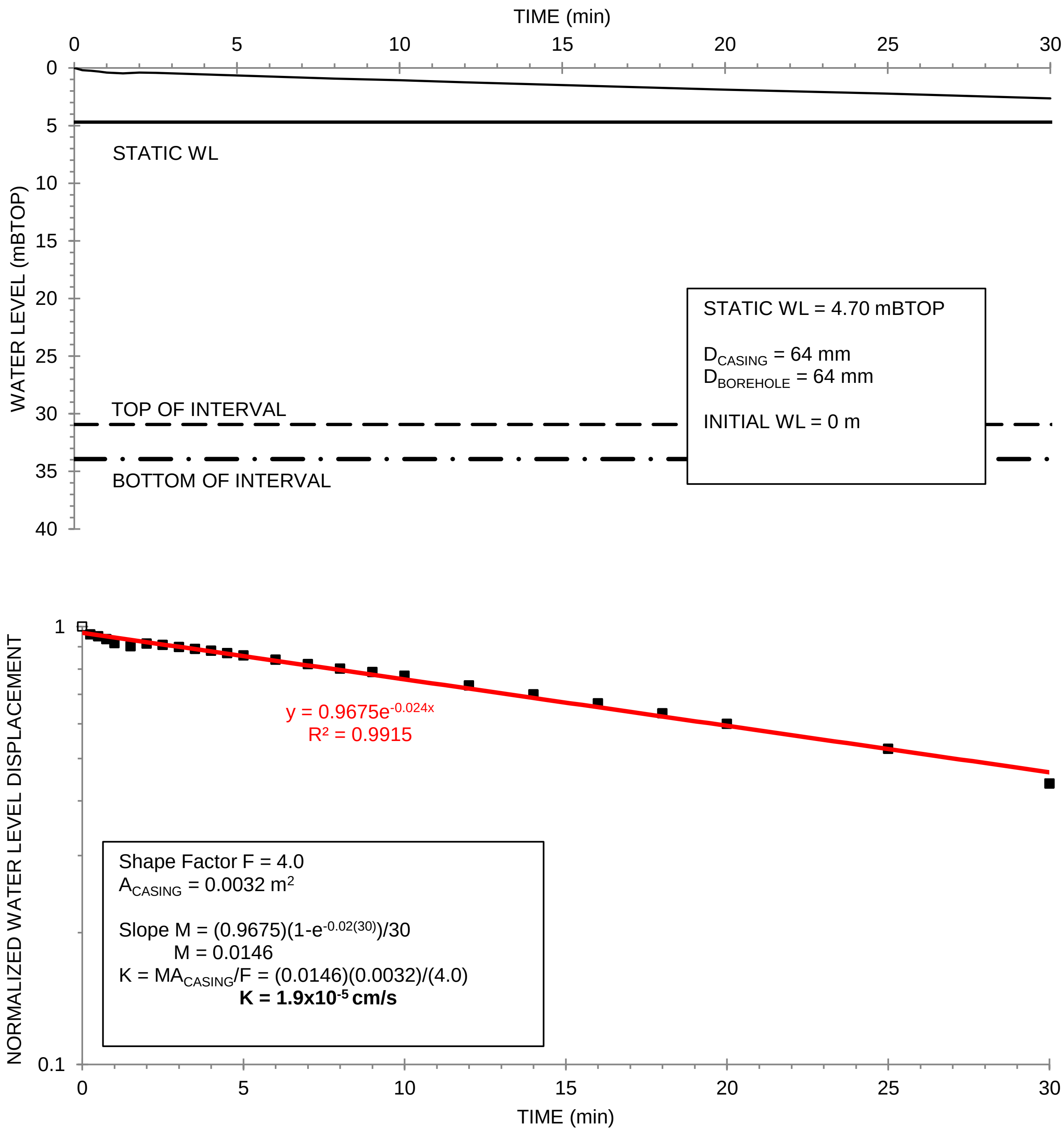


Figure 1-6-1

MW16-6 (7.6m - 9.1m)

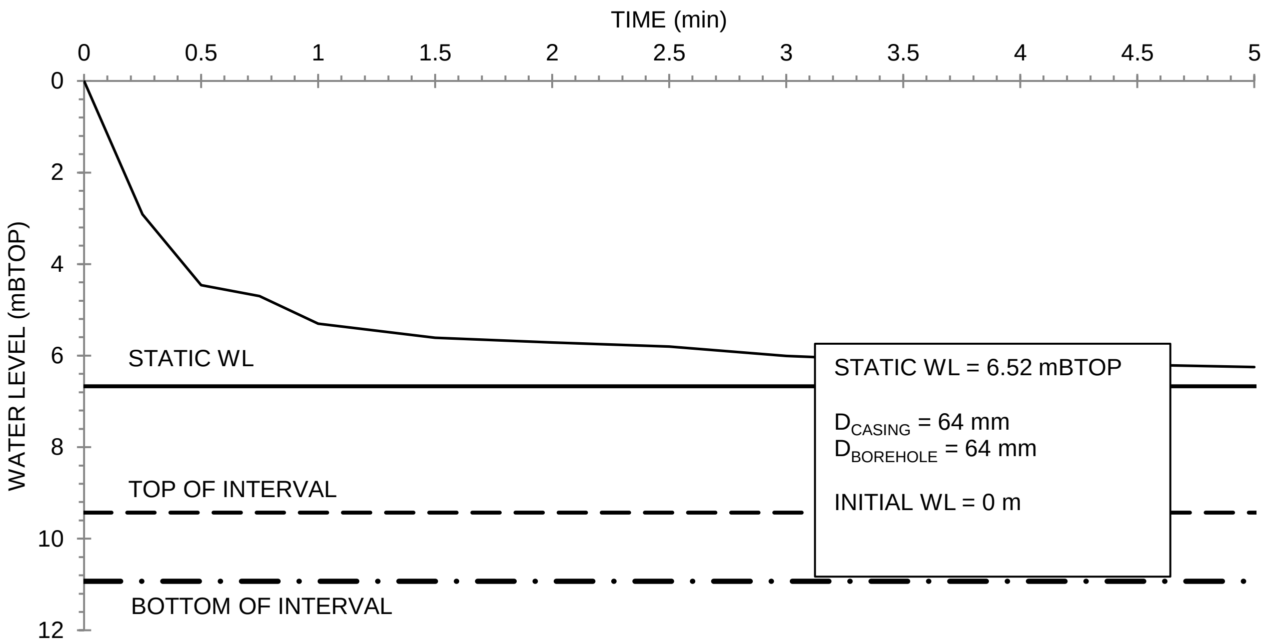
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 19-21, 2016

Performed by: SK



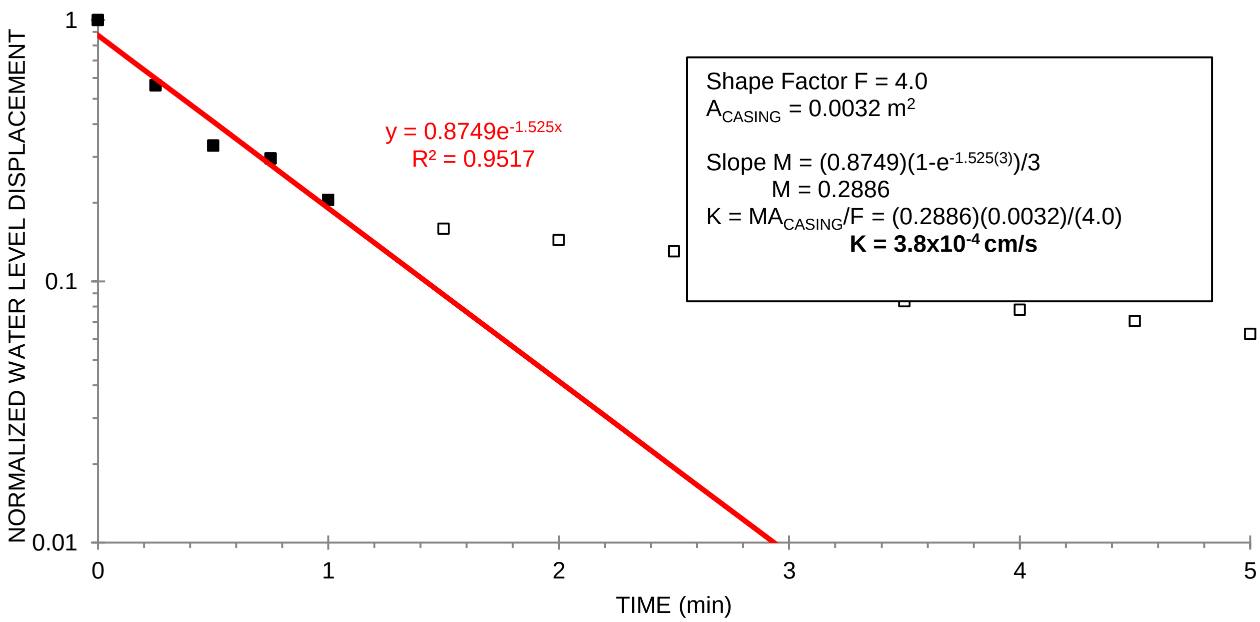


Figure 1-6-2

MW16-6 (9.1m - 13.6m)

Falling Head Packer Test Analysis

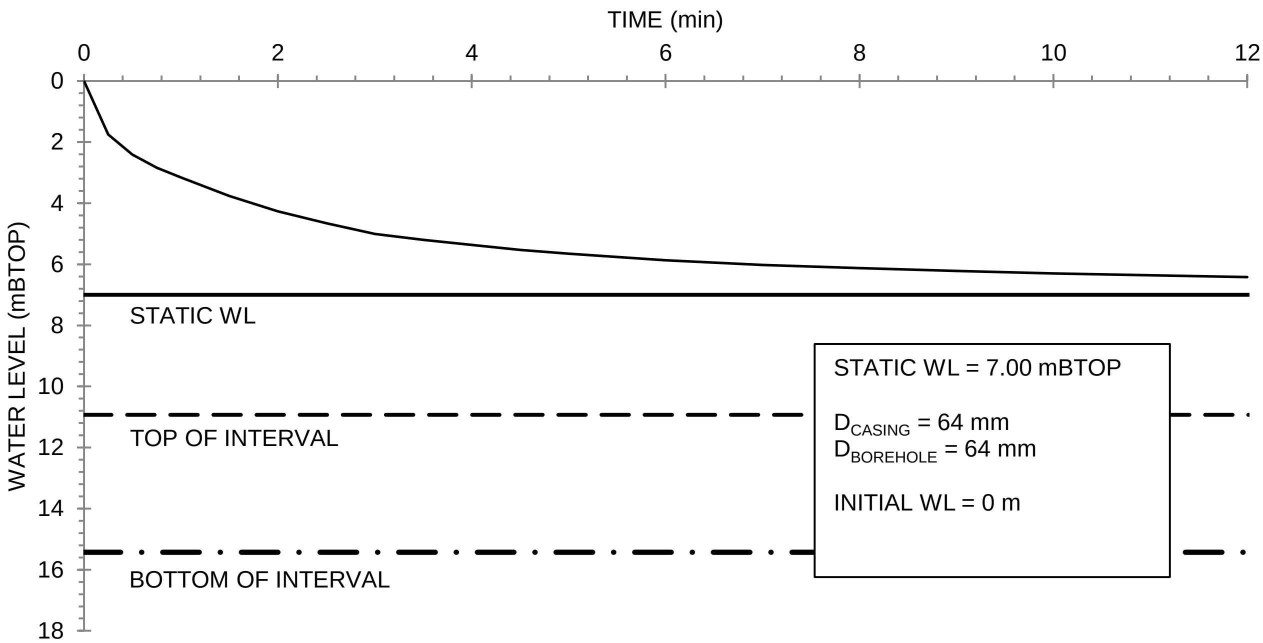
Hvorslev Method

Proposed Upper's Quarry

wsp

Date: October 19-21, 2016

Performed by: SK



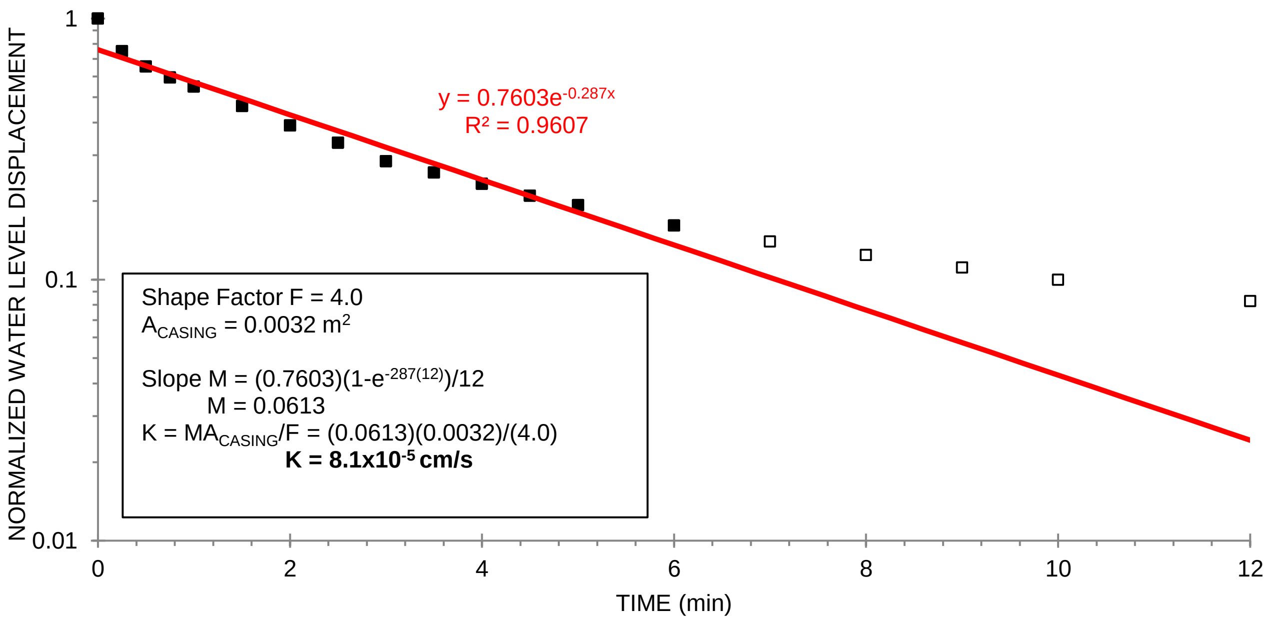


Figure 1-6-3

MW16-6 (13.6m - 16.8m)

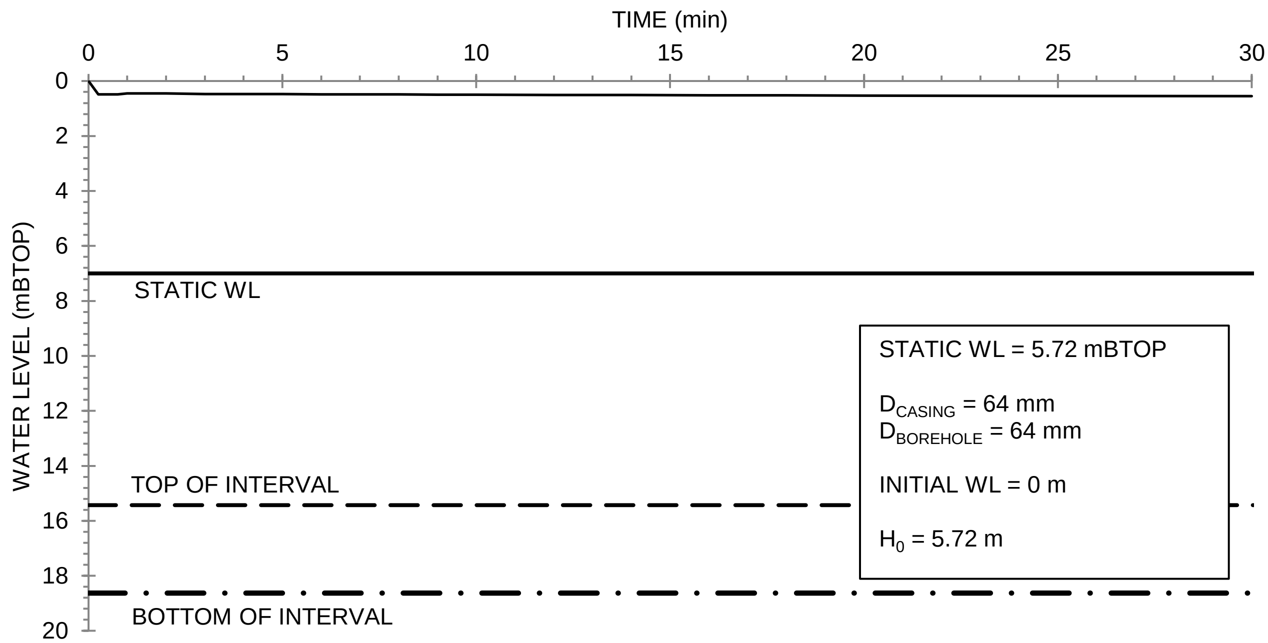
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 19-21, 2016

Performed by: SK

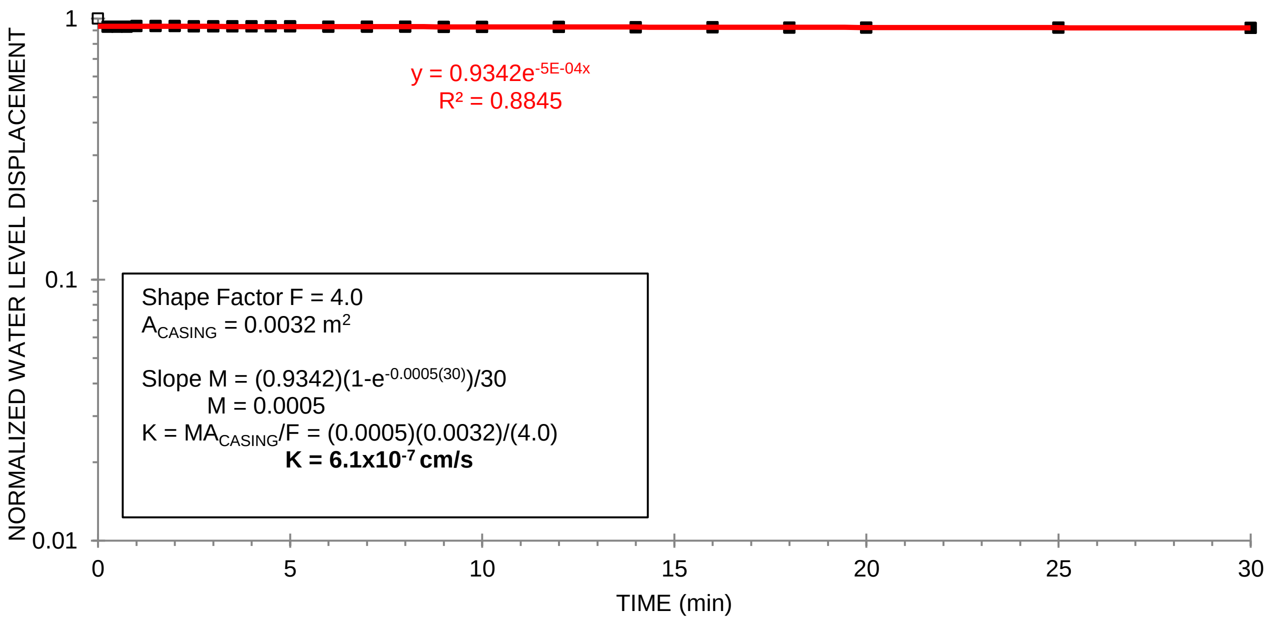


STATIC WL = 5.72 mBTOP

D_{CASING} = 64 mm
$D_{BOREHOLE}$ = 64 mm

INITIAL WL = 0 m

H_0 = 5.72 m



Shape Factor F = 4.0
$A_{CASING} = 0.0032\ m^2$

Slope M = $(0.9342)(1-e^{-0.0005(30)})/30$
M = 0.0005
K = MA_{CASING}/F = (0.0005)(0.0032)/(4.0)
K = 6.1×10^{-7} cm/s

Figure 1-6-4

MW16-6 (16.8m - 19.7m)

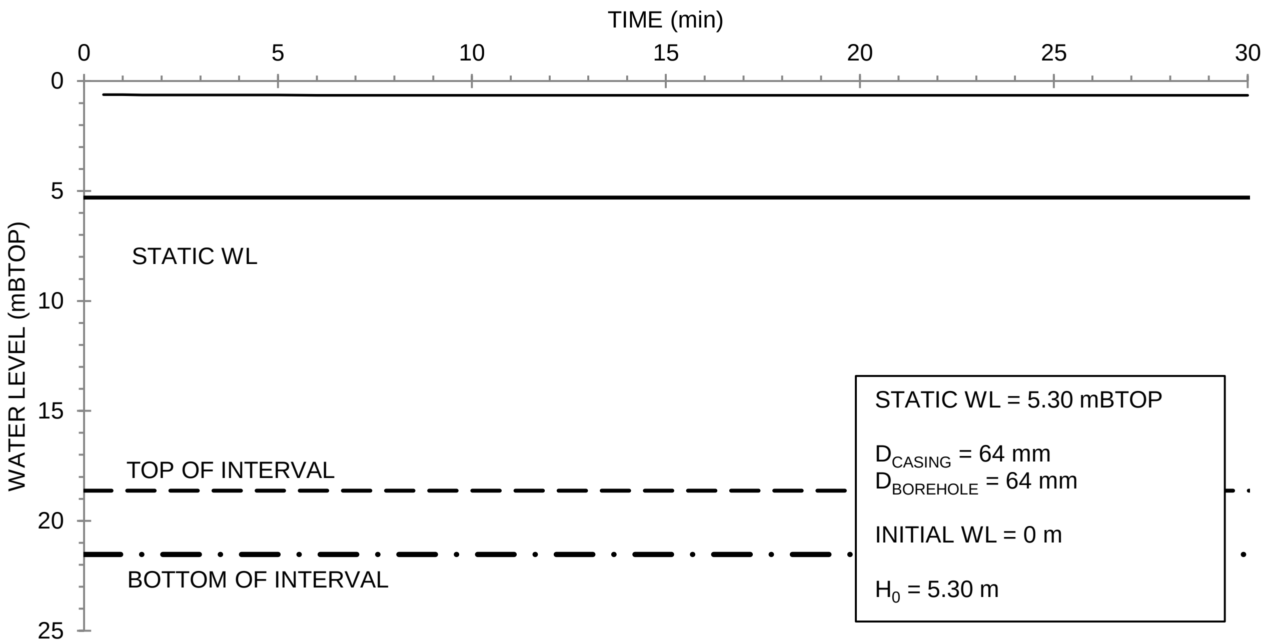
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 19-21, 2016

Performed by: SK



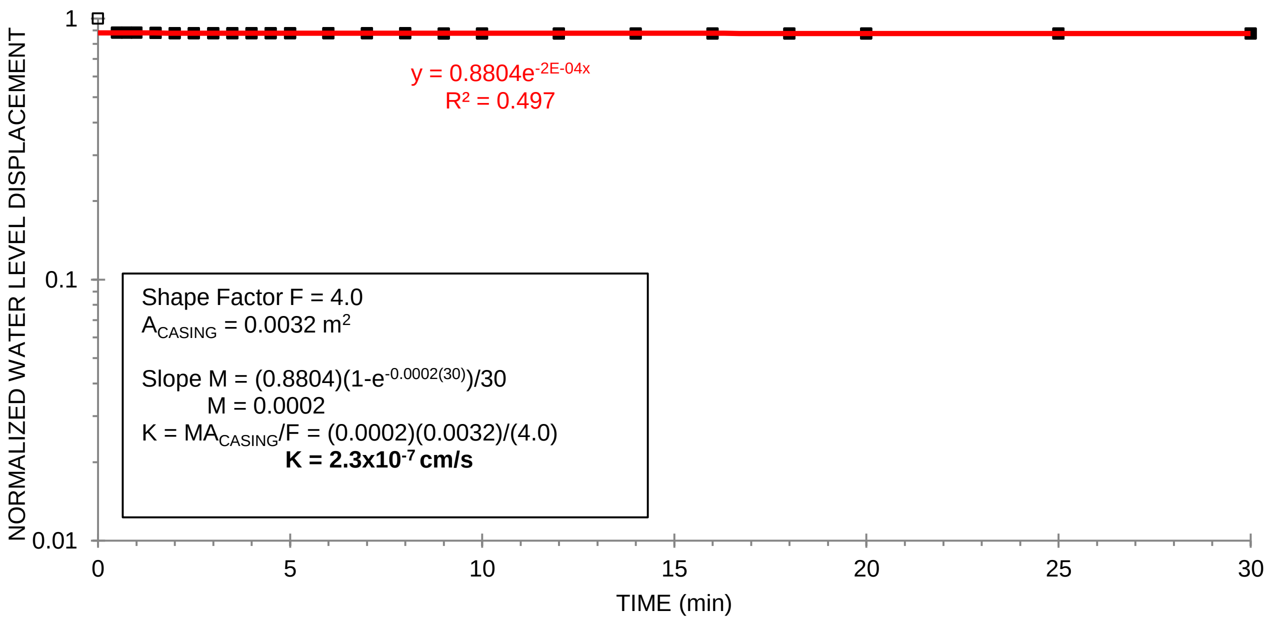


Figure 1-6-5

MW16-6 (19.7m - 22.9m)

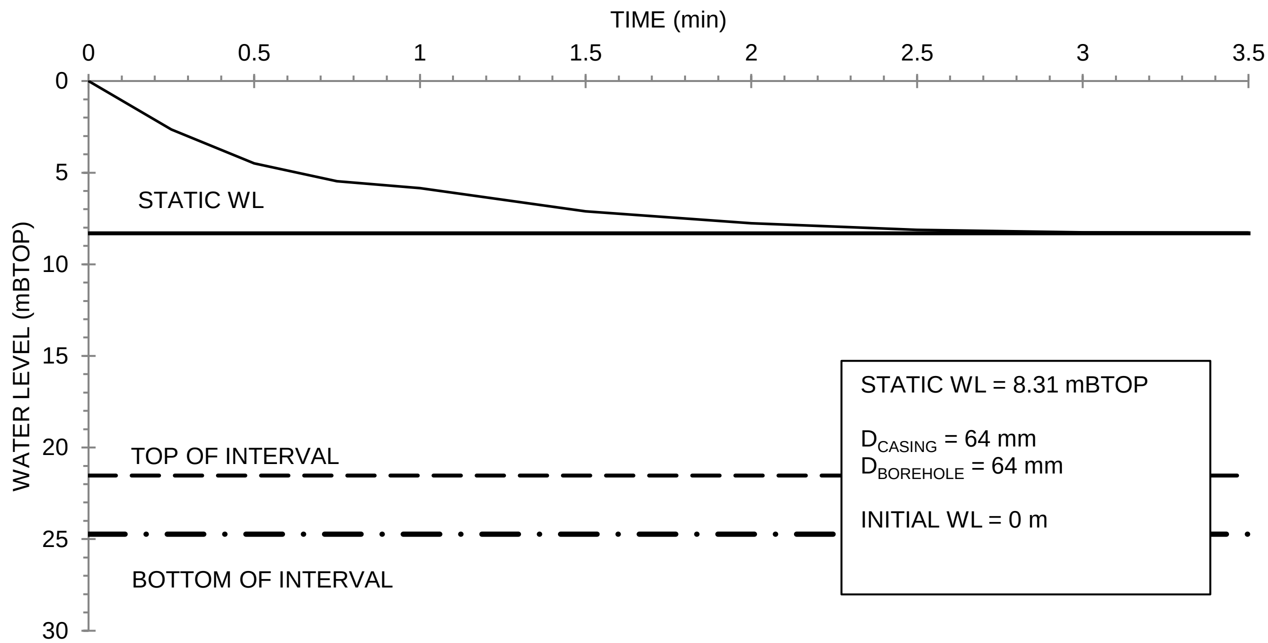
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 19-21, 2016

Performed by: SK



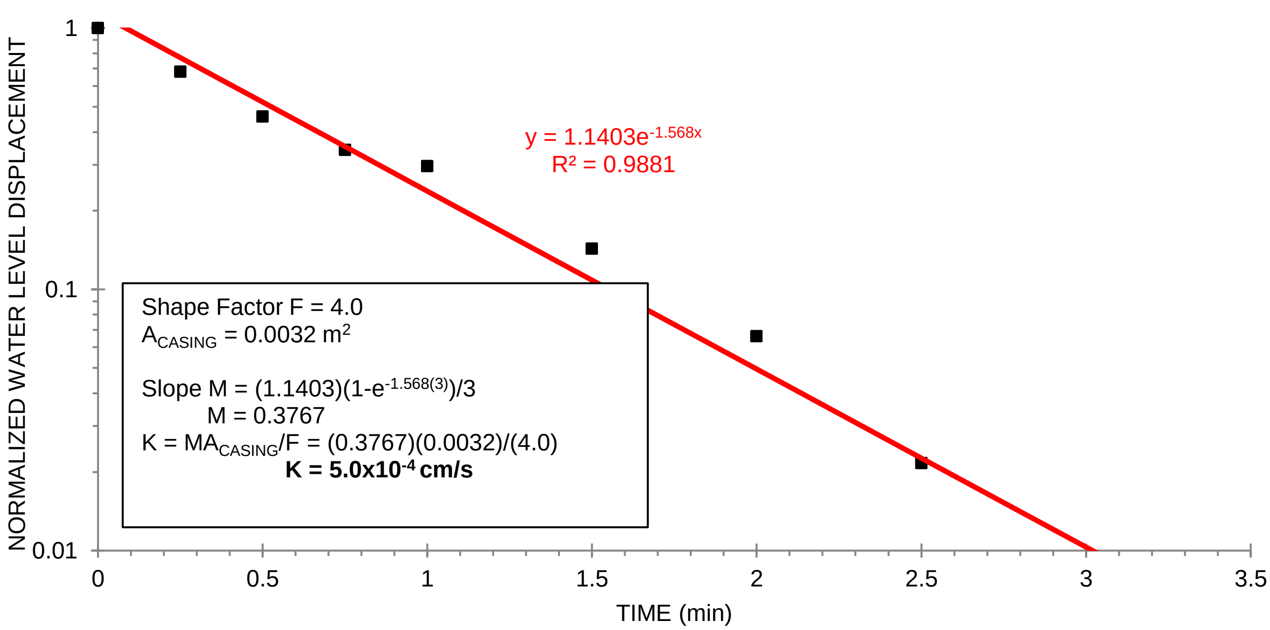


Figure 1-6-6

MW16-6 (22.9m - 25.9m)

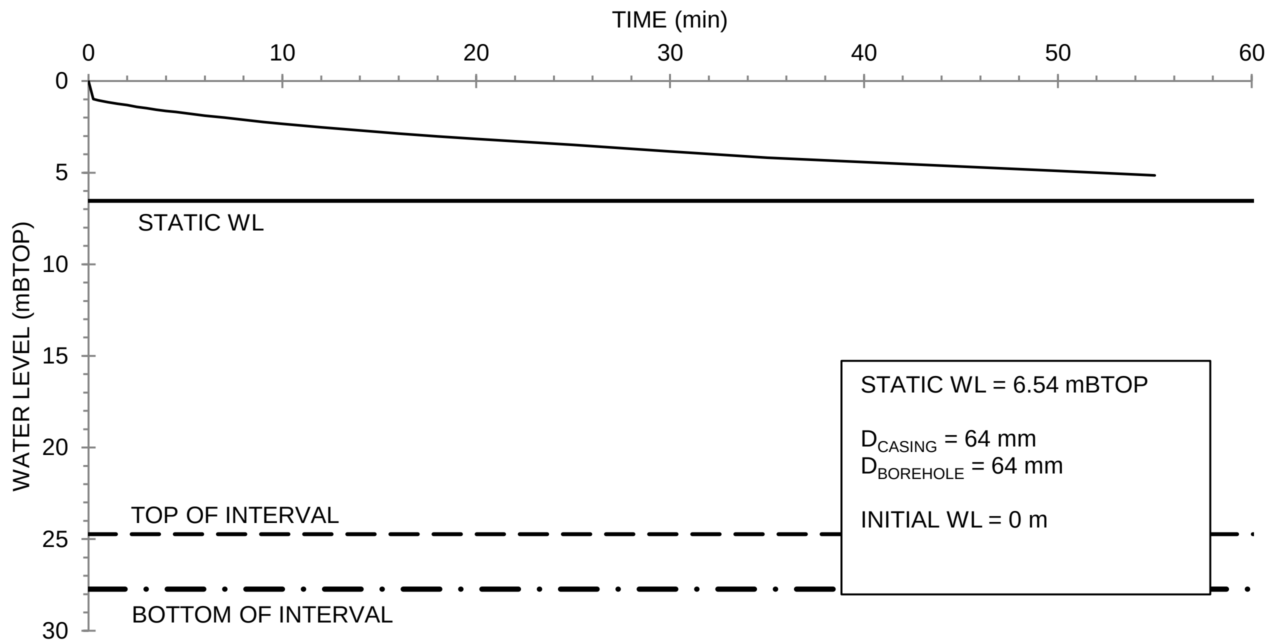
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 19-21, 2016

Performed by: SK



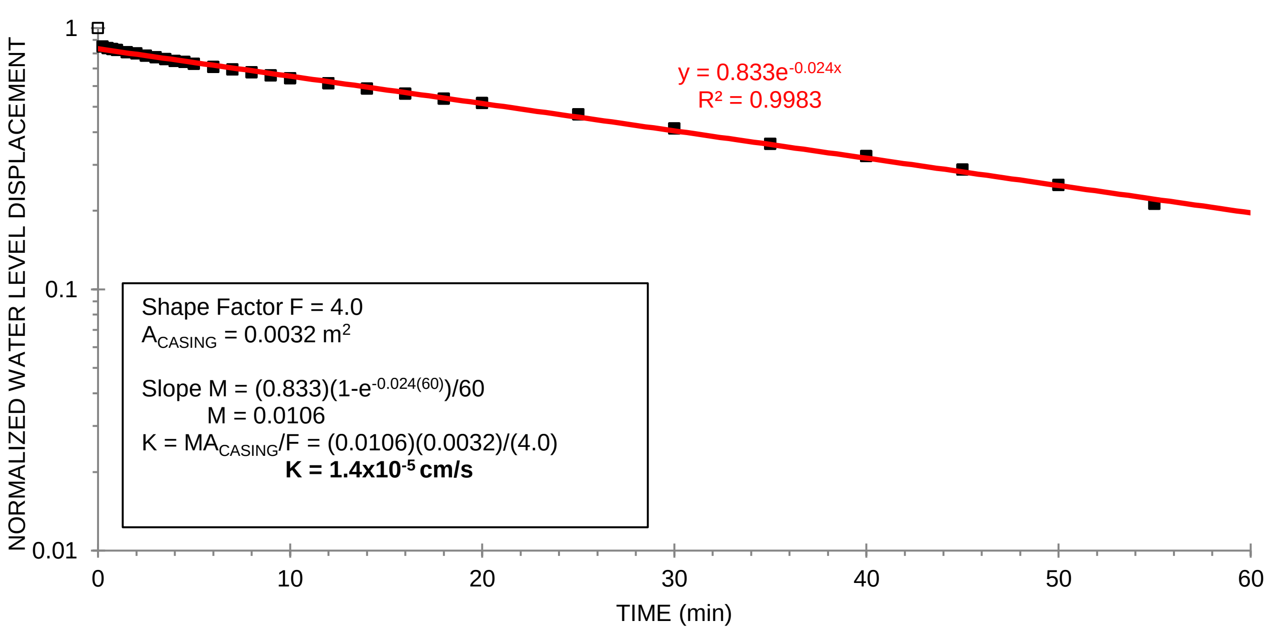


Figure 1-6-7

MW16-6 (25.9m - 28.9m)

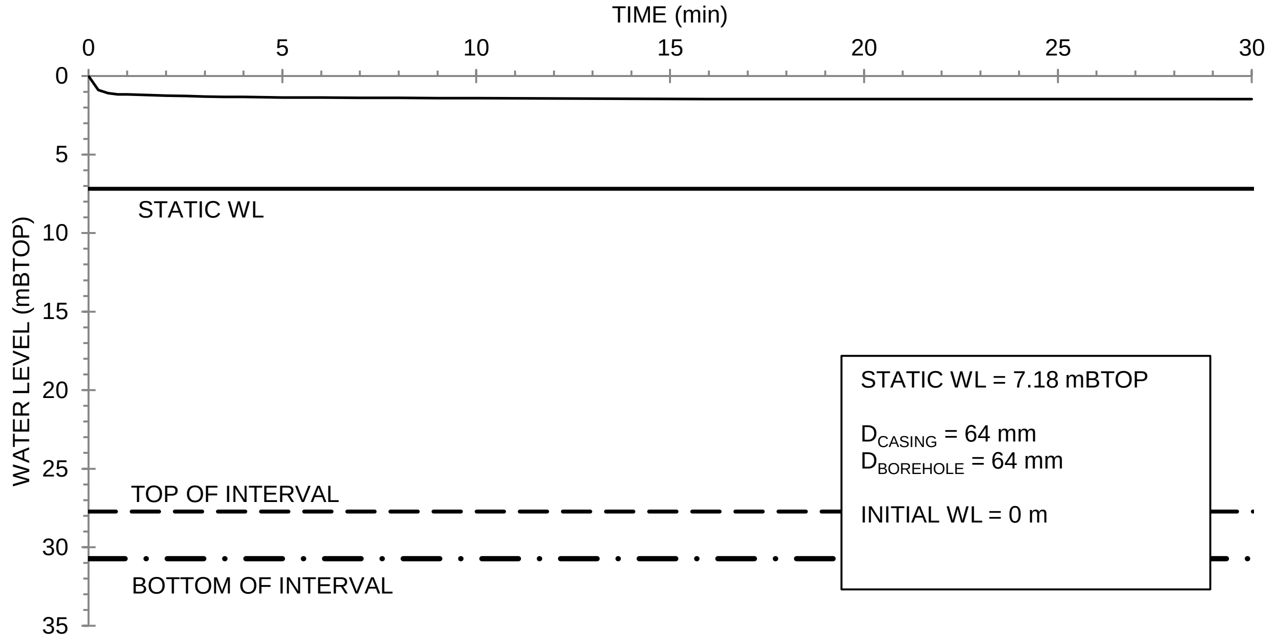
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 19-21, 2016

Performed by: SK



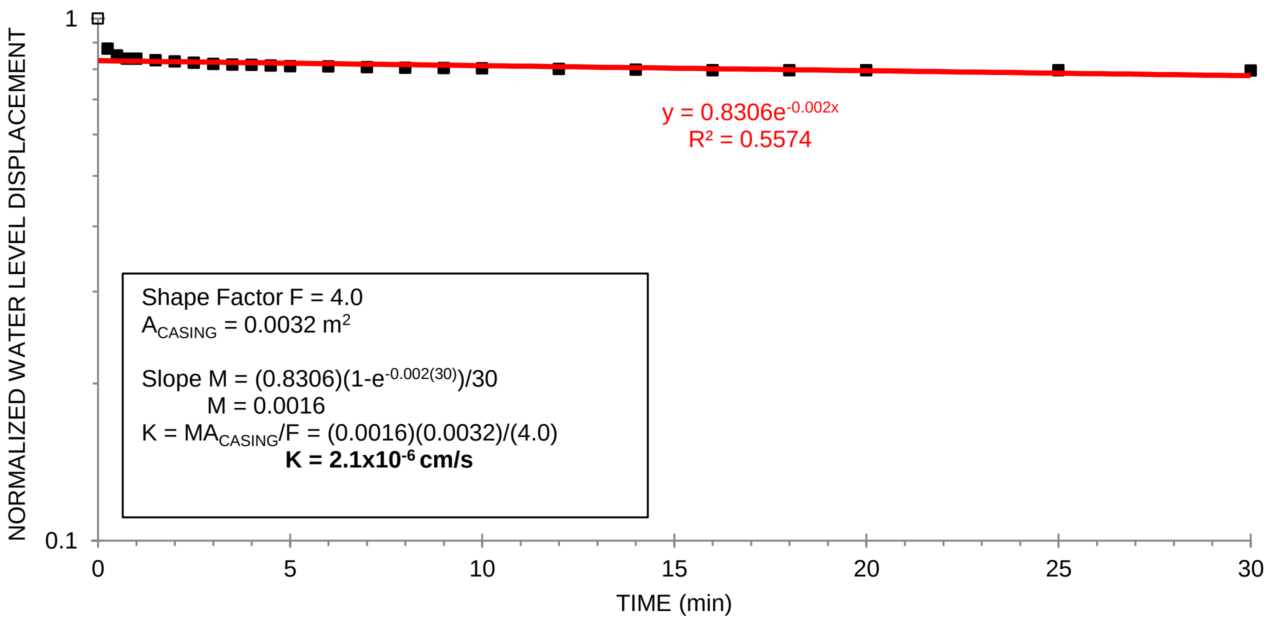


Figure 1-6-8

MW16-6 (28.9m - 31.9m)

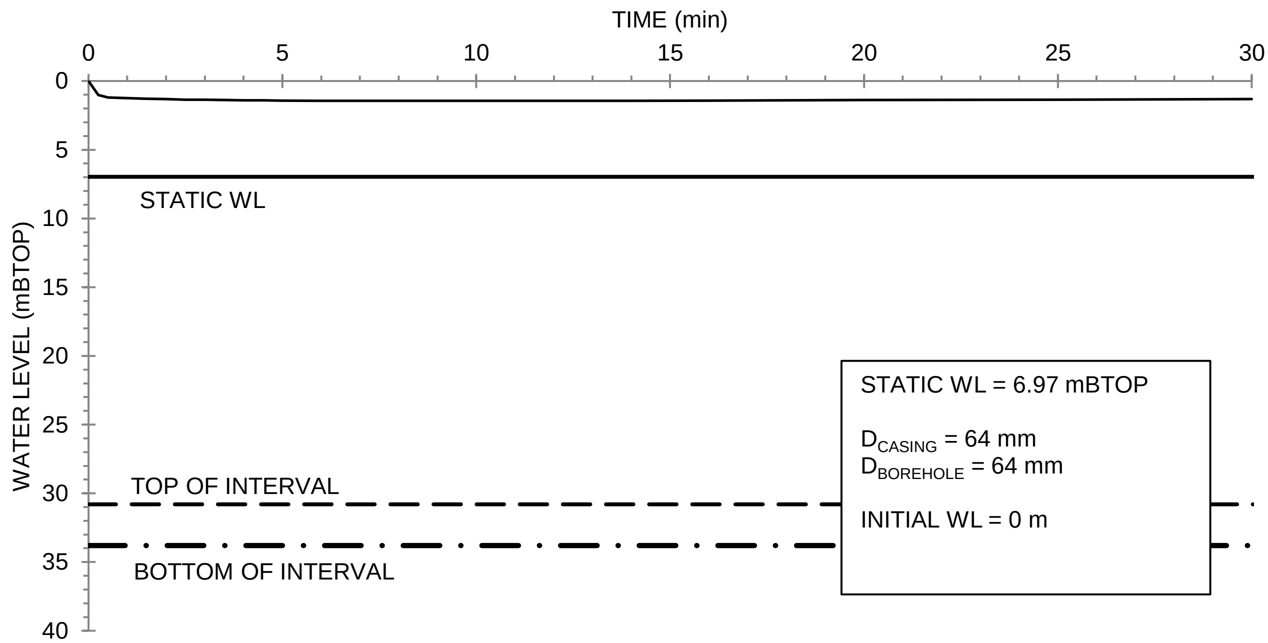
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 19-21, 2016

Performed by: SK



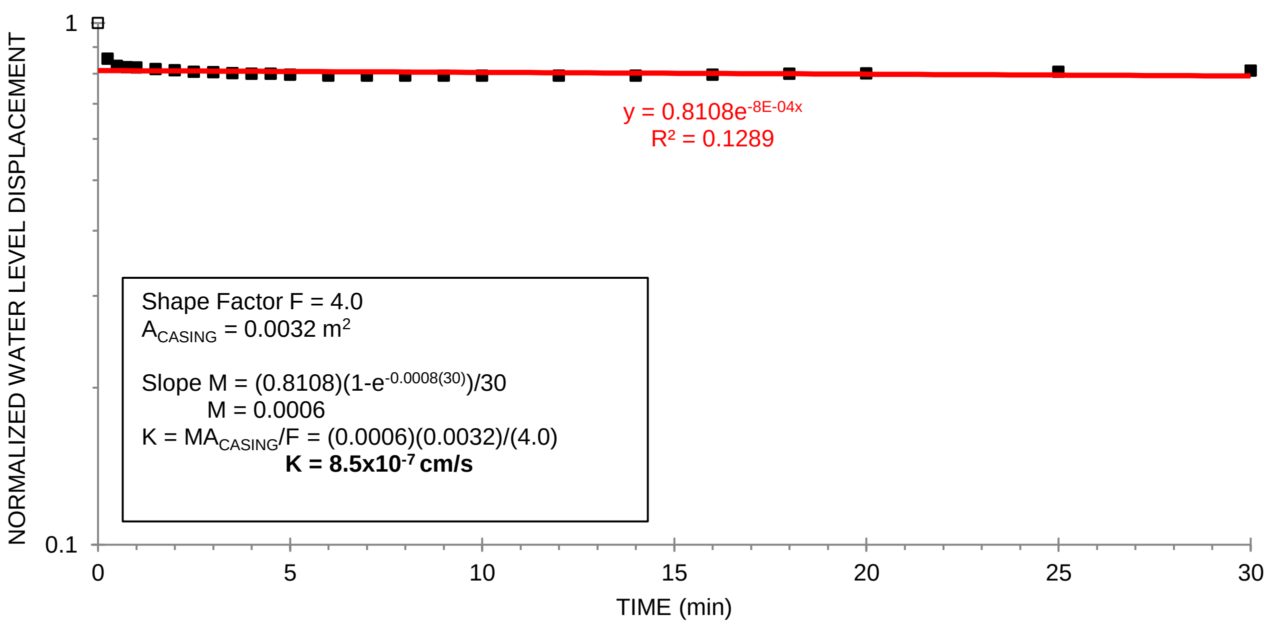


Figure 1-8-1

MW16-8 (12.8m - 15.1m)

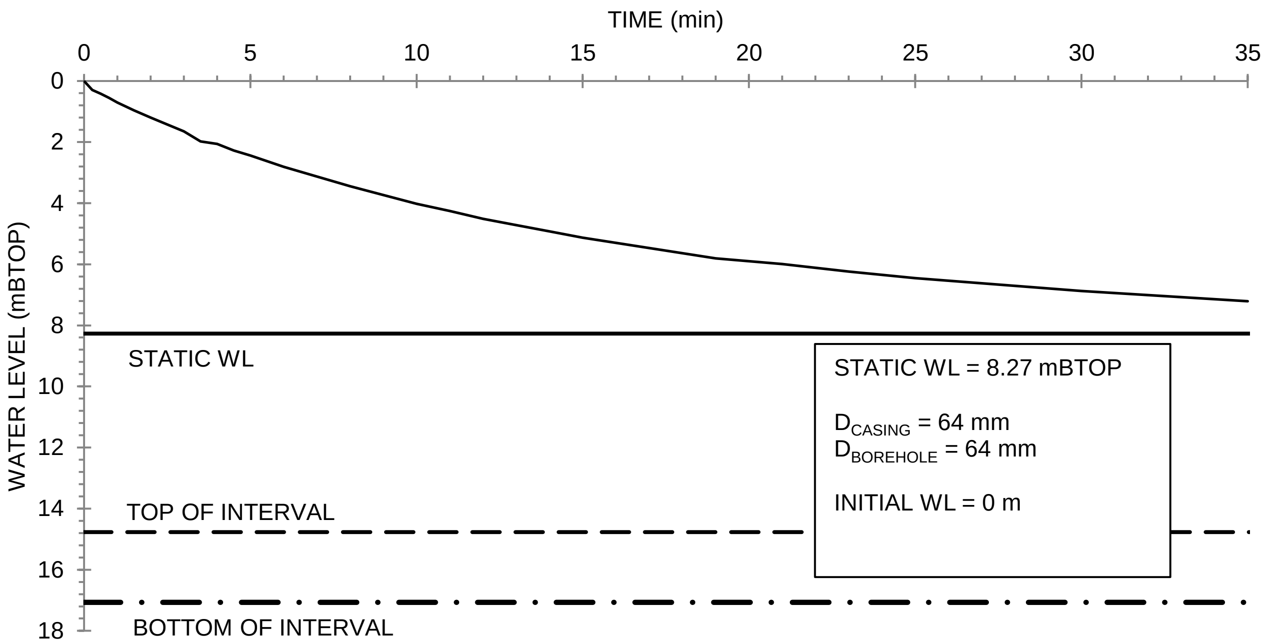
Falling Head Packer Test Analysis

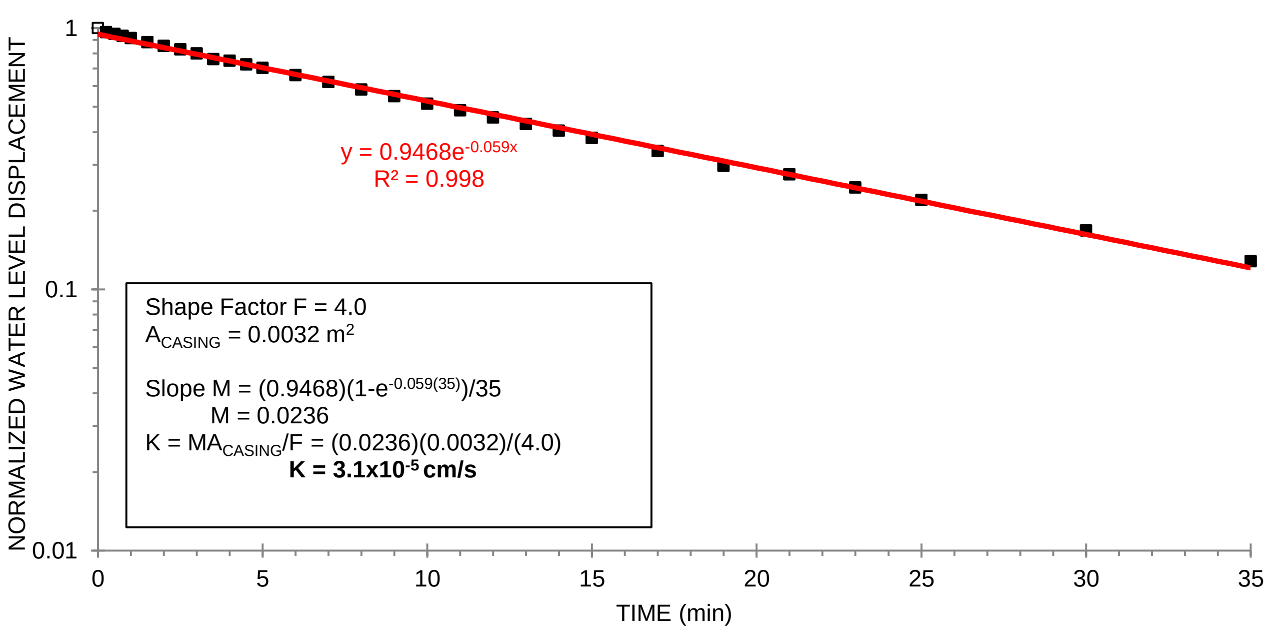
Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK





Shape Factor F = 4.0
A_{CASING} = 0.0032 m^2

Slope M = $(0.9468)(1-e^{-0.059(35)})/35$
M = 0.0236
K = MA_{CASING}/F = (0.0236)(0.0032)/(4.0)
K = 3.1×10^{-5} cm/s

Figure 1-8-2

MW16-8 (15.1m - 16.7m)

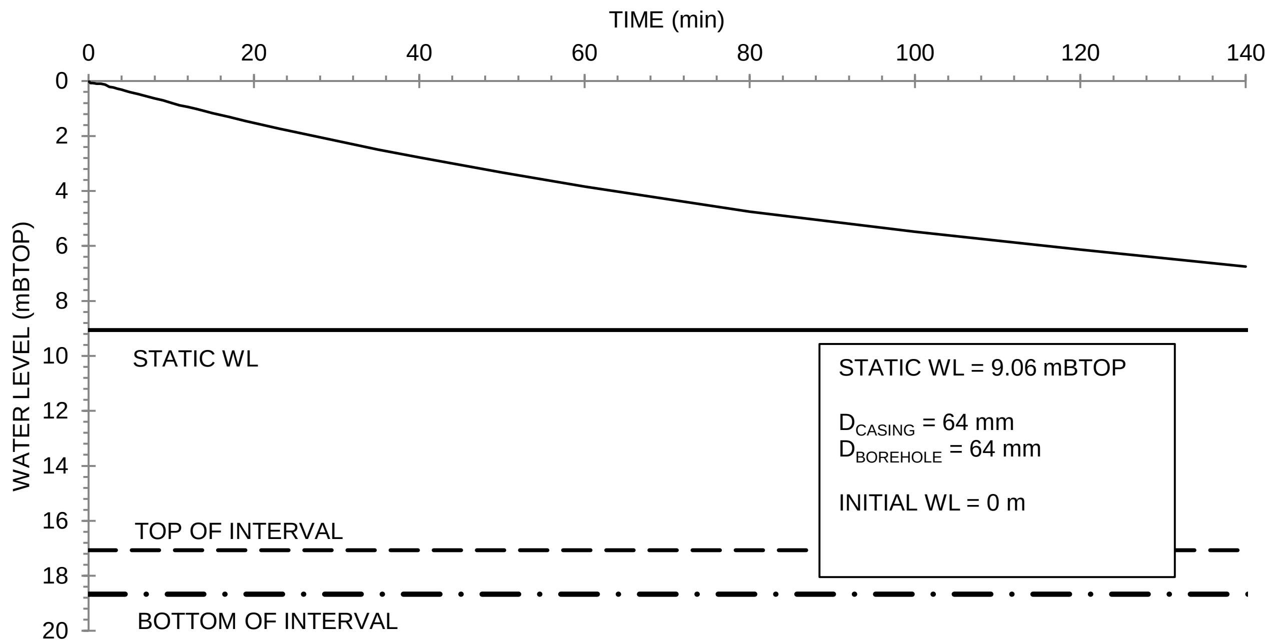
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



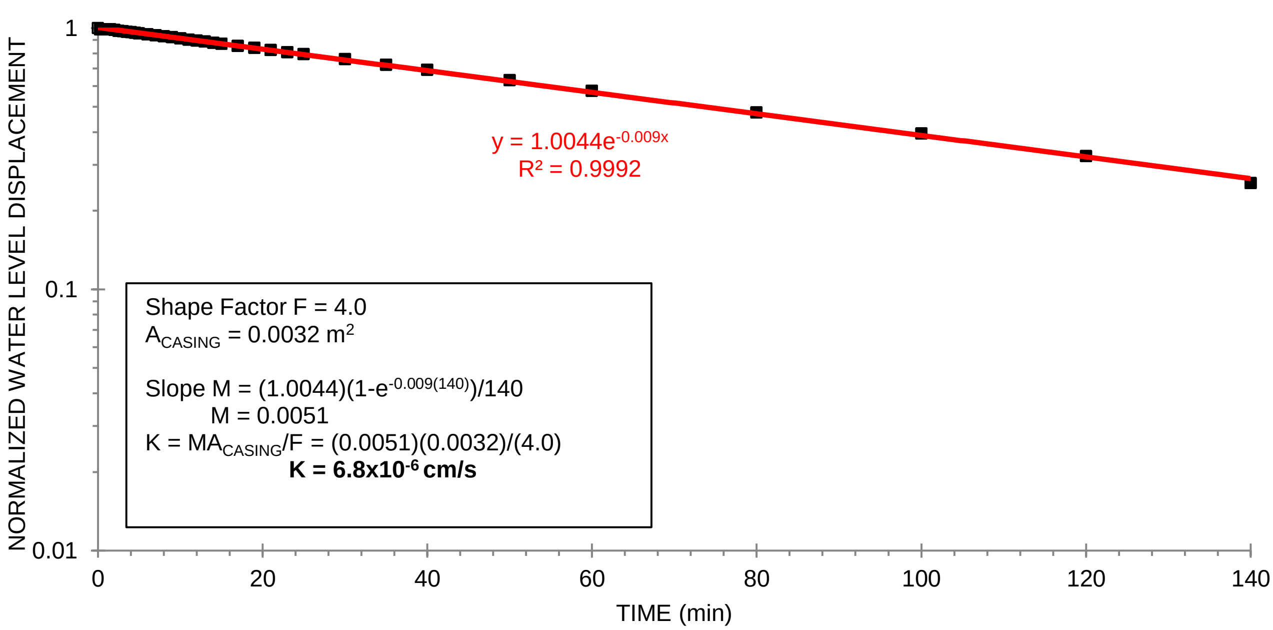


Figure 1-8-3

MW16-8 (16.7m - 19.7m)

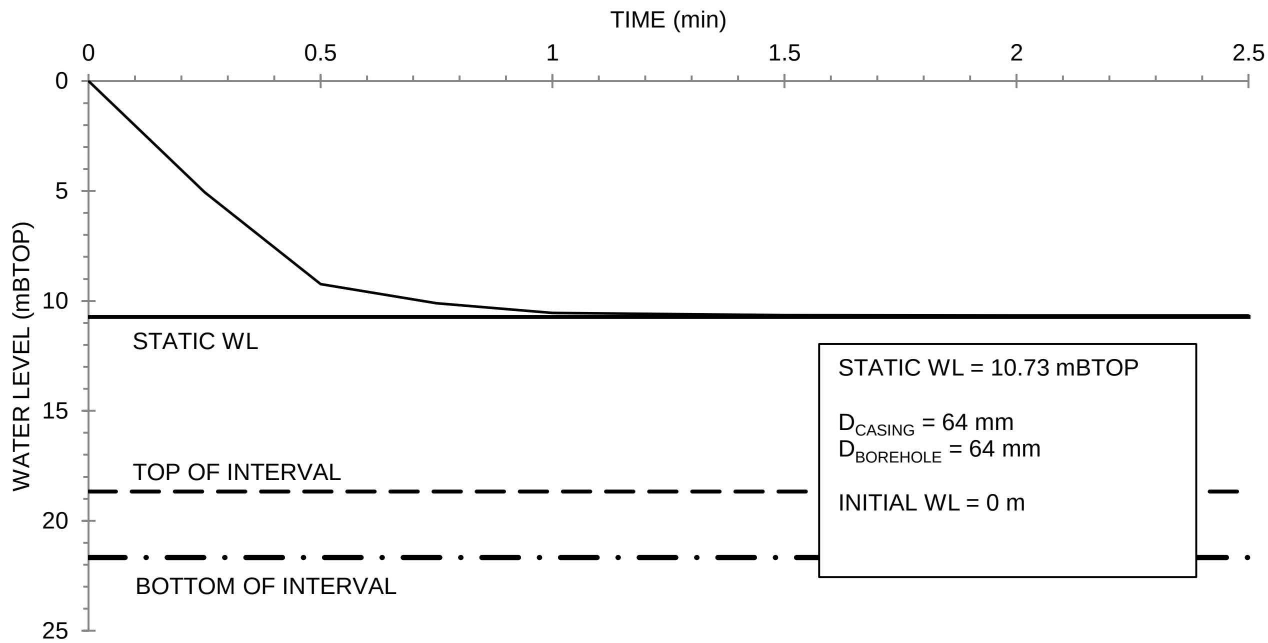
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



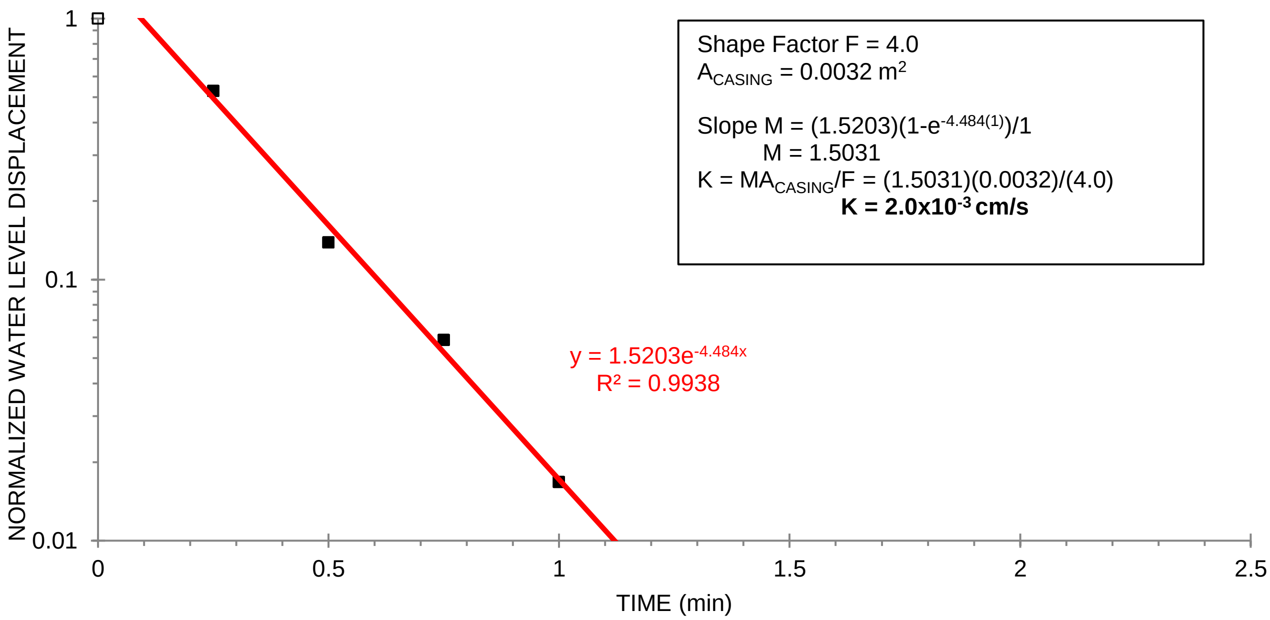


Figure 1-8-4

MW16-8 (19.7m - 22.7m)

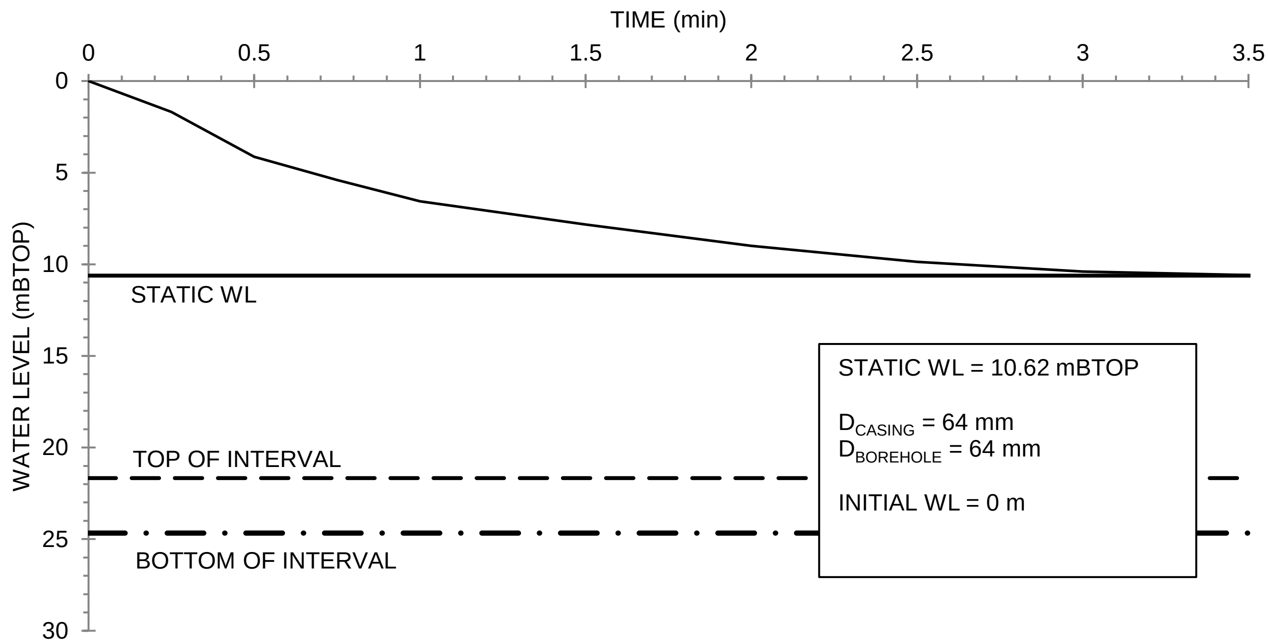
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



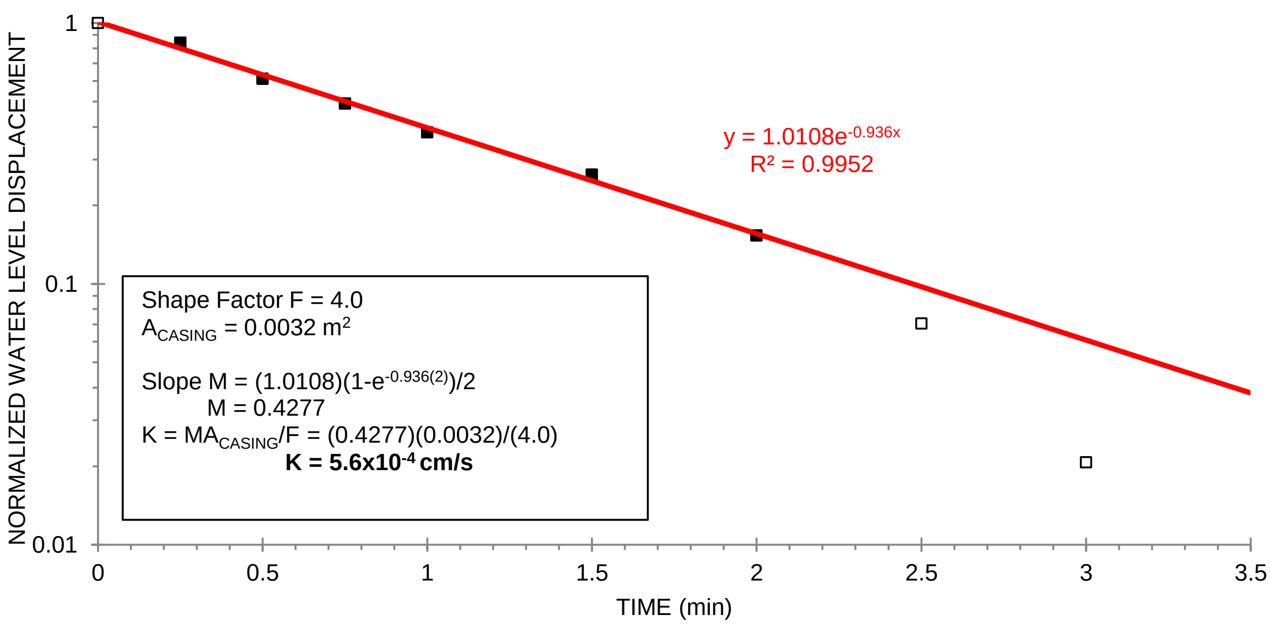


Figure 1-8-5

MW16-8 (22.7m - 25.9m)

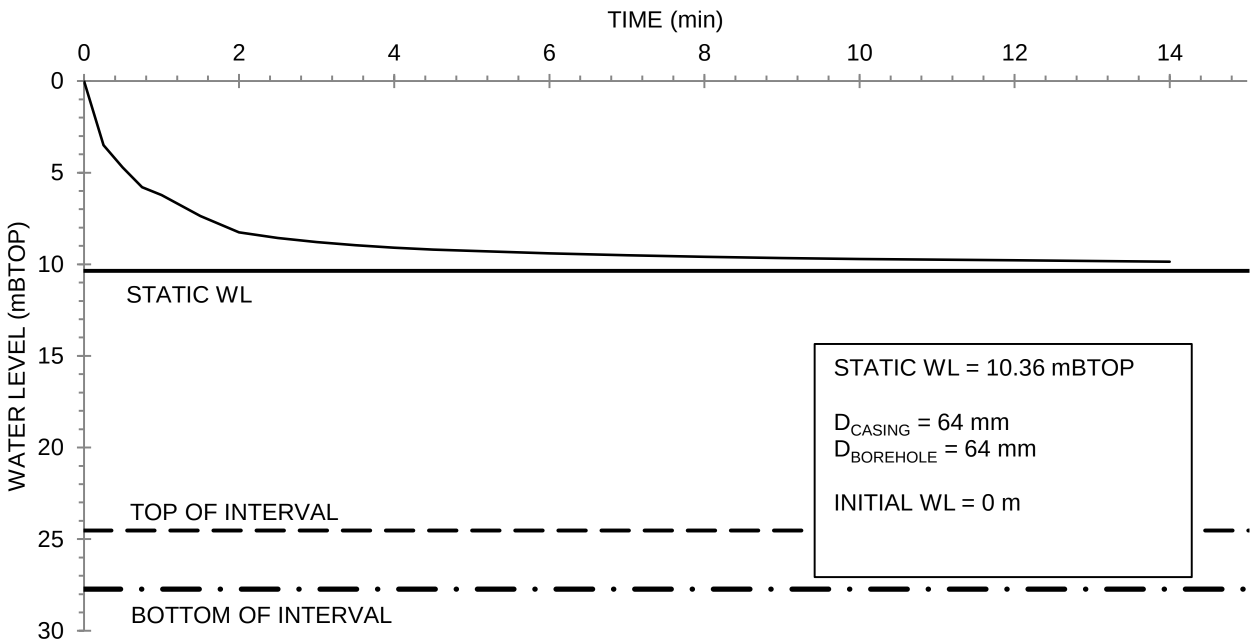
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



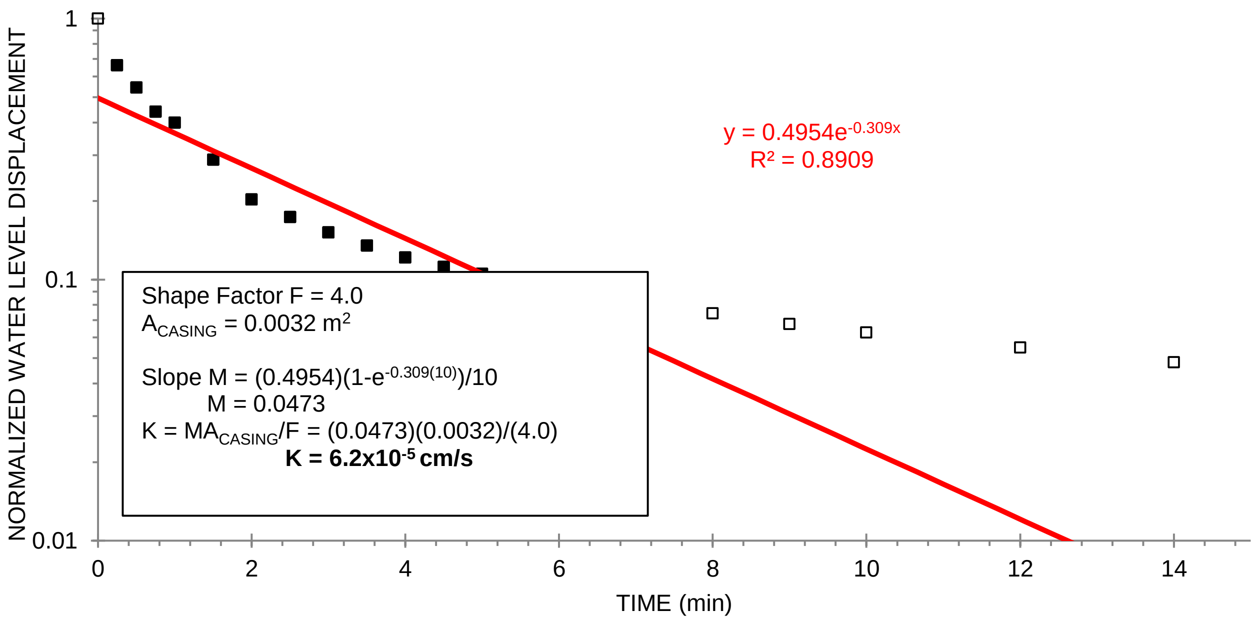


Figure 1-8-6

MW16-8 (25.9m - 28.9m)

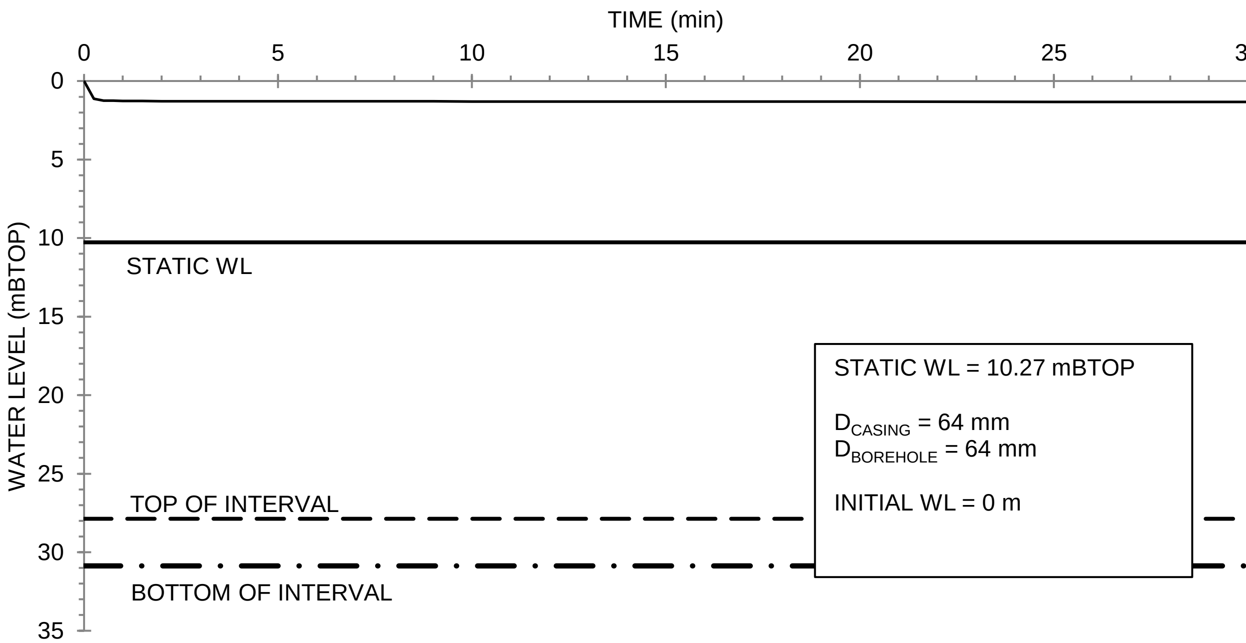
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



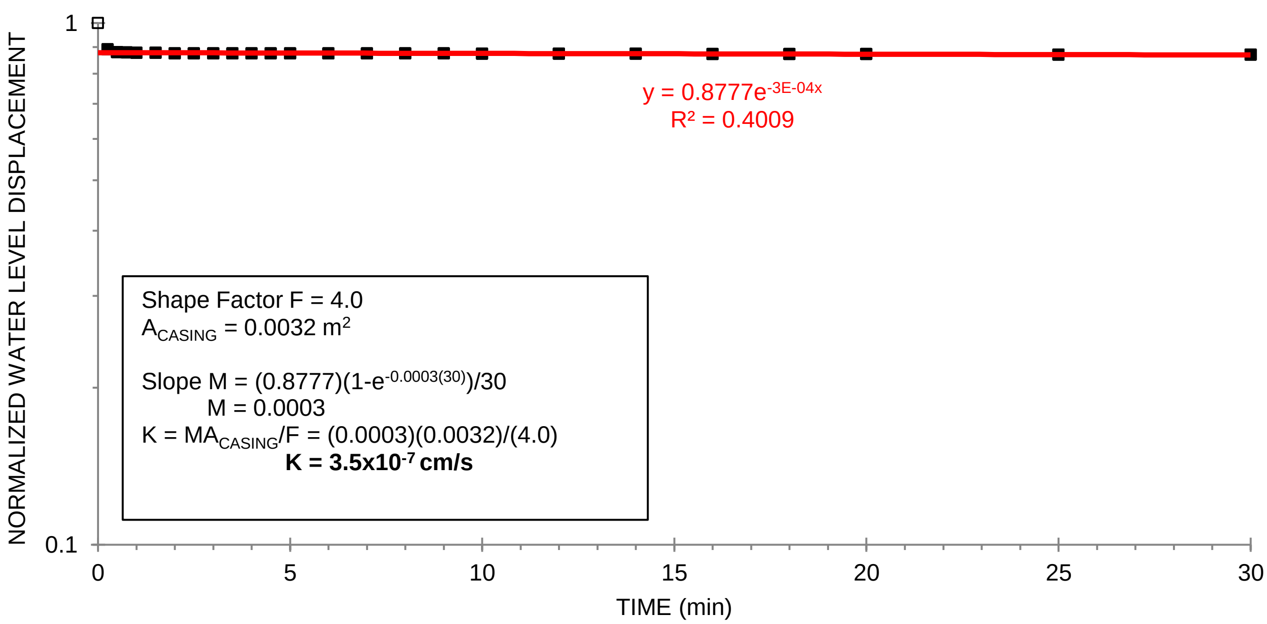


Figure 1-8-7

MW16-8 (28.9m - 32.1m)

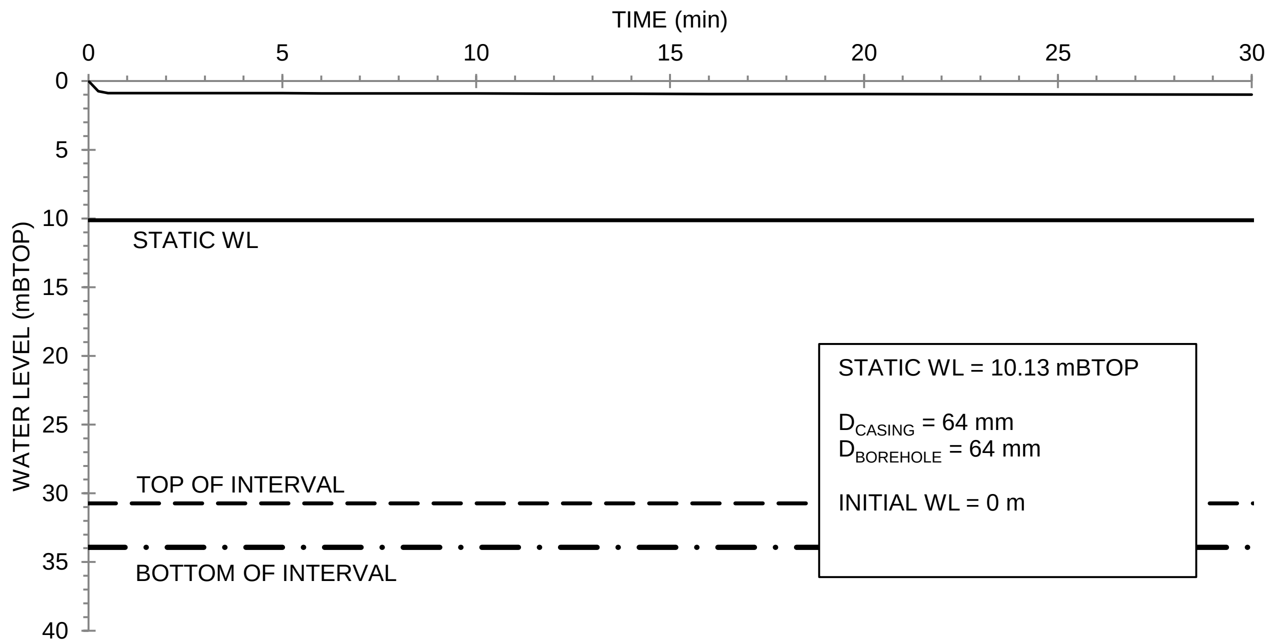
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



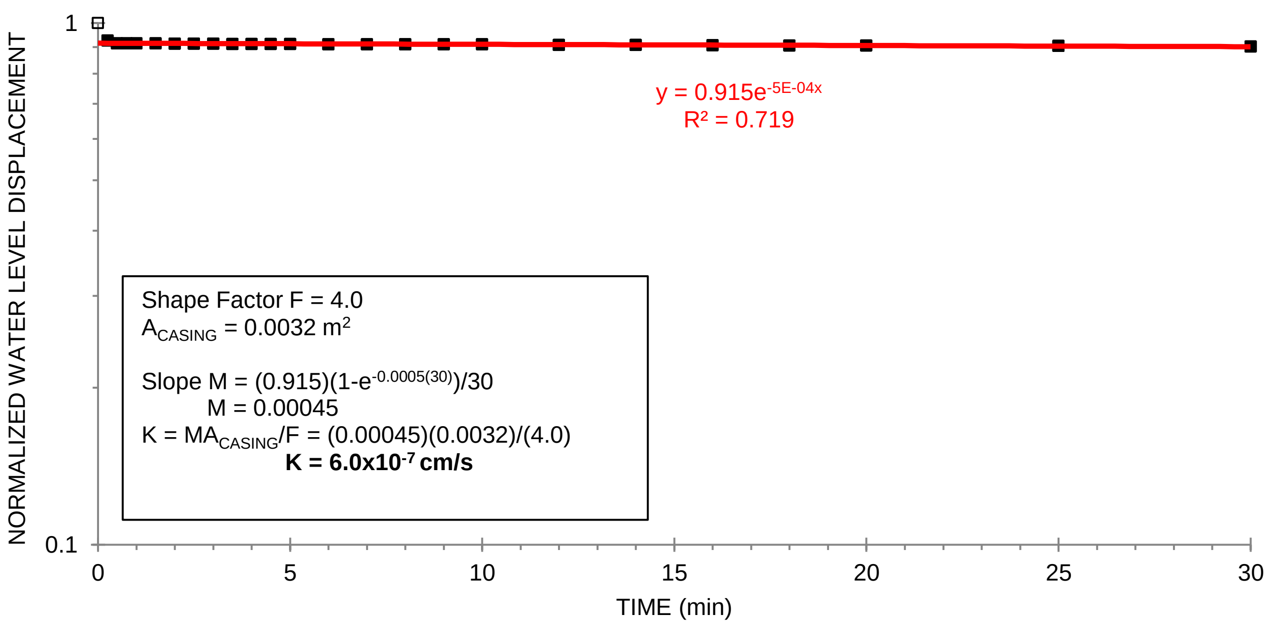


Figure 1-8-8

MW16-8 (32.1m - 35.1m)

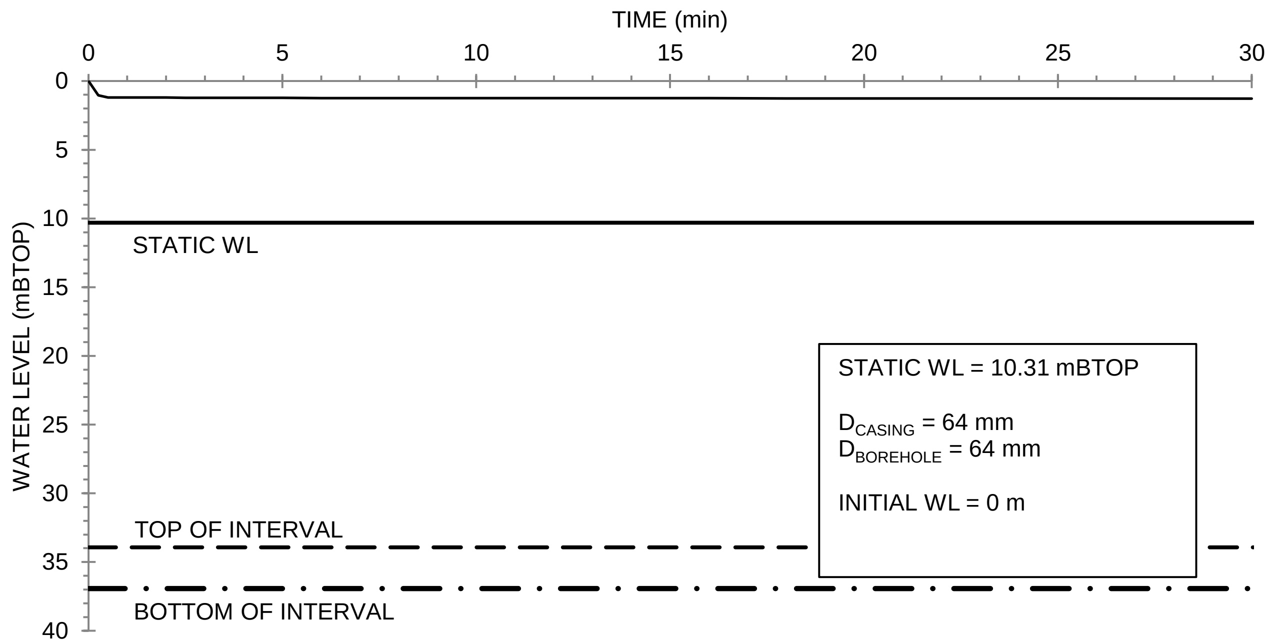
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



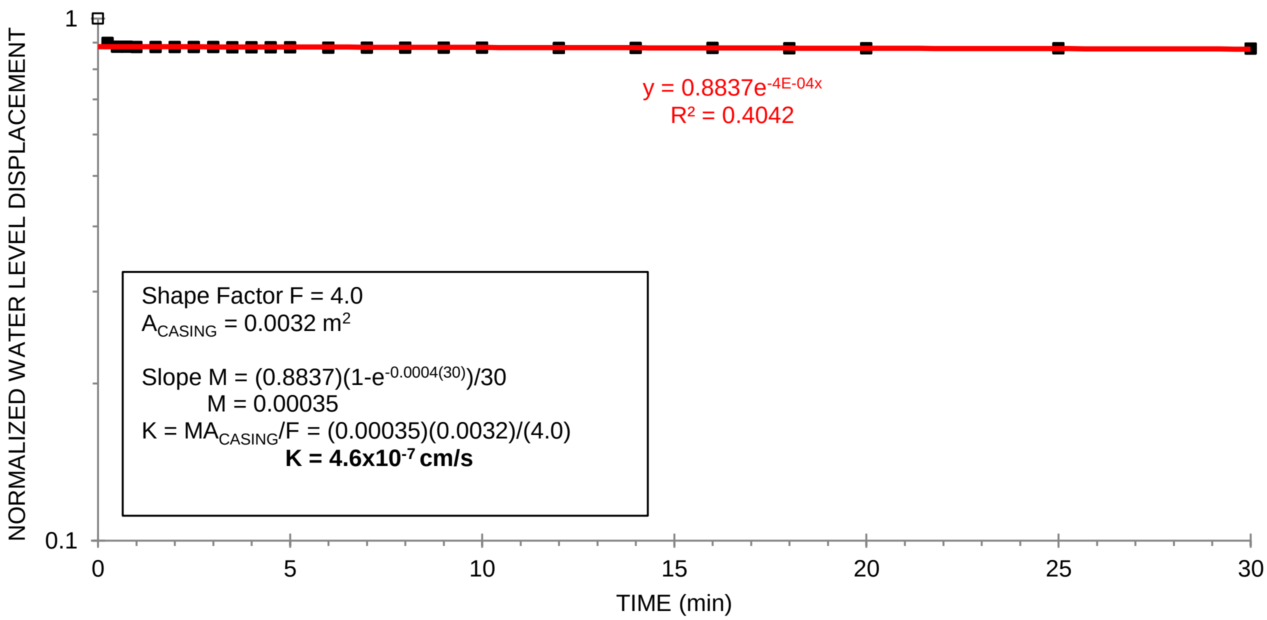


Figure 1-8-9

MW16-8 (35.1m - 38.2m)

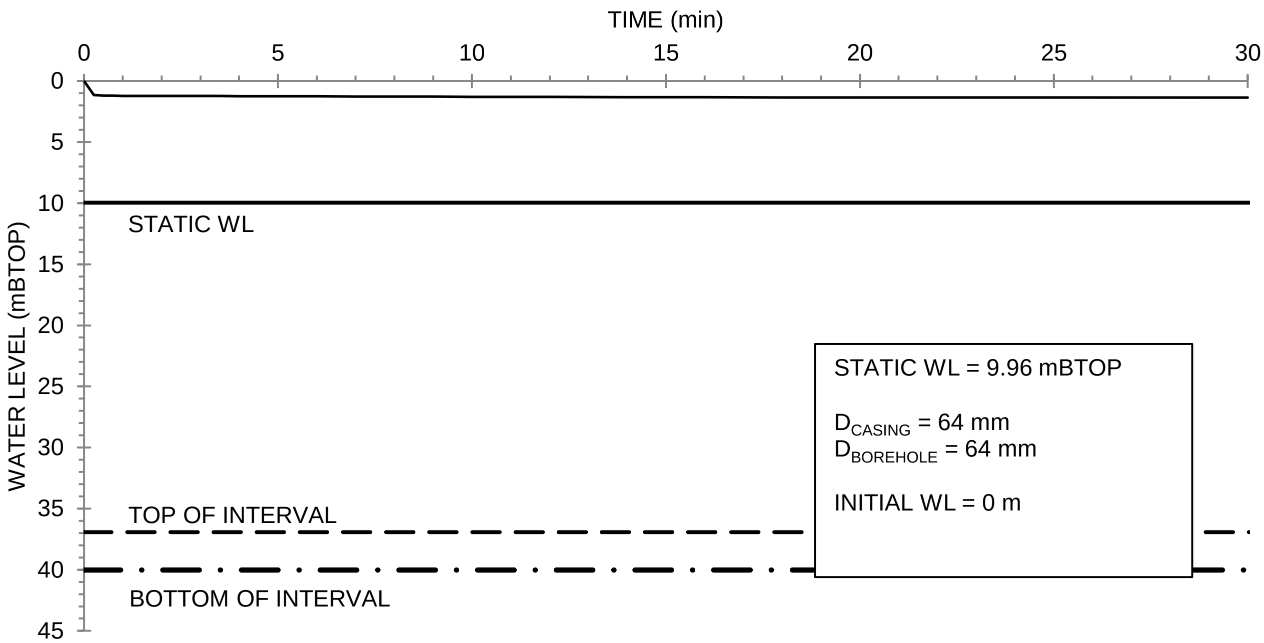
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



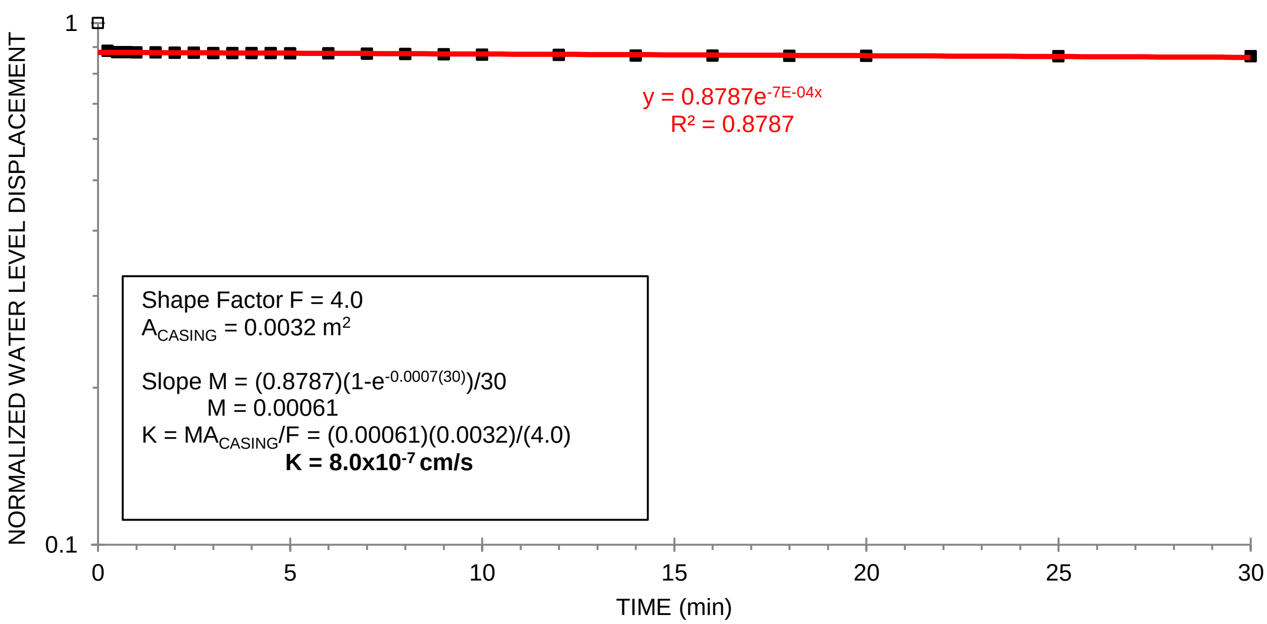


Figure 1-8-10

MW16-8 (38.2m - 41.2m)

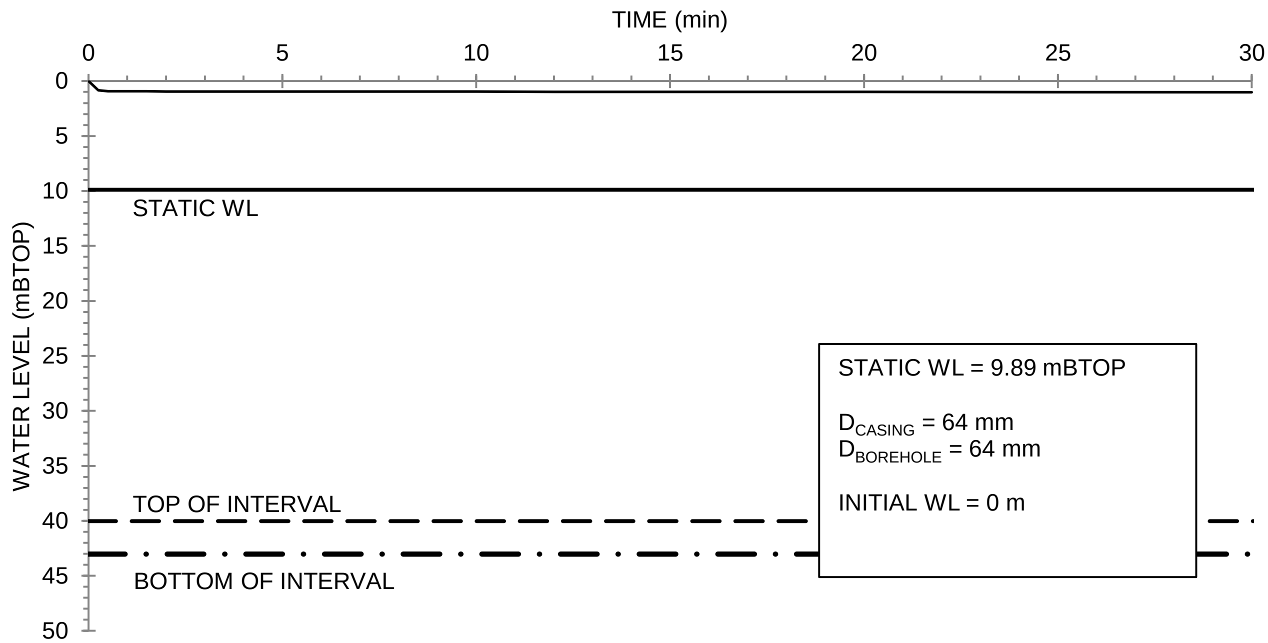
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



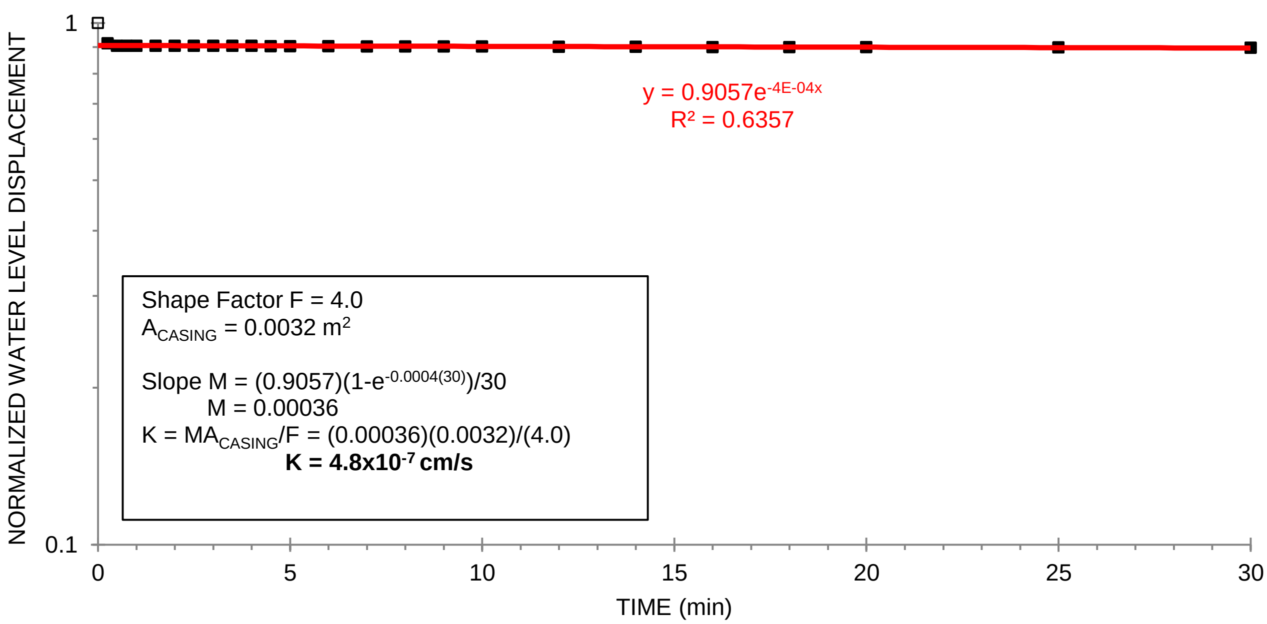


Figure 1-8-11

MW16-8 (41.2m - 44.2m)

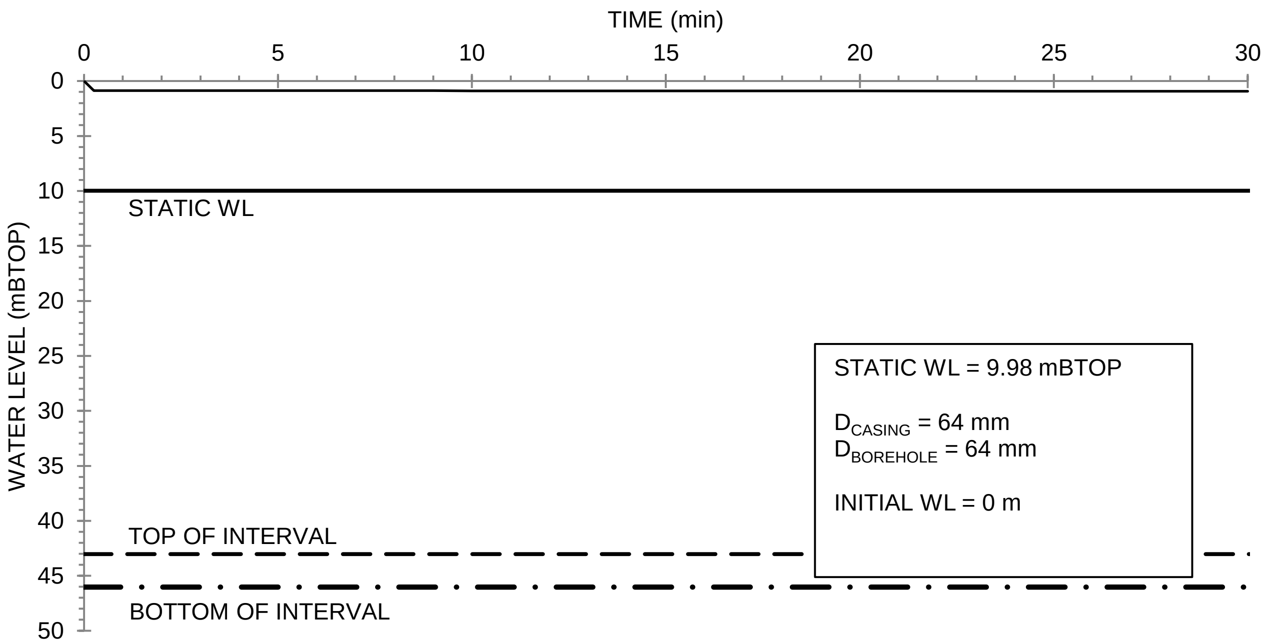
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



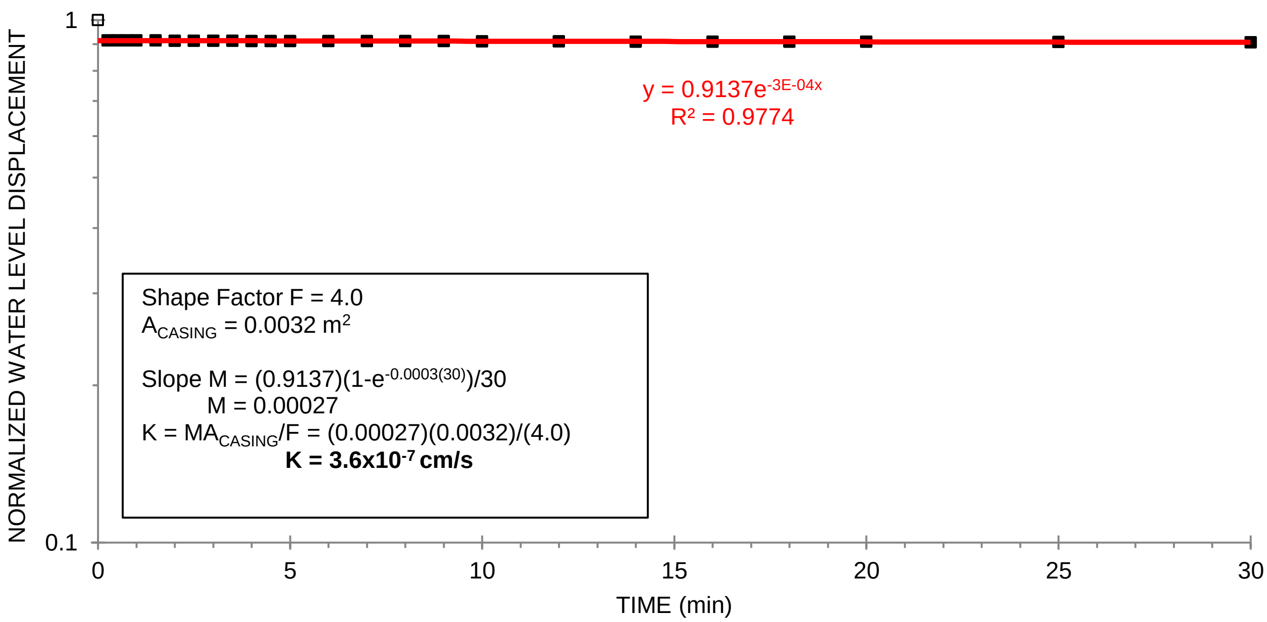


Figure 1-8-12

MW16-8 (44.2m - 47.1m)

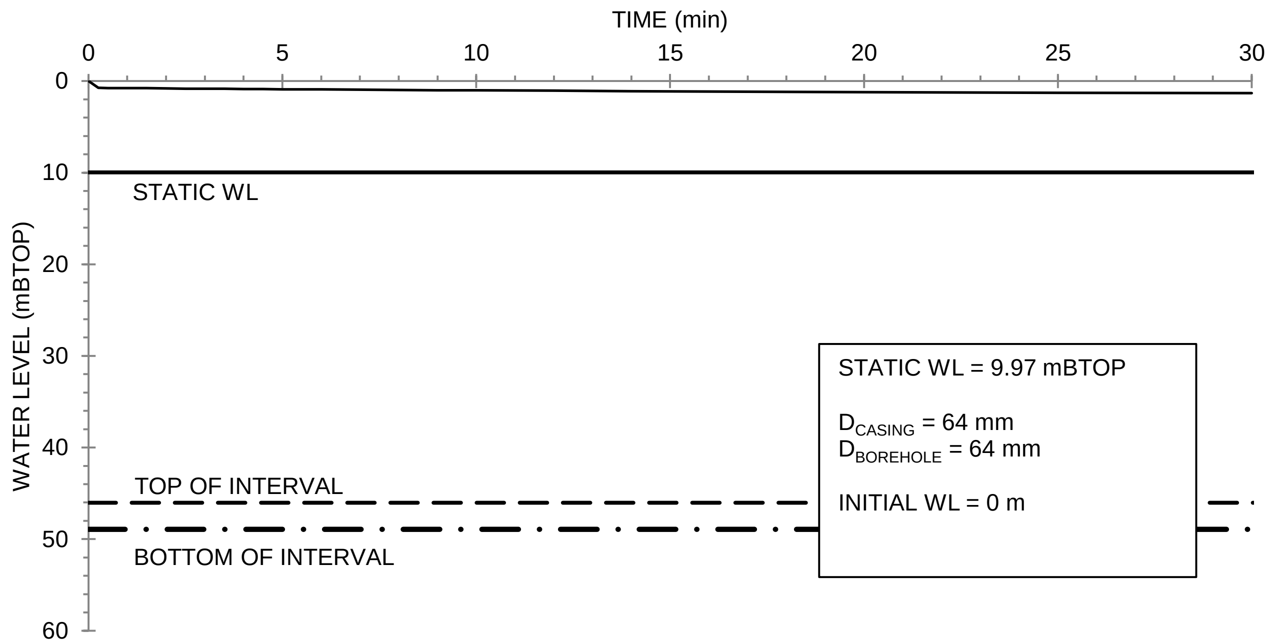
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: October 5-7, 2016

Performed by: SK



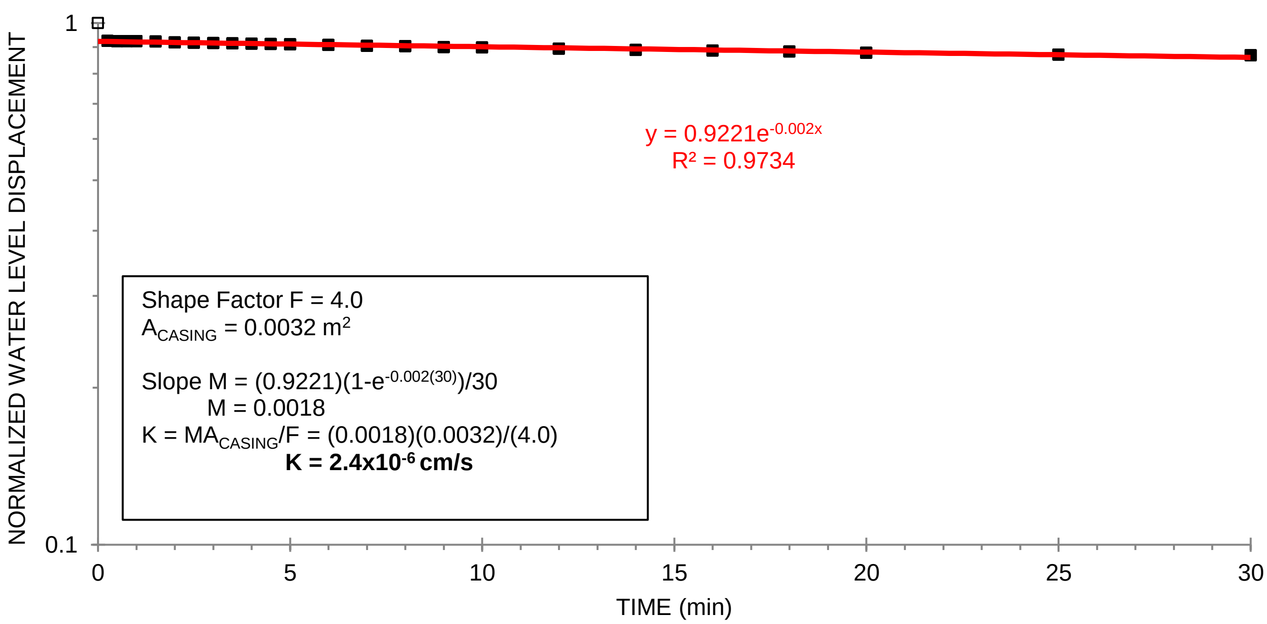


Figure 1-10-2

MW16-10 (10.7m - 13.8m)

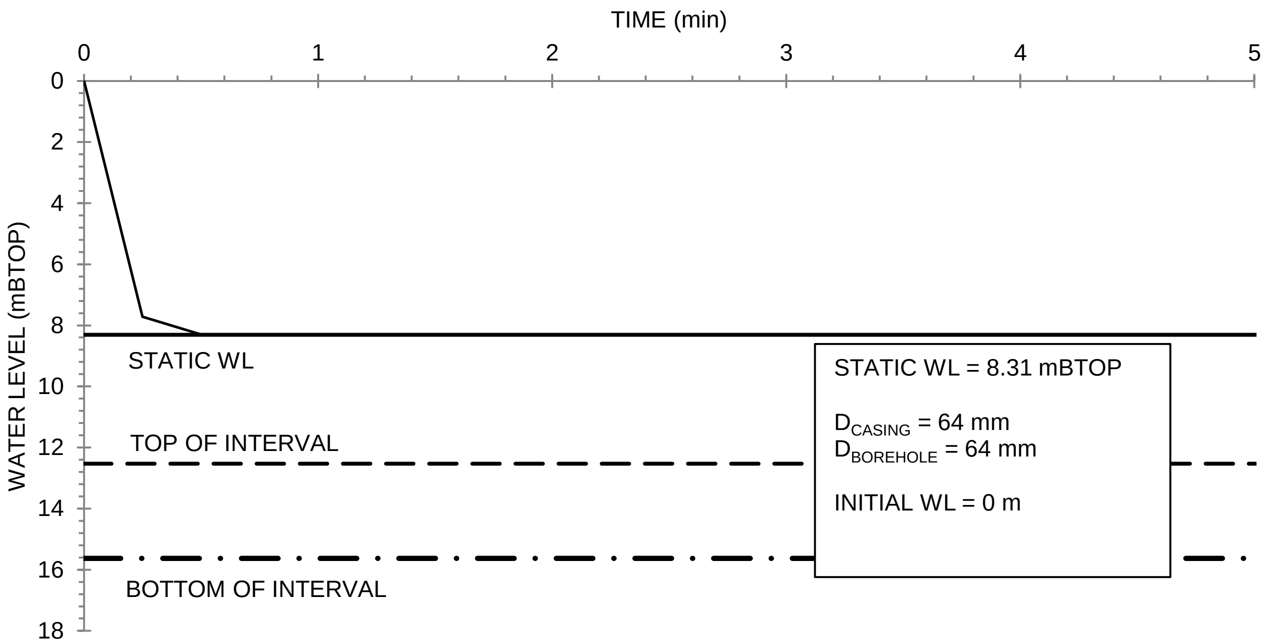
Falling Head Packer Test Analysis

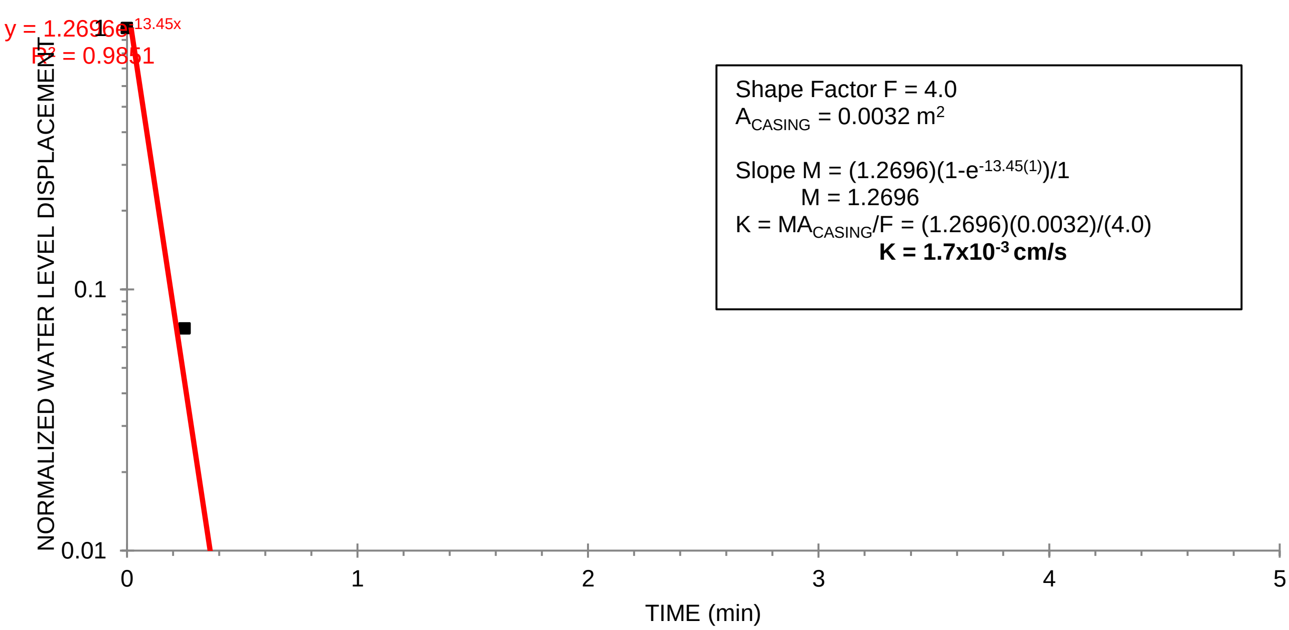
Hvorslev Method

Proposed Upper's Quarry

Date: November 24-28, 2016

Performed by: SK





Shape Factor F = 4.0

A_{CASING} = 0.0032 m^2

Slope M = $(1.2696)(1-e^{-13.45(1)})/1$

M = 1.2696

K = MA_{CASING}/F = (1.2696)(0.0032)/(4.0)

K = $1.7x10^{-3}$ cm/s

Figure 1-10-3

MW16-10 (13.8m - 16.8m)

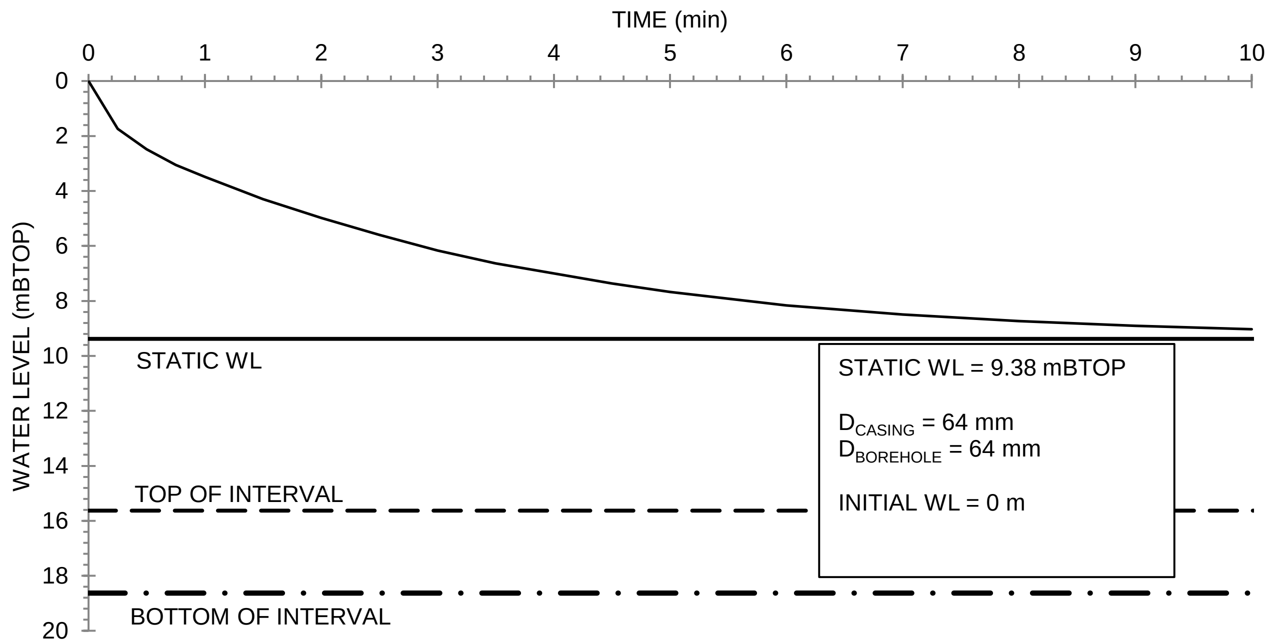
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 24-28, 2016

Performed by: SK



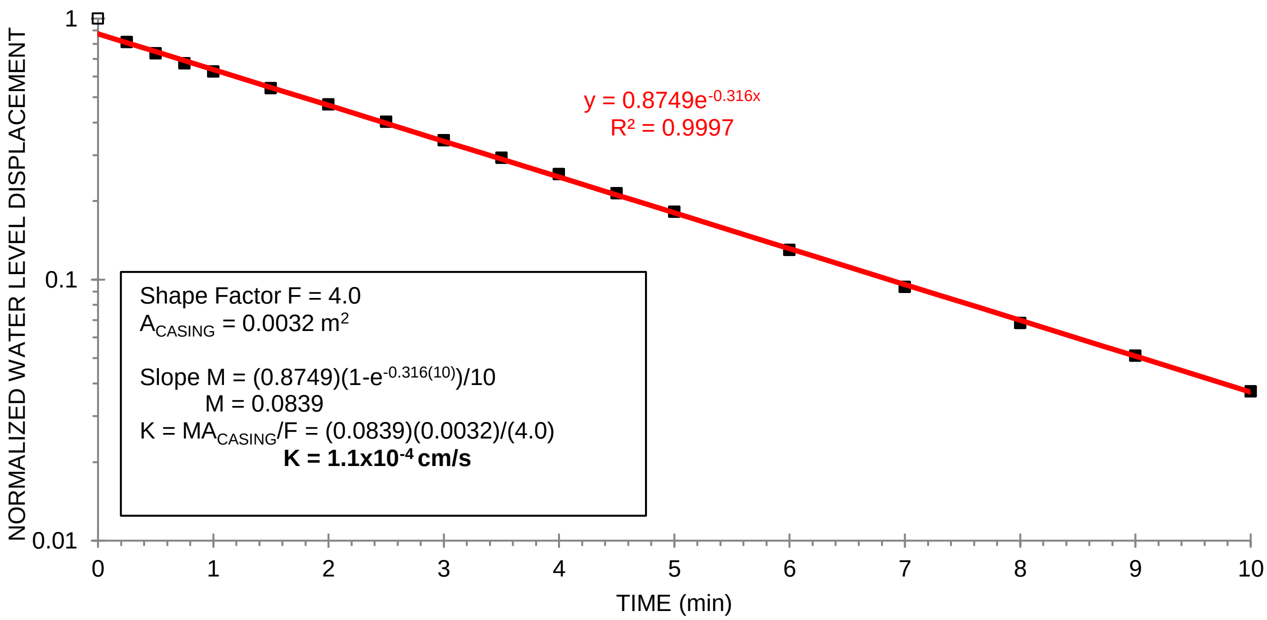


Figure 1-10-4

MW16-10 (16.8m - 19.9m)

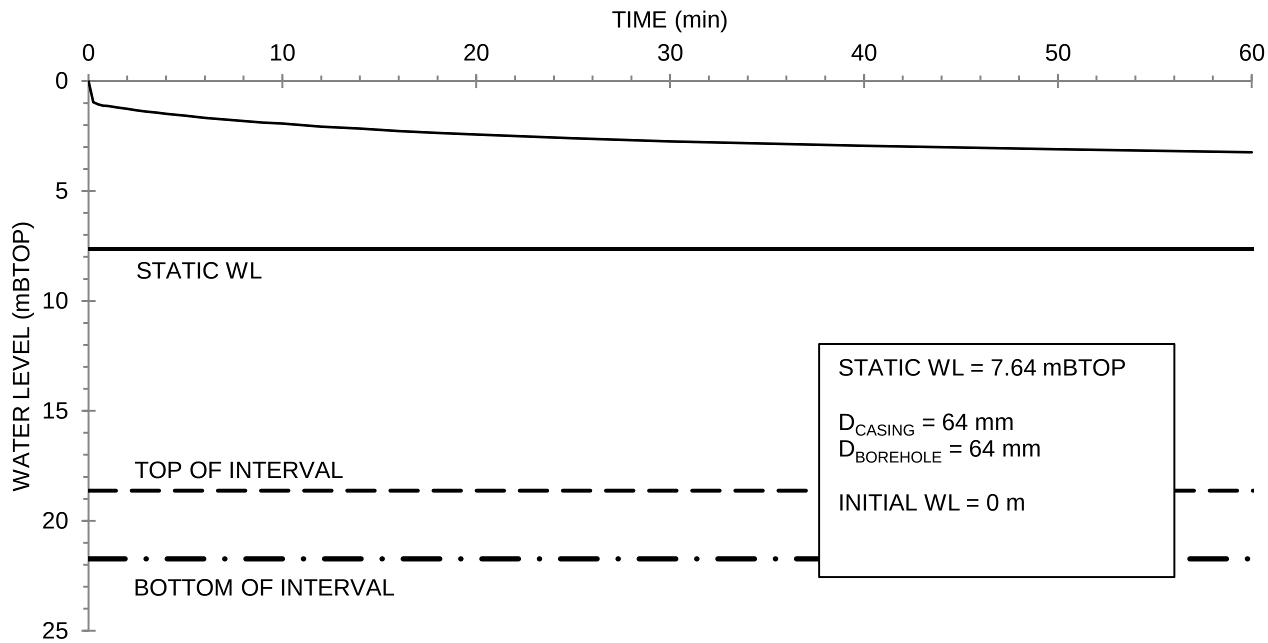
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 24-28, 2016

Performed by: SK



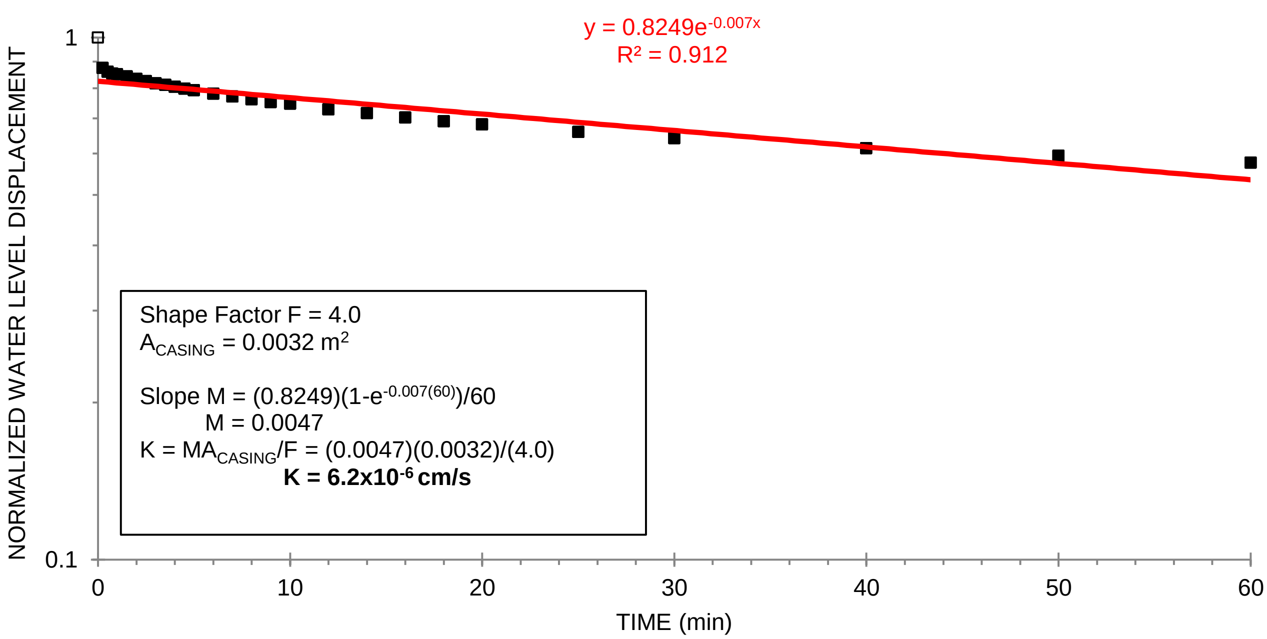


Figure 1-10-5

MW16-10 (19.9m - 23.0m)

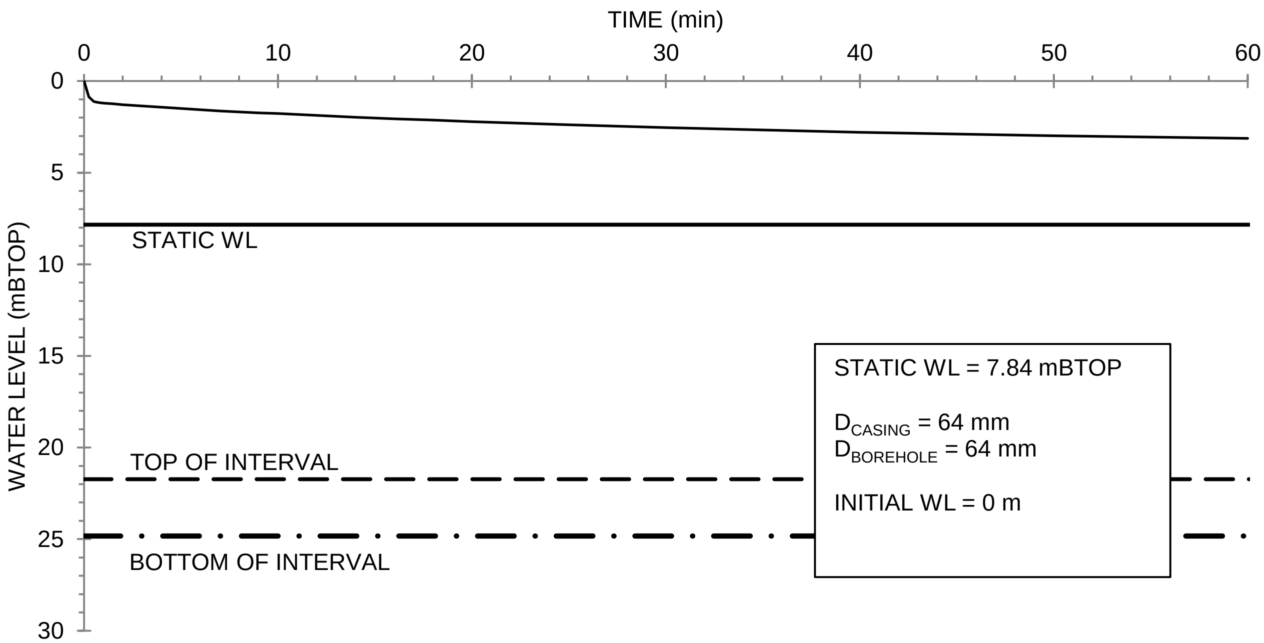
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 24-28, 2016

Performed by: SK



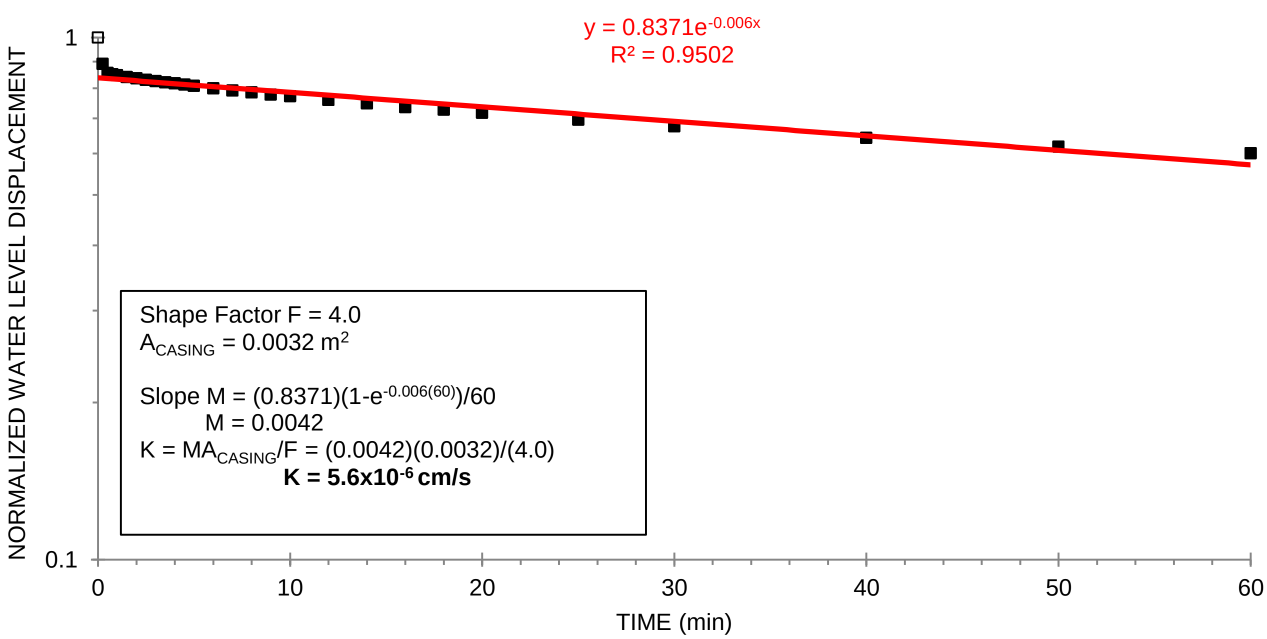


Figure 1-10-6

MW16-10 (23.0m - 26.0m)

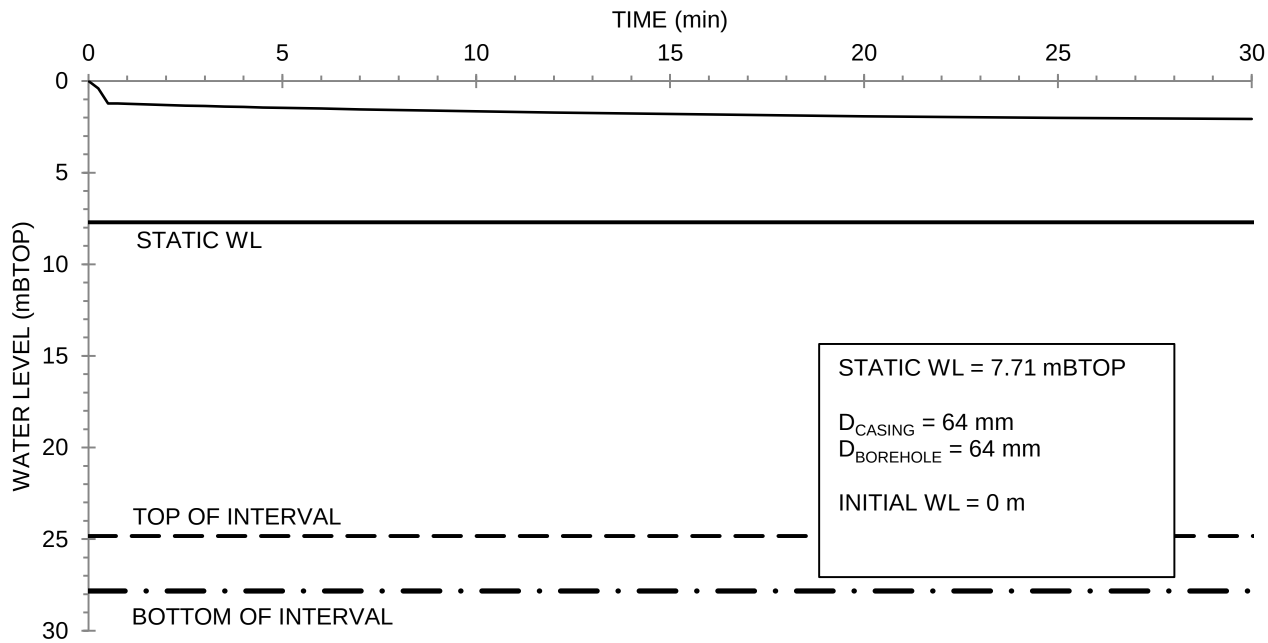
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 24-28, 2016

Performed by: SK



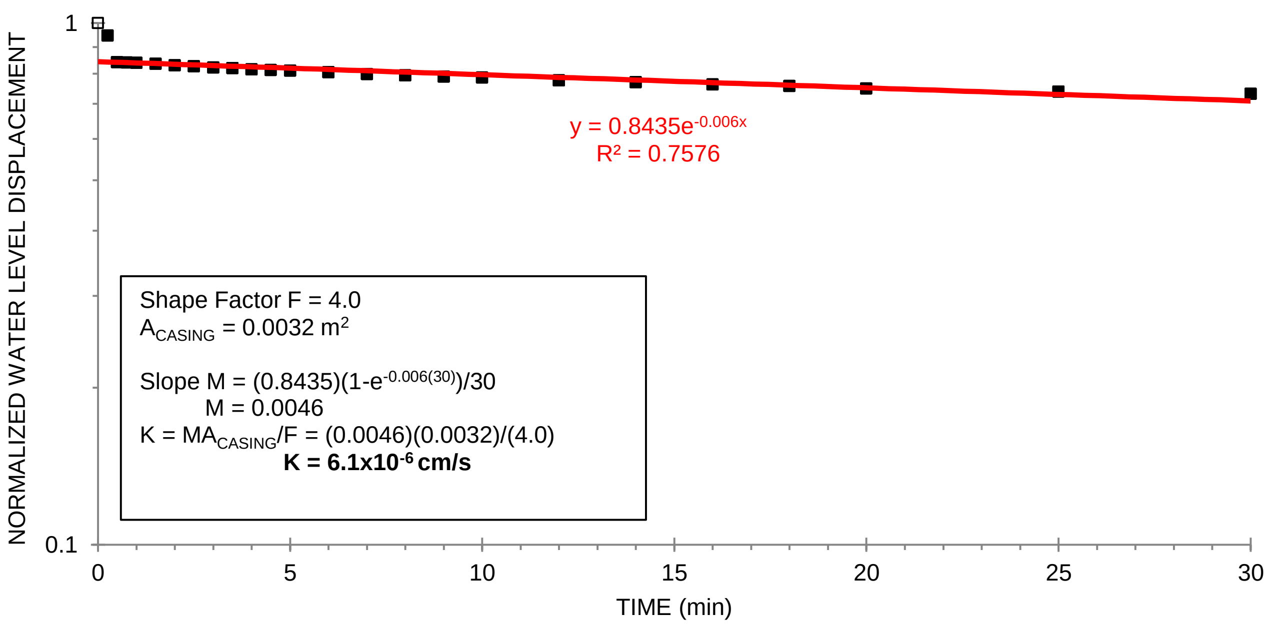


Figure 1-10-7

MW16-10 (26.0m - 29.1m)

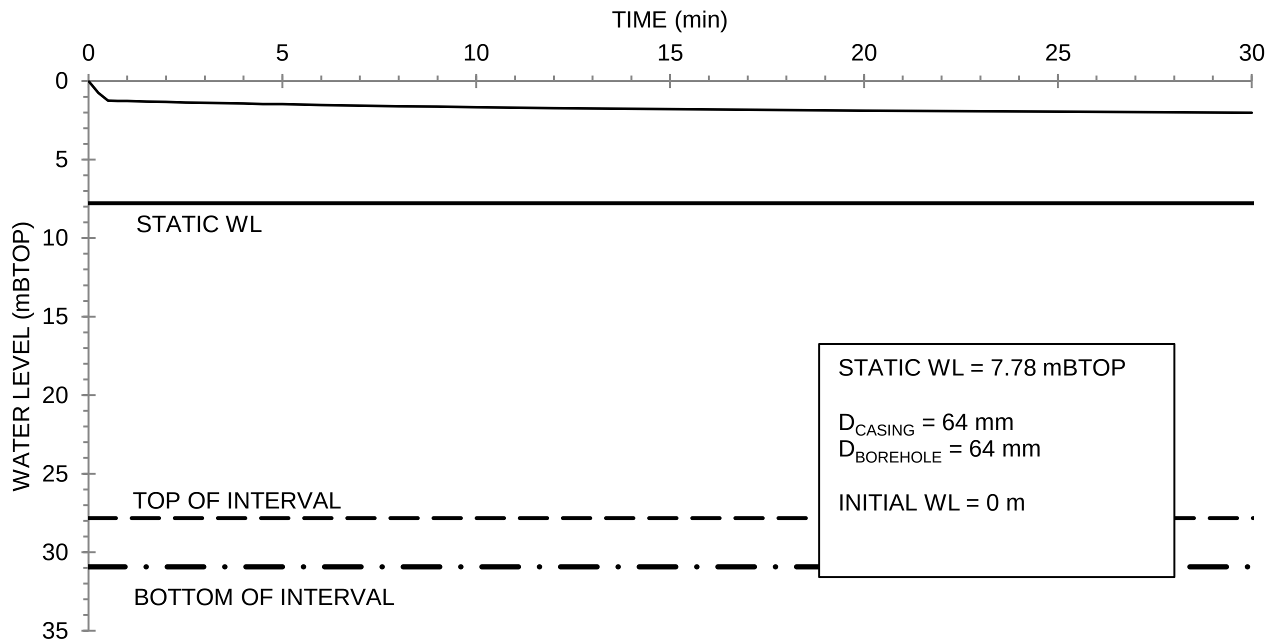
Falling Head Packer Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 24-28, 2016

Performed by: SK



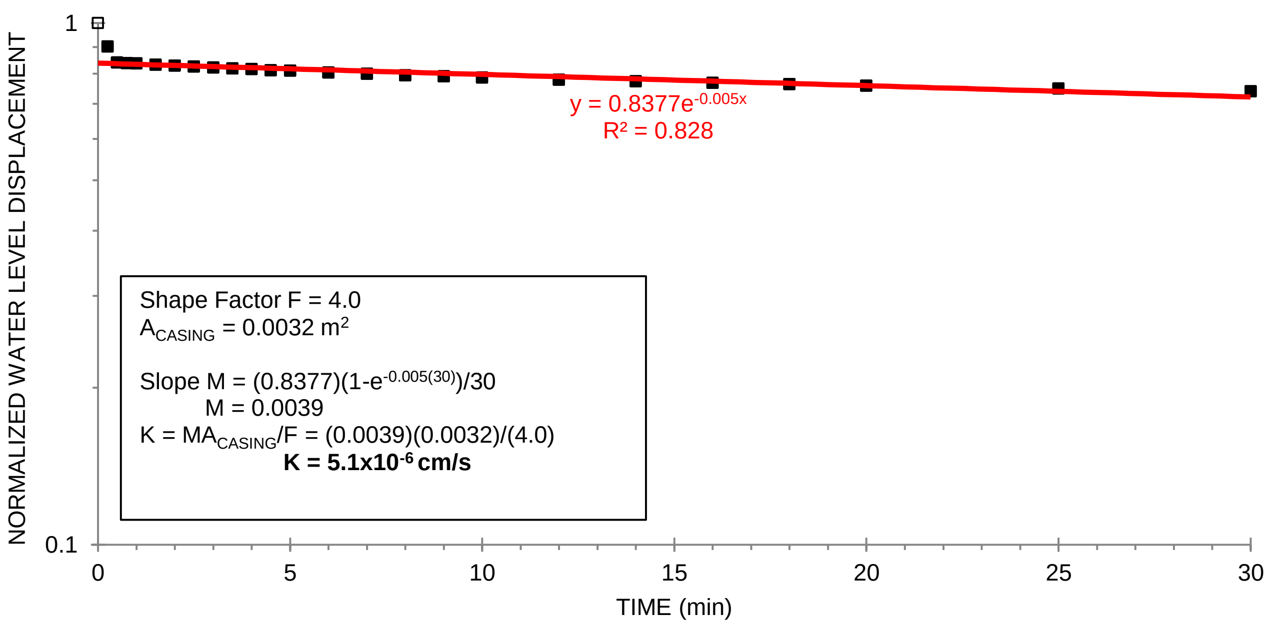


Figure 1-10-8

MW16-10 (29.1m - 32.1m)

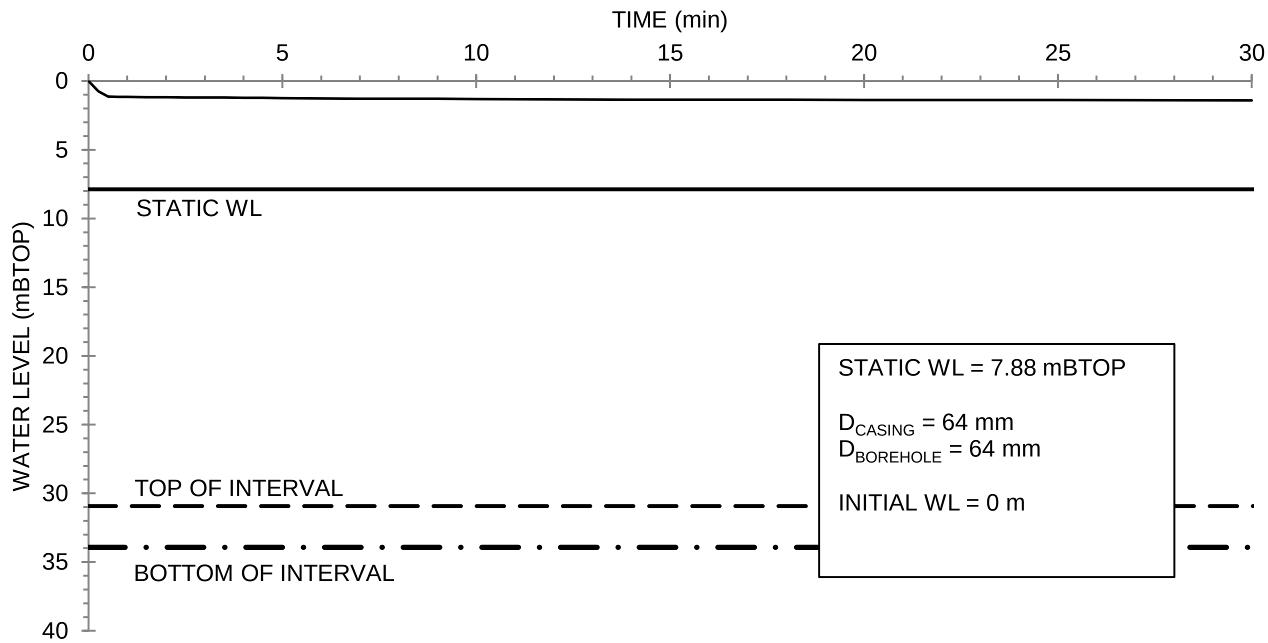
Falling Head Packer Test Analysis

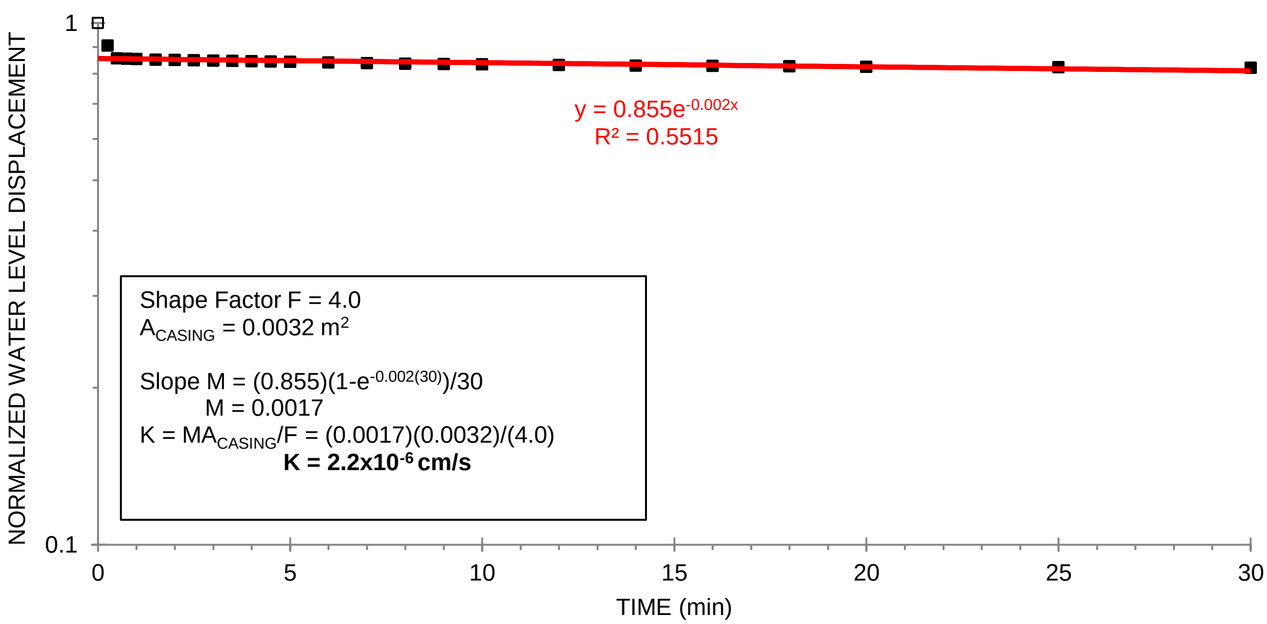
Hvorslev Method

Proposed Upper's Quarry

Date: November 24-28, 2016

Performed by: SK





APPENDIX

D-2 SLUG TEST ANALYSES

Figure 2-1

MW11-1OB

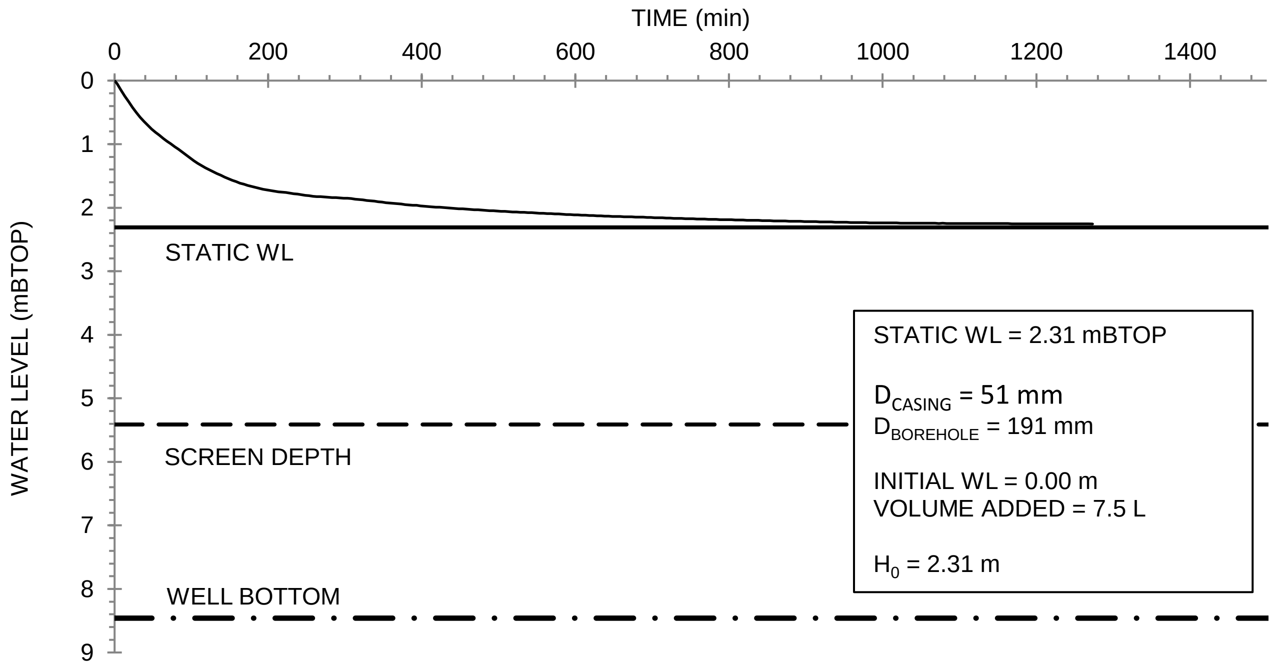
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 1, 2017

Performed by: SM / CS



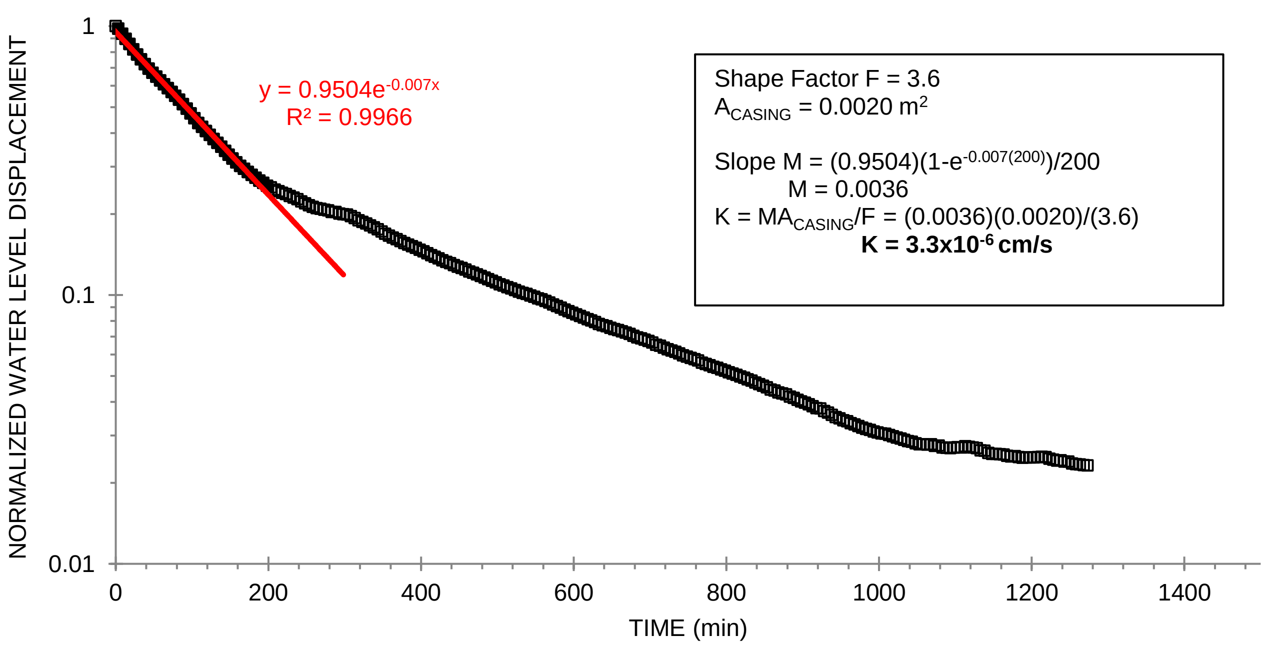


Figure 2-2

MW11-2OB

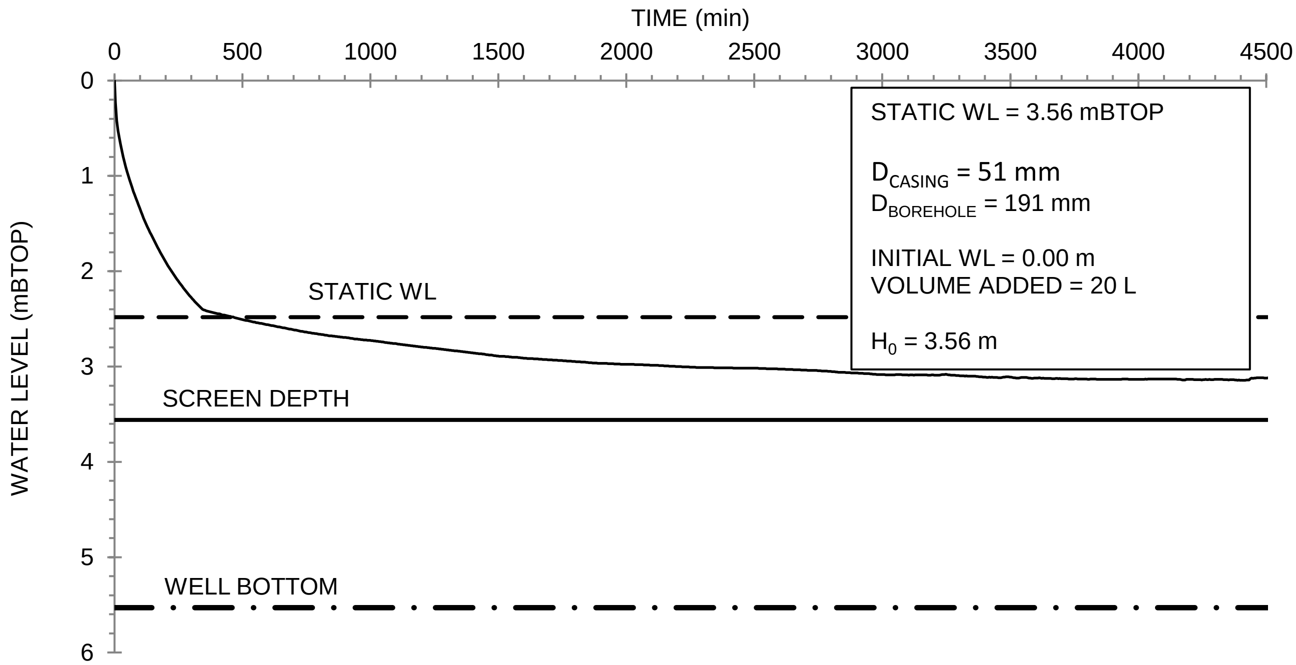
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 1, 2017

Performed by: SM / CS



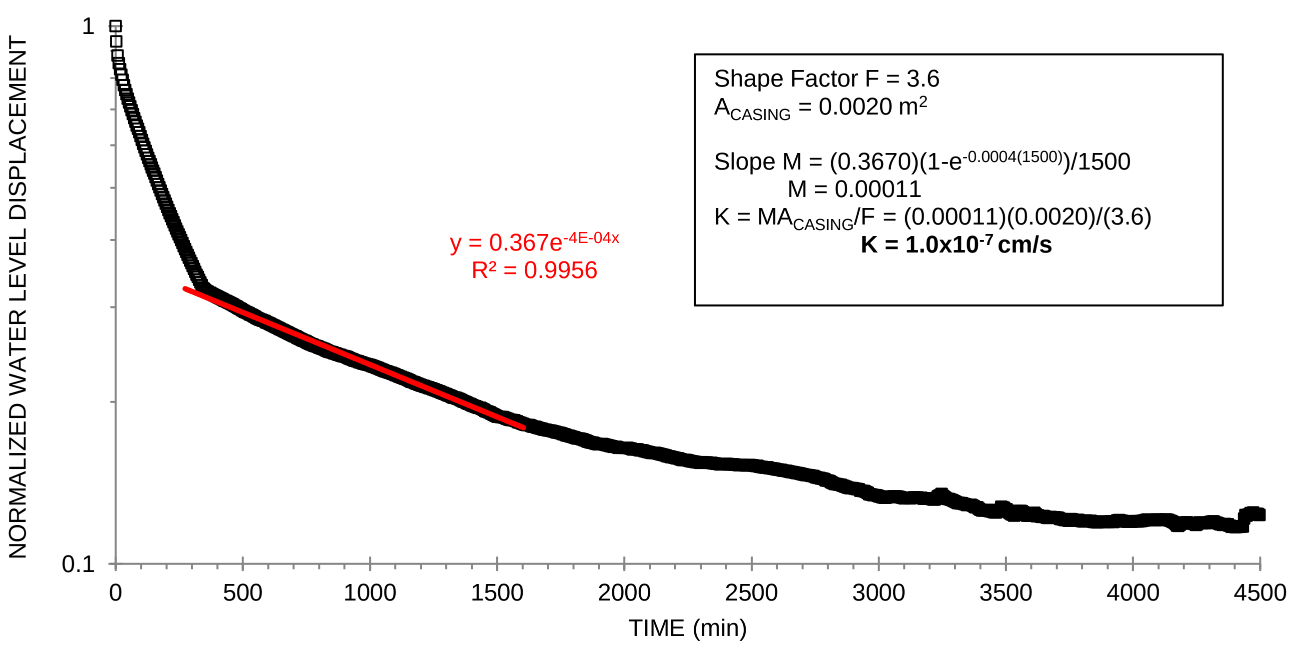


Figure 2-3

MW11-3OBR

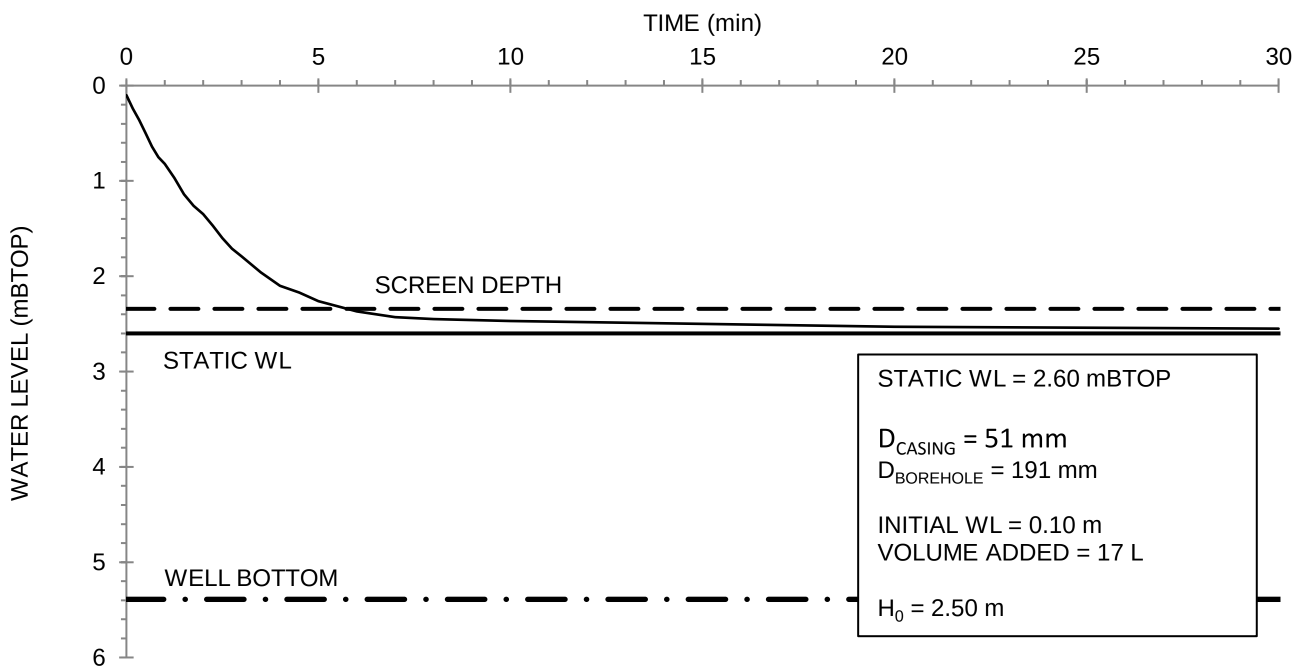
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 1, 2017

Performed by: SM / CS



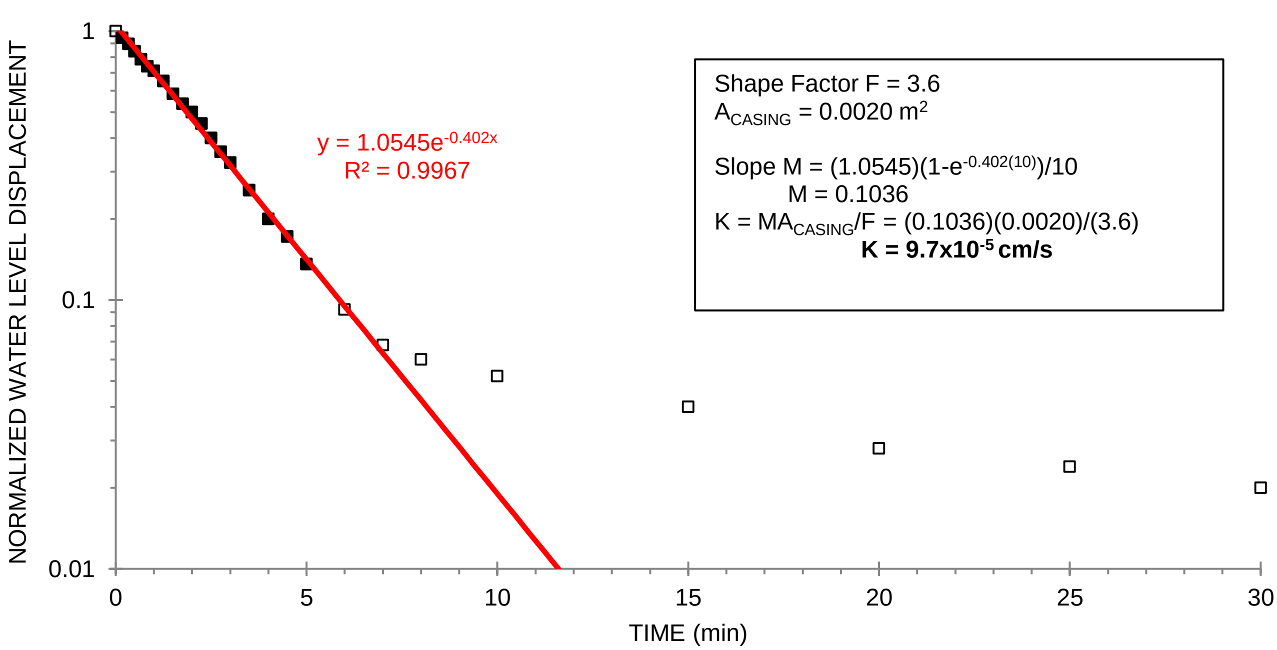


Figure 2-4

MW11-4OB

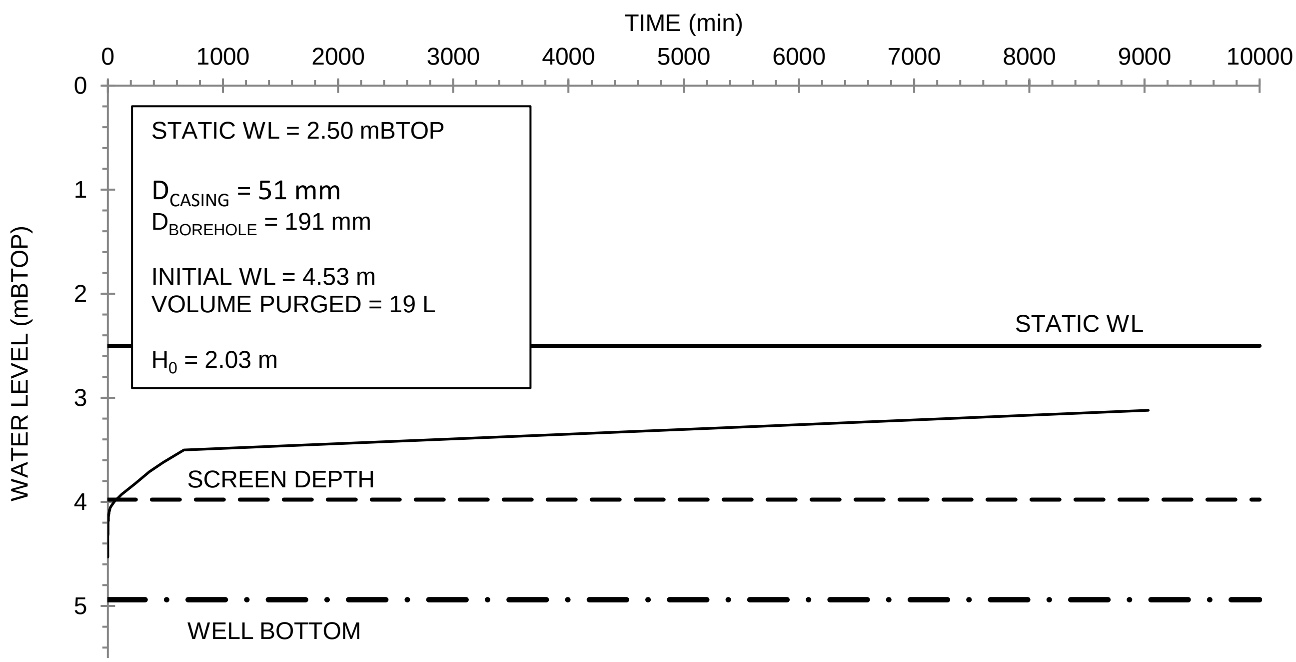
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 11, 2016

Performed by: BC / SM



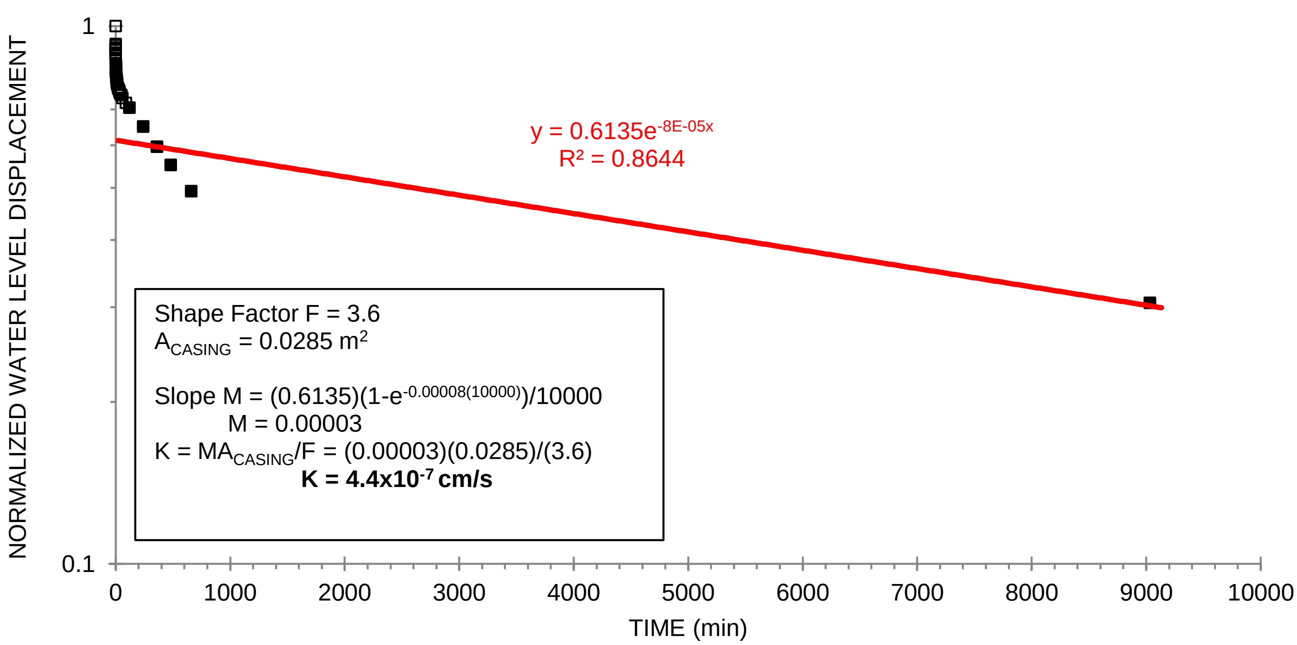


Figure 2-5

MW16-5OB

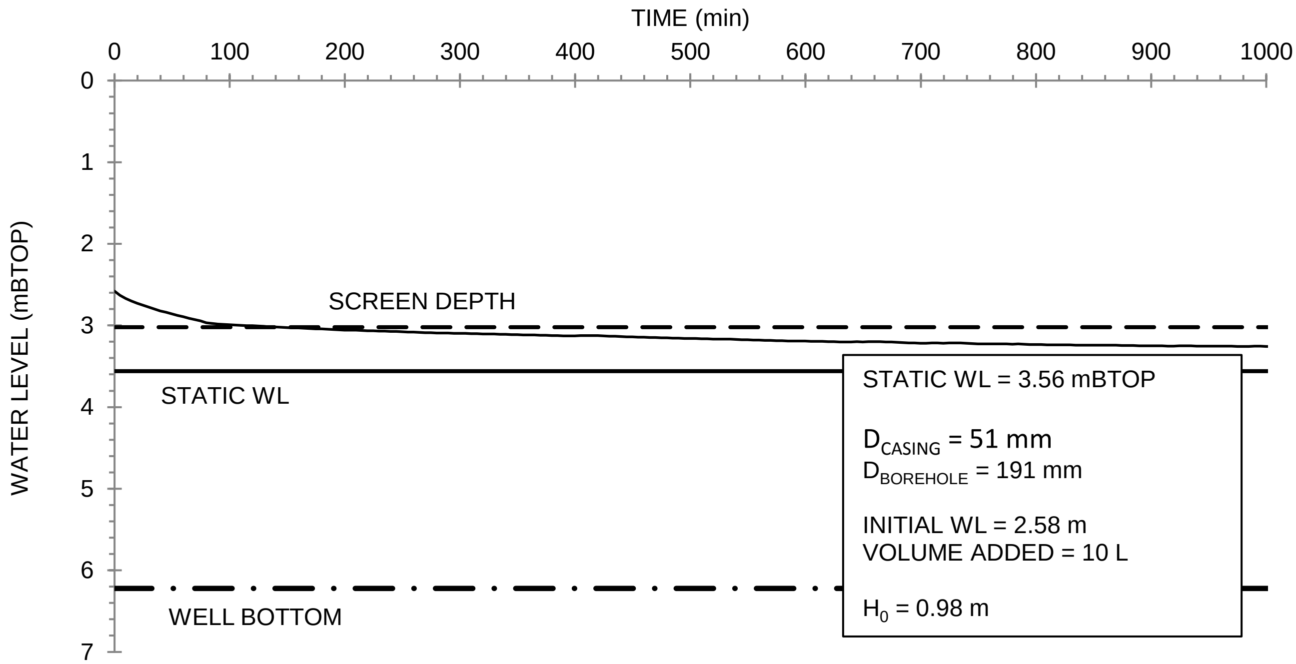
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 3, 2017

Performed by: SM / CS



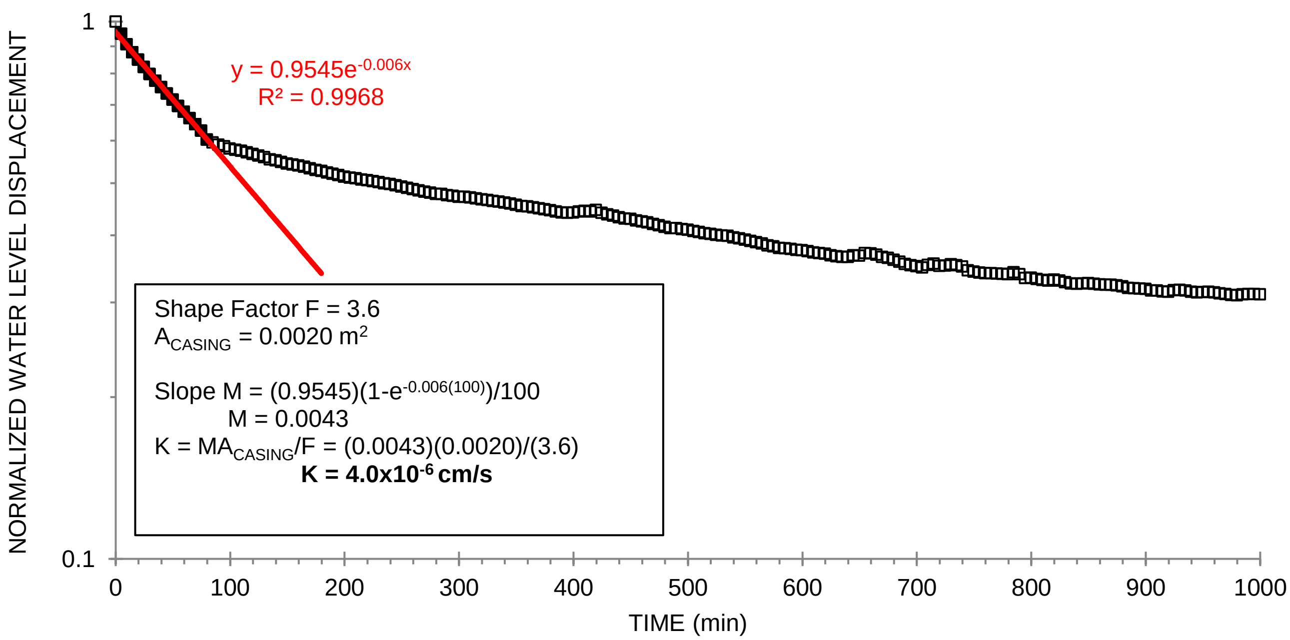


Figure 2-6

MW16-7OB

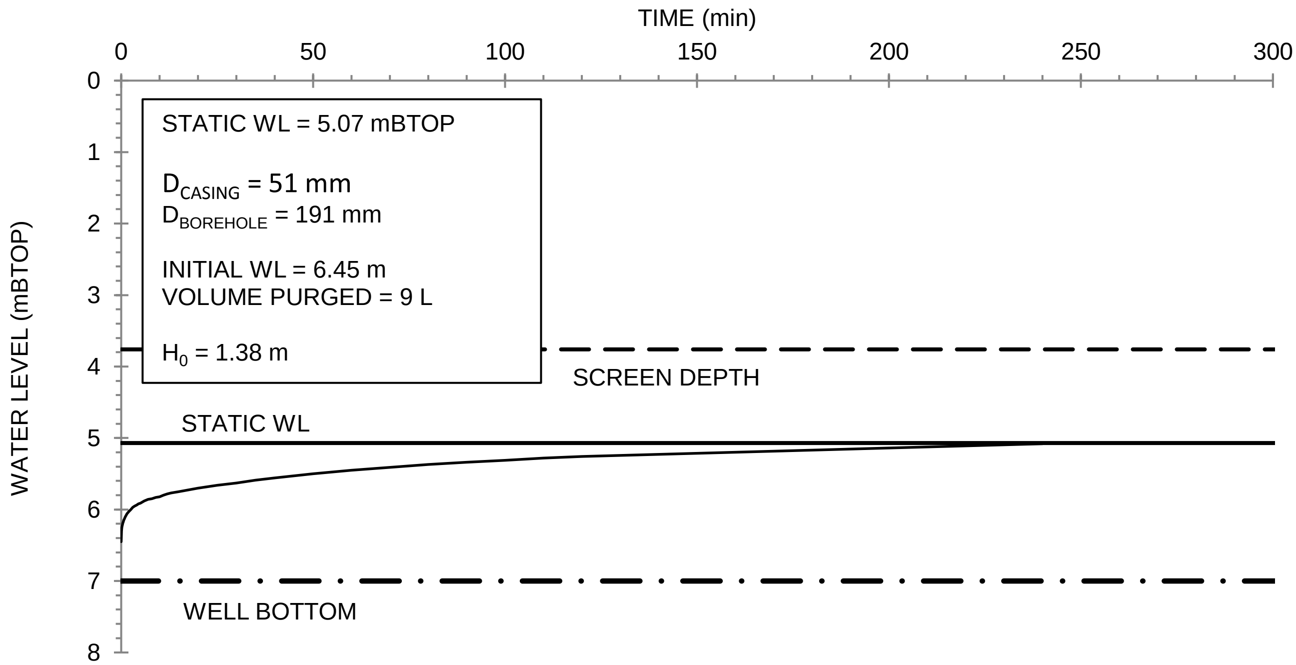
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 8, 2016

Performed by: BC / SM



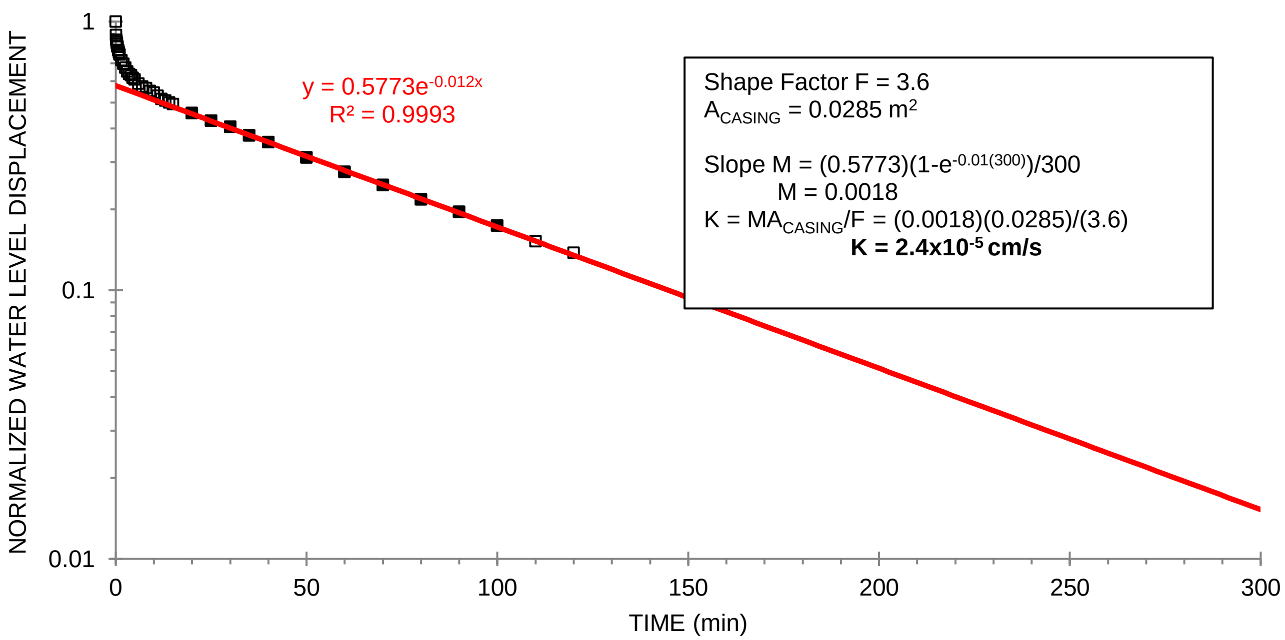
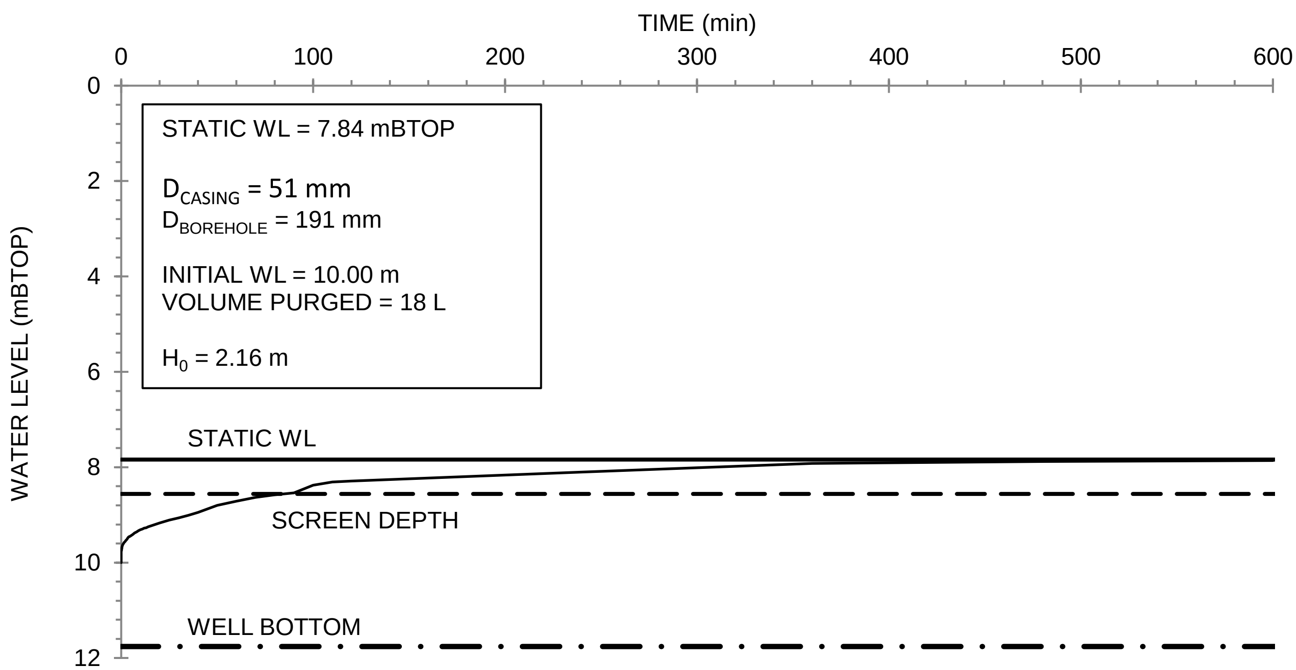


Figure 2-7 **MW16-8OB** Rising Head Slug Test Analysis Hvorslev Method Proposed Upper's Quarry	wsp Date: November 8, 2016 Performed by: BC / SM



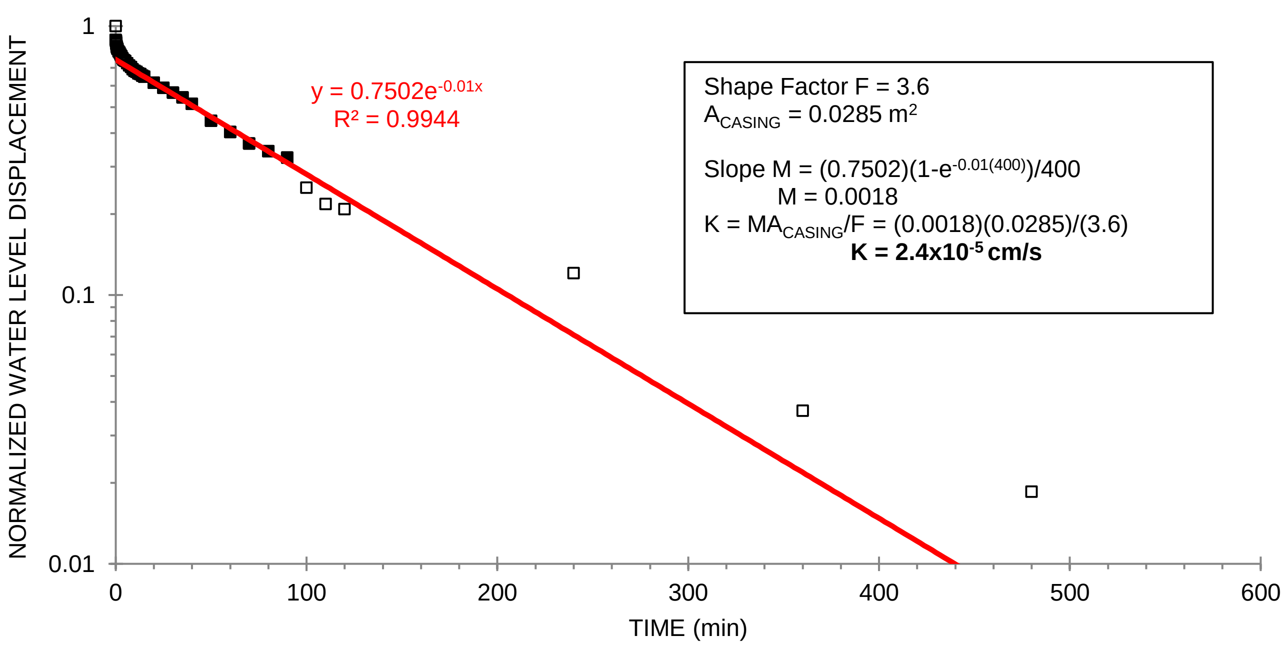


Figure 2-8

MW16-9OB

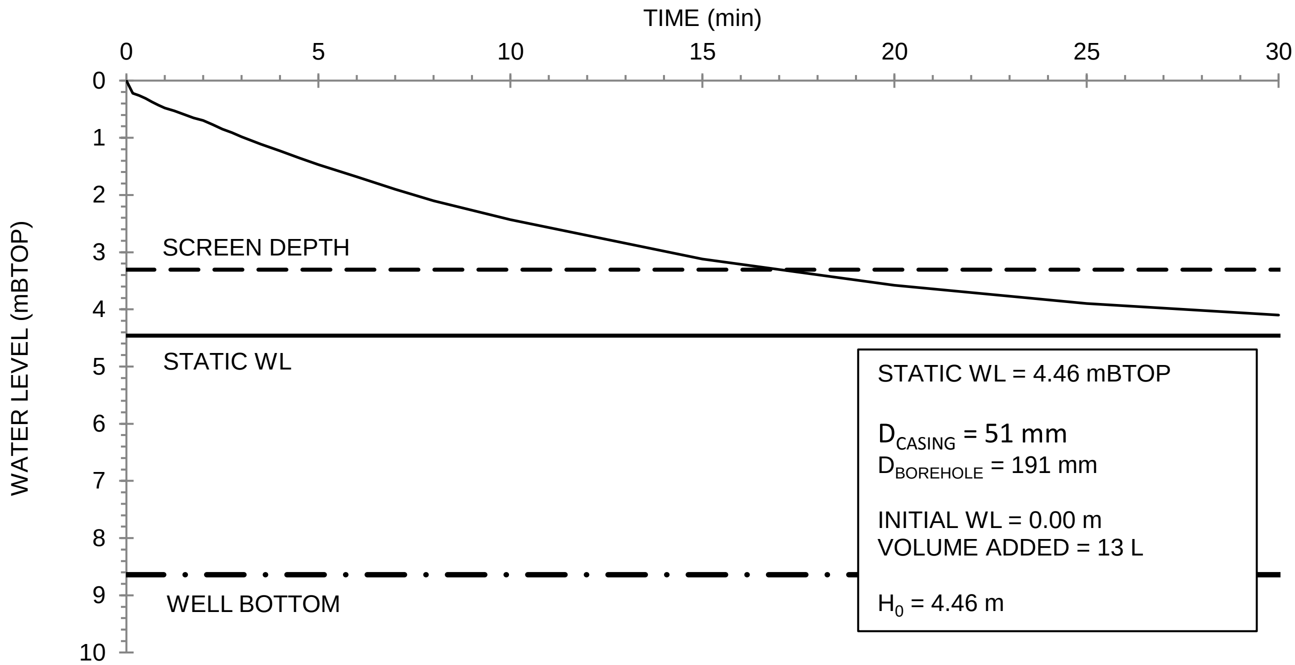
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 2, 2017

Performed by: SM / CS



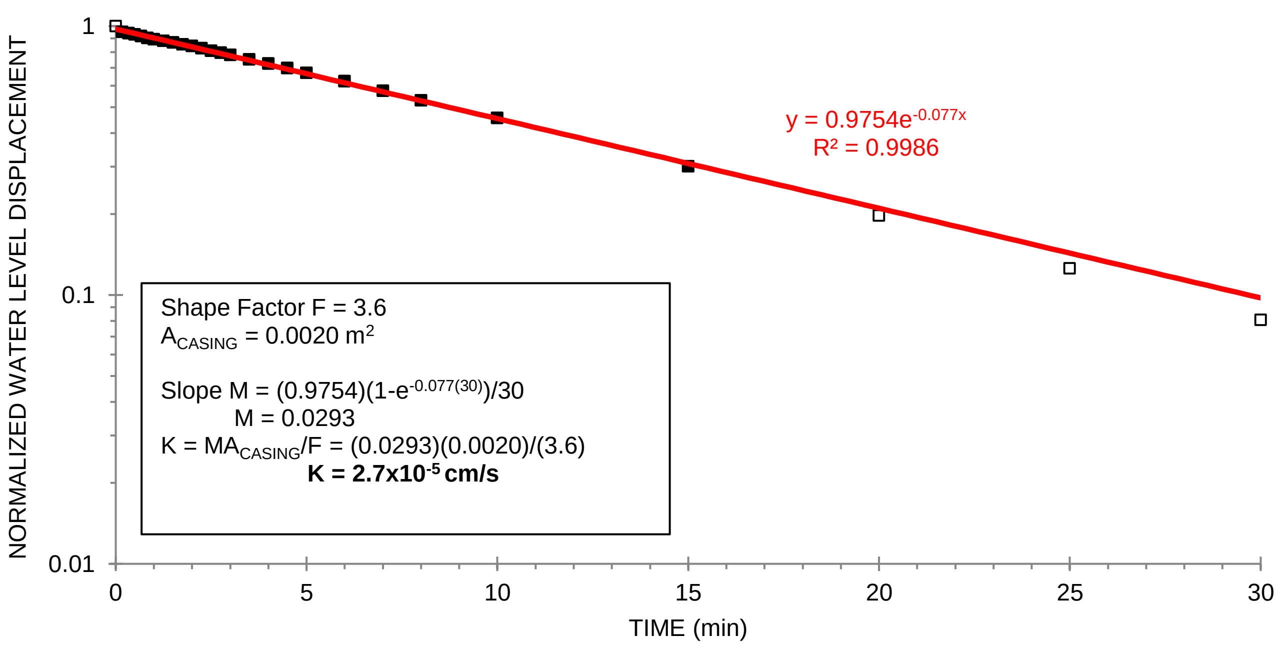


Figure 2-9

MW16-9SP

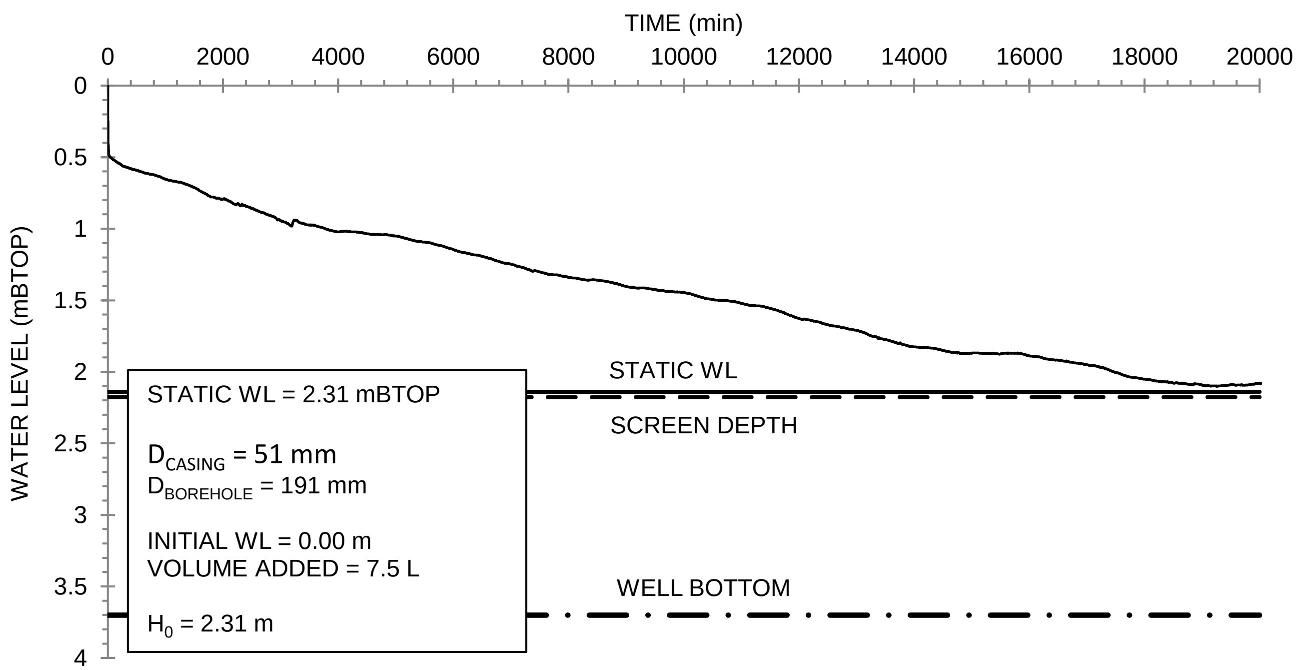
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 2, 2017

Performed by: SM / CS



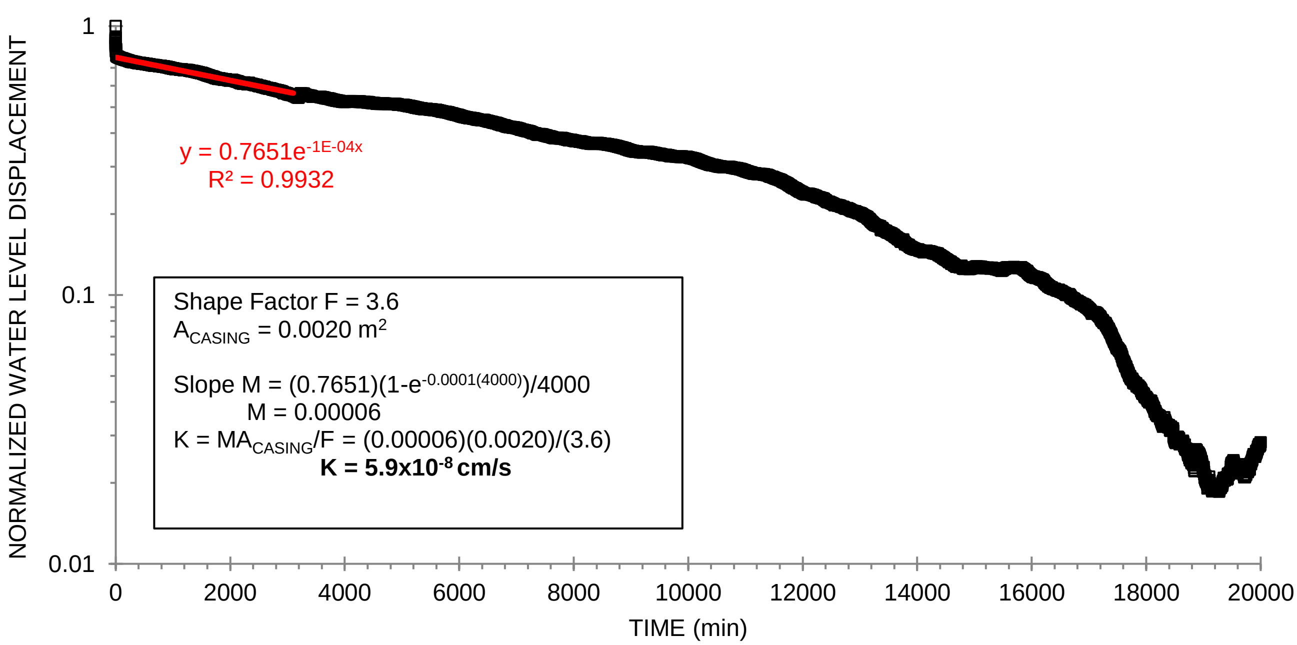


Figure 2-10

MW16-10OB

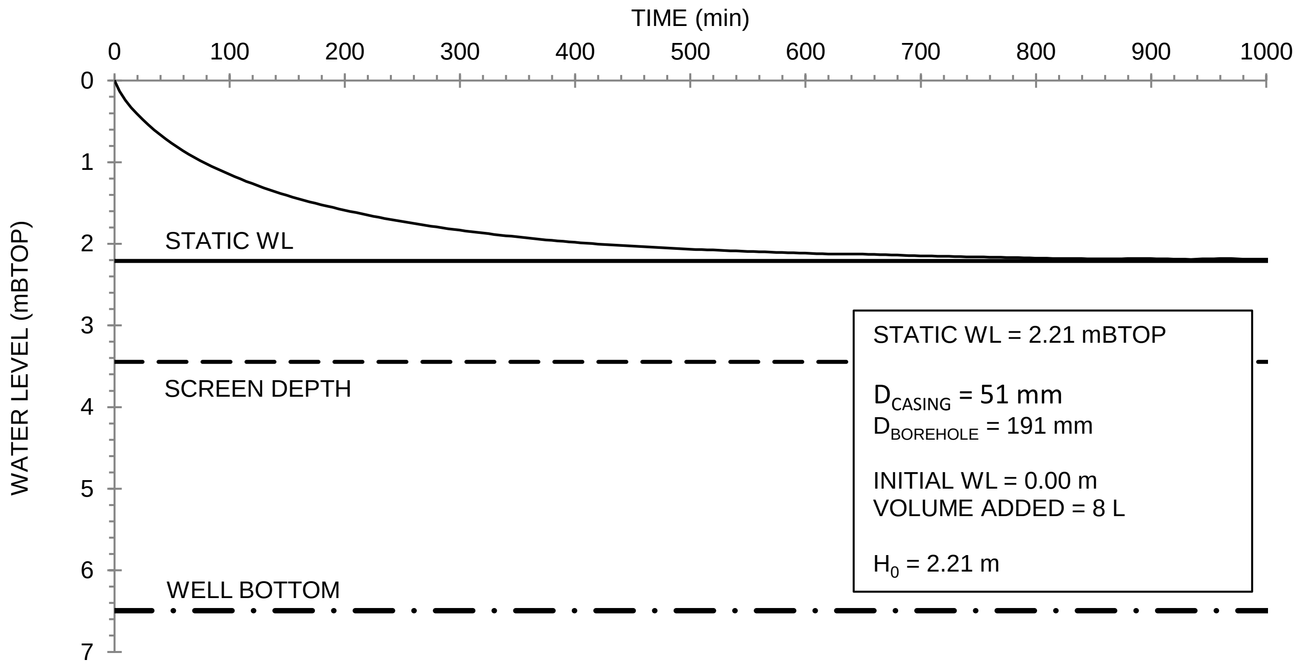
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 3, 2017

Performed by: CS / SV



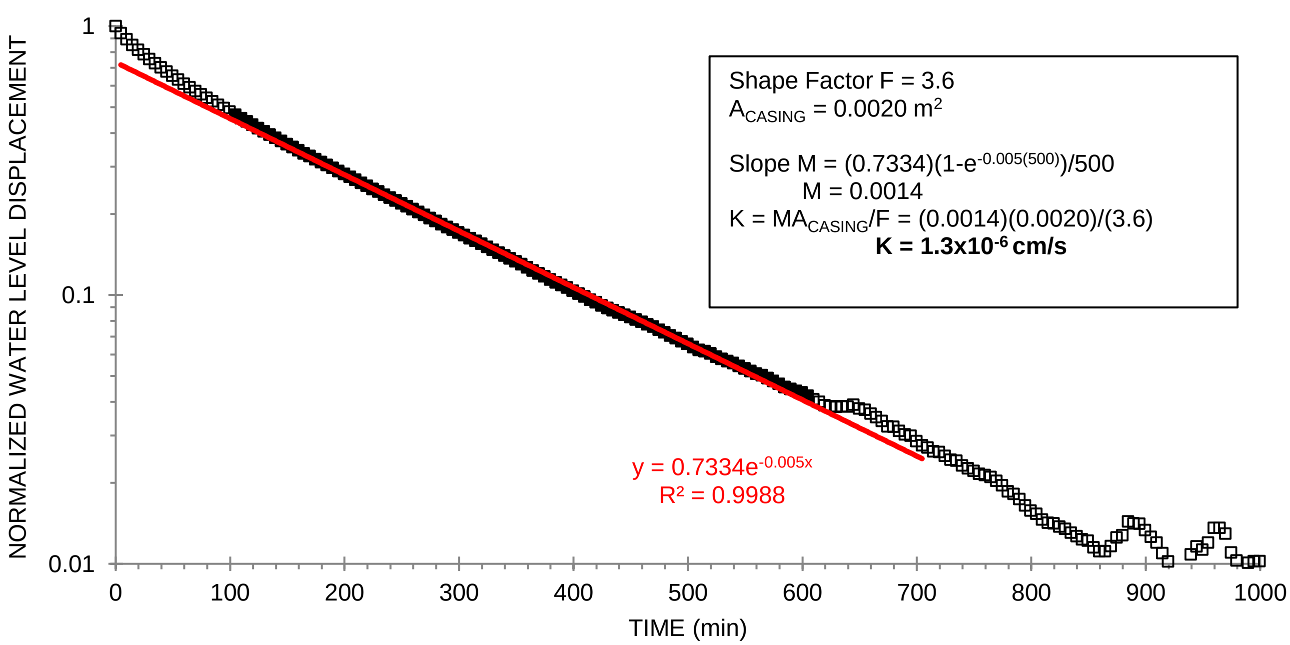


Figure 2-11

MW16-11

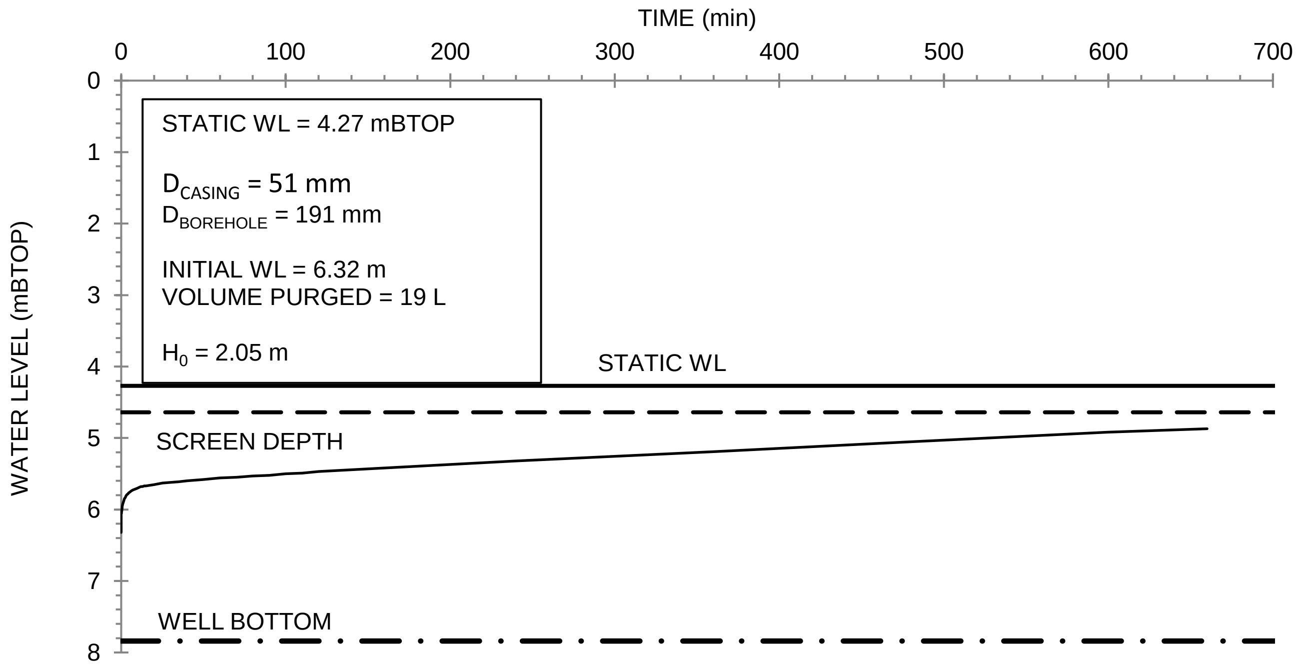
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 10, 2016

Performed by: BC / SM



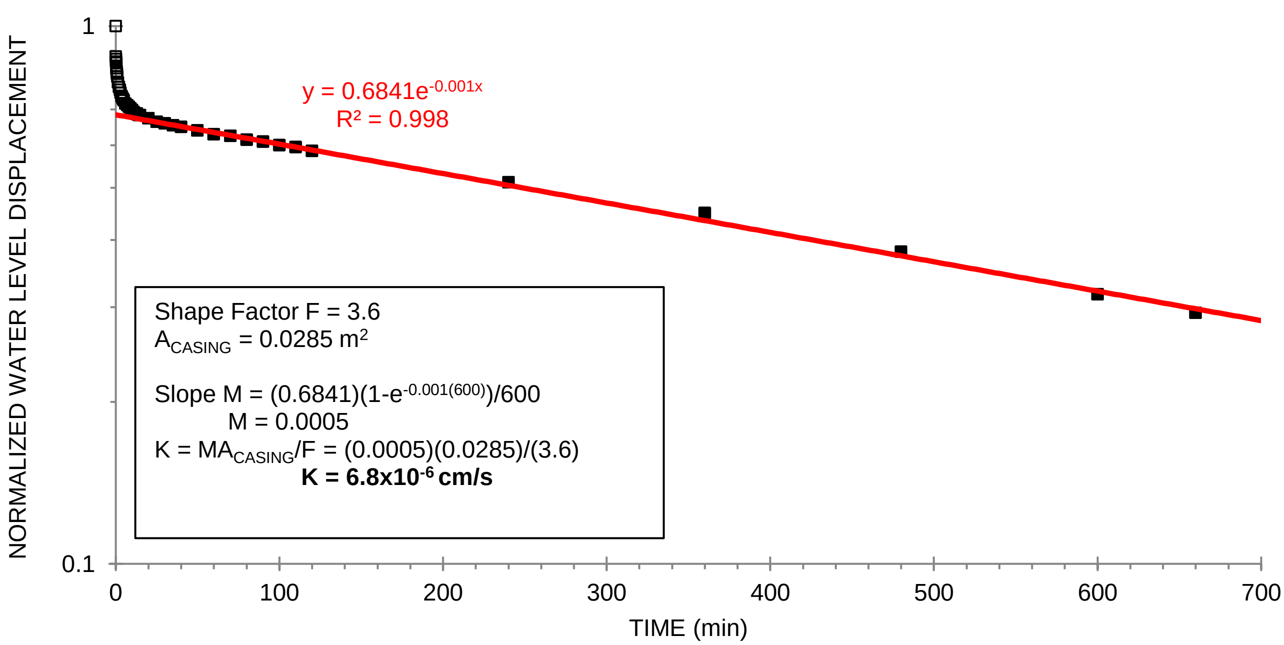


Figure 2-12

MW16-16

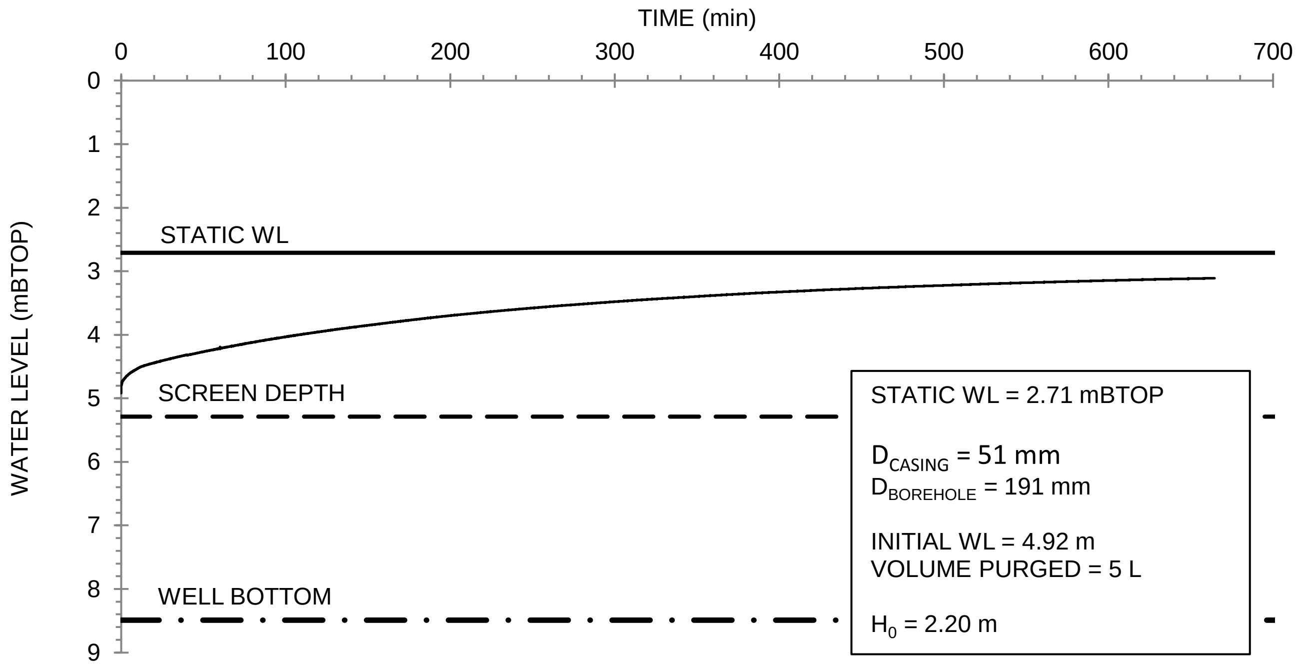
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 8, 2016

Performed by: BC / SM



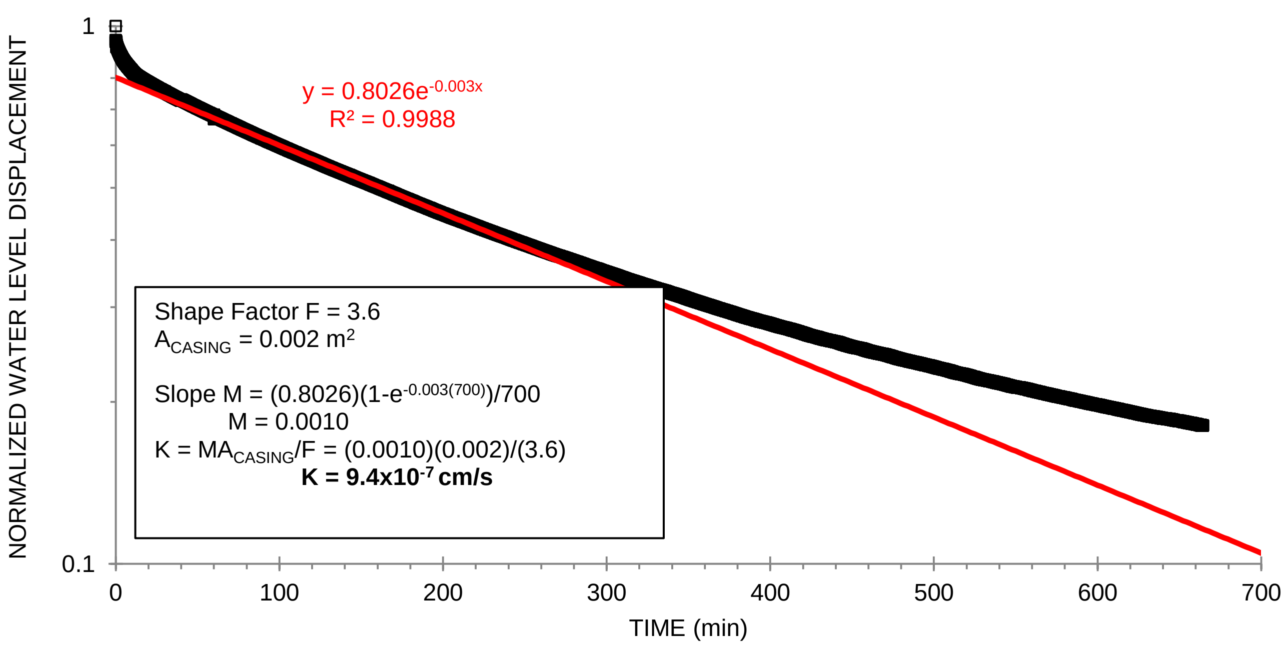


Figure 2-13

MW16-17

Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 21, 2016

Performed by: BC / SM

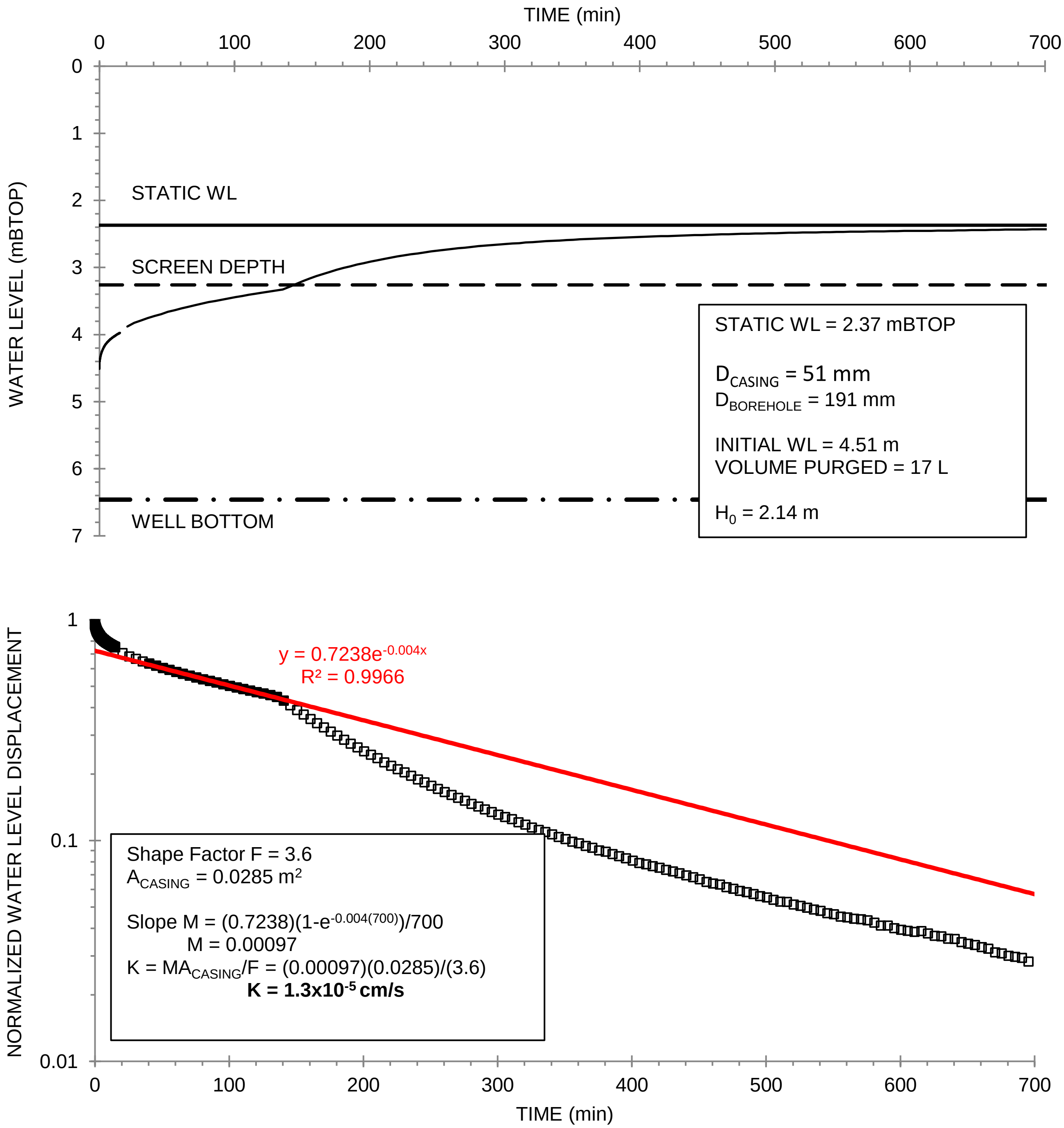


Figure 2-14

MW16-18OB

Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 3, 2017

Performed by: SM / CS

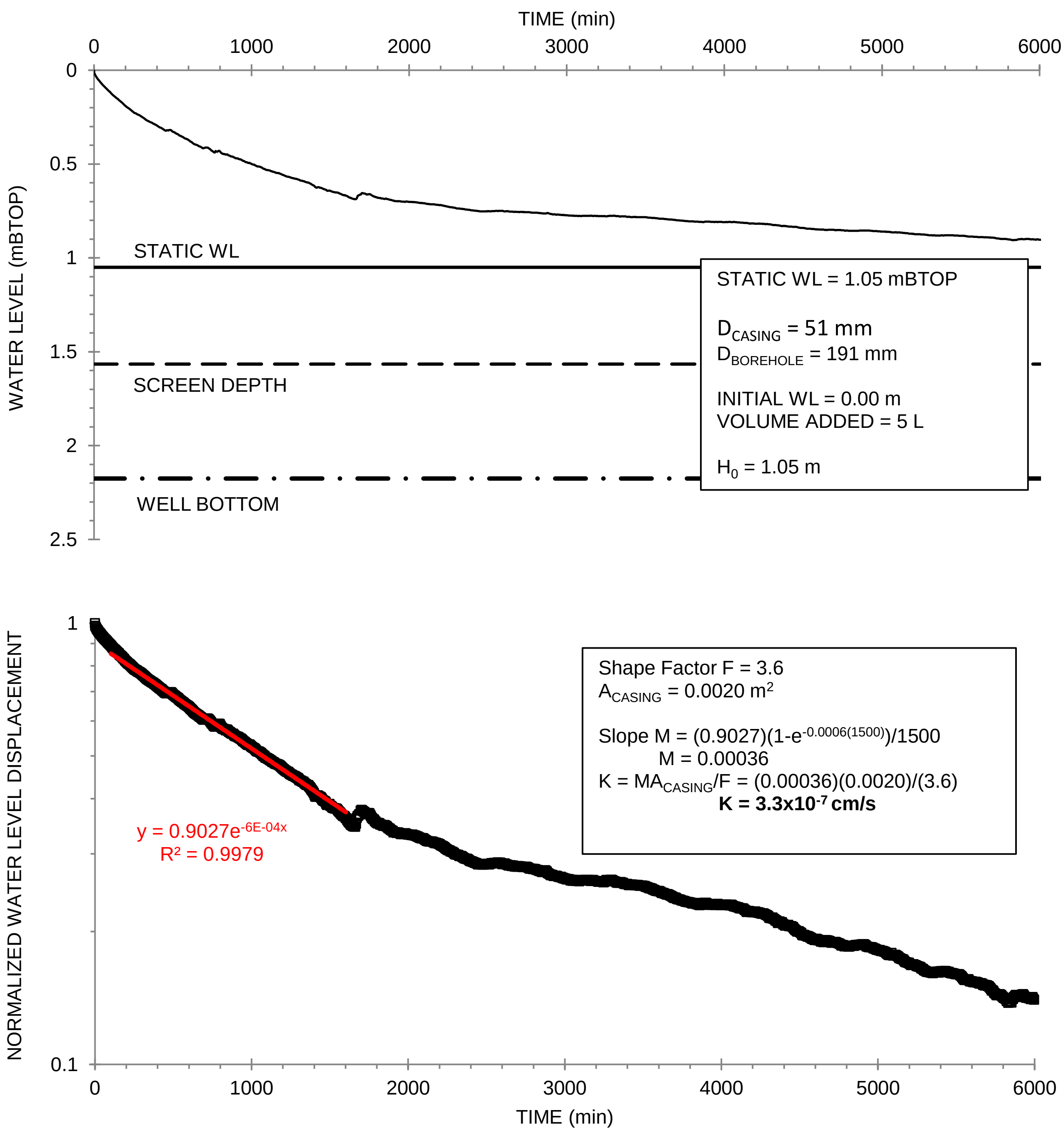


Figure 2-15

MW16-19OB

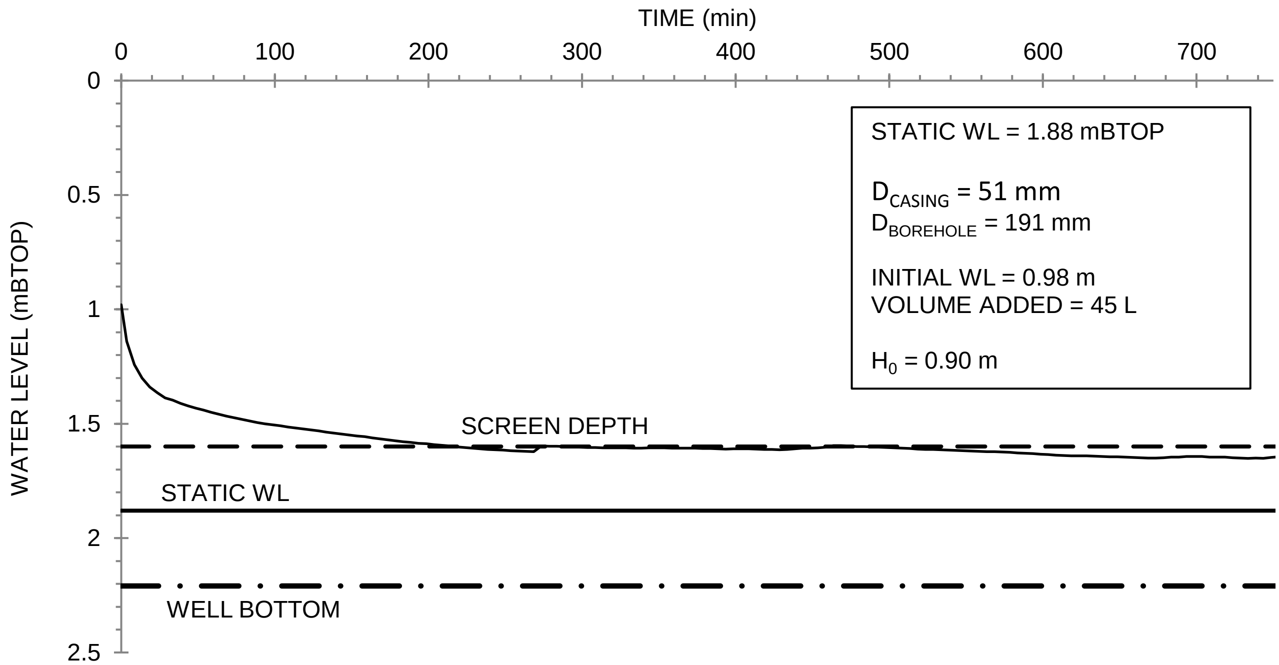
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 3, 2017

Performed by: SM / CS



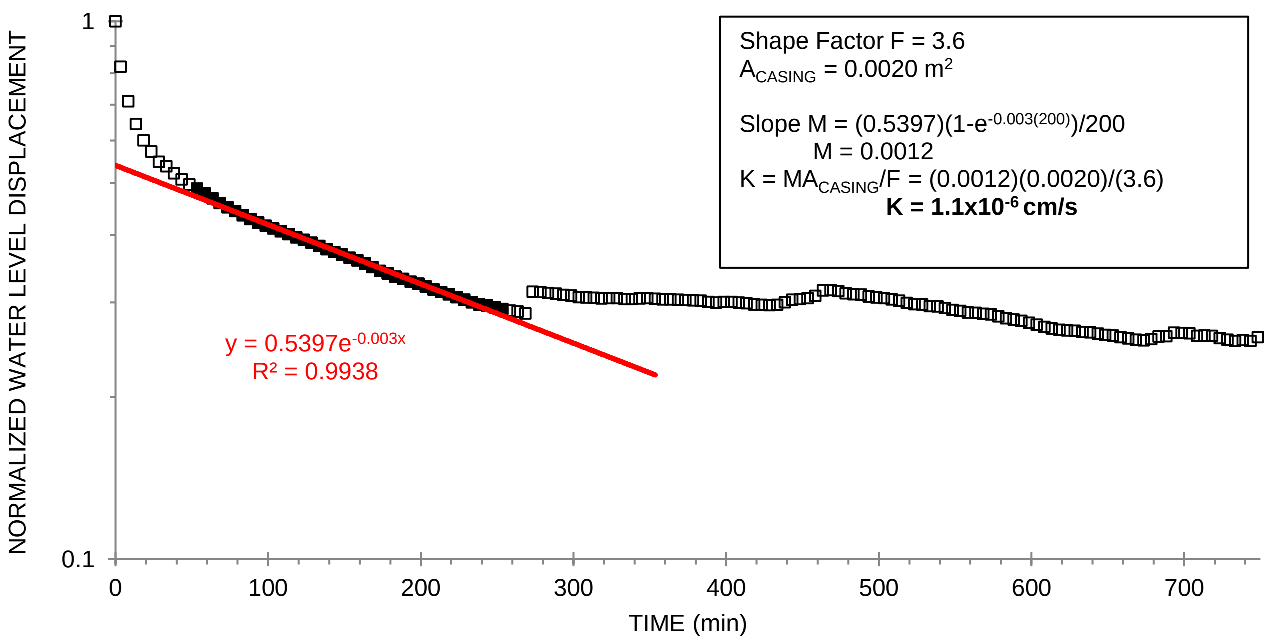


Figure 2-16

MW17-20OB

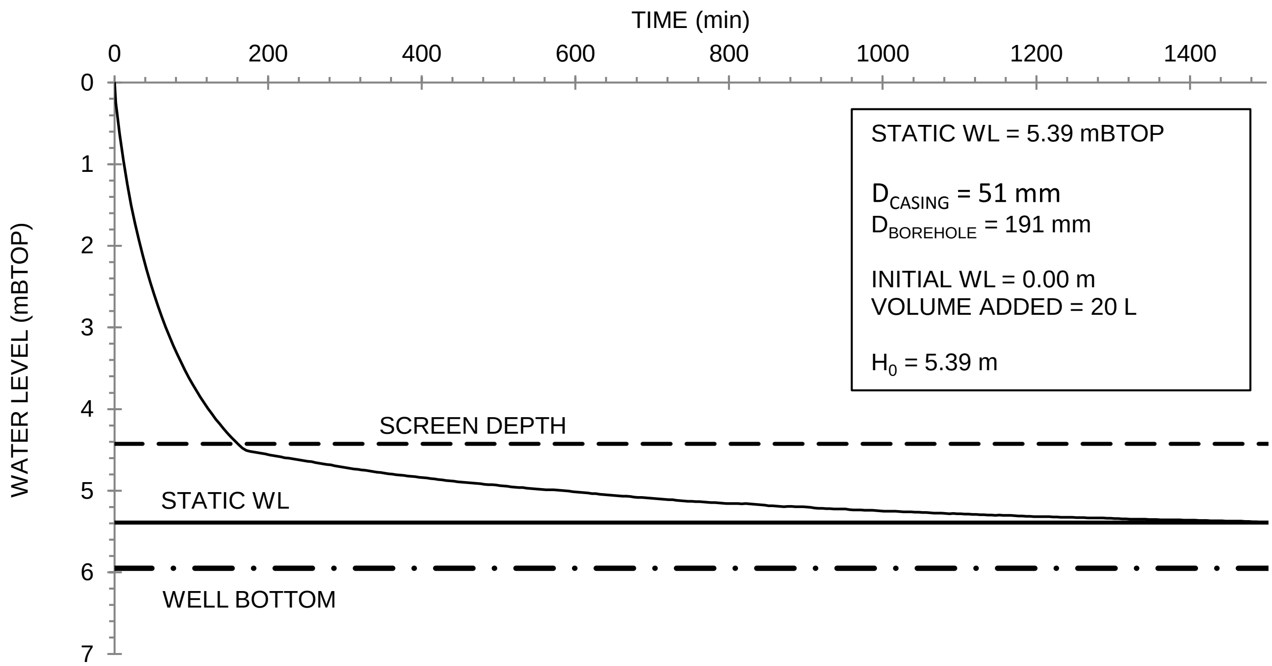
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 3, 2017

Performed by: SM / CS



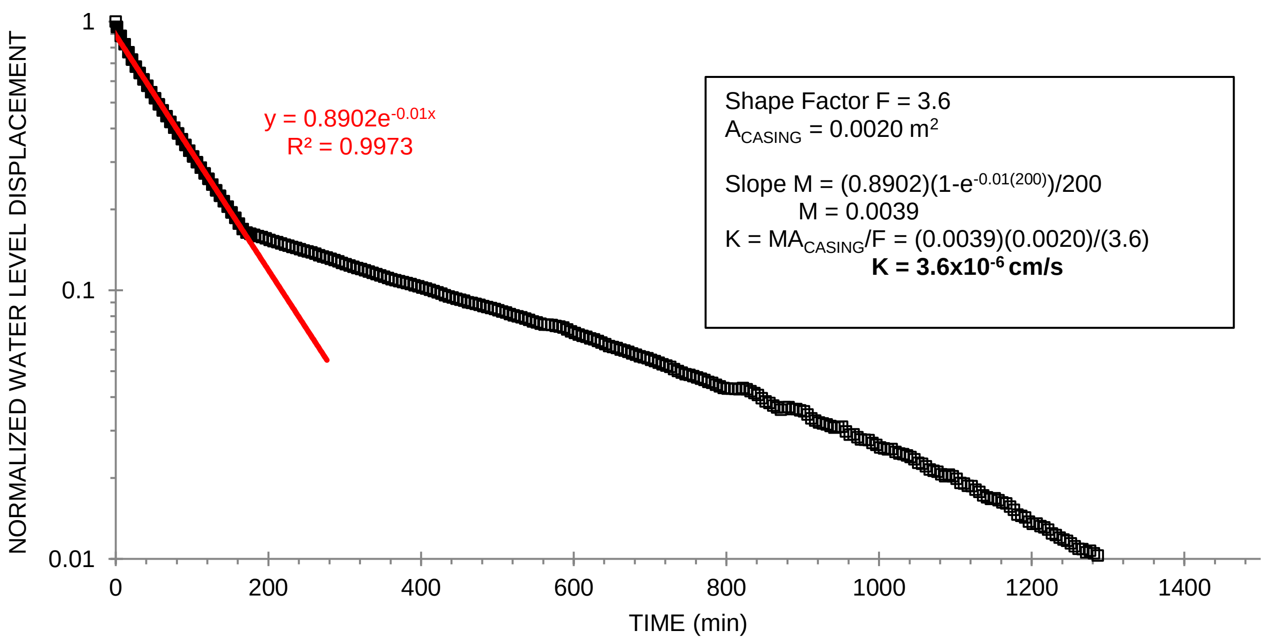


Figure 2-17

MW17-20SP

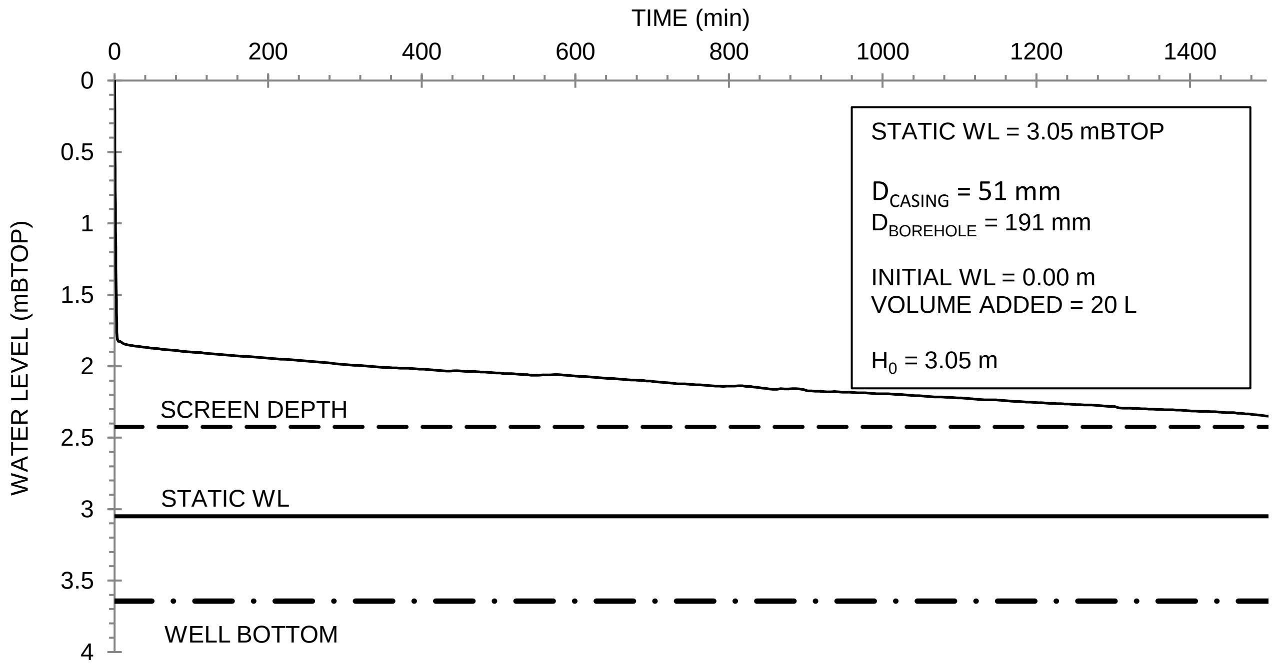
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 3, 2017

Performed by: SM / CS



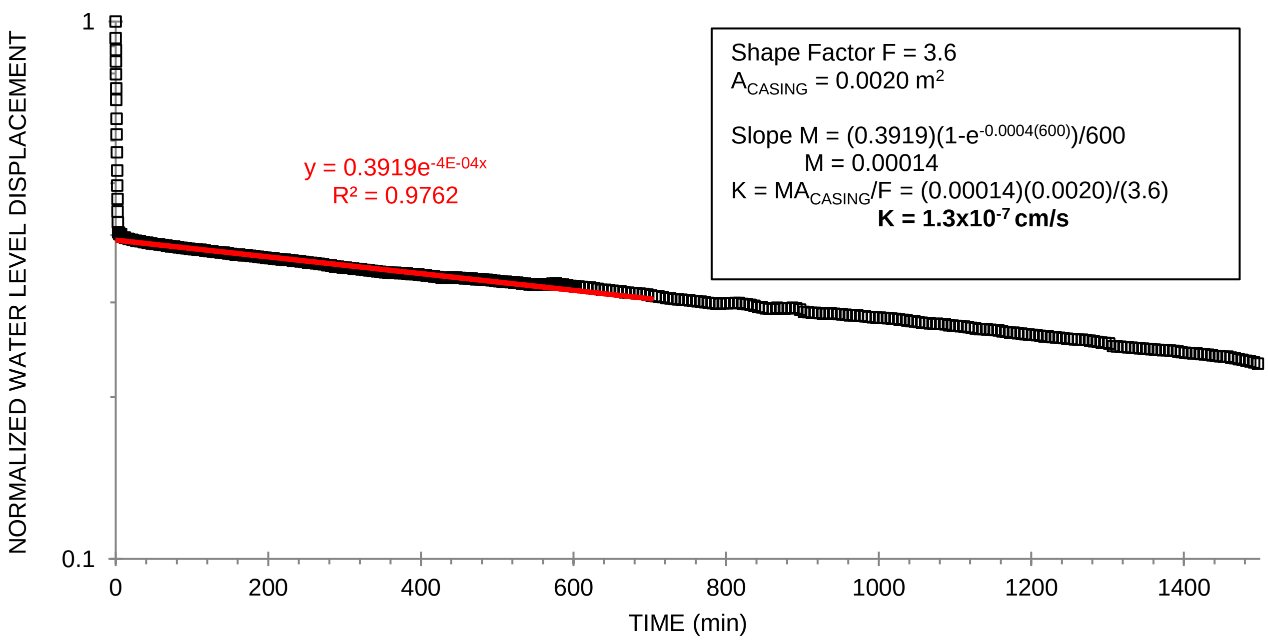


Figure 2-18

MW17-21OB

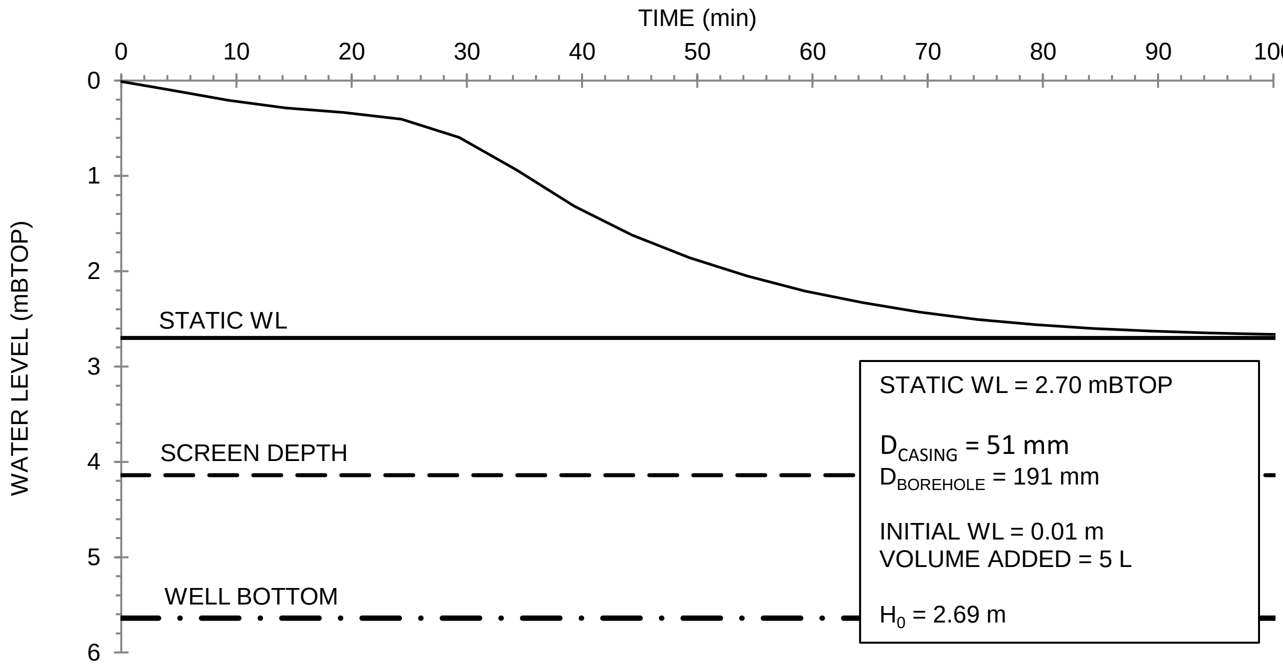
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 1, 2017

Performed by: SM / CS



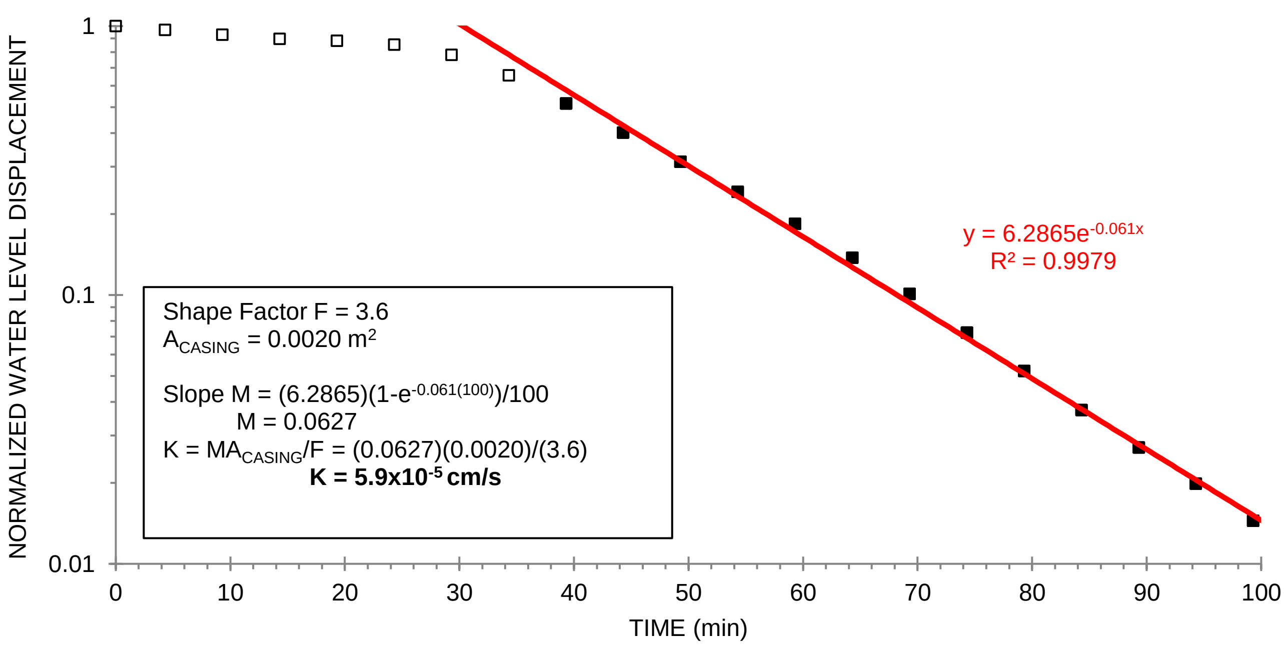


Figure 2-19

MW17-21SP

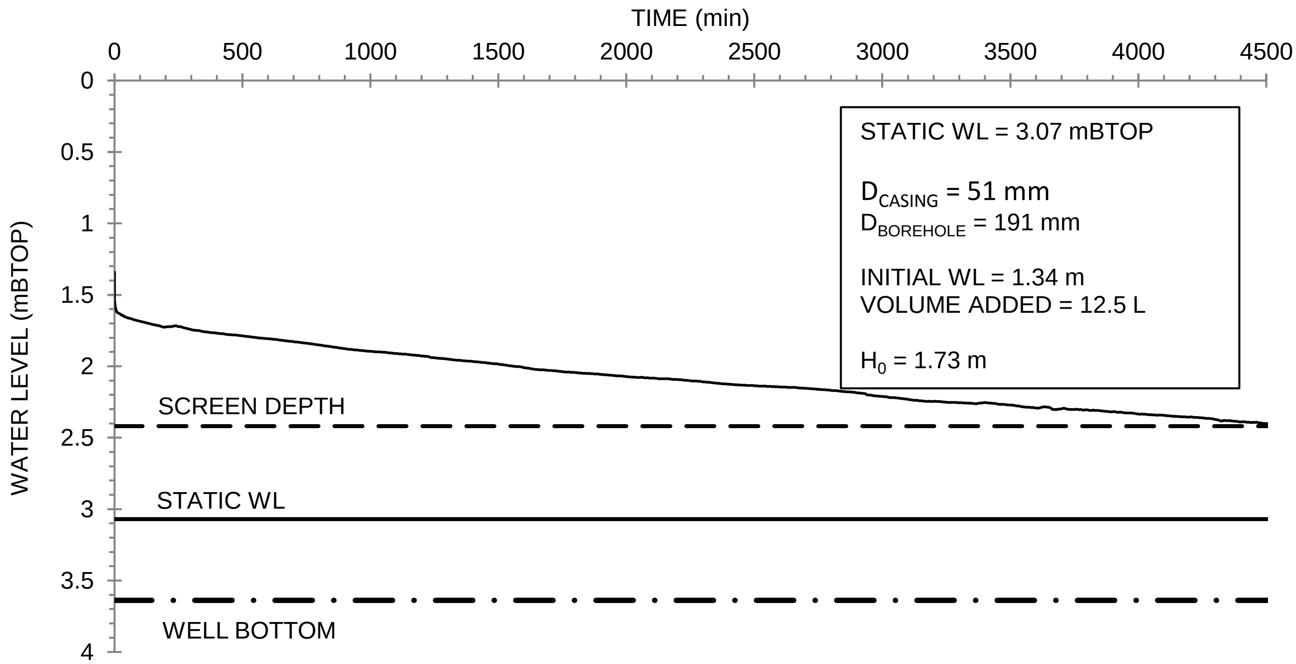
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 1, 2017

Performed by: SM / CS



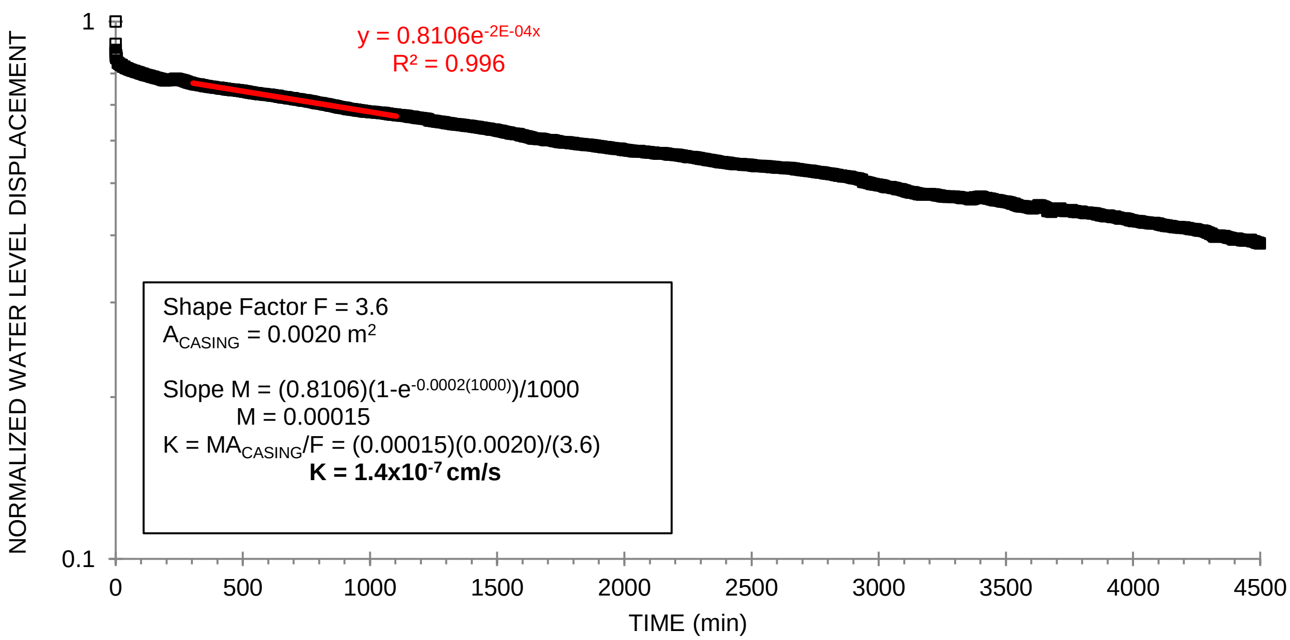


Figure 2-20

MW17-22OB

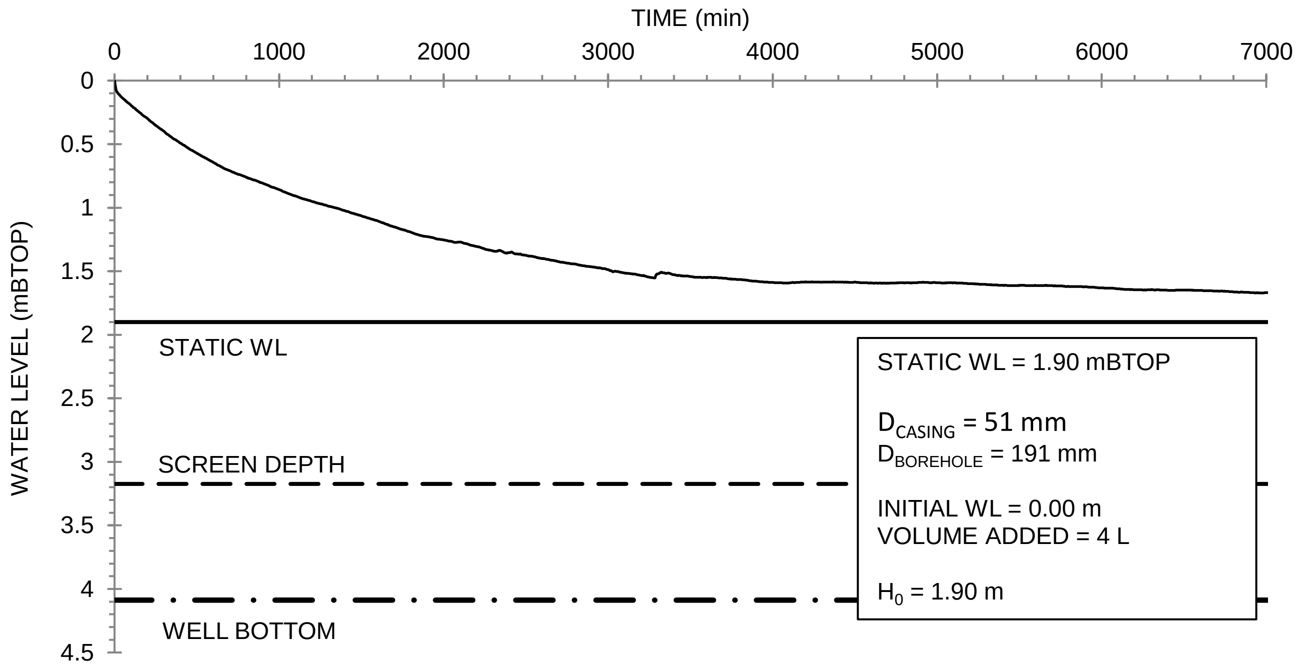
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 2, 2017

Performed by: SM / CS



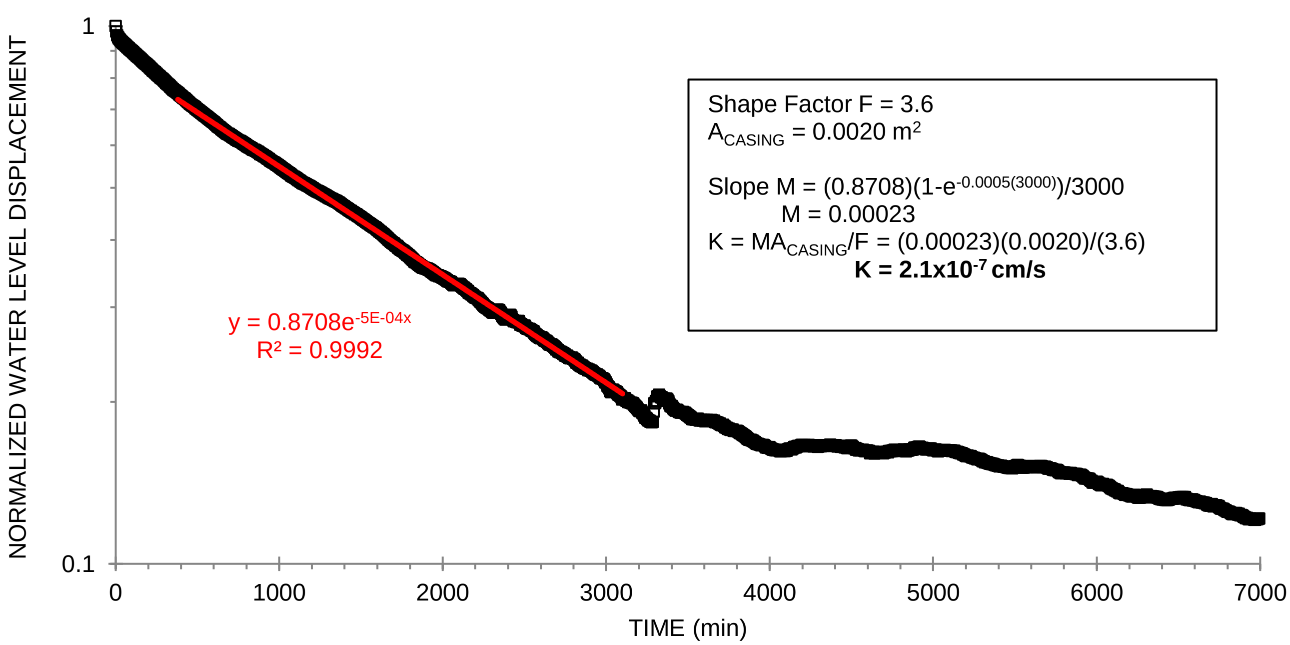


Figure 2-21

MW17-22SP

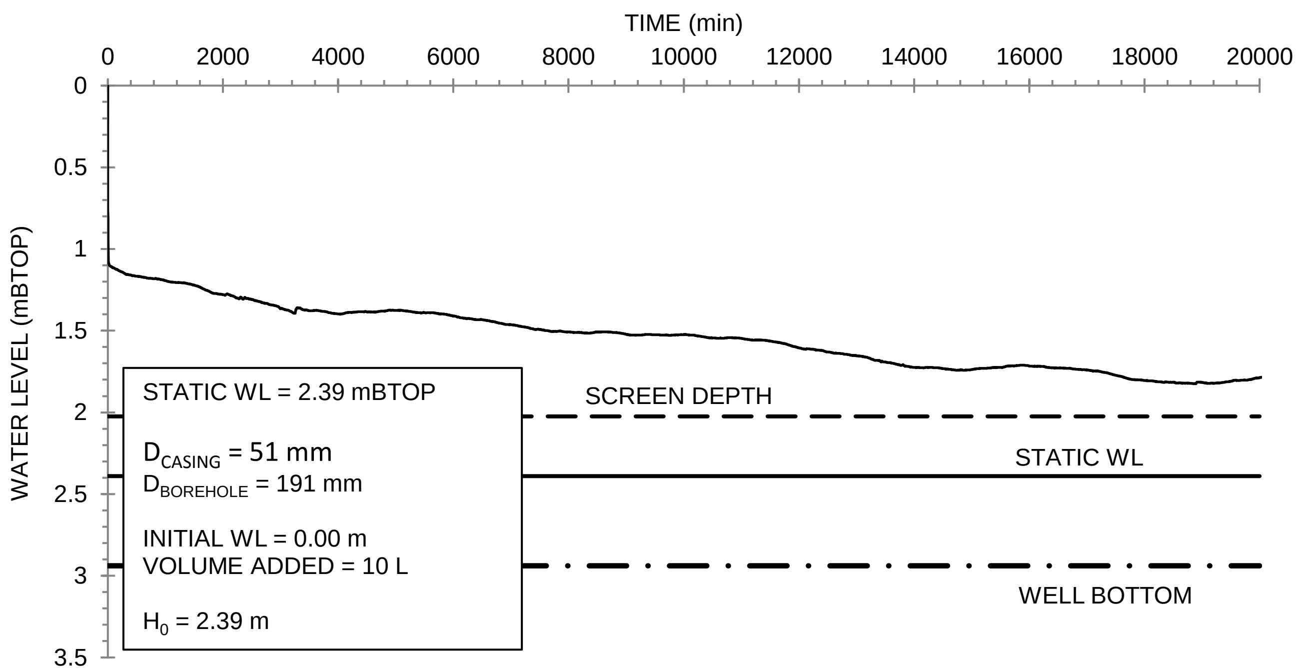
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 2, 2017

Performed by: SM / CS



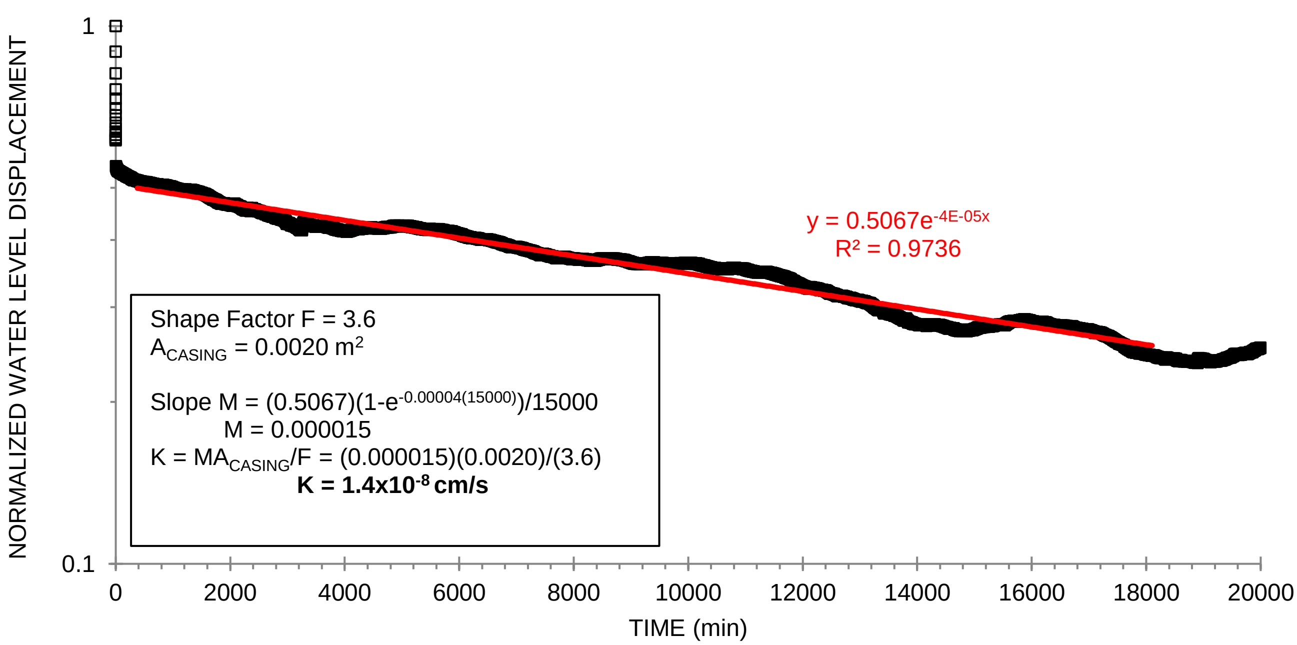


Figure 2-22

MW17-23OB

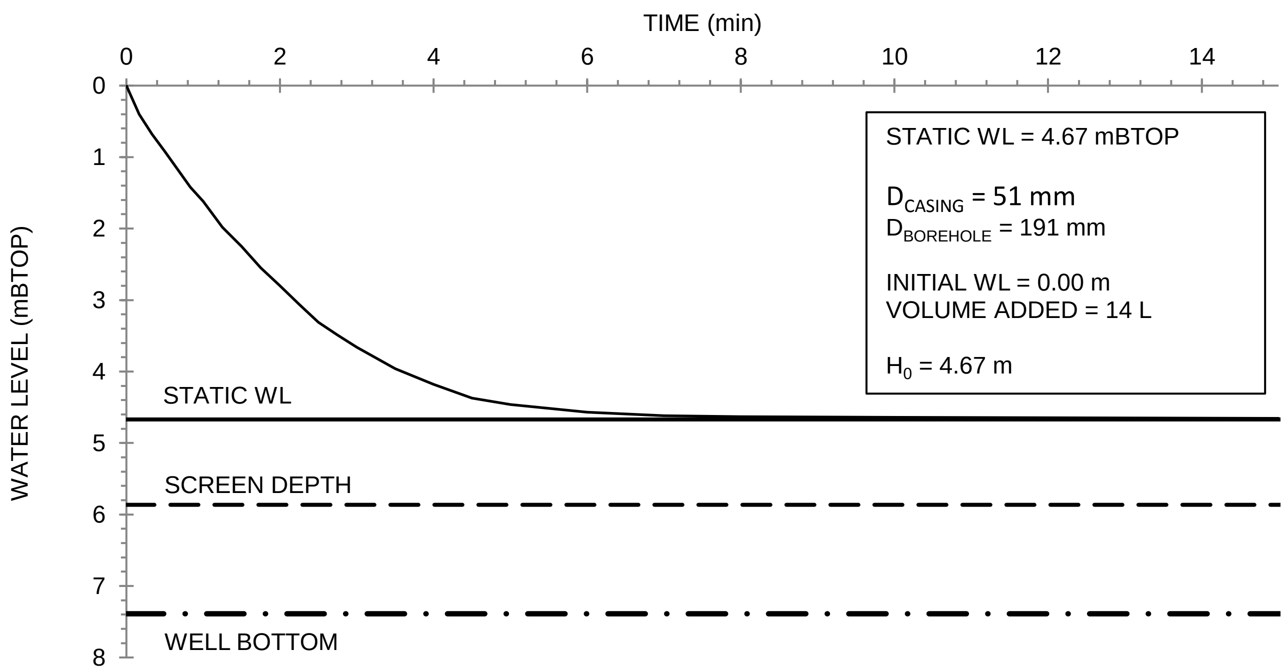
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 2, 2017

Performed by: SM / CS



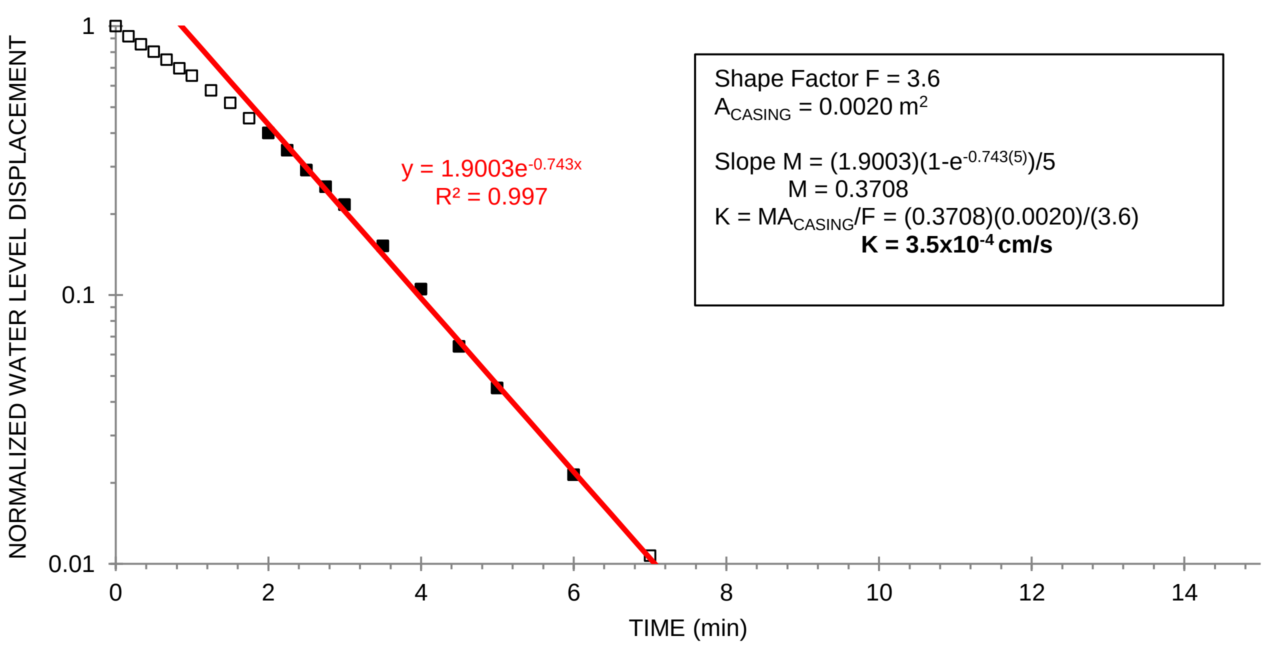


Figure 2-23

MW17-23SP

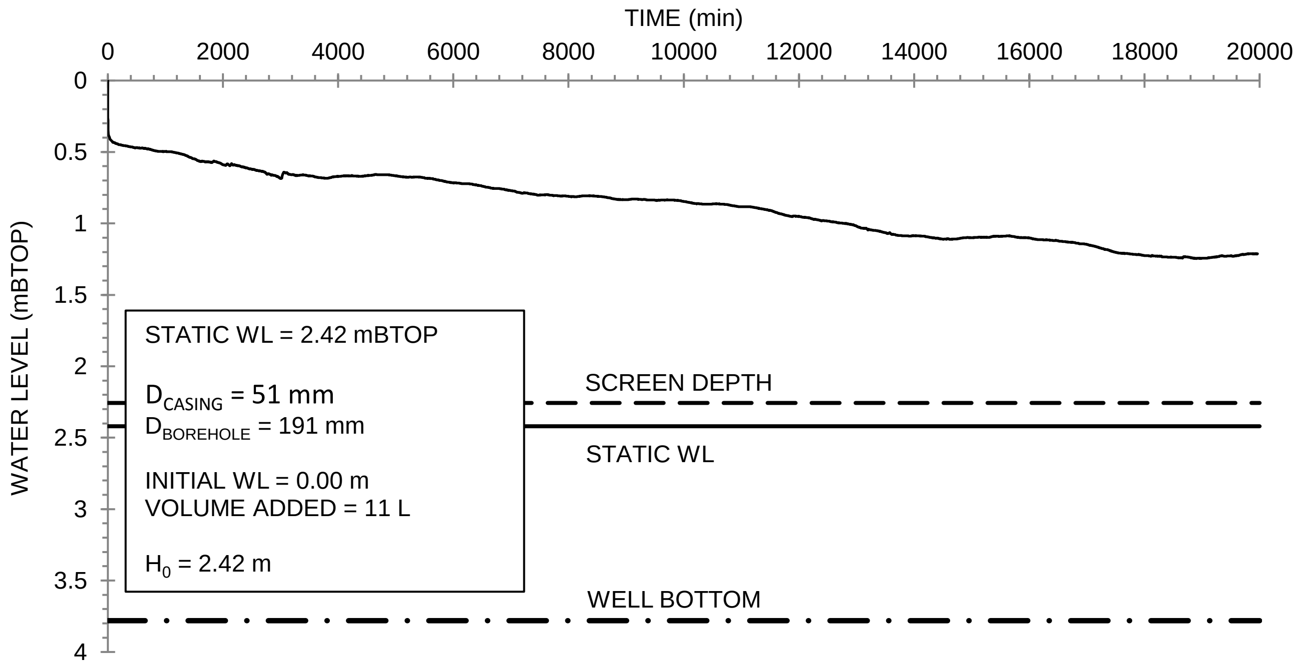
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: August 2, 2017

Performed by: SM / CS



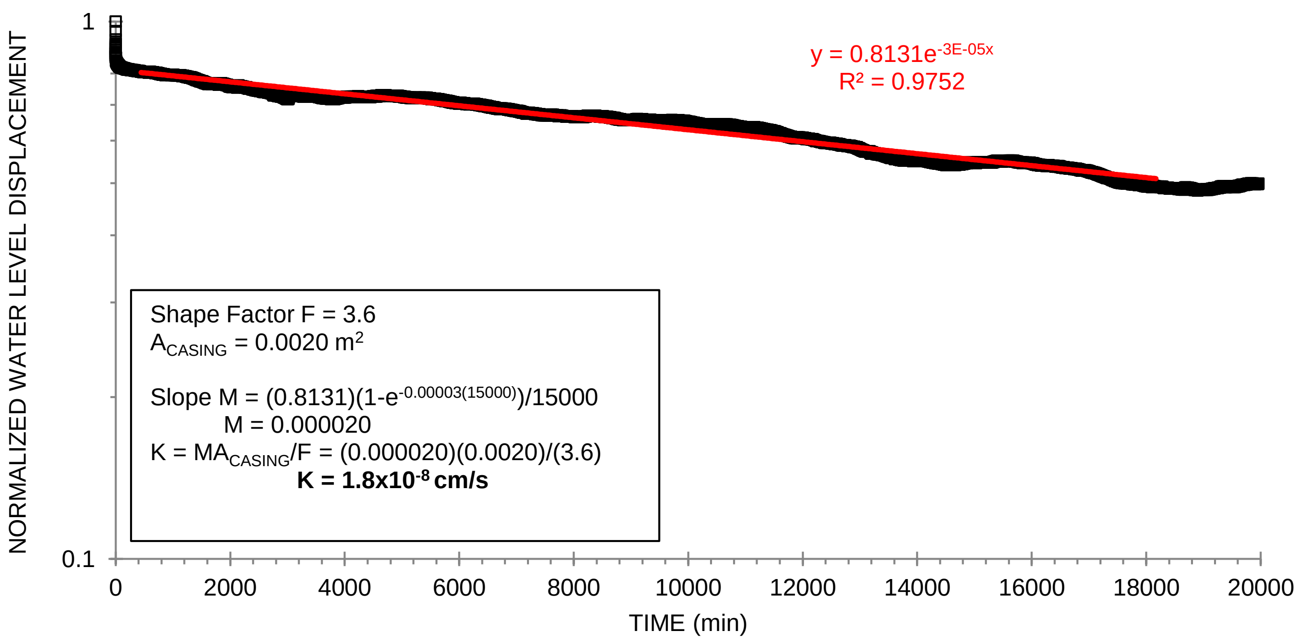


Figure 2-24

BH03-2B

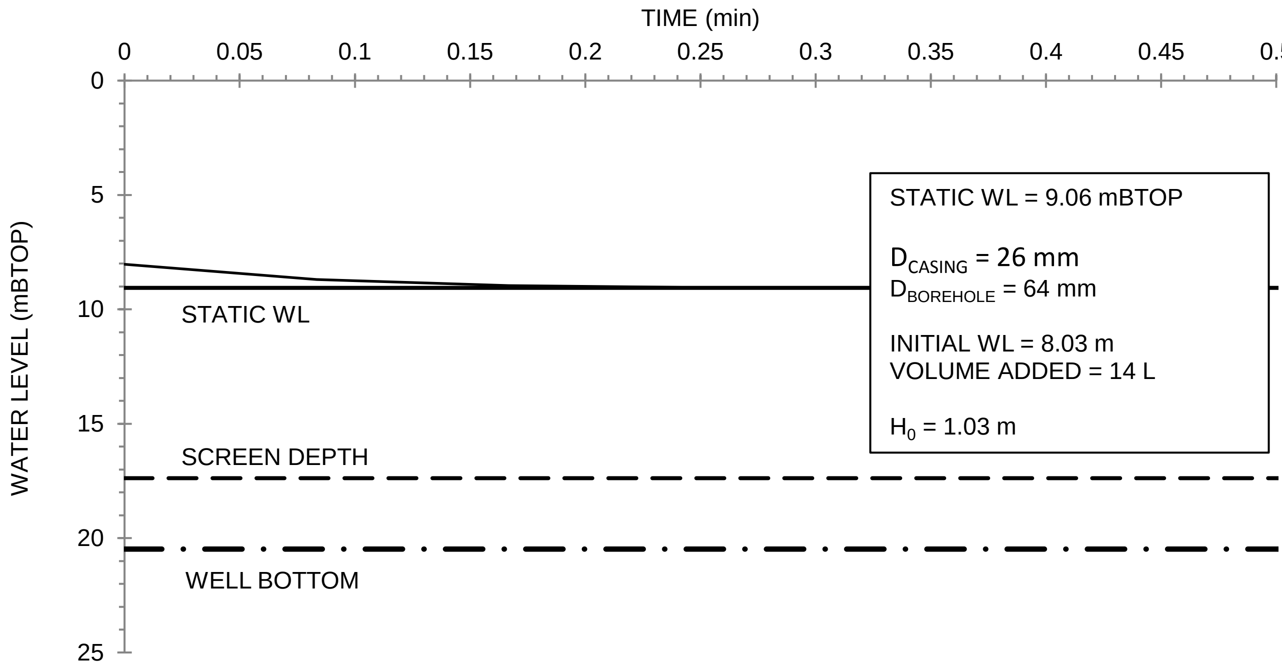
Falling Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 11, 2016

Performed by: BC / SM



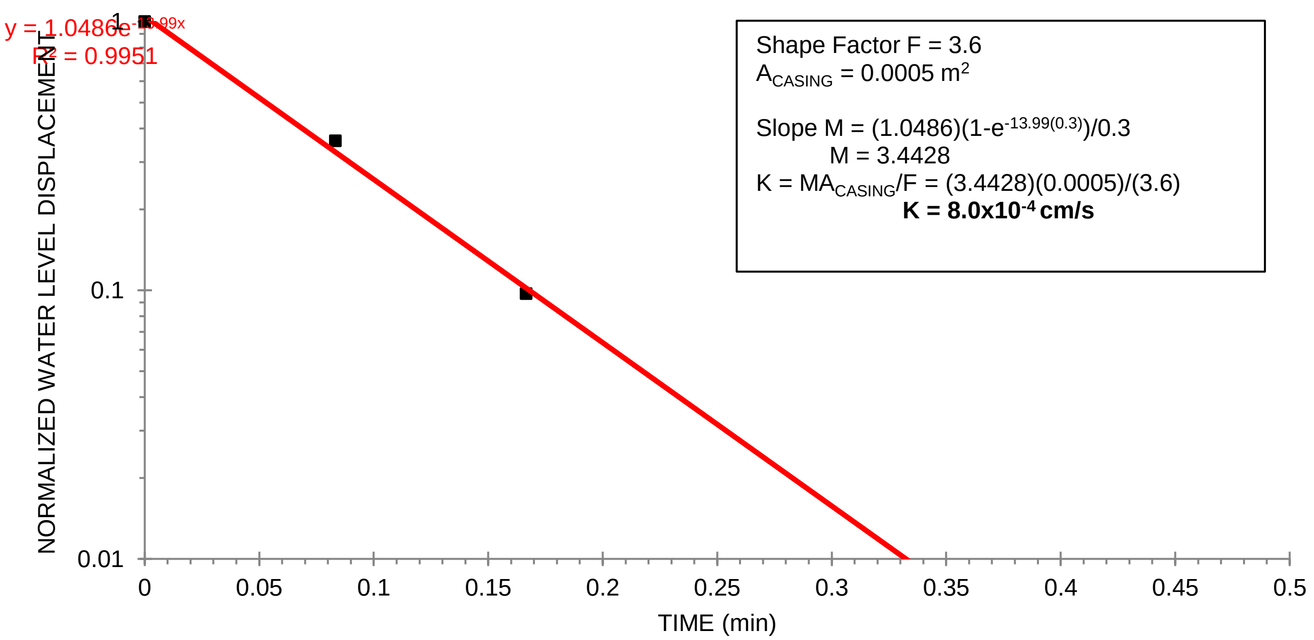


Figure 2-25

MW11-2B

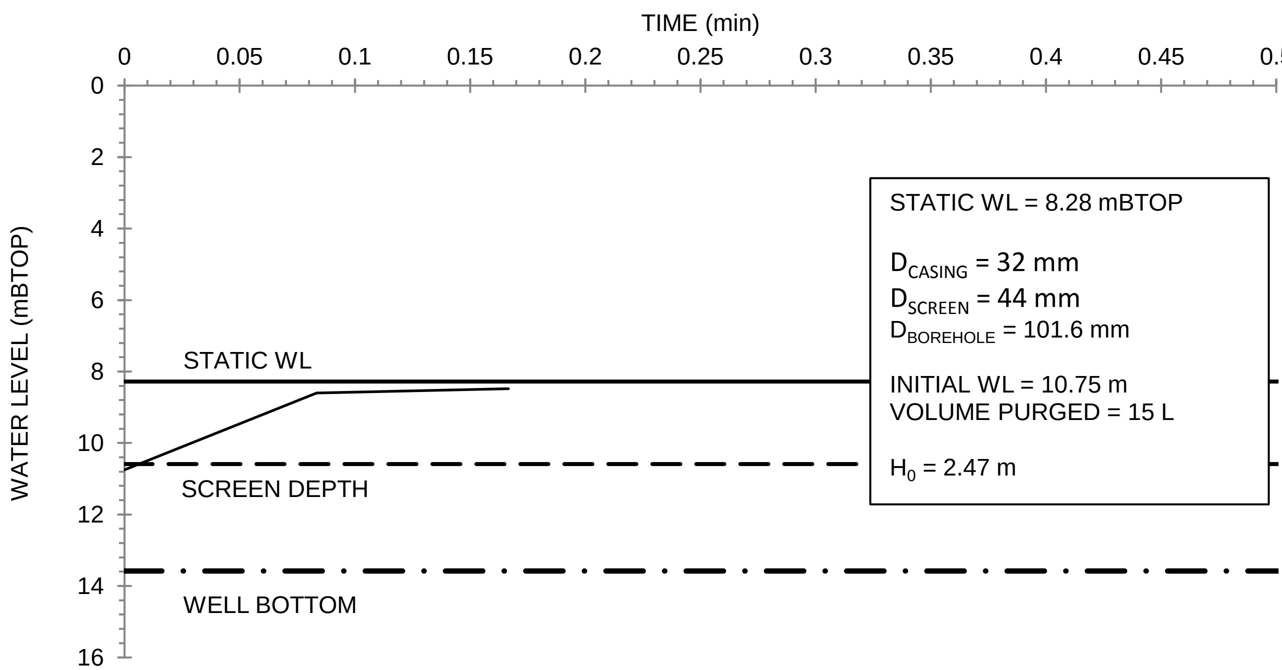
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 9, 2016

Performed by: BC / SM



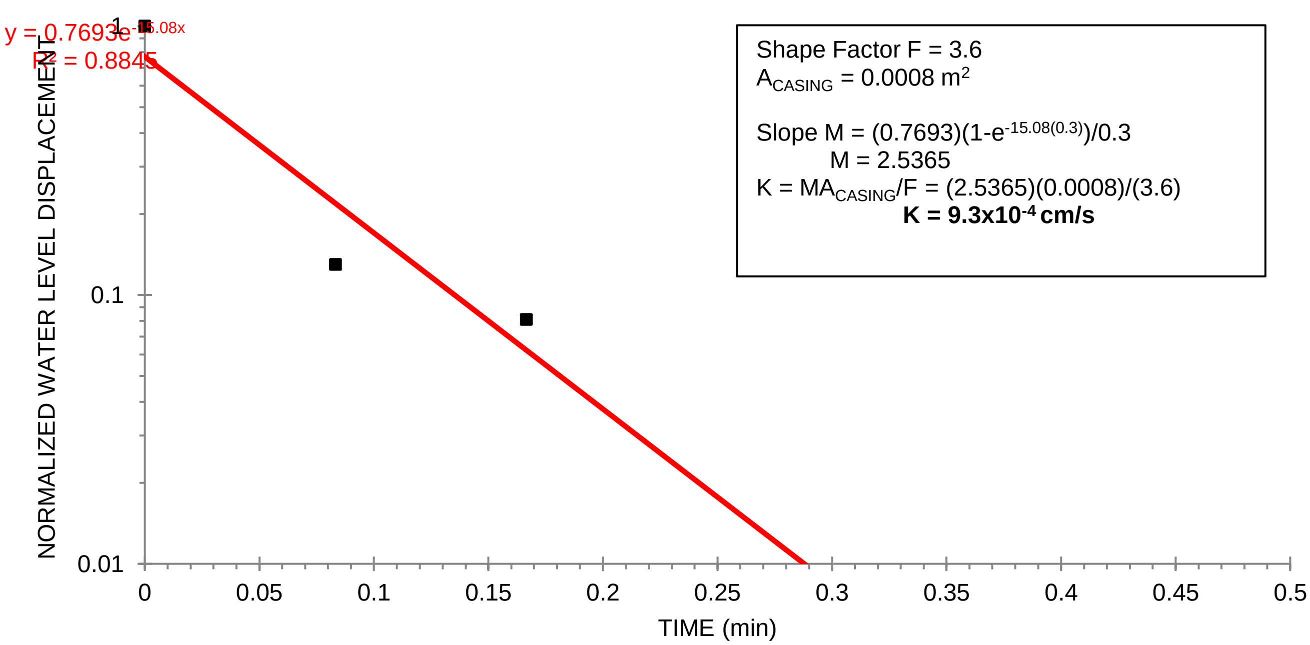


Figure 2-26

MW11-3BR

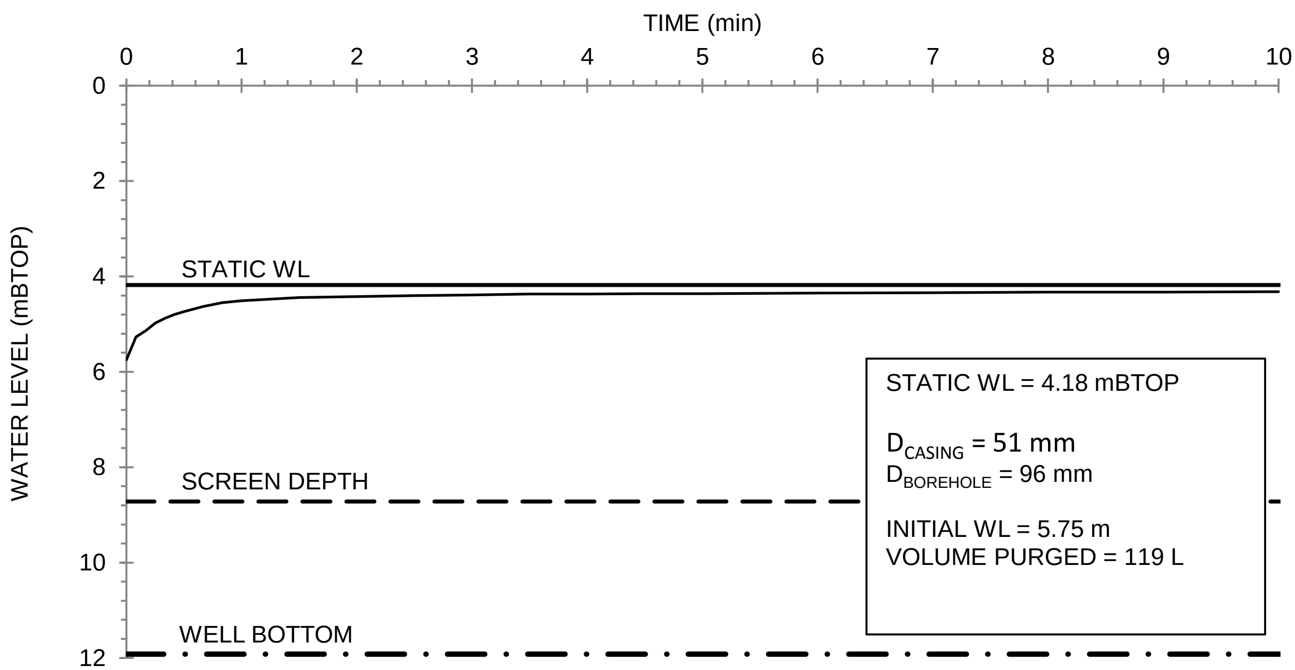
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 9, 2016

Performed by: BC / SM



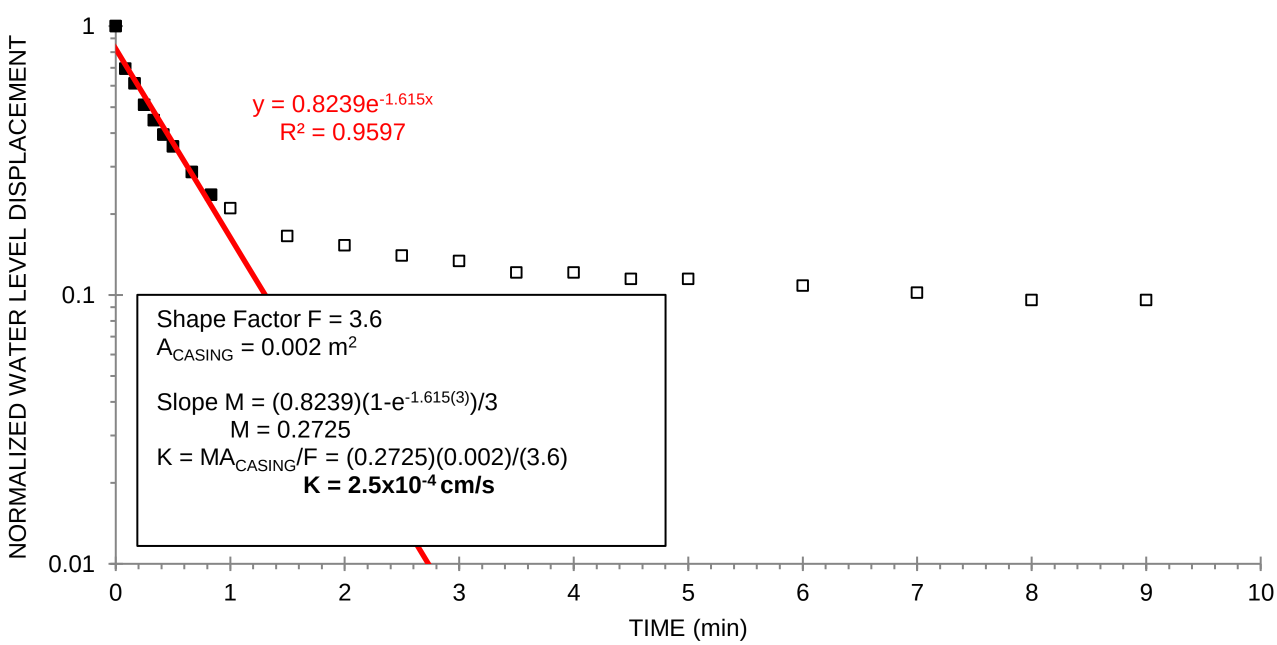


Figure 2-27

MW11-4B

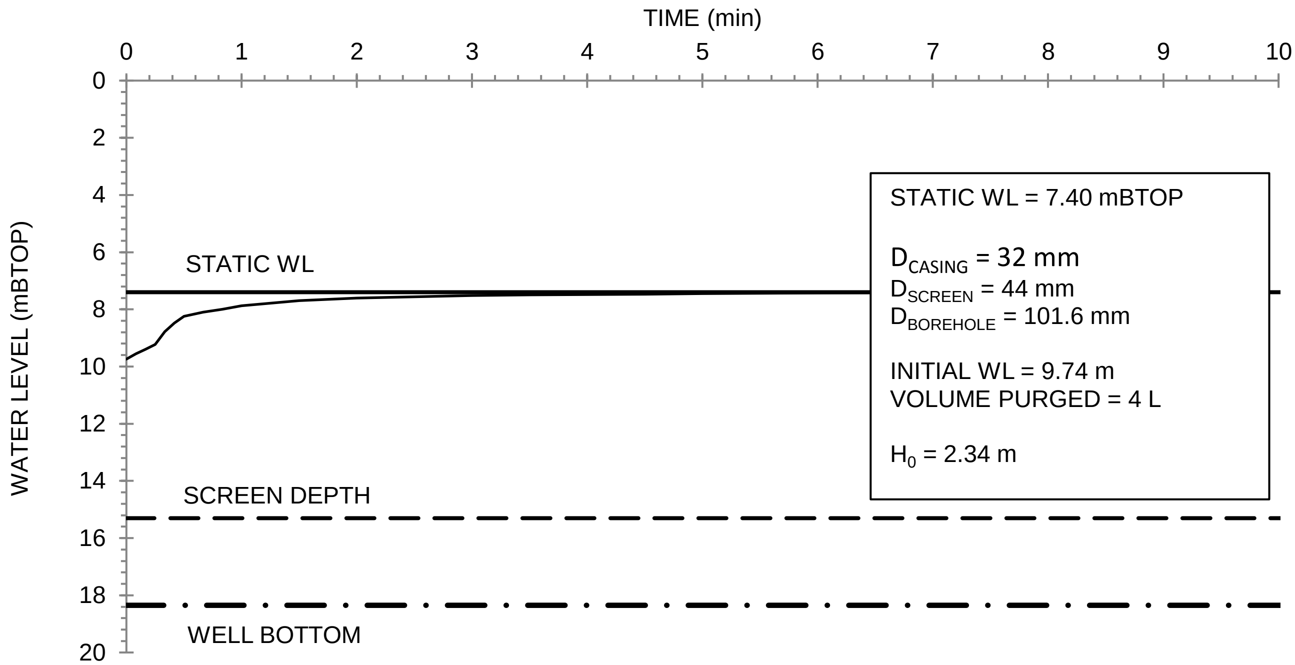
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 11, 2016

Performed by: BC / SM



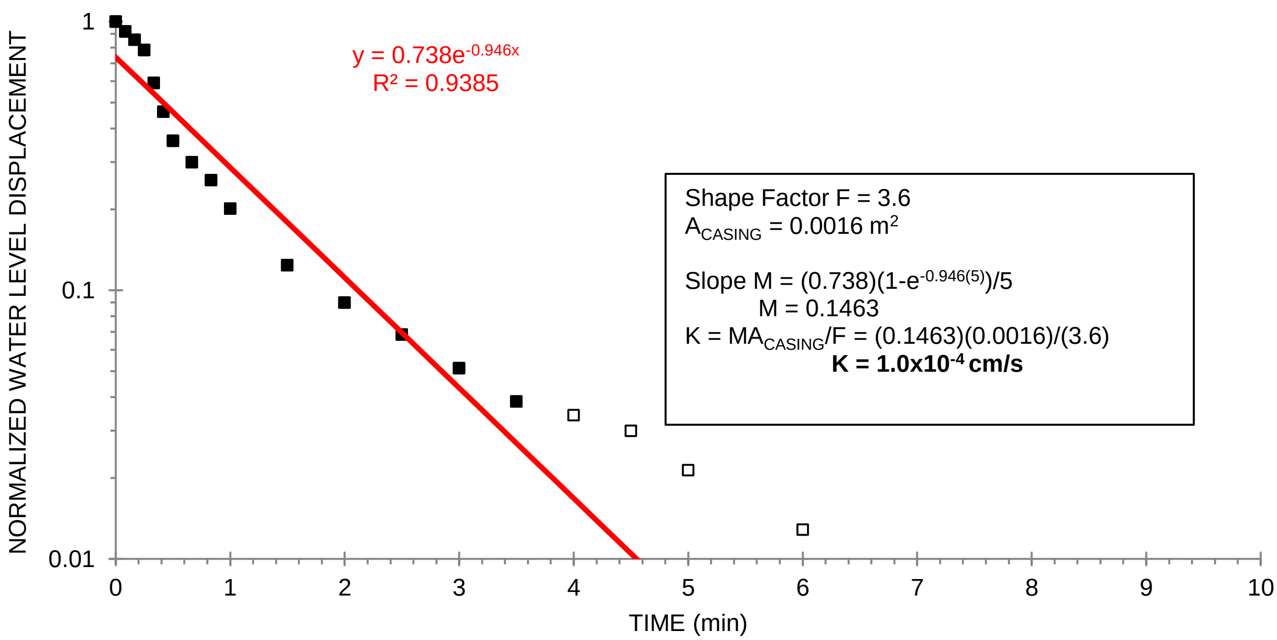


Figure 2-28

MW16-5B

Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: September 14, 2017

Performed by: BC

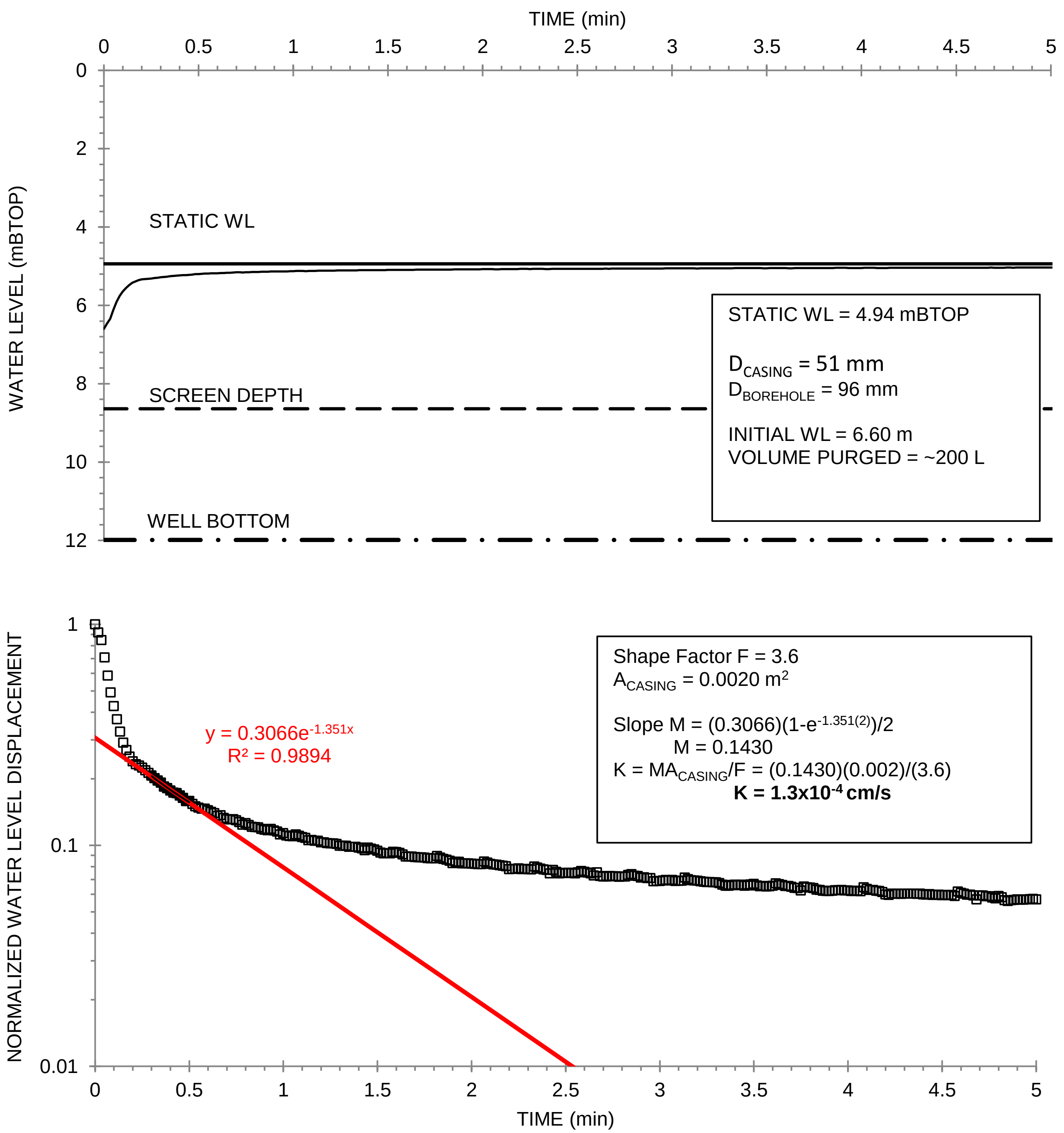


Figure 2-29

MW16-6B

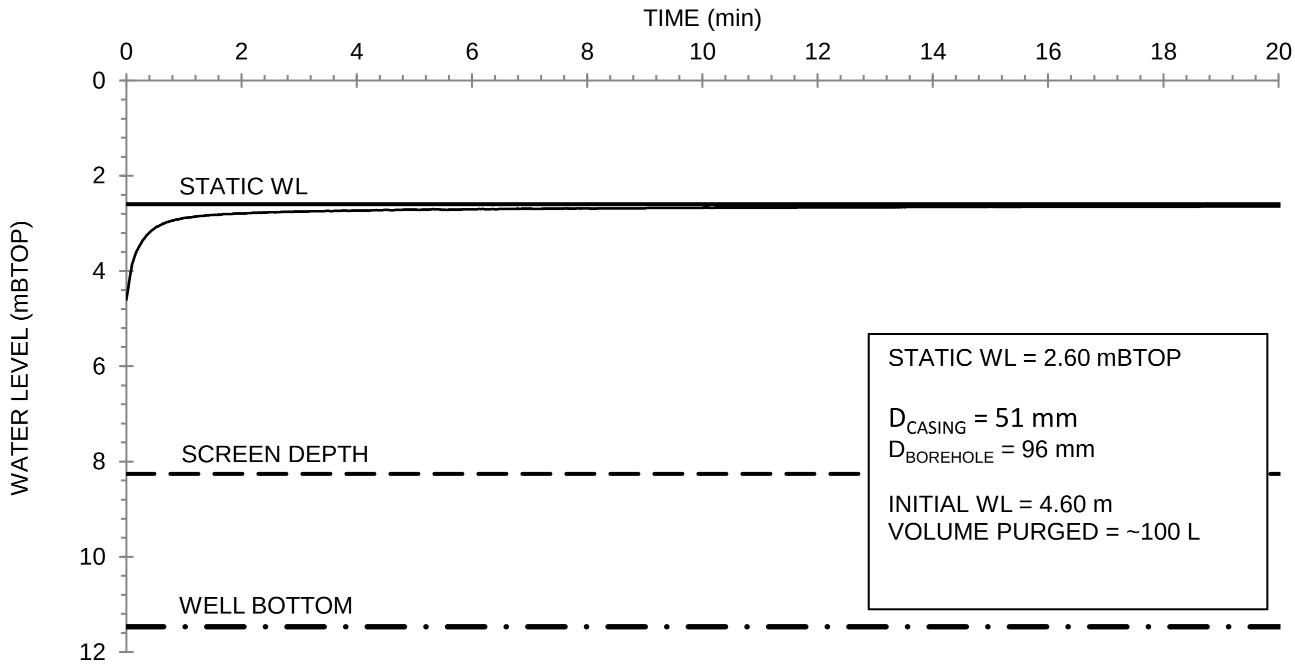
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: September 14, 2017

Performed by: BC



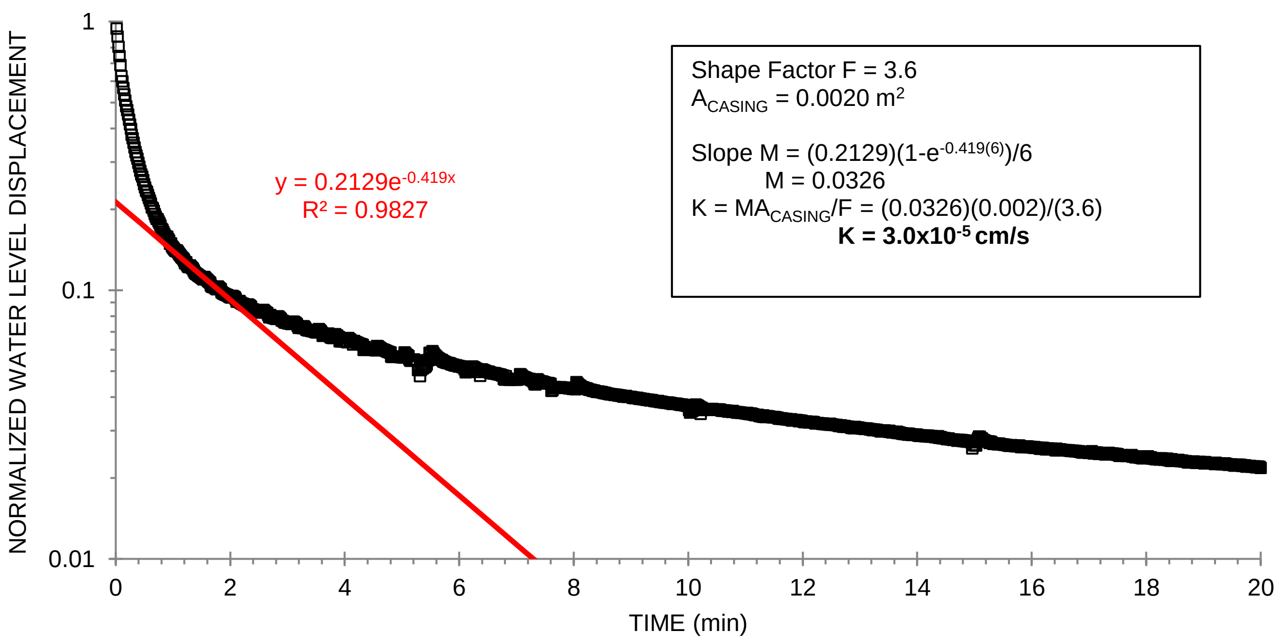


Figure 2-30

MW16-7B

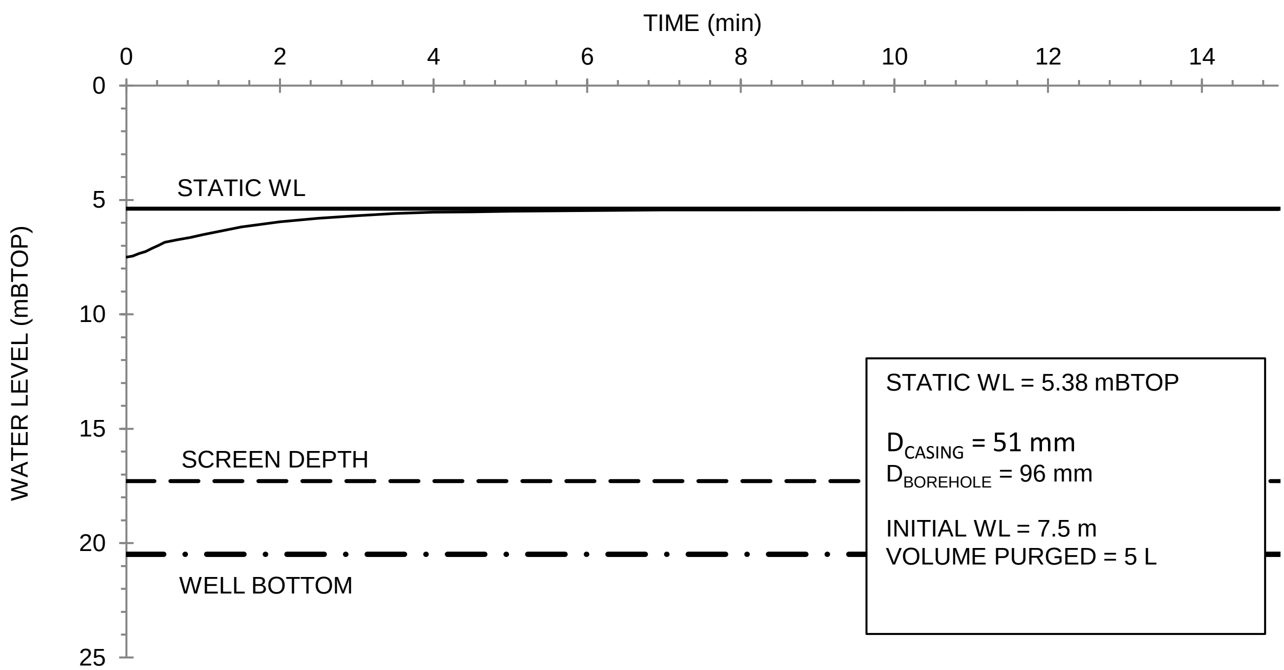
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 8, 2016

Performed by: BC / SM



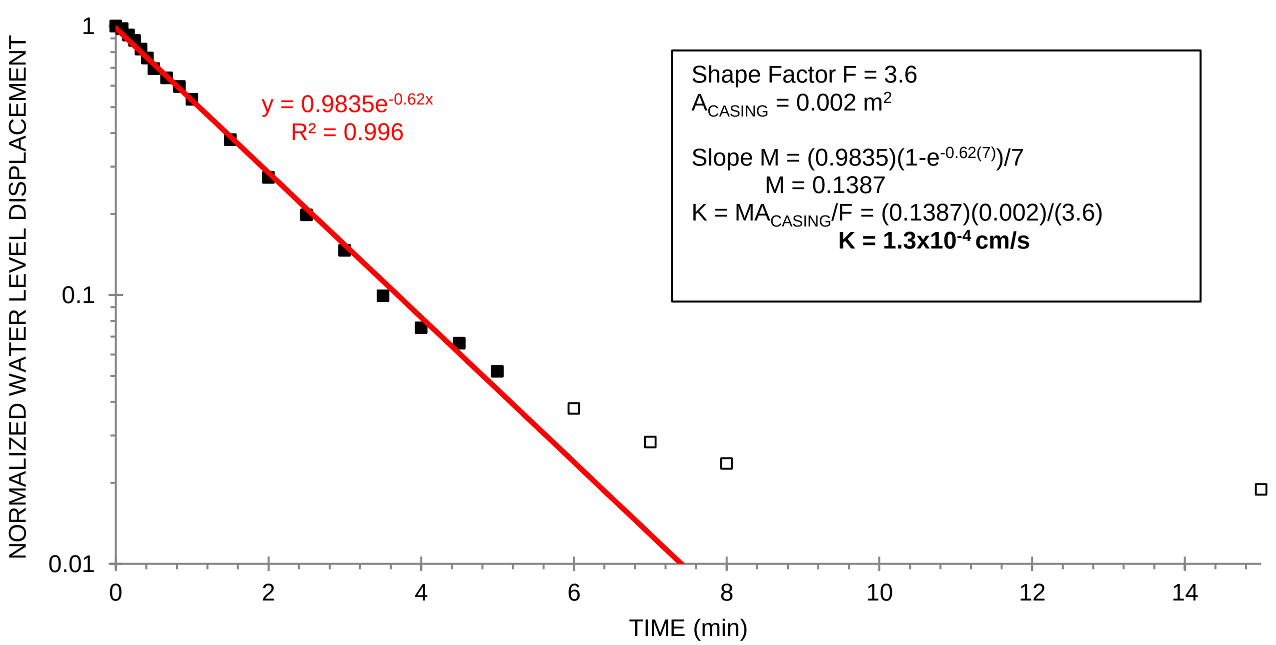


Figure 2-31

MW16-8B

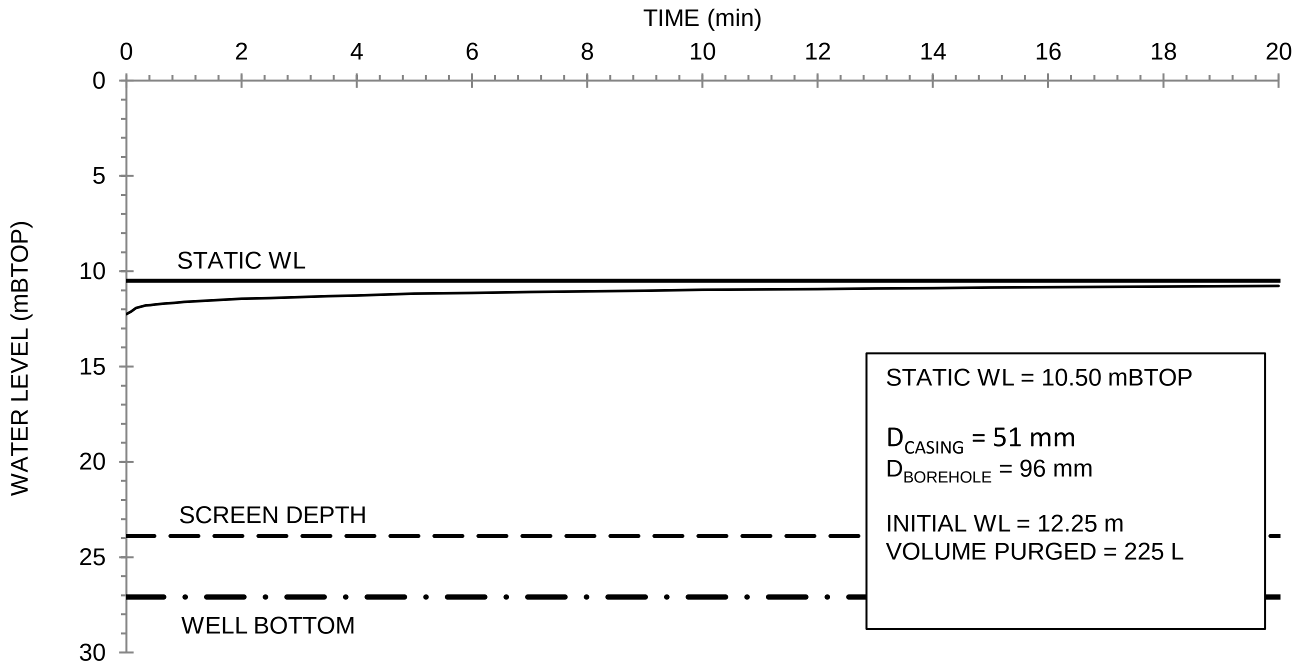
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 9, 2016

Performed by: BC / SM



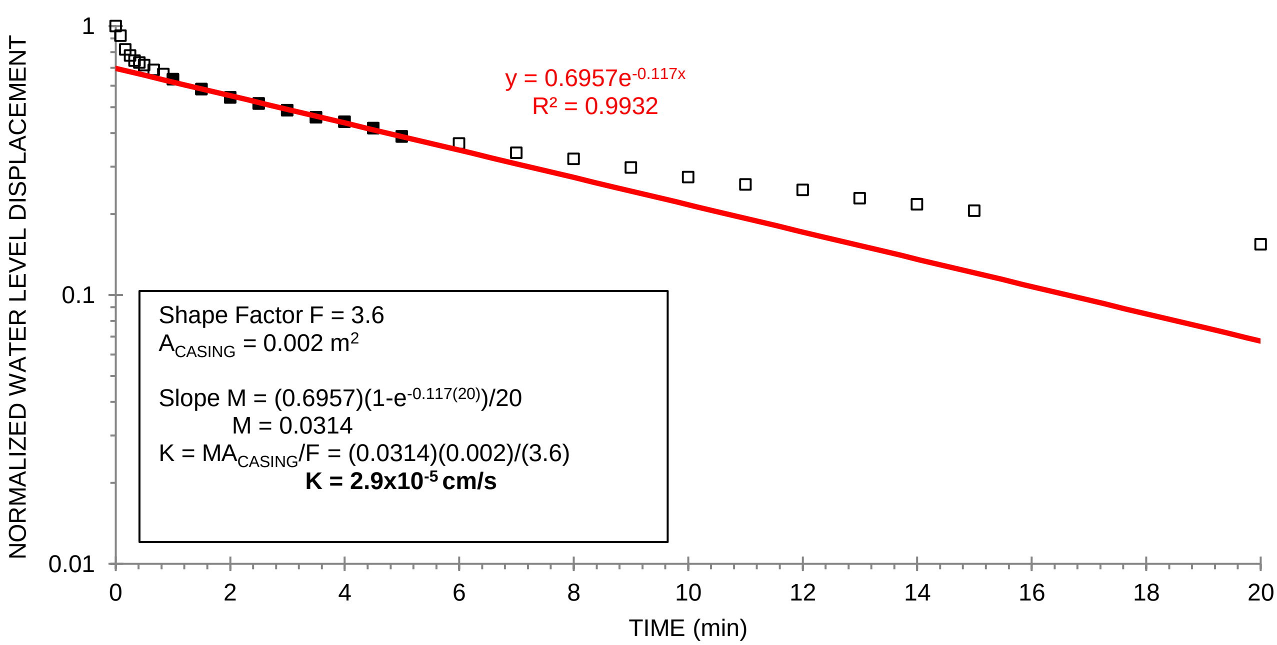


Figure 2-32

MW16-9B

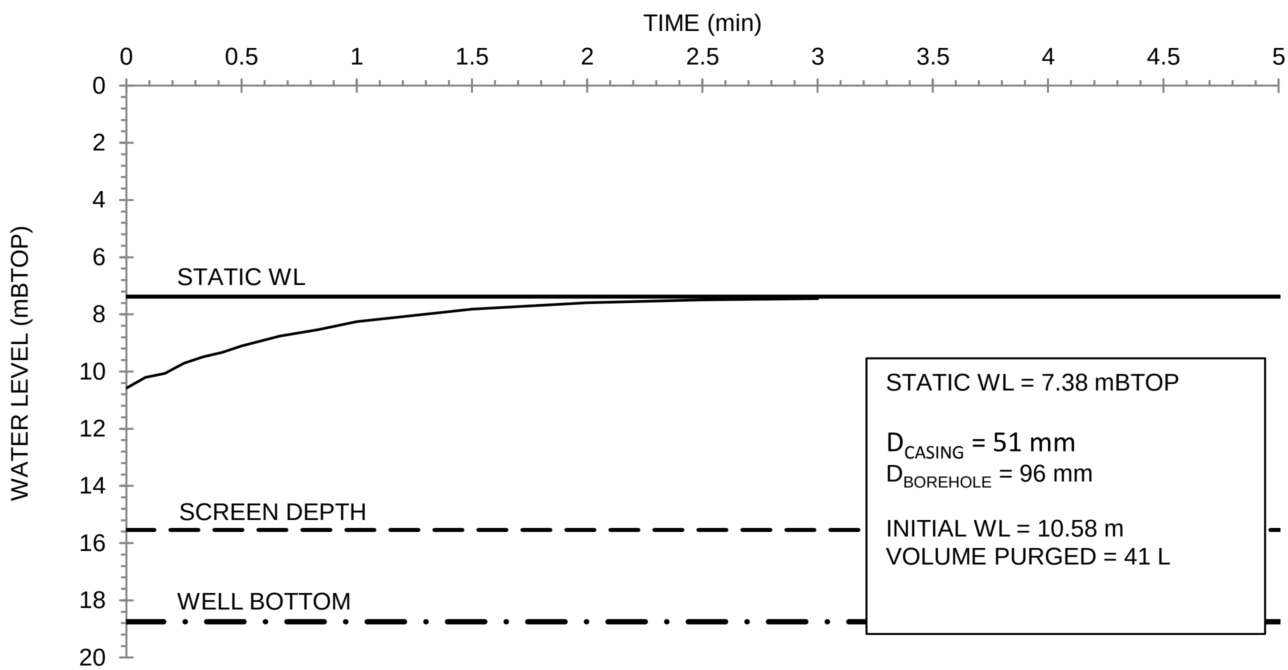
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 25, 2016

Performed by: BC / SM



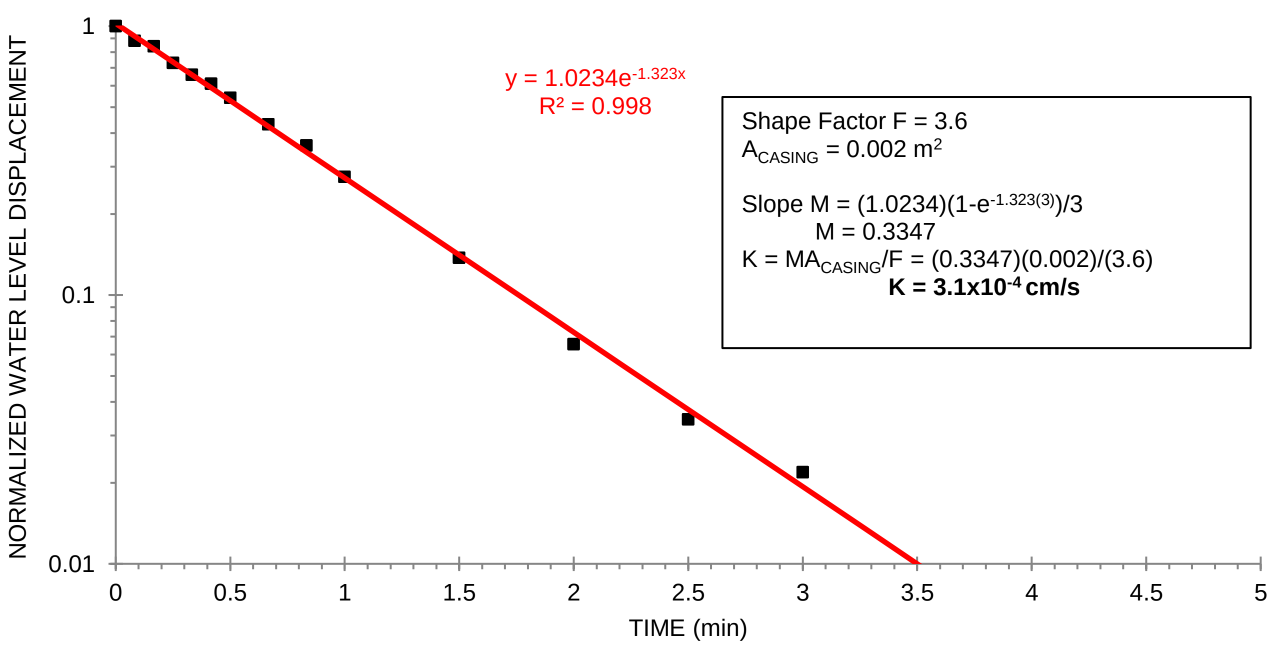


Figure 2-33

MW16-10B

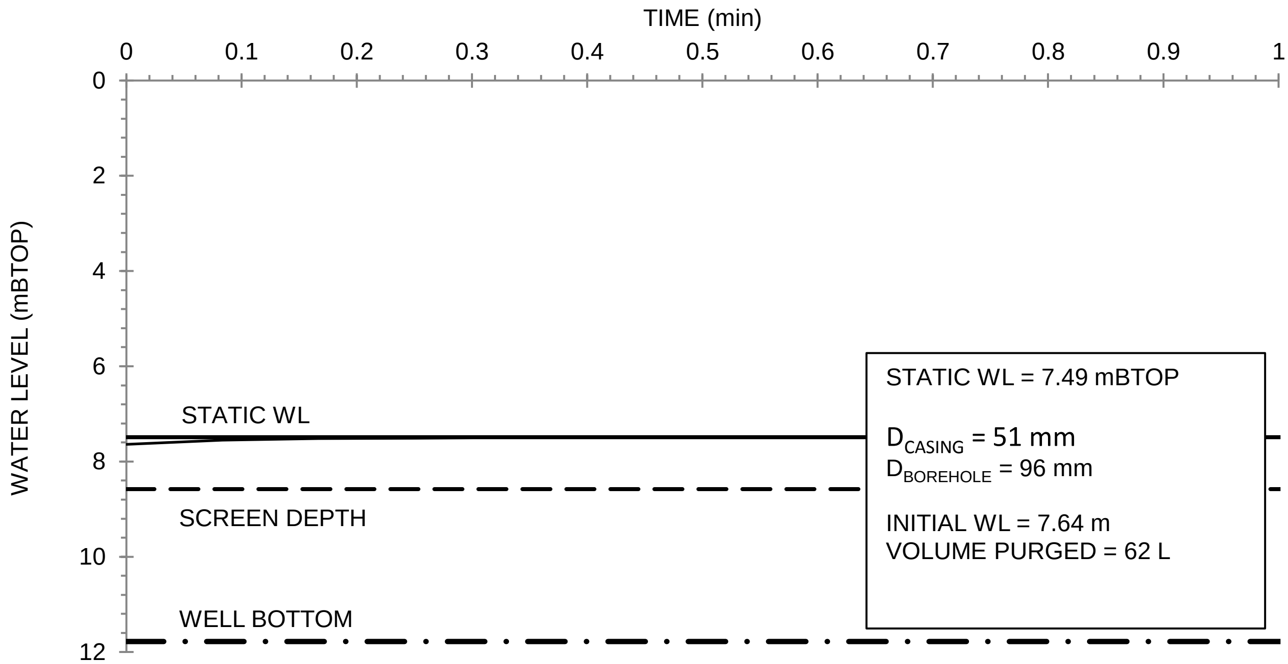
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 30, 2016

Performed by: BC / SM



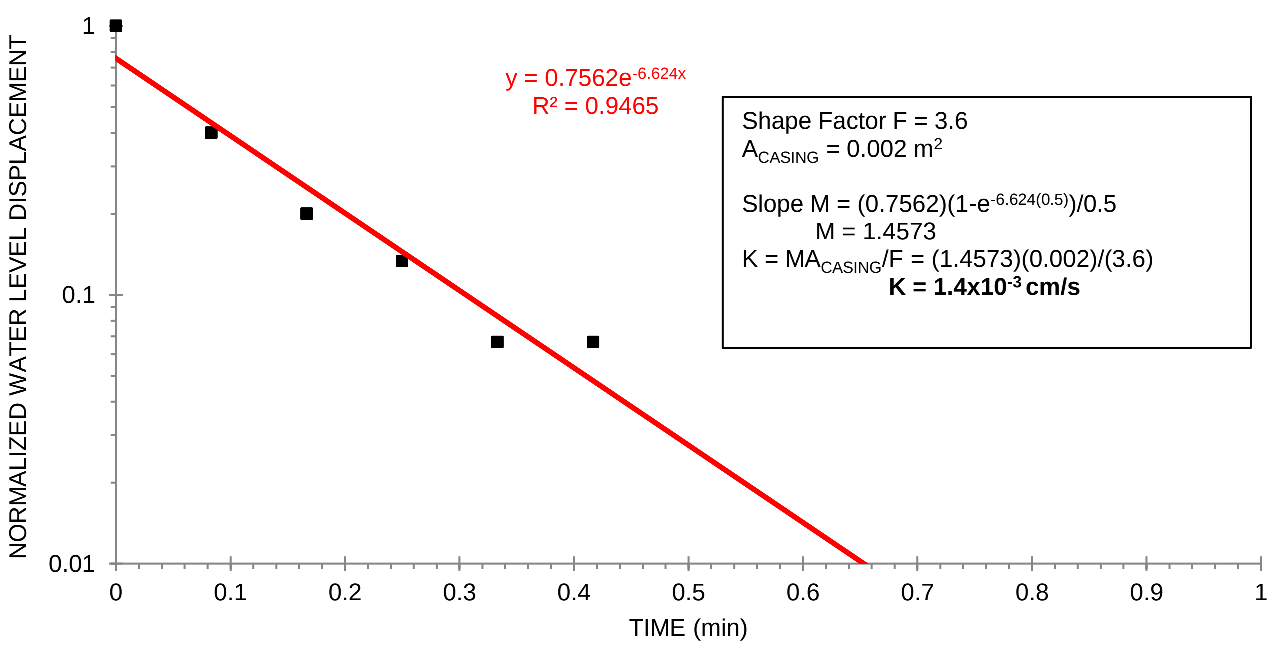


Figure 2-34

MW16-13B

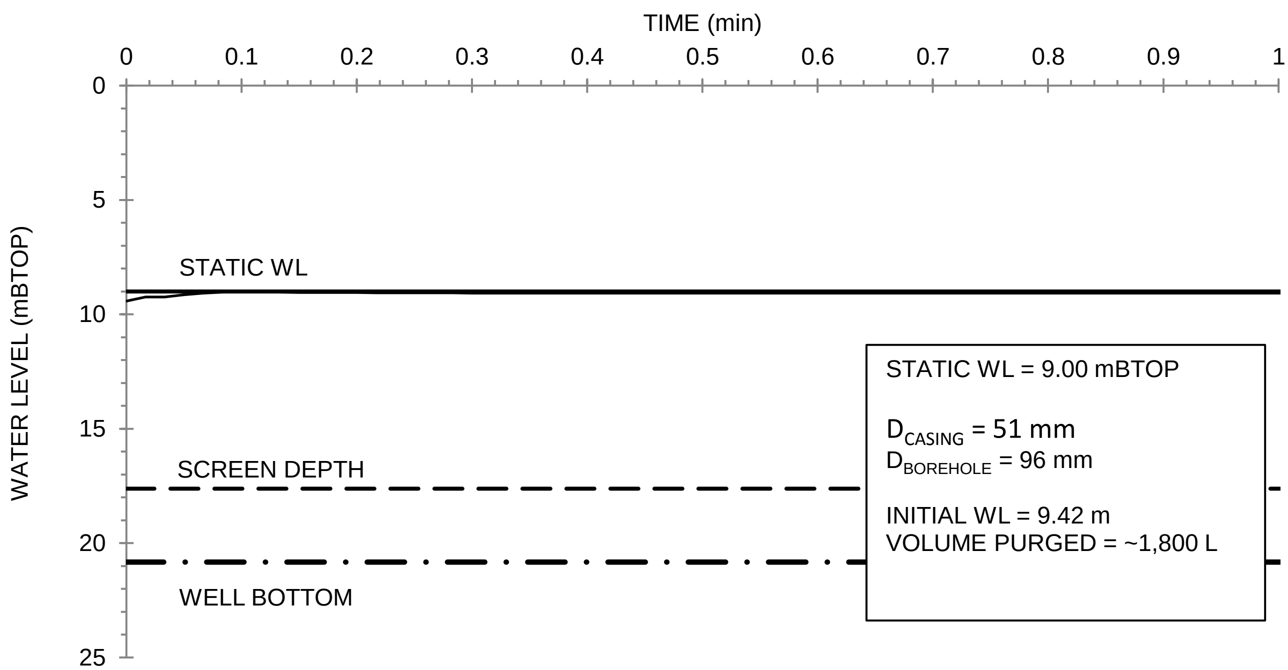
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: September 14, 2017

Performed by: BC



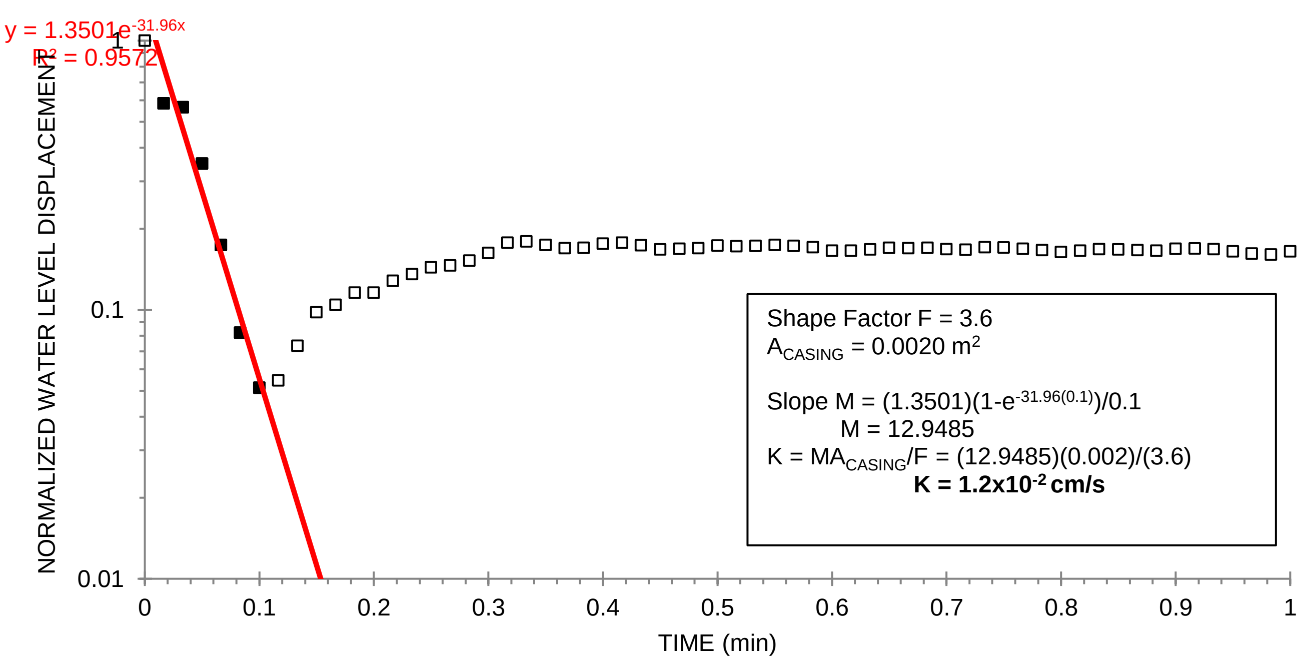


Figure 2-35

MW16-18B

Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: September 14, 2017

Performed by: BC

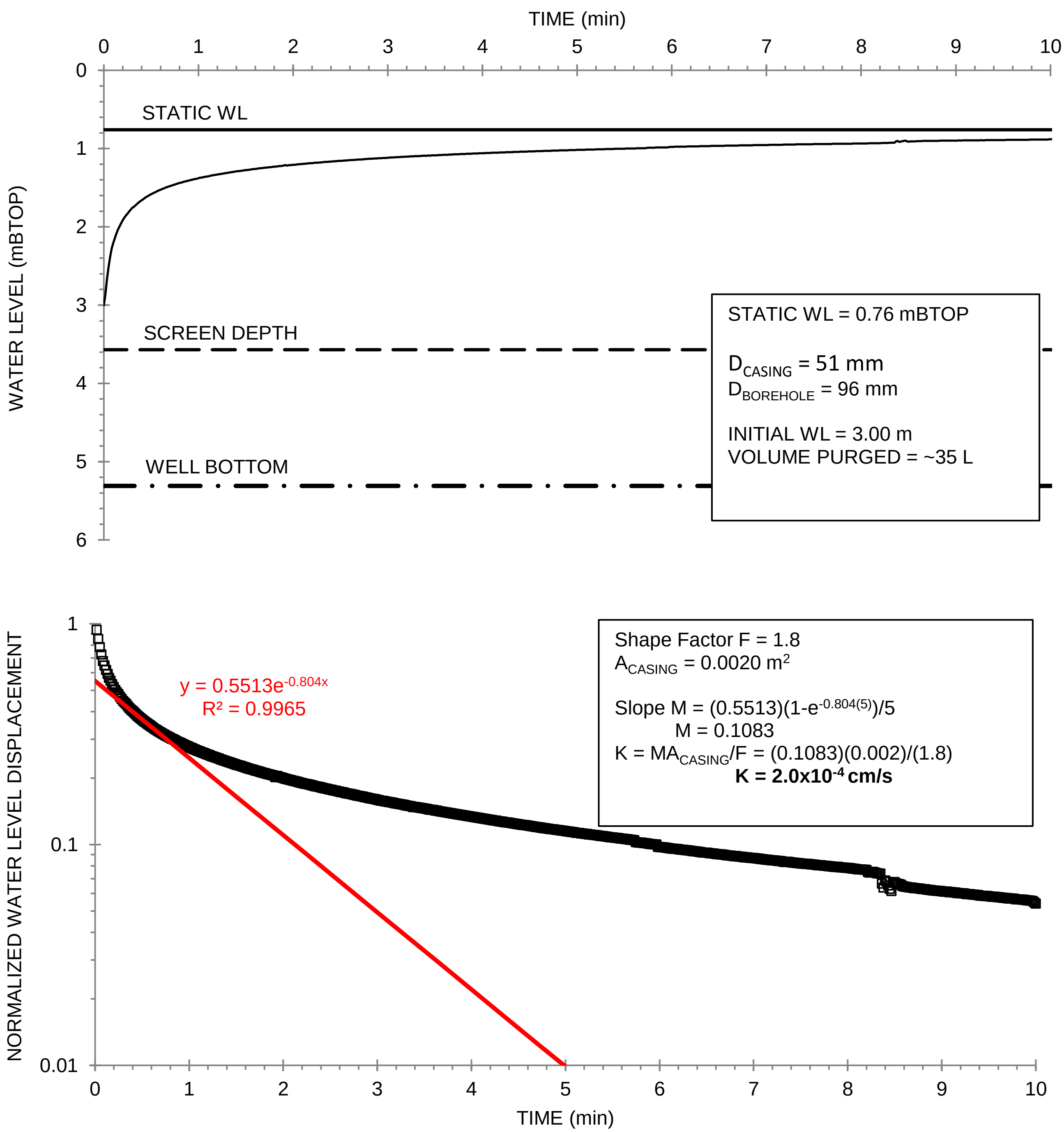


Figure 2-36

MW16-19B

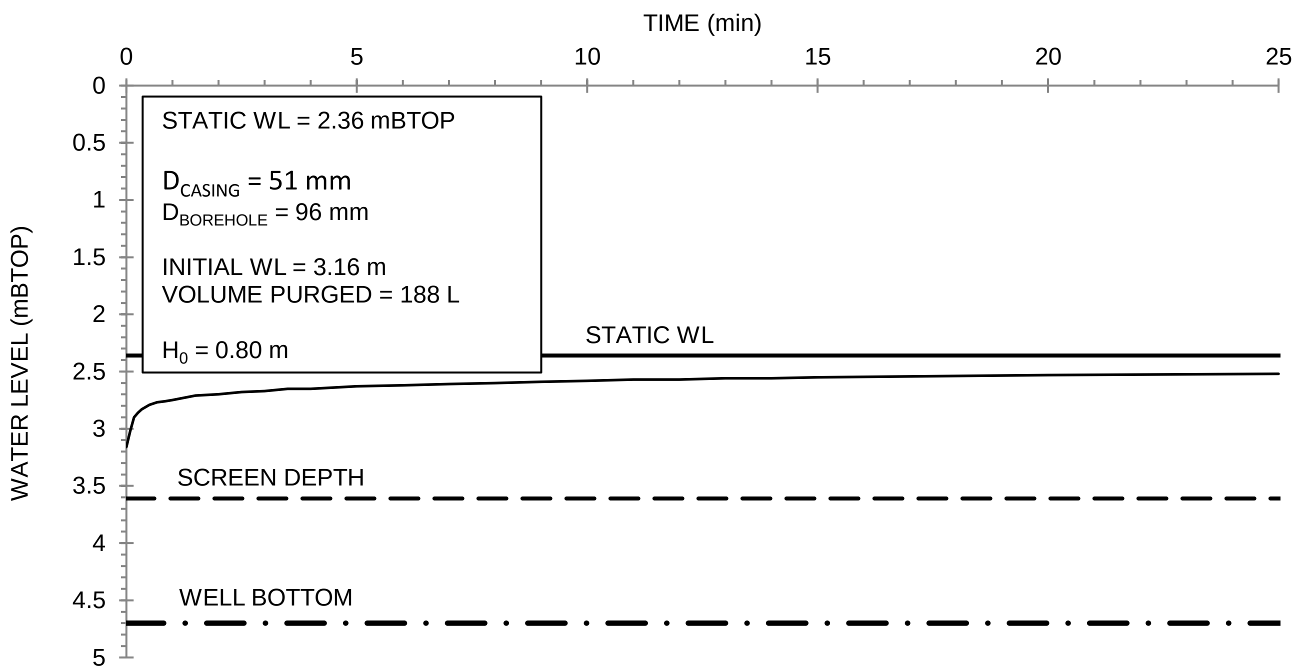
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 17, 2016

Performed by: BC / SM



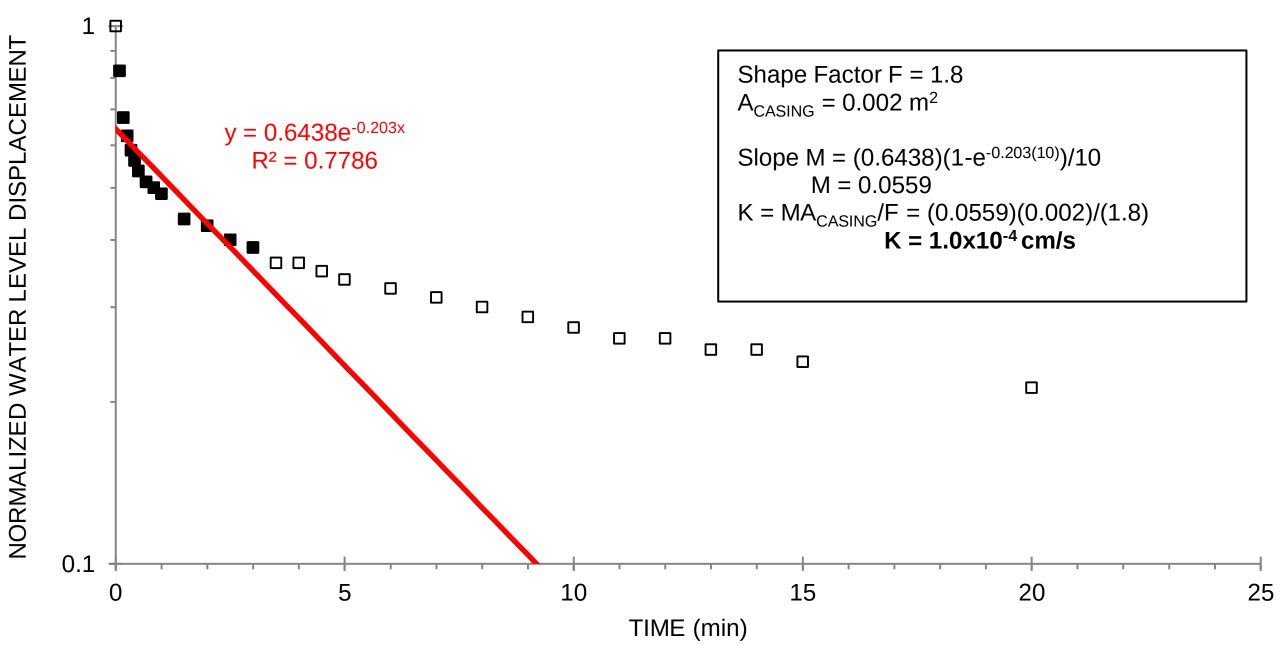


Figure 2-37

MW17-20B

Rising Head Slug Test Analysis

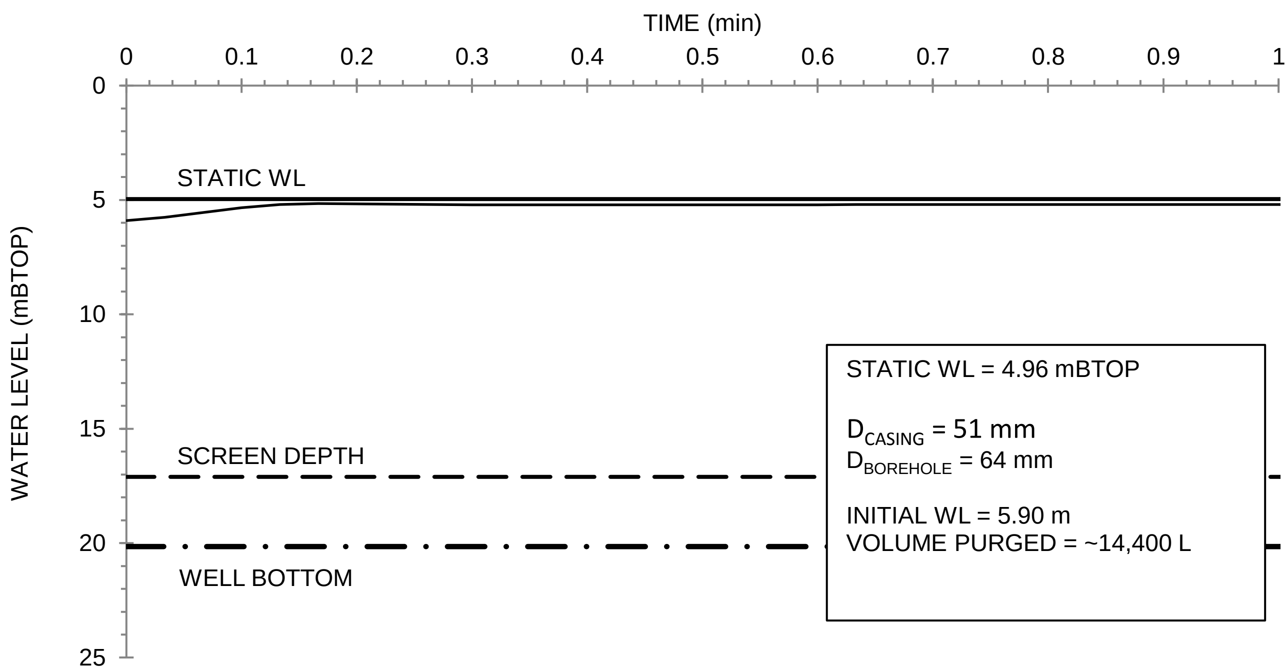
Hvorslev Method

Proposed Upper's Quarry

wsp

Date: September 13, 2017

Performed by: BC



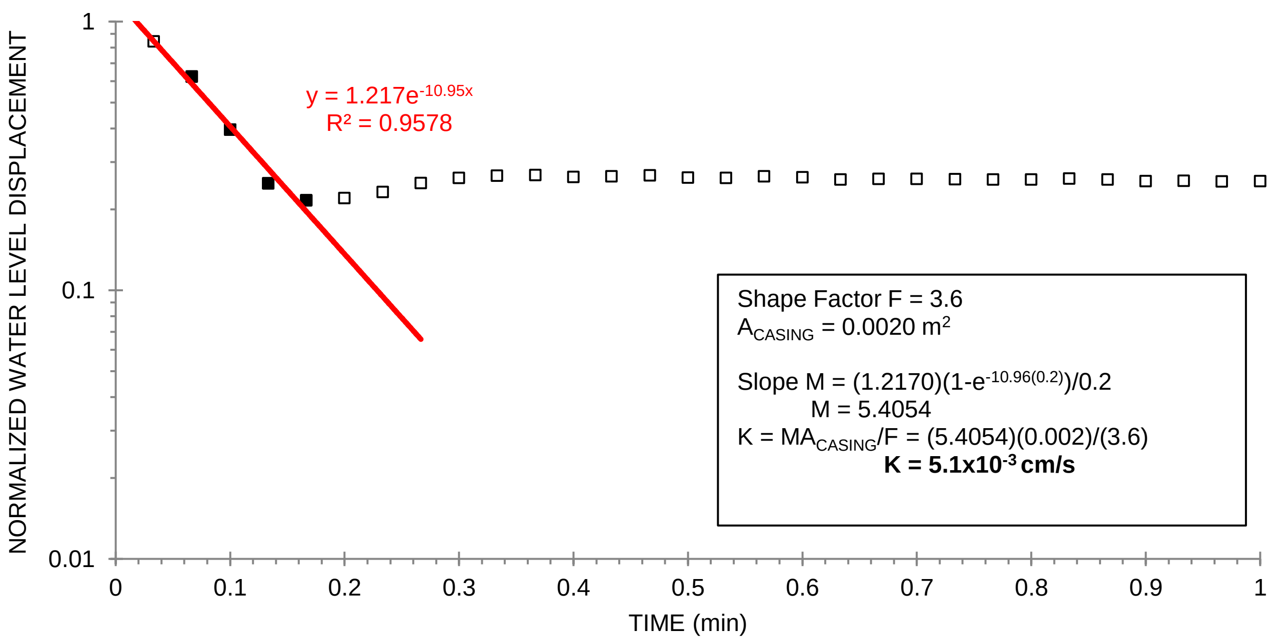


Figure 2-38

MW17-21B

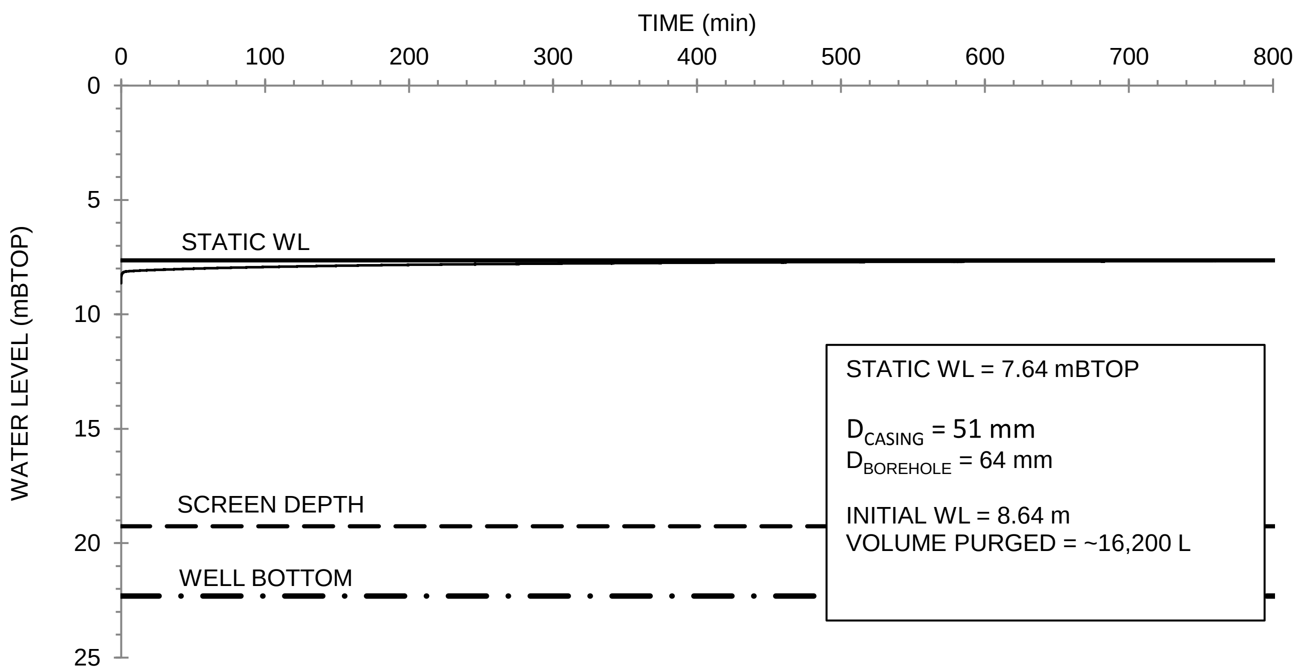
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: September 12, 2017

Performed by: BC



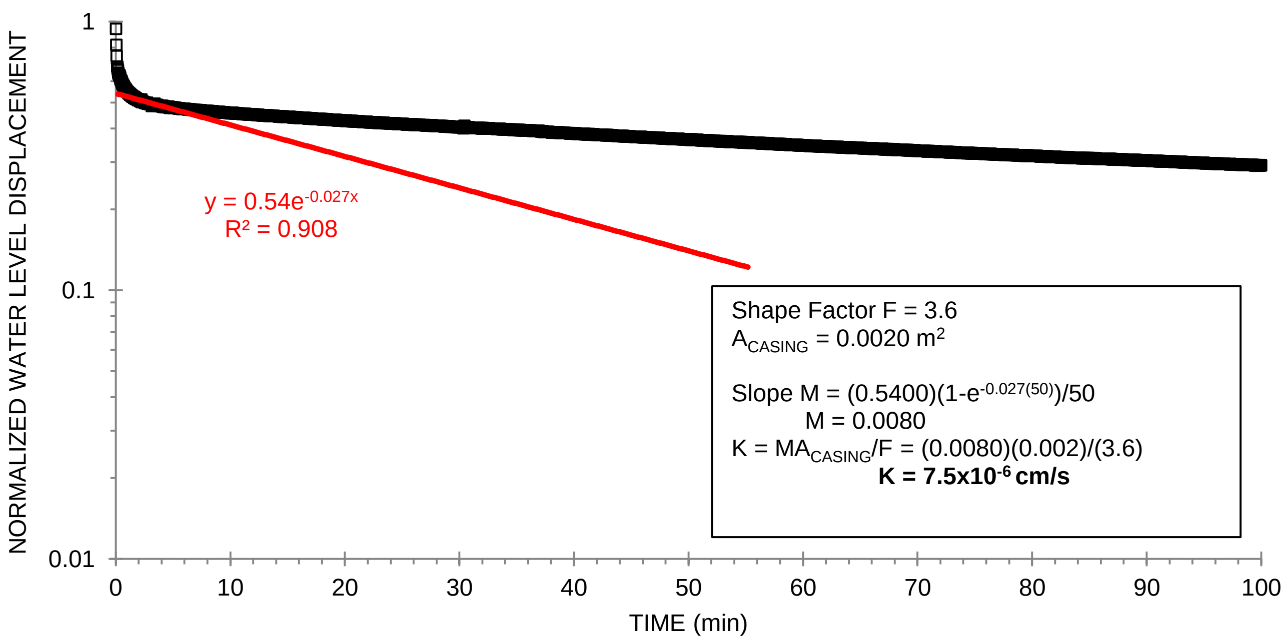


Figure 2-39

MW17-22B

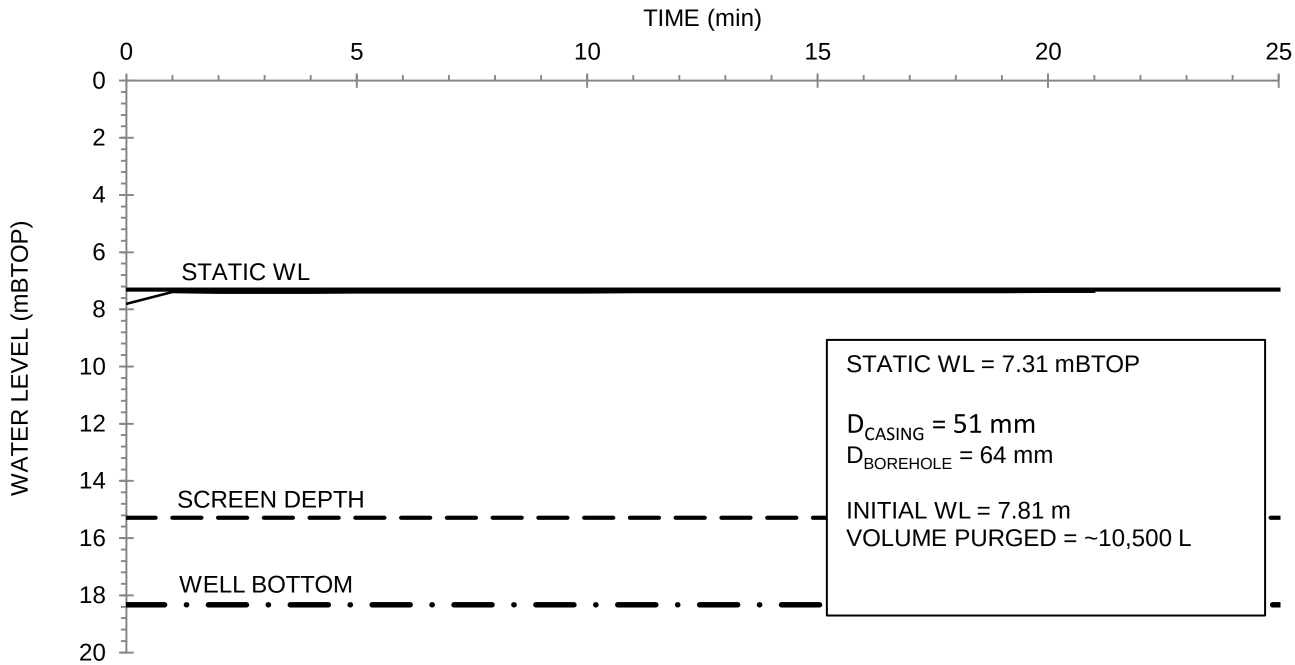
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: September 5, 2017

Performed by: BC



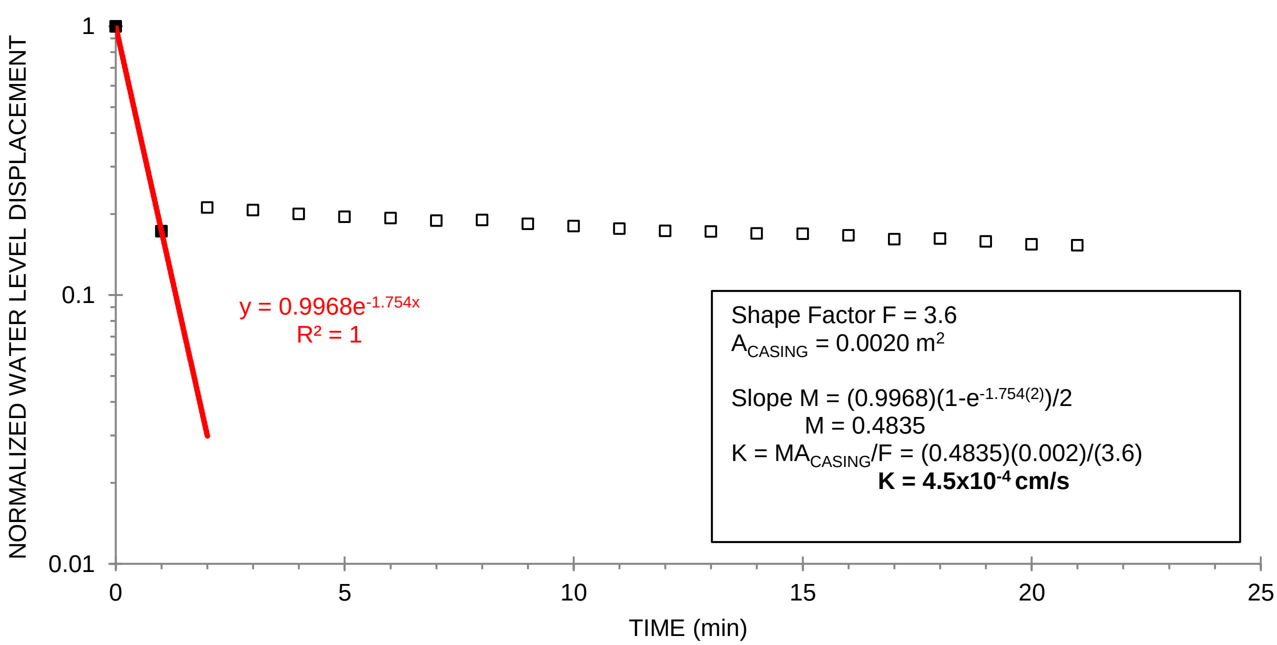


Figure 2-40

MW17-23B

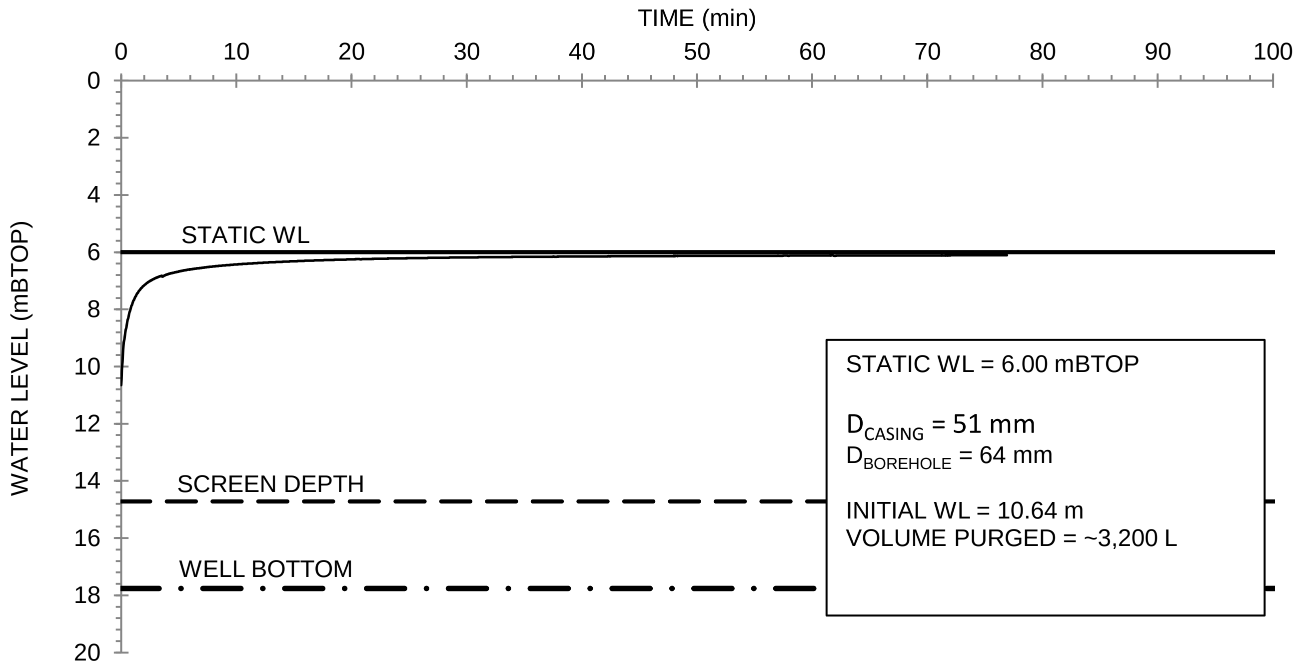
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: September 7, 2017

Performed by: BC



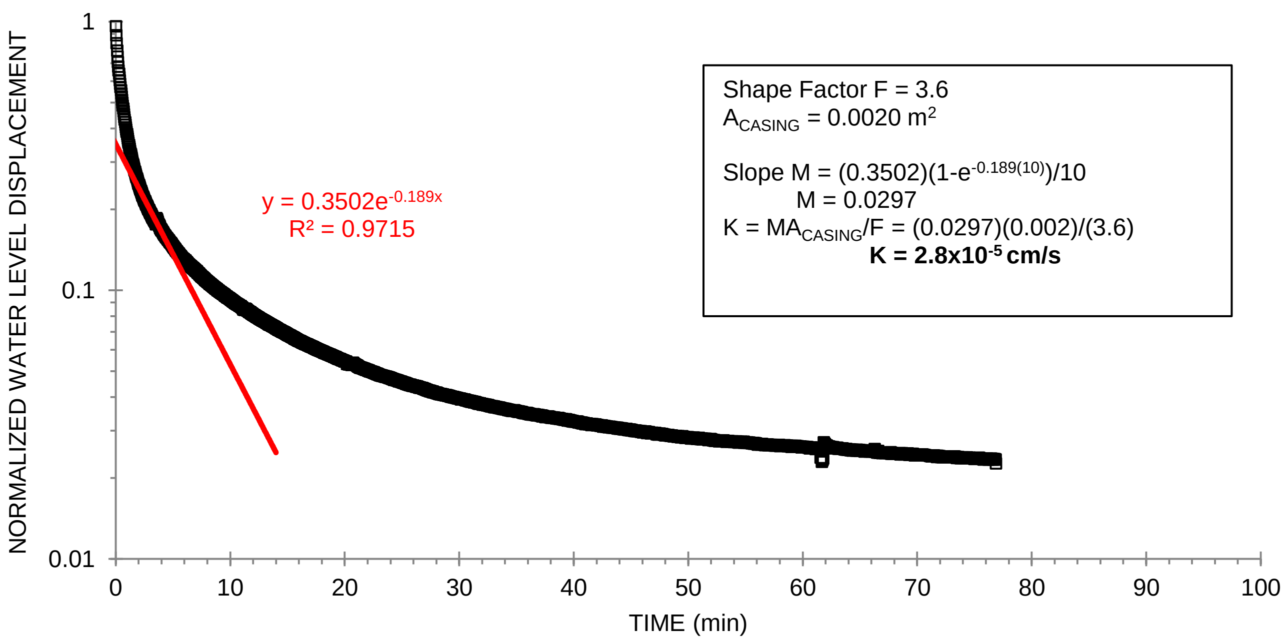


Figure 2-41

BH03-2A

Falling Head Slug Test Analysis

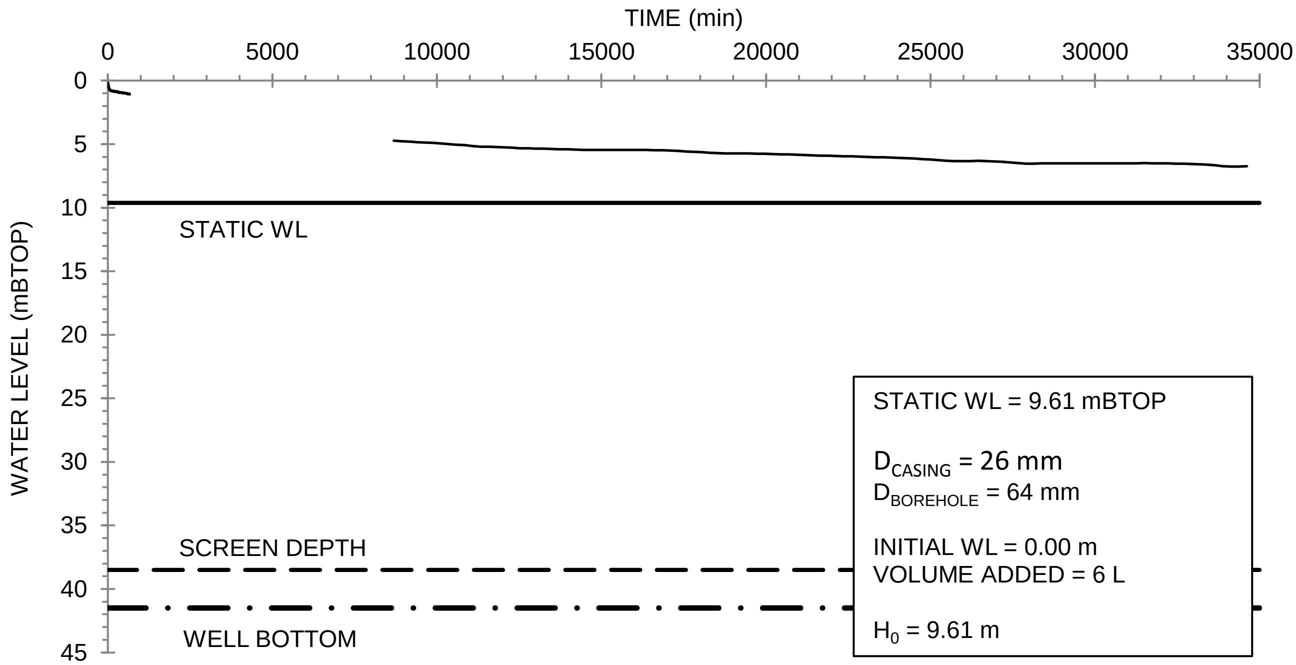
Hvorslev Method

Proposed Upper's Quarry

wsp

Date: November 11, 2016

Performed by: BC / SM



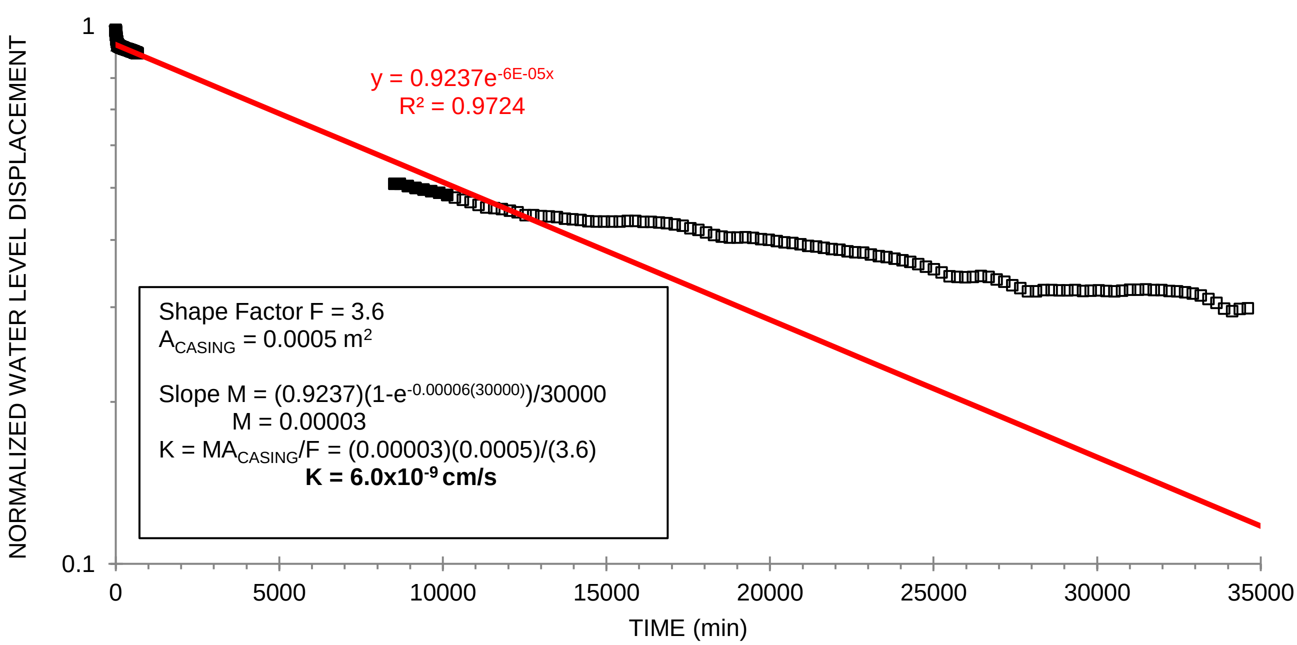


Figure 2-42

MW16-5A

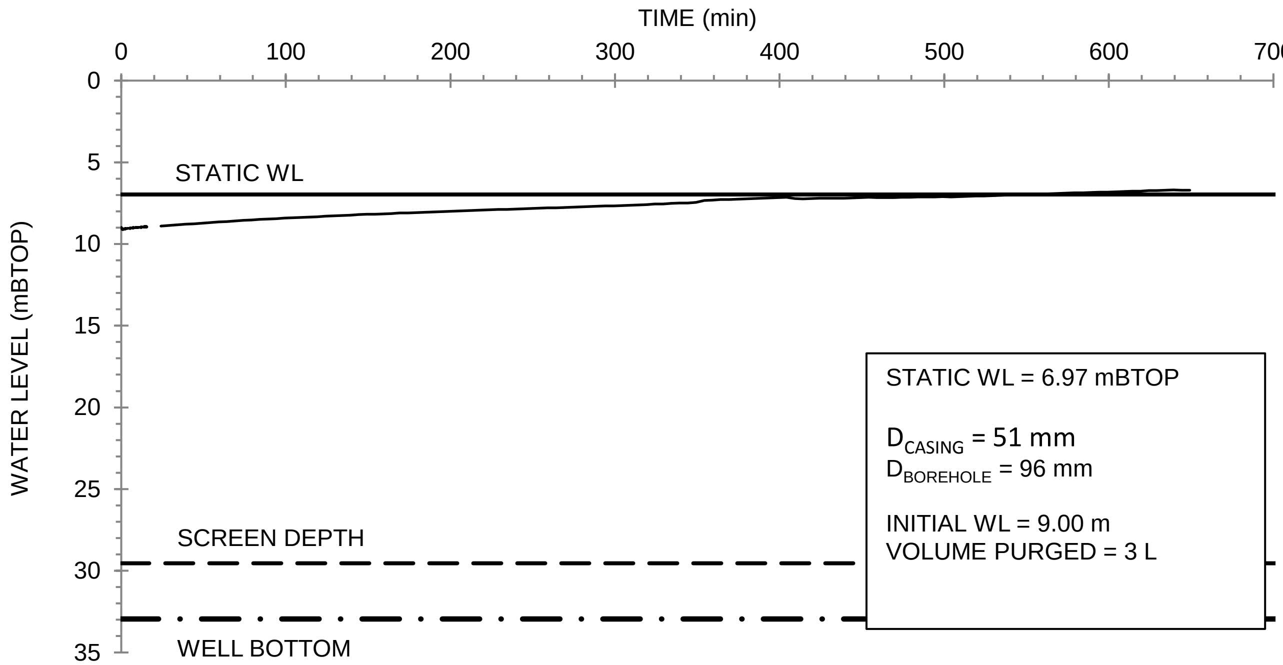
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 17, 2016

Performed by: BC / SM



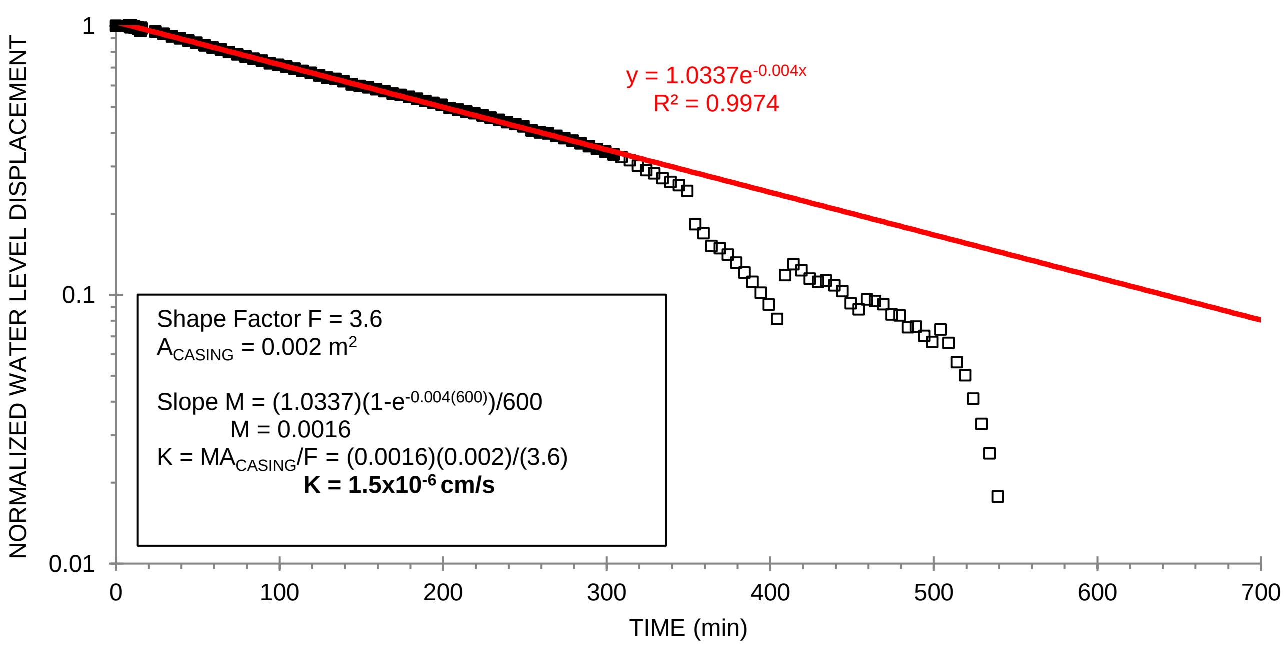


Figure 2-43

MW16-6A

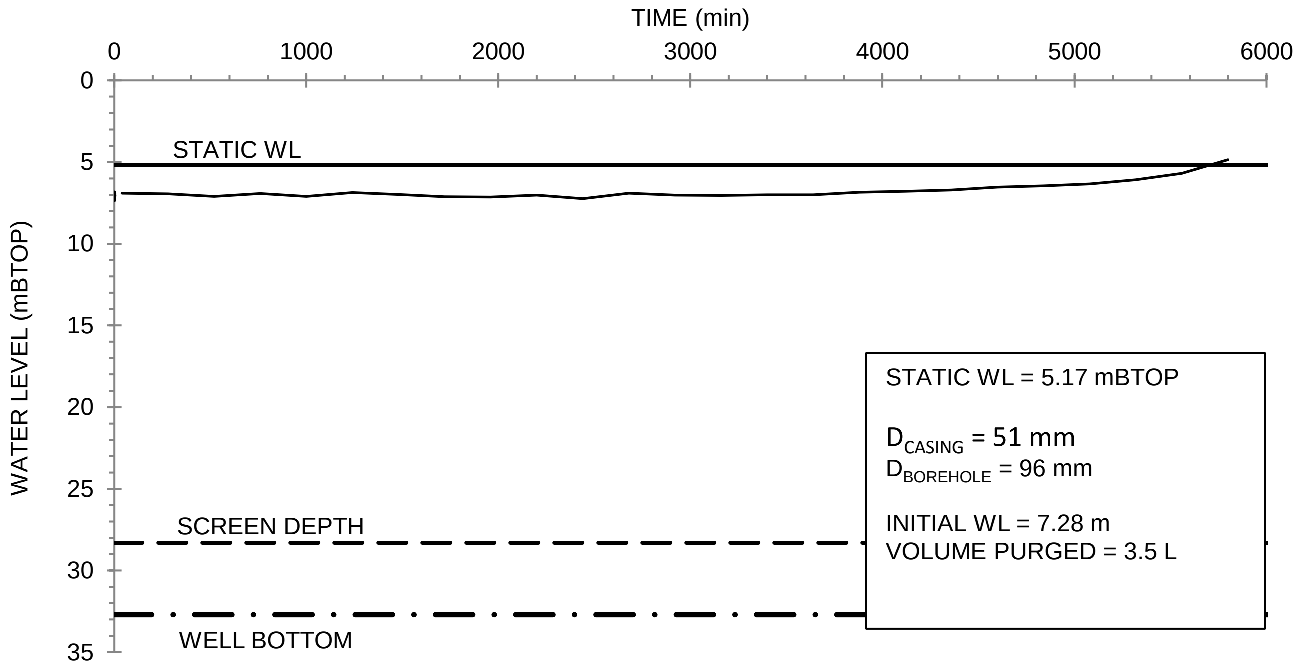
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 10, 2016

Performed by: BC / SM



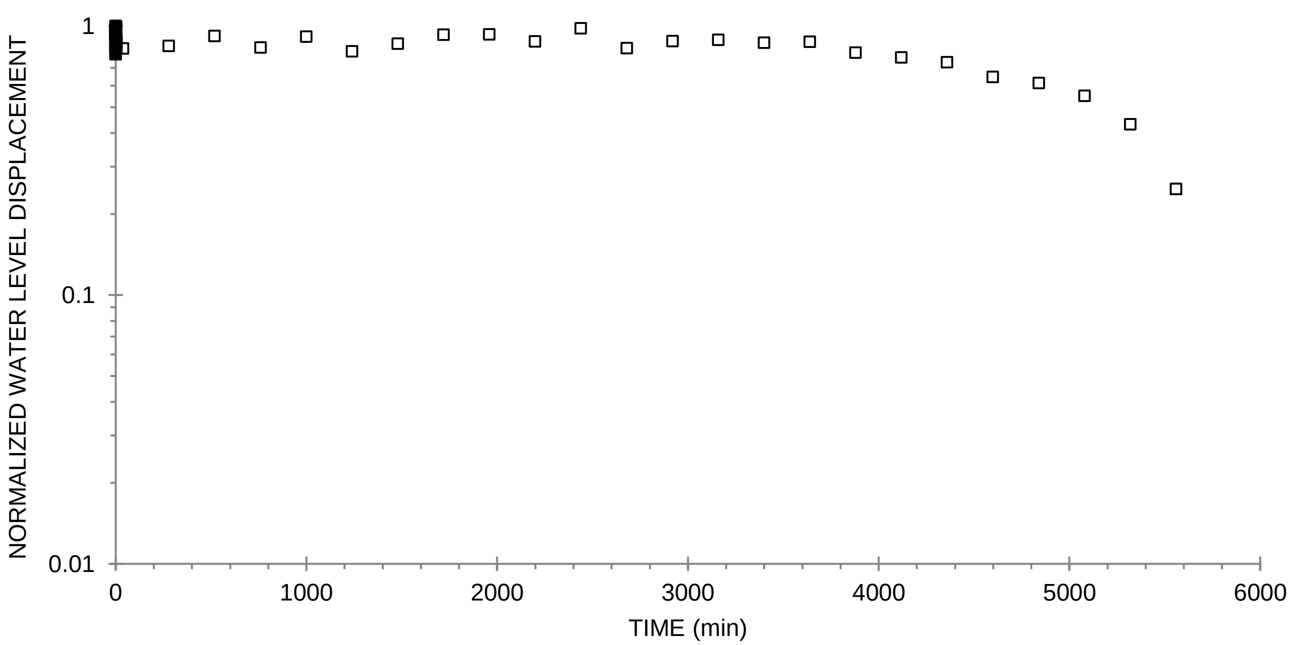


Figure 2-44

MW16-7A

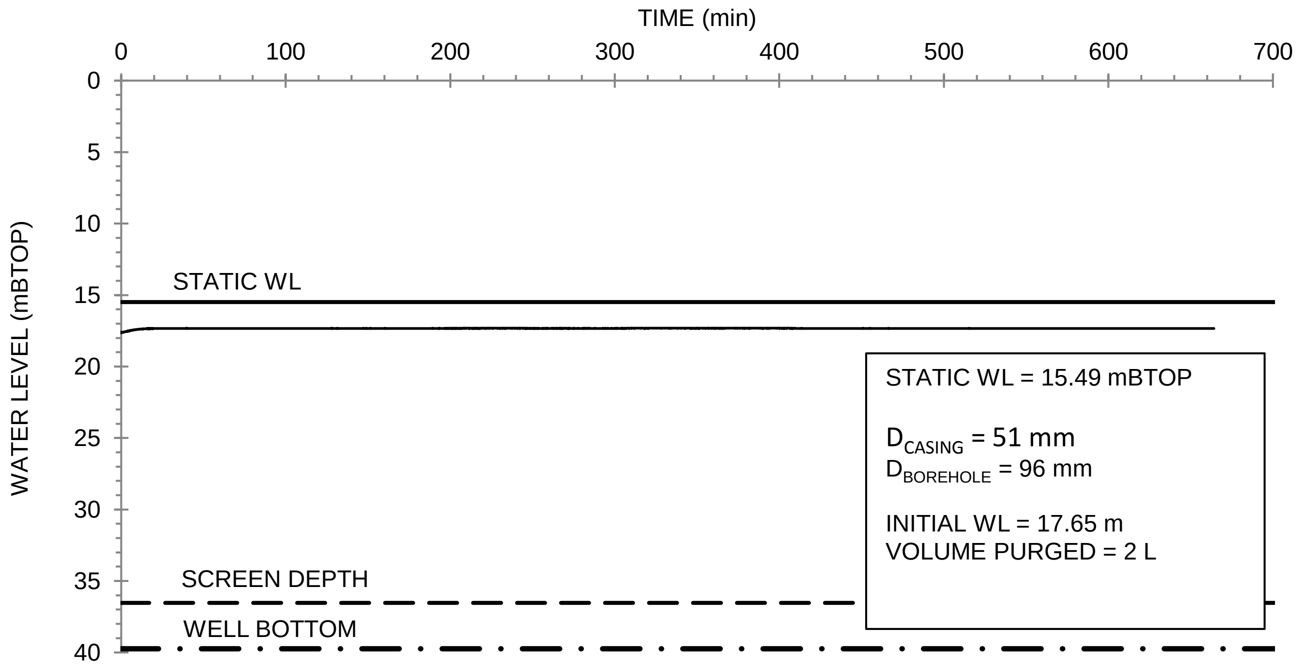
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 8, 2016

Performed by: BC / SM



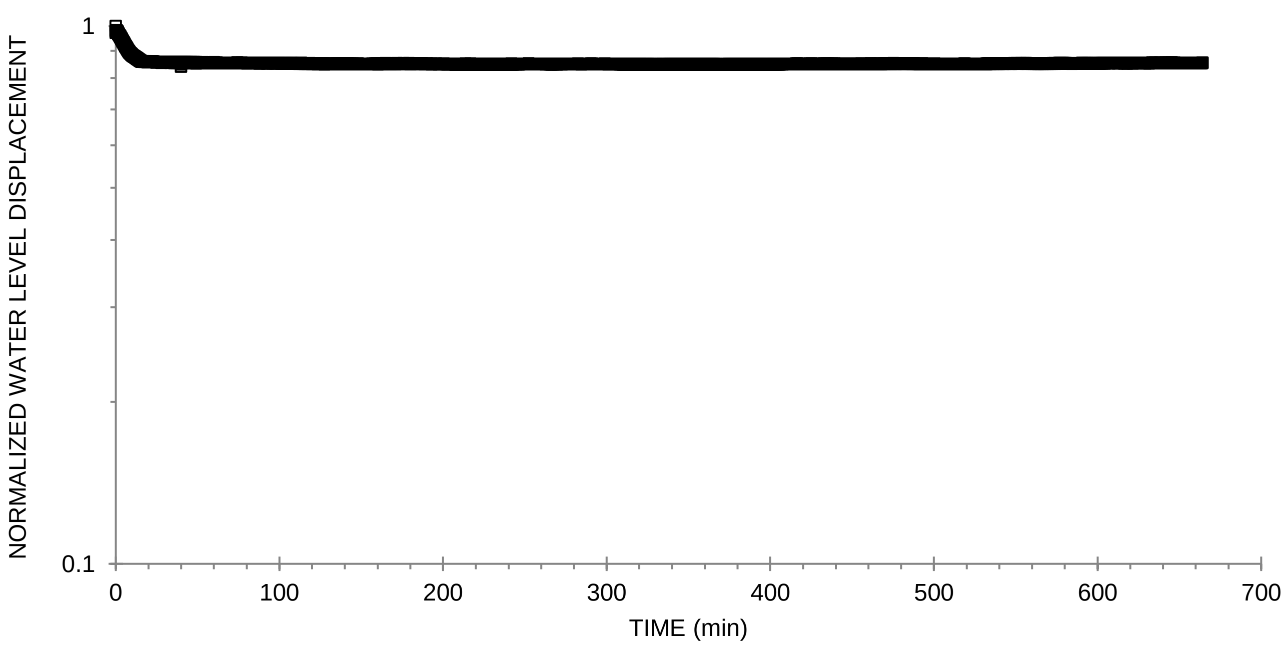


Figure 2-45

MW16-8A

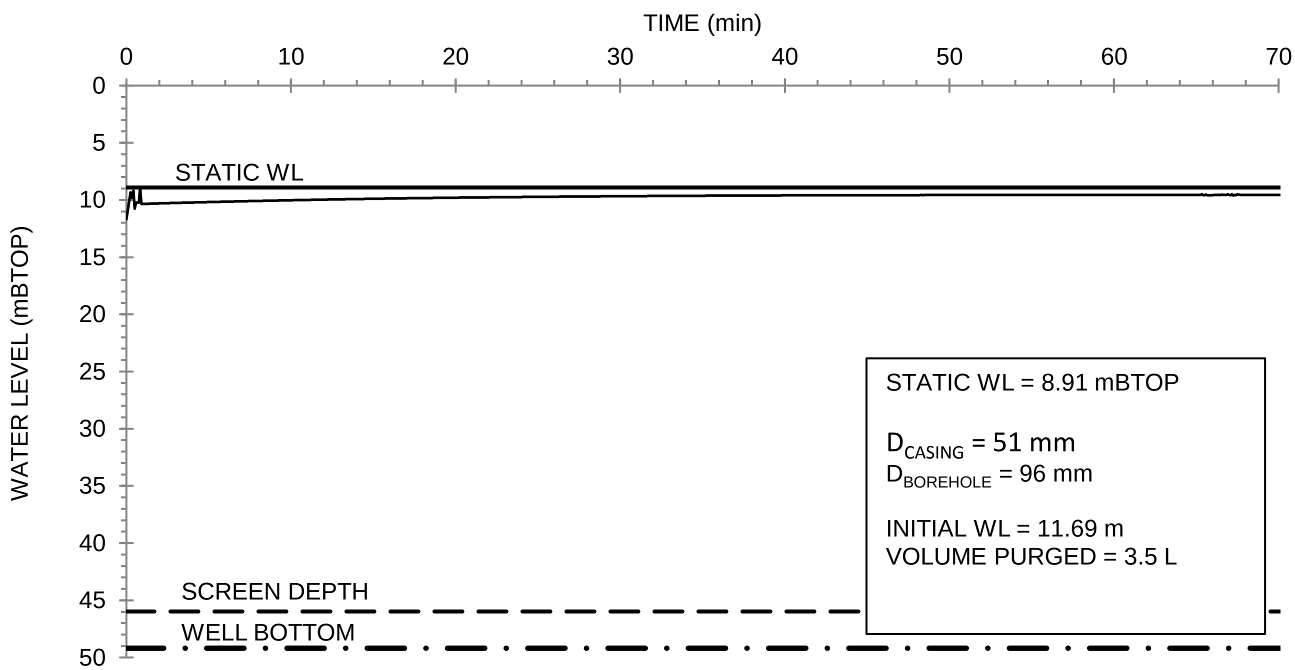
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 8, 2016

Performed by: BC / SM



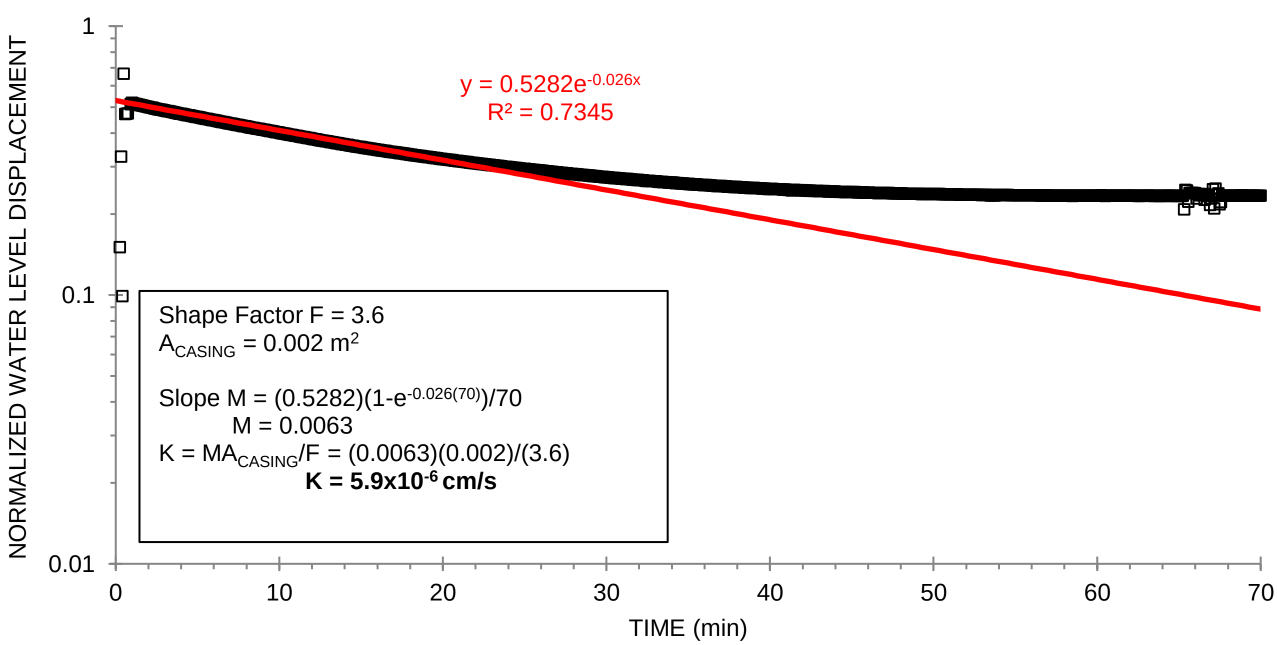


Figure 2-46

MW16-9A

Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 25, 2016

Performed by: BC / SM

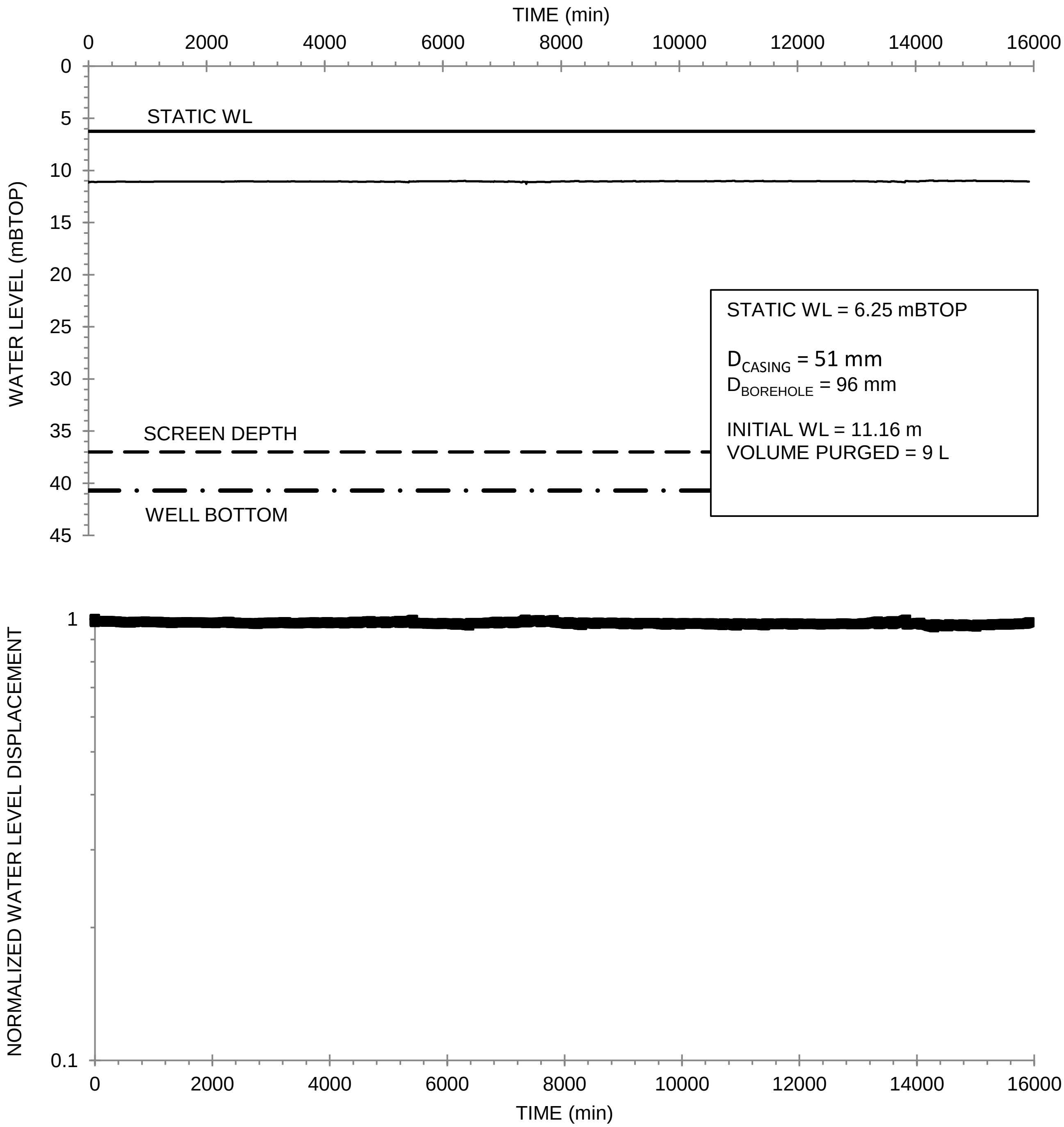


Figure 2-47

MW16-10A

Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 30, 2016

Performed by: BC / SM

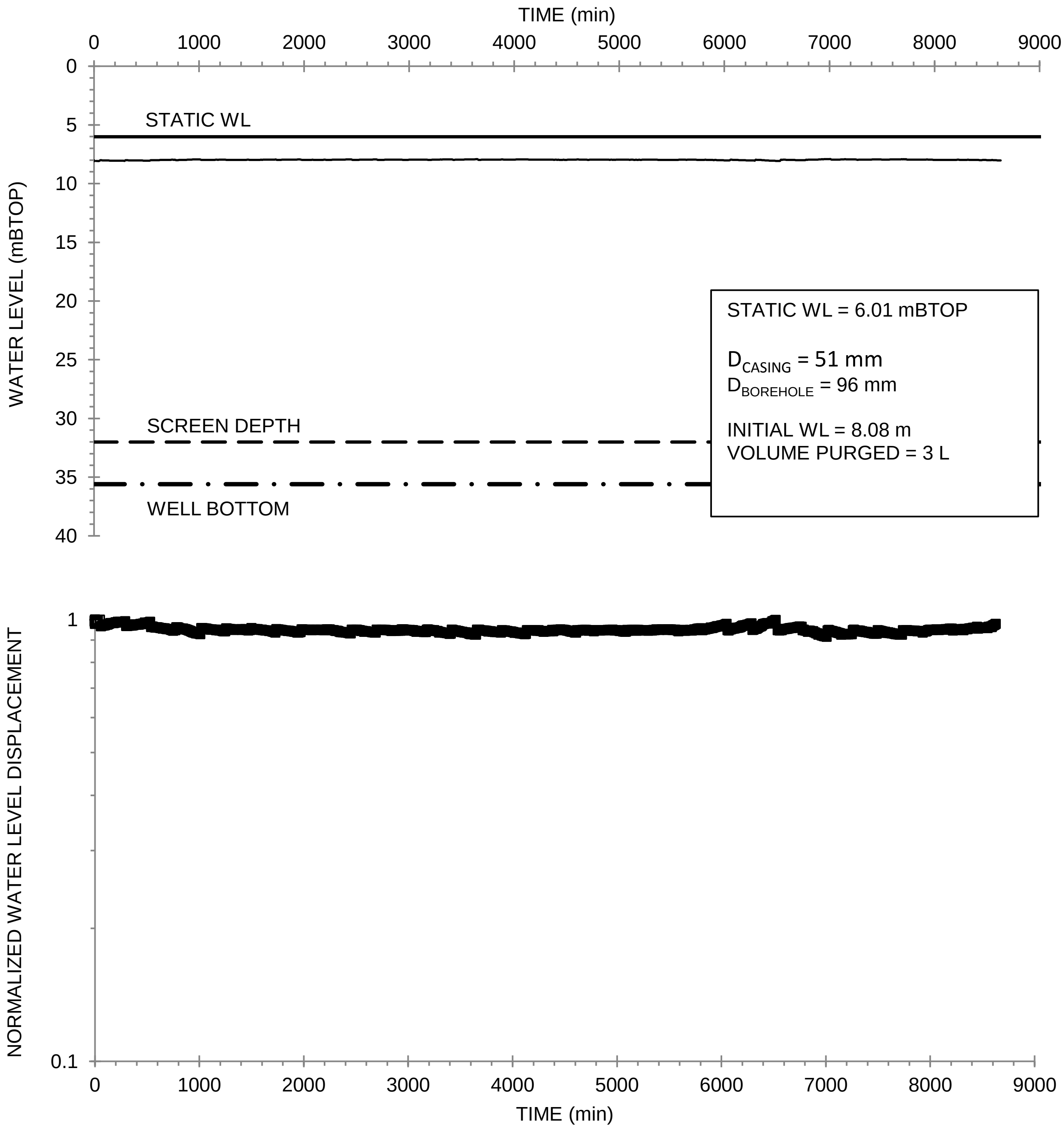


Figure 2-48

MW16-13A

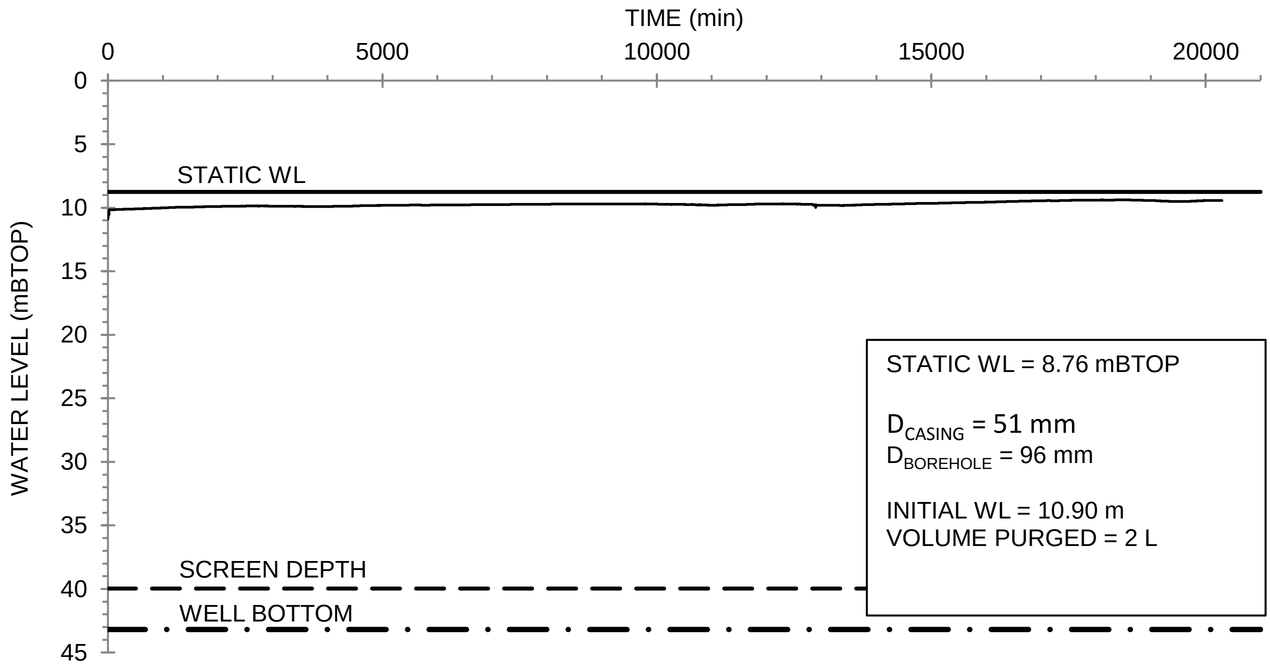
Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry

Date: November 21, 2016

Performed by: BC / SM



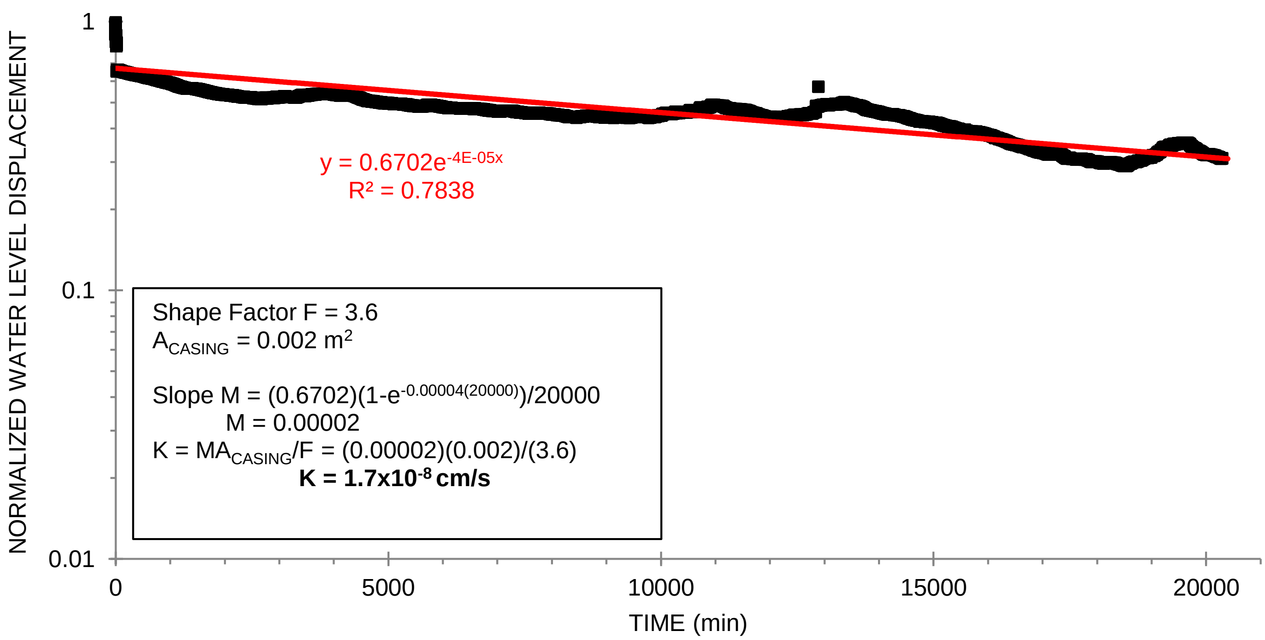


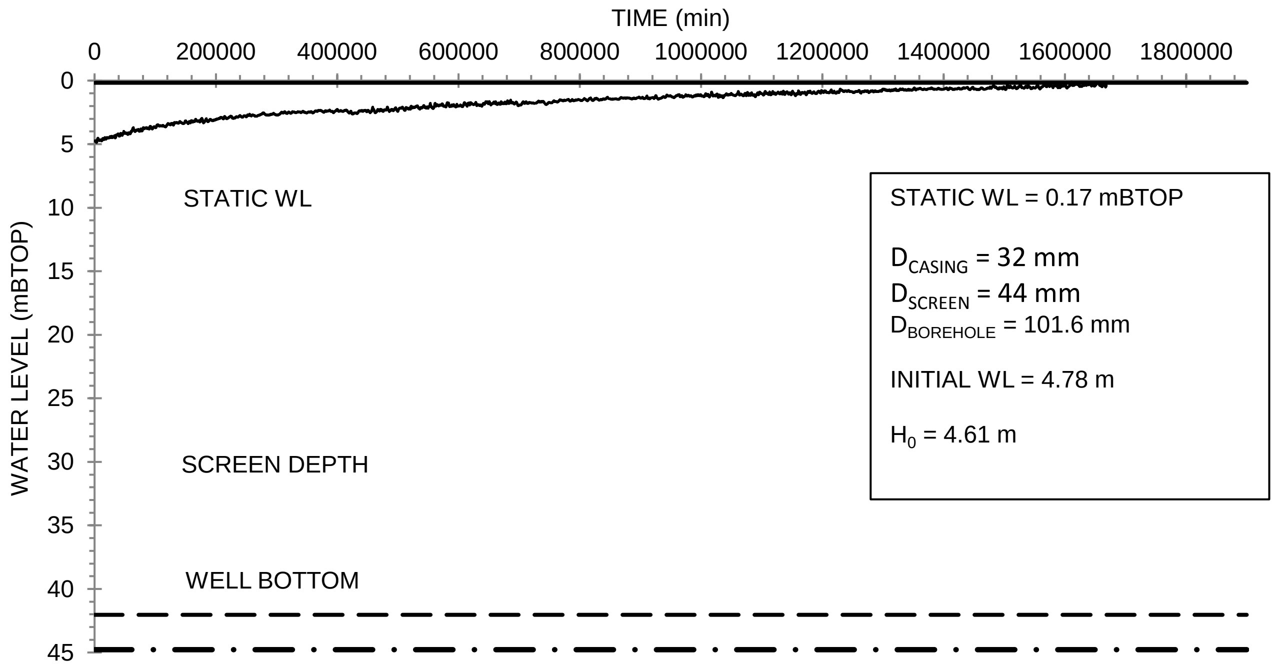
Figure 2-49

MW11-1A

Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry



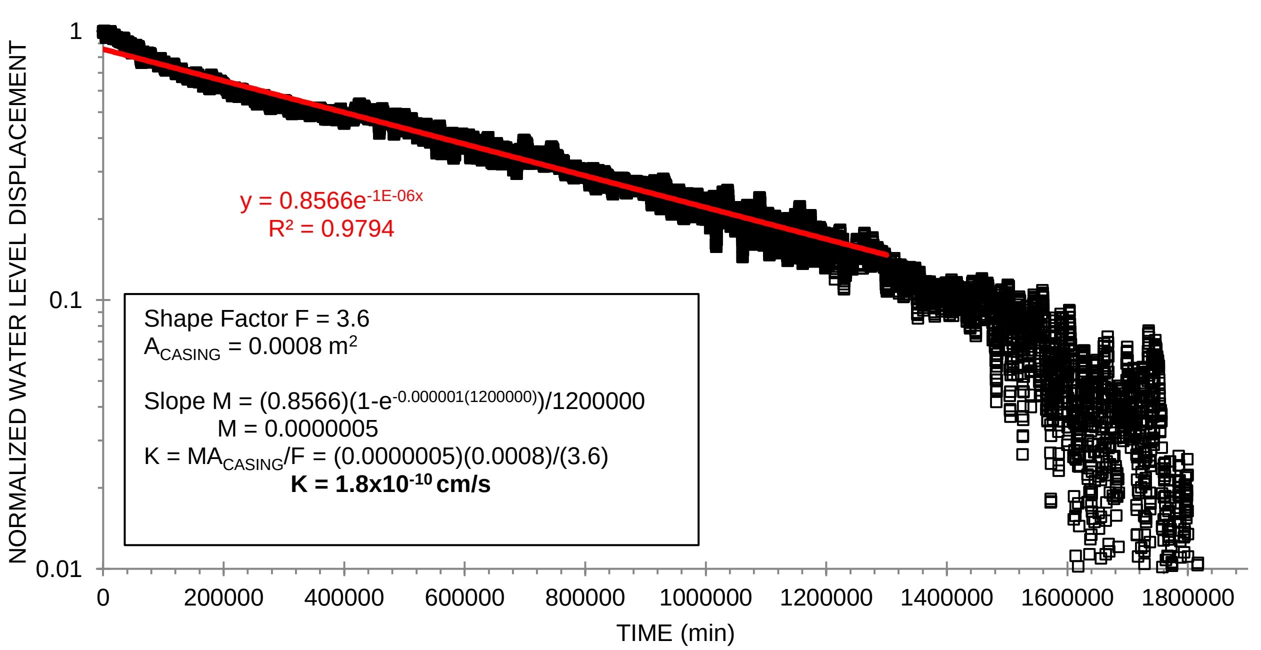


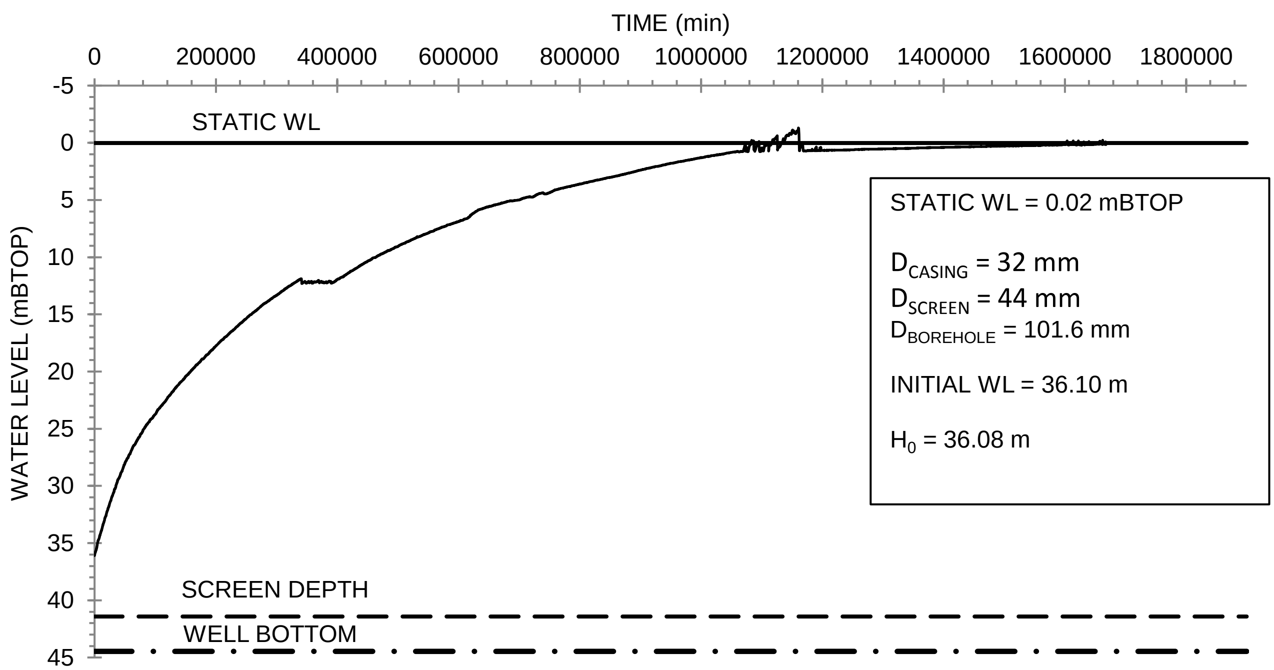
Figure 2-50

MW11-2A

Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry



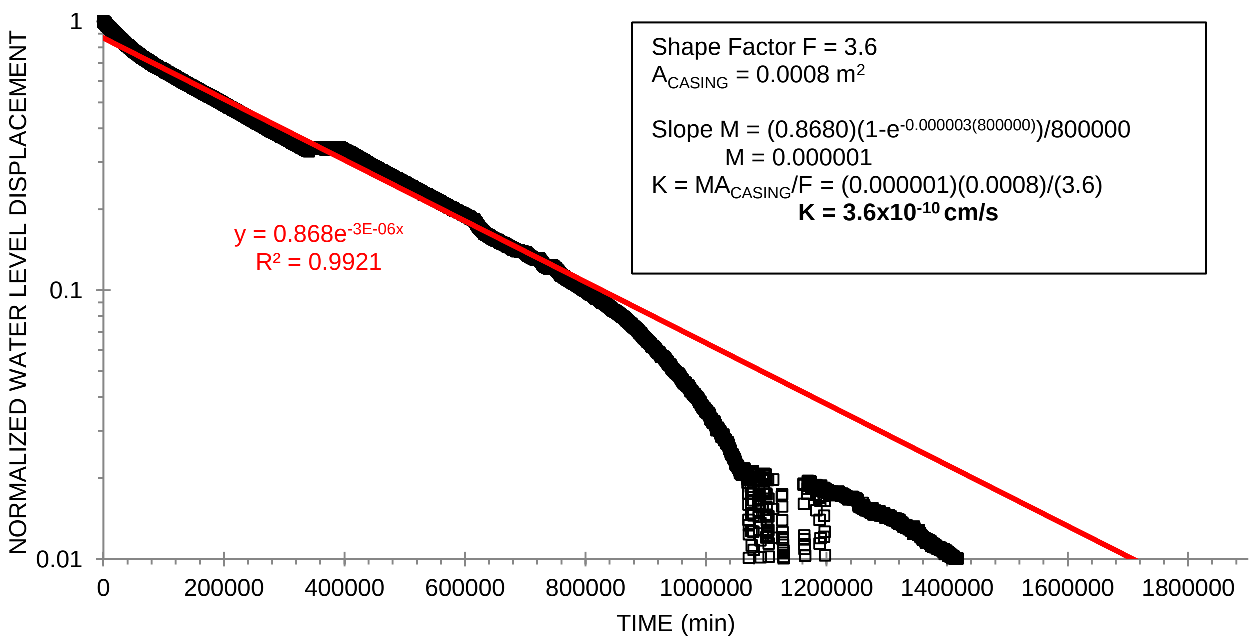


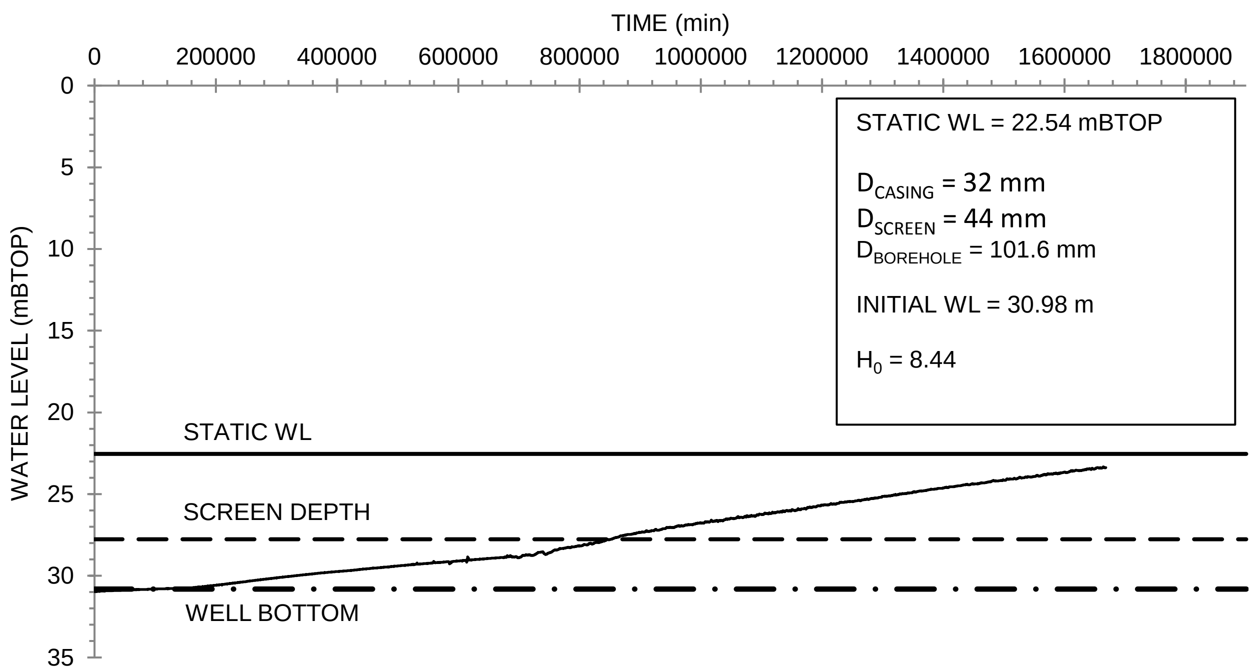
Figure 2-51

MW11-3A

Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry



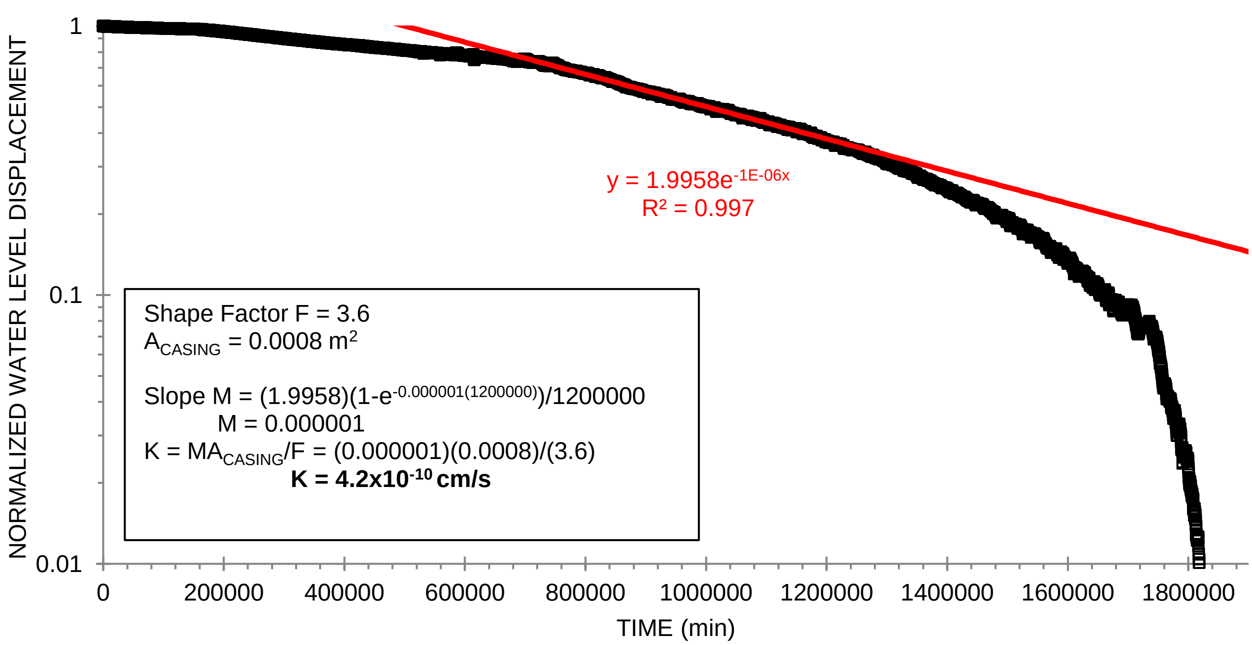


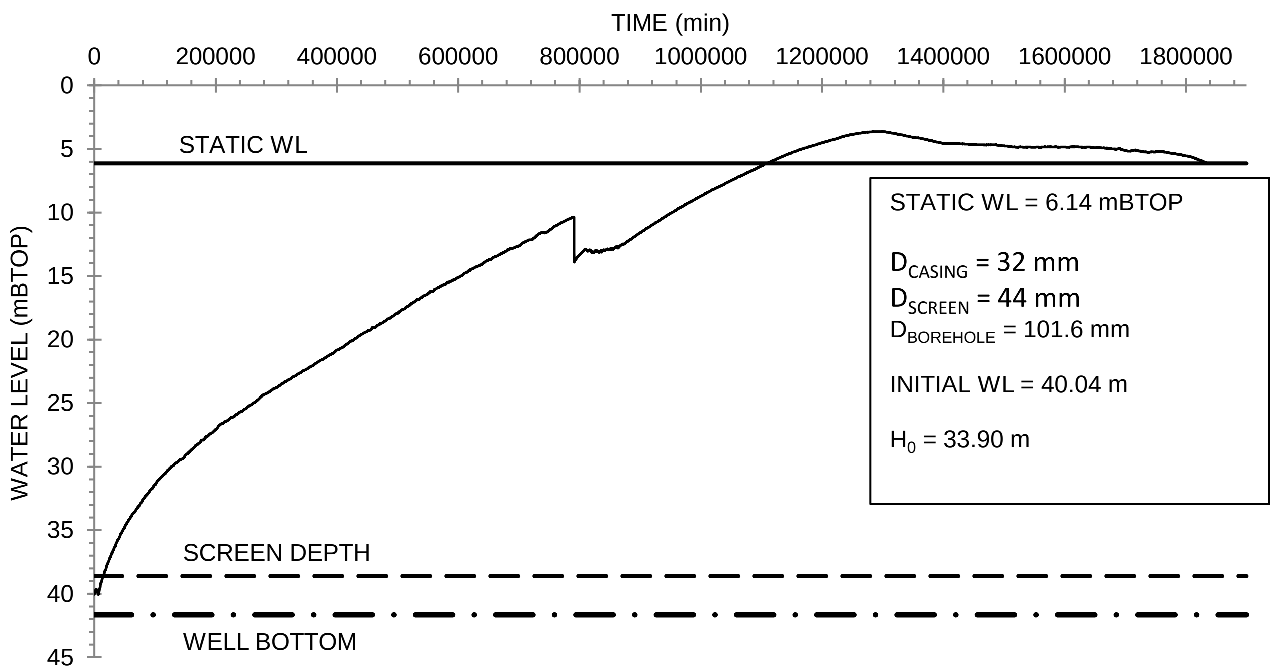
Figure 2-52

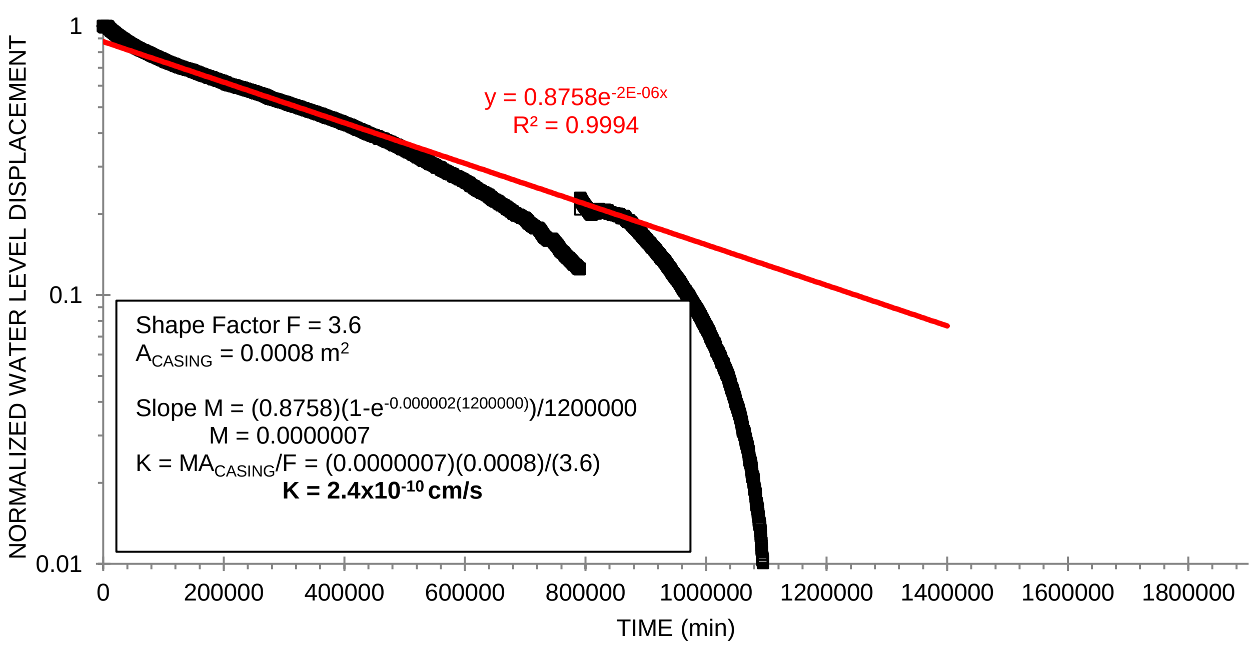
MW11-4A

Rising Head Slug Test Analysis

Hvorslev Method

Proposed Upper's Quarry





APPENDIX

D-3 2017 PUMPING TEST ANALYSES

Figure 3 -1 - PW1 Step Test Water Levels
February 7 - 8, 2017

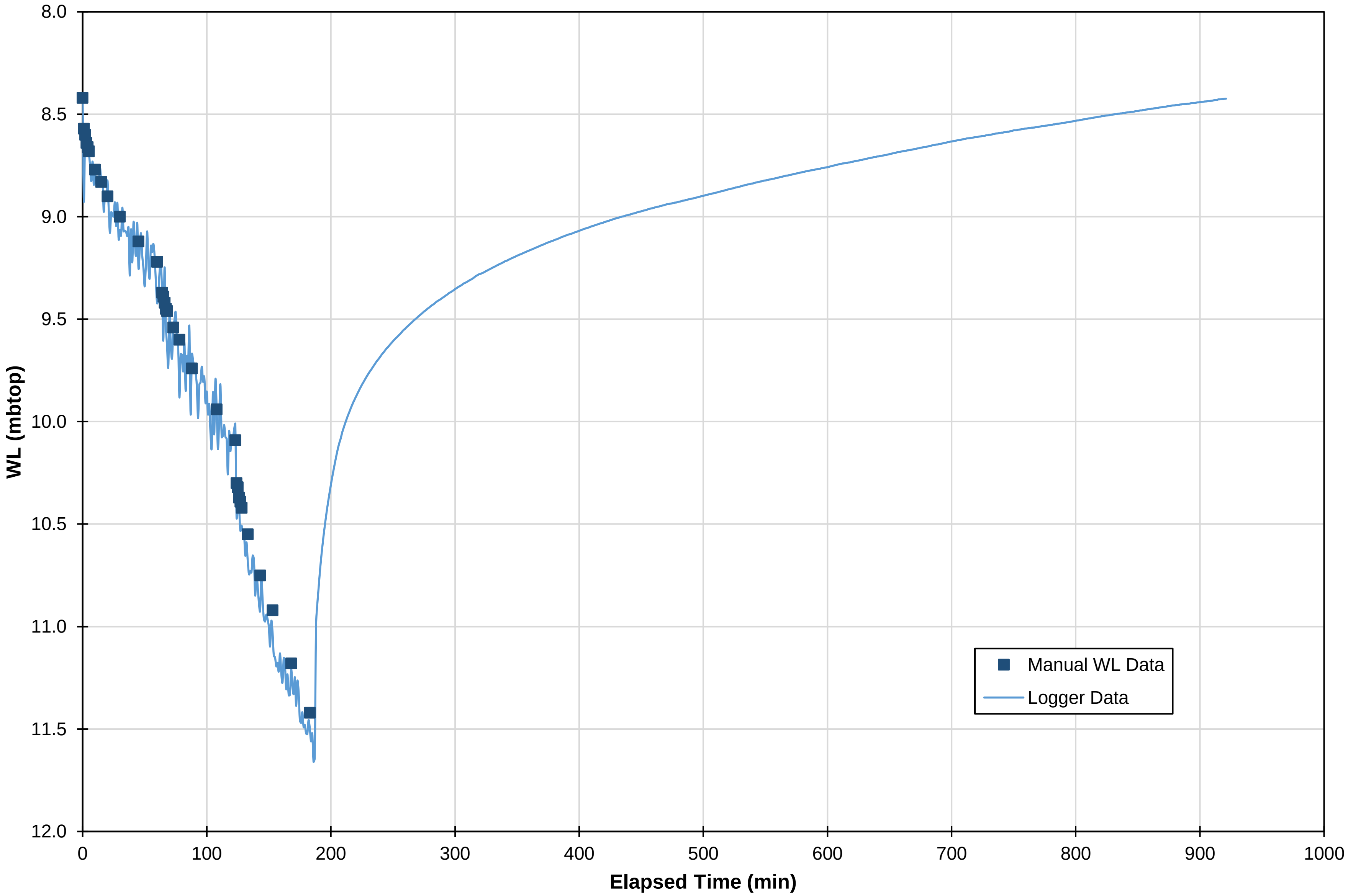
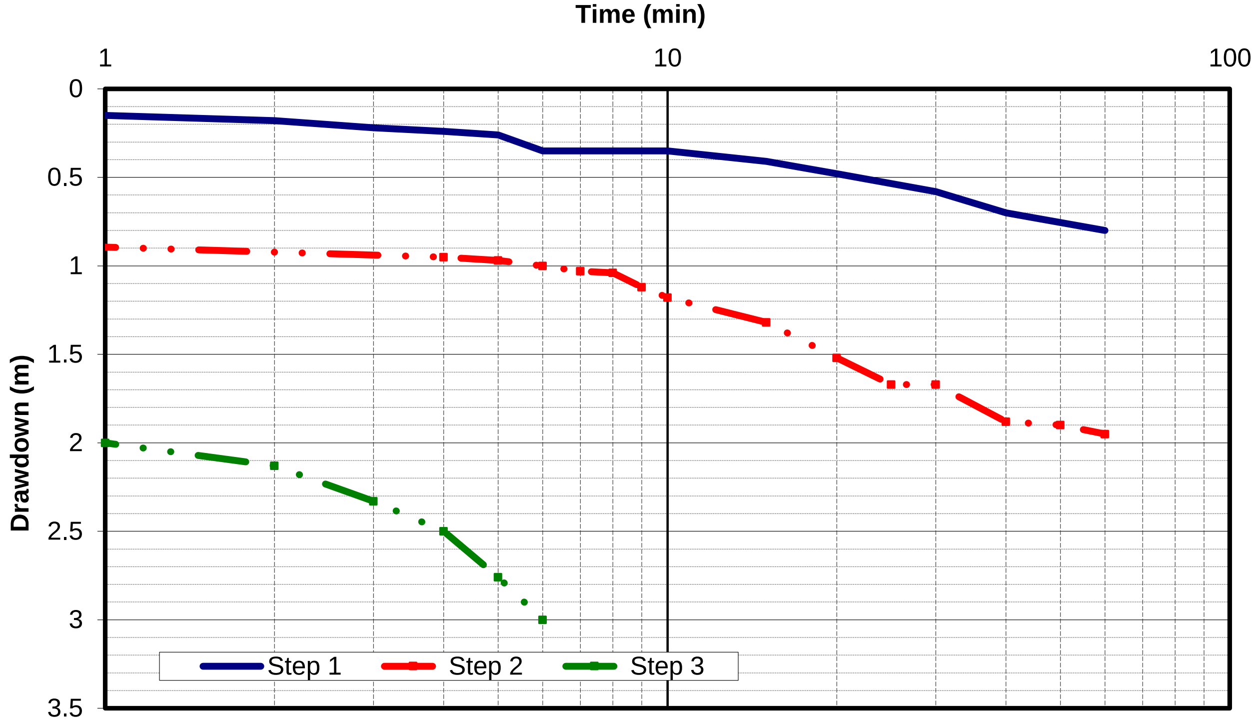


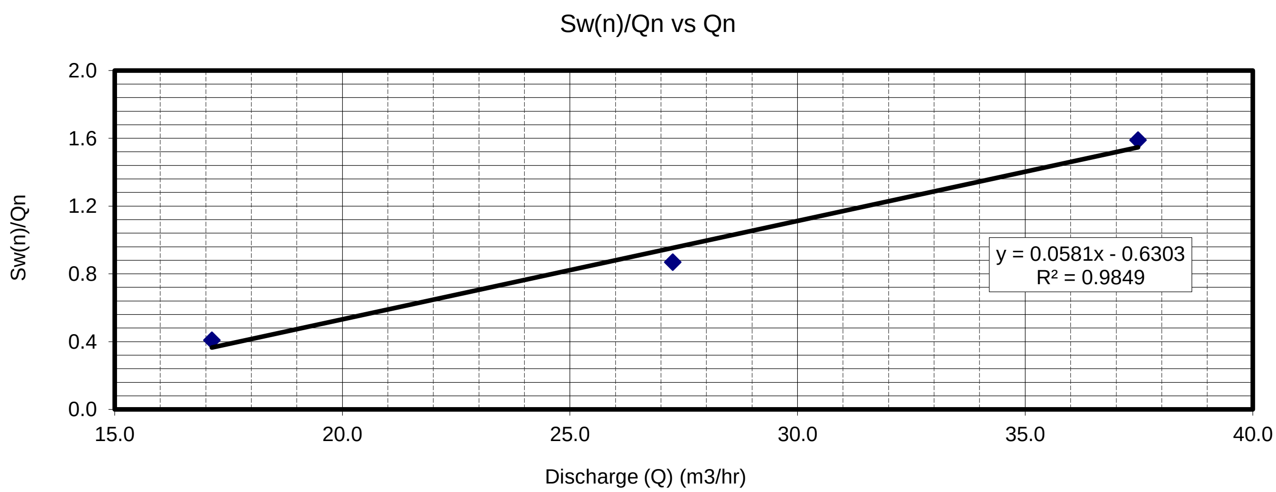
Figure 3-2 - Step Test Analysis - PW1



Interval (n)	Qn m^3/hr	^deltaSwn m	Sw(n) m	Swn/Qn hr/m^2	Well Efficiency %
1	17.1	6.98	6.98	0.41	39%
2	27.3	16.7	23.68	0.87	28%
3	37.5	35.87	59.55	1.59	22%

Constants (from Graph): B = 0.6303 Intercept

C = 0.0581 Slope



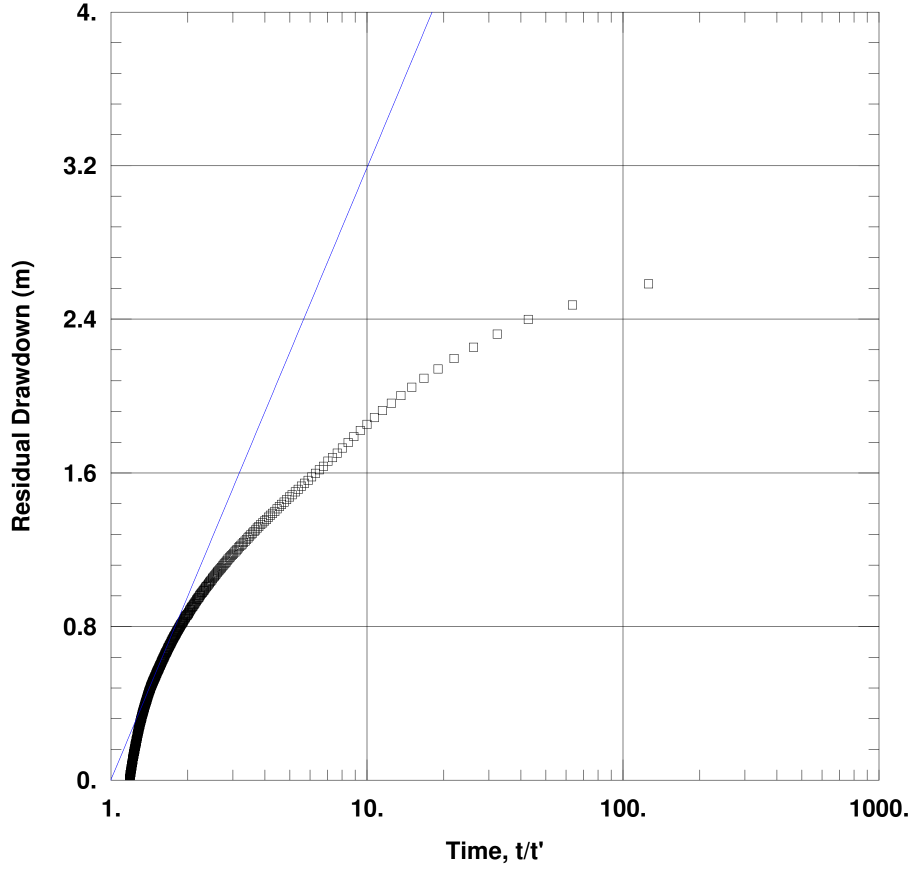


FIGURE 3-3 - PW1 STEP TEST RECOVERY

Data Set: H:\...\PW1 Step Test Recovery.aqt
Date: 06/12/20 Time: 15:27:01

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 7-Feb-2017

SOLUTION

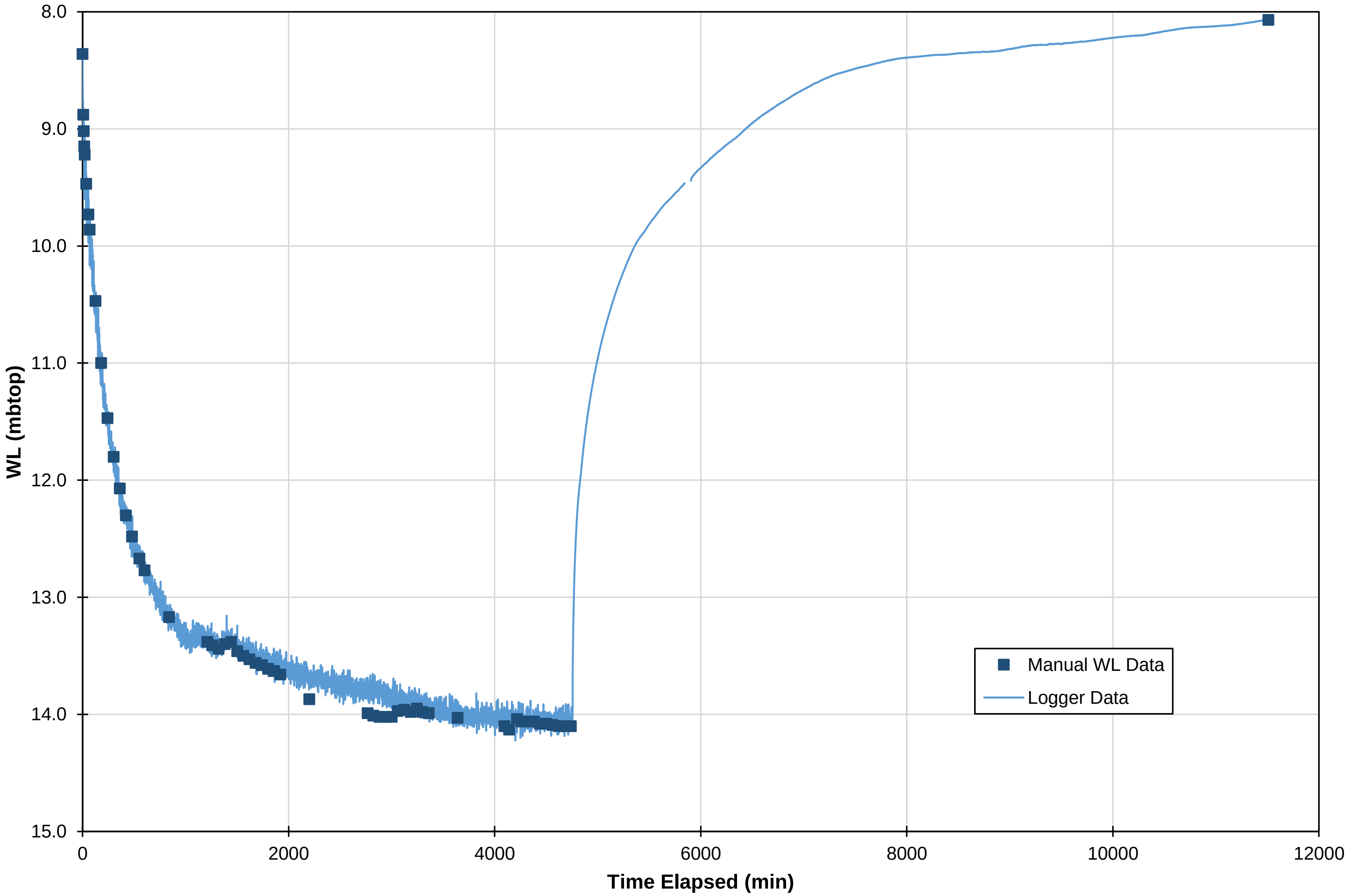
Aquifer Model: Confined
Solution Method: Theis (Recovery)
T = 62.12 m^2/day
S/S' = 1.

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

Figure 3-4 - PW1 Pumping Test Water Levels
February 8 - 16, 2017



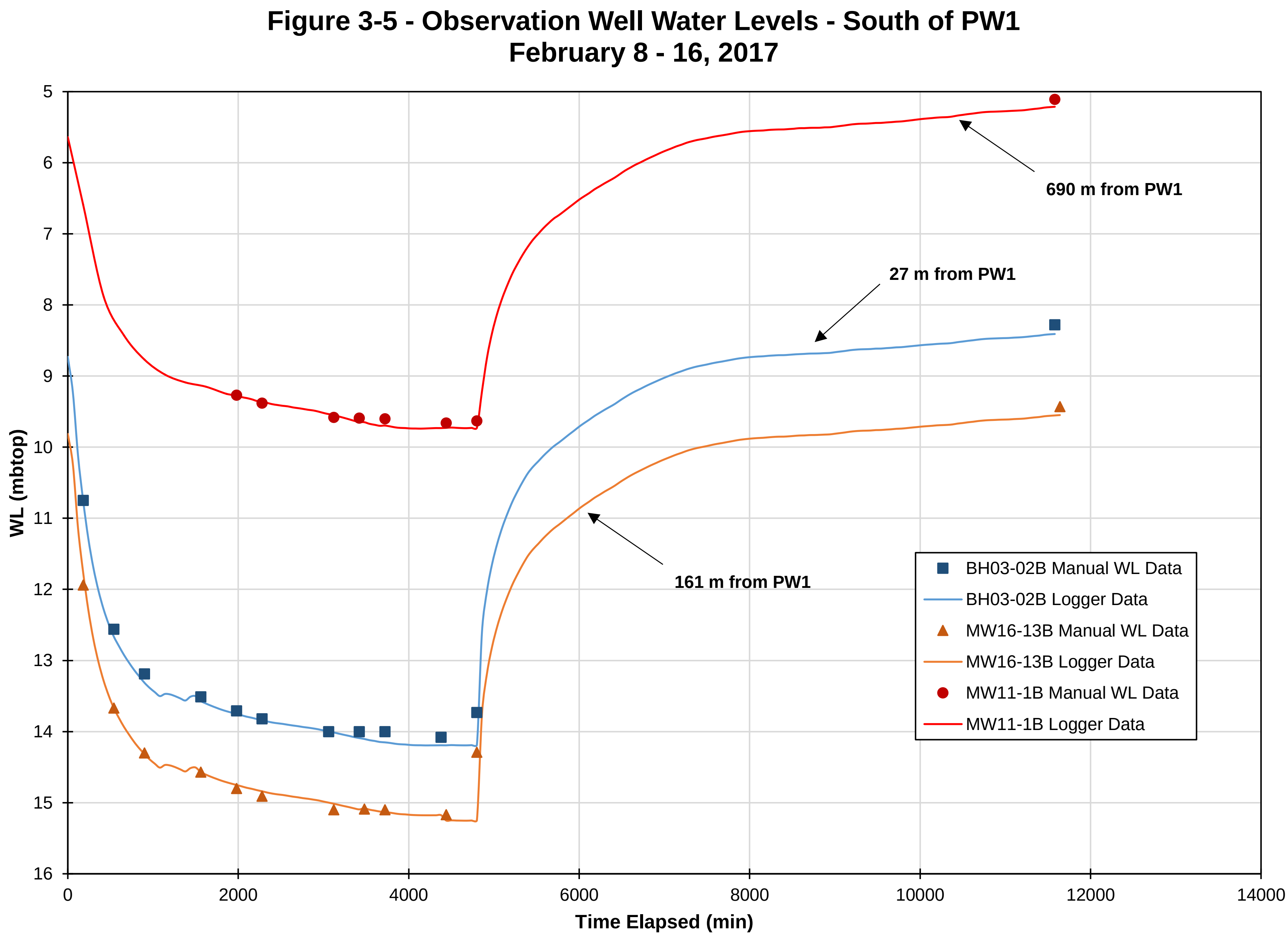


Figure 3-5 - Observation Well Water Levels - South of PW1
February 8 - 16, 2017
WL (mbtop)
Time Elapsed (min)
690 m from PW1
27 m from PW1
161 m from PW1
BH03-02B Manual WL Data
BH03-02B Logger Data
MW16-13B Manual WL Data
MW16-13B Logger Data
MW11-1B Manual WL Data
MW11-1B Logger Data
5
6
7
8
9
10
11
12
13
14
15
16
0
2000
4000
6000
8000
10000
12000
14000

Figure 3-6 - Observation Well Water Levels - North of PW1
February 8 - 16, 2017

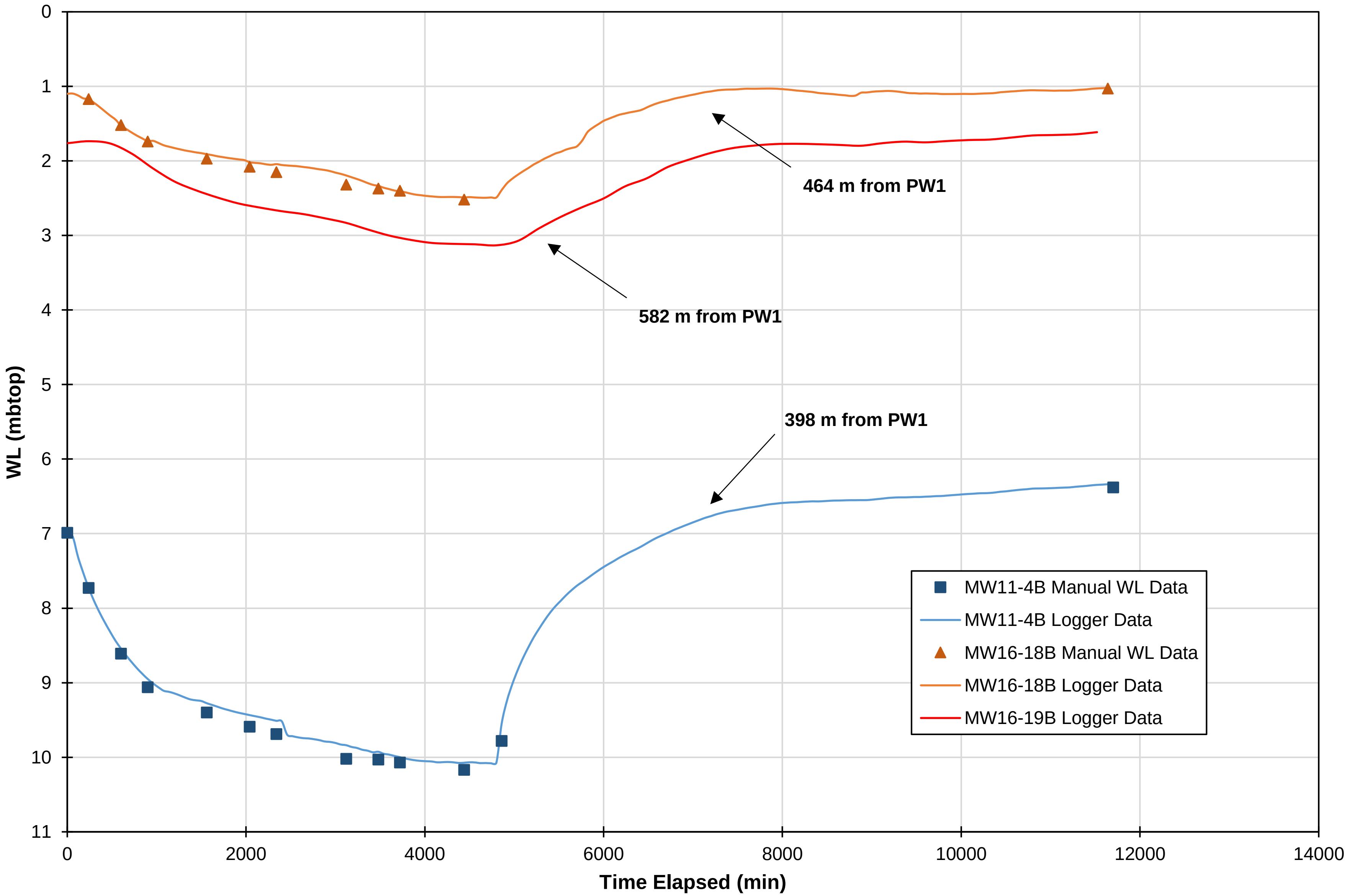
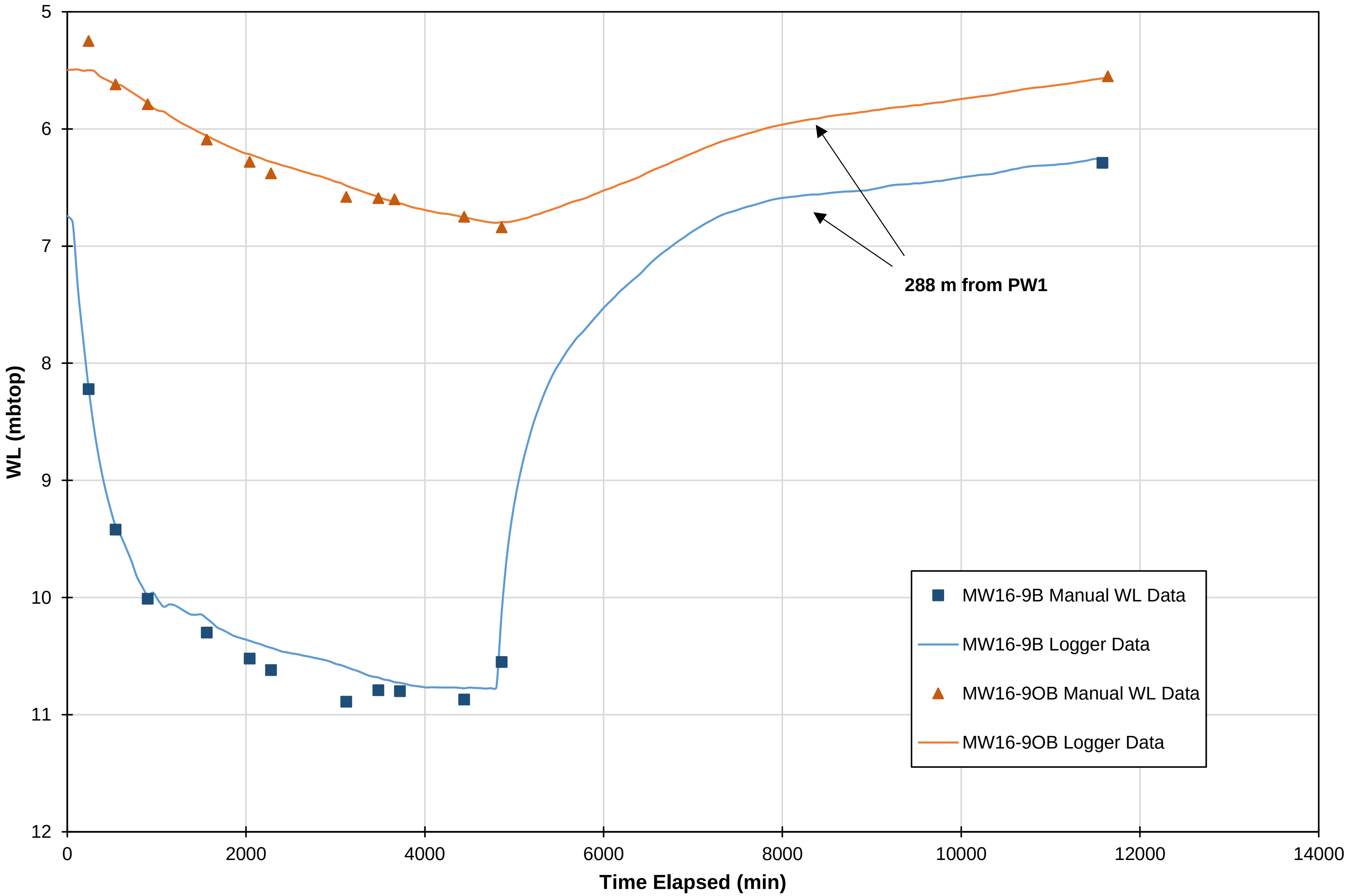


Figure 3-7 - Observation Well Water Levels - West of PW1
February 8 - 16, 2017



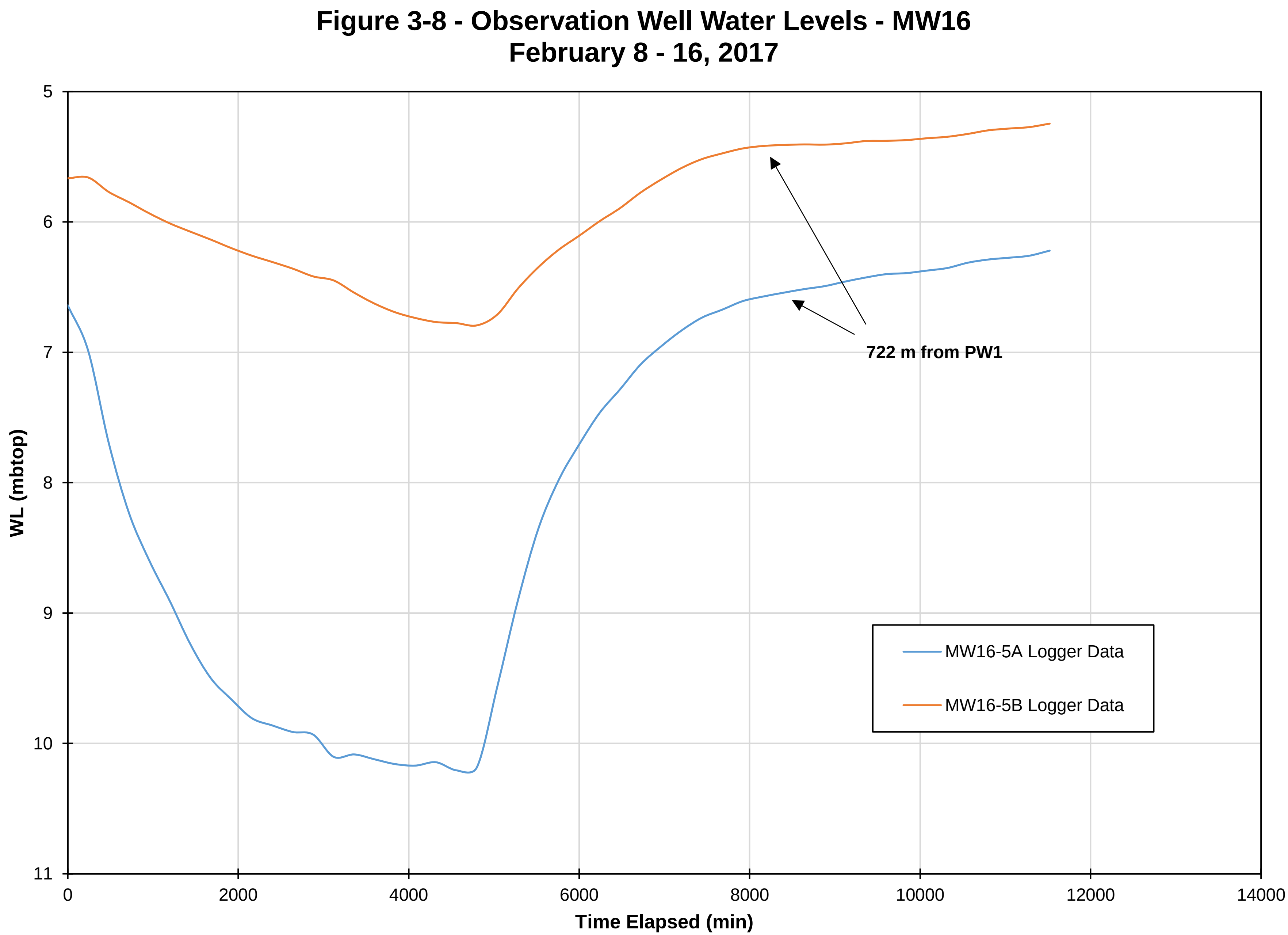


Figure 3-8 - Observation Well Water Levels - MW16
February 8 - 16, 2017
WL (mbtop)
Time Elapsed (min)
5
6
7
8
9
10
11
0
2000
4000
6000
8000
10000
12000
14000
722 m from PW1
MW16-5A Logger Data
MW16-5B Logger Data

Figure 3-9 - Observation Well Water Levels - Southeast of PW1
February 8 - 16, 2017

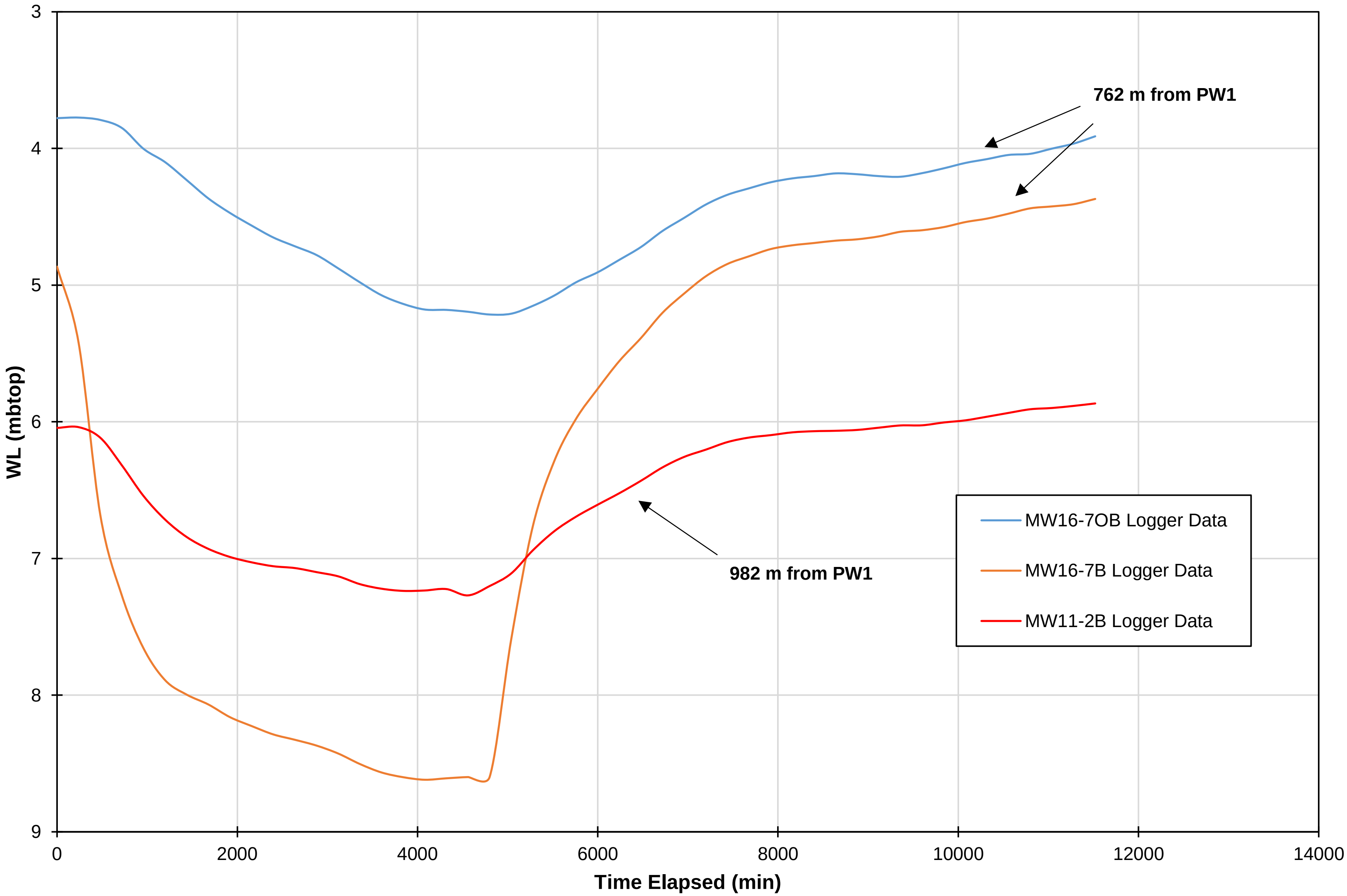
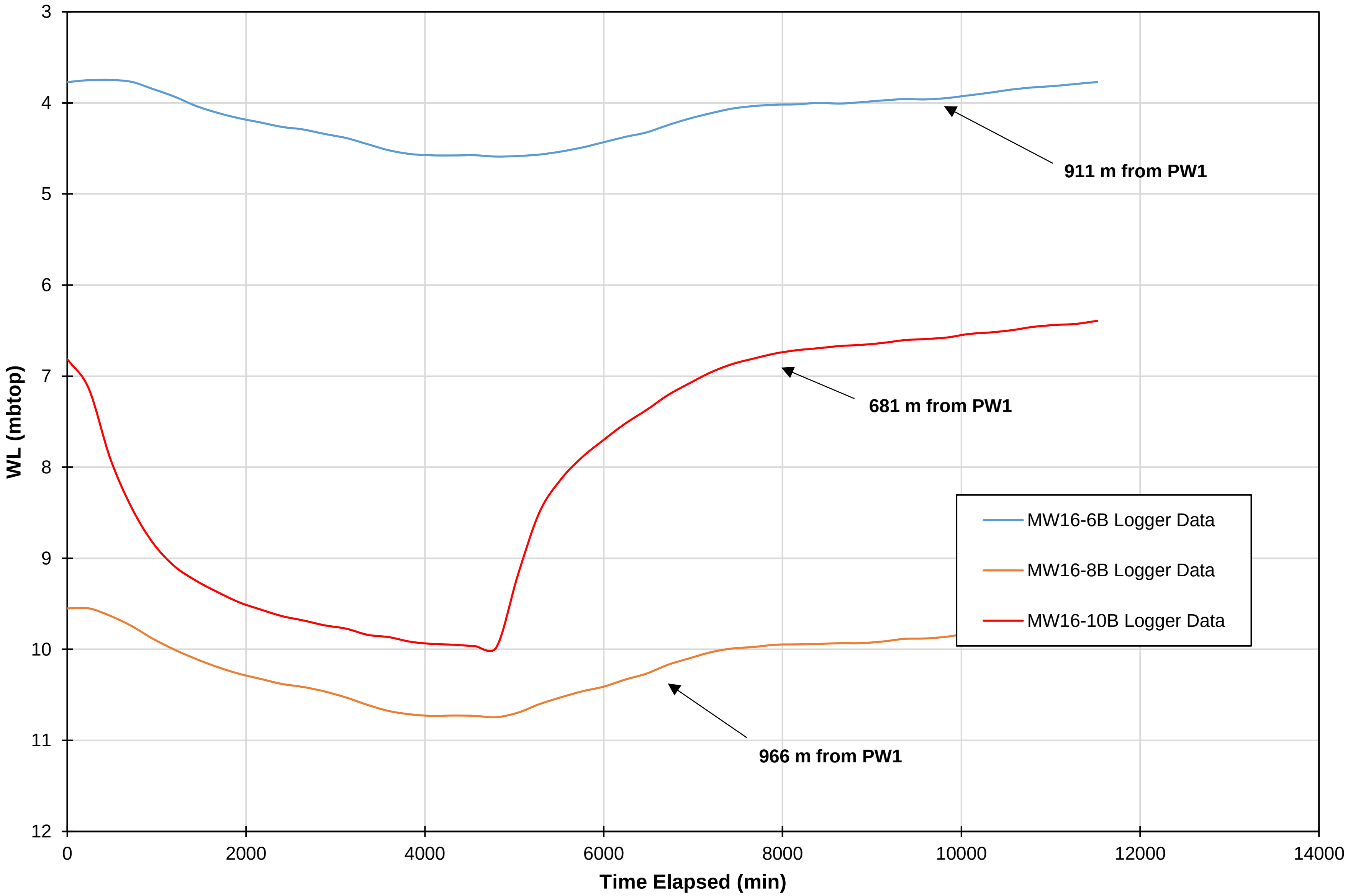


Figure 3-10 - Observation Well Water Levels - Distant Wells
February 8 - 16, 2017



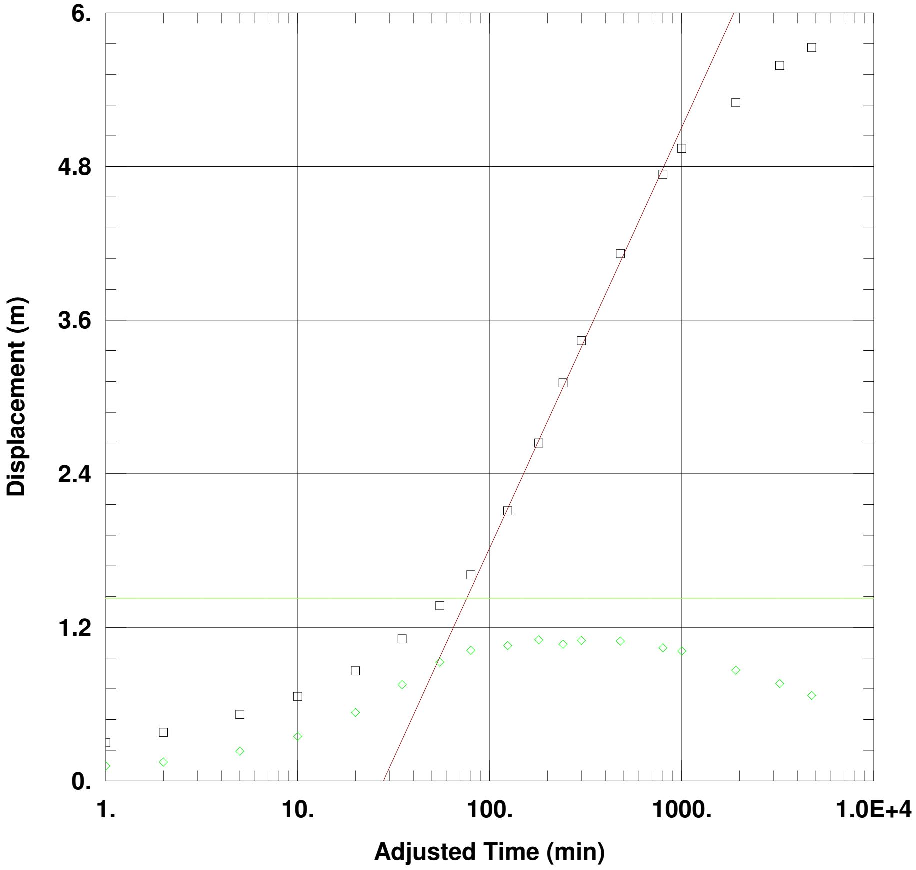


FIGURE 3-11 - 2017 PT - PW1 DDN CJSL ANALYSIS

Data Set: H:\...\2017 PW1 ddn - CJSL.aqt
Date: 06/12/20 Time: 15:00:02

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 46.01 m^2/day
S = 194.9

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

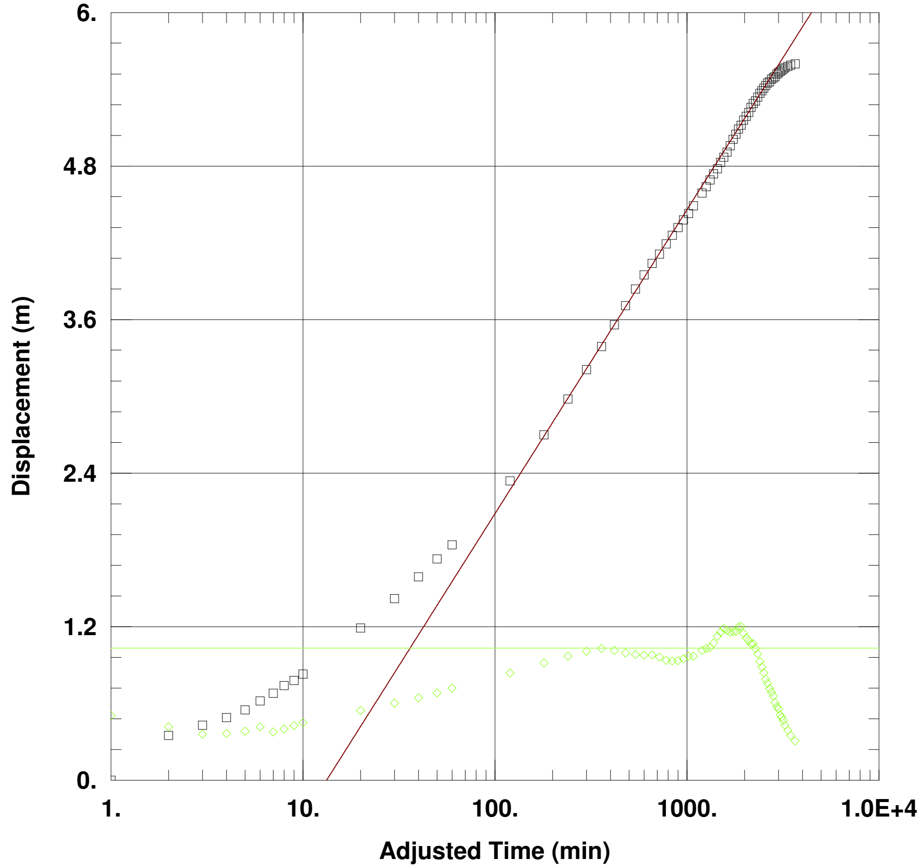


FIGURE 3-12 - 2017 PT - PW1 REC CJSL ANALYSIS

Data Set: H:\...\2017 PW1 rec - CJSL.aqt
Date: 06/12/20 Time: 15:04:35

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 63.63 m^2/day
S = 128.2

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

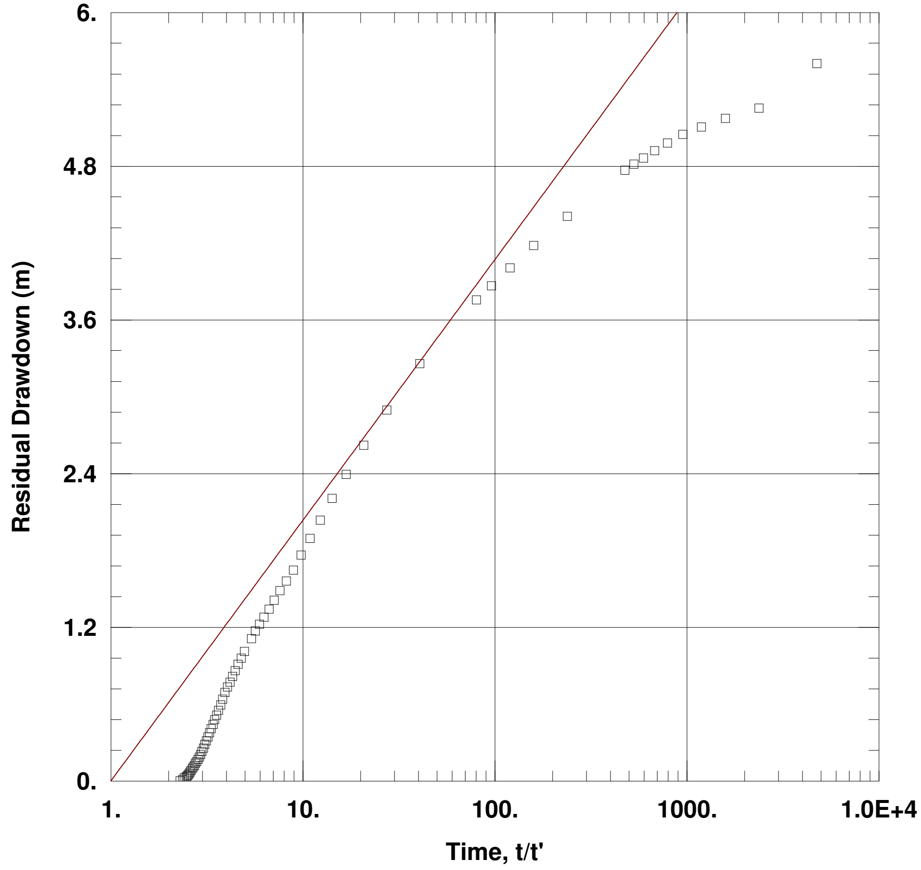


FIGURE 3-13 - 2017 PT - PW1 THEIS REC ANALYSIS

Data Set: H:\...\2017 PW1 rec - Theis.aqt
Date: 06/12/20 Time: 15:07:24

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 74.31 m^2/day
S/S' = 1.

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

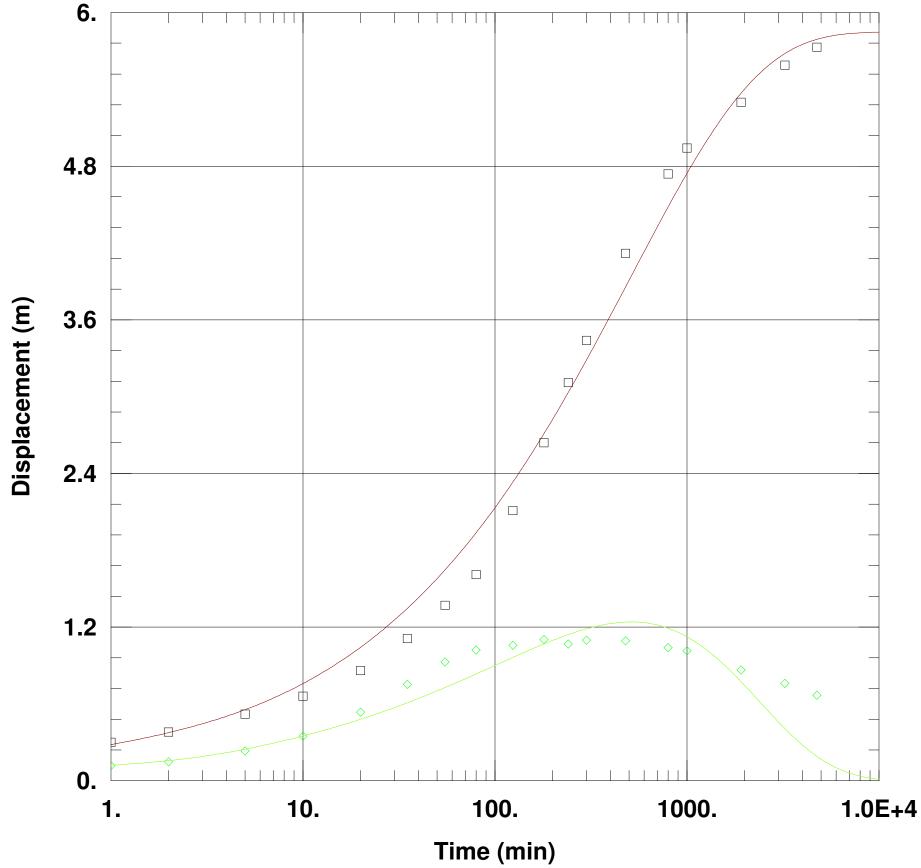


FIGURE 3-14 - 2017 PT - PW1 DDN ANALYSIS

Data Set: H:\...\2017 PW1 ddn.aqt
Date: 06/12/20 Time: 15:09:17

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Leaky
Solution Method: Moench (Case 3)

T = 20.11 m^2/day
S = 0.3157
r/B' = 0.704
ß' = 0.02432
r/B" = 10.
ß" = 2.366
Sw = -3.799
r(w) = 0.1015 m
r(c) = 0.1015 m

AQUIFER DATA

Saturated Thickness: 17.4 m
Aquitard Thickness (b'): 4.5 m

Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 22. m

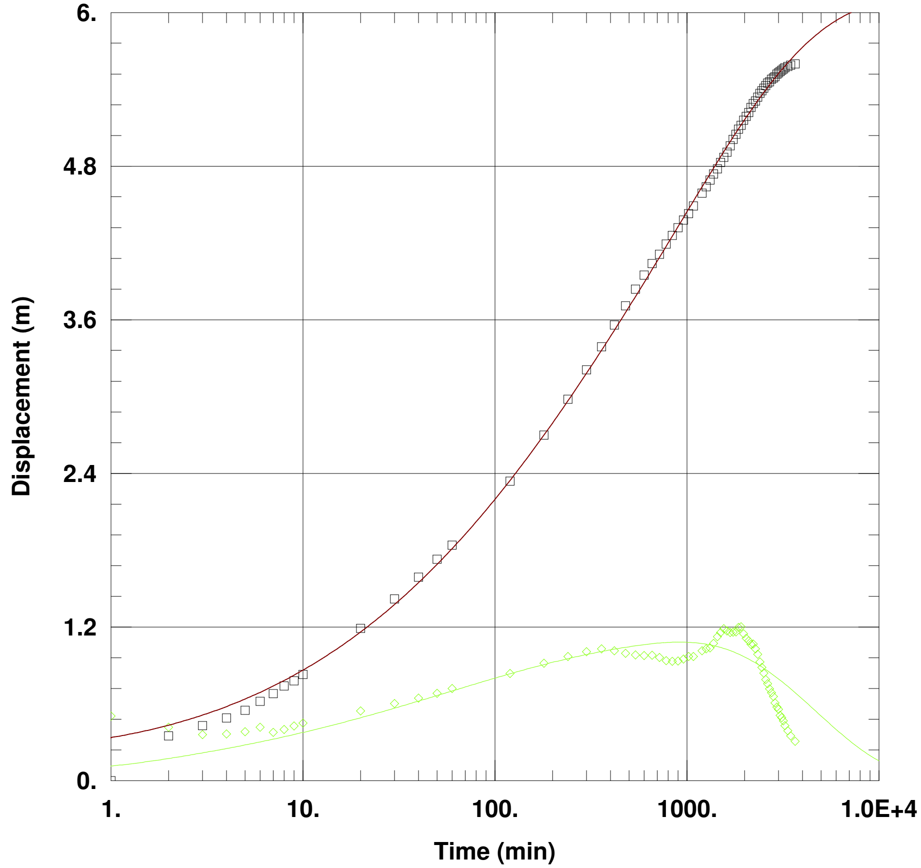


FIGURE 3-15 - 2017 PT - PW1 REC ANALYSIS

Data Set: H:\...\2017 PW1 rec.aqt
Date: 06/12/20 Time: 15:10:52

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Leaky
Solution Method: Moench (Case 3)

T = 32.87 m^2/day
S = 0.1687
r/B' = 0.2873
ß' = 0.2459
r/B" = 10.
ß" = 6.809
Sw = -2.916
r(w) = 0.1015 m
r(c) = 0.1015 m

AQUIFER DATA

Saturated Thickness: 17.4 m
Aquitard Thickness (b'): 4.5 m

Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 22. m

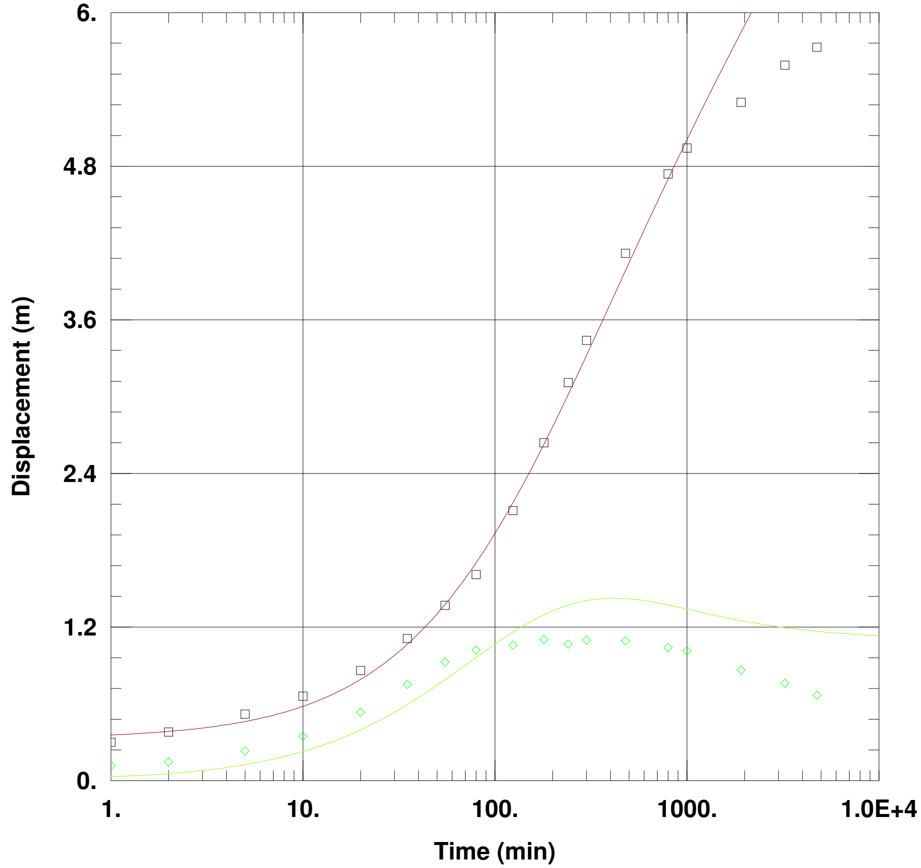


FIGURE 3-16 - 2017 PT - PW1 DDN ANALYSIS

Data Set: H:\...\2017 PW1 ddn - Butler.aqt
Date: 06/12/20 Time: 15:32:03

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Confined
Solution Method: Butler

T1 = 2282.9 m^2/day
S1 = 0.0001289
T2 = 50. m^2/day
S2 = 2.06E-5
R = 200. m

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

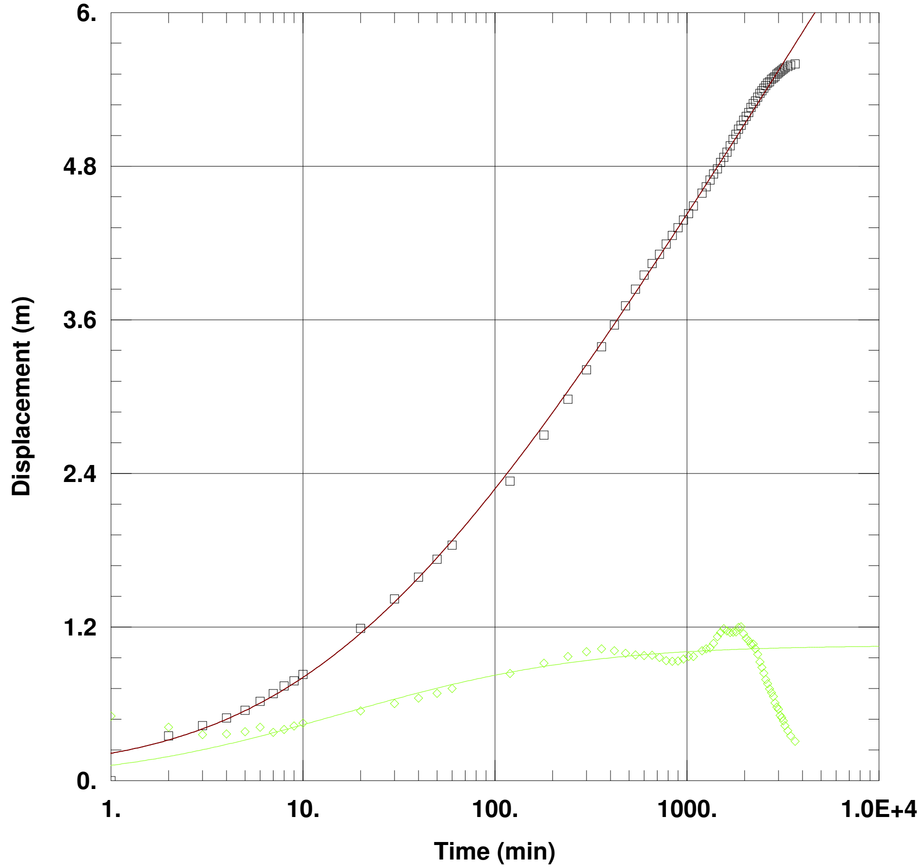


FIGURE 3-17 - 2017 PT - PW1 REC ANALYSIS

Data Set: H:\...\2017 PW1 rec - Butler.aqt
Date: 06/12/20 Time: 15:33:44

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Confined
Solution Method: Butler

T1 = 1.161E+4 m^2/day
S1 = 1.678E-5
T2 = 51.67 m^2/day
S2 = 3.457E-5
R = 200. m

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

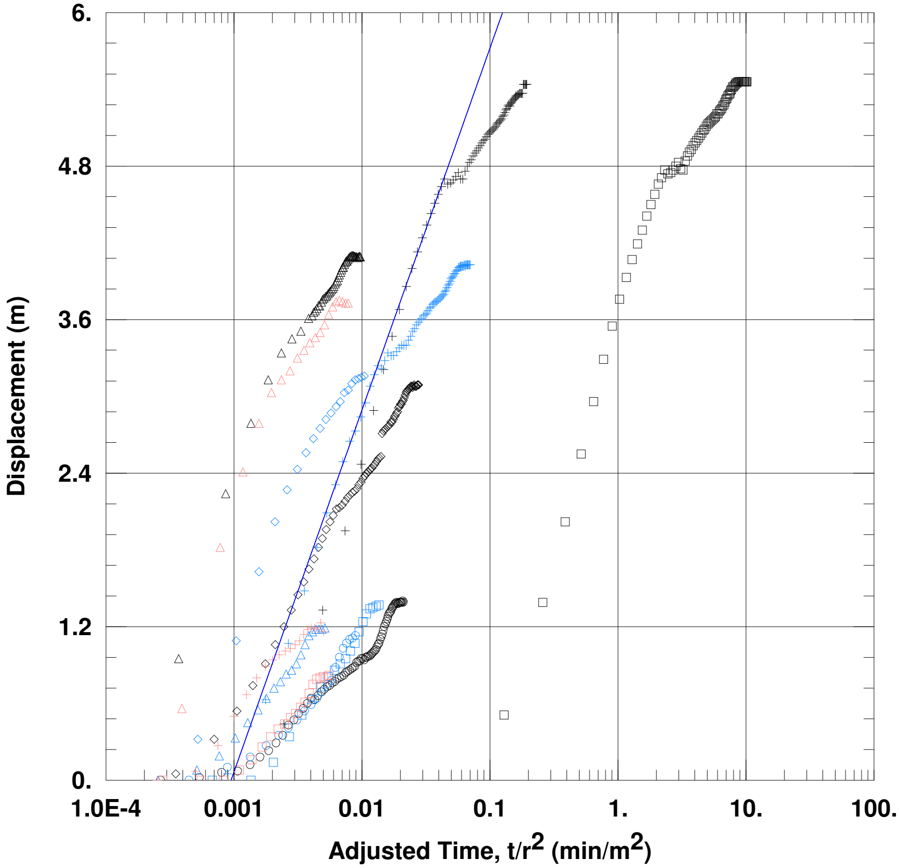


FIGURE 3-18 - 2017 PT - CJSL COMP ANALYSIS

Data Set: H:\...\2017 Obs Well CJ Composite Analysis.aqt
Date: 06/12/20 Time: 15:34:55

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 53.44 m^2/day
S = 7.934E-5

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

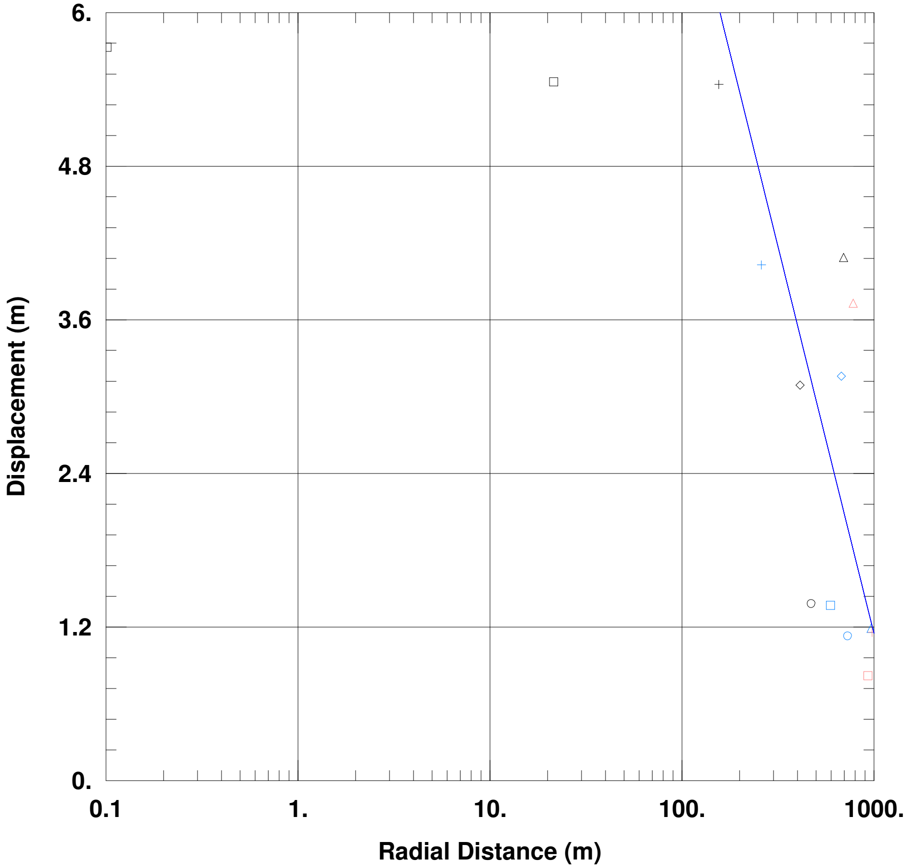


FIGURE 3-19 2017 - PT - OBS WELL COOPER-JACOB COMP ANALYSIS

Data Set: H:\...\2017 Obs Well CJ Dist-Ddn.aqt
Date: 06/12/20 Time: 15:36:49

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 50. m^2/day
S = 0.0001556

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

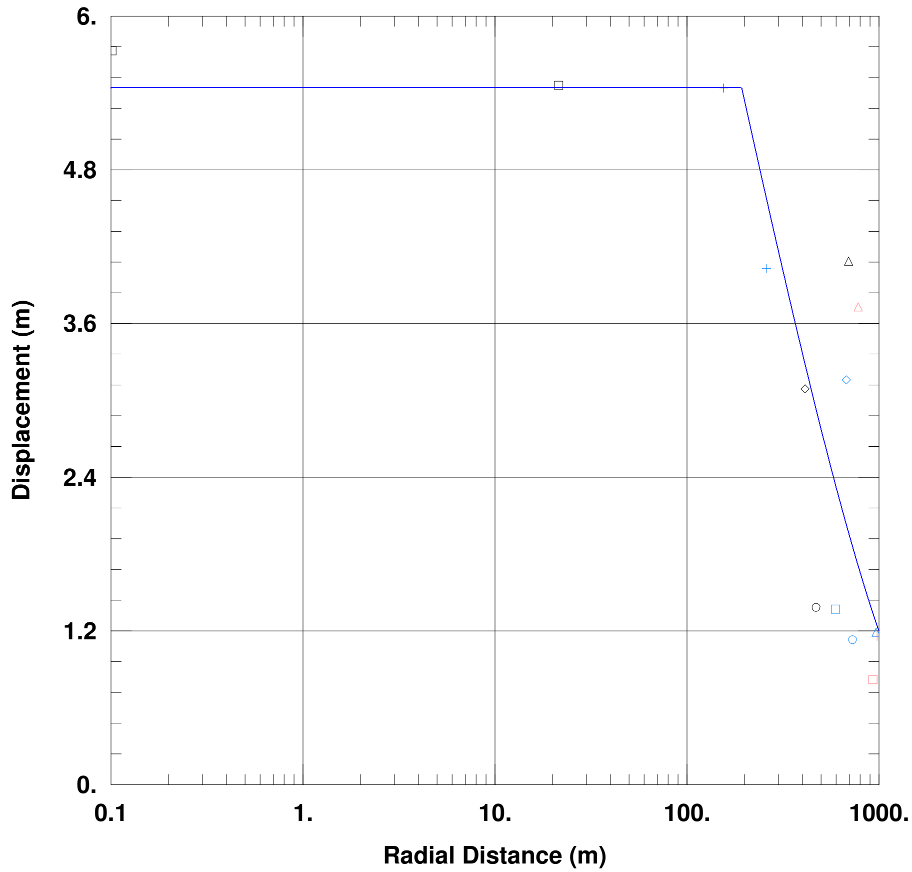


FIGURE 3-20 - 2017 PT - LEAKY AQUIFER DIST-DDN ANALYSIS

Data Set: H:\...\2017 Obs Well LA Dist-Ddn.aqt
Date: 06/12/20 Time: 15:37:46

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Leaky
Solution Method: Moench (Case 3)

T = 44.62 m^2/day
S = 1.047E-5
1/B' = 1.72 m^{-1}
ß'/r = 0.973 m^{-1}
1/B" = 98.52 m^{-1}
ß"/r = 73.37 m^{-1}
Sw = -7.55
r(w) = 0.1015 m
r(c) = 0.1015 m

AQUIFER DATA

Saturated Thickness: 17.4 m
Aquitard Thickness (b'): 4.5 m

Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 22. m

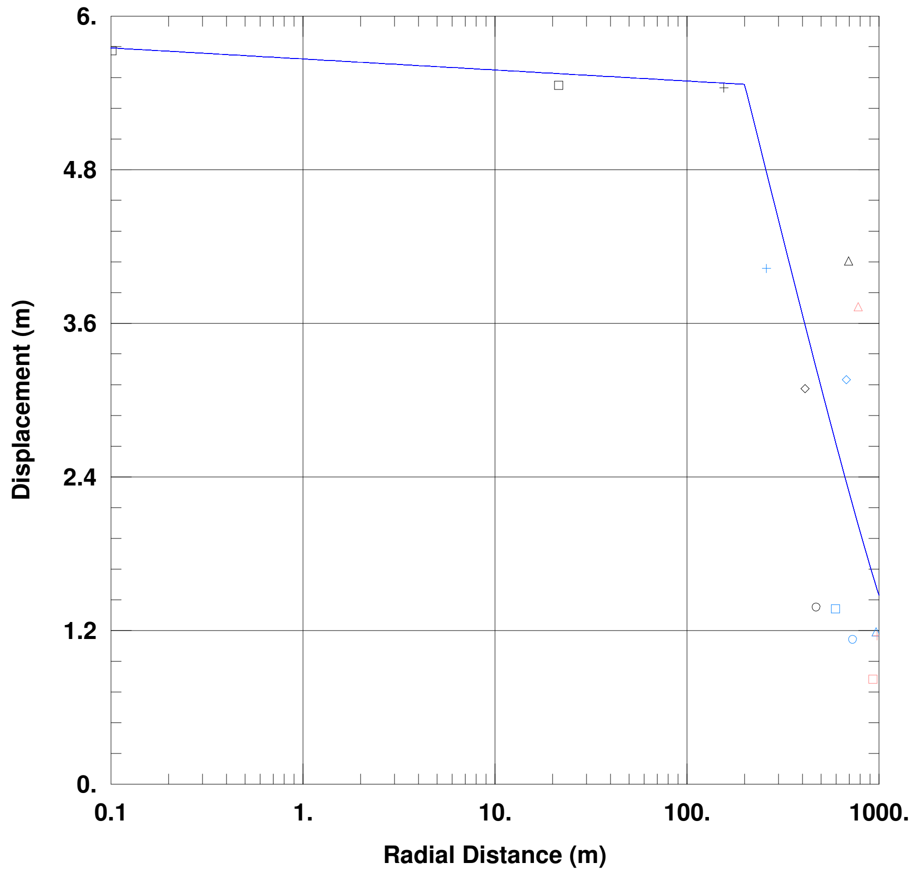


FIGURE 3-21 - 2017 PT - LEAKY AQ DIST-DDN ANALYSIS

Data Set: H:\...\2017 Obs Well Butler Dist-Ddn.aqt
Date: 06/12/20 Time: 15:38:59

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 8-Feb-2017

SOLUTION

Aquifer Model: Confined
Solution Method: Butler

T1 = 3507.3 m^2/day
S1 = 1.782E-5
T2 = 50. m^2/day
S2 = 0.0001585
R = 200. m

AQUIFER DATA

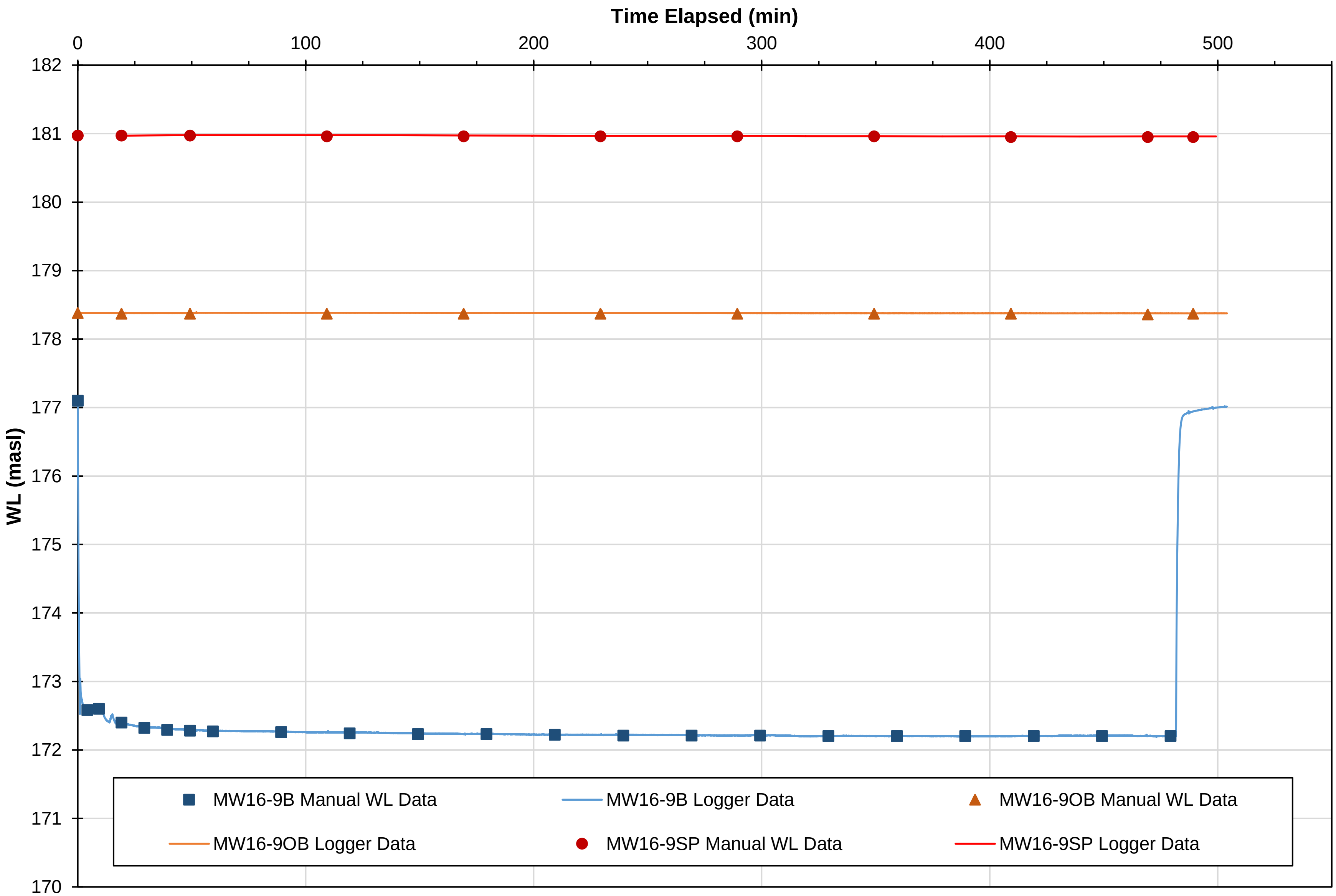
Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

APPENDIX

D-4 SHORT-TERM PUMPING TEST HYDROGRAPHS

Figure 4-1 - Well Nest MW16-9 Hydrographs
Short-Term Pumping Test - September 6, 2017



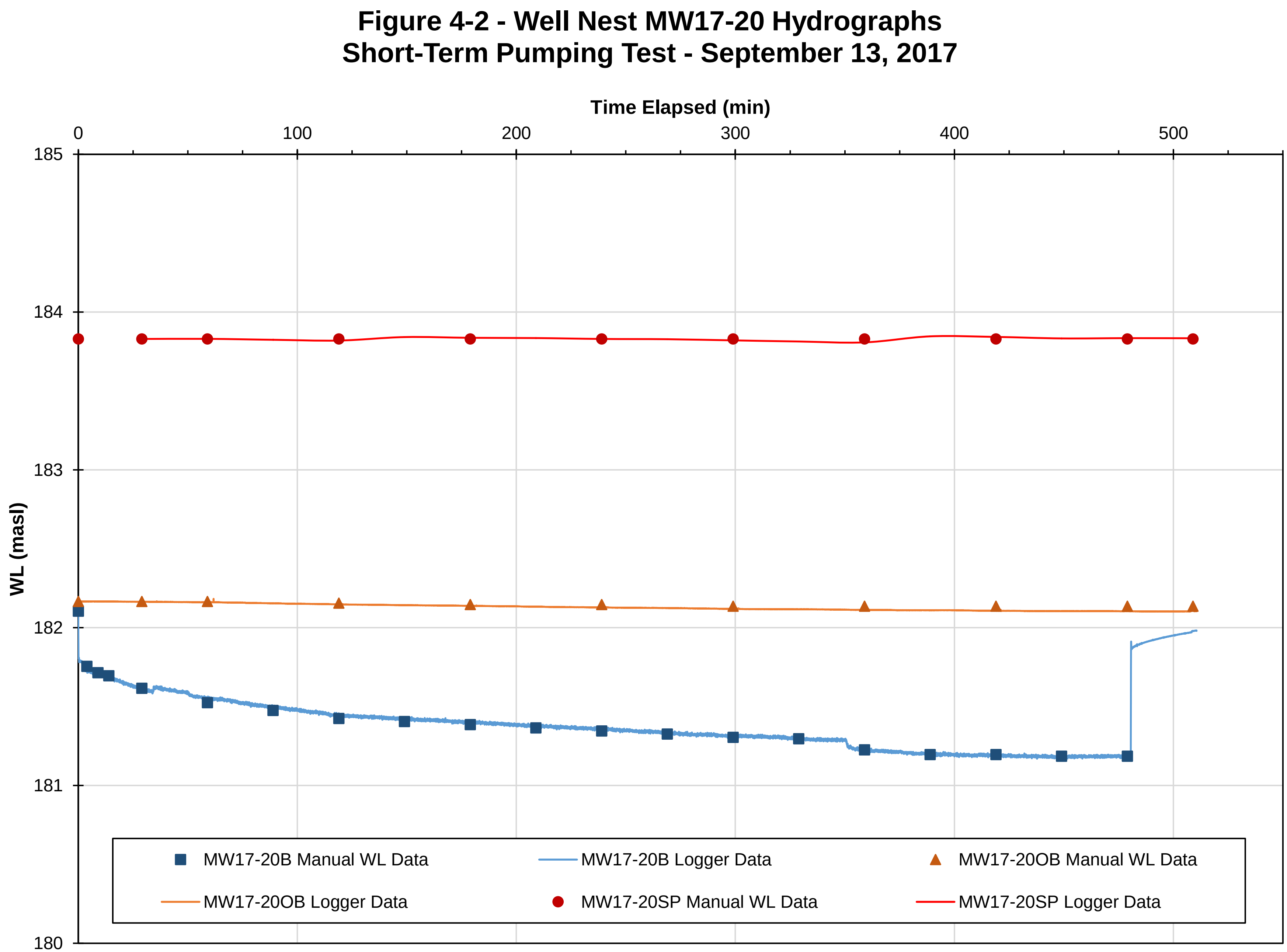


Figure 4-2 - Well Nest MW17-20 Hydrographs
Short-Term Pumping Test - September 13, 2017
Time Elapsed (min)
0
100
200
300
400
500
WL (masl)
185
184
183
182
181
180
MW17-20B Manual WL Data
MW17-20B Logger Data
MW17-20OB Manual WL Data
MW17-20OB Logger Data
MW17-20SP Manual WL Data
MW17-20SP Logger Data

Figure 4-3 - Well Nest MW17-21 Hydrographs
Short-Term Pumping Test - September 12, 2017

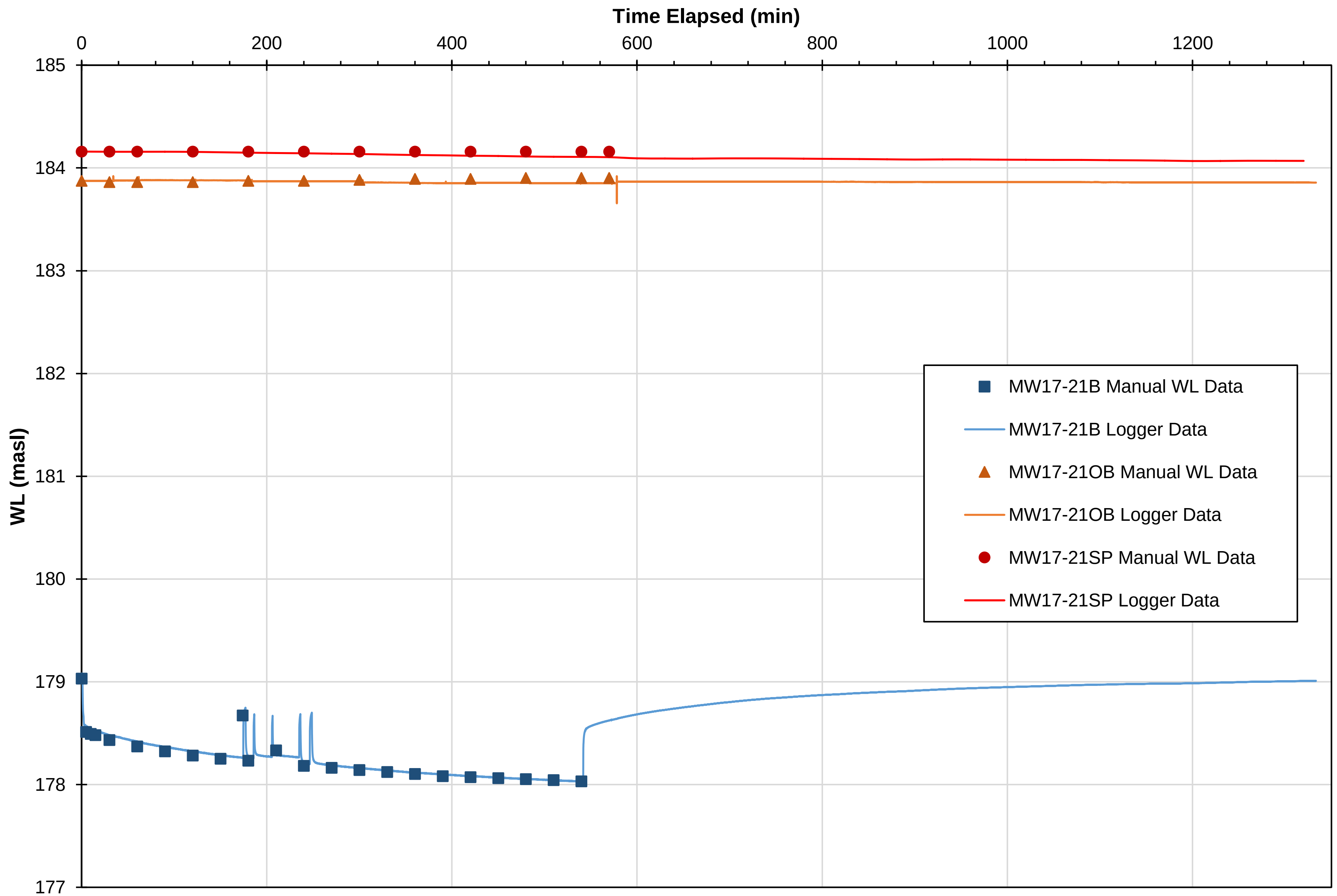


Figure 4-4 - Well Nest MW17-22 Hydrographs
Short-Term Pumping Test - September 5, 2017

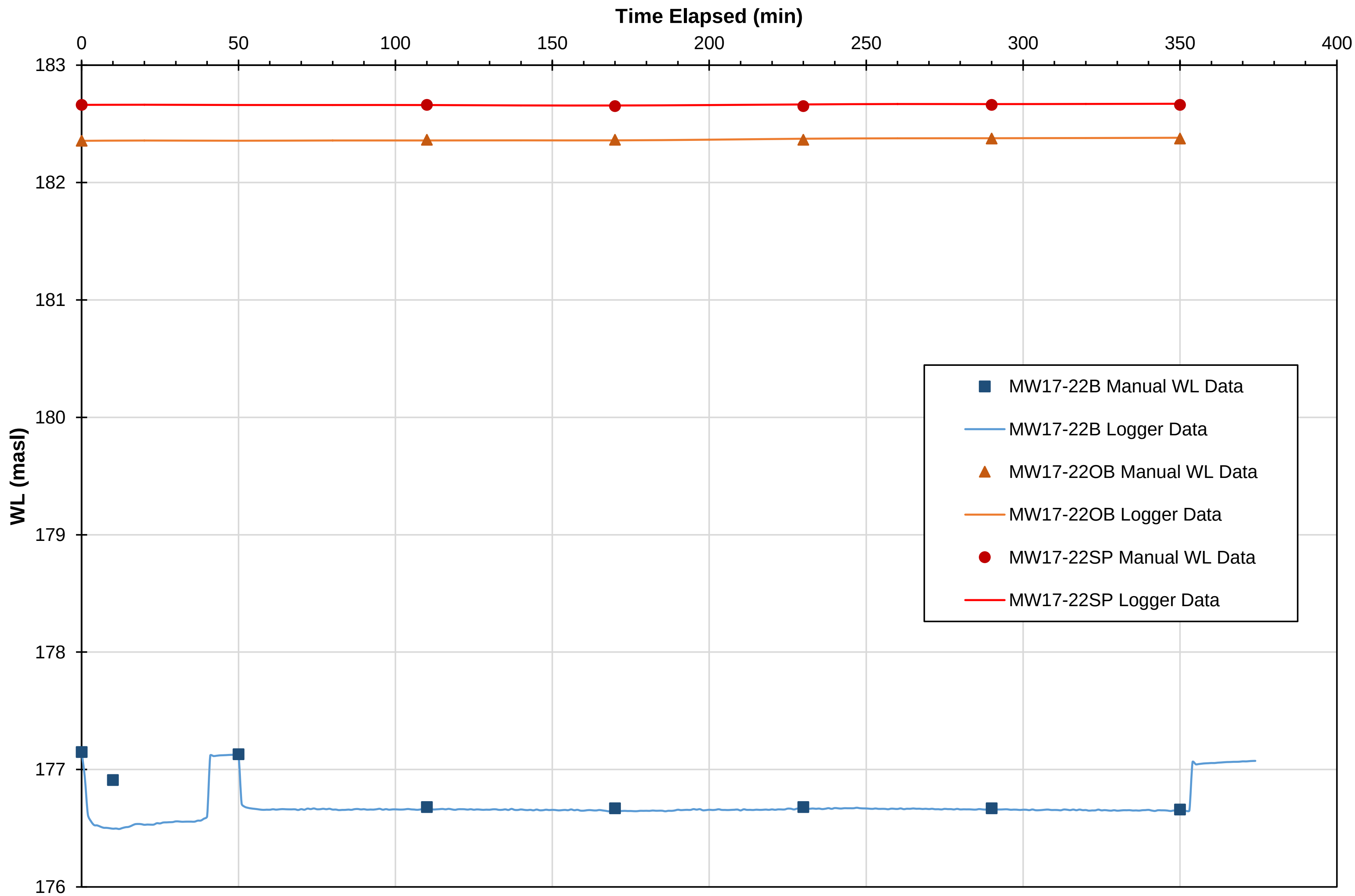
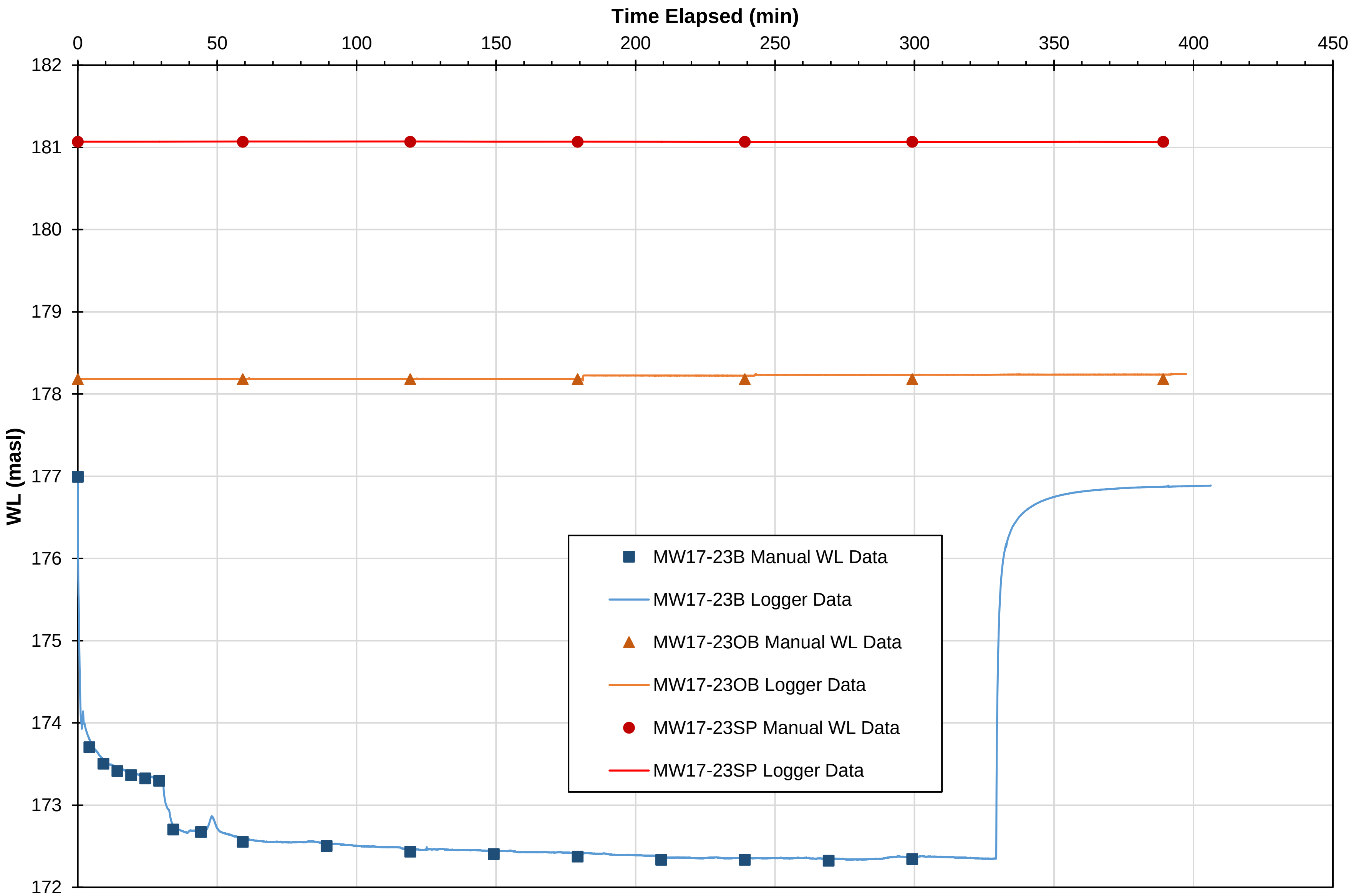


Figure 4-5 - Well Nest MW17-23 Hydrographs
Short-Term Pumping Test - September 7, 2017



APPENDIX

D-5 PERMEAMETER TESTING

Figure 5-1

PERM1

Permeameter Test Analysis

Nova Scotia Method

Proposed Upper's Quarry

Date: July 13, 2018

Performed by: SK

Permeameter Details

Auger Hole Diameter 7.5 cm

Air Inlet Height 20 cm

CSS Soil Factor * 31.4

ELAPSED TIME min	WATER LEVEL cm	RATE OF FALL cm / min	COMMENTS	
0	57.6	-	Soil:	Silty Clay
1	57.4	0.2	Depth (m):	0.3
2	57.2	0.2		
3	57.0	0.2		
4	56.8	0.2		
5	56.6	0.2		
			Average Rate of Fall (cm / min):	
			0.2	

Calculations

K_fs = Saturated Field Hydraulic Conductivity = Avg Rate of Fall x CSS Soil Factor

K_fs = 6.3 mm / day

K_fs = 7.3E-06 cm / s

	Auger Hole Diameter (cm)							
CSS Soil Factor	7	7.5	8	8.5	9	9.5	10	10.5
Coarse Sands (CS)	72.0	69.8	67.3	65.1	62.2	58.9	58.7	55.5
Structured Soils (SS)	56.3	54.5	52.5	50.8	47.2	46.2	45.3	44.0
Clays (US)	32.4	31.4	30.5	29.5	28.0	27.4	26.3	25.9

Note: * Soil factors were calculated by Canadian Sewage Solutions Inc. (CSS) based on research from Mooers, J.D., and Waller, D.H. 1993. On-Site Wastewater Disposal in Nova Scotia, Final Report, On-Site Wastewater Management Research Program Phase 2 1990-1993. Technical University of Nova Scotia.

Figure 5-2

PERM2

Permeameter Test Analysis

Nova Scotia Method

Proposed Upper's Quarry

Date: July 12, 2018

Performed by: SK

Permeameter Details

Auger Hole Diameter	7.5	cm
Air Inlet Height	20	cm
CSS Soil Factor *	31.4	

ELAPSED TIME min	WATER LEVEL cm	RATE OF FALL cm / min	COMMENTS	
0	56.8	-	Soil:	Silty Clay
1	56.7	0.1	Depth (m):	0.3
2	56.7	0		
3	56.7	0		
4	56.6	0.1		
5	56.5	0.1		
6	56.5	0		
7	56.4	0.1		
8	56.3	0.1		
9	56.2	0.1		
			Average Rate of Fall (cm / min):	
			0.067	

Calculations

K_fs = Saturated Field Hydraulic Conductivity = Avg Rate of Fall x CSS Soil Factor

K_fs = 2.1 mm / day

K_fs = 2.4E-06 cm / s

	Auger Hole Diameter (cm)							
CSS Soil Factor	7	7.5	8	8.5	9	9.5	10	10.5
Coarse Sands (CS)	72.0	69.8	67.3	65.1	62.2	58.9	58.7	55.5
Structured Soils (SS)	56.3	54.5	52.5	50.8	47.2	46.2	45.3	44.0
Clays (US)	32.4	31.4	30.5	29.5	28.0	27.4	26.3	25.9

Note: * Soil factors were calculated by Canadian Sewage Solutions Inc. (CSS) based on research from Mooers, J.D., and Waller, D.H. 1993. On-Site Wastewater Disposal in Nova Scotia, Final Report, On-Site Wastewater Management Research Program Phase 2 1990-1993. Technical University of Nova Scotia.

Figure 5-3

PERM3

Permeameter Test Analysis

Nova Scotia Method

Proposed Upper's Quarry

Date: July 12, 2018

Performed by: SK

Permeameter Details

Auger Hole Diameter 7.5 cm
Air Inlet Height 20 cm
CSS Soil Factor * 31.4

ELAPSED TIME min	WATER LEVEL cm	RATE OF FALL cm / min	COMMENTS	
0	56.6	-	Soil:	Silty Clay
0.5	56.5	0.2	Depth (m):	0.3
1	56.4	0.2		
2	56.2	0.2		
3	55.9	0.3		
4	55.7	0.2		
5	55.5	0.2		
6	55.3	0.2		
			Average Rate of Fall (cm / min):	
			0.22	

Calculations

K_fs = Saturated Field Hydraulic Conductivity = Avg Rate of Fall x CSS Soil Factor

K_fs = 6.8 mm / day

K_fs = 7.9E-06 cm / s

	Auger Hole Diameter (cm)							
CSS Soil Factor	7	7.5	8	8.5	9	9.5	10	10.5
Coarse Sands (CS)	72.0	69.8	67.3	65.1	62.2	58.9	58.7	55.5
Structured Soils (SS)	56.3	54.5	52.5	50.8	47.2	46.2	45.3	44.0
Clays (US)	32.4	31.4	30.5	29.5	28.0	27.4	26.3	25.9

Note: * Soil factors were calculated by Canadian Sewage Solutions Inc. (CSS) based on research from Mooers, J.D., and Waller, D.H. 1993. On-Site Wastewater Disposal in Nova Scotia, Final Report, On-Site Wastewater Management Research Program Phase 2 1990-1993. Technical University of Nova Scotia.

Figure 5-4

PERM4

Permeameter Test Analysis

Nova Scotia Method

Proposed Upper's Quarry

Date: July 12, 2018

Performed by: SK

Permeameter Details

Auger Hole Diameter	7.5	cm
Air Inlet Height	20	cm
CSS Soil Factor *	31.4	

ELAPSED TIME min	WATER LEVEL cm	RATE OF FALL cm / min	COMMENTS	
0	57.5	-	Soil:	Silty Clay
1	57.5	0	Depth (m):	0.3
2	57.5	0		
3	57.5	0		
4	57.5	0		
5	57.5	0		
10	57.4	0.02		
15	57.3	0.02		
20	57.2	0.02		
			Average Rate of Fall (cm / min):	
			0.015	

Calculations

K_fs = Saturated Field Hydraulic Conductivity = Avg Rate of Fall x CSS Soil Factor

K_fs = 0.5 mm / day

K_fs = 5.5E-07 cm / s

	Auger Hole Diameter (cm)							
CSS Soil Factor	7	7.5	8	8.5	9	9.5	10	10.5
Coarse Sands (CS)	72.0	69.8	67.3	65.1	62.2	58.9	58.7	55.5
Structured Soils (SS)	56.3	54.5	52.5	50.8	47.2	46.2	45.3	44.0
Clays (US)	32.4	31.4	30.5	29.5	28.0	27.4	26.3	25.9

Note: * Soil factors were calculated by Canadian Sewage Solutions Inc. (CSS) based on research from Mooers, J.D., and Waller, D.H. 1993. On-Site Wastewater Disposal in Nova Scotia, Final Report, On-Site Wastewater Management Research Program Phase 2 1990-1993. Technical University of Nova Scotia.

Figure 5-5

PERM5

Permeameter Test Analysis

Nova Scotia Method

Proposed Upper's Quarry

Date: July 12, 2018

Performed by: SK

Permeameter Details

Auger Hole Diameter	7.5	cm
Air Inlet Height	20	cm
CSS Soil Factor *	31.4	

ELAPSED TIME min	WATER LEVEL cm	RATE OF FALL cm / min	COMMENTS	
0	56.2	-	Soil:	Silty Clay
1	56.0	0.2	Depth (m):	0.3
2	55.8	0.2		
3	55.5	0.3		
4	55.2	0.3		
5	55.0	0.2		
6	54.8	0.2		
7	54.5	0.3		
8	54.3	0.2		
9	54.1	0.2		
10	53.9	0.2		
			Average Rate of Fall (cm / min):	
			0.23	

Calculations

K_fs = Saturated Field Hydraulic Conductivity = Avg Rate of Fall x CSS Soil Factor

K_fs = 7.2 mm / day

K_fs = 8.4E-06 cm / s

	Auger Hole Diameter (cm)							
CSS Soil Factor	7	7.5	8	8.5	9	9.5	10	10.5
Coarse Sands (CS)	72.0	69.8	67.3	65.1	62.2	58.9	58.7	55.5
Structured Soils (SS)	56.3	54.5	52.5	50.8	47.2	46.2	45.3	44.0
Clays (US)	32.4	31.4	30.5	29.5	28.0	27.4	26.3	25.9

Note: * Soil factors were calculated by Canadian Sewage Solutions Inc. (CSS) based on research from Mooers, J.D., and Waller, D.H. 1993. On-Site Wastewater Disposal in Nova Scotia, Final Report, On-Site Wastewater Management Research Program Phase 2 1990-1993. Technical University of Nova Scotia.

Figure 5-6

PERM6

Permeameter Test Analysis

Nova Scotia Method

Proposed Upper's Quarry

Date: July 13, 2018

Performed by: SK

Permeameter Details

Auger Hole Diameter	7.5	cm
Air Inlet Height	20	cm
CSS Soil Factor *	31.4	

ELAPSED TIME min	WATER LEVEL cm	RATE OF FALL cm / min	COMMENTS	
0	57.8	-	Soil:	Silty Clay
1	57.5	0.3	Depth (m):	0.3
2	57.2	0.3		
3	57.0	0.2		
4	56.8	0.2		
5	56.5	0.3		
6	56.2	0.3		
7	55.9	0.3		
			Average Rate of Fall (cm / min):	
			0.27	

Calculations

K_fs = Saturated Field Hydraulic Conductivity = Avg Rate of Fall x CSS Soil Factor

K_fs = 8.5 mm / day

K_fs = 9.9E-06 cm / s

	Auger Hole Diameter (cm)							
CSS Soil Factor	7	7.5	8	8.5	9	9.5	10	10.5
Coarse Sands (CS)	72.0	69.8	67.3	65.1	62.2	58.9	58.7	55.5
Structured Soils (SS)	56.3	54.5	52.5	50.8	47.2	46.2	45.3	44.0
Clays (US)	32.4	31.4	30.5	29.5	28.0	27.4	26.3	25.9

Note: * Soil factors were calculated by Canadian Sewage Solutions Inc. (CSS) based on research from Mooers, J.D., and Waller, D.H. 1993. On-Site Wastewater Disposal in Nova Scotia, Final Report, On-Site Wastewater Management Research Program Phase 2 1990-1993. Technical University of Nova Scotia.

Figure 5-7

PERM7

Permeameter Test Analysis

Nova Scotia Method

Proposed Upper's Quarry

Date: July 13, 2018

Performed by: SK

Permeameter Details

Auger Hole Diameter	7.5	cm
Air Inlet Height	20	cm
CSS Soil Factor *	31.4	

ELAPSED TIME min	WATER LEVEL cm	RATE OF FALL cm / min	COMMENTS	
0	57.9	-	Soil:	Silty Clay
1	57.6	0.3	Depth (m):	0.3
2	57.2	0.4		
3	56.9	0.3		
4	56.7	0.2		
5	56.4	0.3		
6	56.1	0.3		
7	55.8	0.3		
			Average Rate of Fall (cm / min):	
			0.30	

Calculations

K_fs = Saturated Field Hydraulic Conductivity = Avg Rate of Fall x CSS Soil Factor

K_fs = 9.4 mm / day

K_fs = 1.1E-05 cm / s

	Auger Hole Diameter (cm)							
CSS Soil Factor	7	7.5	8	8.5	9	9.5	10	10.5
Coarse Sands (CS)	72.0	69.8	67.3	65.1	62.2	58.9	58.7	55.5
Structured Soils (SS)	56.3	54.5	52.5	50.8	47.2	46.2	45.3	44.0
Clays (US)	32.4	31.4	30.5	29.5	28.0	27.4	26.3	25.9

Note: * Soil factors were calculated by Canadian Sewage Solutions Inc. (CSS) based on research from Mooers, J.D., and Waller, D.H. 1993. On-Site Wastewater Disposal in Nova Scotia, Final Report, On-Site Wastewater Management Research Program Phase 2 1990-1993. Technical University of Nova Scotia.

APPENDIX

D-6 2019 PUMPING TEST ANALYSES

Figure 6-1 - Pumping Well PW1 Drawdown
February 20 - March 1, 2019

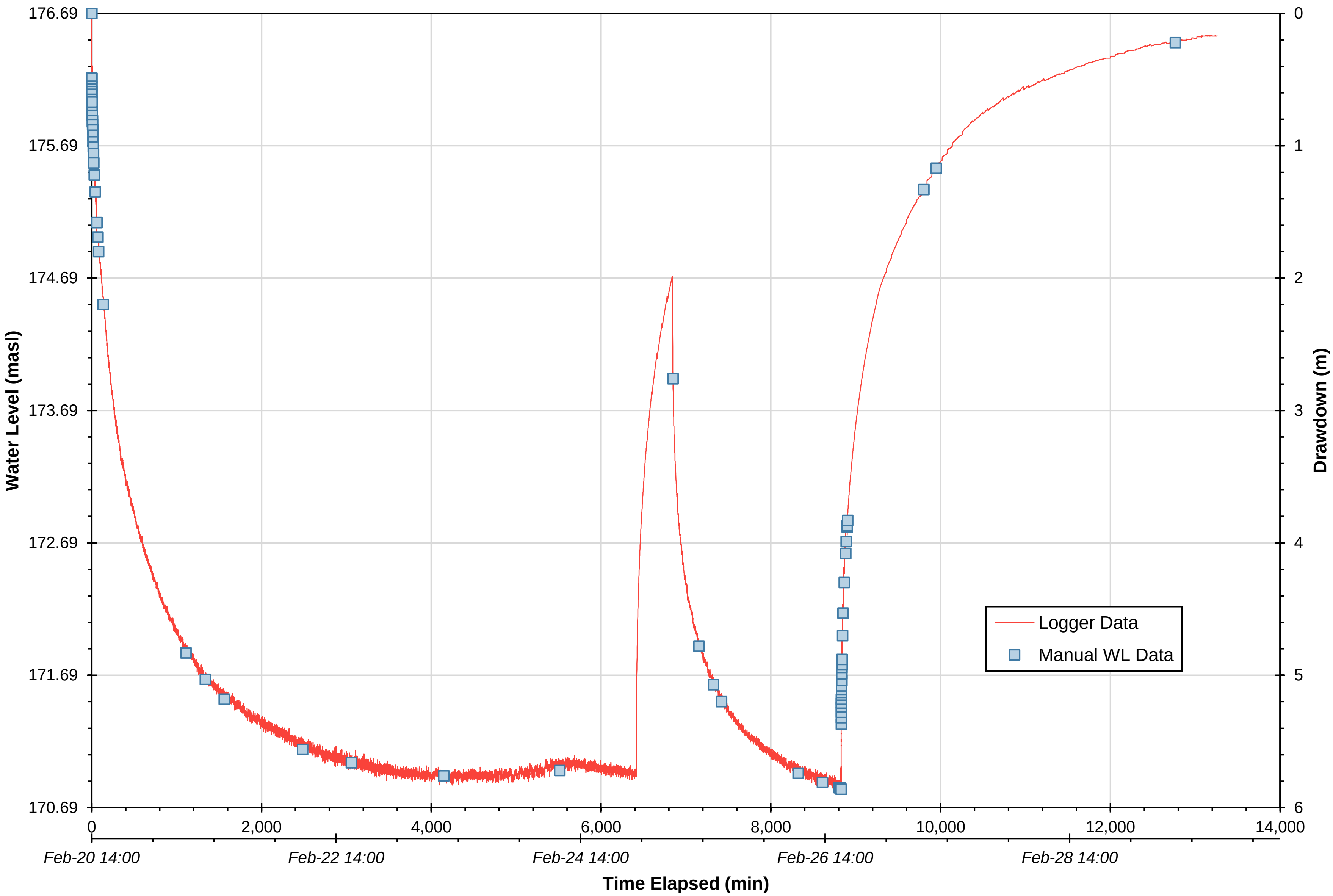


Figure 6-2 - Observation Well BH03-2B Drawdown (27 m from PW1)
February 20 - March 1, 2019

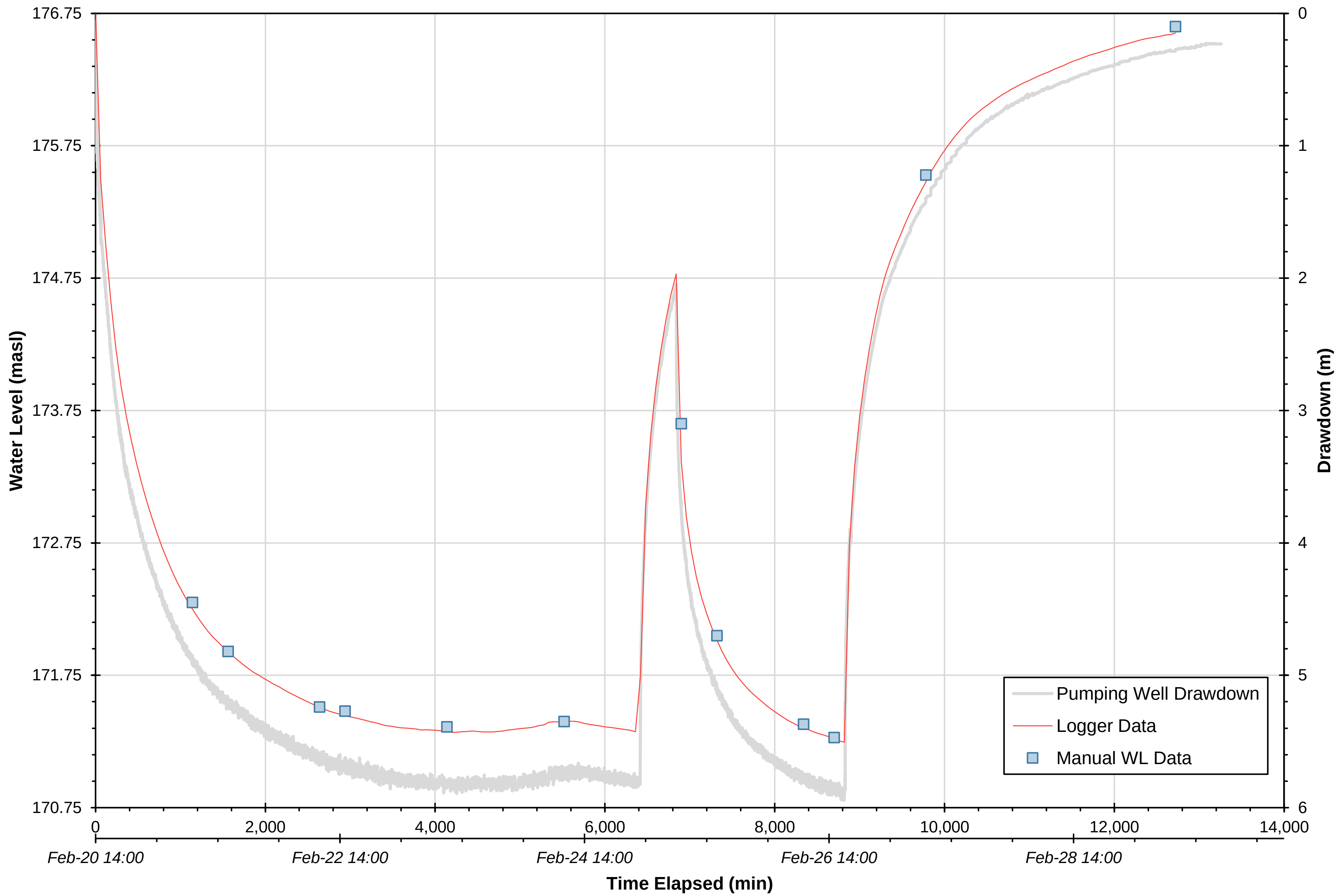


Figure 6-3 - Observation Well MW16-13B Drawdown (161 m from PW1)
February 20 - March 1, 2019

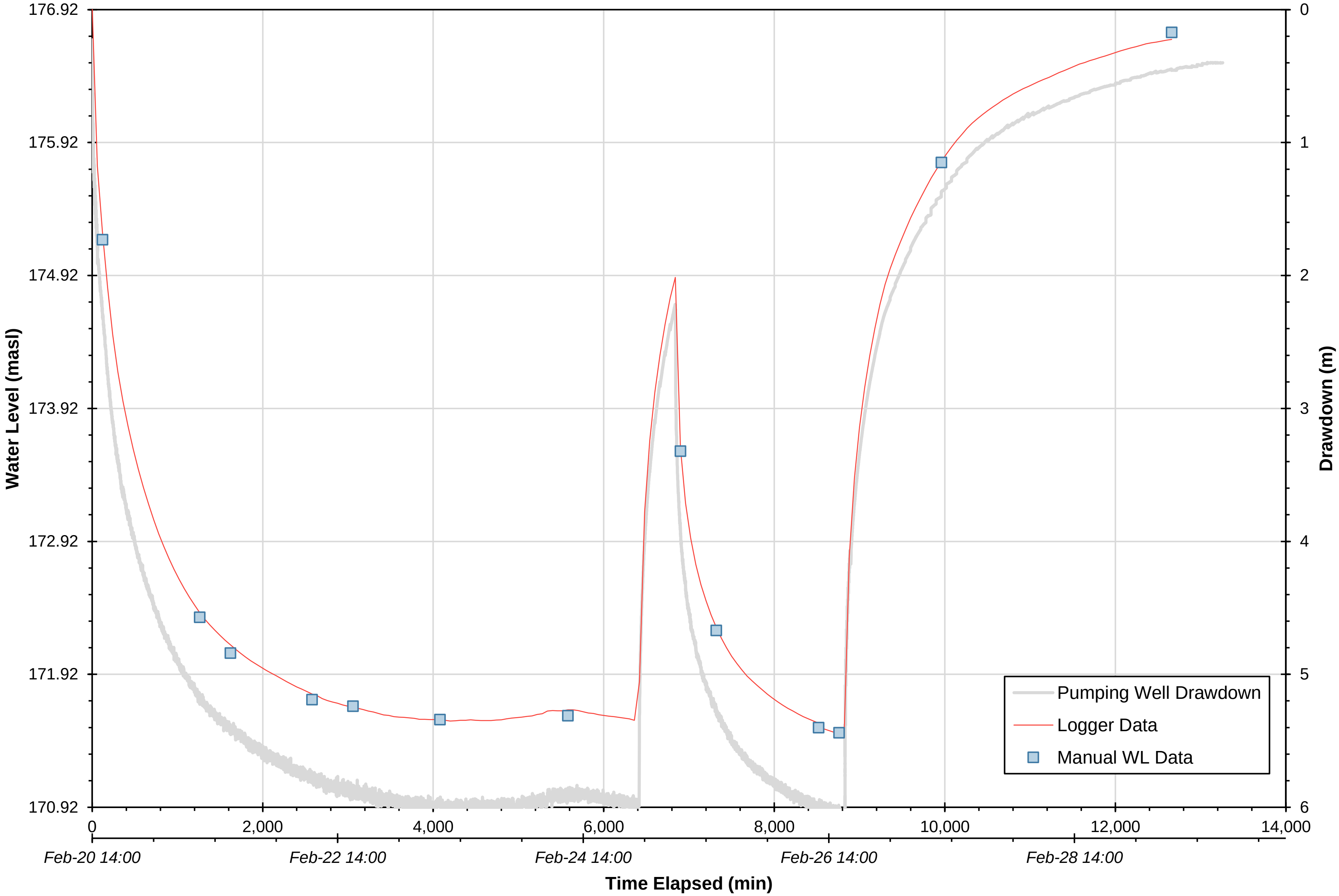


Figure 6-4 - Observation Well MW11-1B Drawdown (690 m from PW1)
February 20 - March 1, 2019

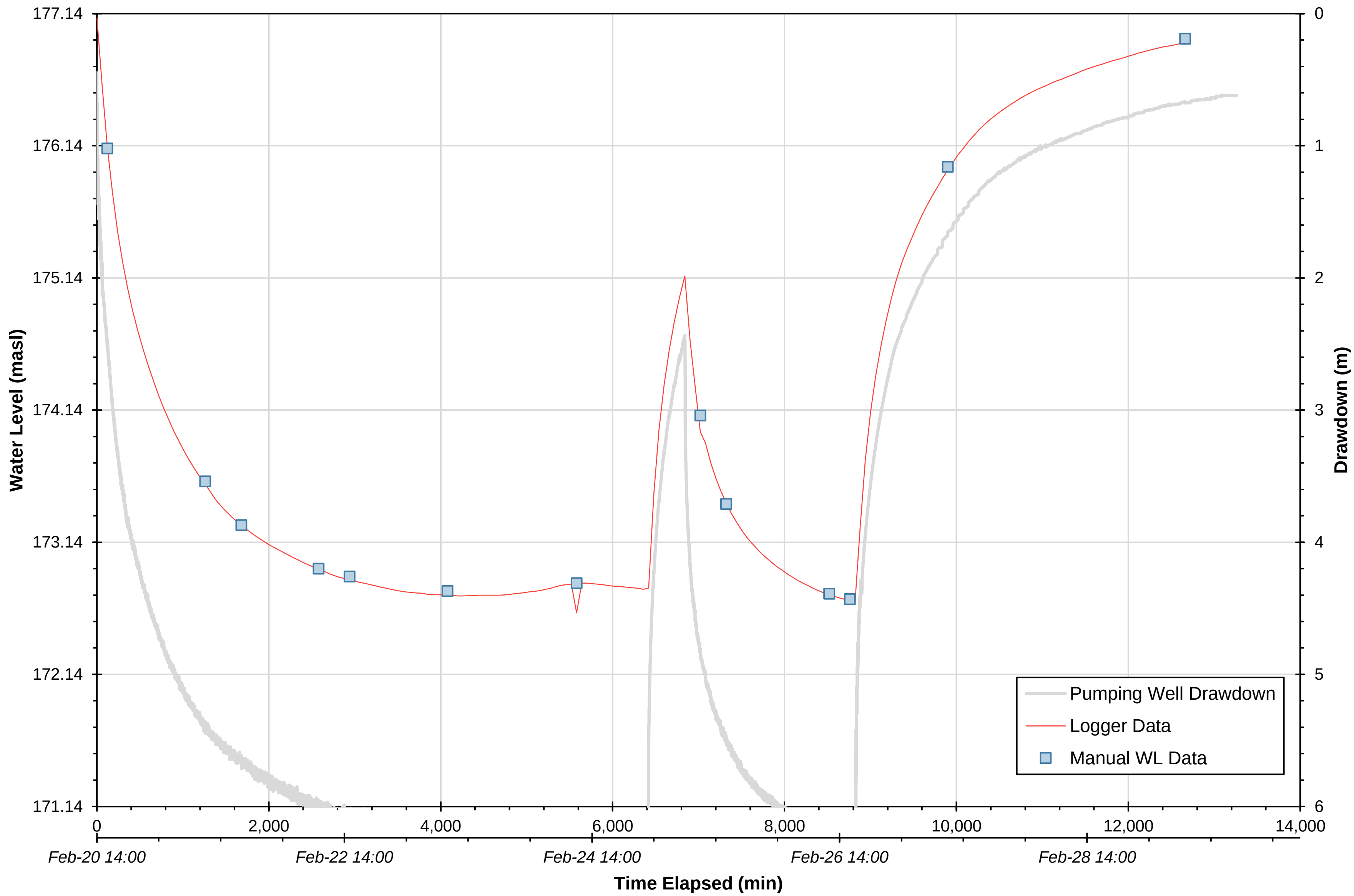
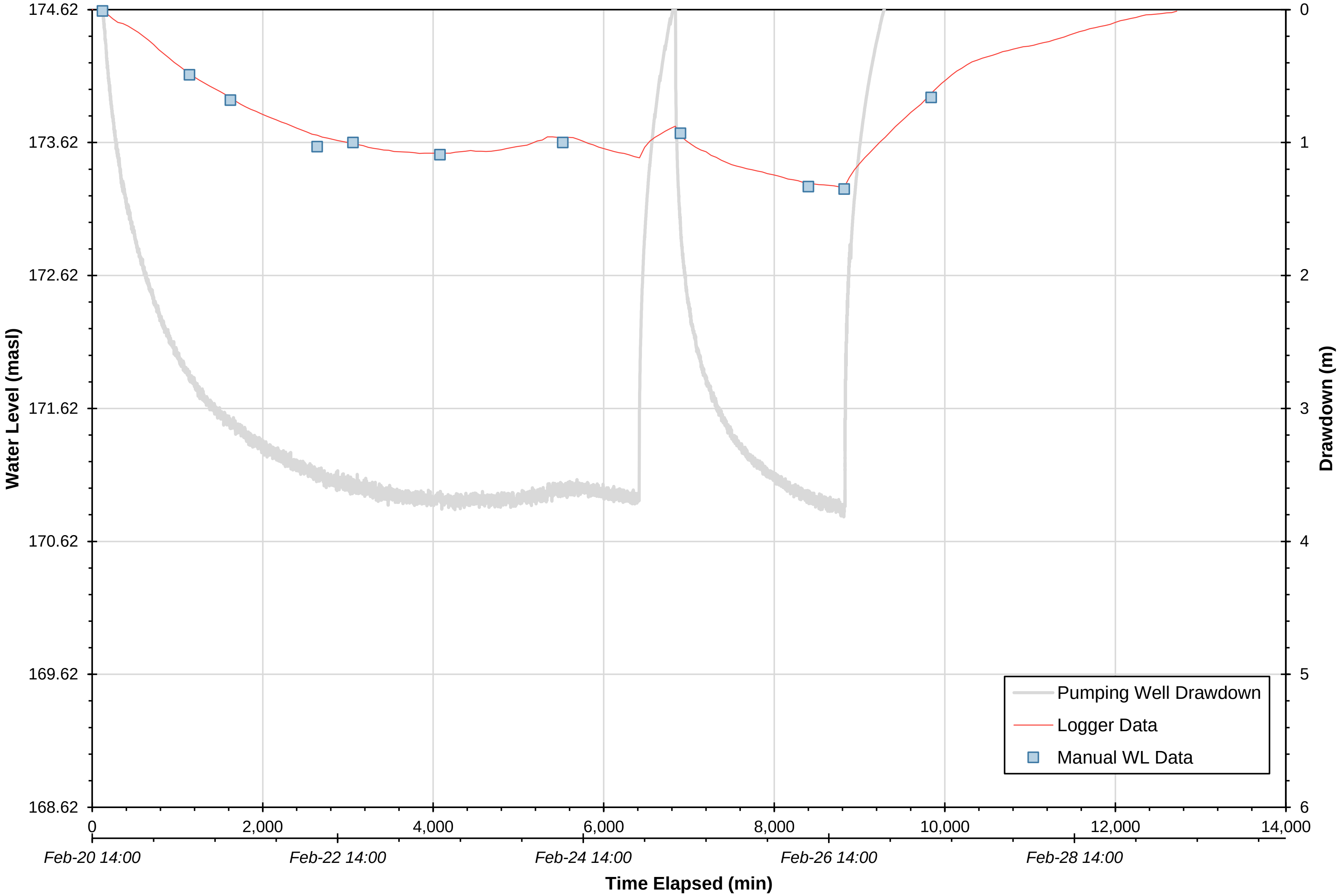


Figure 6-5 - Observation Well MW11-4B Drawdown (398 m from PW1)
February 20 - March 1, 2019



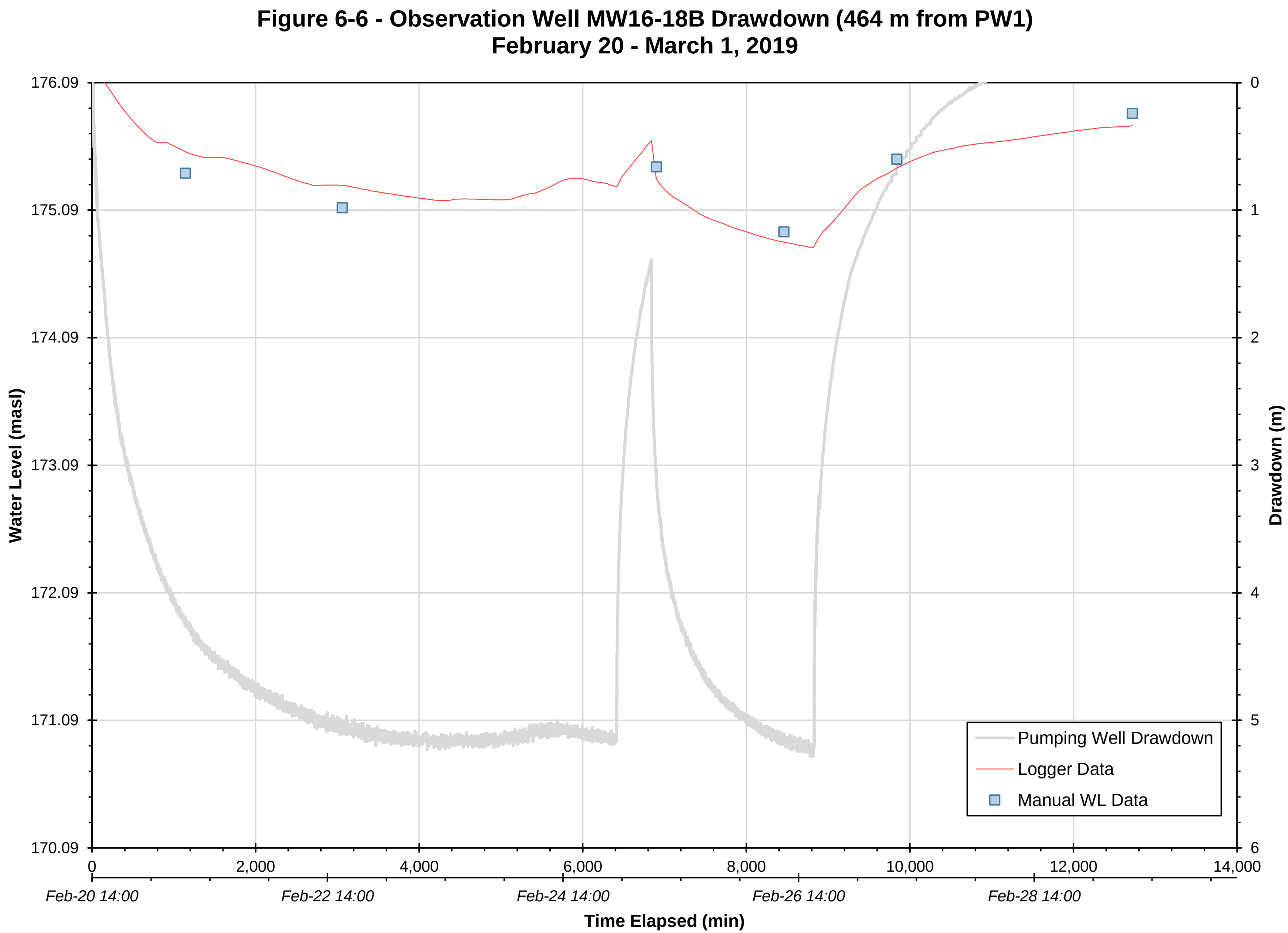


Figure 6-6 - Observation Well MW16-18B Drawdown (464 m from PW1)
February 20 - March 1, 2019
Water Level (masl)
176.09
175.09
174.09
173.09
172.09
171.09
170.09
Drawdown (m)
0
1
2
3
4
5
6
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Feb-20 14:00
Feb-22 14:00
Feb-24 14:00
Feb-26 14:00
Feb-28 14:00
Time Elapsed (min)
Pumping Well Drawdown
Logger Data
Manual WL Data

Figure 6-7 - Observation Well MW16-19B Drawdown (582 m from PW1)
February 20 - March 1, 2019

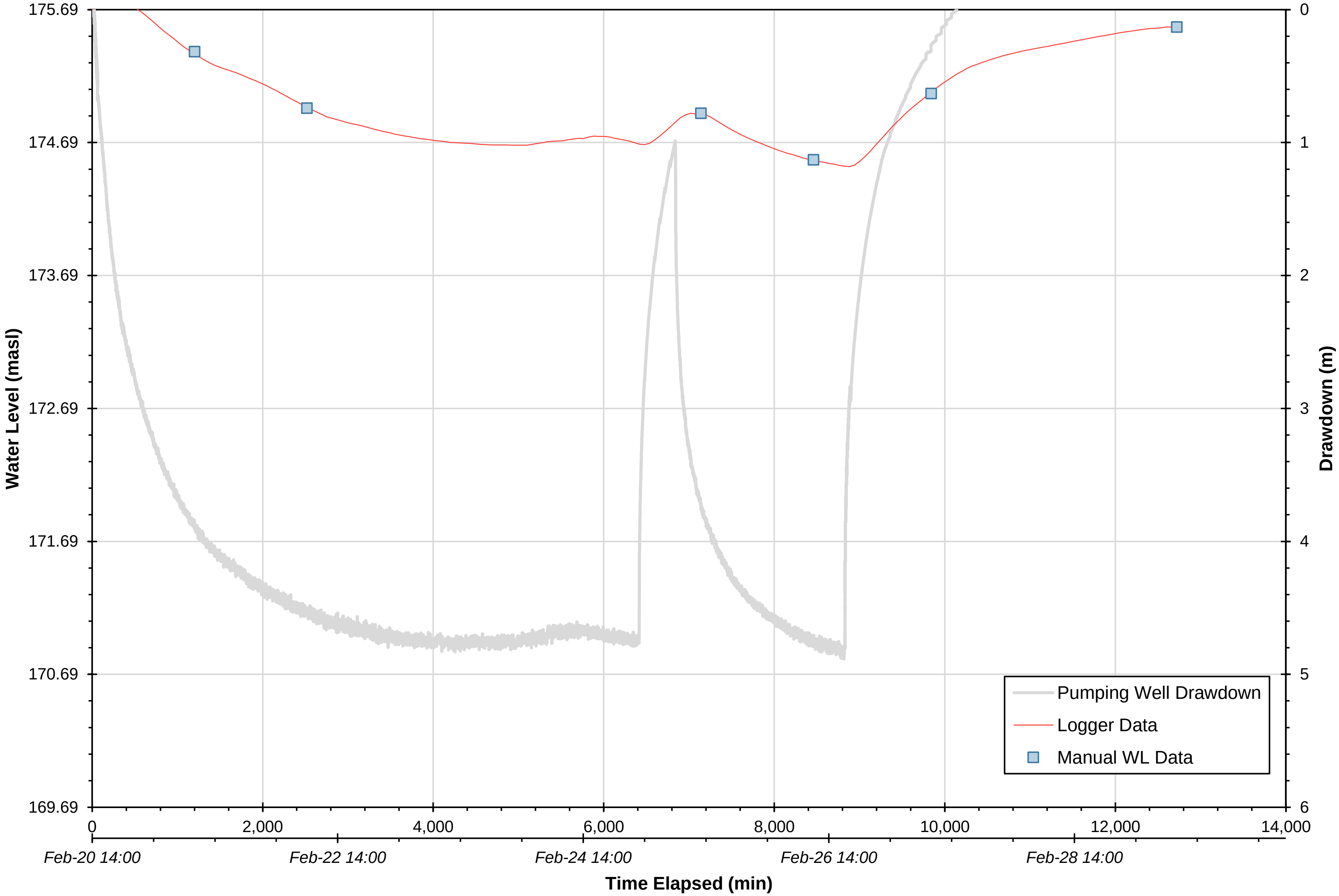


Figure 6-8 - Observation Well MW16-10B Drawdown (681 m from PW1)
February 20 - March 1, 2019

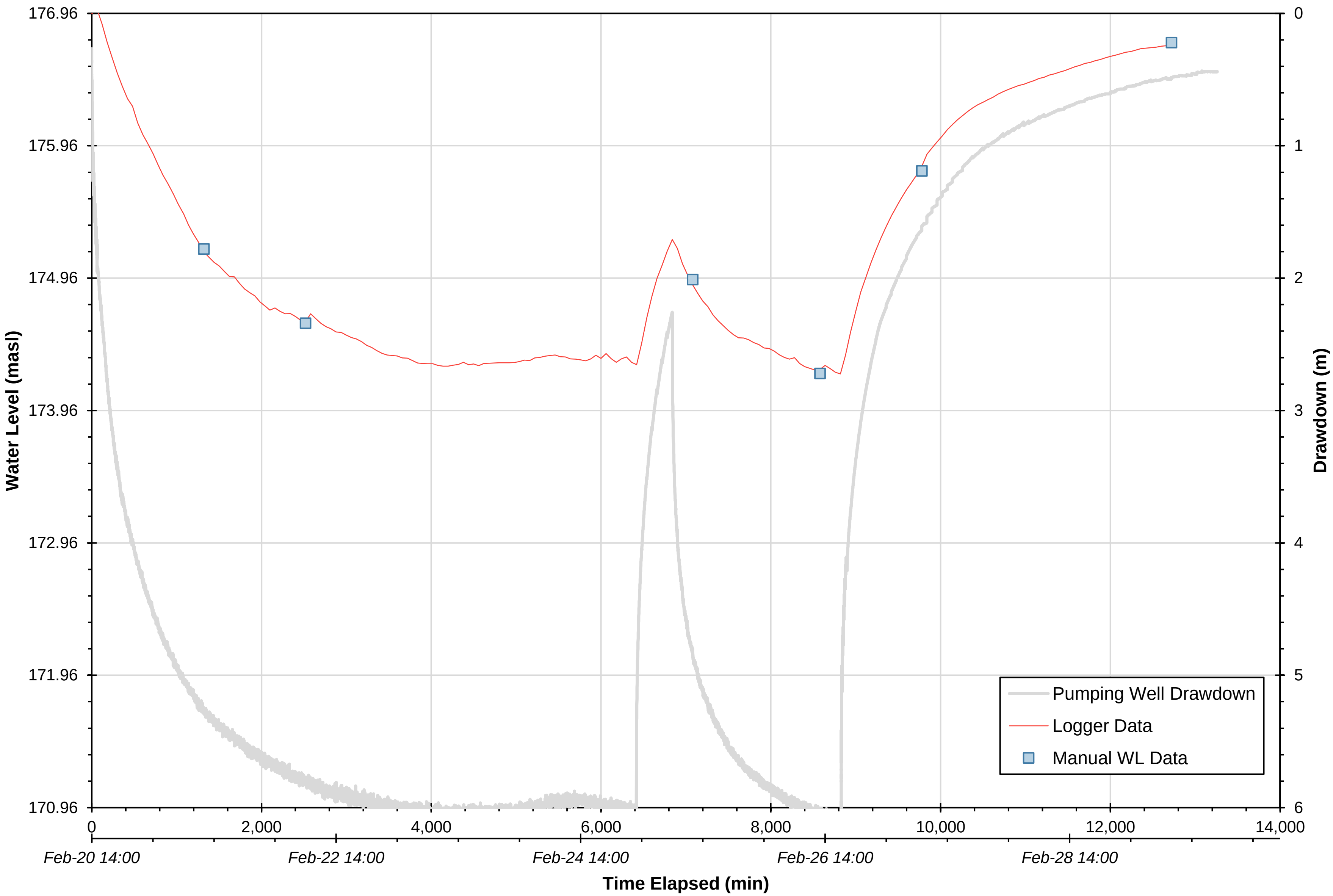
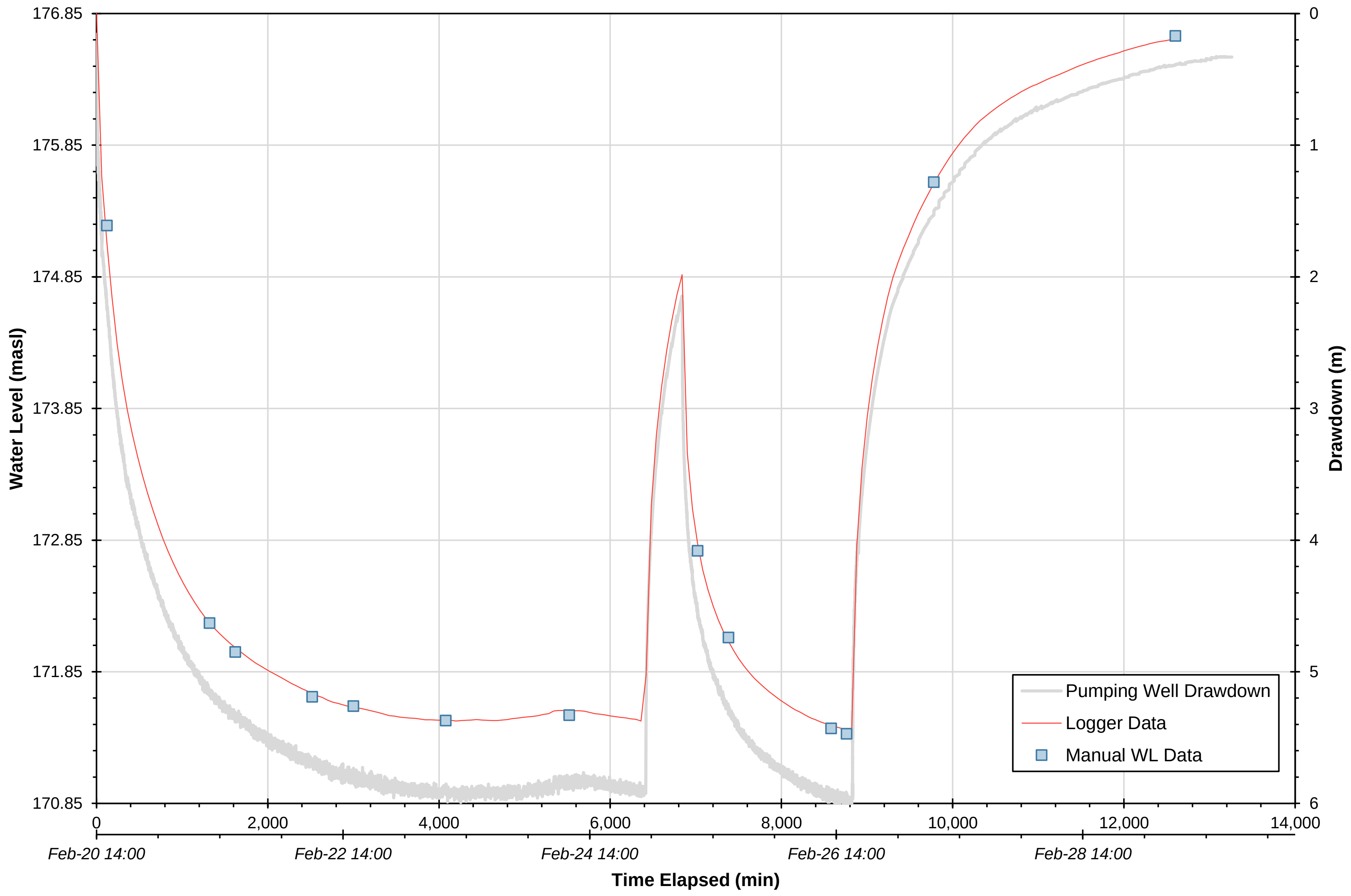


Figure 6-9 - Observation Well BH17-22B Drawdown (122 m from PW1)
February 20 - March 1, 2019



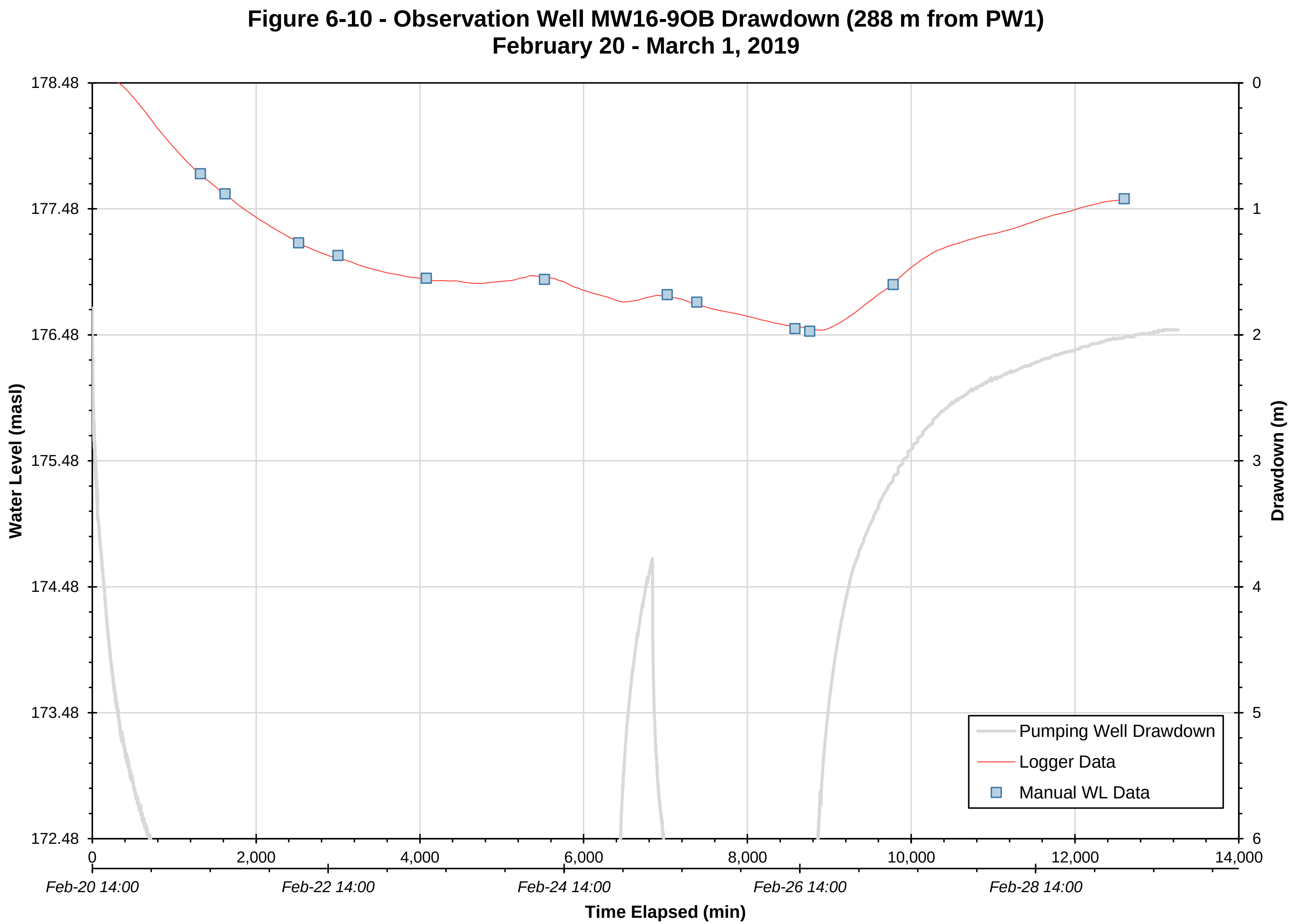


Figure 6-10 - Observation Well MW16-9OB Drawdown (288 m from PW1)
February 20 - March 1, 2019
Water Level (masl)
178.48
177.48
176.48
175.48
174.48
173.48
172.48
Drawdown (m)
0
1
2
3
4
5
6
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Feb-20 14:00
Feb-22 14:00
Feb-24 14:00
Feb-26 14:00
Feb-28 14:00
Time Elapsed (min)
Pumping Well Drawdown
Logger Data
Manual WL Data

Figure 6-11 - Observation Well MW16-9B Drawdown (288 m from PW1)
February 20 - March 1, 2019

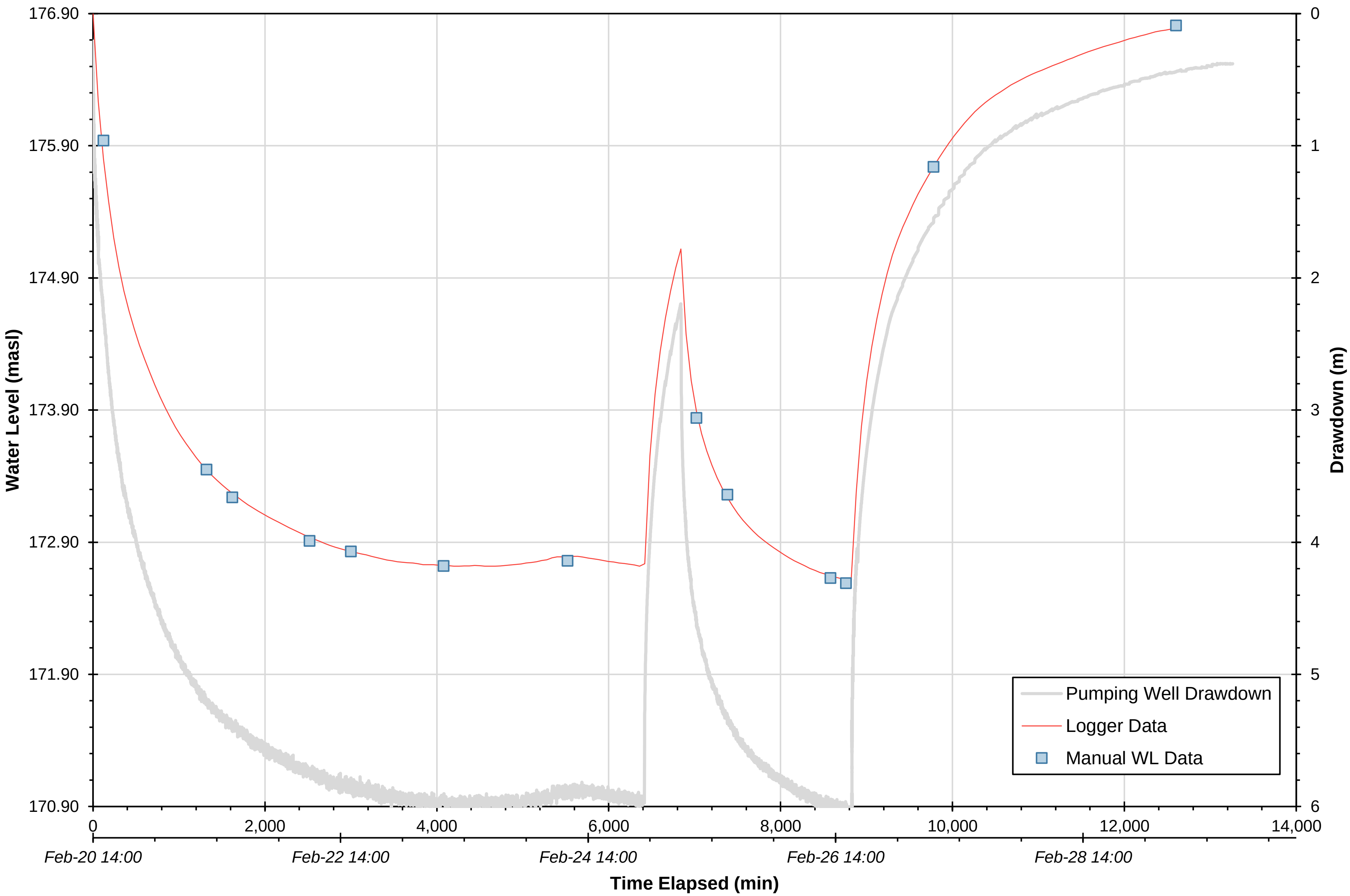
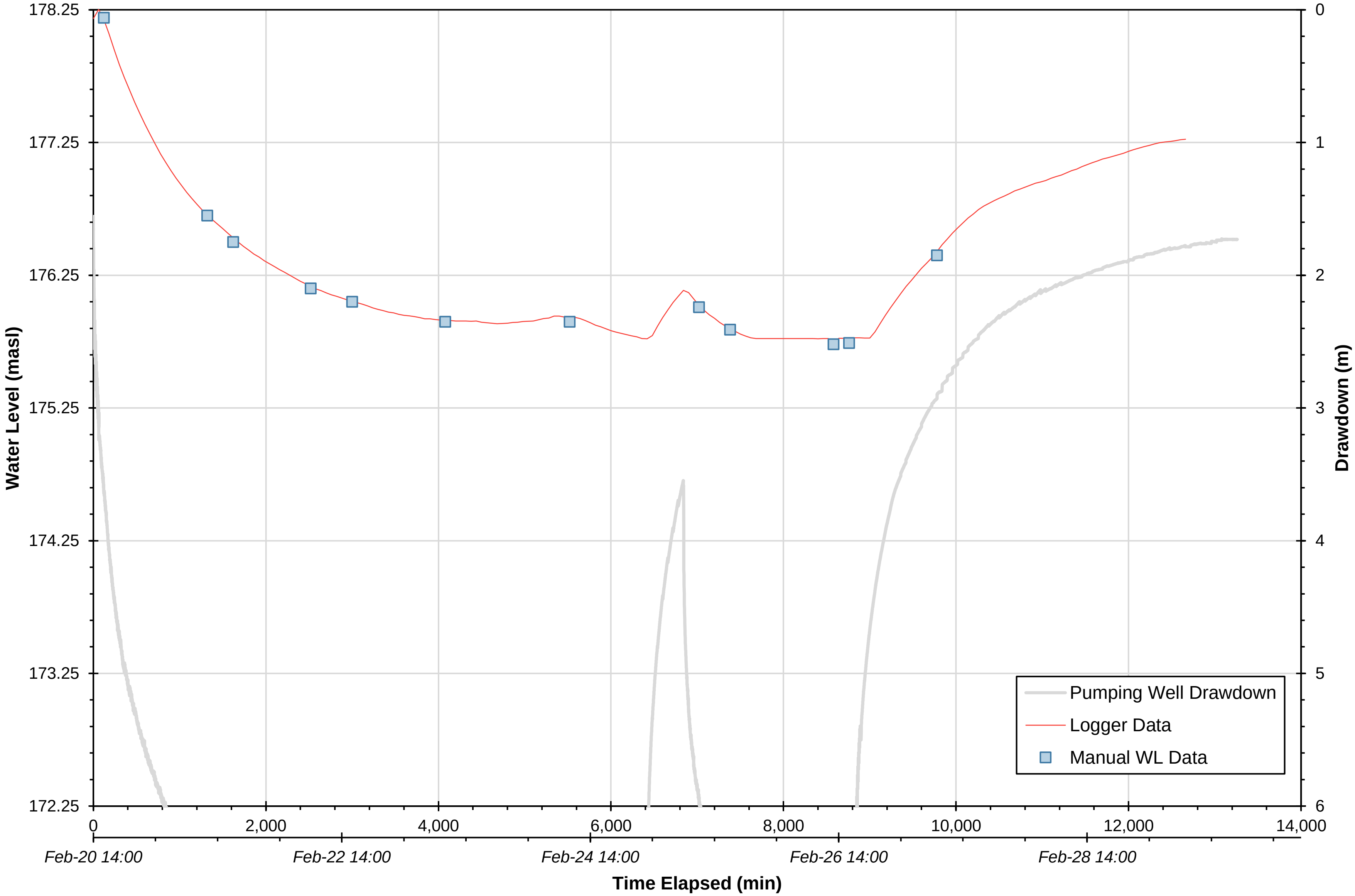


Figure 6-12 - Observation Well MW17-23OB Drawdown (342 m from PW1)
February 20 - March 1, 2019



PROPOSED UPPER'S QUARRY
H:\Projects\2016\161-11633 Uppers Lane\00\03 Level 2 HydroG\Tech\App D_Hyd Cond Testing Data\2019 PW1 Pumping Test\Analysis\2019 Pumping Test 1.xlsx

Figure 6-13 - Observation Well MW17-23B Drawdown (342 m from PW1)
February 20 - March 1, 2019

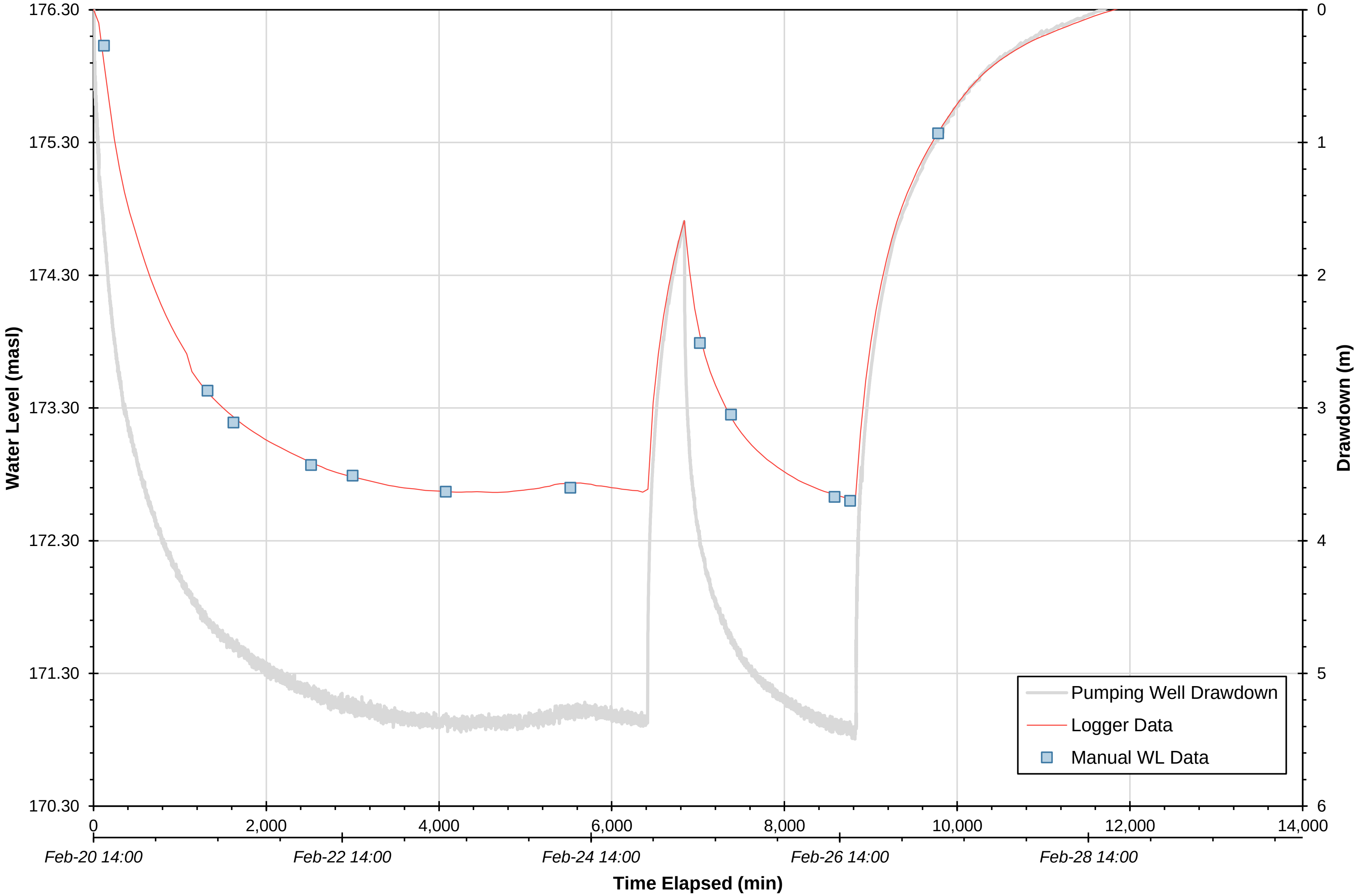


Figure 6-14 - Cricket Ctr Well Drawdown (378 m from PW1)
February 20 - March 1, 2019

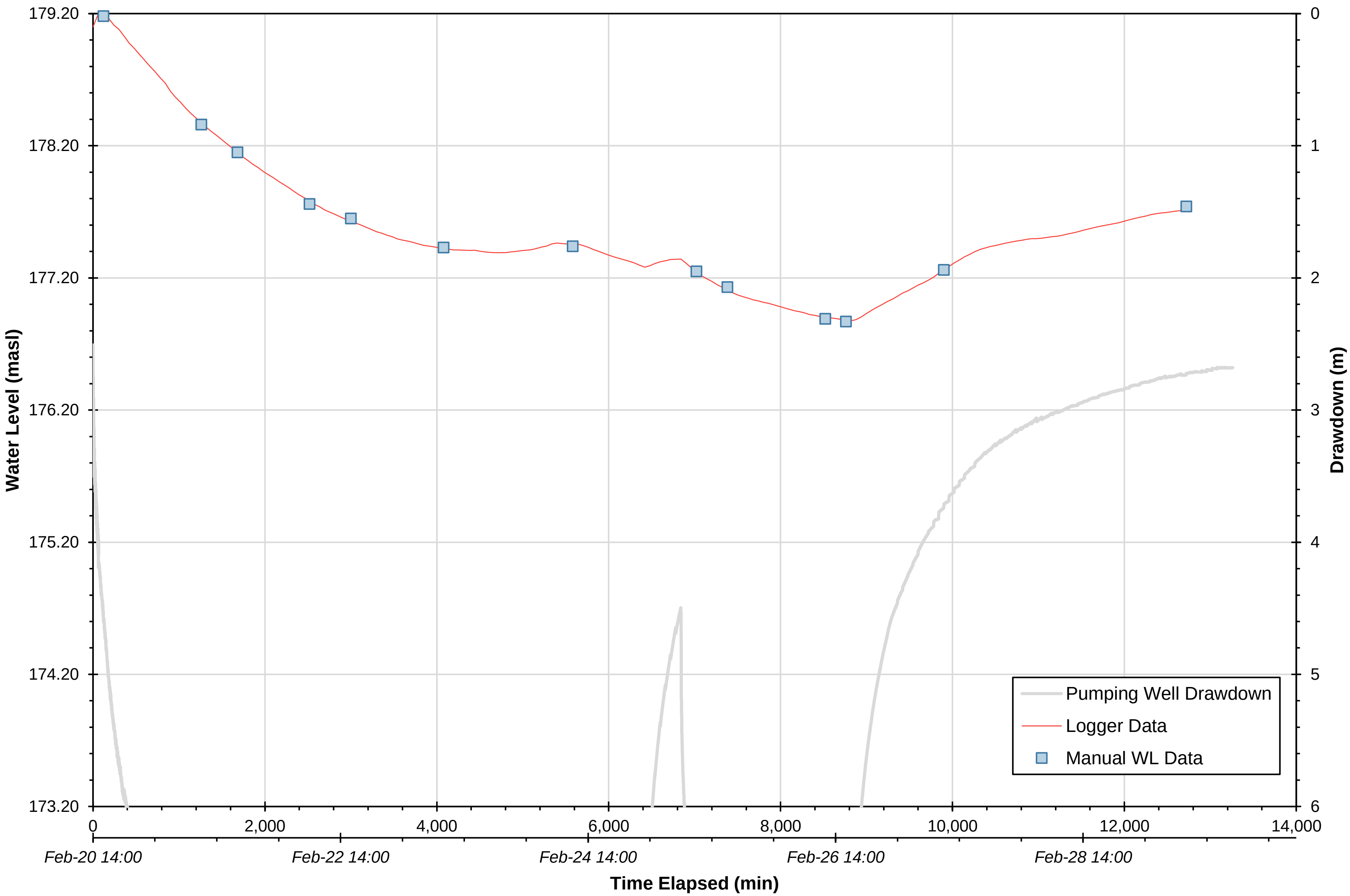


Figure 6-15 - Observation Well MW17-21B Drawdown (468 m from PW1)
February 20 - March 1, 2019

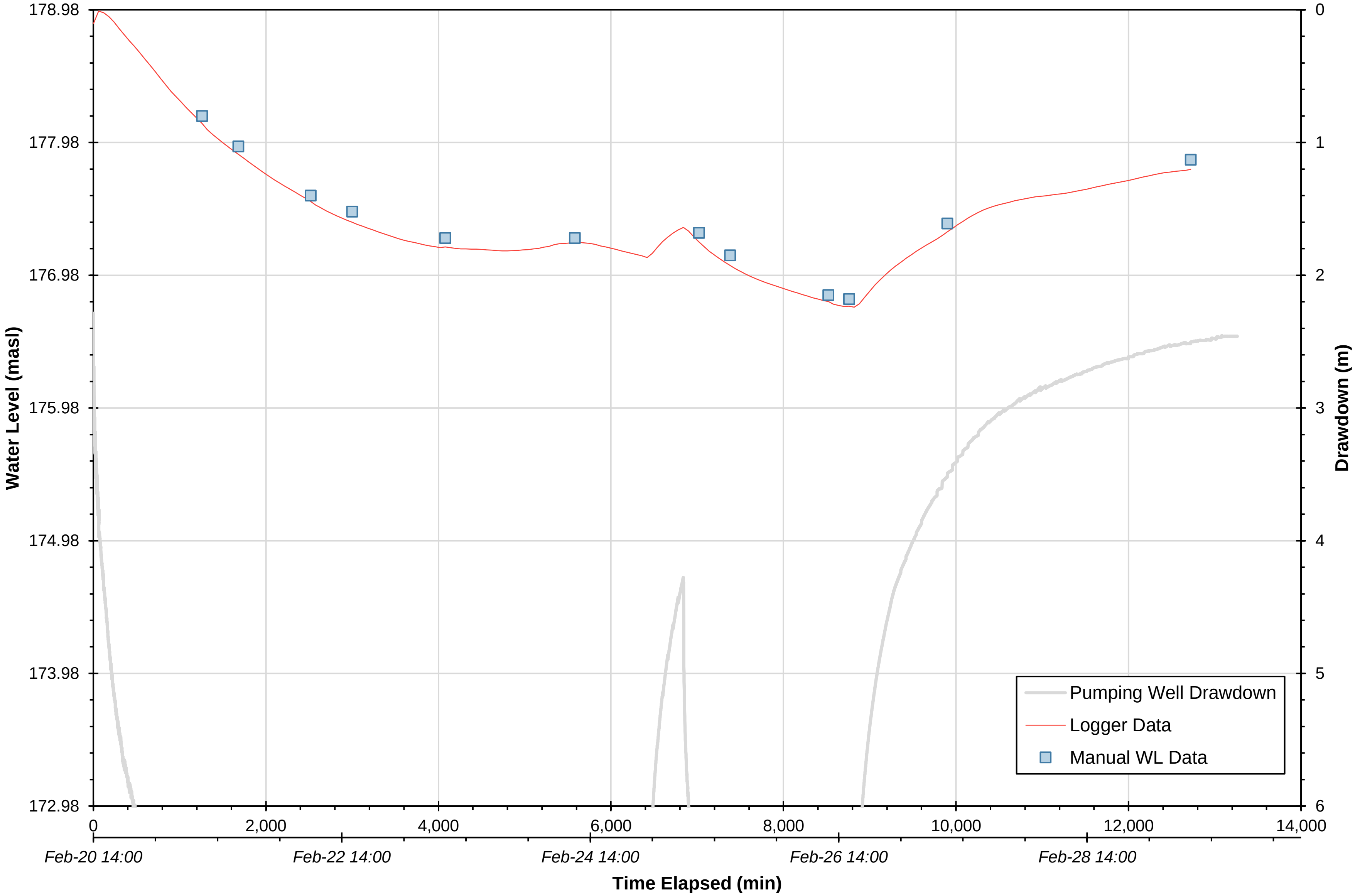


Figure 6-16 - Observation Well MW16-5B Drawdown (722 m from PW1)
February 20 - March 1, 2019

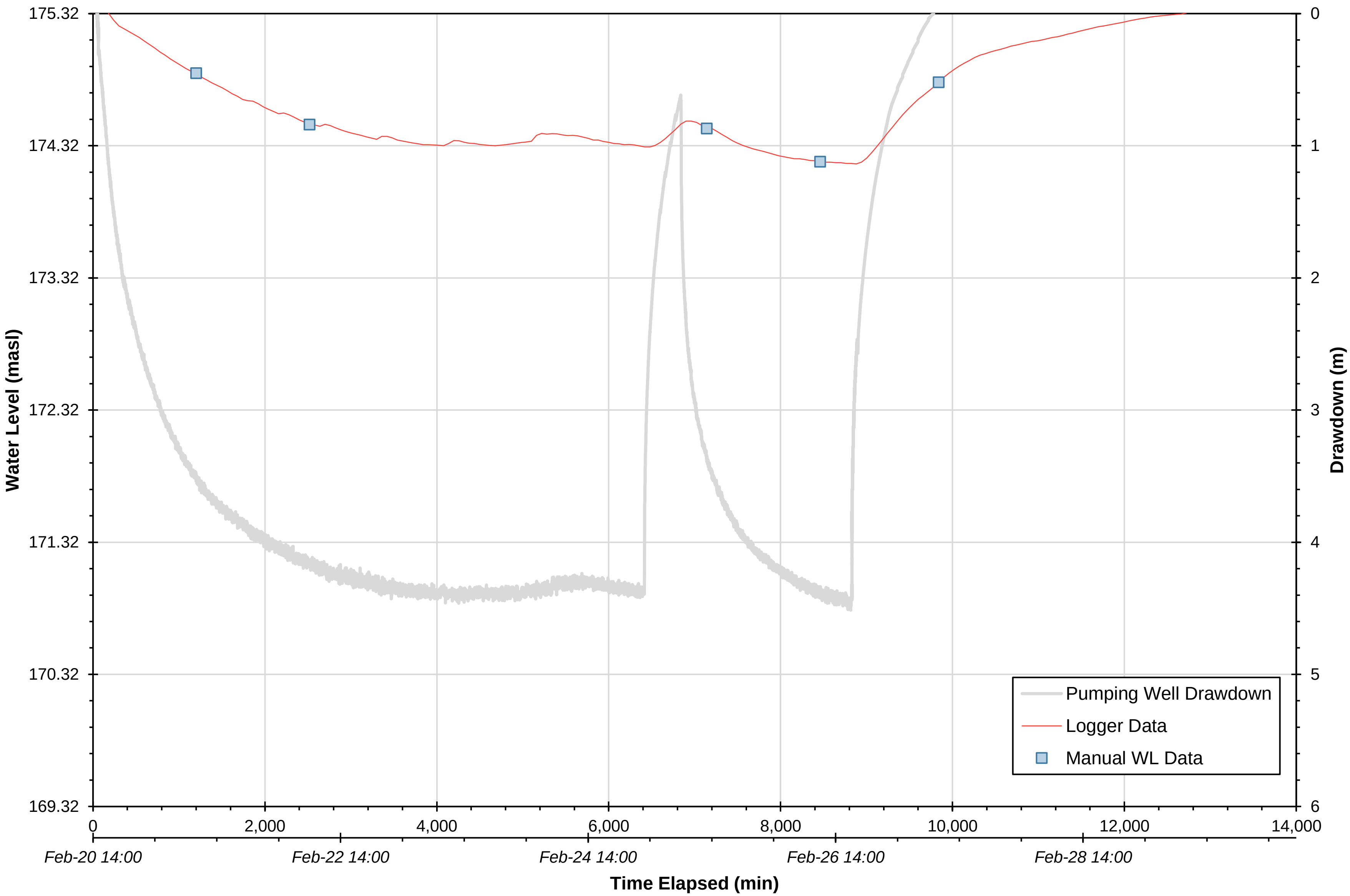
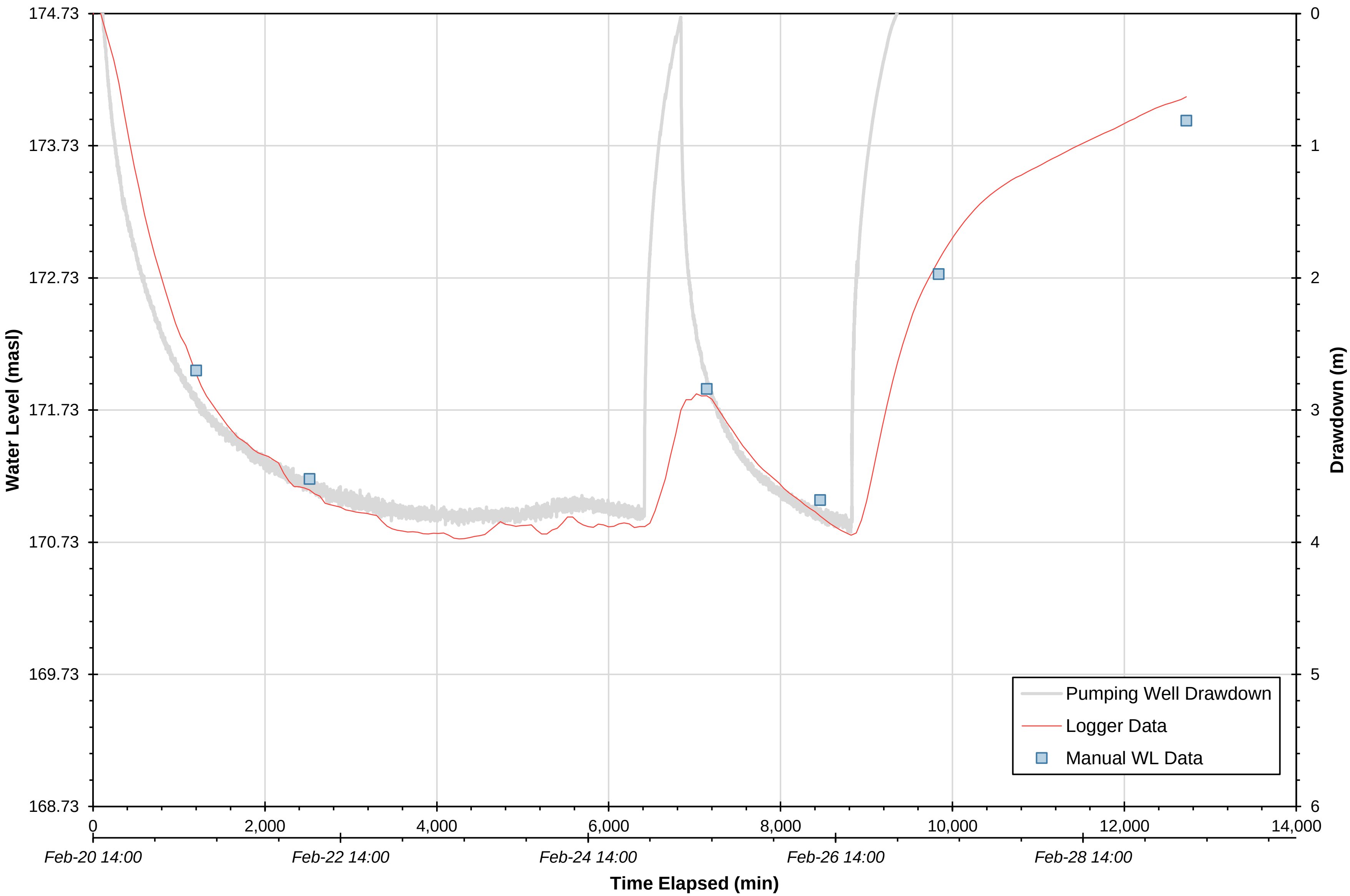
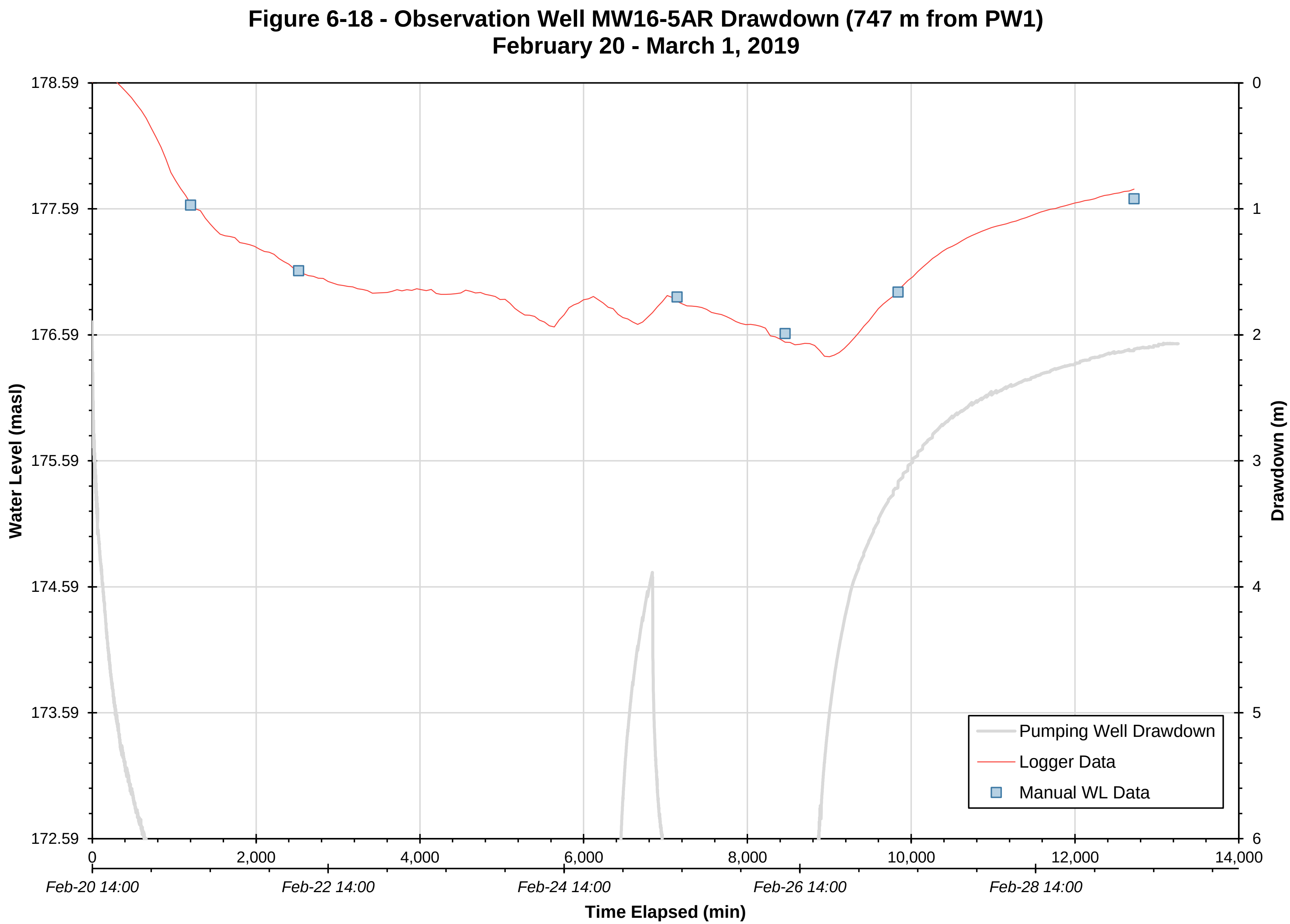
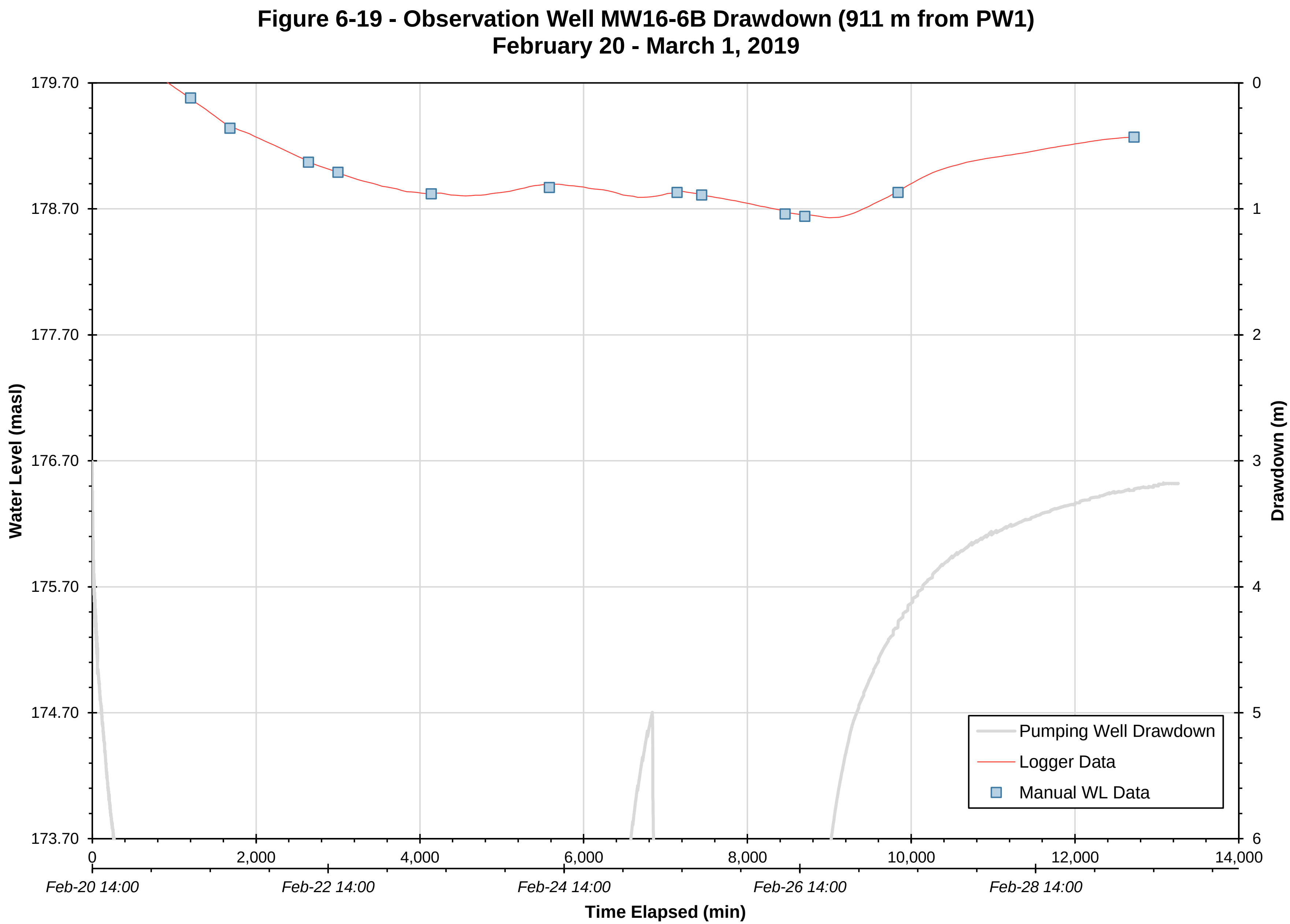


Figure 6-17 - Observation Well MW16-5A Drawdown (722 m from PW1)
February 20 - March 1, 2019



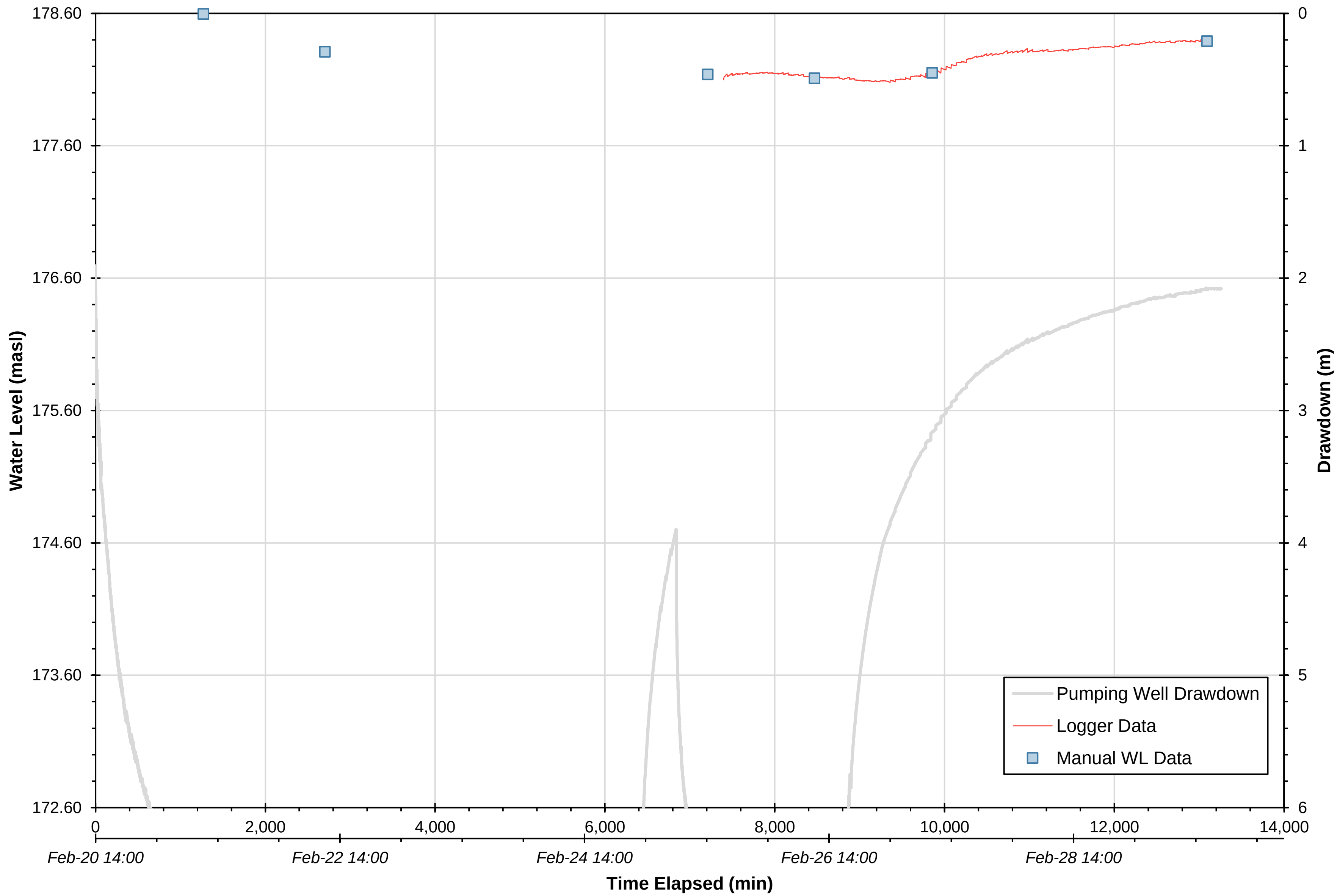


PROPOSED UPPER'S QUARRY
H:\Projects\2016\161-11633 Uppers Lane\00\03 Level 2 HydroG\Tech\App D_Hyd Cond Testing Data\2019 PW1 Pumping Test\Analysis\2019 Pumping Test 1.xlsx



PROPOSED UPPER'S QUARRY
H:\Projects\2016\161-11633 Uppers Lane\00\03 Level 2 HydroG\Tech\App D_Hyd Cond Testing Data\2019 PW1 Pumping Test\Analysis\2019 Pumping Test 1.xlsx

Figure 6-20 - 5205 Beechwood Well Drawdown (1.0 km from PW1)
February 20 - March 1, 2019



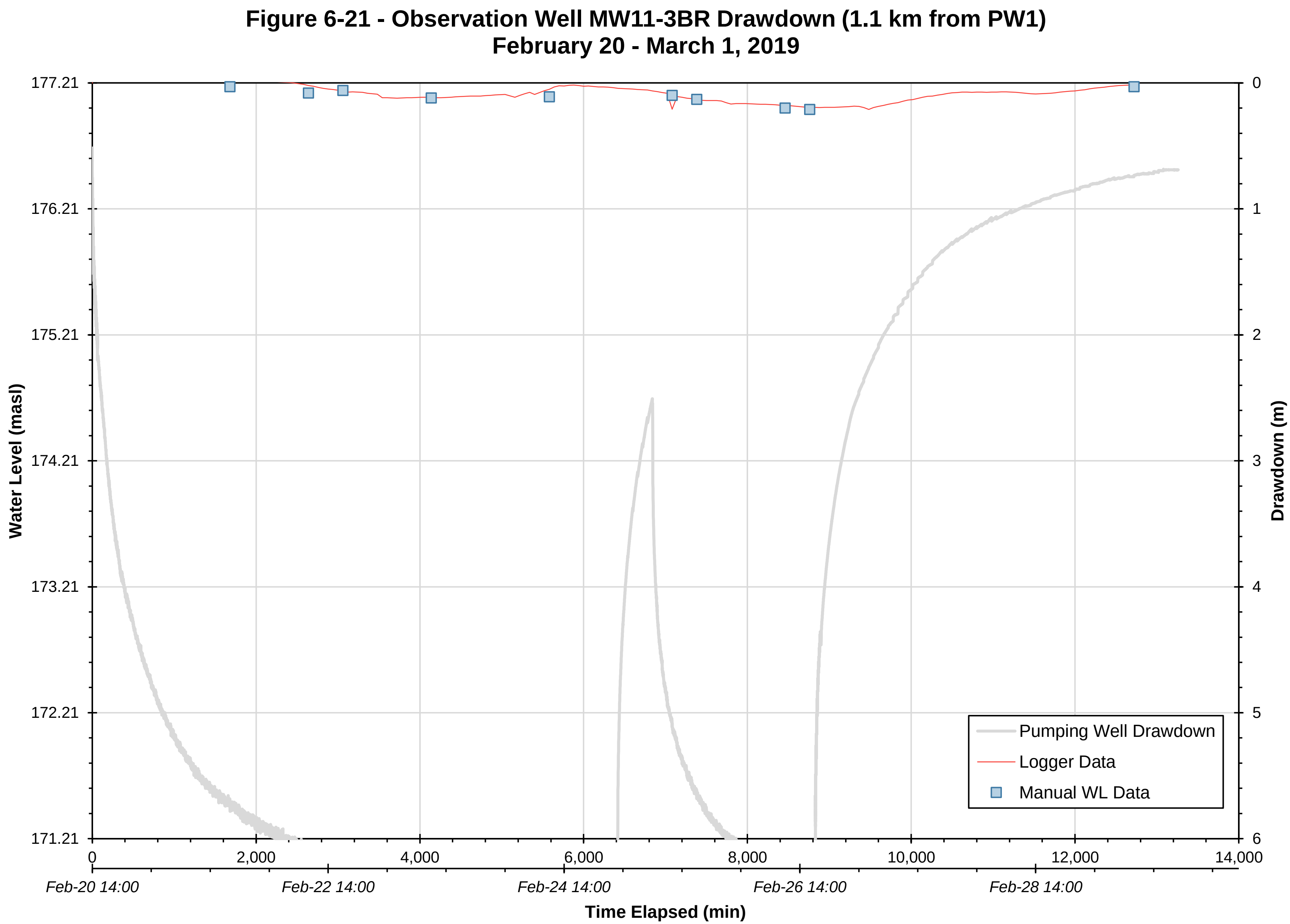


Figure 6-21 - Observation Well MW11-3BR Drawdown (1.1 km from PW1)
February 20 - March 1, 2019
Water Level (masl)
177.21
176.21
175.21
174.21
173.21
172.21
171.21
Drawdown (m)
0
1
2
3
4
5
6
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Feb-20 14:00
Feb-22 14:00
Feb-24 14:00
Feb-26 14:00
Feb-28 14:00
Time Elapsed (min)
Pumping Well Drawdown
Logger Data
Manual WL Data

Figure 6-22 - Observation Well MW16-7OB Drawdown (762 m from PW1)
February 20 - March 1, 2019

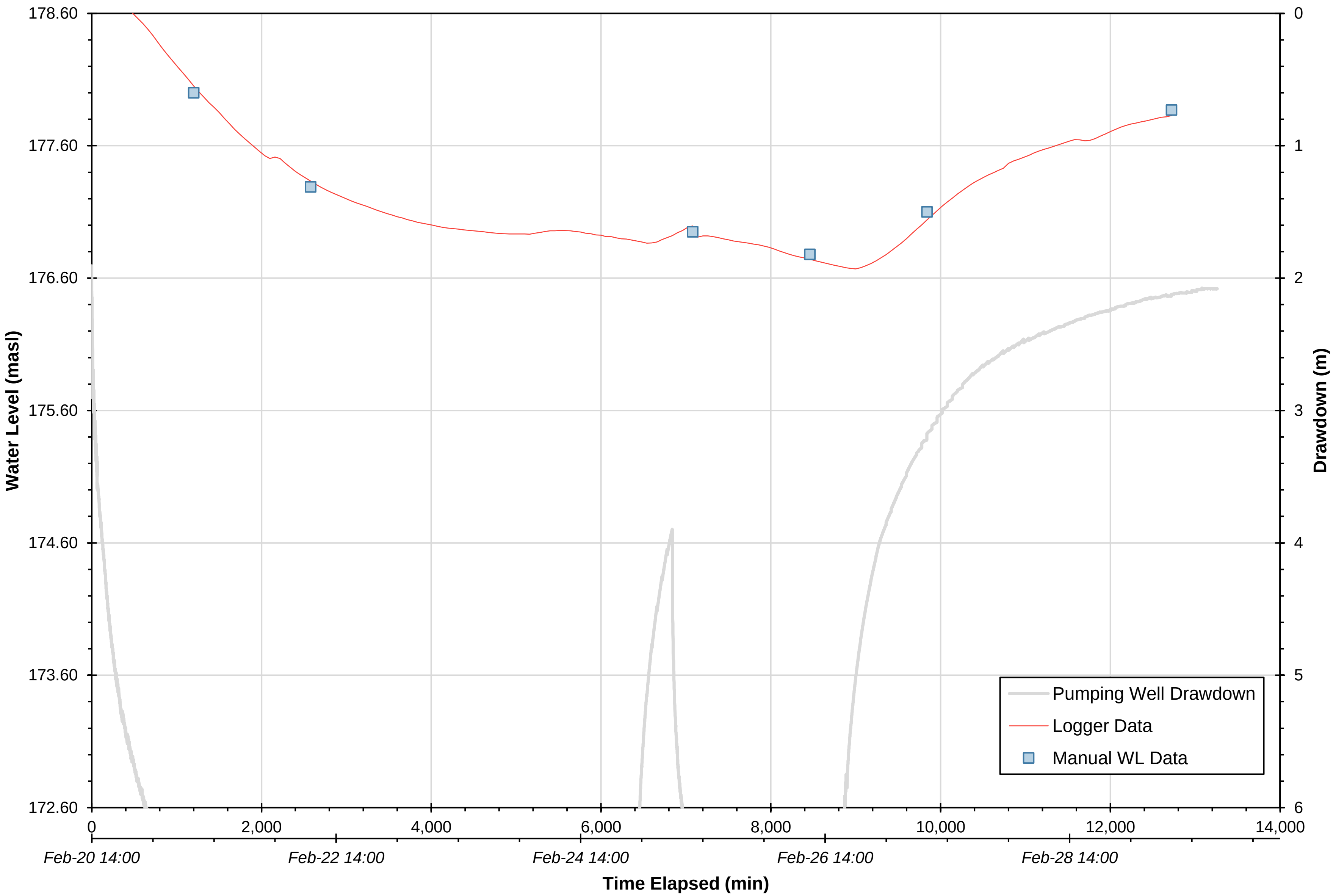
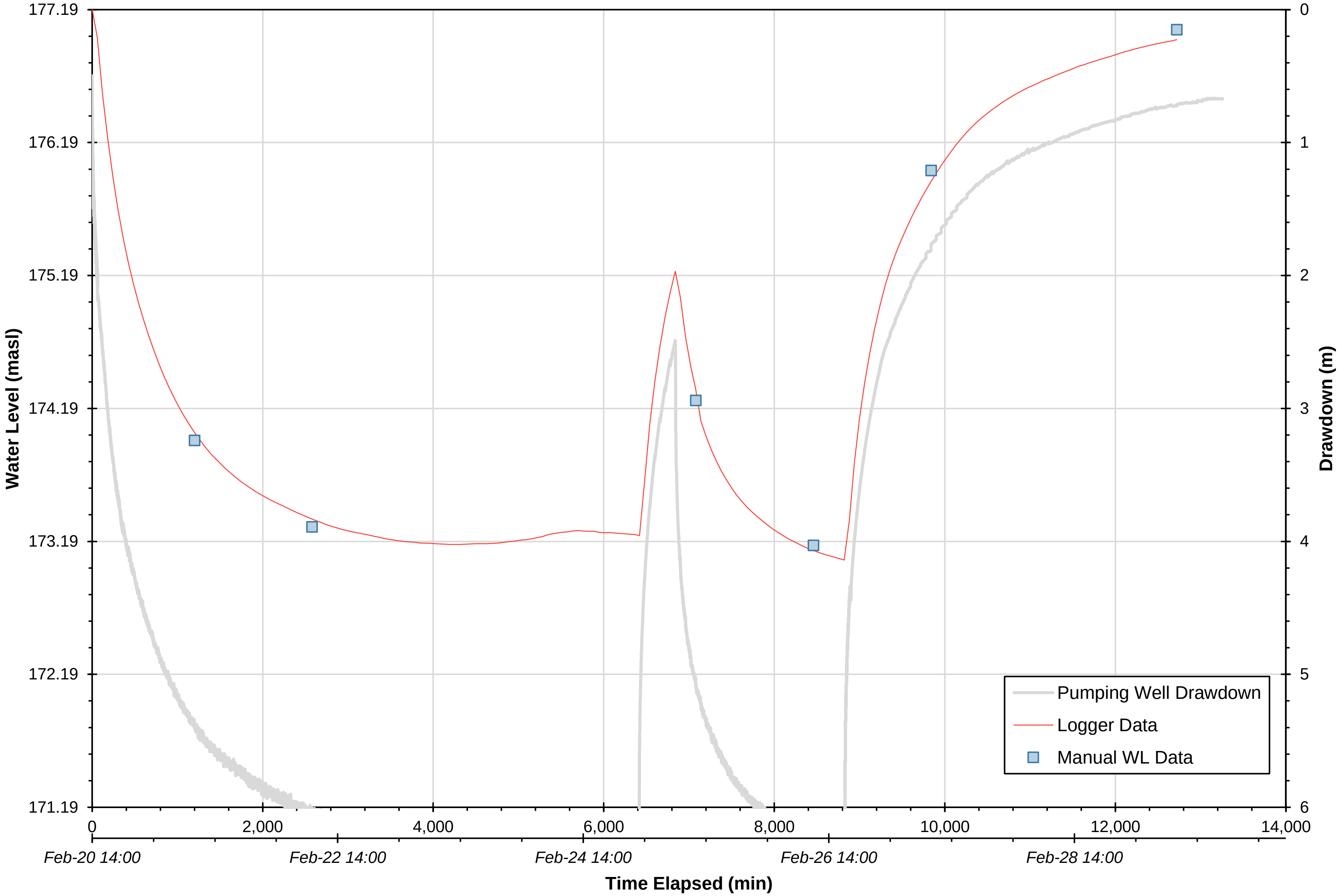


Figure 6-24 - Observation Well MW16-7B Drawdown (762 m from PW1)
February 20 - March 1, 2019



PROPOSED UPPER'S QUARRY
H:\Projects\2016\161-11633 Uppers Lane\00\03 Level 2 HydroG\Tech\App D_Hyd Cond Testing Data\2019 PW1 Pumping Test\Analysis\2019 Pumping Test 1.xlsx

Figure 6-24 - Observation Well MW16-7A Drawdown (762 m from PW1)
February 20 - March 1, 2019

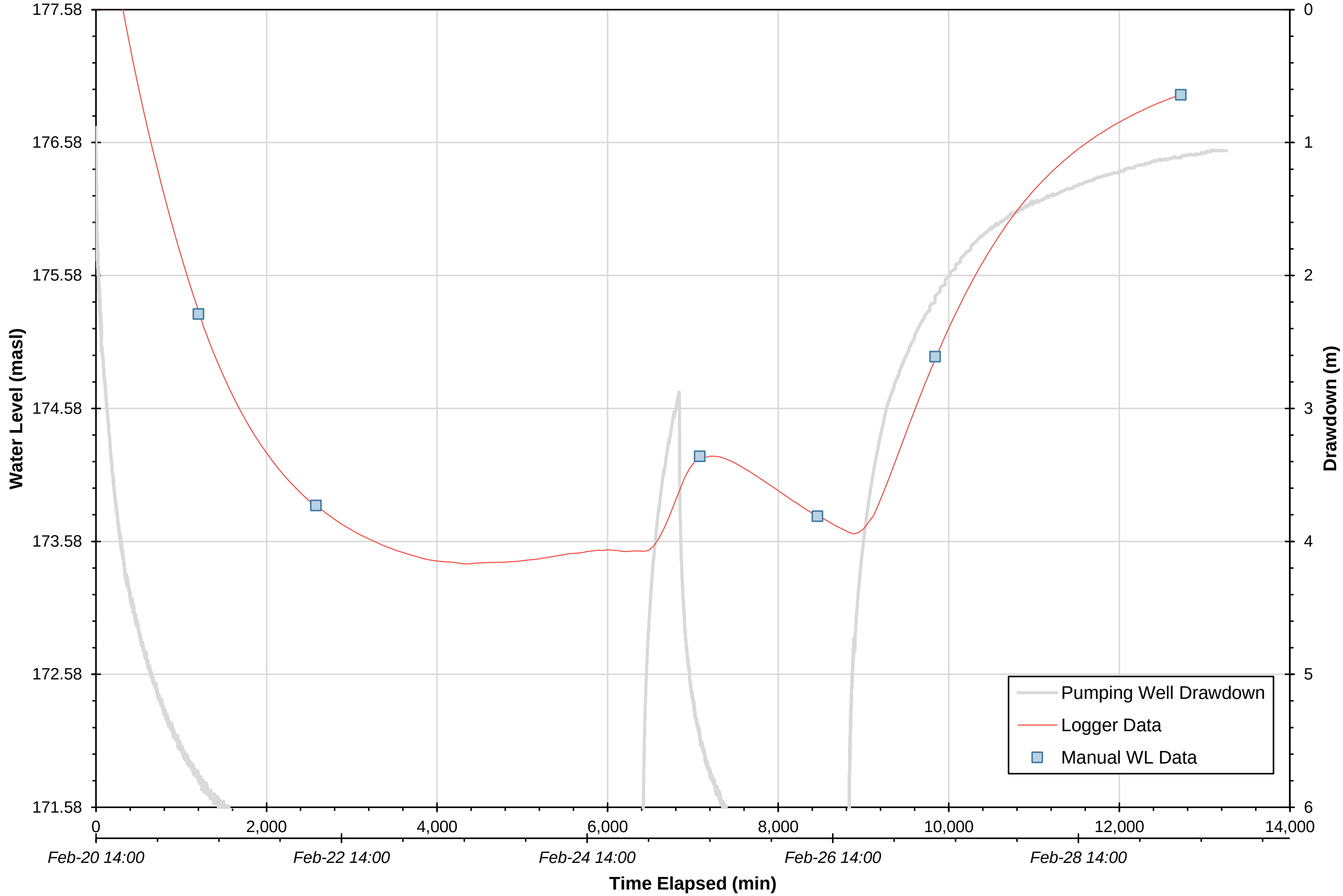
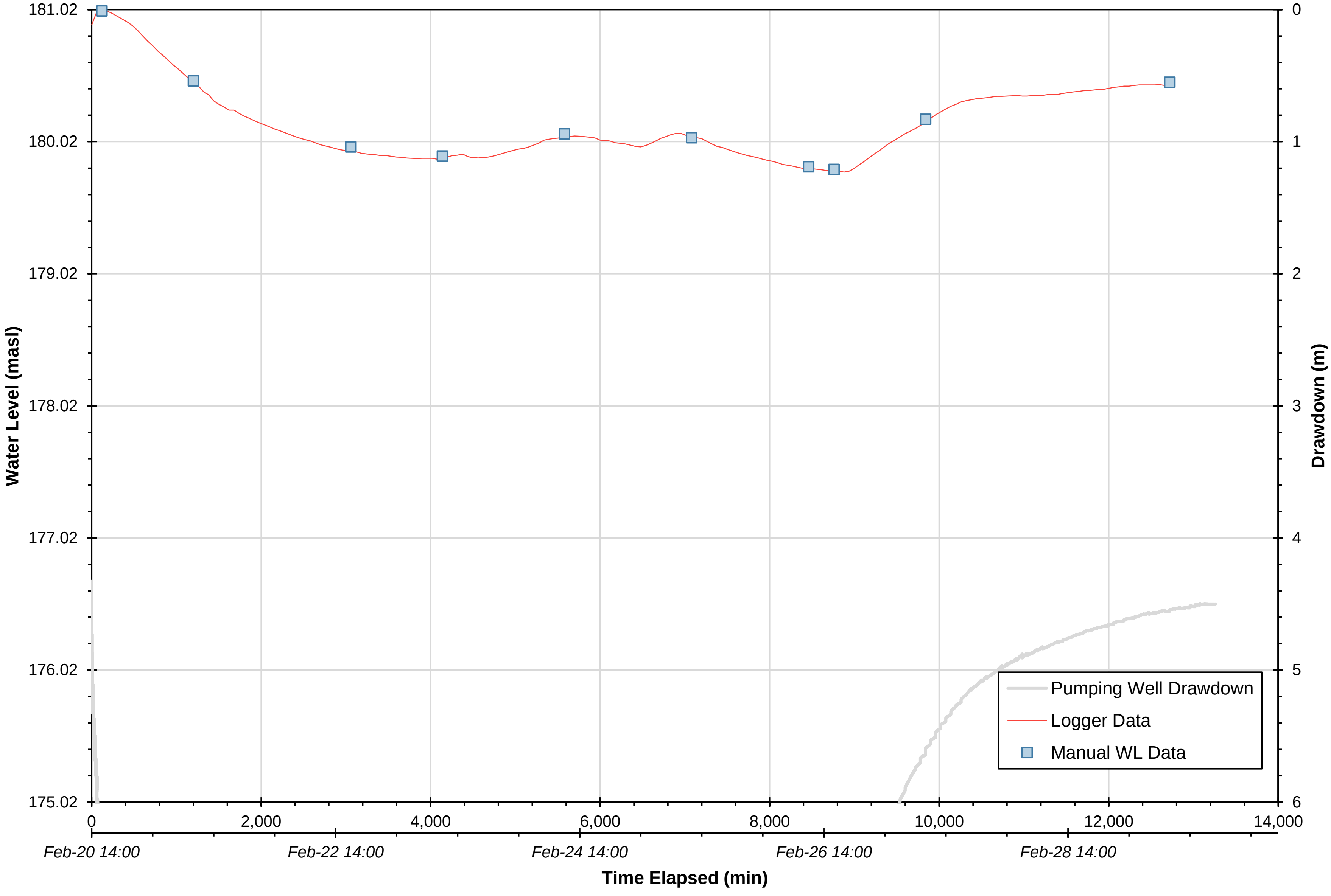


Figure 6-25 - Observation Well MW11-2B Drawdown (982 m from PW1)
February 20 - March 1, 2019



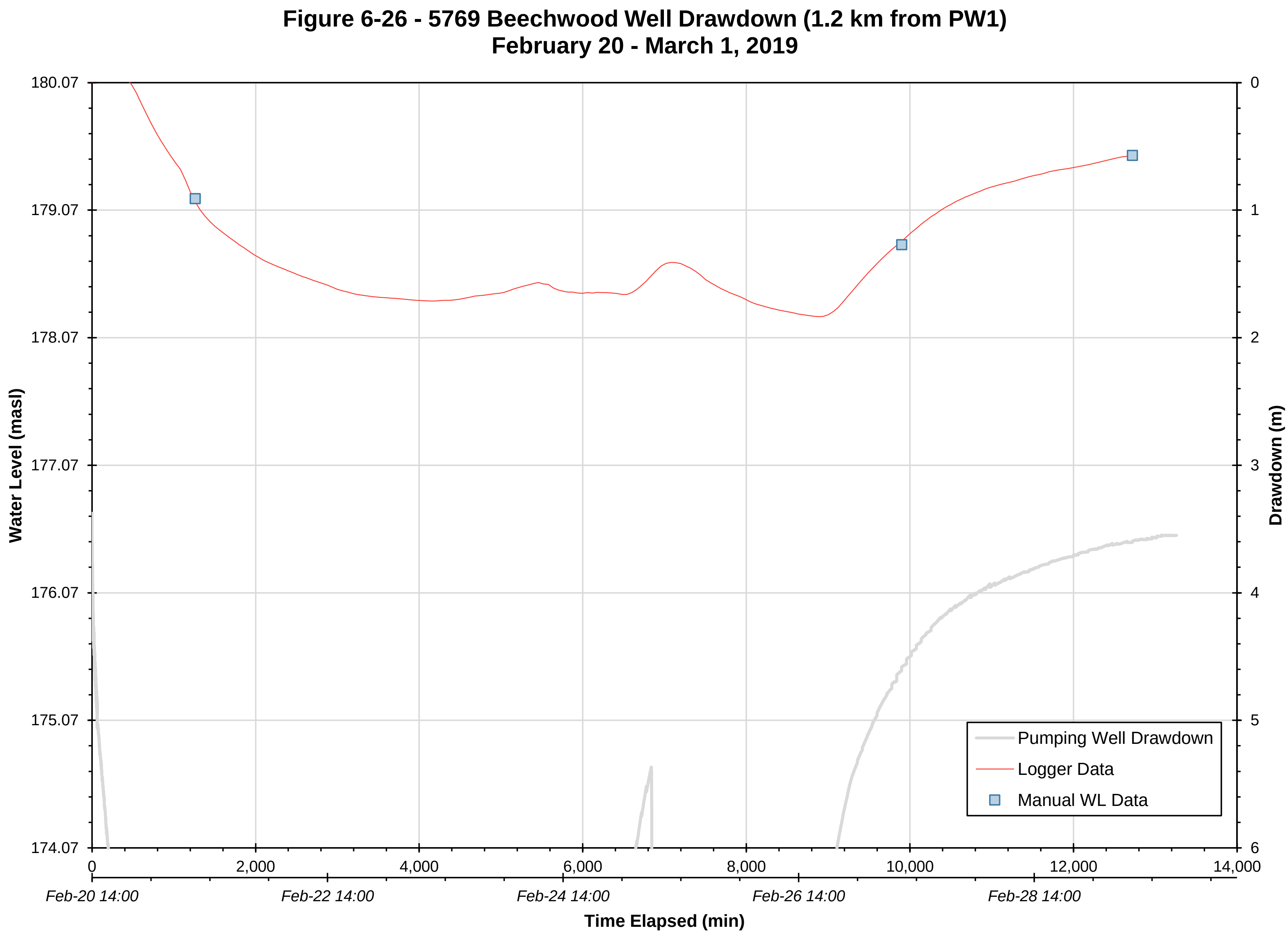
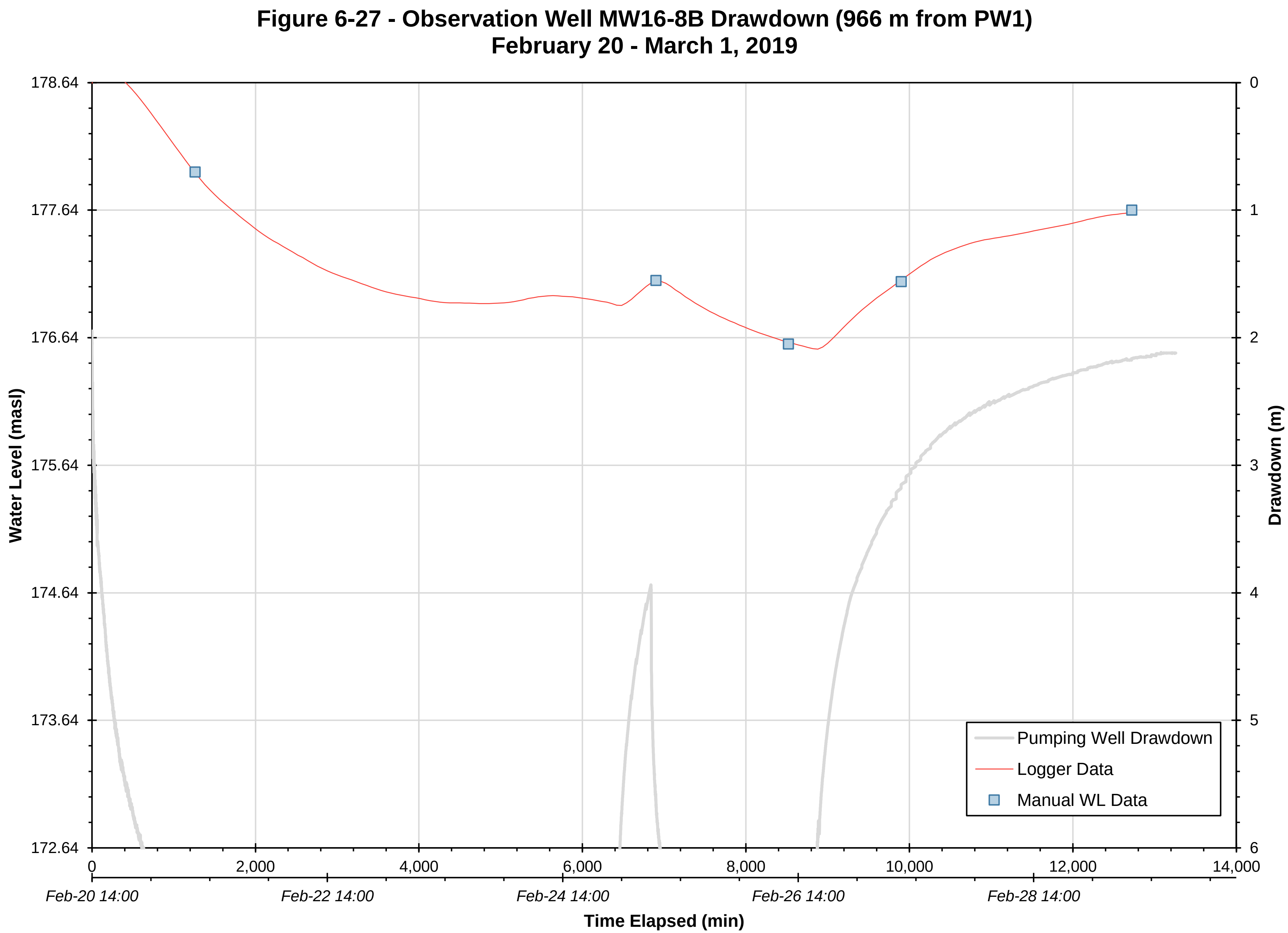


Figure 6-26 - 5769 Beechwood Well Drawdown (1.2 km from PW1)
February 20 - March 1, 2019
Water Level (masl)
Drawdown (m)
180.07
179.07
178.07
177.07
176.07
175.07
174.07
0
1
2
3
4
5
6
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
Feb-20 14:00
Feb-22 14:00
Feb-24 14:00
Feb-26 14:00
Feb-28 14:00
Time Elapsed (min)
Pumping Well Drawdown
Logger Data
Manual WL Data



PROPOSED UPPER'S QUARRY
H:\Projects\2016\161-11633 Uppers Lane\00\03 Level 2 HydroG\Tech\App D_Hyd Cond Testing Data\2019 PW1 Pumping Test\Analysis\2019 Pumping Test 1.xlsx

Figure 6-28 - Lundy's Manor Well Drawdown (1.1 km from PW1)
February 20 - March 1, 2019

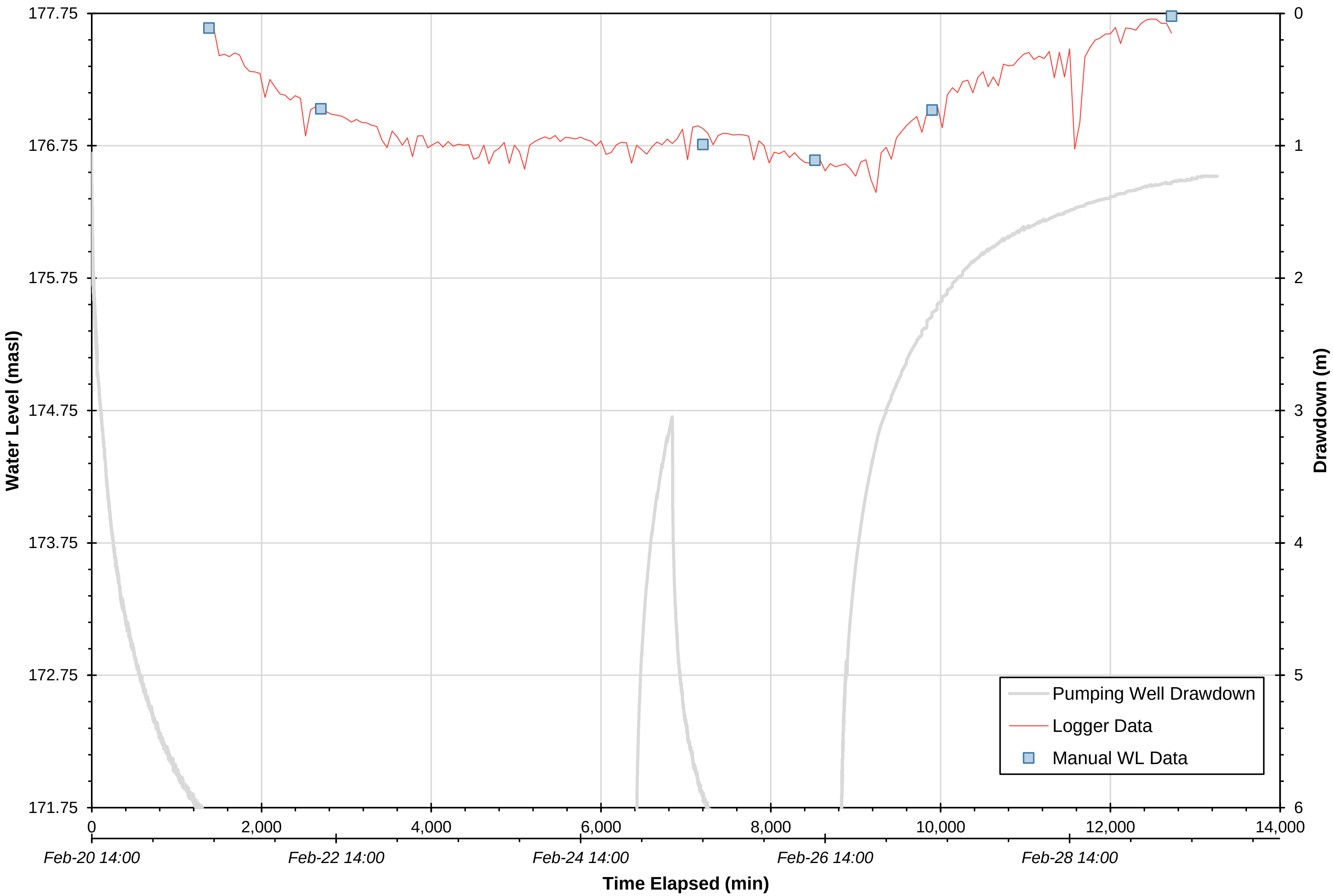
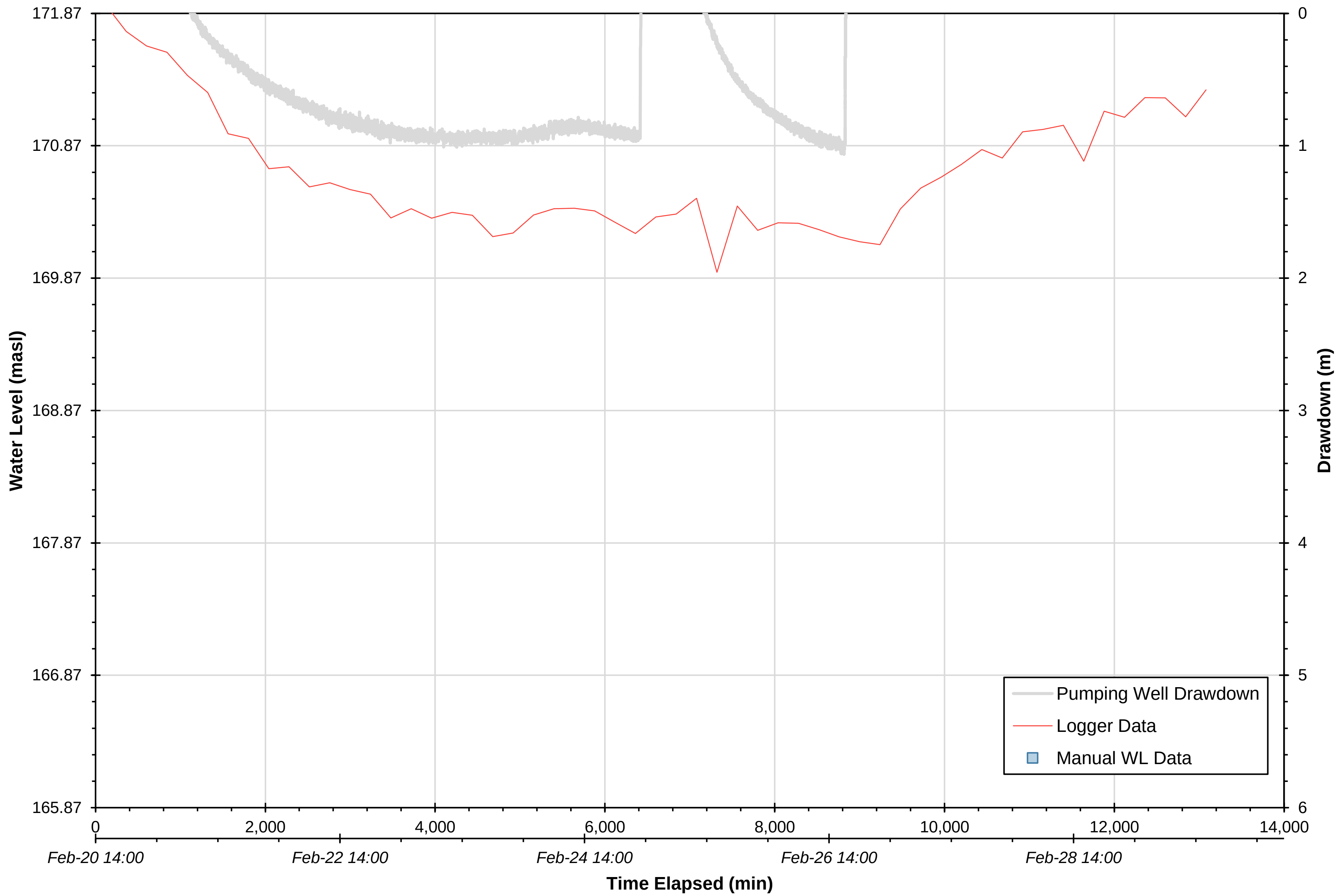


Figure 6-29 - Country Basket Well Drawdown (1.4 km from PW1)
February 20 - March 1, 2019



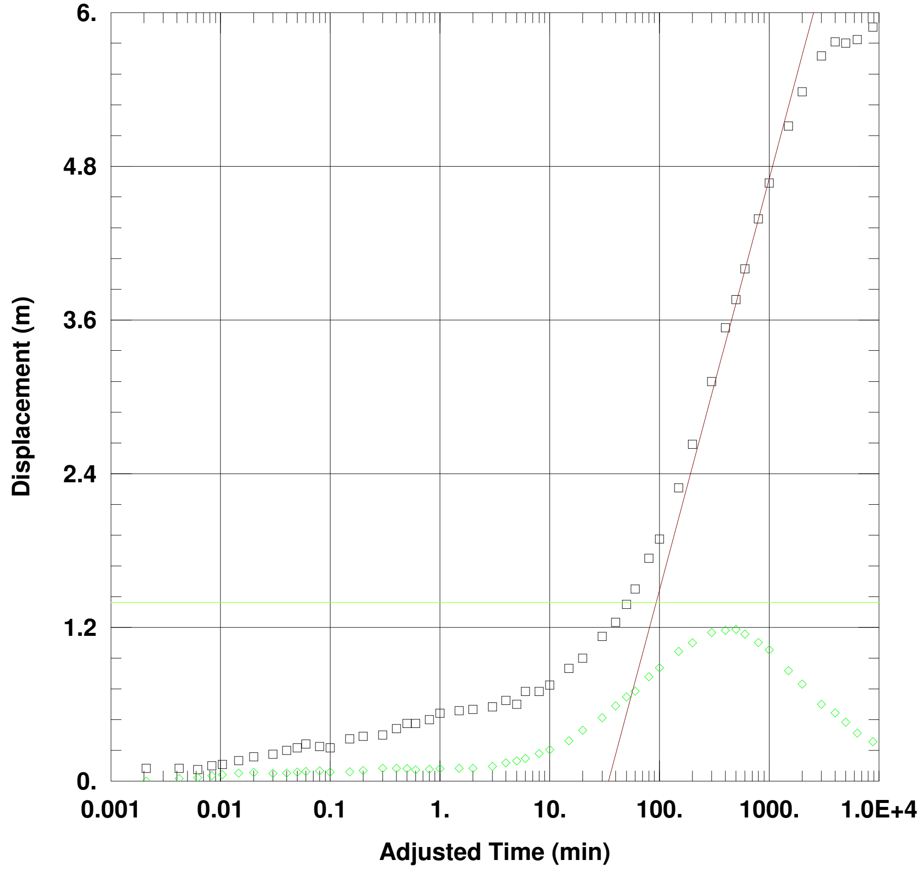


FIGURE 6-30 - 2019 PW1 PT - DDN CJSL ANALYSIS

Data Set: H:\...\2019 PW1 CJSL ddn.aqt
Date: 06/12/20 Time: 15:44:46

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 61.63 m^2/day
S = 320.9

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

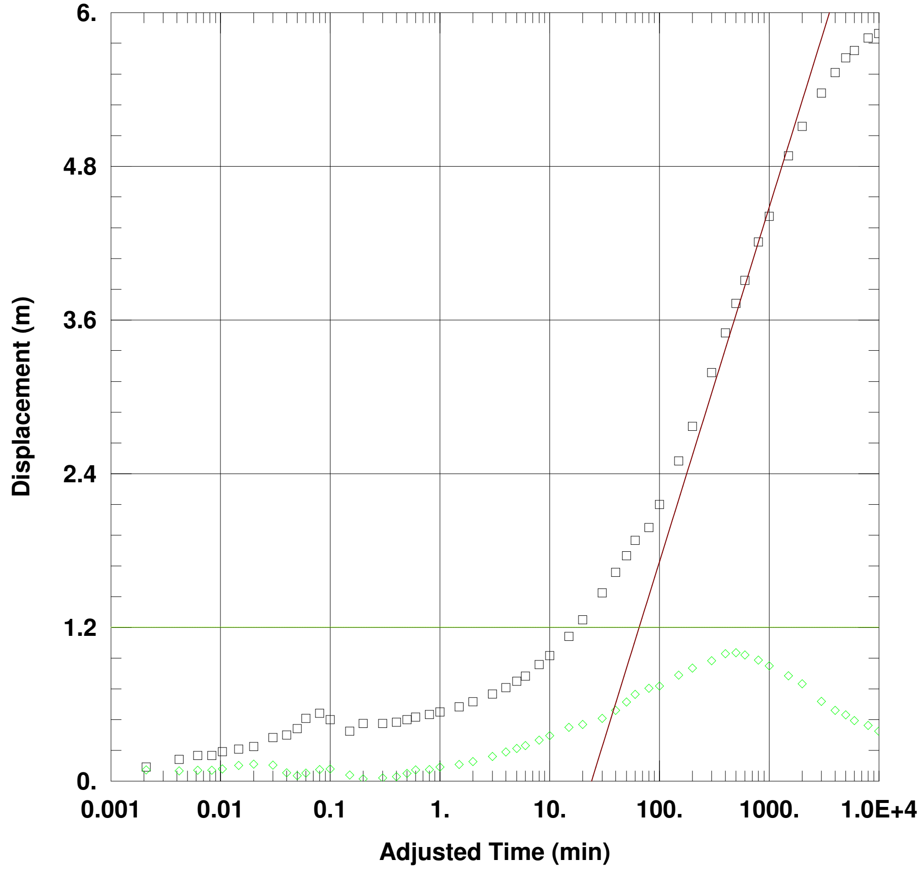


FIGURE 6-31 - 2019 PW1 PT - CJSL REC ANALYSIS

Data Set: H:\...\2019 PW1 CJSL rec.aqt
Date: 06/12/20 Time: 15:46:27

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 71.52 m^2/day
S = 260.9

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

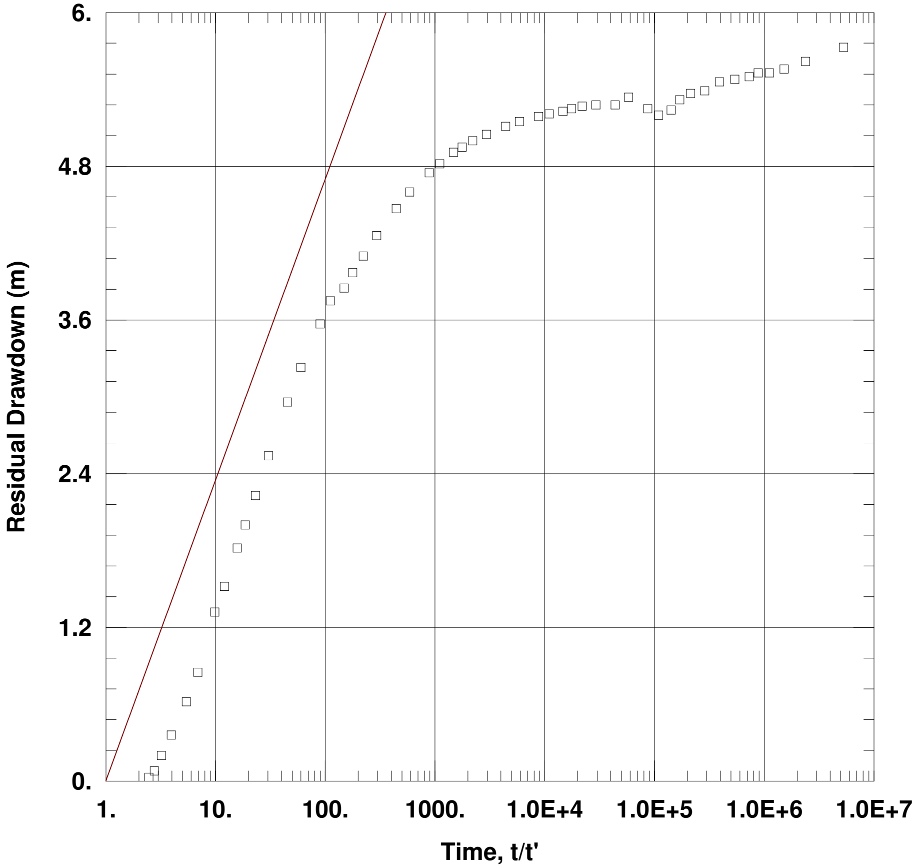


FIGURE 6-32 - 2019 PW1 PT - THEIS REC ANALYSIS

Data Set: H:\...\2019 PW1 rec - Theis.aqt
Date: 06/12/20 Time: 15:48:22

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)
T = 84.22 m^2/day
S/S' = 1.

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

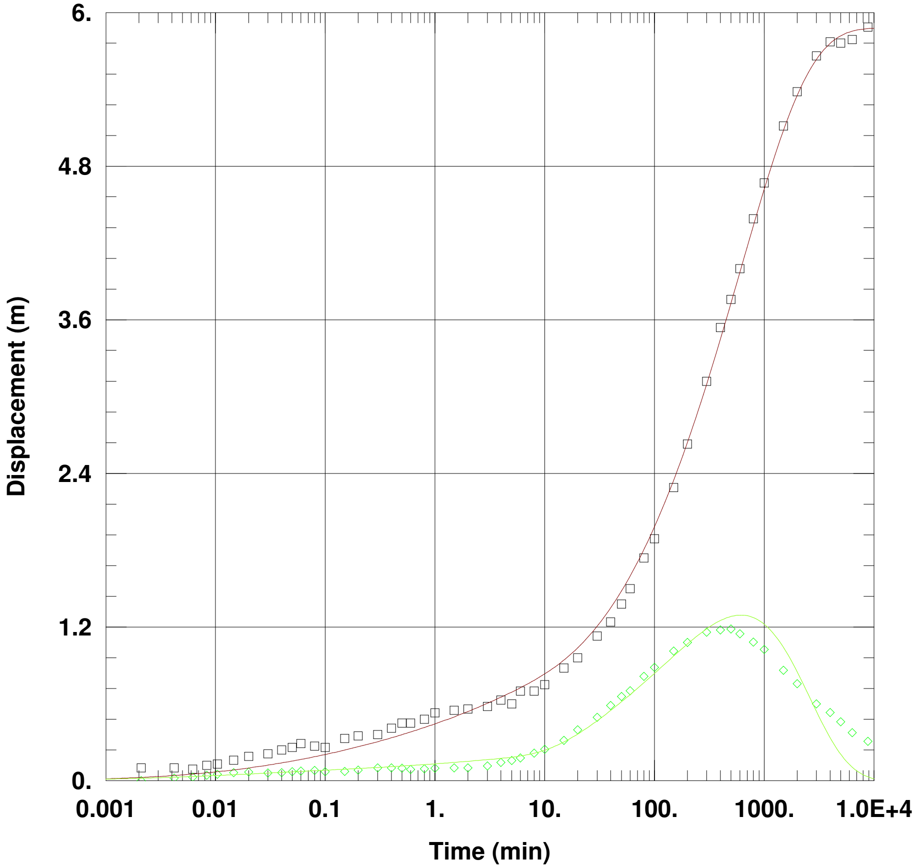


FIGURE 6-33 - 2019 PW1 PT - LEAKY AQ DDN ANALYSIS

Data Set: H:\...\2019 PW1 ddn.aqt
Date: 06/12/20 Time: 15:49:44

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Leaky
Solution Method: Moench (Case 3)

T = 18.35 m^2/day
S = 0.1121
r/B' = 1.158
ß' = 0.4664
r/B" = 8.759
ß" = 10.
Sw = -3.528
r(w) = 0.1015 m
r(c) = 0.1015 m

AQUIFER DATA

Saturated Thickness: 17.4 m
Aquitard Thickness (b'): 4.5 m
Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 22. m

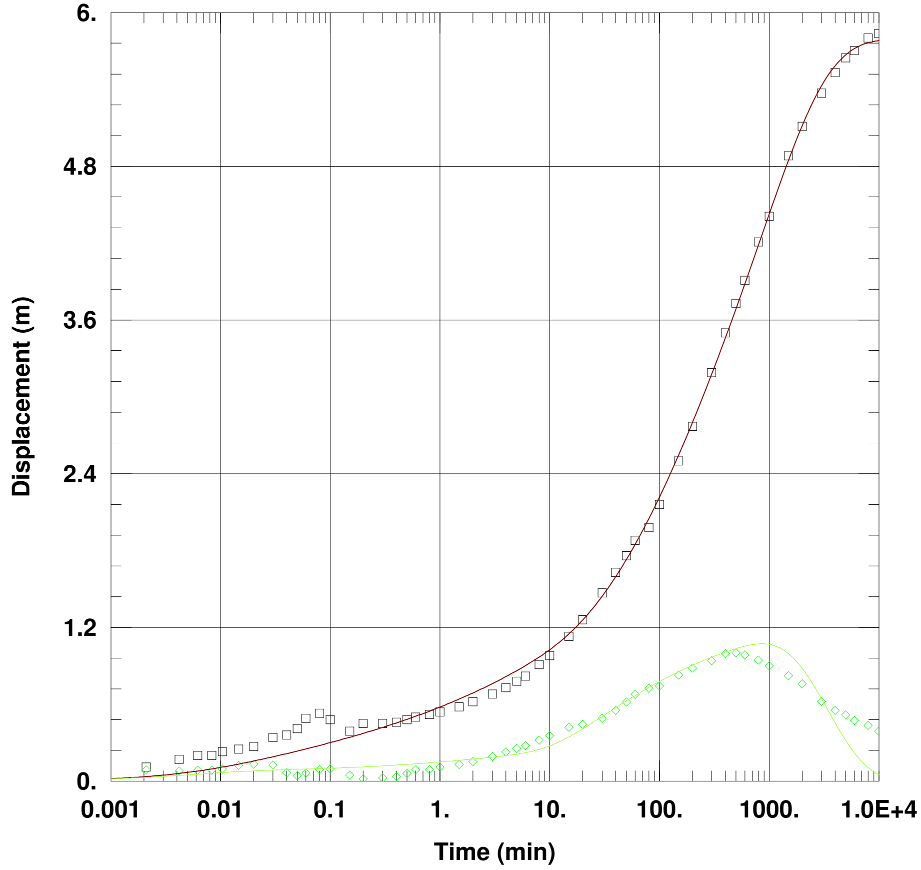


FIGURE 6-34 - 2019 PW1 PT - LEAKY AQ REC ANALYSIS

Data Set: H:\...\2019 PW1 rec.aqt
Date: 06/12/20 Time: 15:51:23

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Leaky
Solution Method: Moench (Case 3)

T = 27.54 m^2/day
S = 0.1813
r/B' = 0.6673
ß' = 2.73
r/B" = 4.317
ß" = 10.
Sw = -2.046
r(w) = 0.1015 m
r(c) = 0.1015 m

AQUIFER DATA

Saturated Thickness: 17.4 m
Aquitard Thickness (b'): 4.5 m
Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 22. m

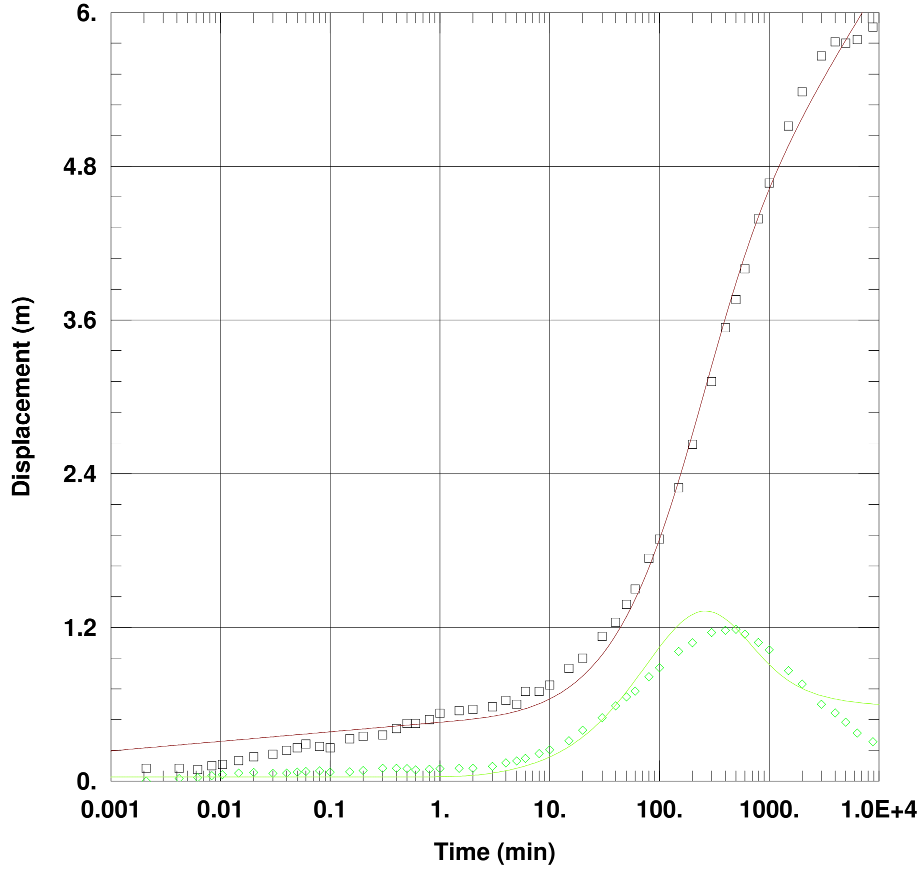


FIGURE 6-35 - 2019 PW1 PT - NON-UNIFORM AQ DDN ANALYSIS

Data Set: H:\...\2019 PW1 ddn - Butler.aqt
Date: 06/12/20 Time: 15:53:05

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Butler

T1 = 2657.3 m^2/day
S1 = 0.0002844
T2 = 151.5 m^2/day
S2 = 2.344E-6
R = 200. m

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

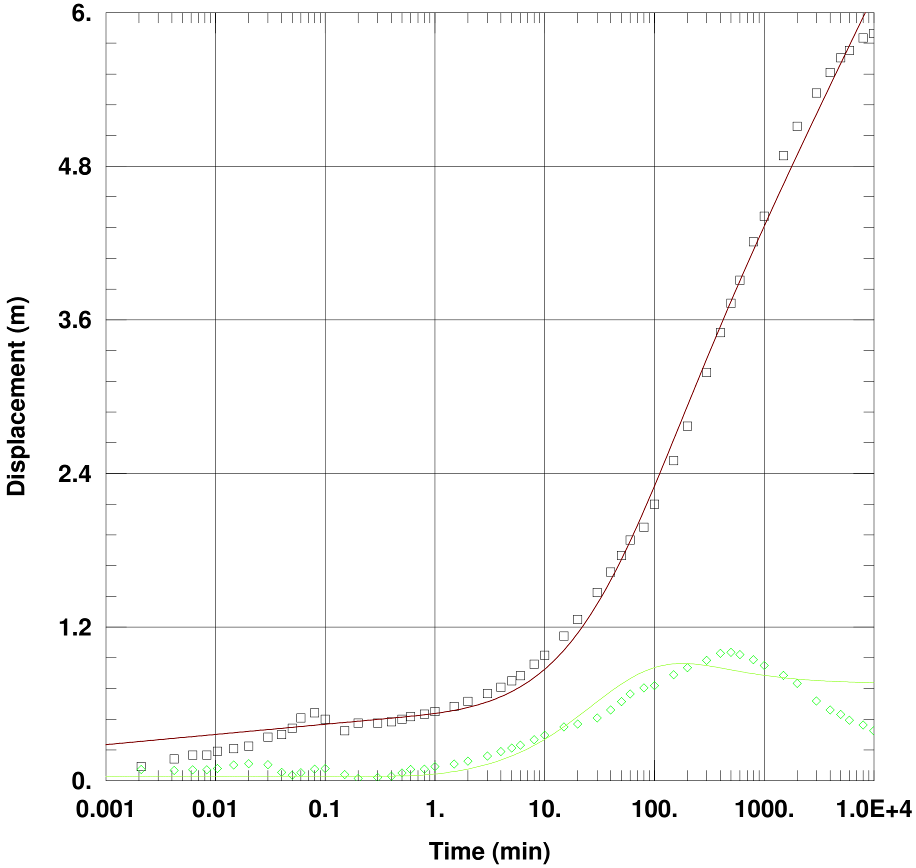


FIGURE 6-36 - 2019 PW1 PT - NON-UNIFORM AQ REC ANALYSIS

Data Set: H:\...\2019 PW1 rec - Butler.aqt
Date: 06/12/20 Time: 15:55:17

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Butler

T1 = 2489.9 m^2/day
S1 = 0.0001116
T2 = 114.1 m^2/day
S2 = 2.55E-5
R = 200. m

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

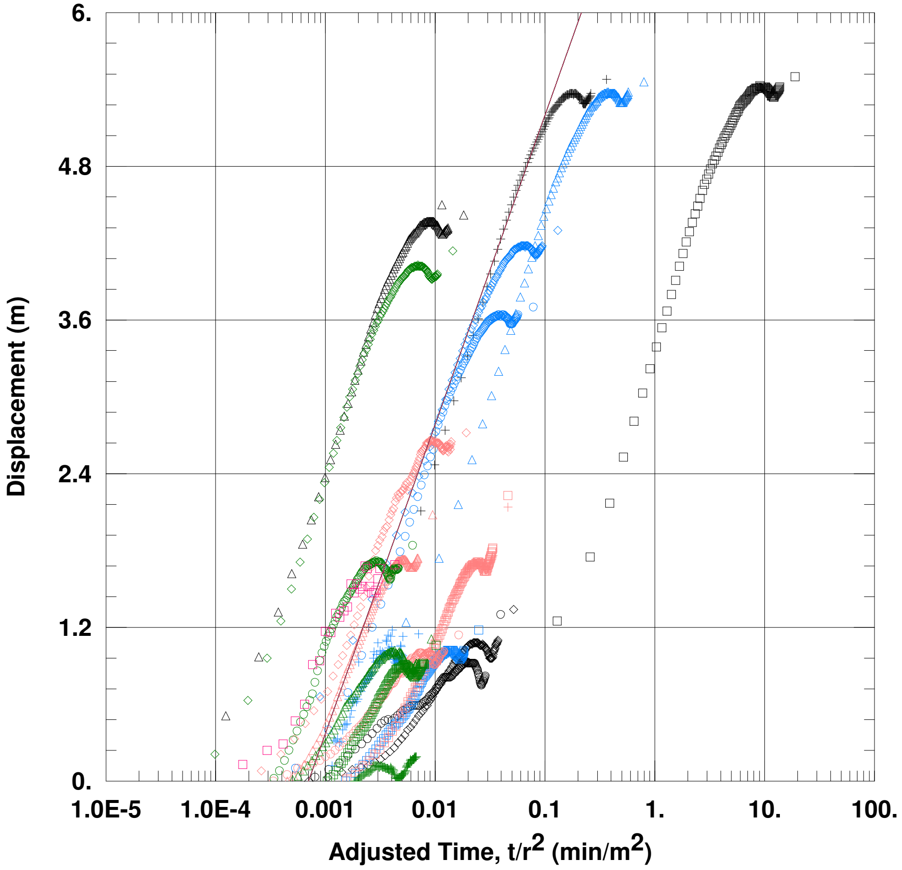


FIGURE 6-37 - 2019 PW1 PT - OW CJSL COMP ANALYSIS

Data Set: H:\...\2019 Obs Well Composite Analysis.aqt
Date: 06/12/20 Time: 15:57:10

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 81.99 m^2/day
S = 8.968E-5

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

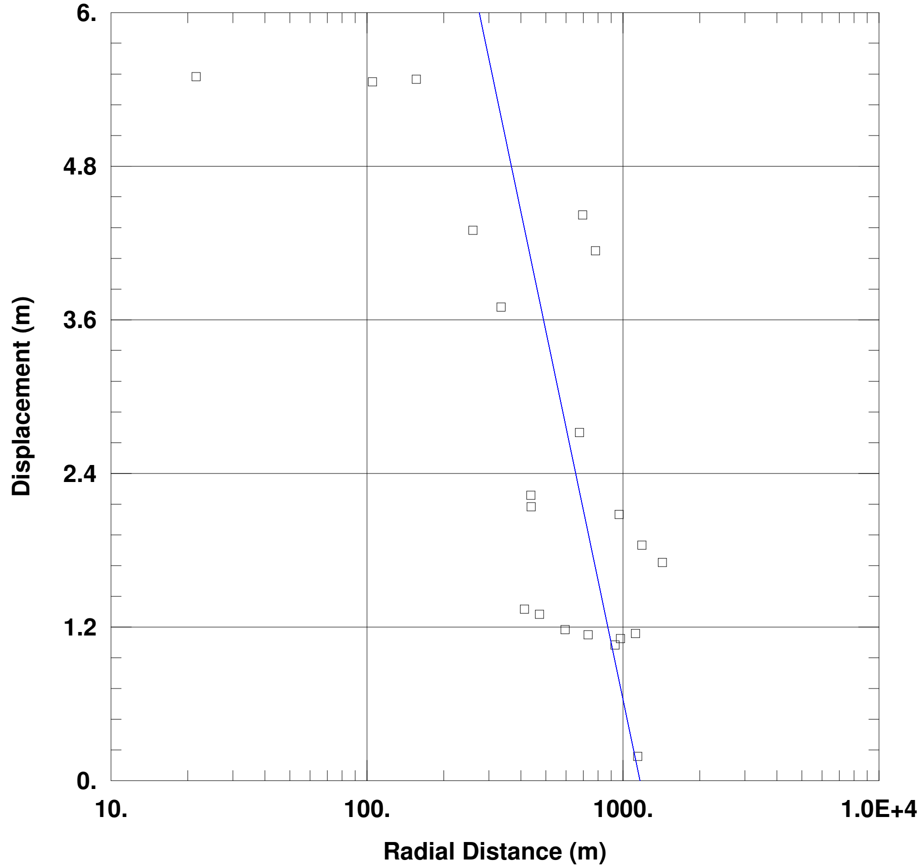


FIGURE 6-38 - 2019 PW1 PT - OW CJ DIST-DDN ANALYSIS

Data Set: H:\...\2019 Obs Well CJ Dist-Ddn.aqt
Date: 06/12/20 Time: 16:00:03

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 41.43 m^2/day
S = 0.0004187

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

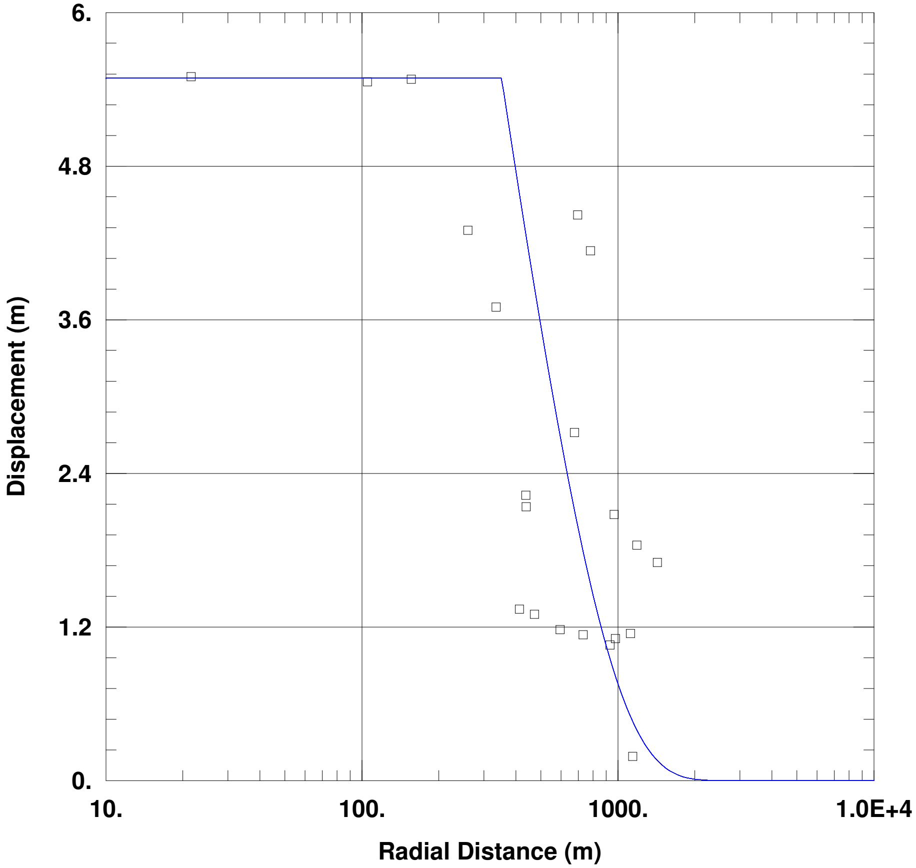


FIGURE 6-39 - 2019 PW1 PT - OW LA DIST-DDN ANALYSIS

Data Set: H:\...\2019 Obs Well Leaky Aq Dist-Ddn.aqt
Date: 06/12/20 Time: 16:01:43

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Leaky
Solution Method: Moench (Case 3)

T = 29.9 m^2/day
S = 0.0009051
1/B' = 0.005981 m^{-1}
ß'/r = 2.734E-5 m^{-1}
1/B" = 6.592E-17 m^{-1}
ß"/r = 0.002321 m^{-1}
Sw = -8.15
r(w) = 0.1015 m
r(c) = 0.1015 m

AQUIFER DATA

Saturated Thickness: 17.4 m
Aquitard Thickness (b'): 4.5 m
Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 22. m

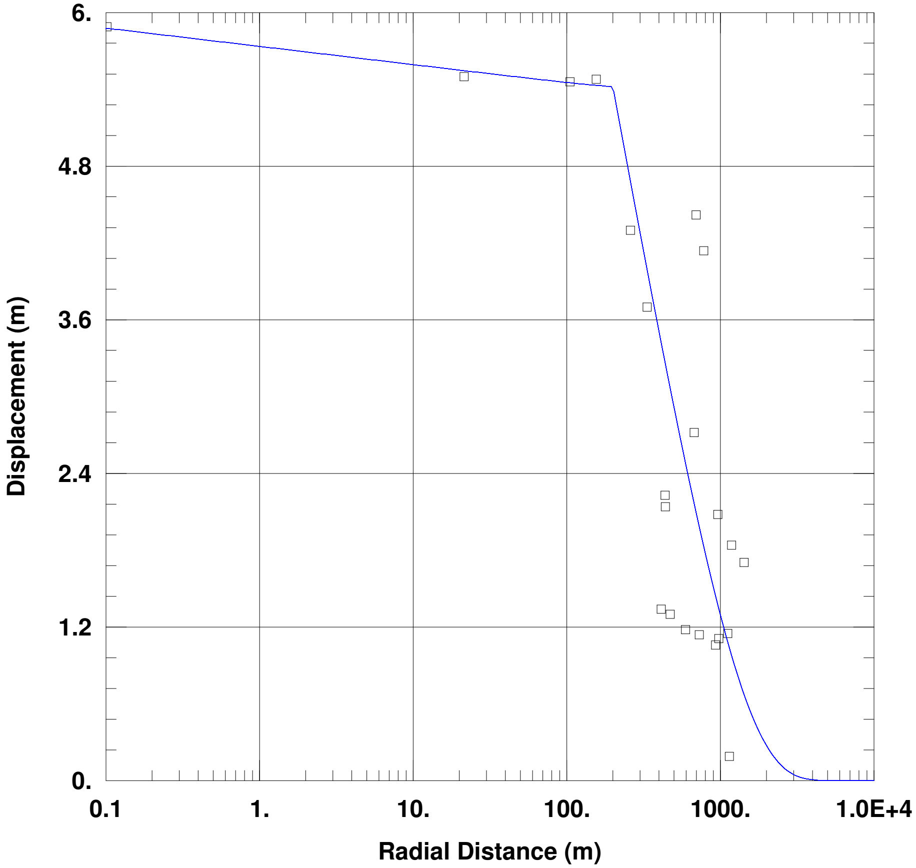


FIGURE 6-40 - 2019 PW1 PT - OW NU DIST-DDN ANALYSIS

Data Set: H:\...\2019 Obs Well Non-Uniform Aq Dist-Ddn.aqt
Date: 06/12/20 Time: 16:03:24

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: PW1
Test Date: 20-Feb-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Butler

T1 = 2777. m^2/day
S1 = 0.005951
T2 = 35.16 m^2/day
S2 = 0.0001676
R = 200. m

AQUIFER DATA

Saturated Thickness: 17.4 m

Anisotropy Ratio (Kz/Kr): 0.1

Figure 6-41 - 5205 Beechwood Well Drawdown
March 5 - 11, 2019

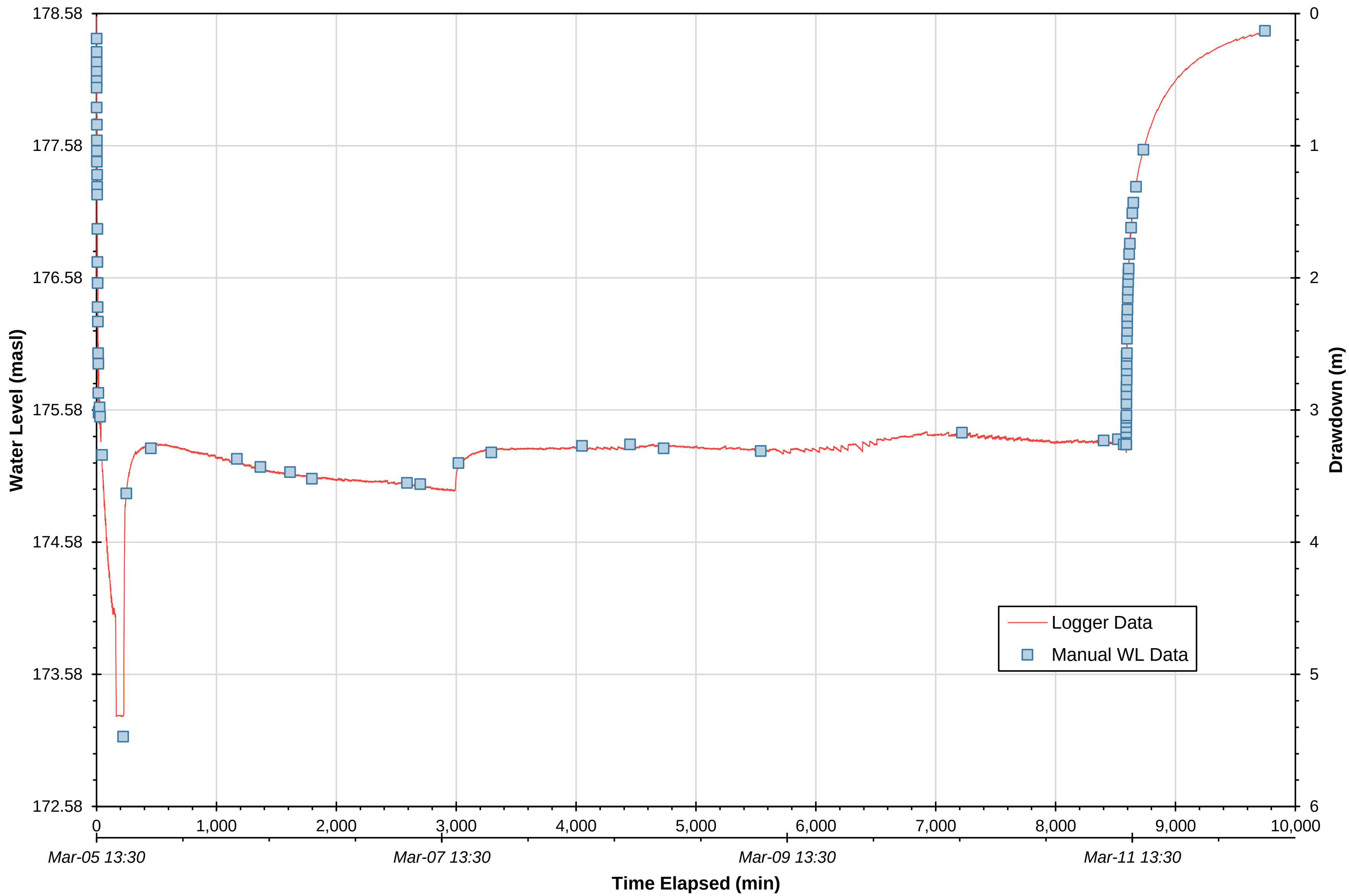
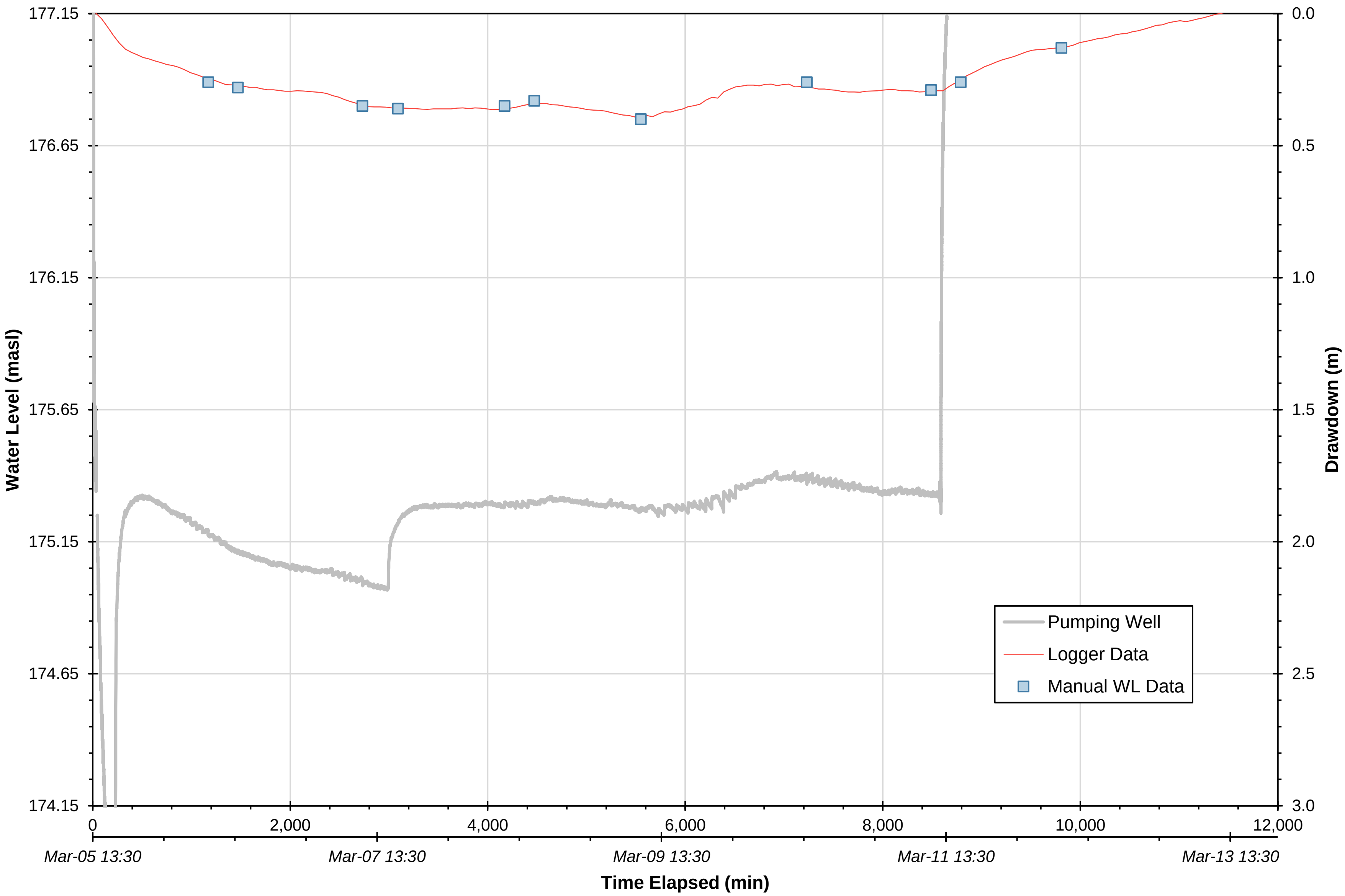


Figure 6-42 - Observation Well MW11-3OBR Drawdown (206 m from PW)
March 5 - 11, 2019



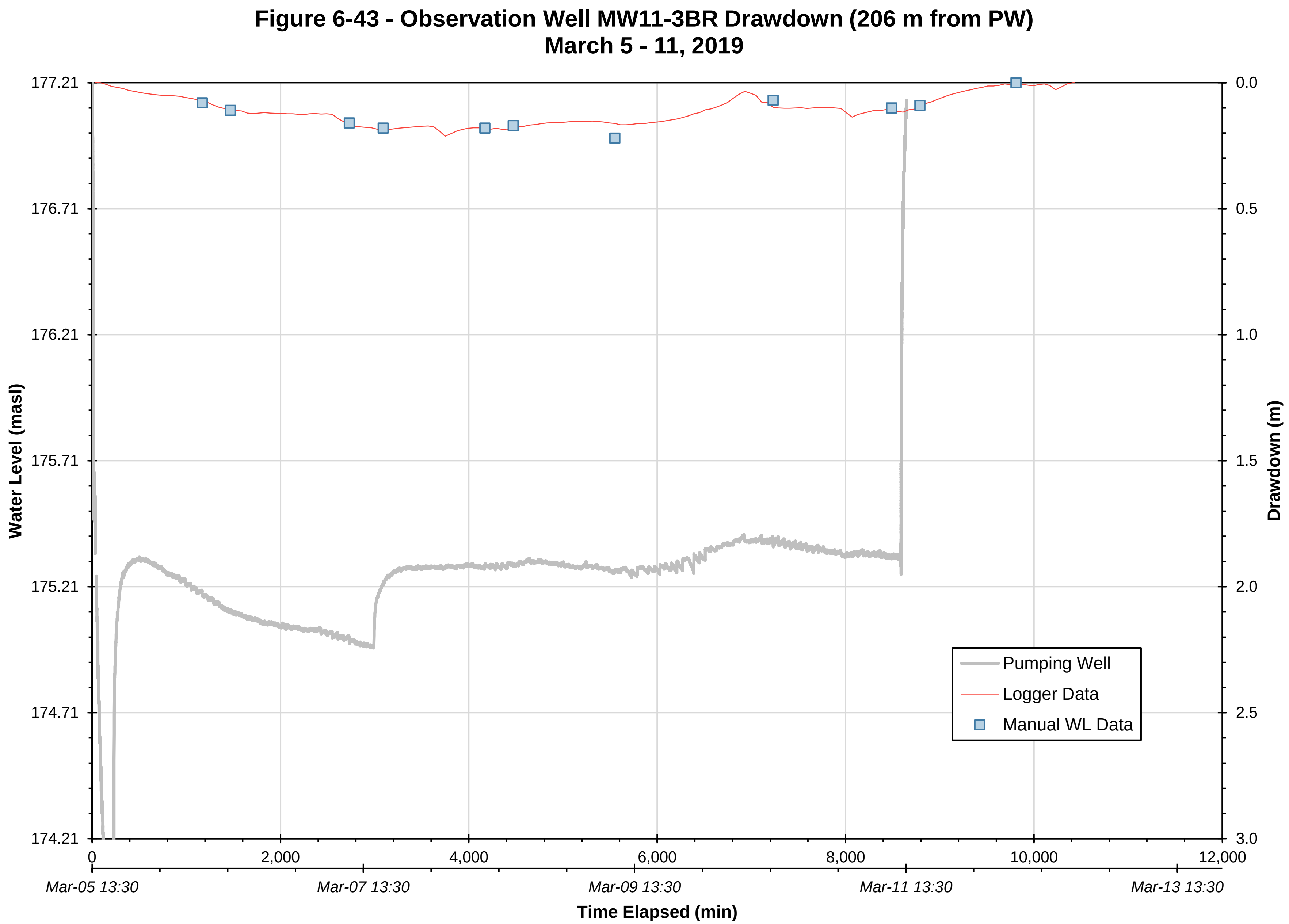


Figure 6-43 - Observation Well MW11-3BR Drawdown (206 m from PW)
March 5 - 11, 2019
Water Level (masl)
177.21
176.71
176.21
175.71
175.21
174.71
174.21
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
2,000
4,000
6,000
8,000
10,000
12,000
Mar-05 13:30
Mar-07 13:30
Mar-09 13:30
Mar-11 13:30
Mar-13 13:30
Time Elapsed (min)
Pumping Well
Logger Data
Manual WL Data

Figure 6-44 - 9602 Beaverdams Well Drawdown (394 m from PW)
March 5 - 11, 2019

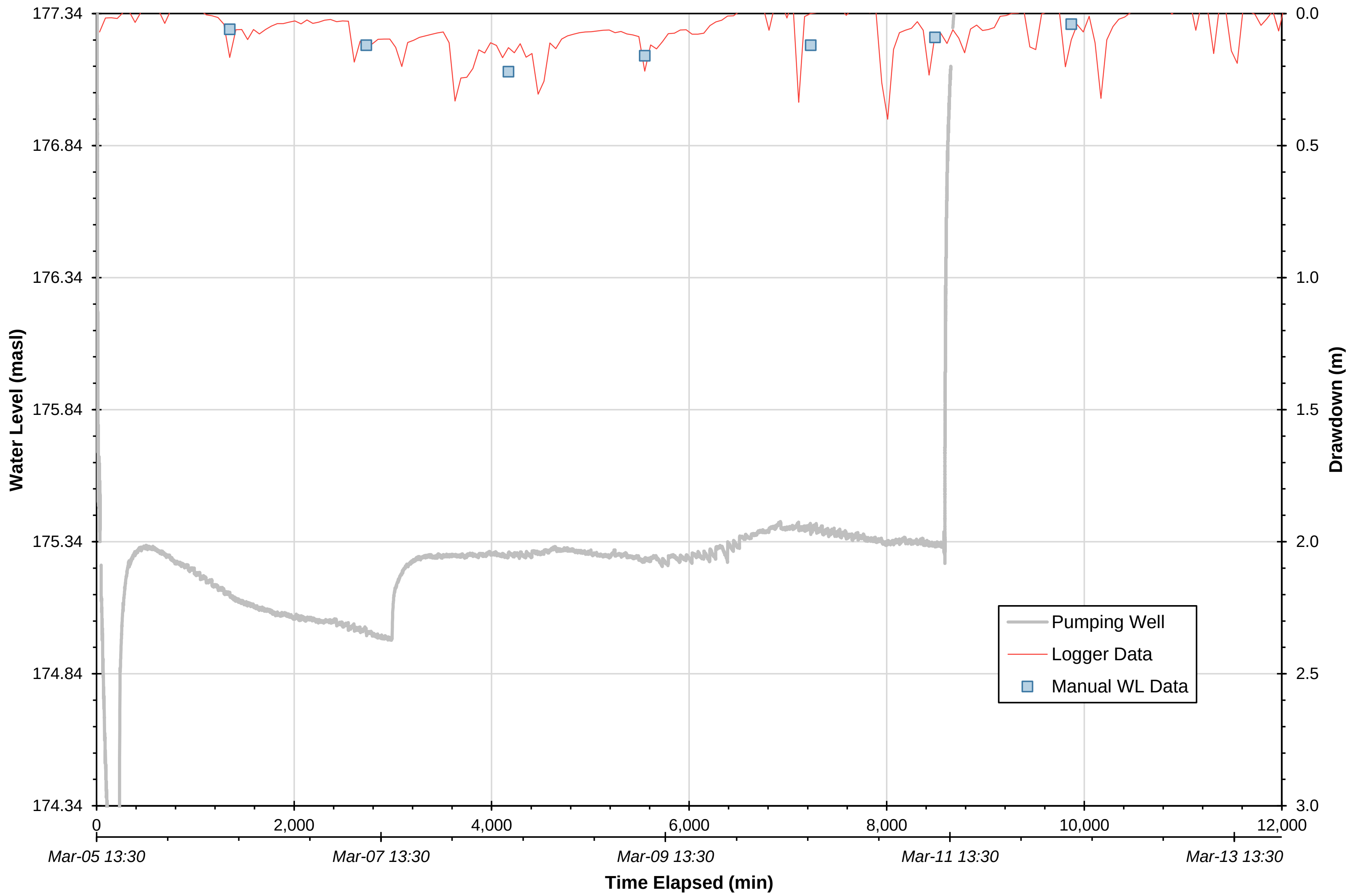
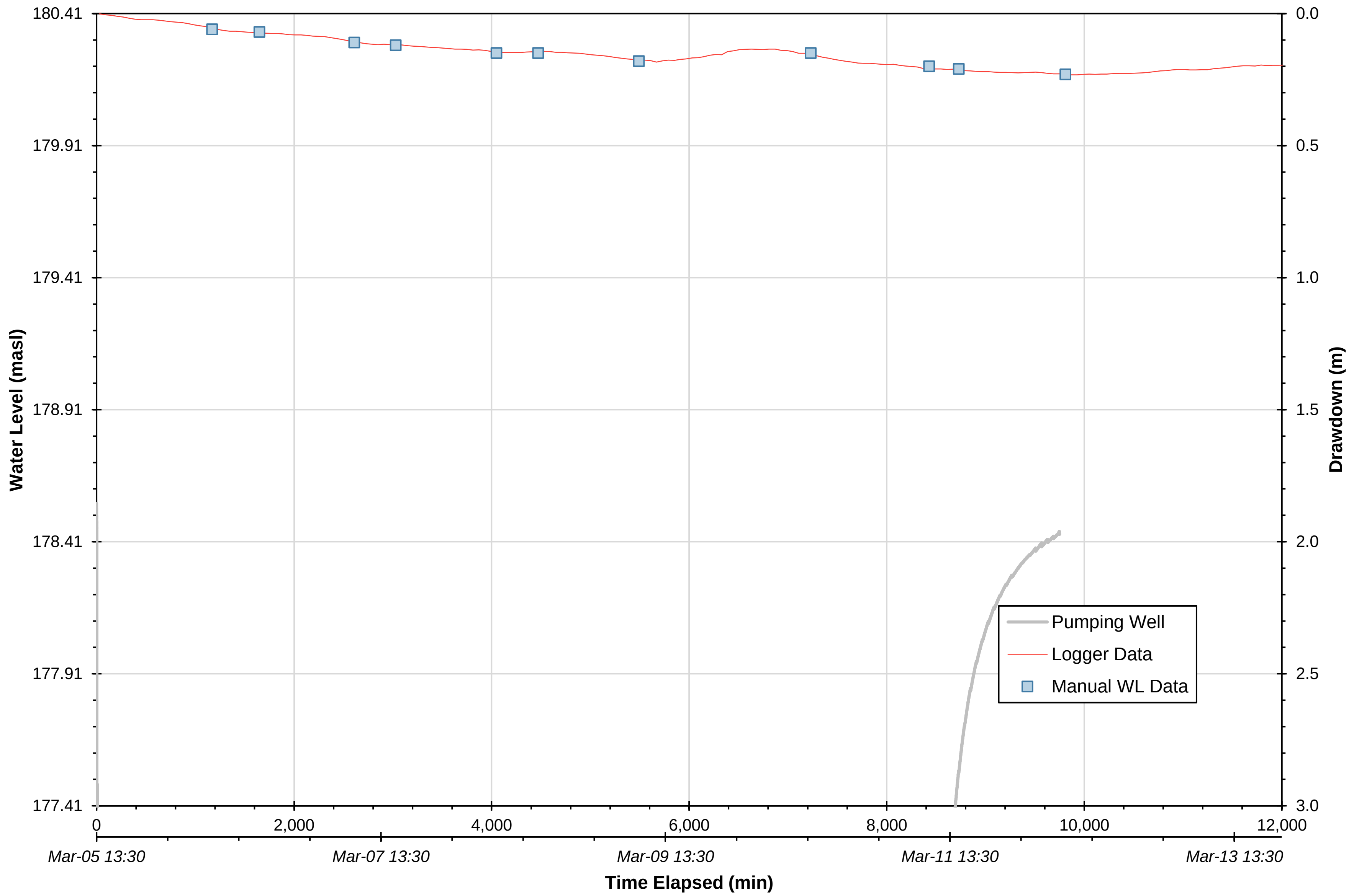


Figure 6-45 - Observation Well MW16-6OB Drawdown (138 m from PW)
March 5 - 11, 2019



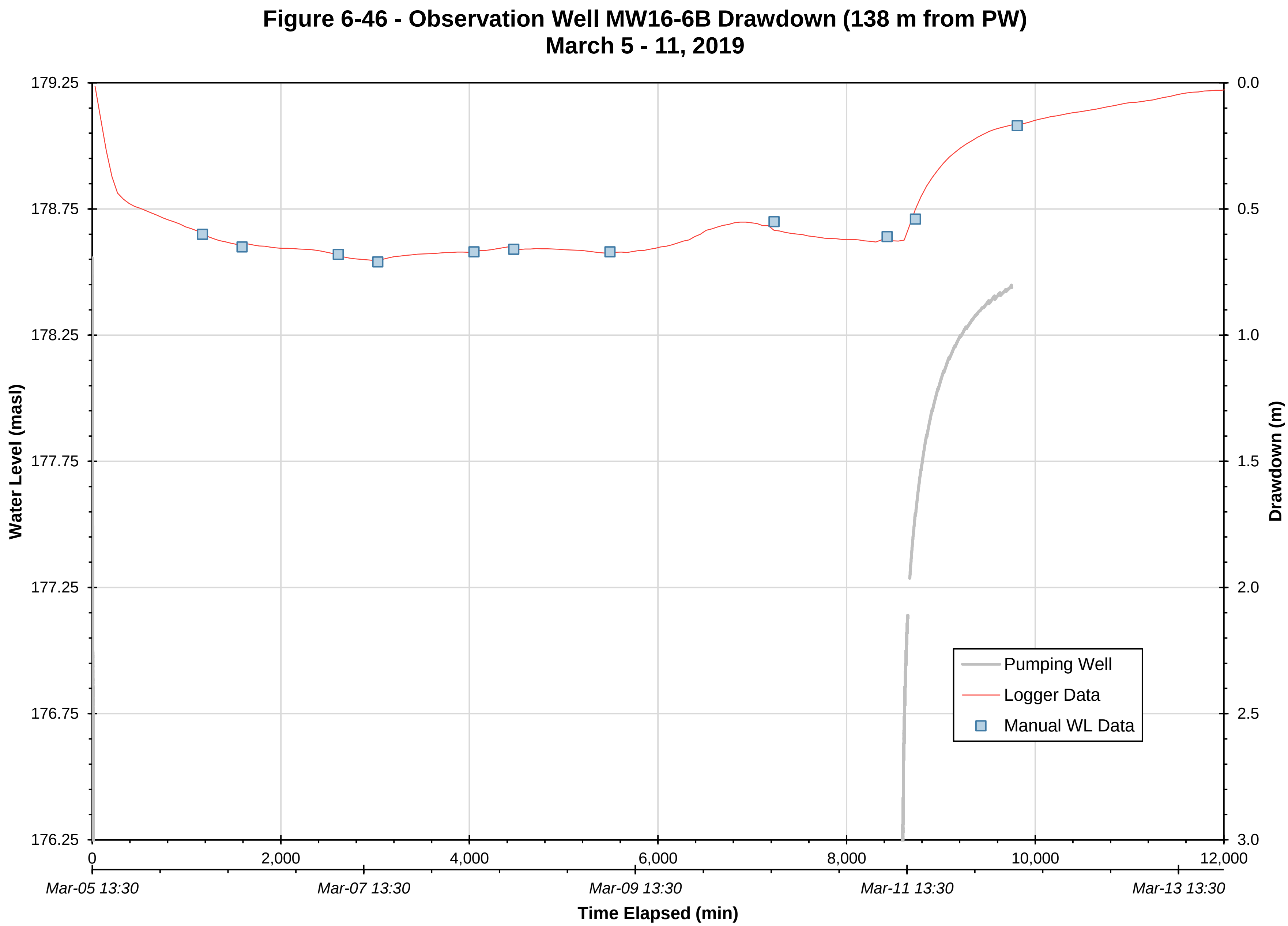


Figure 6-46 - Observation Well MW16-6B Drawdown (138 m from PW)
March 5 - 11, 2019
Water Level (masl)
179.25
178.75
178.25
177.75
177.25
176.75
176.25
Drawdown (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
2,000
4,000
6,000
8,000
10,000
12,000
Mar-05 13:30
Mar-07 13:30
Mar-09 13:30
Mar-11 13:30
Mar-13 13:30
Time Elapsed (min)
Pumping Well
Logger Data
Manual WL Data

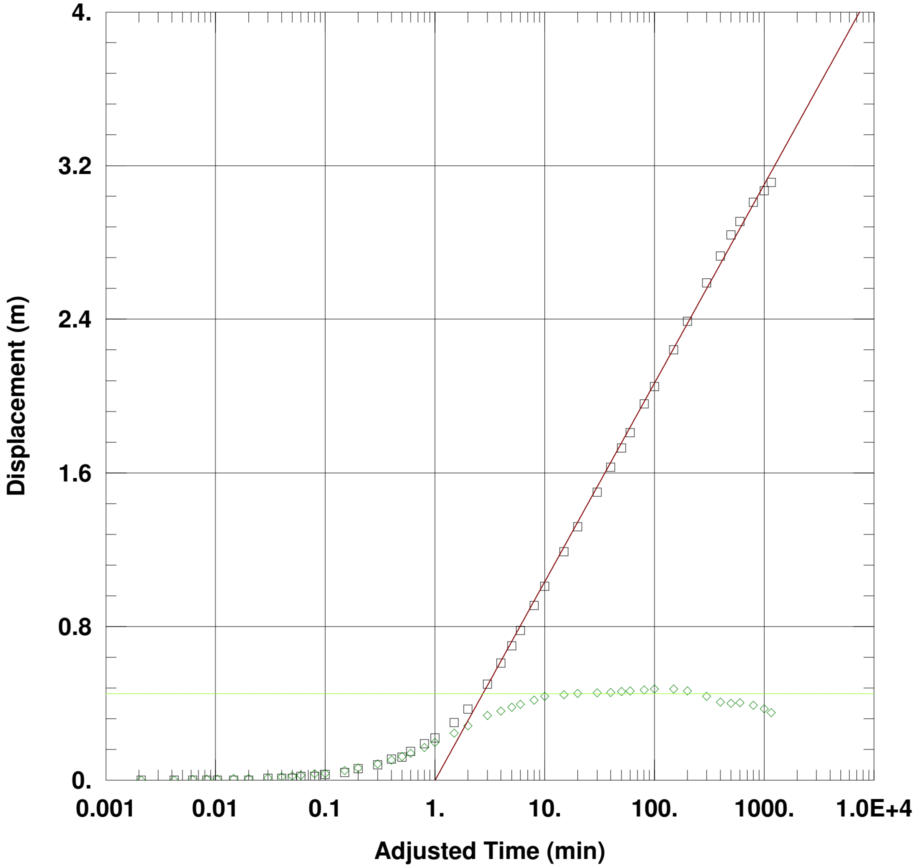


FIGURE 6-47 - 5205 BEECHWOOD WELL - CJSL REC ANALYSIS

Data Set: H:\...\5205 CJSL rec.aqt
Date: 06/12/20 Time: 16:21:21

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: 5205 Beechwood Well
Test Date: 5-Mar-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 3.751 m^2/day
S = 1.011

AQUIFER DATA

Saturated Thickness: 6.8 m

Anisotropy Ratio (Kz/Kr): 0.1

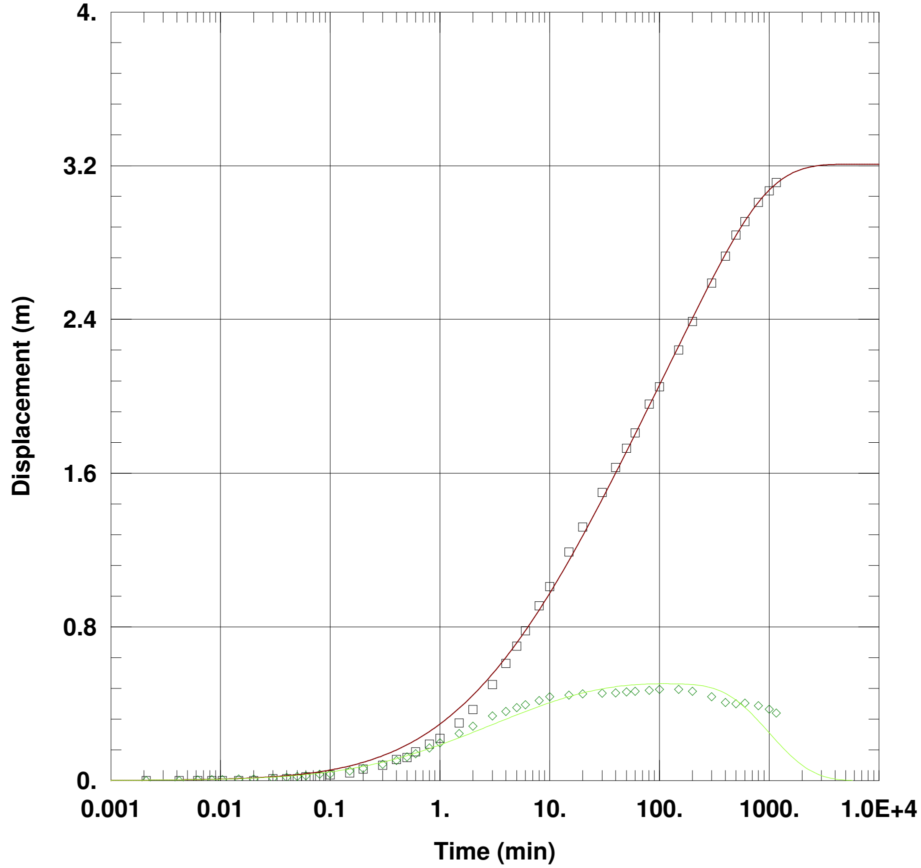


FIGURE 6-48 - 5205 BEECHWOOD PT - LA REC ANALYSIS

Data Set: H:\...\5205 rec.aqt
Date: 06/12/20 Time: 16:23:48

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: 5205 Beechwood Well
Test Date: 5-Mar-2019

SOLUTION

Aquifer Model: Leaky
Solution Method: Moench (Case 3)

T = 1.922 m^2/day
S = 0.6517
r/B' = 0.2013
ß' = 0.08371
r/B" = 0.
ß" = 0.
Sw = -0.888
r(w) = 0.0762 m
r(c) = 0.0762 m

AQUIFER DATA

Saturated Thickness: 6.8 m
Aquitard Thickness (b'): 4.5 m

Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b"): 22. m

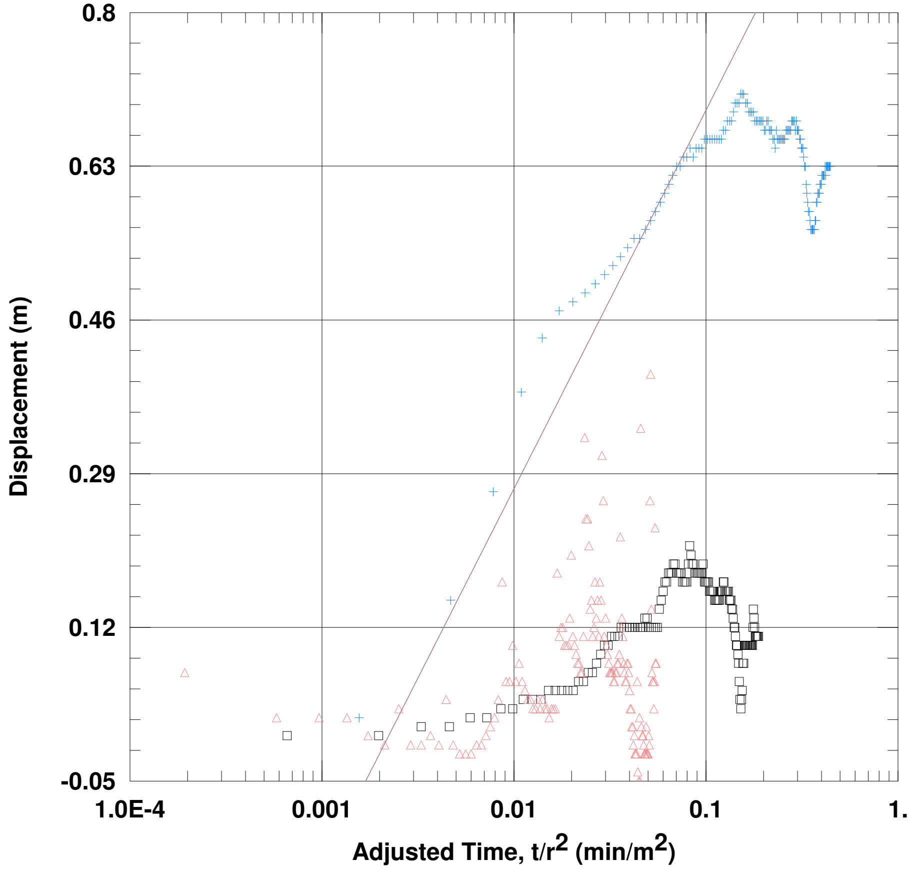


FIGURE 6-49 - 5205 BEECHWOOD PT - CJ COMP ANALYSIS

Data Set: H:\...\PT2 composite analysis.aqt
Date: 06/12/20 Time: 16:25:22

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: 5205 Beechwood Well
Test Date: 5-Mar-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 9.264 m^2/day
S = 3.22E-5

AQUIFER DATA

Saturated Thickness: 6.8 m

Anisotropy Ratio (Kz/Kr): 0.1

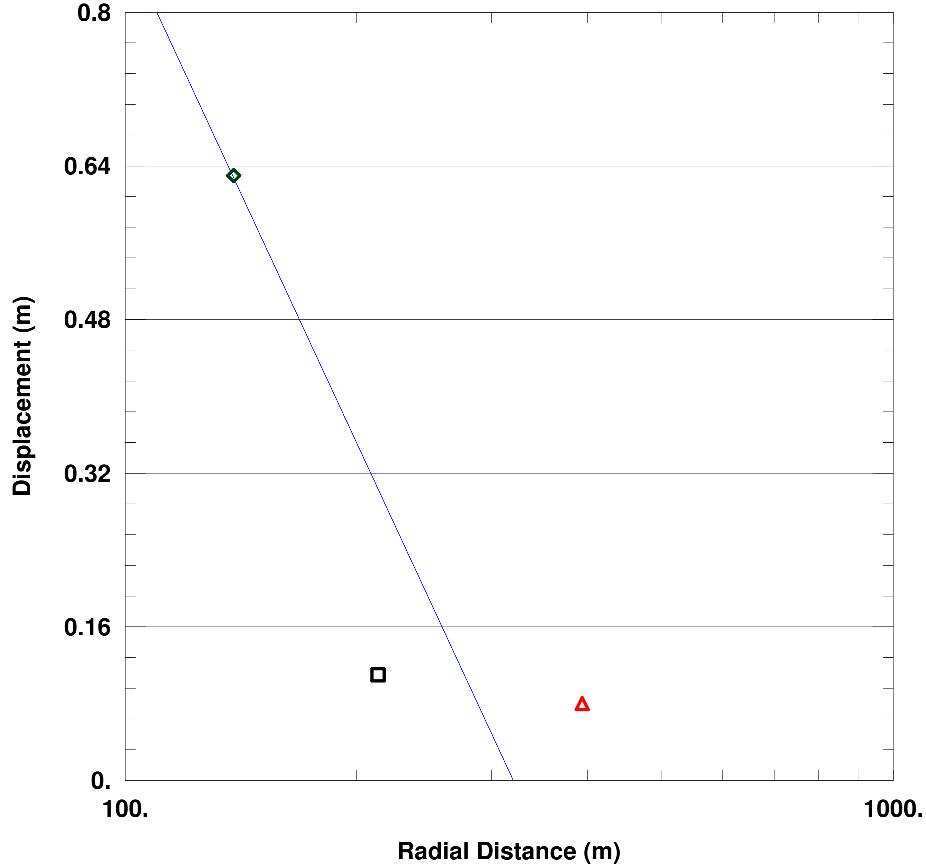


FIGURE 6-50 - 5205 BEECHWOOD PT - CJ DIST-DDN ANALYSIS

Data Set: H:\...\PT2 dist-ddn.aqt
Date: 06/12/20 Time: 16:26:43

PROJECT INFORMATION

Company: WSP
Client: Walker Aggregates Inc.
Project: 161-11633-00
Location: Proposed Upper's Quarry
Test Well: 5205 Beechwood Well
Test Date: 5-Mar-2019

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 4.501 m^2/day
S = 0.0005854

AQUIFER DATA

Saturated Thickness: 6.8 m

Anisotropy Ratio (Kz/Kr): 0.1

Figure 6-51 - 5205 Beechwood Well Step Test Water Levels
March 15, 2019

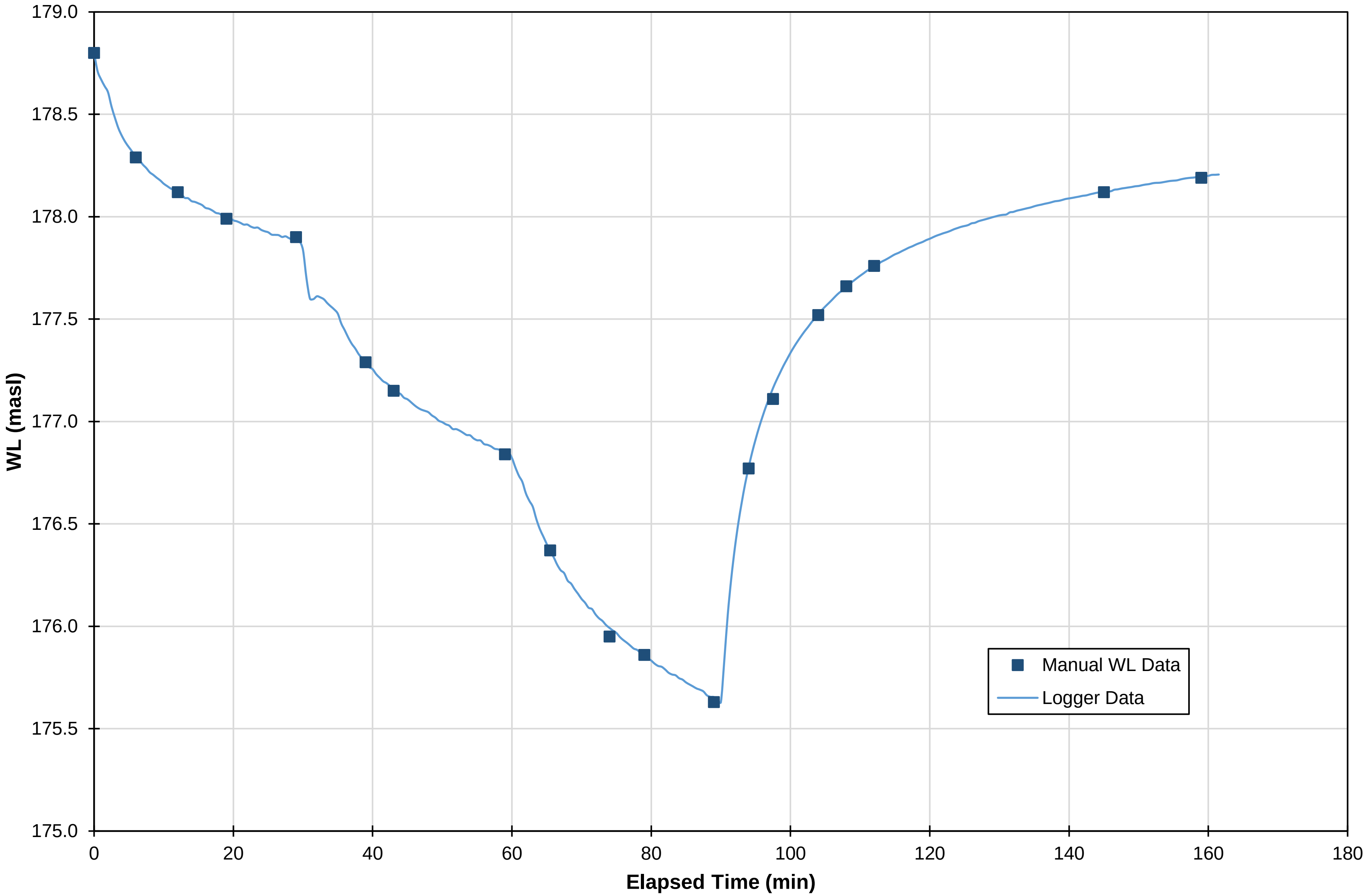
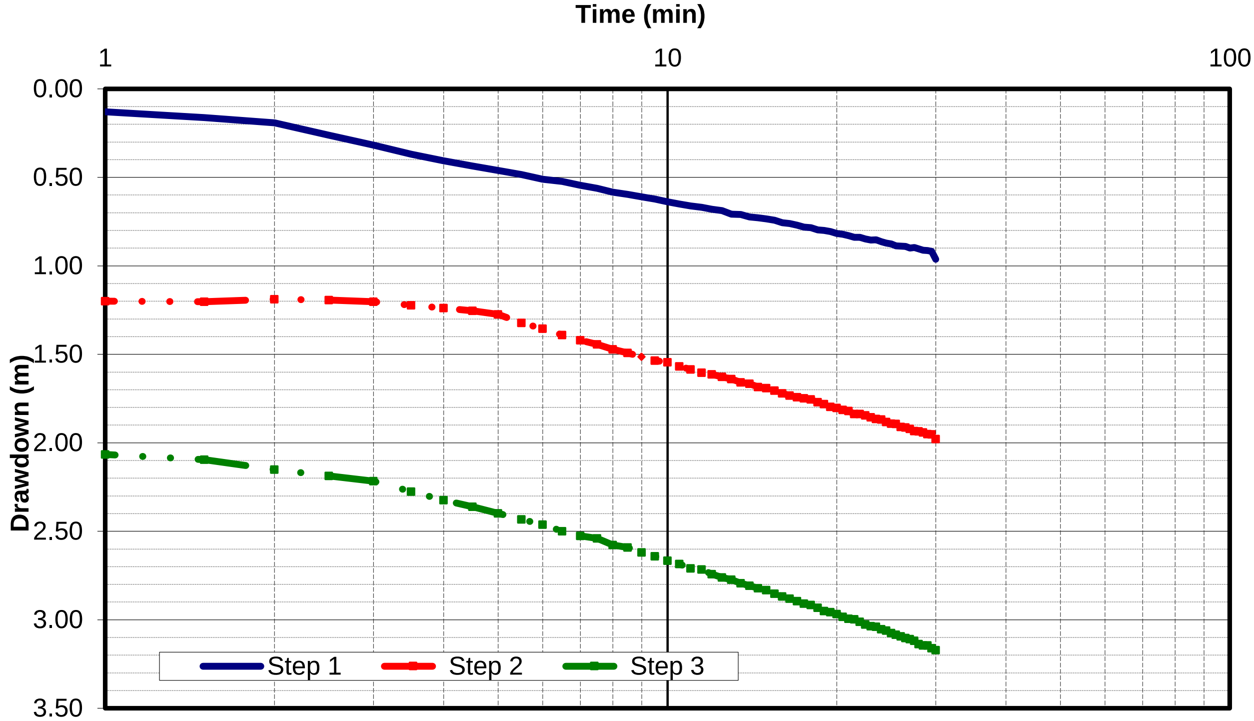
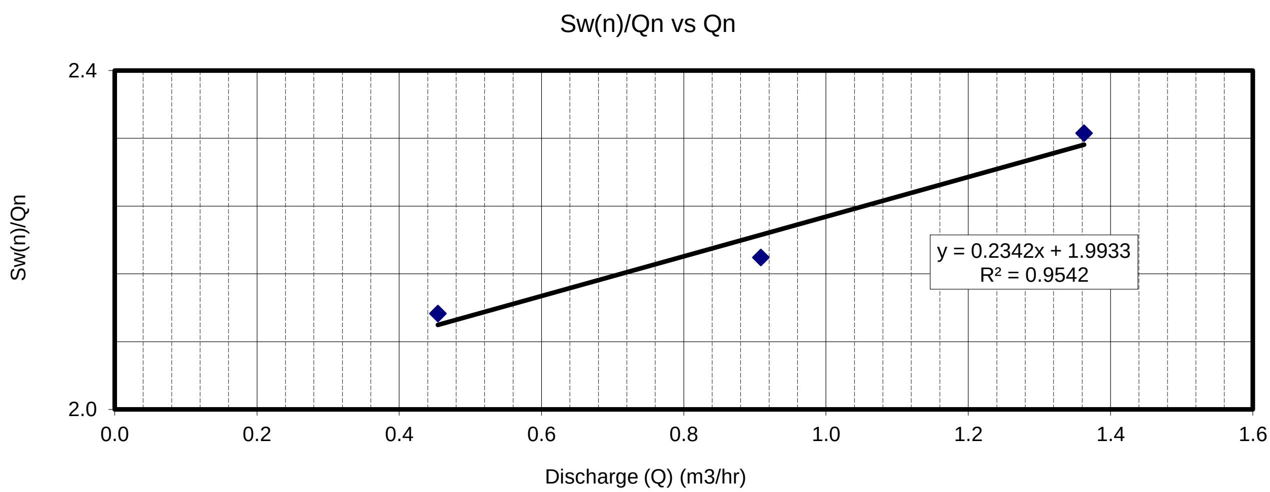


Figure 6-52 - Step Test Analysis - 5205 Beechwood Well



Interval (n)	Qn m^3/hr	^deltaSwn m	Sw(n) m	Swn/Qn hr/m^2	Well Efficiency %
1	0.5	0.96	0.96	2.11	95%
2	0.9	1.02	1.98	2.18	90%
3	1.4	1.19	3.17	2.33	86%

Constants (from Graph): B = 1.9933 Intercept
C = 0.2342 Slope



APPENDIX

E WATER LEVEL DATA

Figure E-1 - Groundwater Hydrograph for Well Nest BH03-2

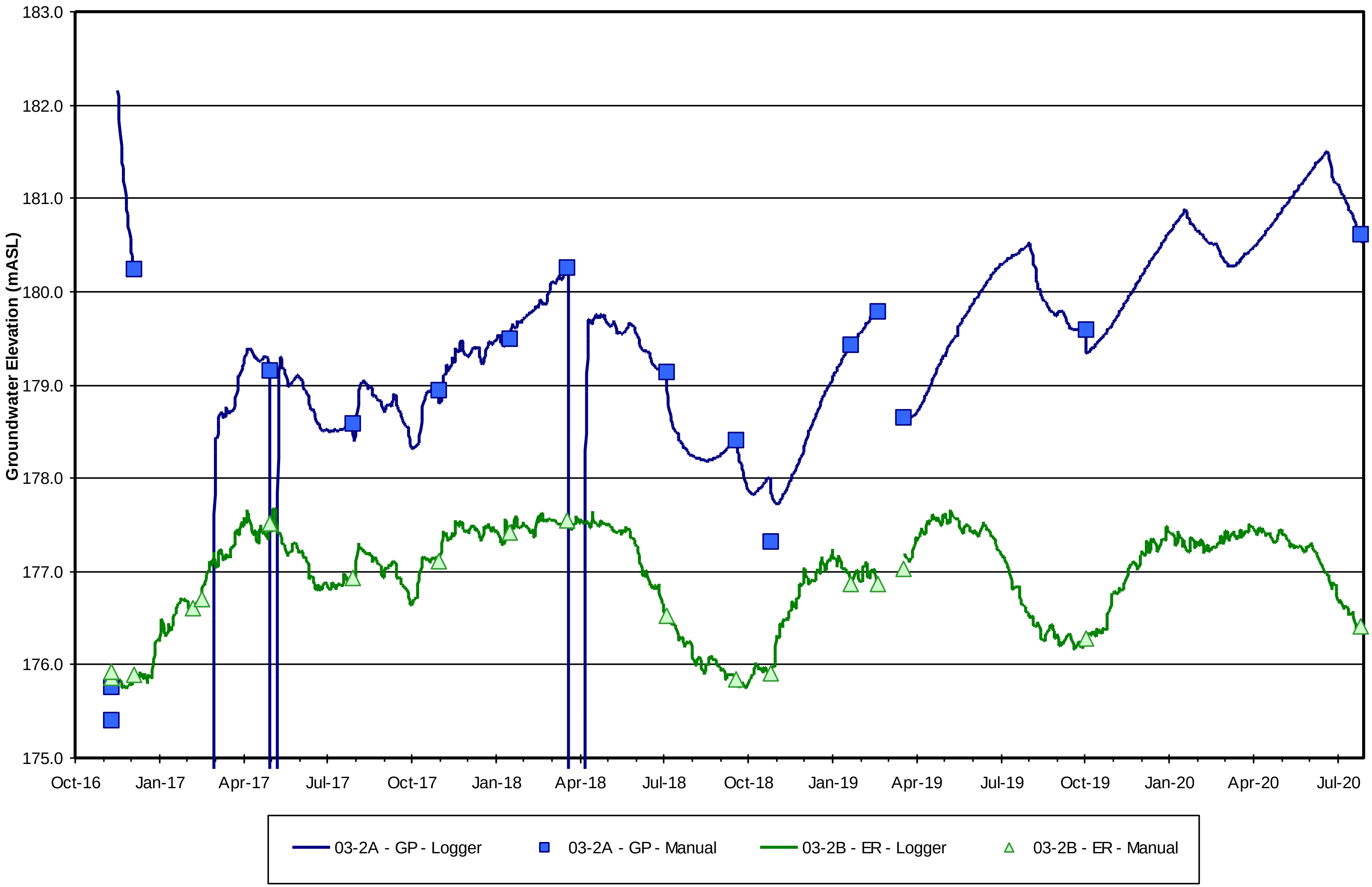


Figure E-2 - Groundwater Hydrograph for Well Nest MW11-1

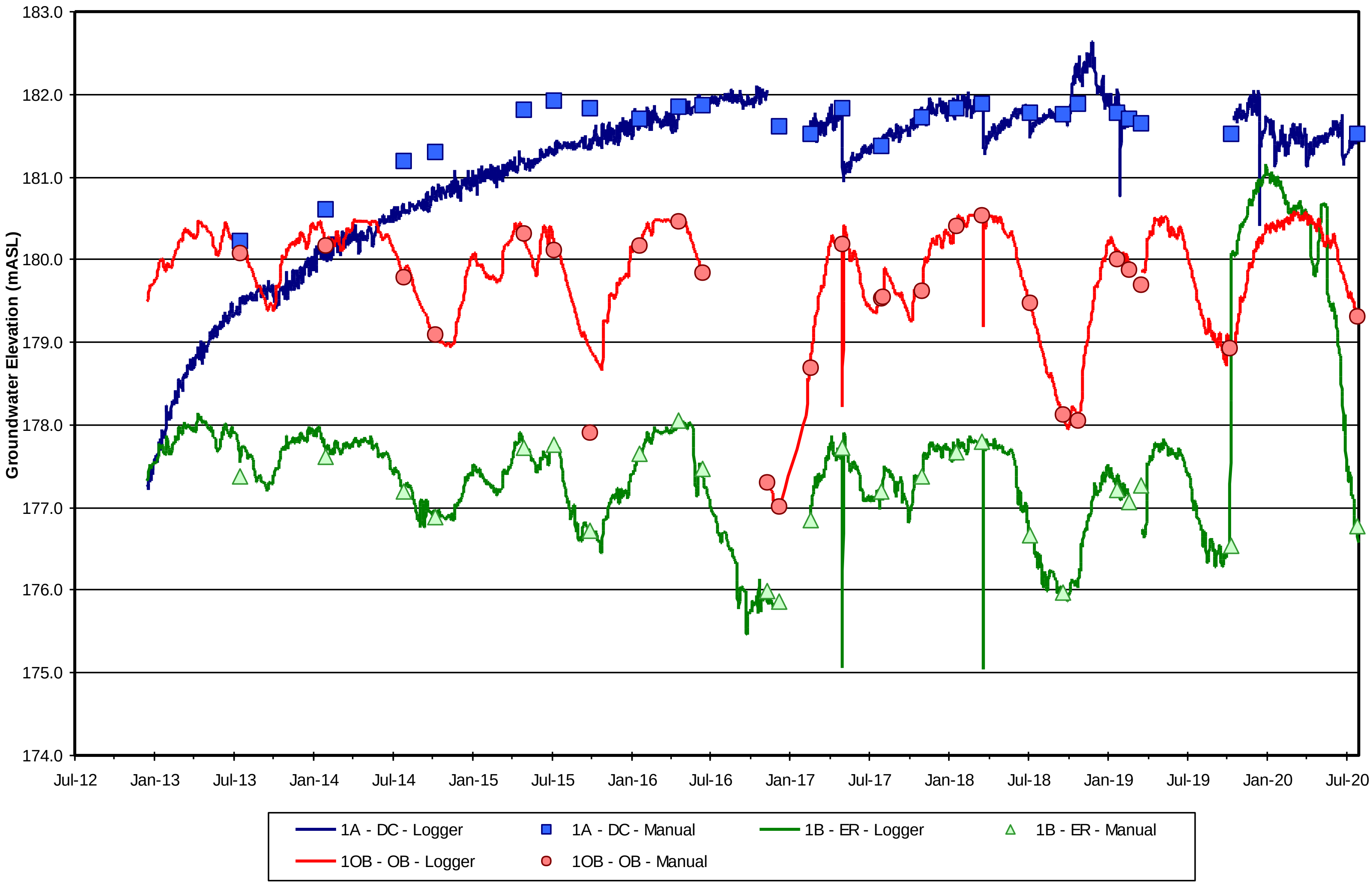


Figure E-3 - Groundwater Hydrograph for Well Nest MW11-2

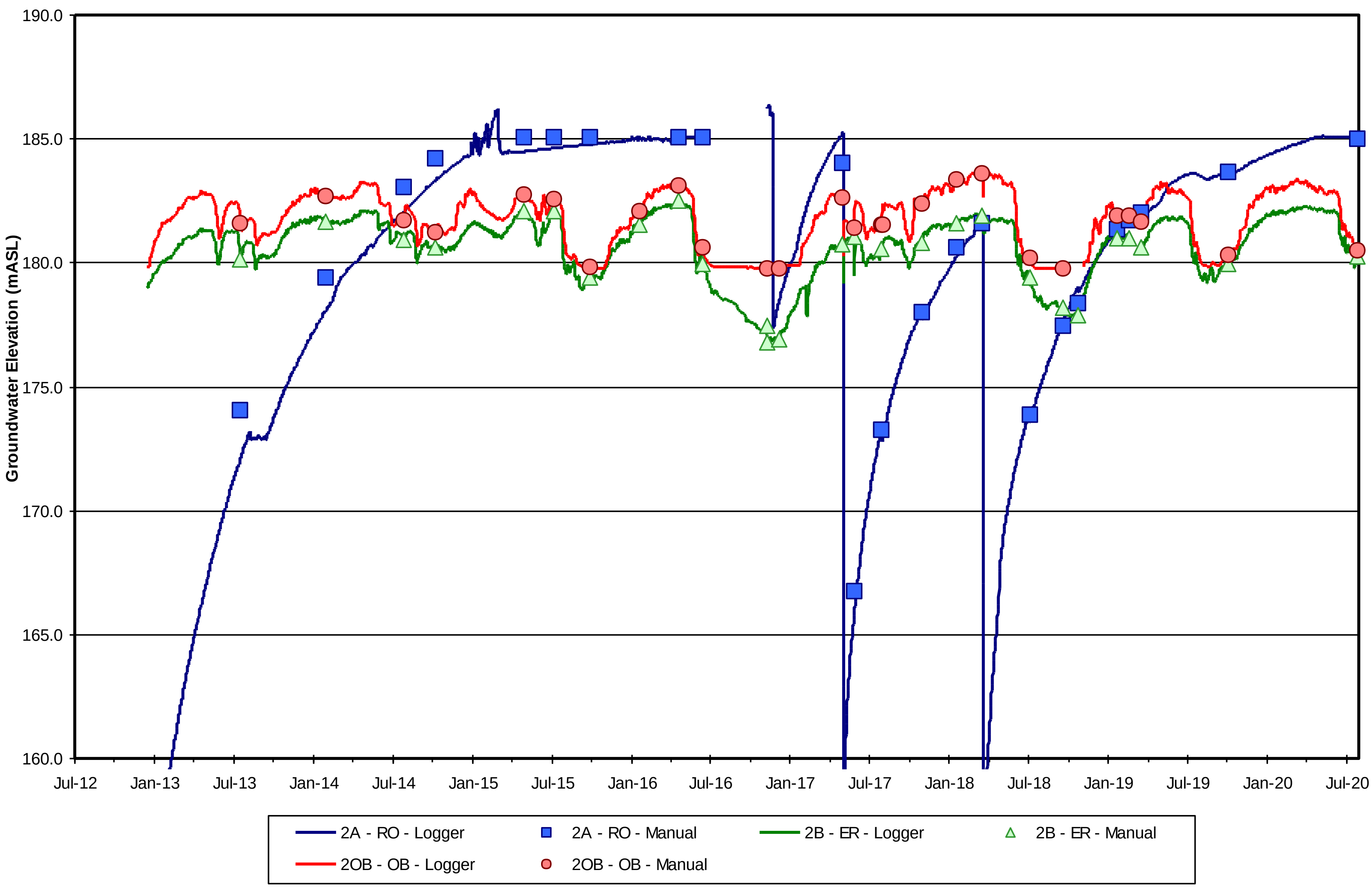


Figure E-4 - Groundwater Hydrograph for Well Nest MW11-3

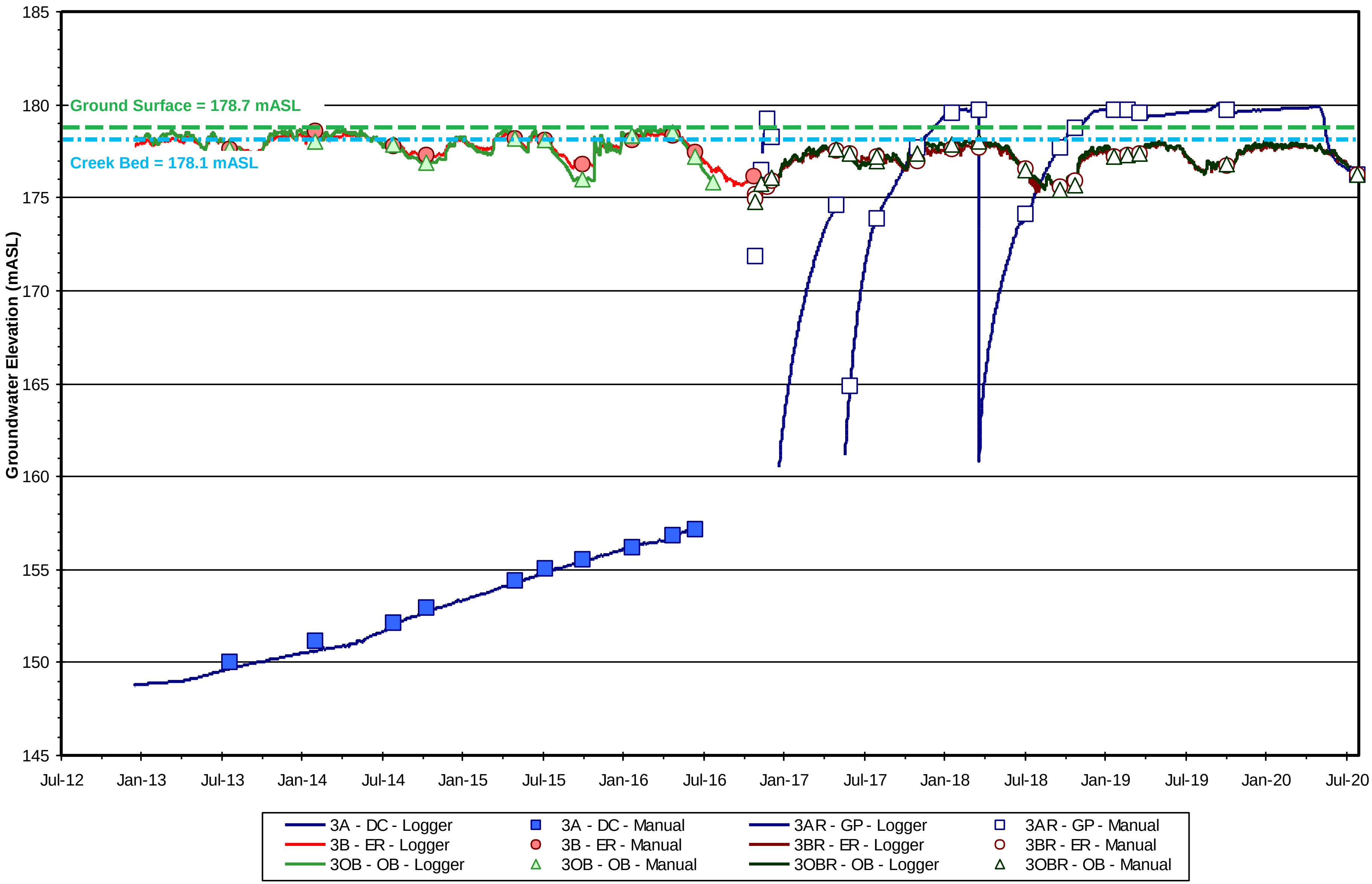


Figure E-5 - Groundwater Hydrograph for Well Nest MW11-4

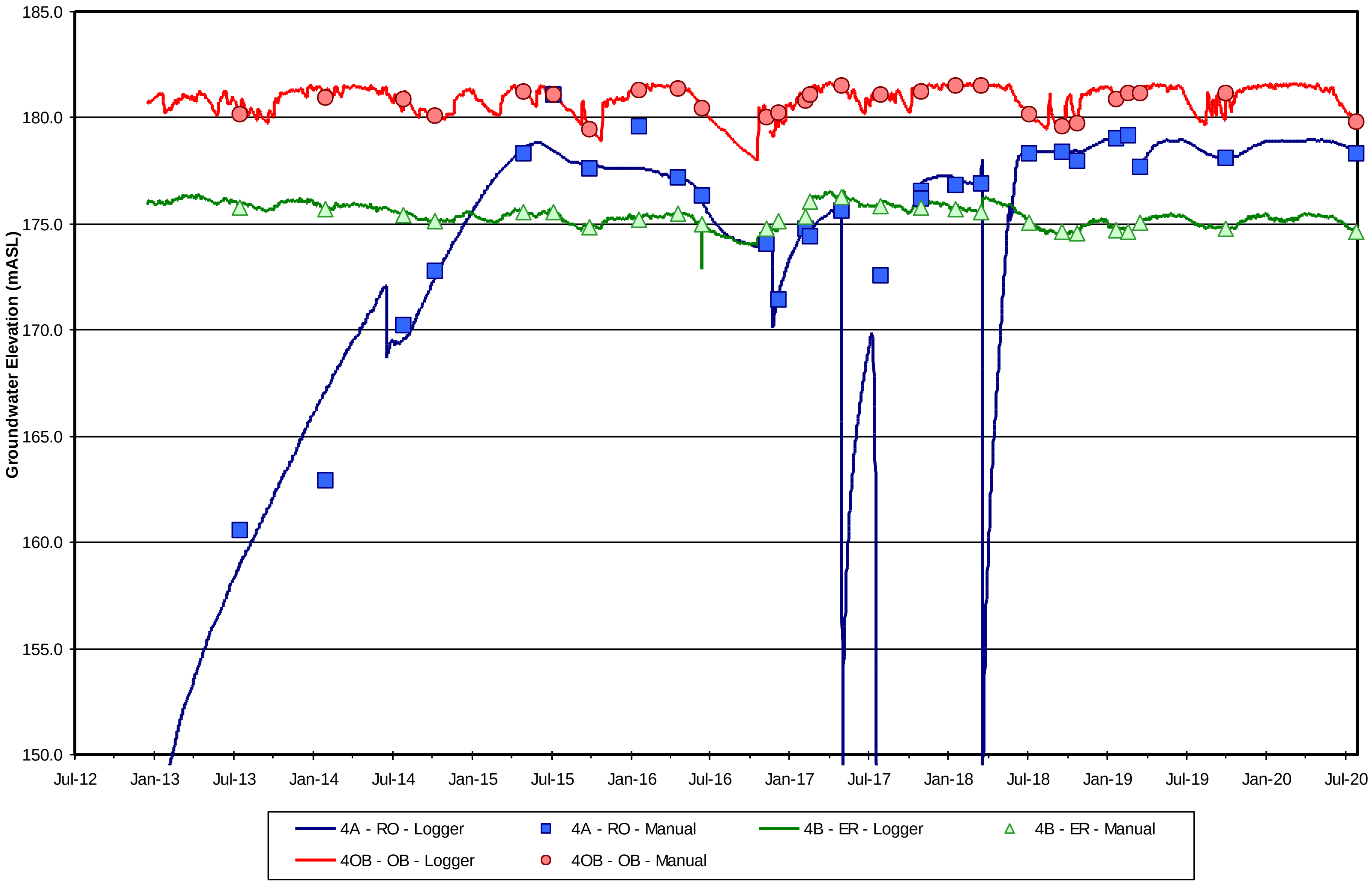


Figure E-6 - Groundwater Hydrograph for Well Nest MW16-5

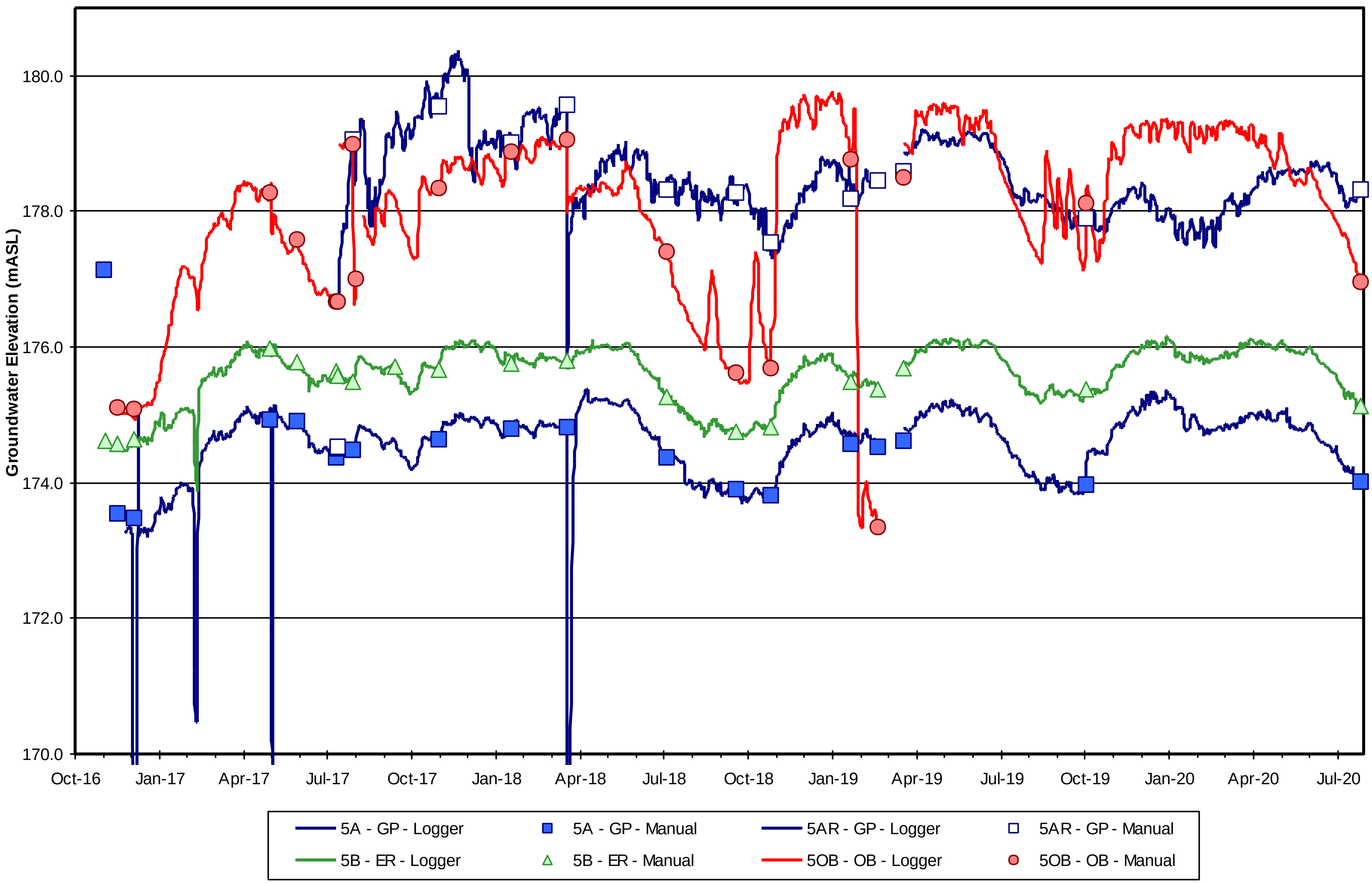


Figure E-7 - Groundwater Hydrograph for Well Nest MW16-6

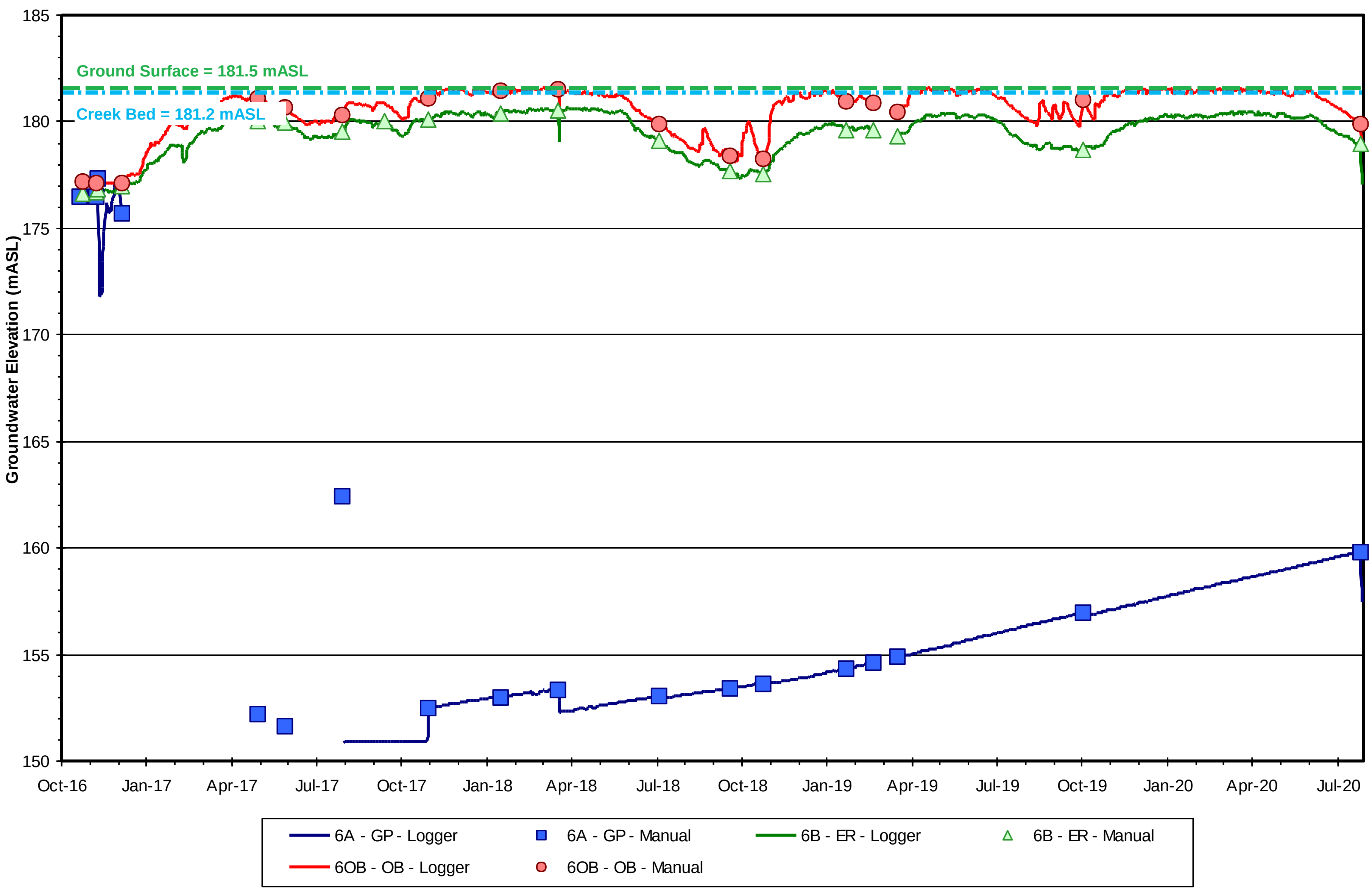


Figure E-8 - Groundwater Hydrograph for Well Nest MW16-7

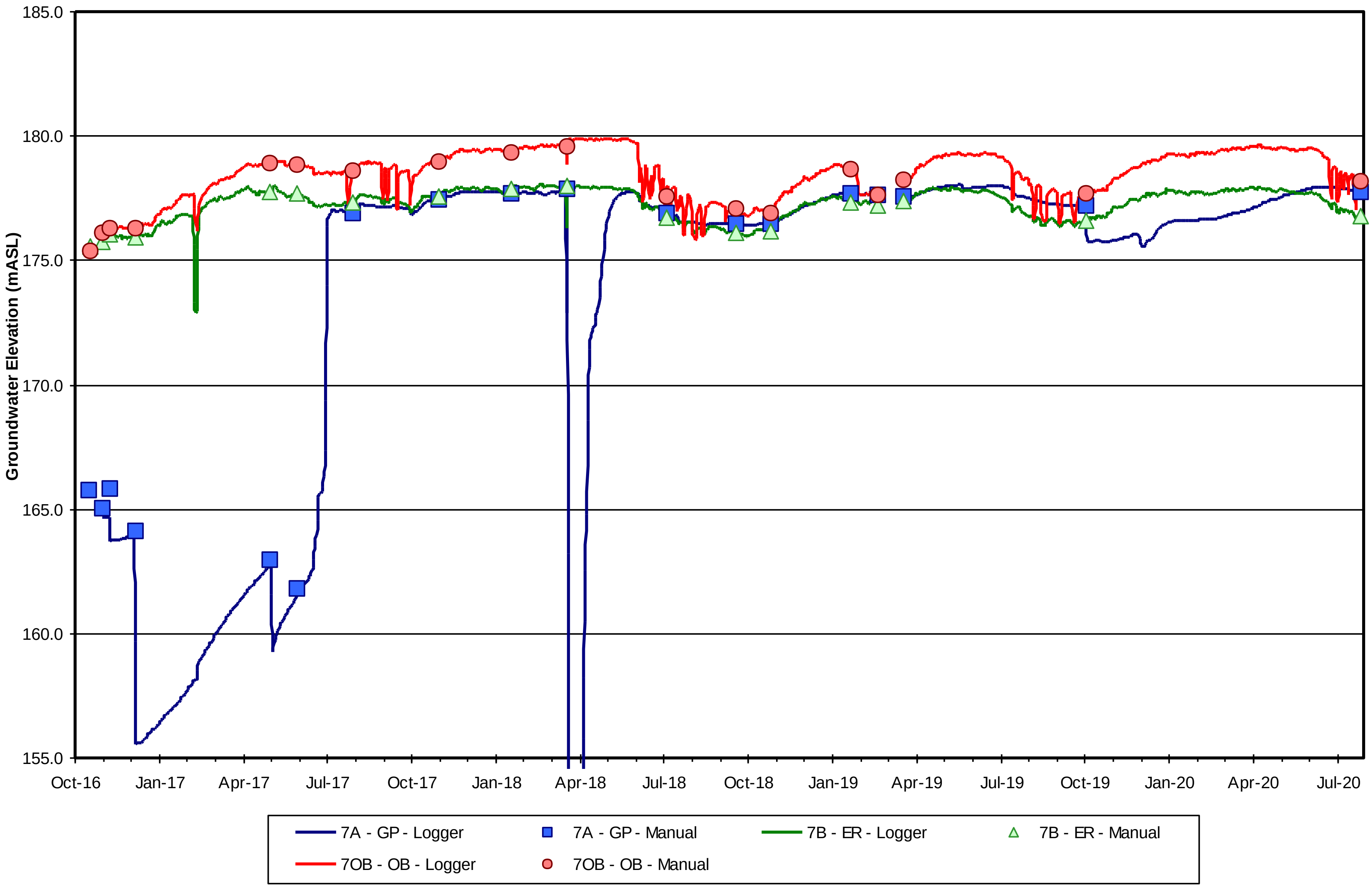


Figure E-9 - Groundwater Hydrograph for Well Nest MW16-8

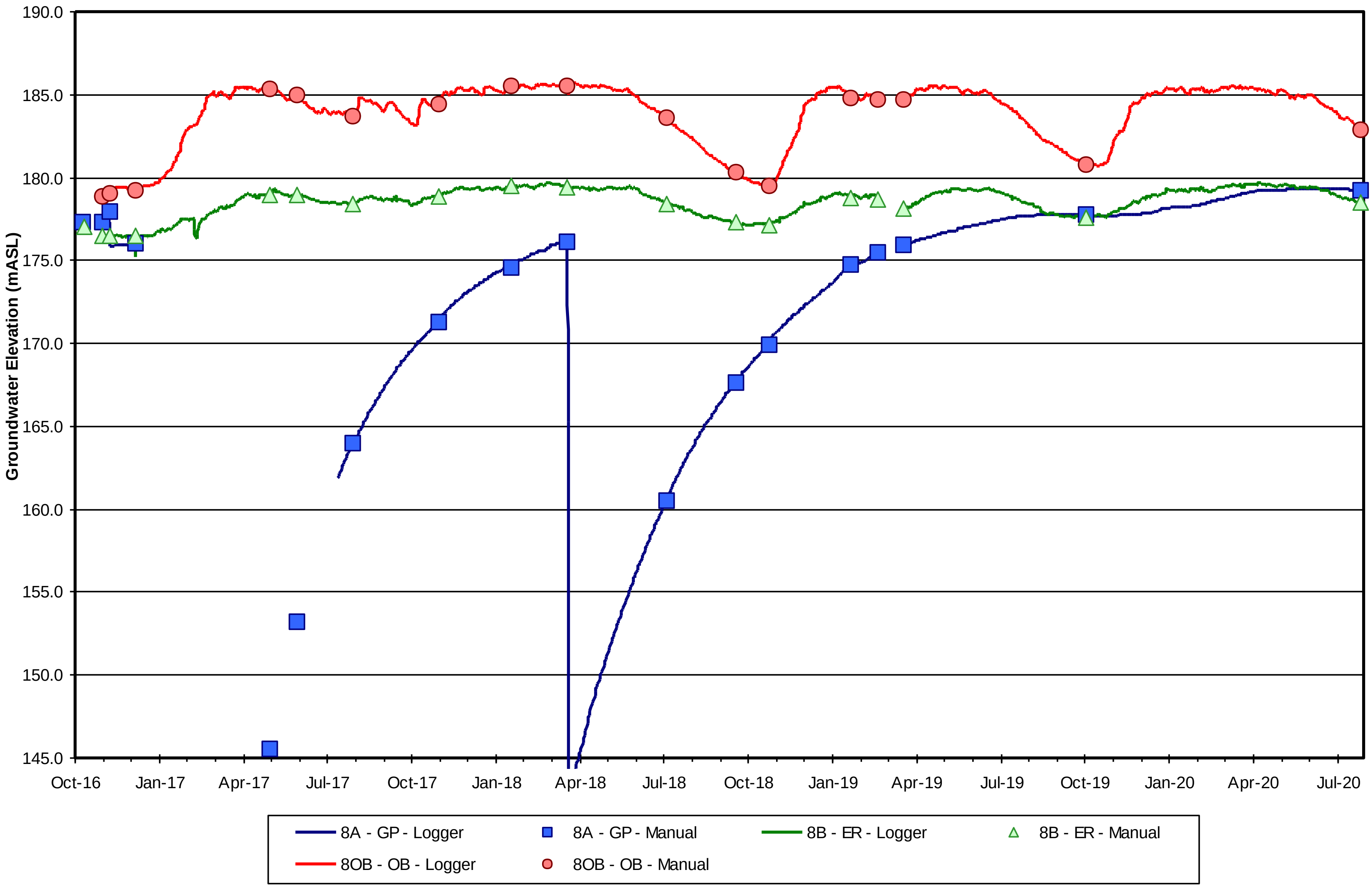


Figure E-10 - Groundwater Hydrograph for Well Nest MW16-9

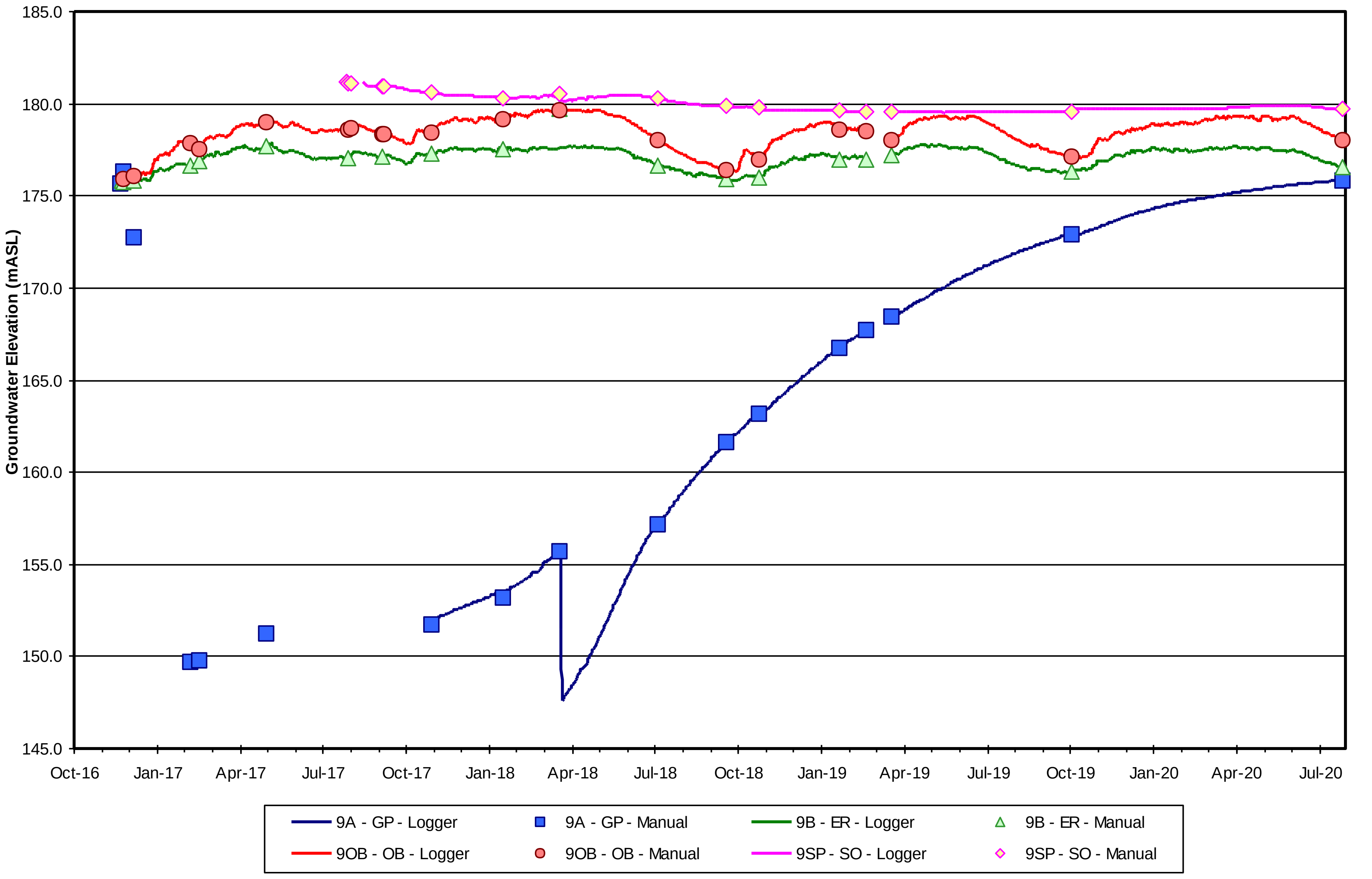
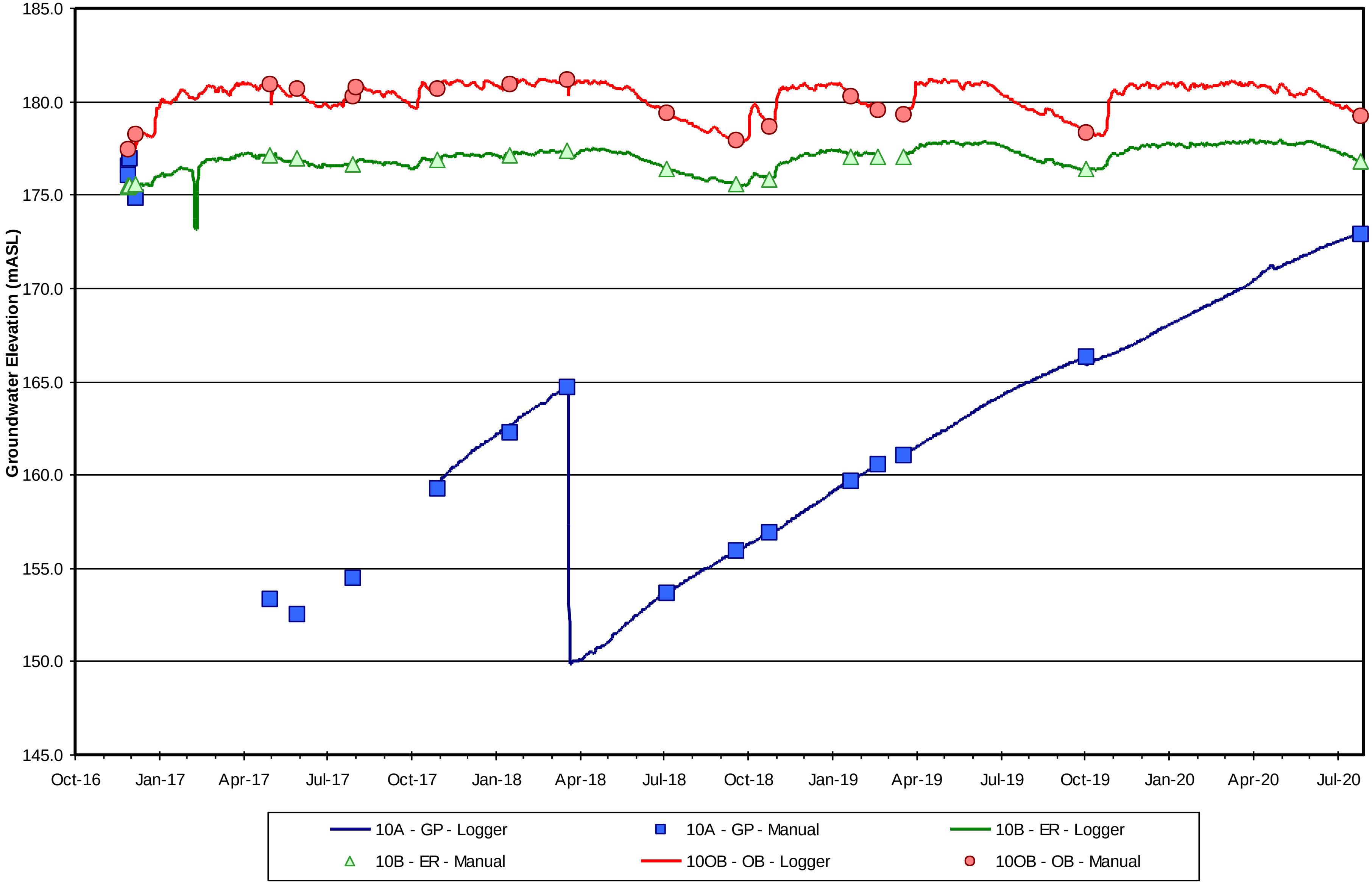


Figure E-11 - Groundwater Hydrograph for Well Nest MW16-10



PROPOSED UPPER'S QUARRY
UPPERS_REPORTS.ACCDB

Figure E-12 - Groundwater Hydrograph for Well MW16-11

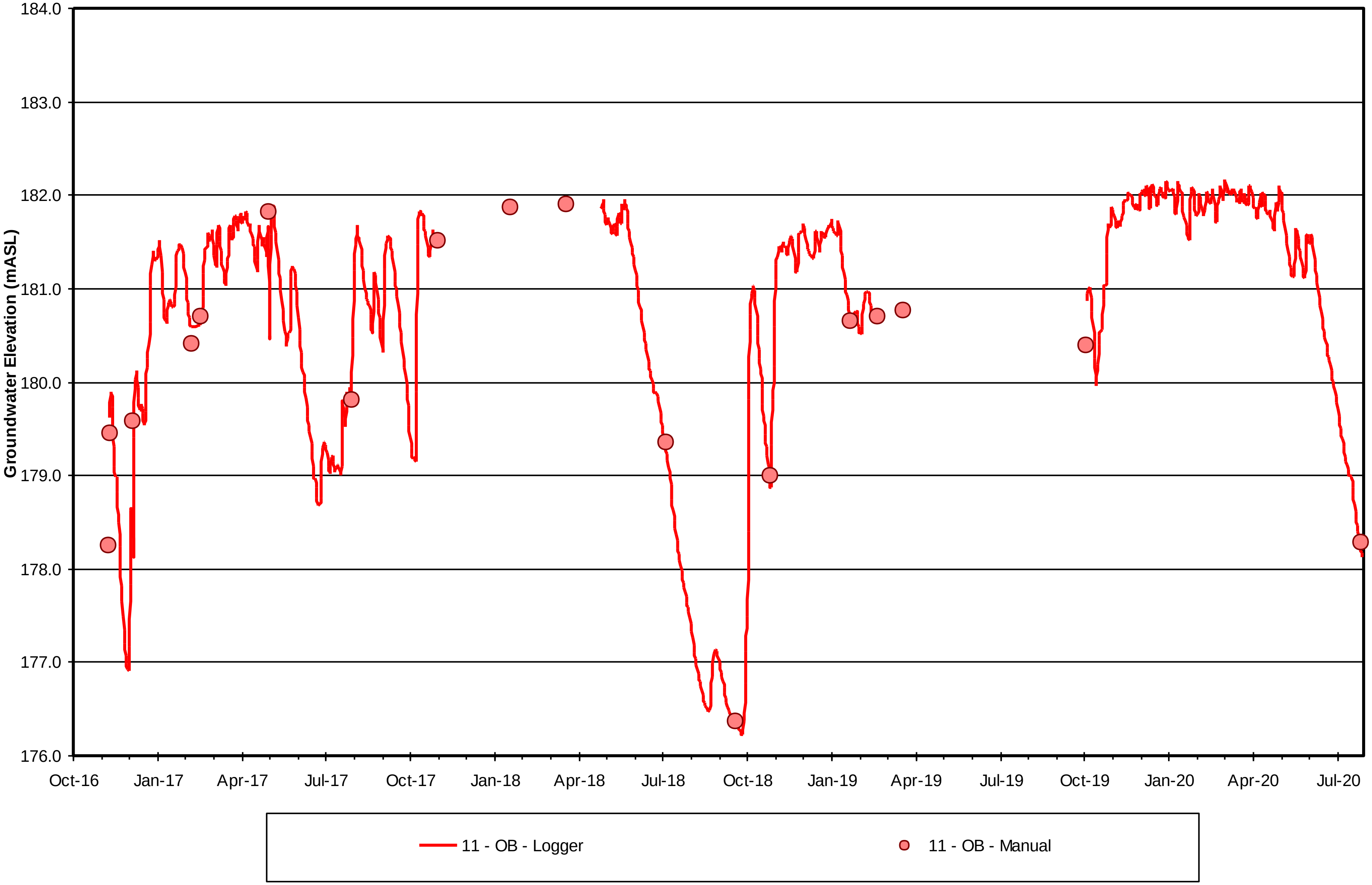


Figure E-13 - Groundwater Hydrograph for Well MW16-12

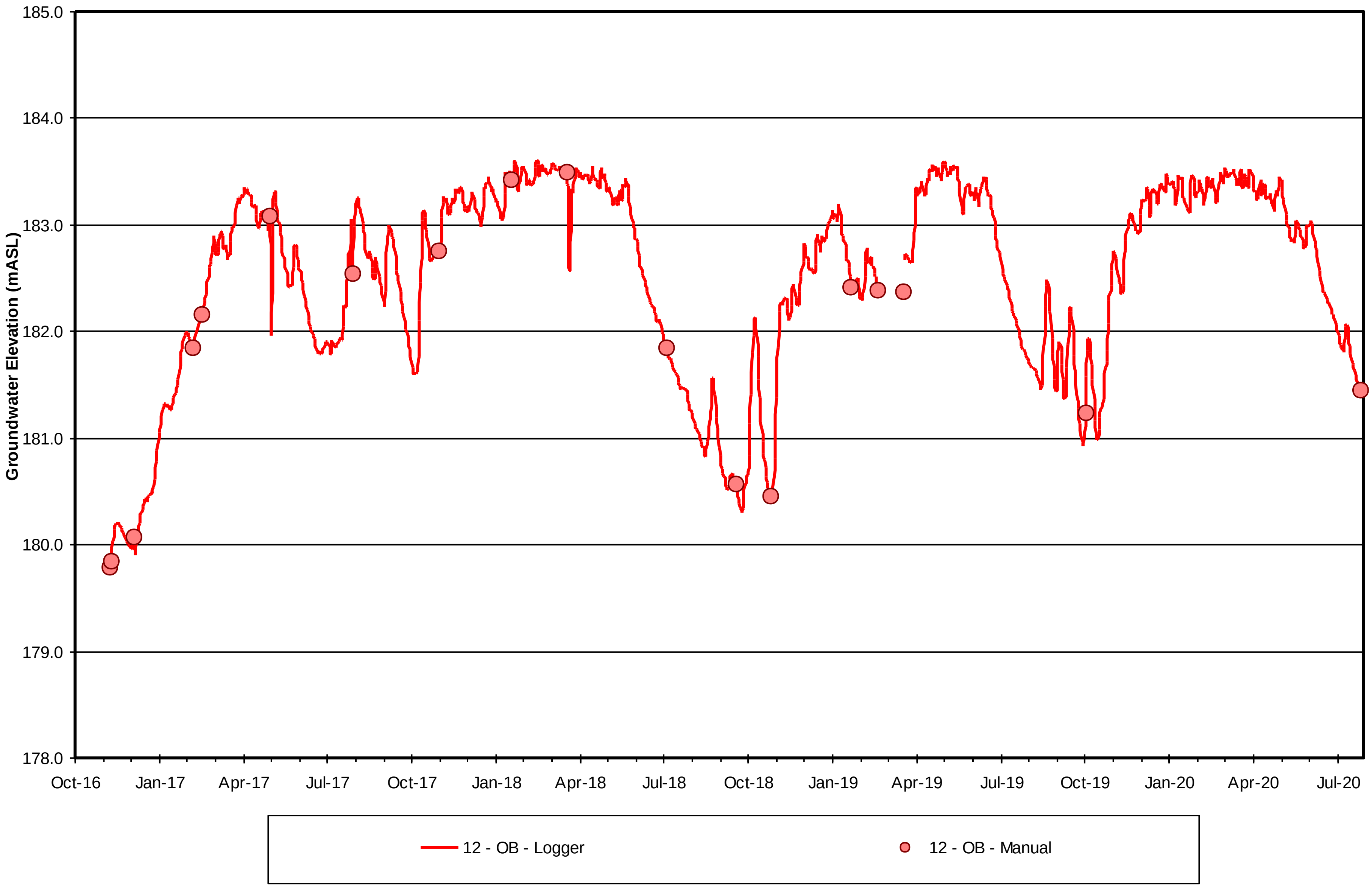


Figure E-14 - Groundwater Hydrograph for Well Nest MW16-13

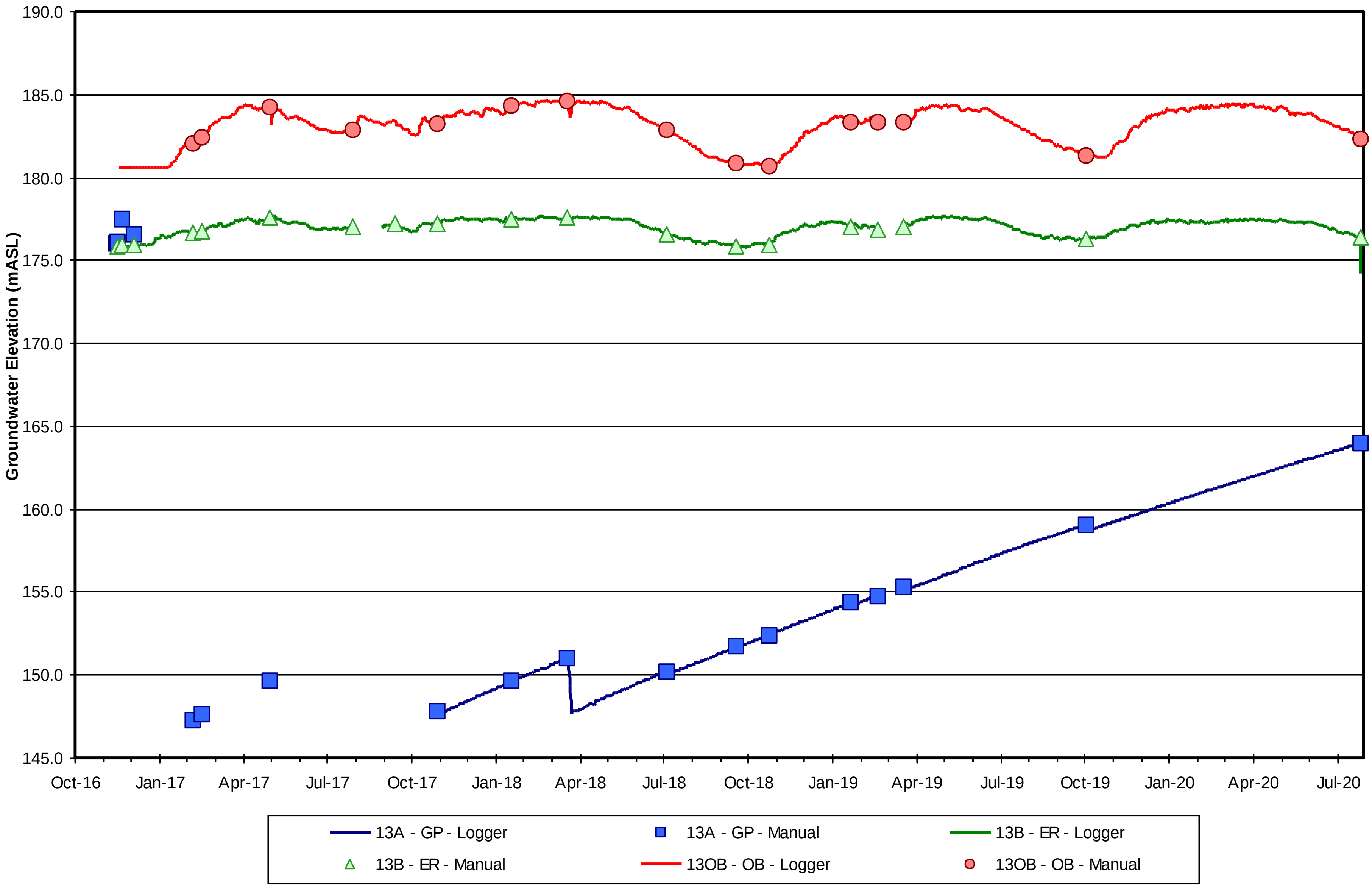
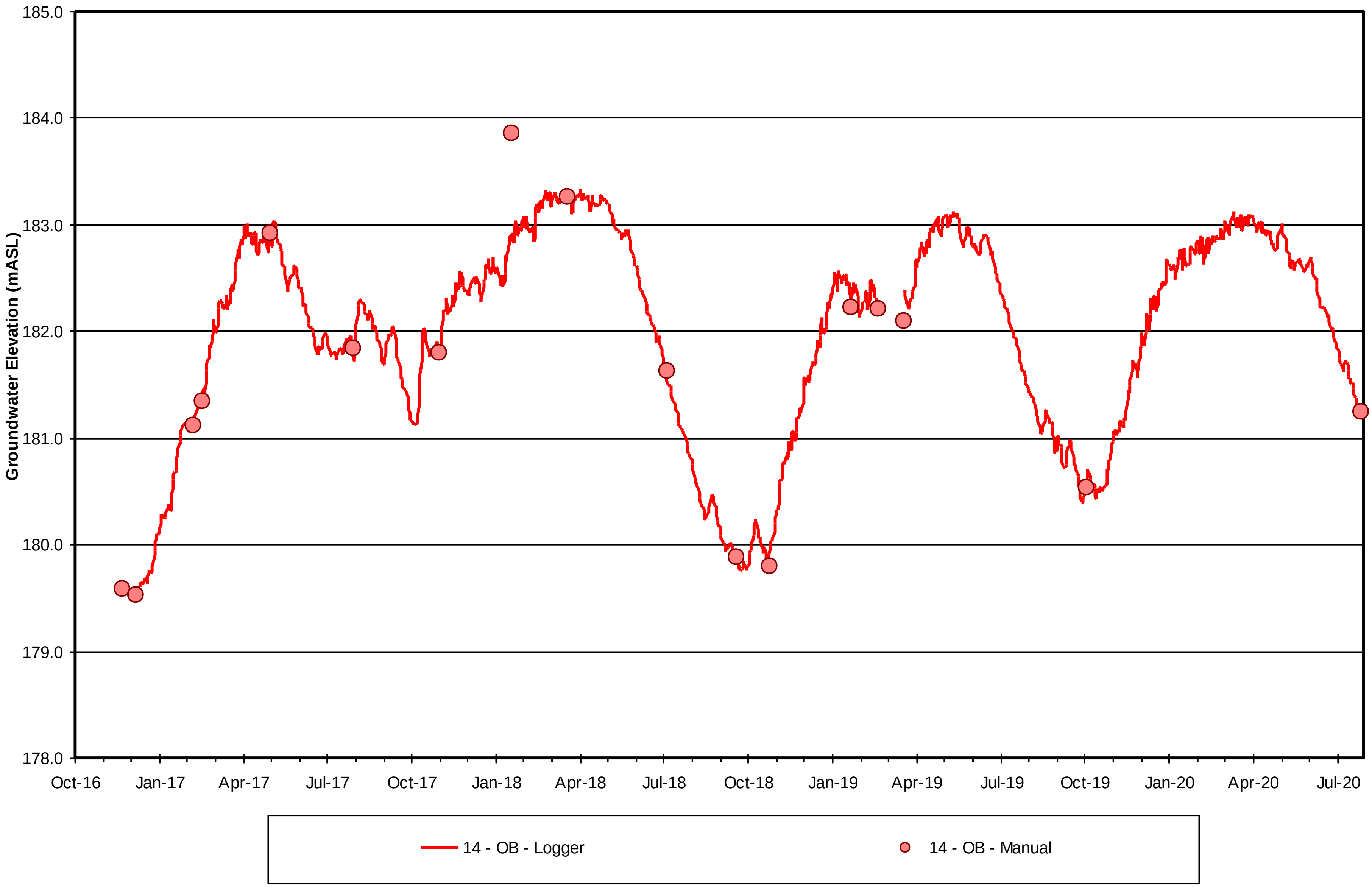


Figure E-15 - Groundwater Hydrograph for Well MW16-14



PROPOSED UPPER'S QUARRY
UPPERS_REPORTS.ACCDB

Figure E-16 - Groundwater Hydrograph for Well MW16-15

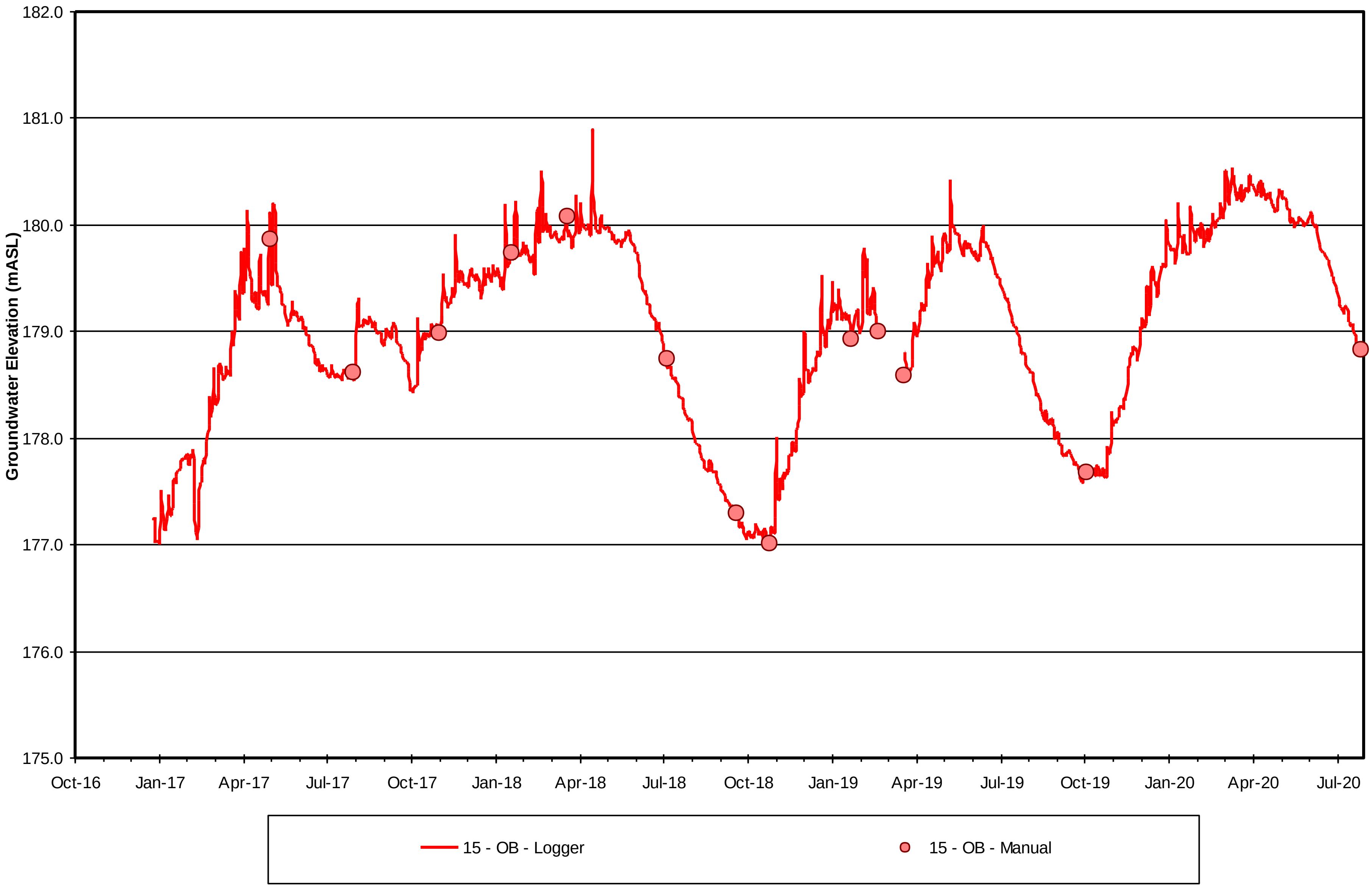
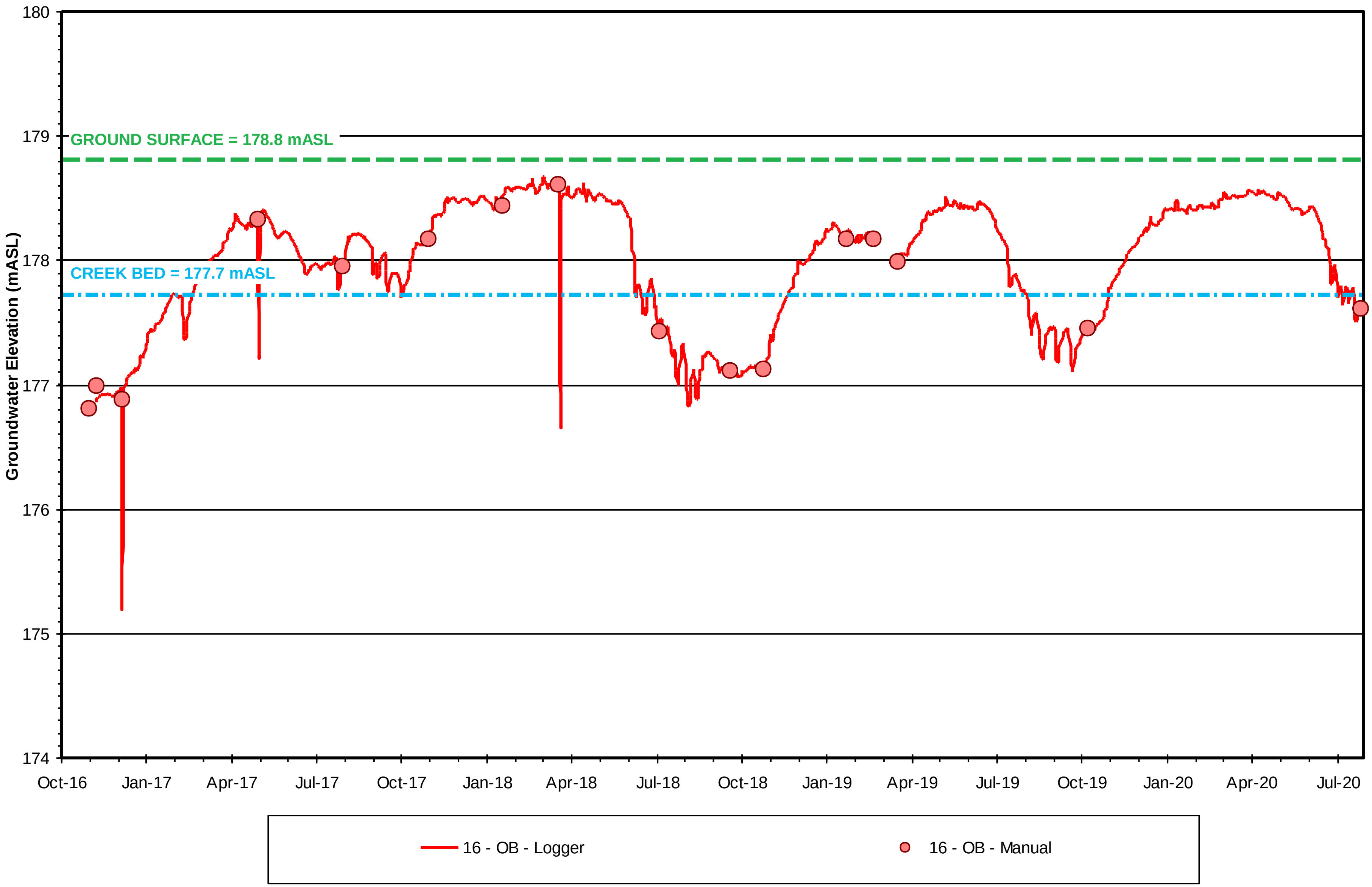
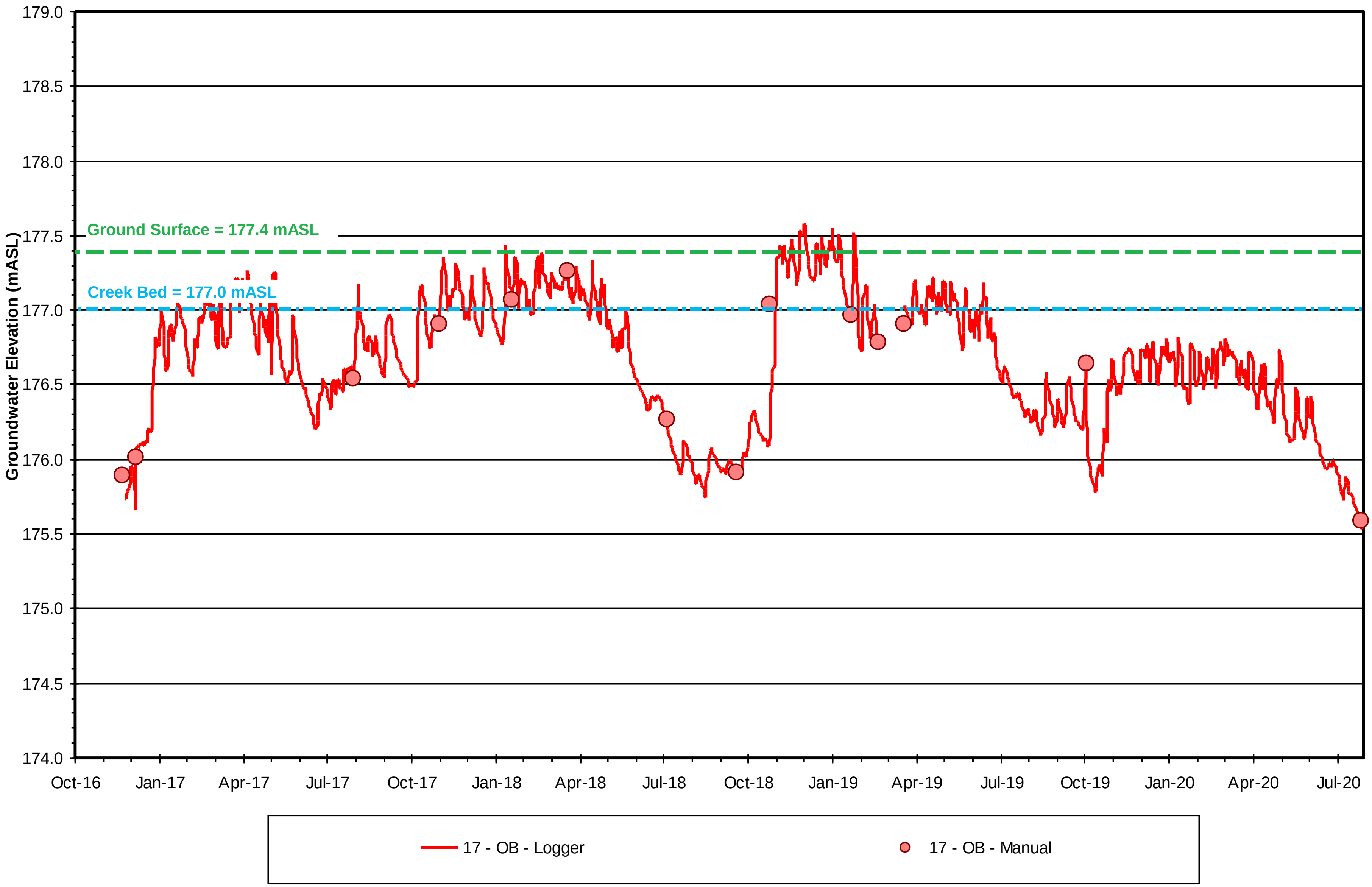


Figure E-17 - Groundwater Hydrograph for Well MW16-16



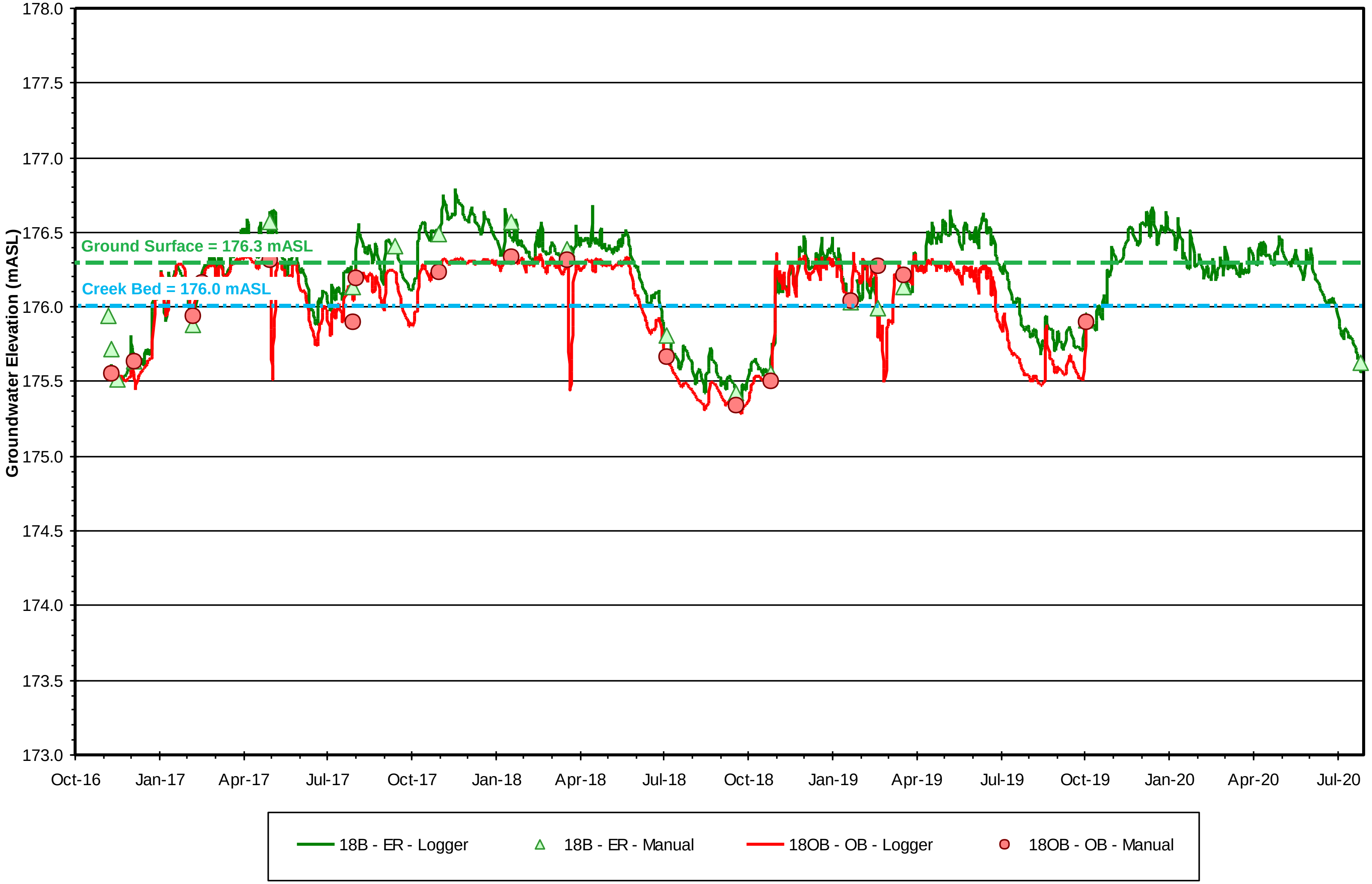
PROPOSED UPPER'S QUARRY
UPPERS_REPORTS.ACCDB

Figure E-18 - Groundwater Hydrograph for Well MW16-17



PROPOSED UPPER'S QUARRY
UPPERS_REPORTS.ACCDB

Figure E-19 - Groundwater Hydrograph for Well Nest MW16-18



PROPOSED UPPER'S QUARRY
UPPERS_REPORTS.ACCDB

Figure E-20 - Groundwater Hydrograph for Well Nest MW16-19

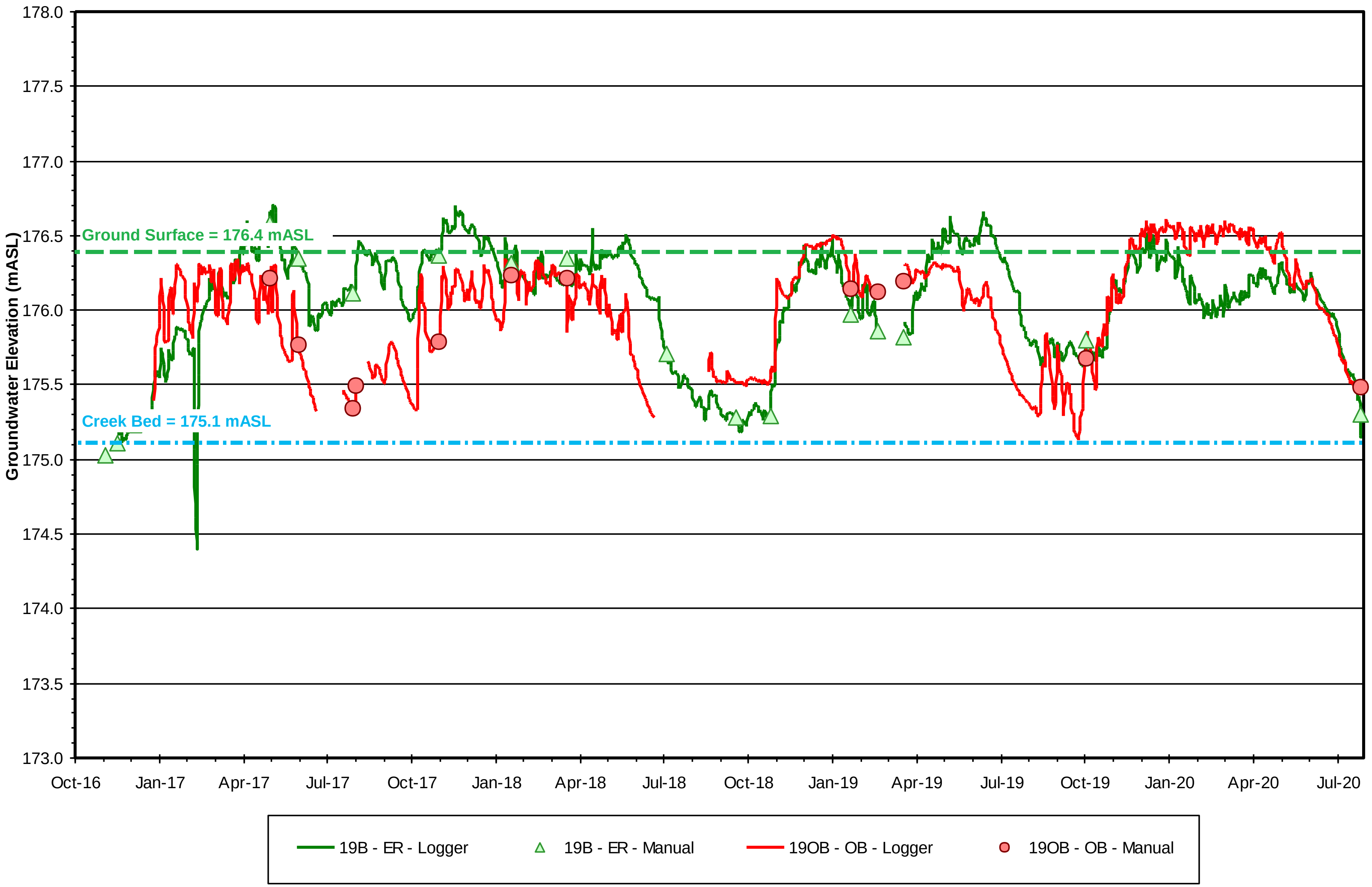
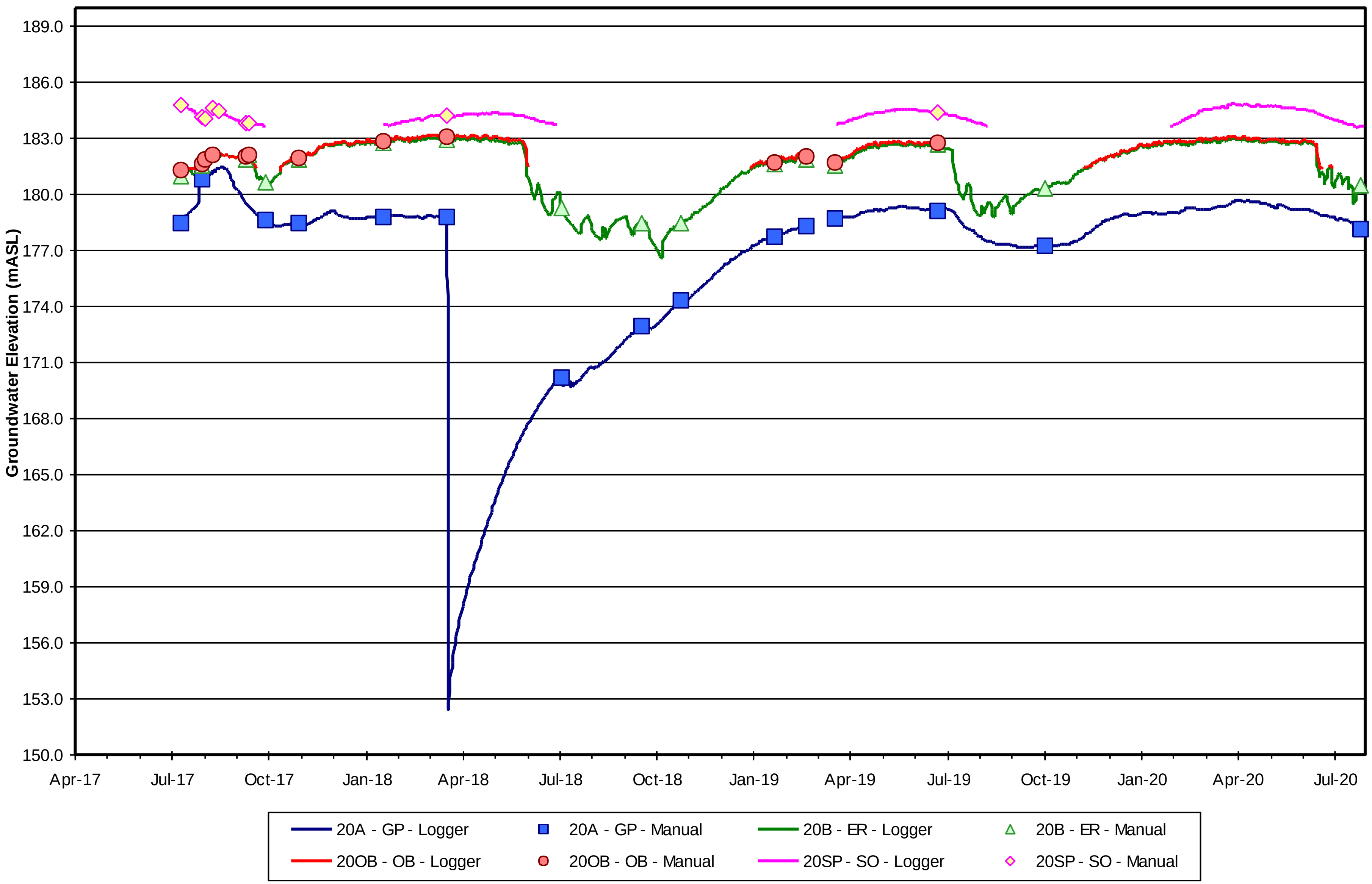


Figure E-21 - Groundwater Hydrograph for Well Nest MW17-20



PROPOSED UPPER'S QUARRY
UPPERS_REPORTS.ACCDB

Figure E-22 - Groundwater Hydrograph for Well Nest MW17-21

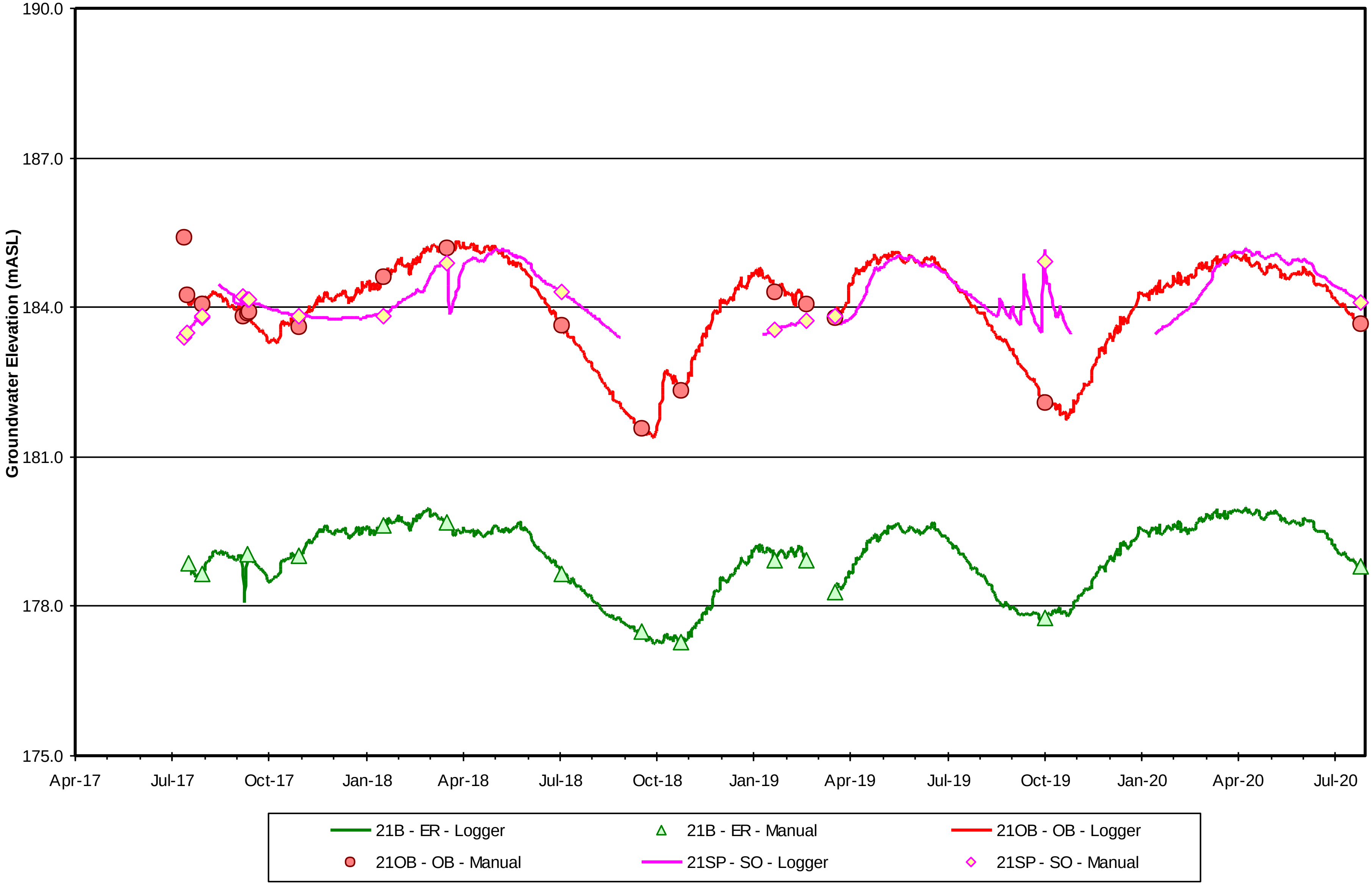


Figure E-23 - Groundwater Hydrograph for Well Nest MW17-22

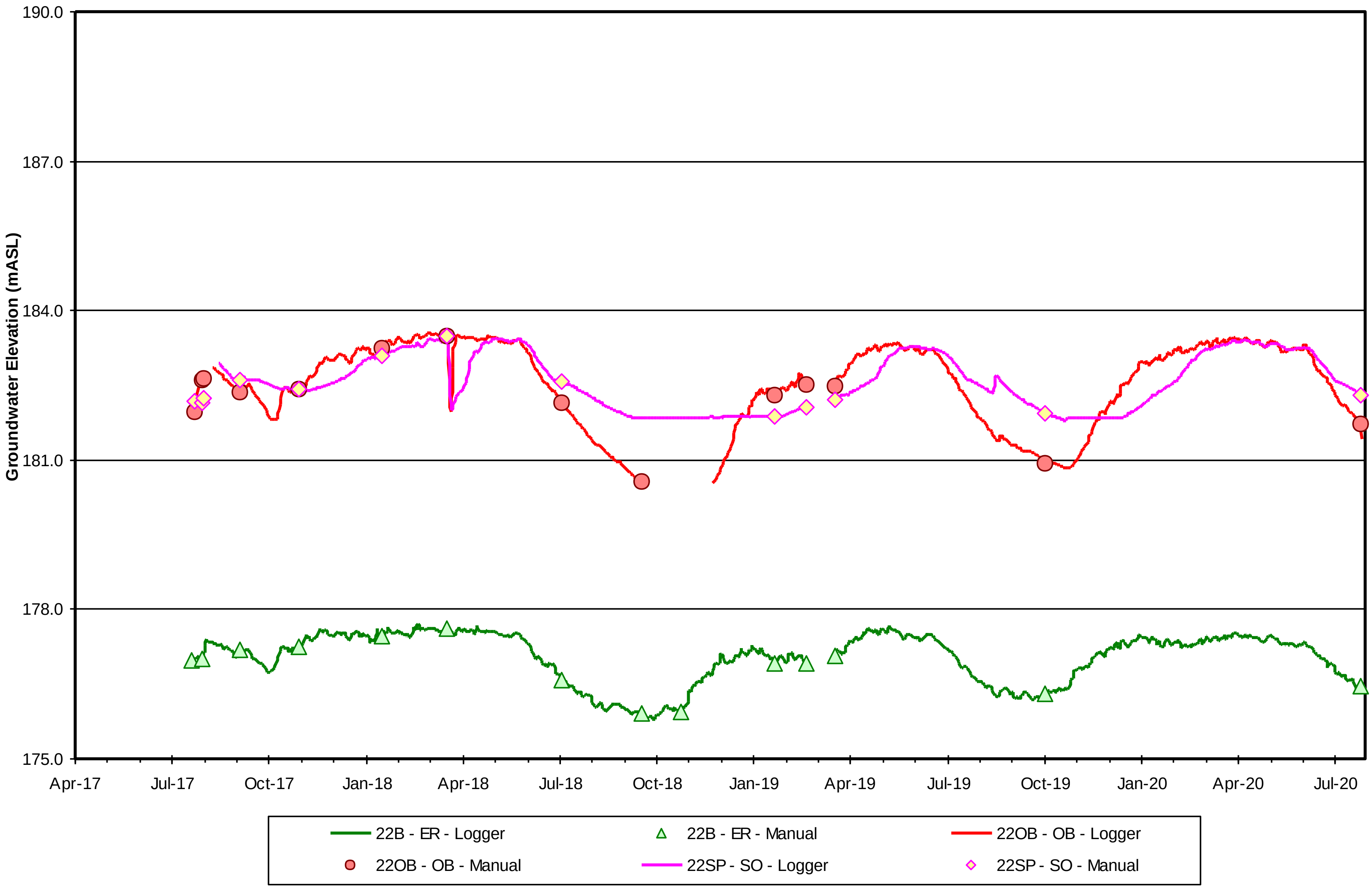


Figure E-24 - Groundwater Hydrograph for Well Nest MW17-23

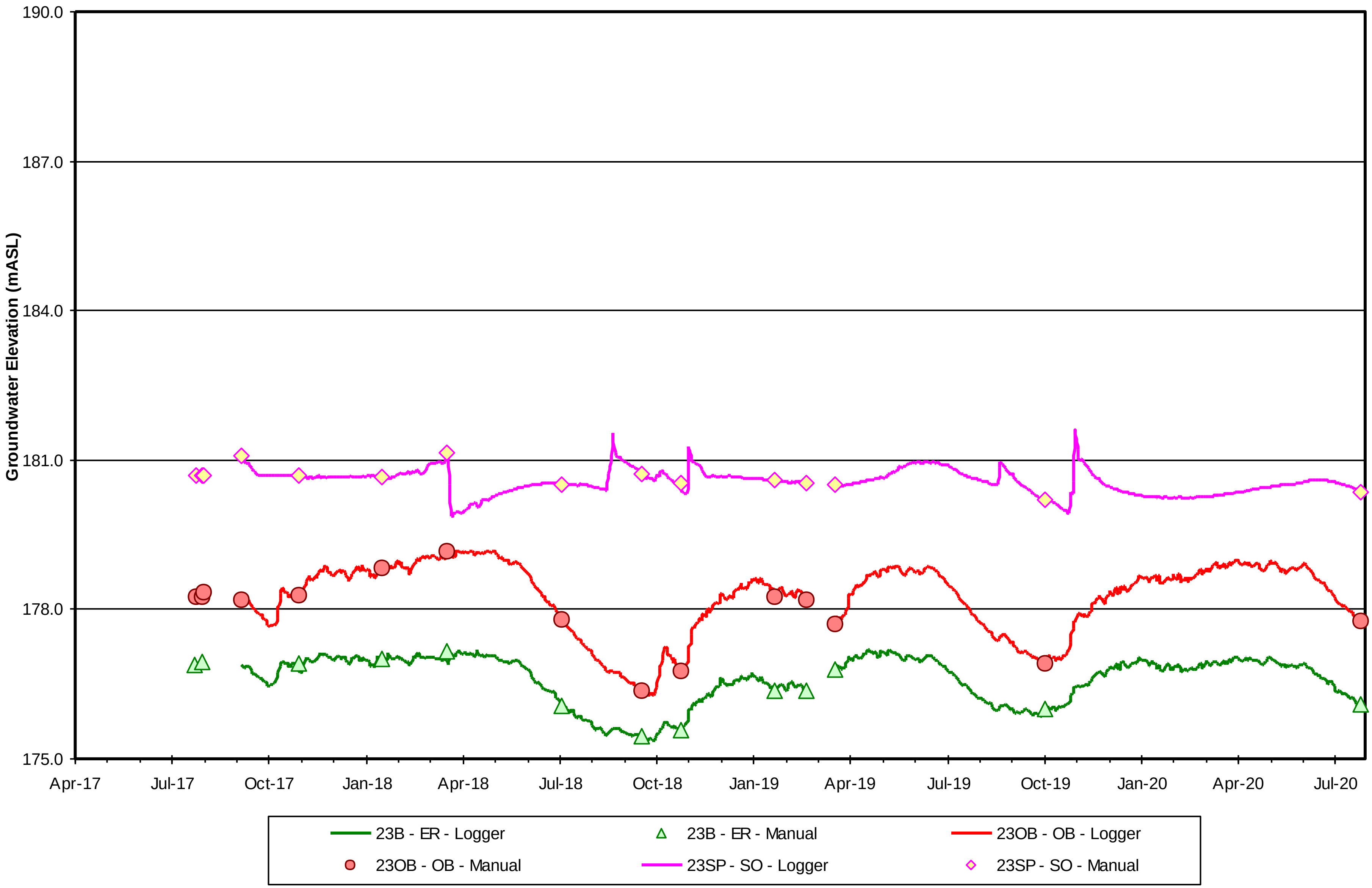


Figure E-25 - Stage-Discharge Curve
Staff Gauge SW1

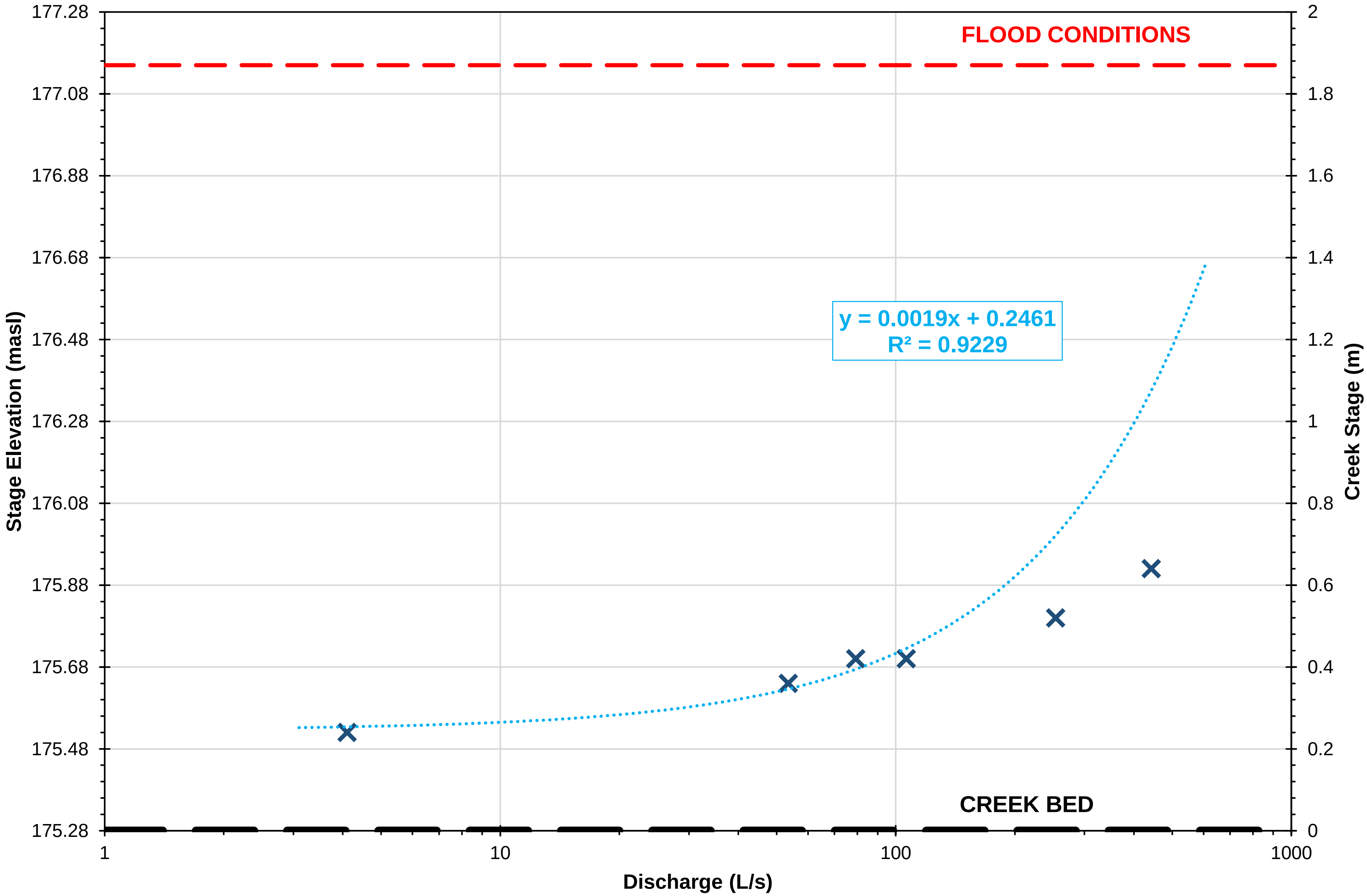
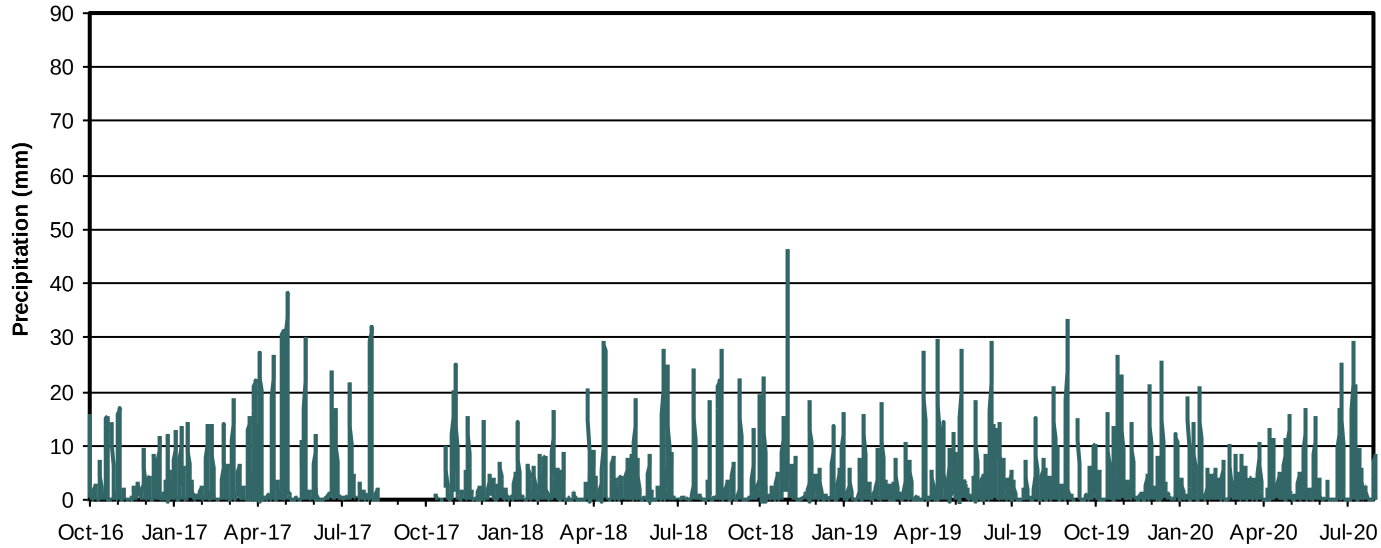


Figure E-26 - Hydrograph for Surface Water Station SW1



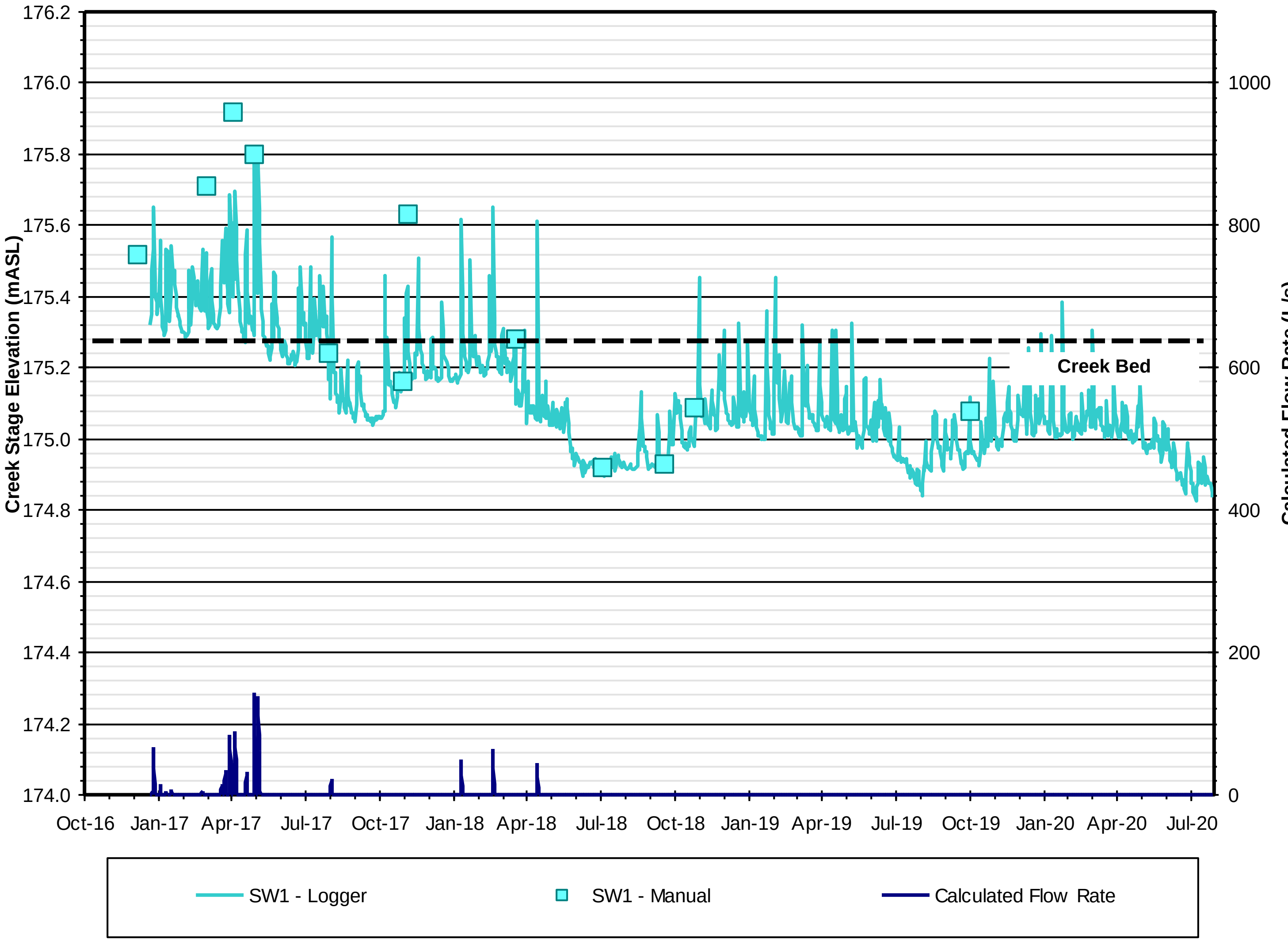


Figure E-27 - Stage-Discharge Curve
Staff Gauge SW2

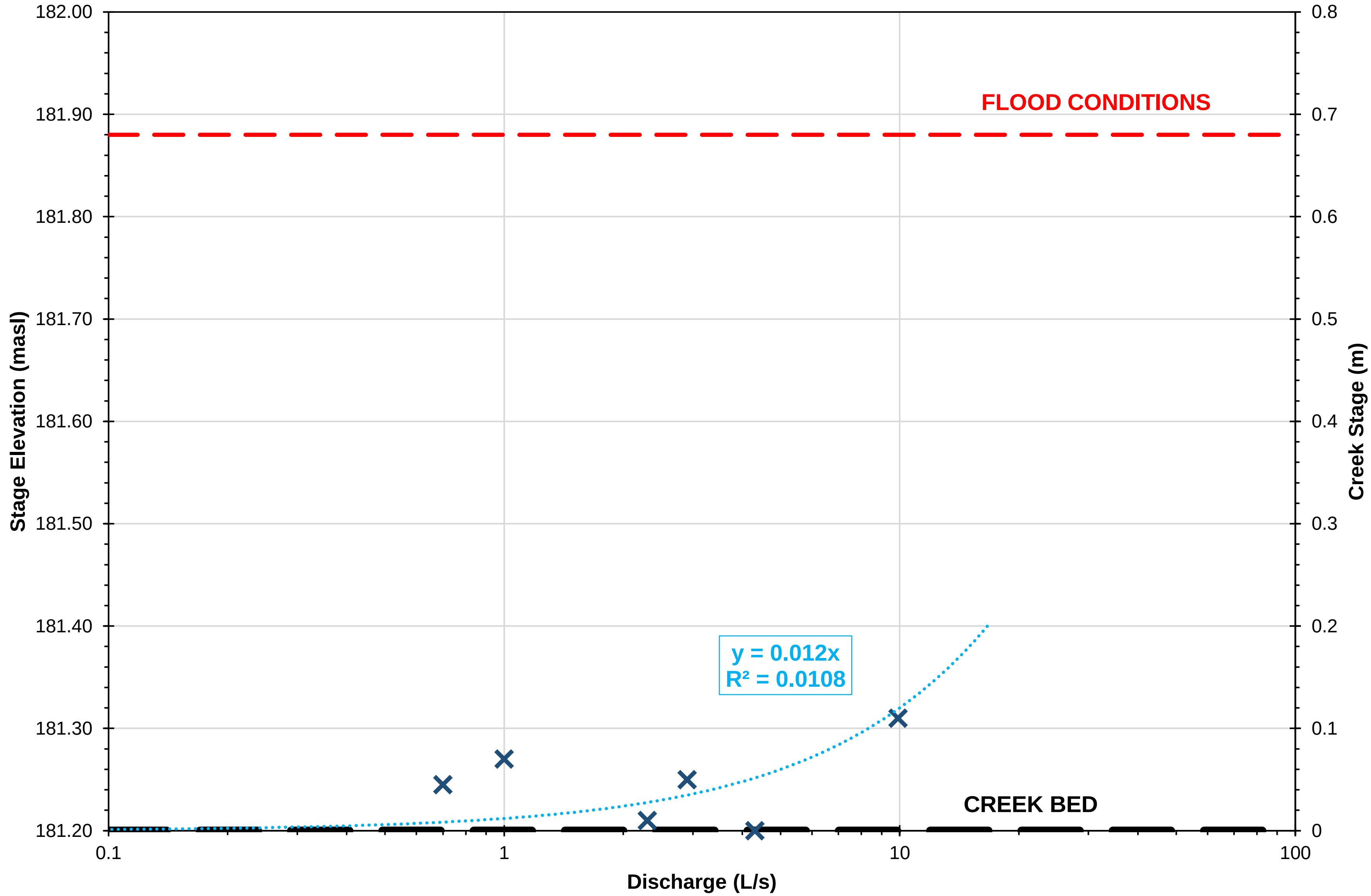
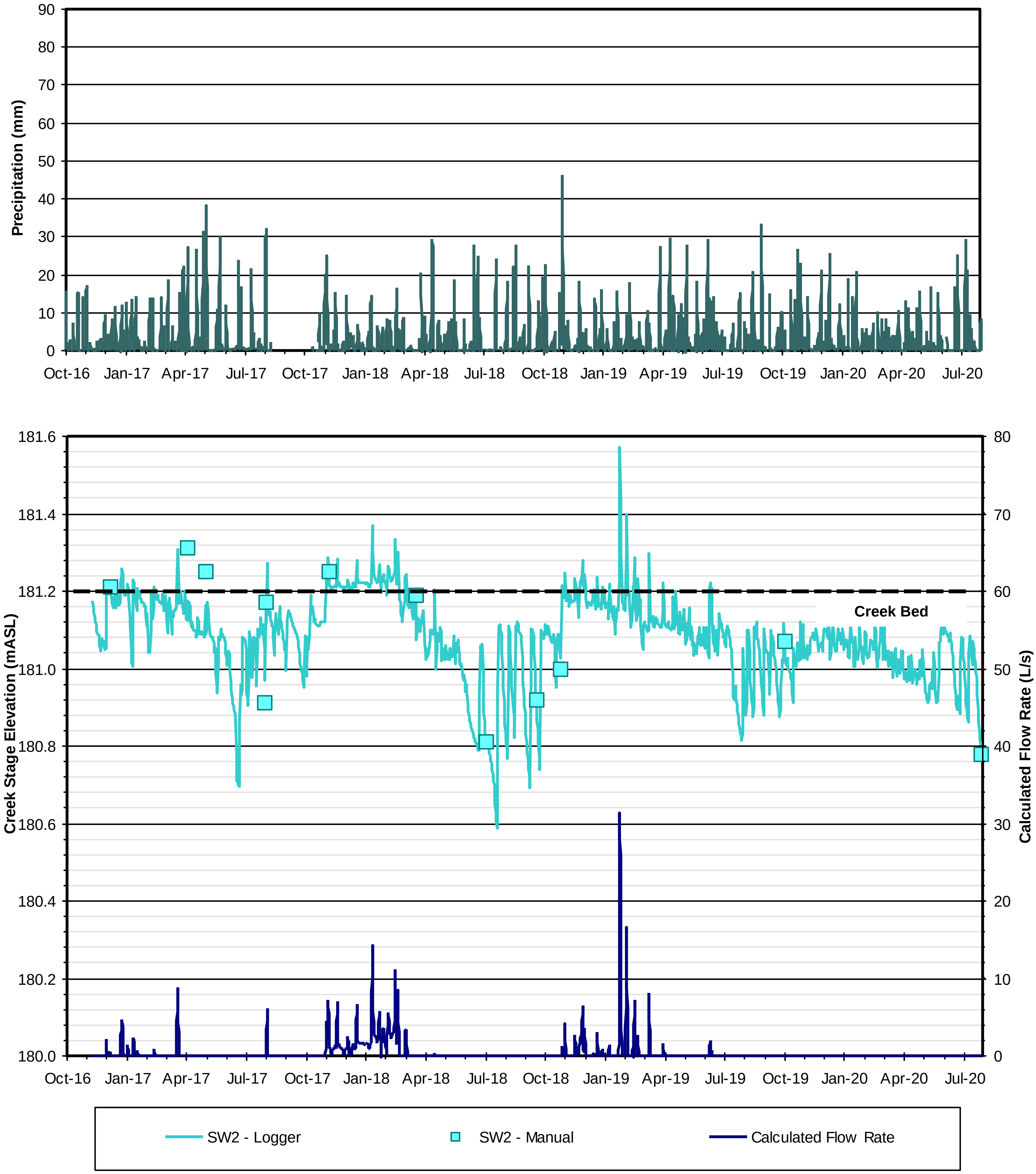


Figure E-28 - Hydrograph for Surface Water Station SW2



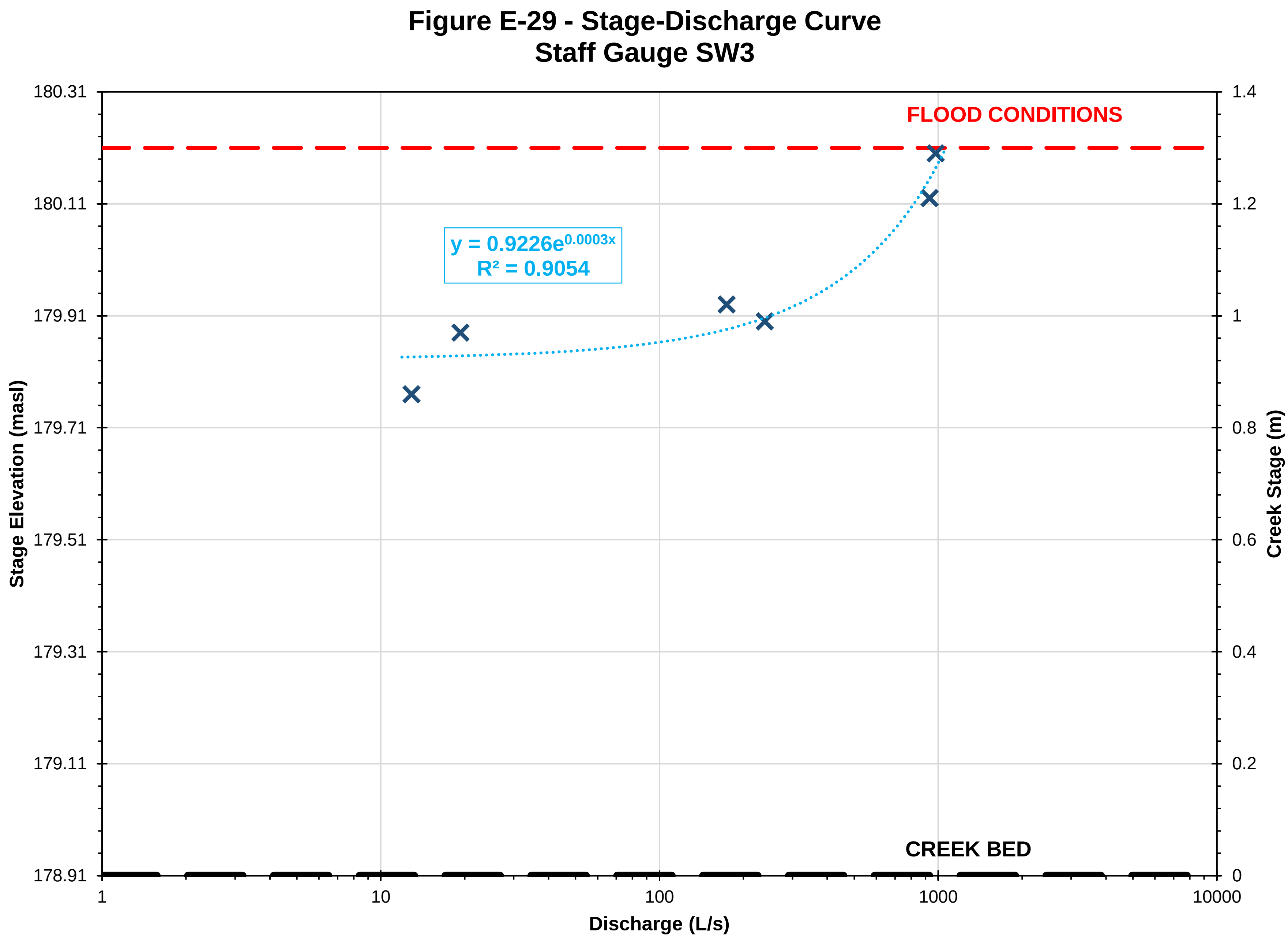


Figure E-29 - Stage-Discharge Curve
Staff Gauge SW3
FLOOD CONDITIONS
y = 0.9226e^0.0003x
R² = 0.9054
CREEK BED
Stage Elevation (masl)
Creek Stage (m)
Discharge (L/s)
180.31
180.11
179.91
179.71
179.51
179.31
179.11
178.91
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
10
100
1000
10000

Figure E-30 - Hydrograph for Surface Water Station SW3

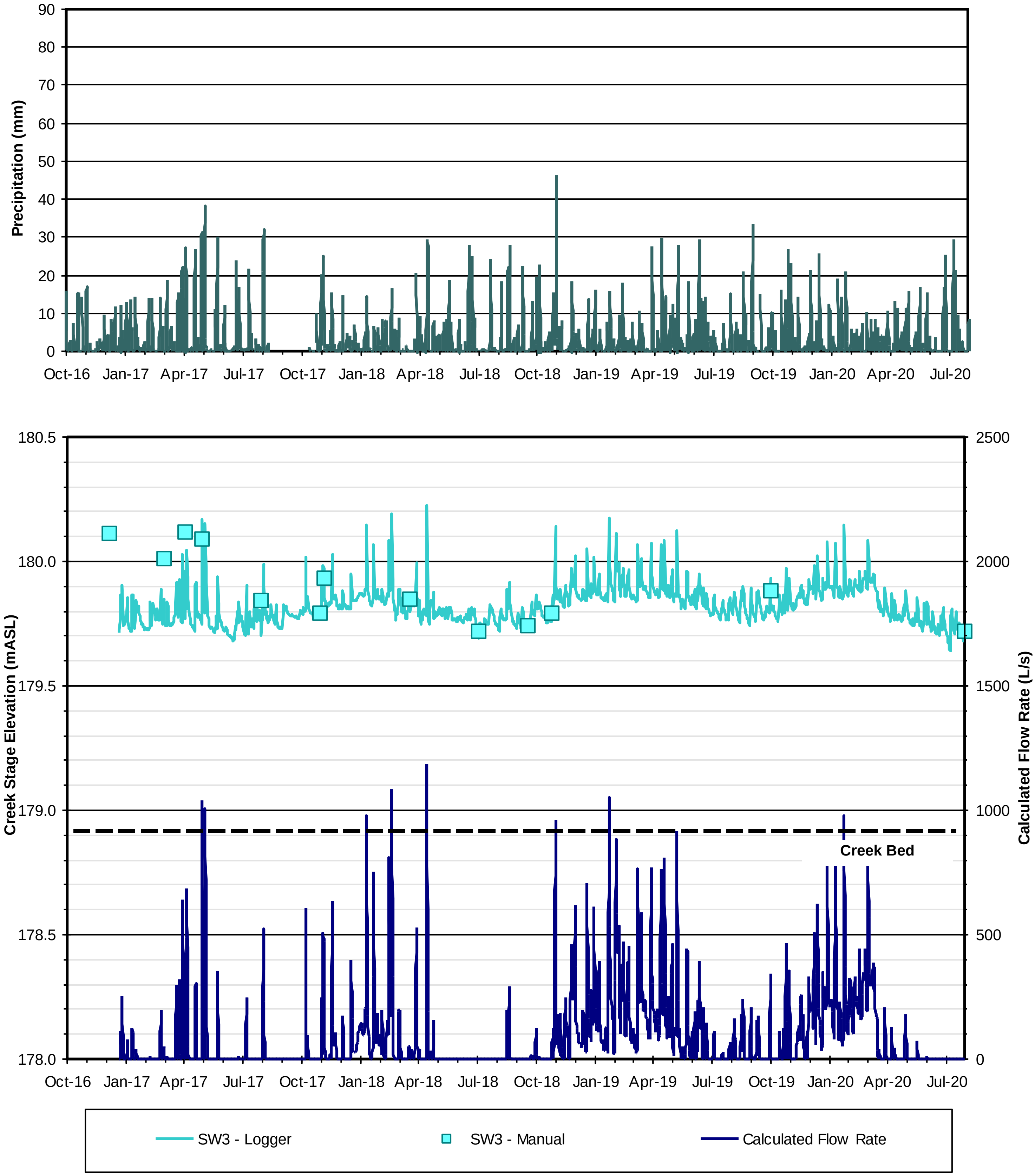


Figure E-31 - Stage-Discharge Curve
Staff Gauge SW4

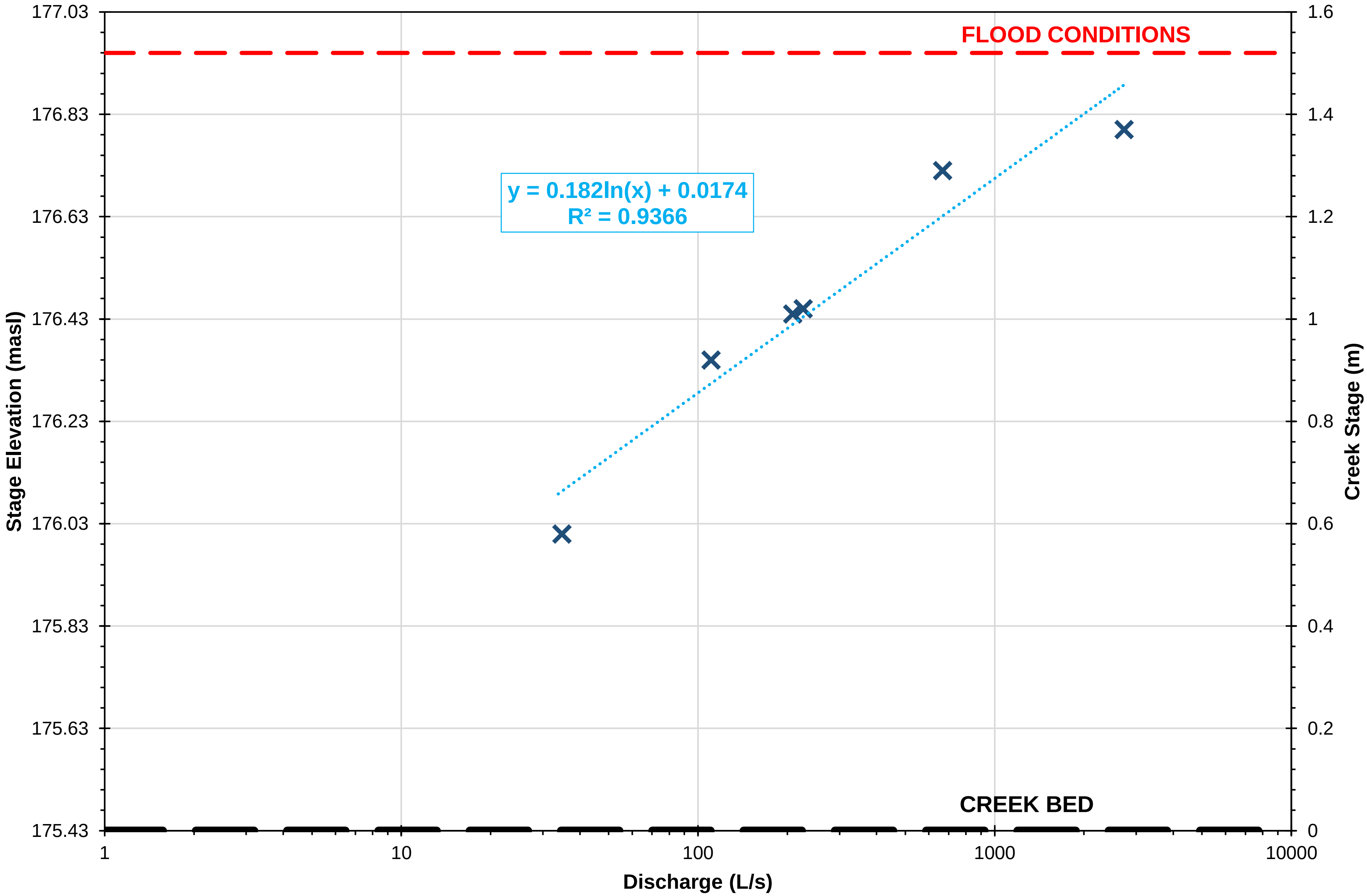
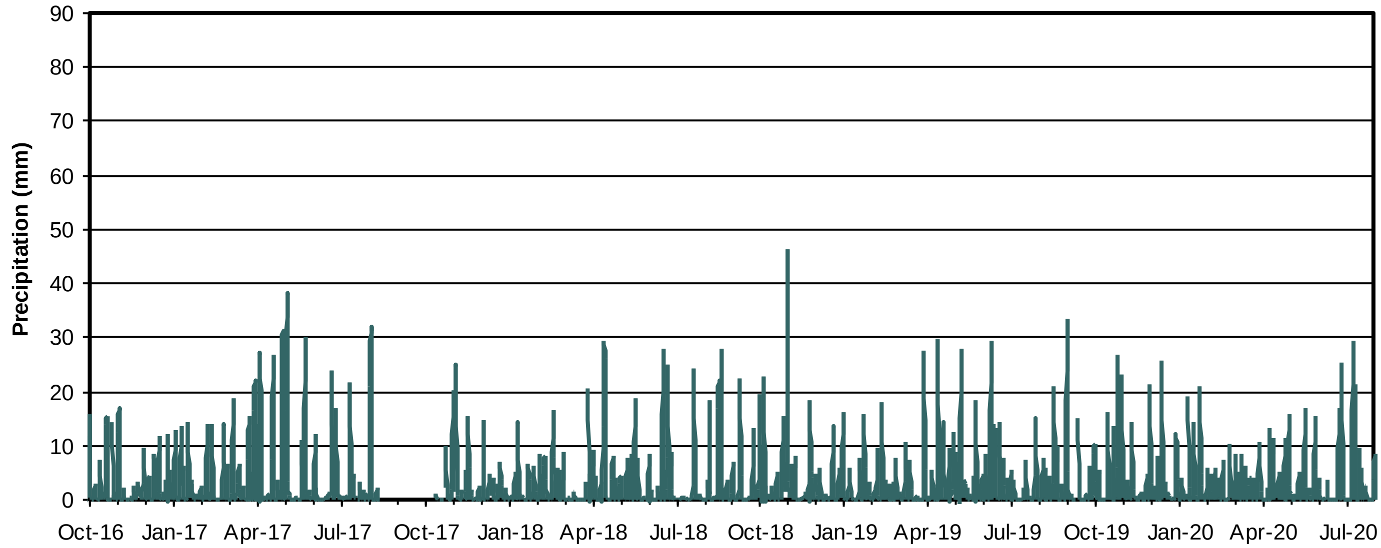


Figure E-32 - Hydrograph for Surface Water Station SW4



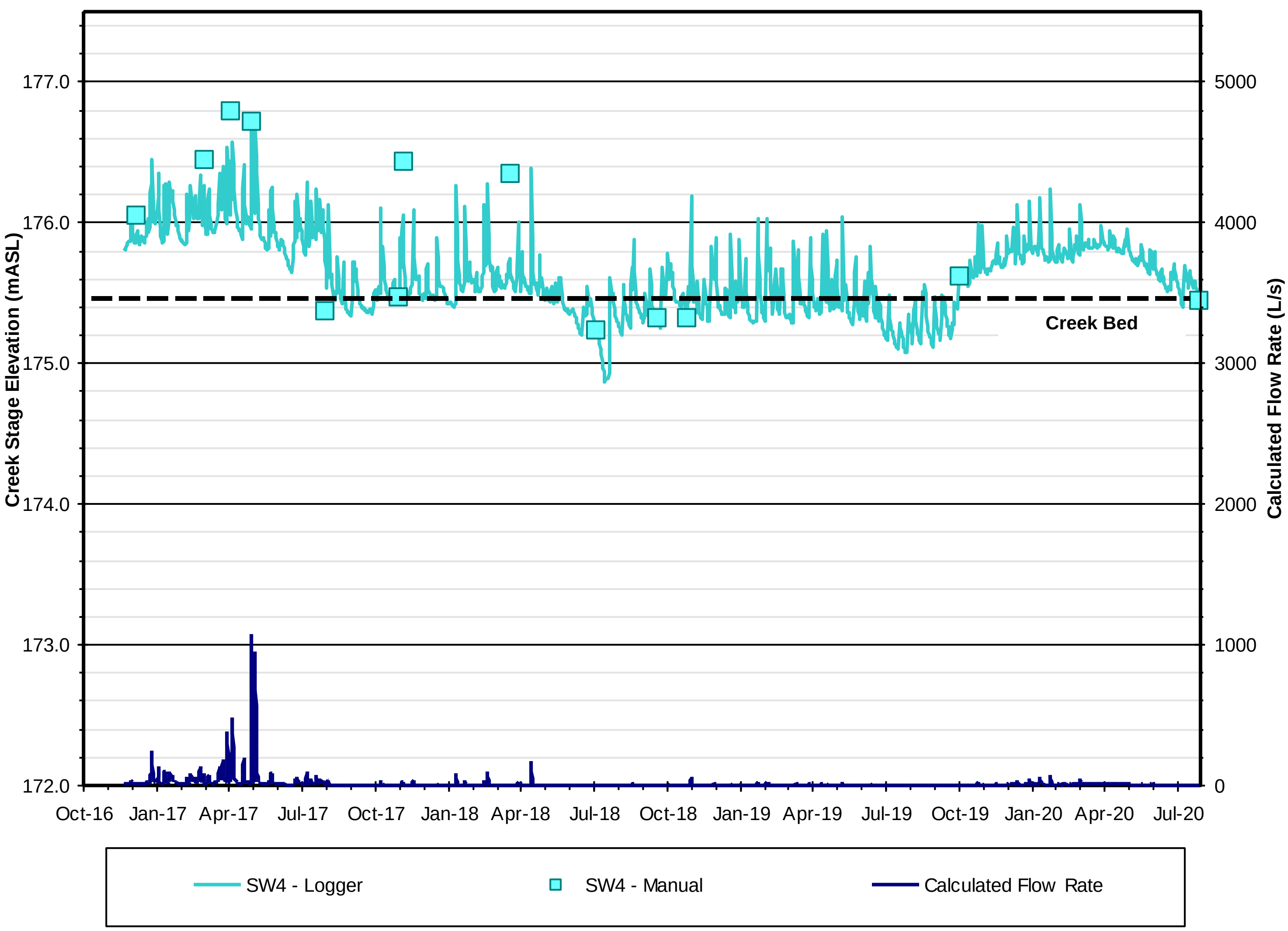
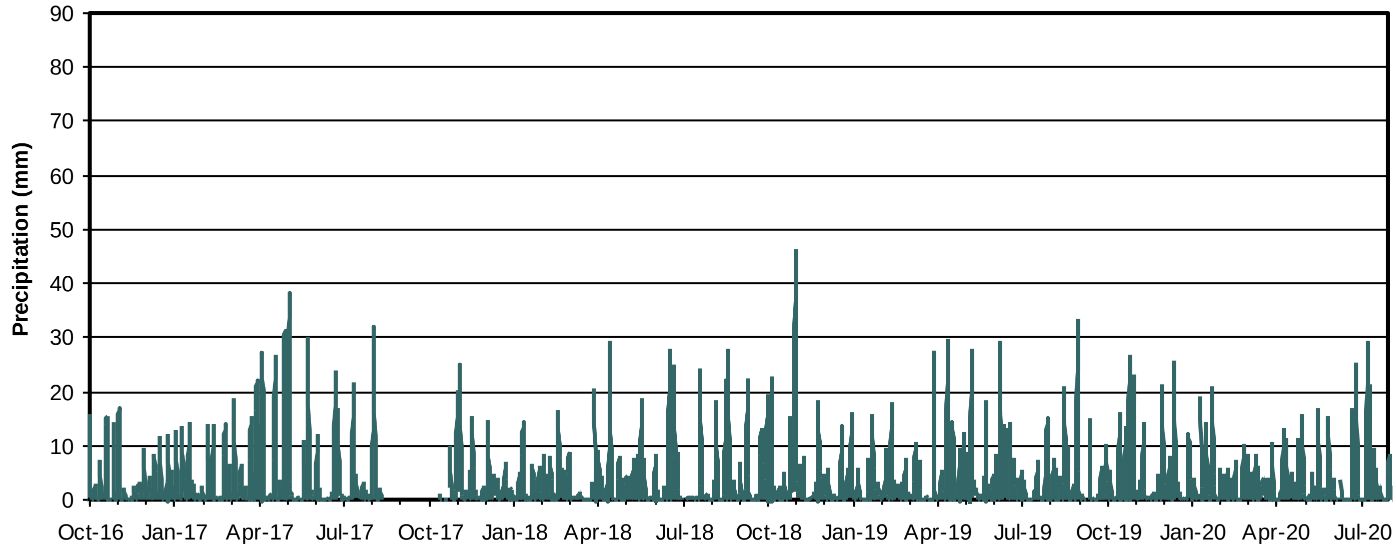


Figure E-33 - Hydrograph for Drivepoint DP1



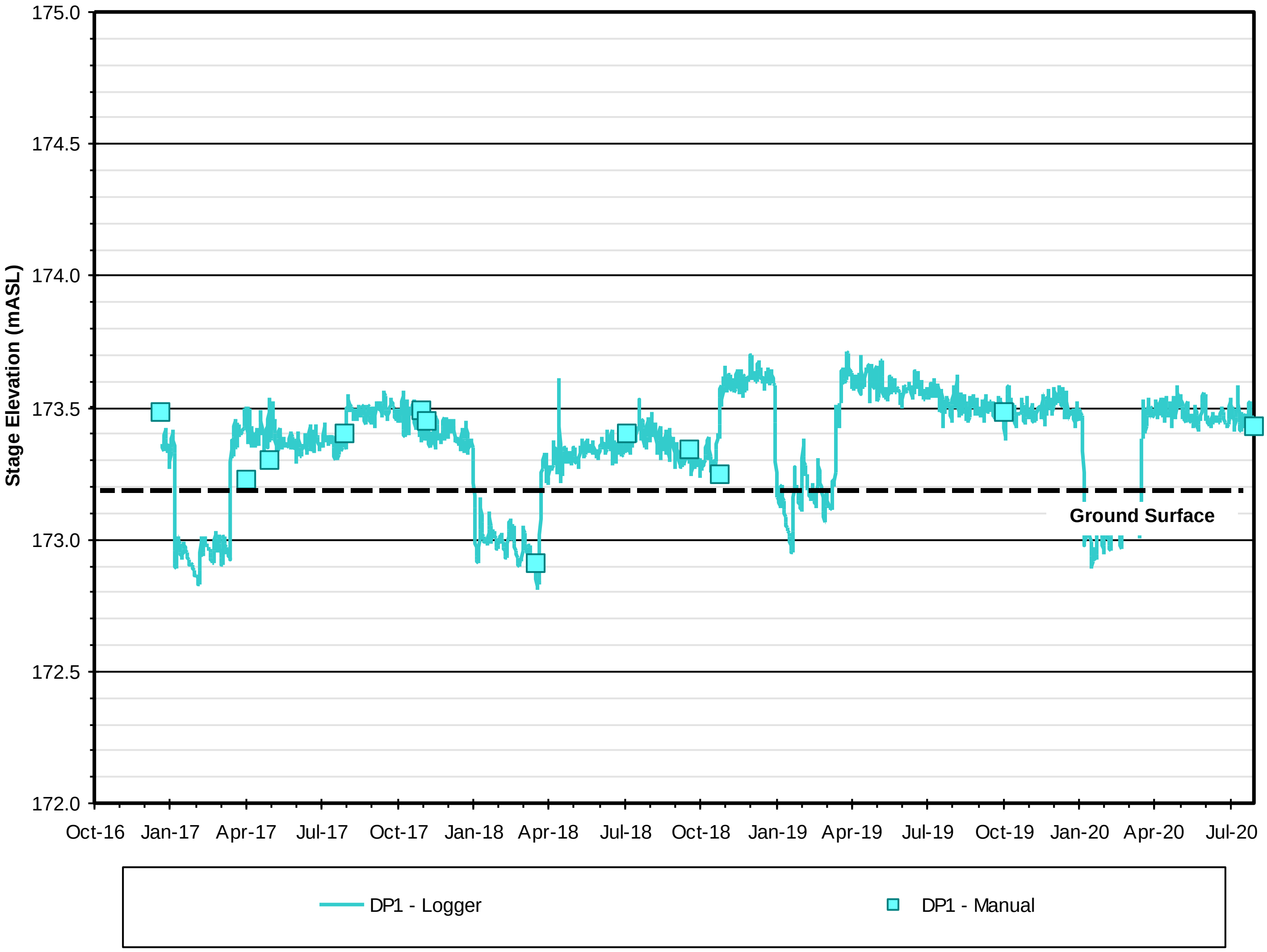


Figure E-34 - Hydrograph for Drivepoint DP2

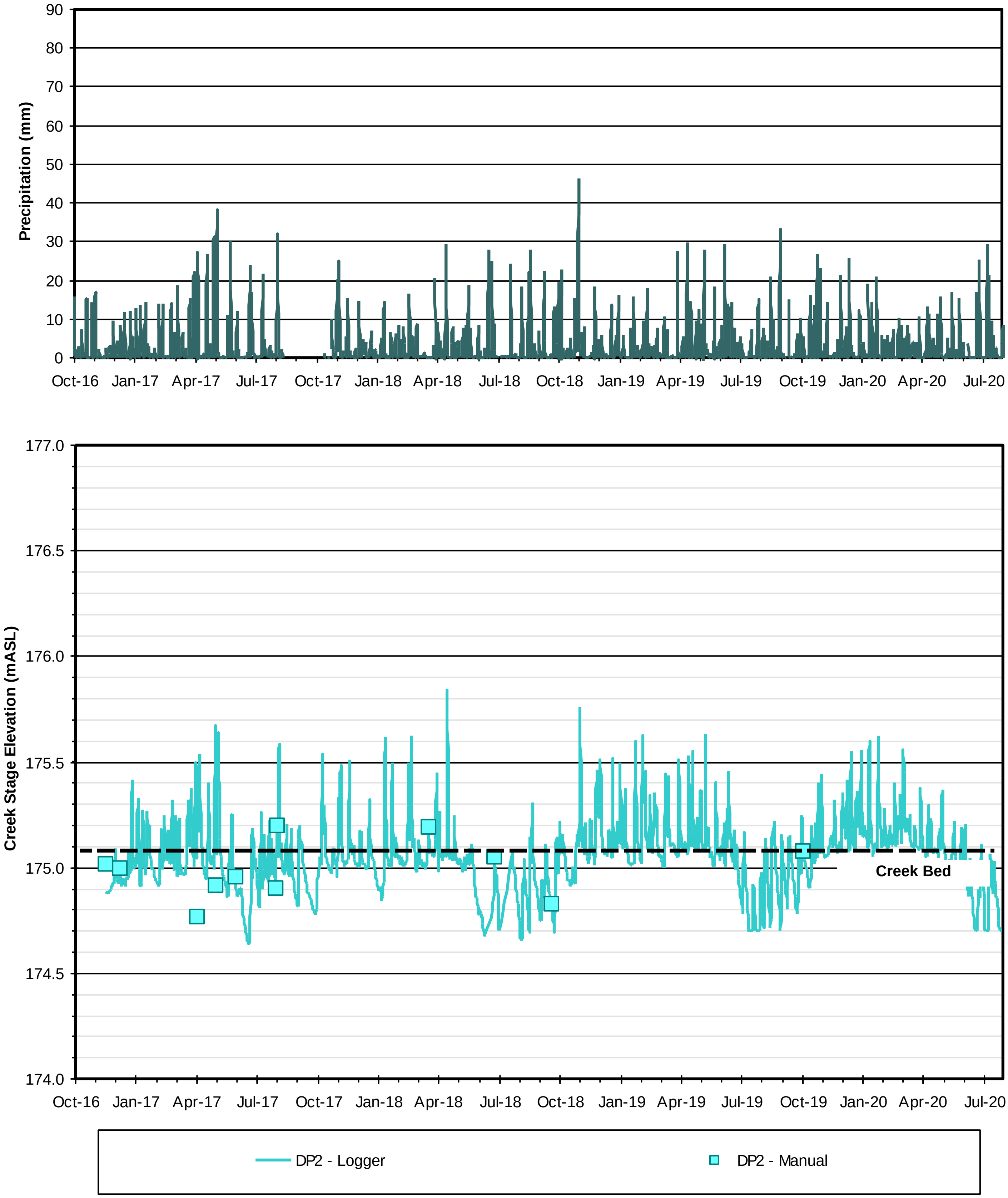


Figure E-35 - Hydrograph for Drivepoint DP3

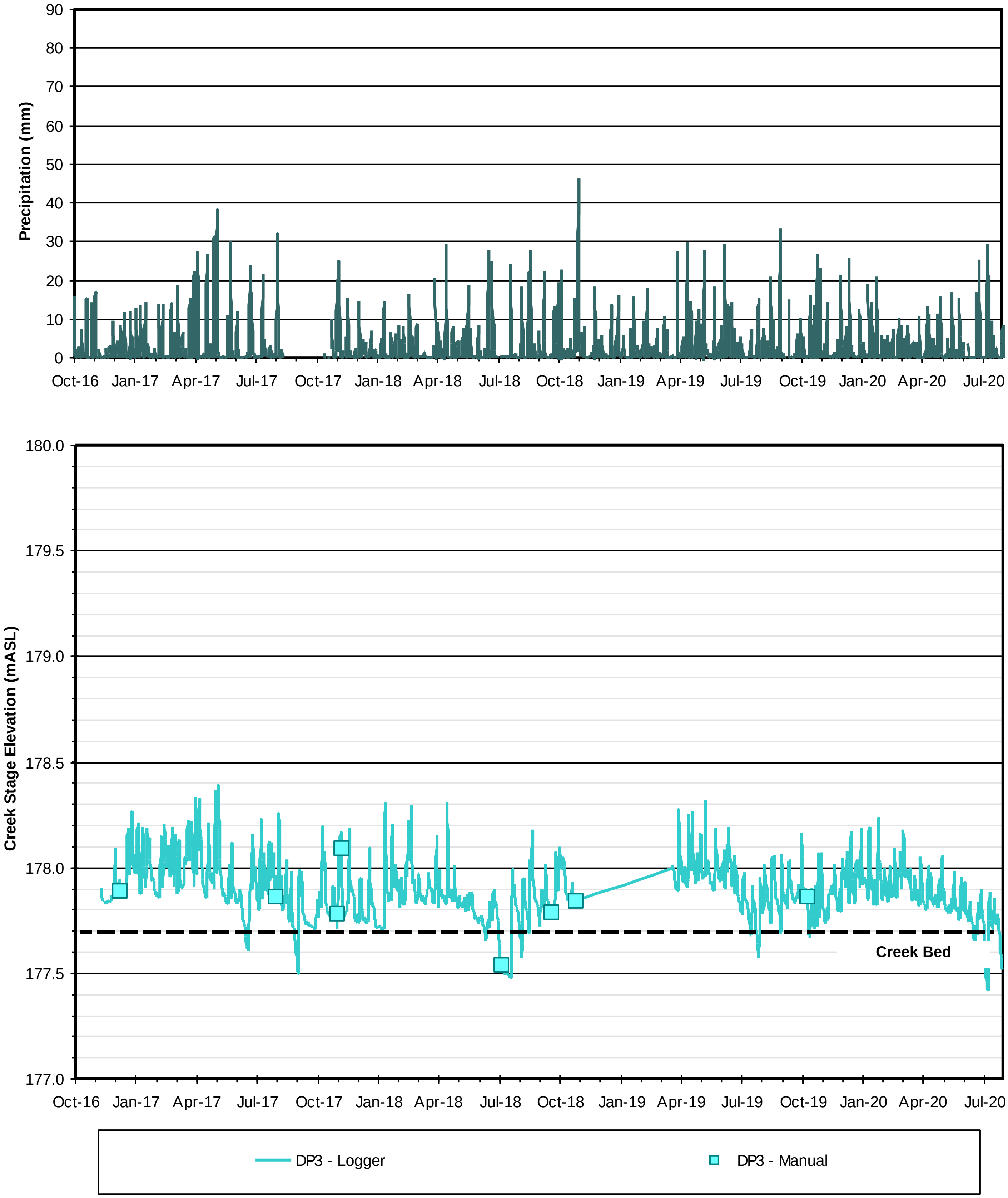


Figure E-36 - Hydrograph for Drivepoint DP4

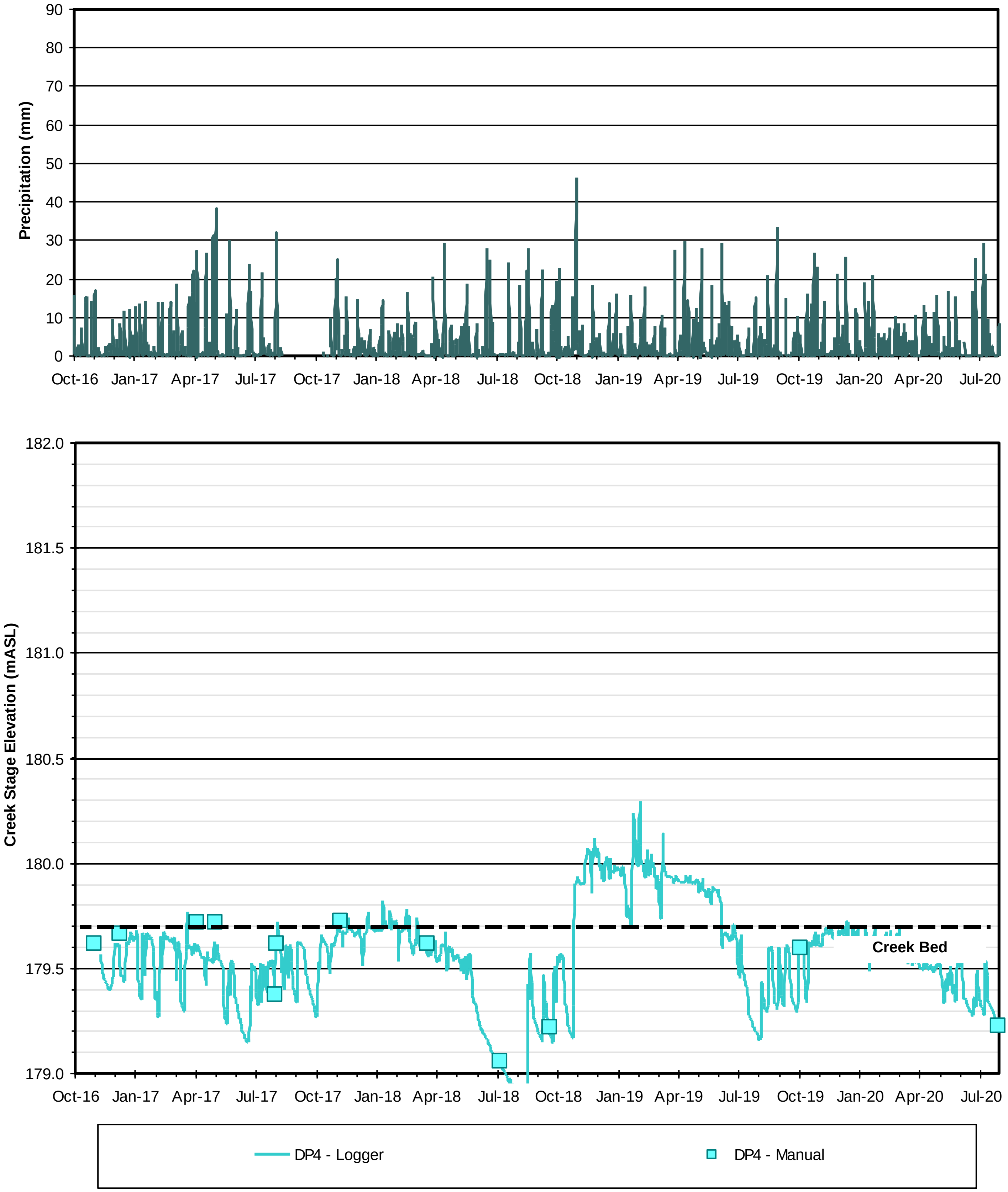
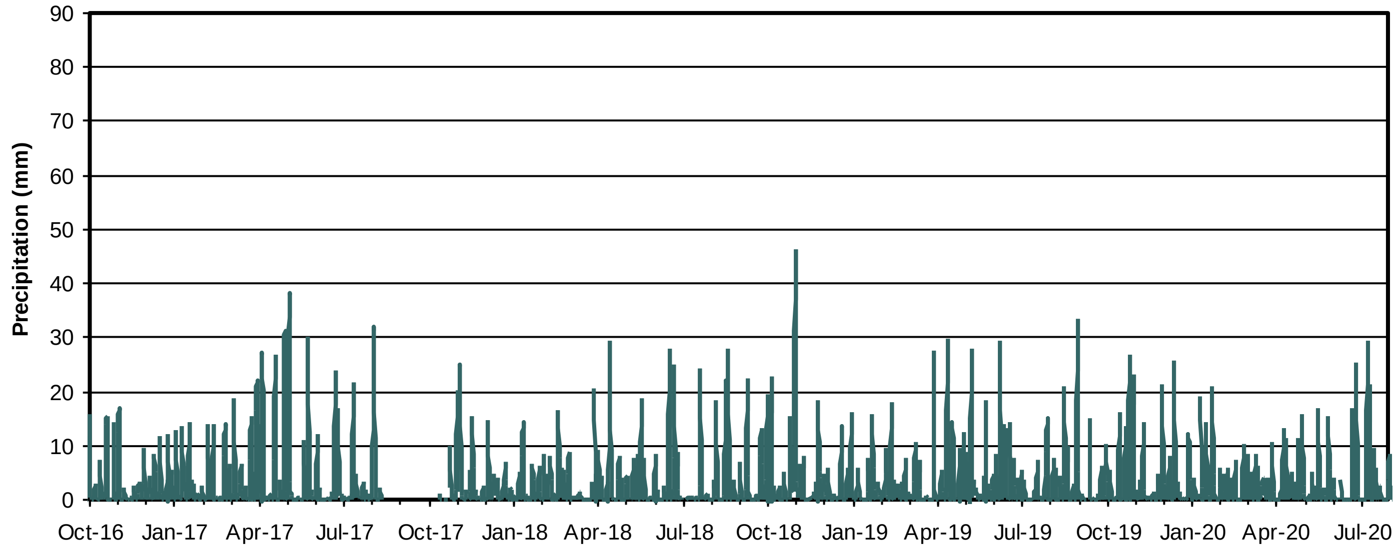


Figure E-37 - Hydrograph for Drivepoint DP5



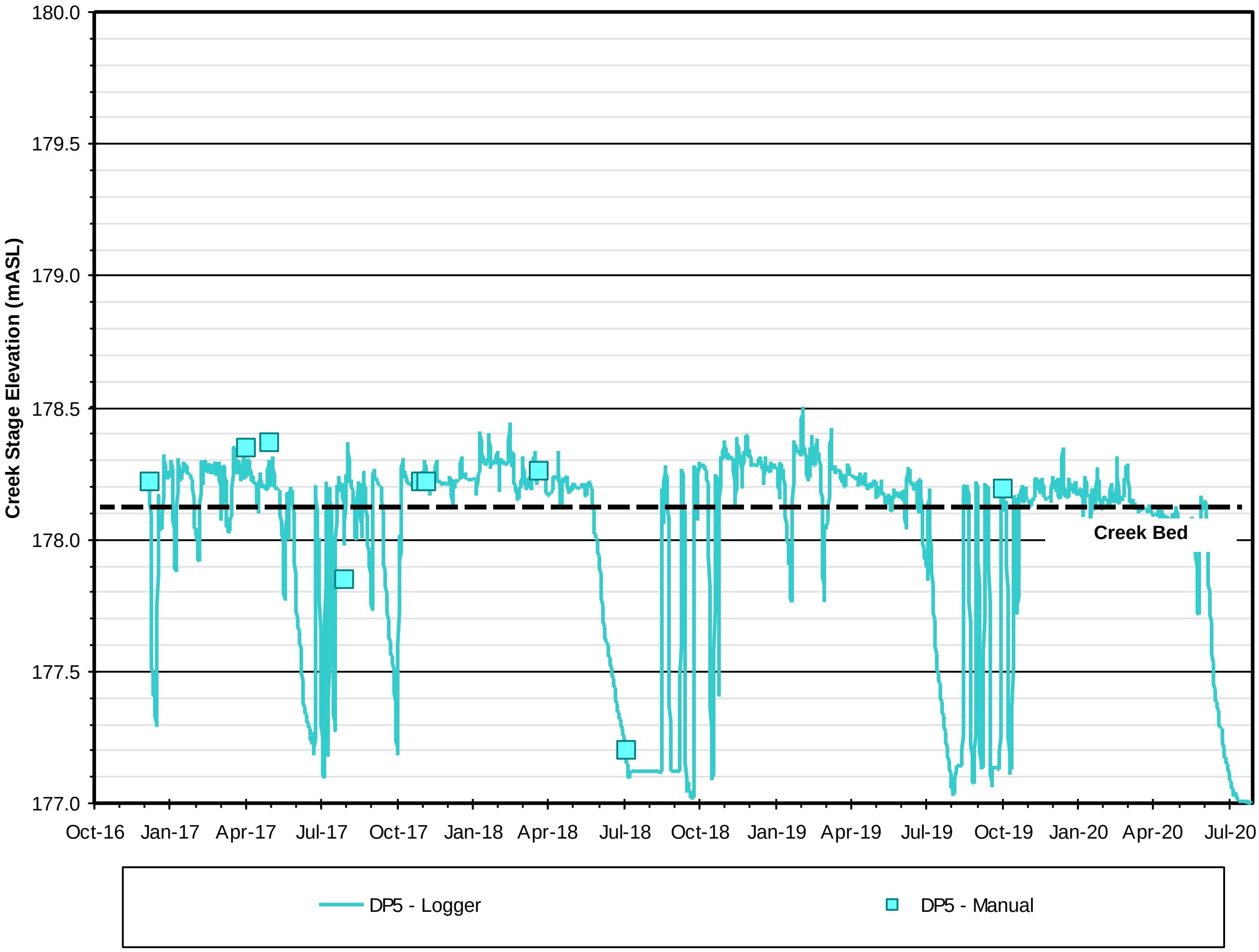
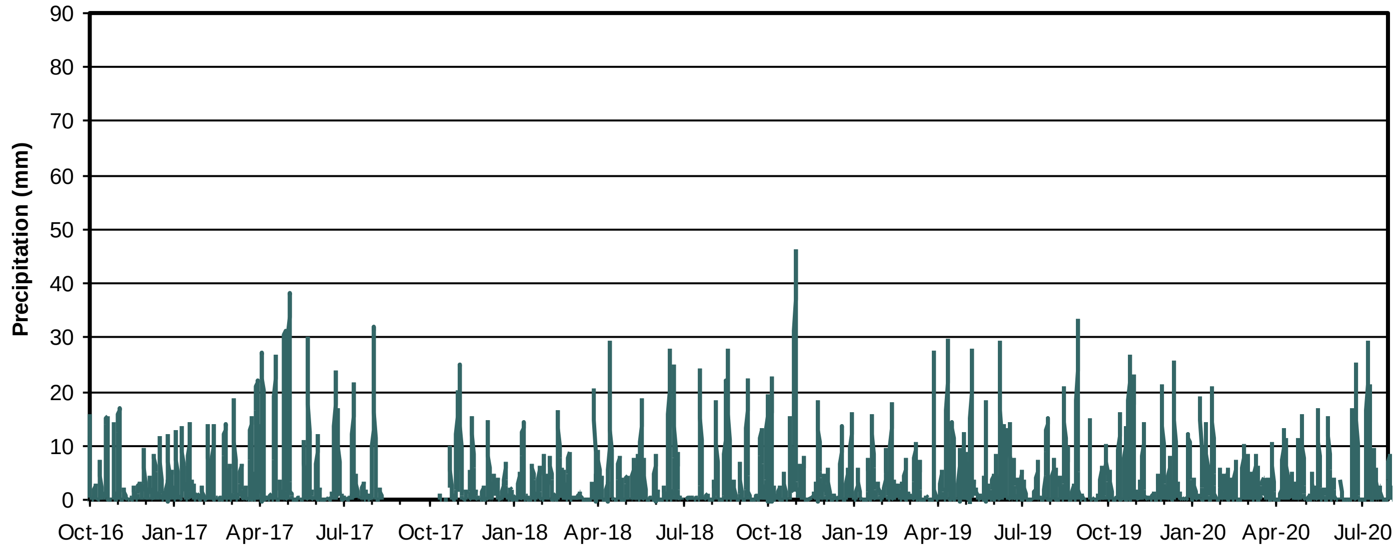


Figure E-38 - Hydrograph for Drivepoint DP6



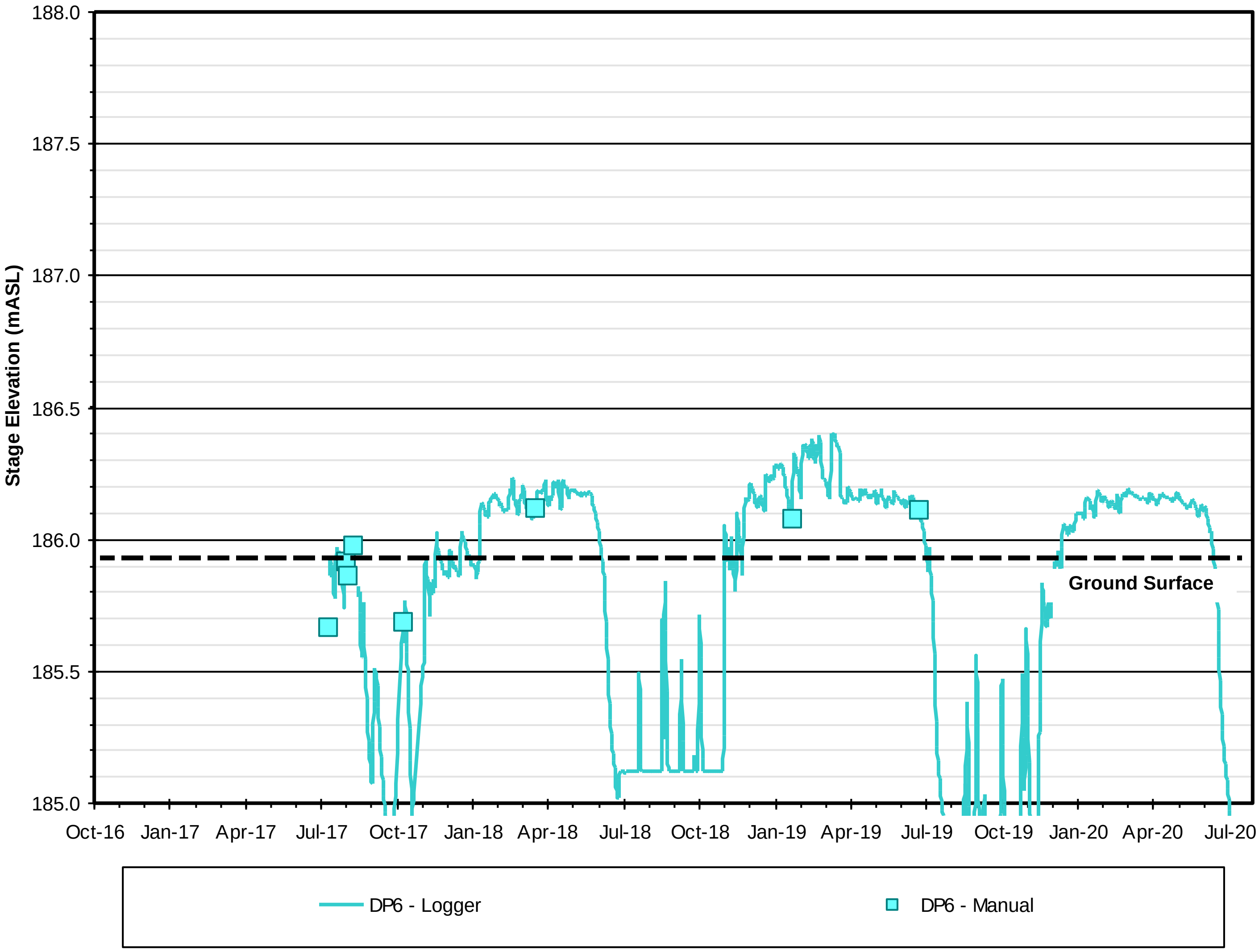
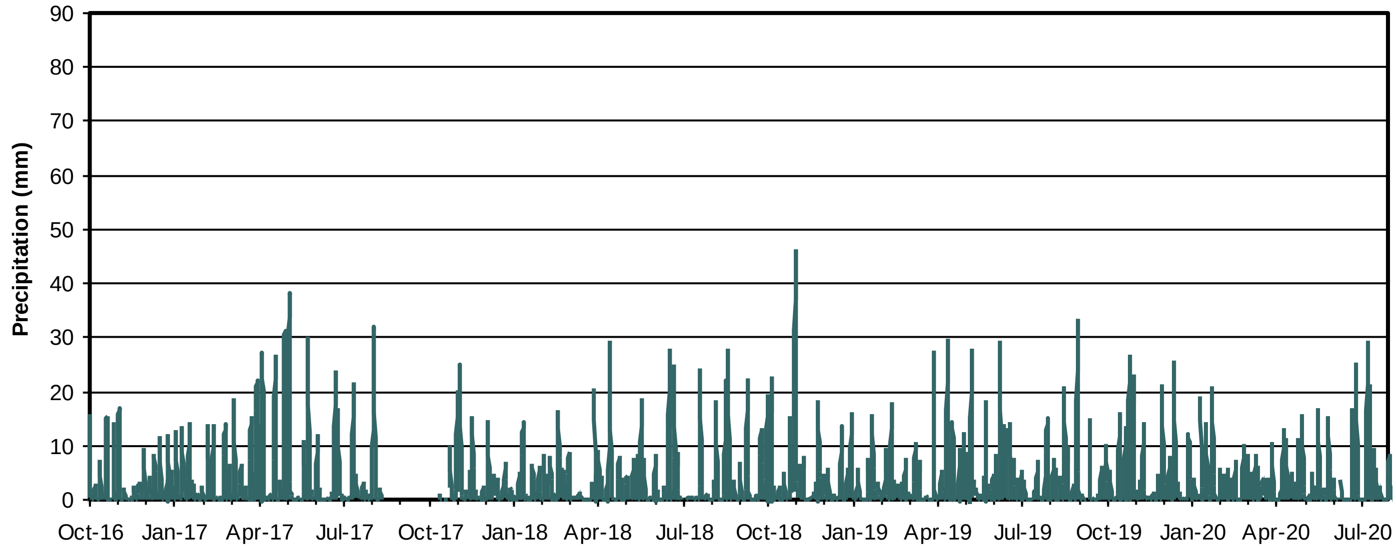


Figure E-39 - Hydrograph for Drivepoint DP7



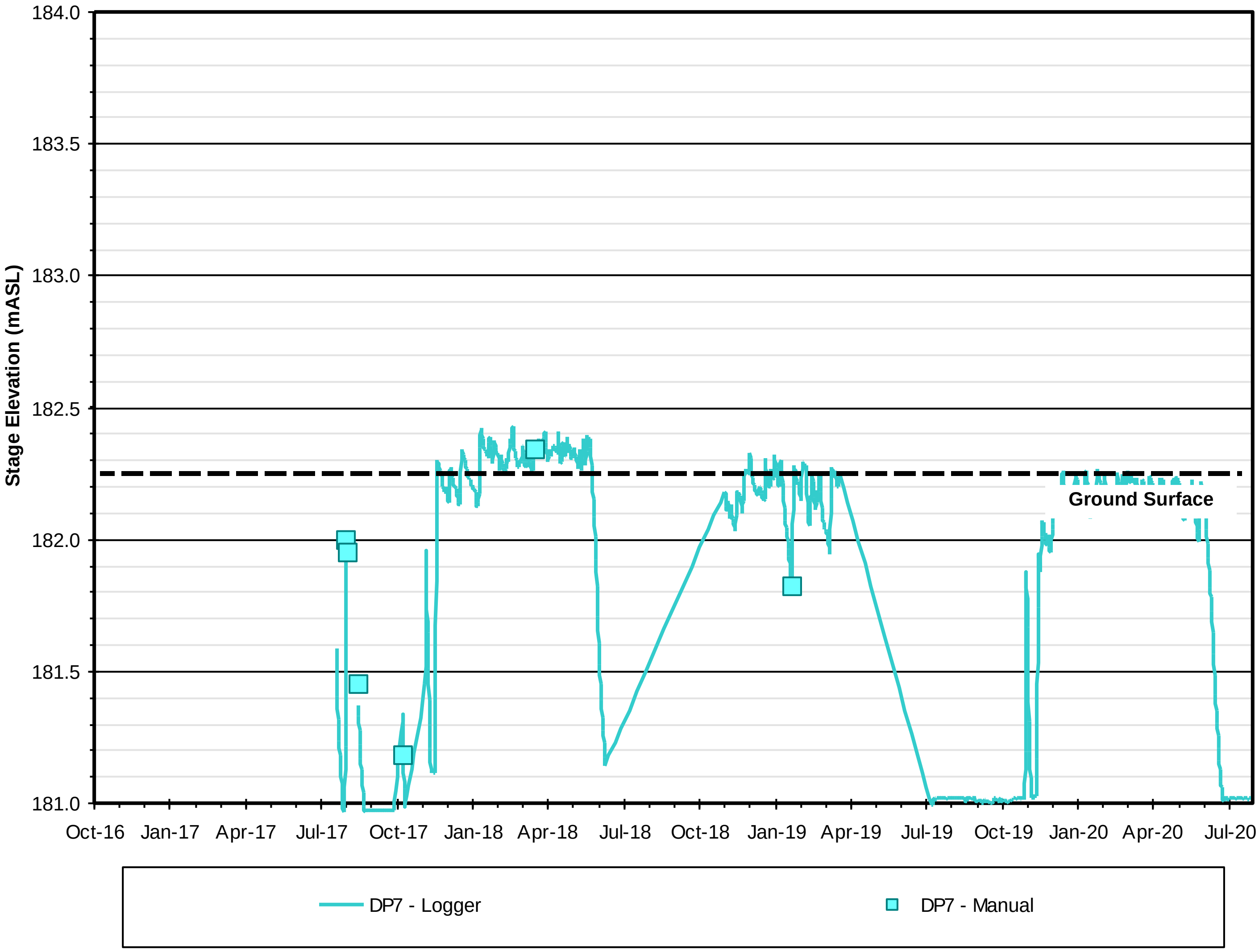
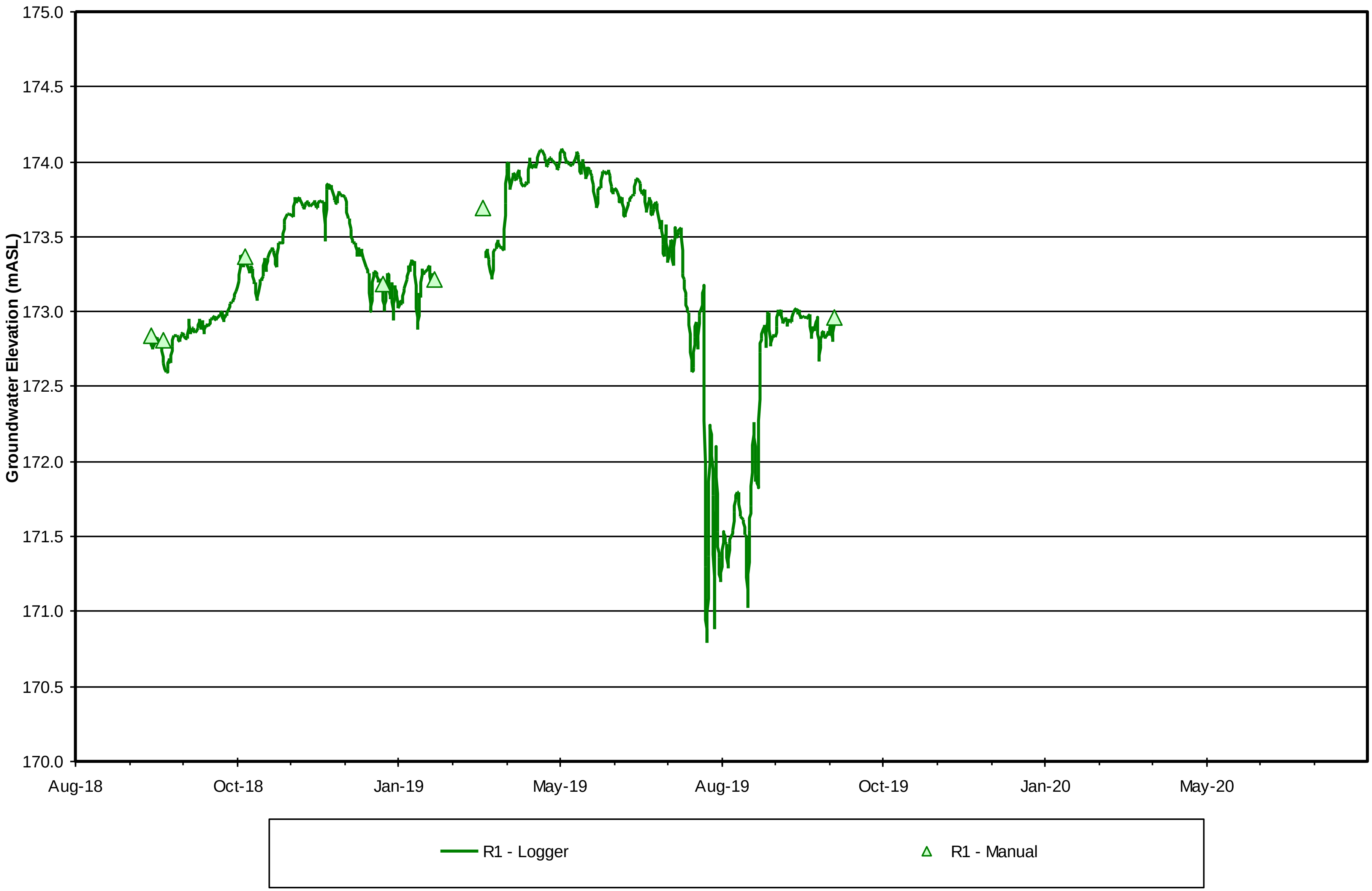
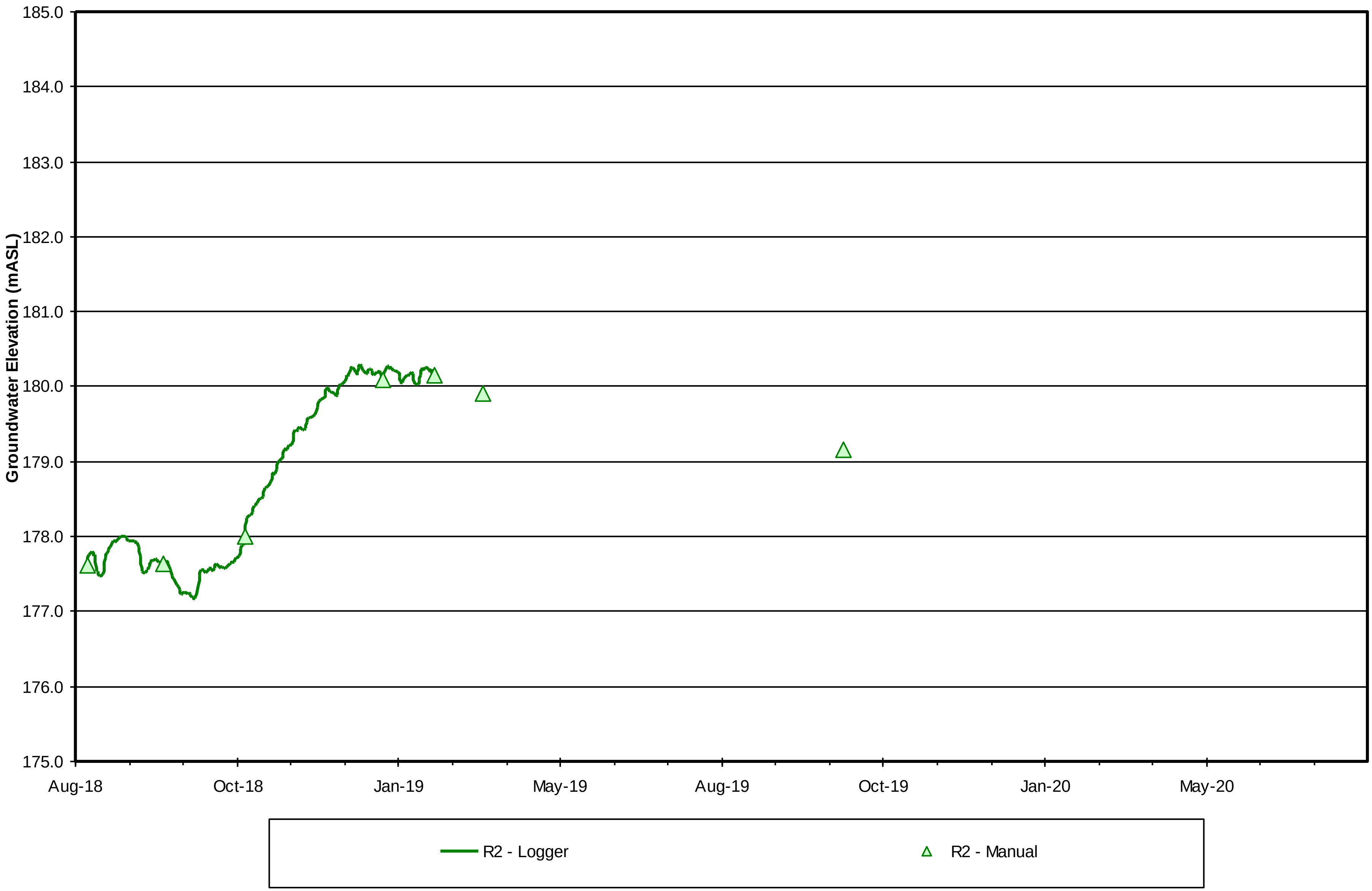


Figure E-40 - Hydrograph for R1 - 1024 Beaverdams Road



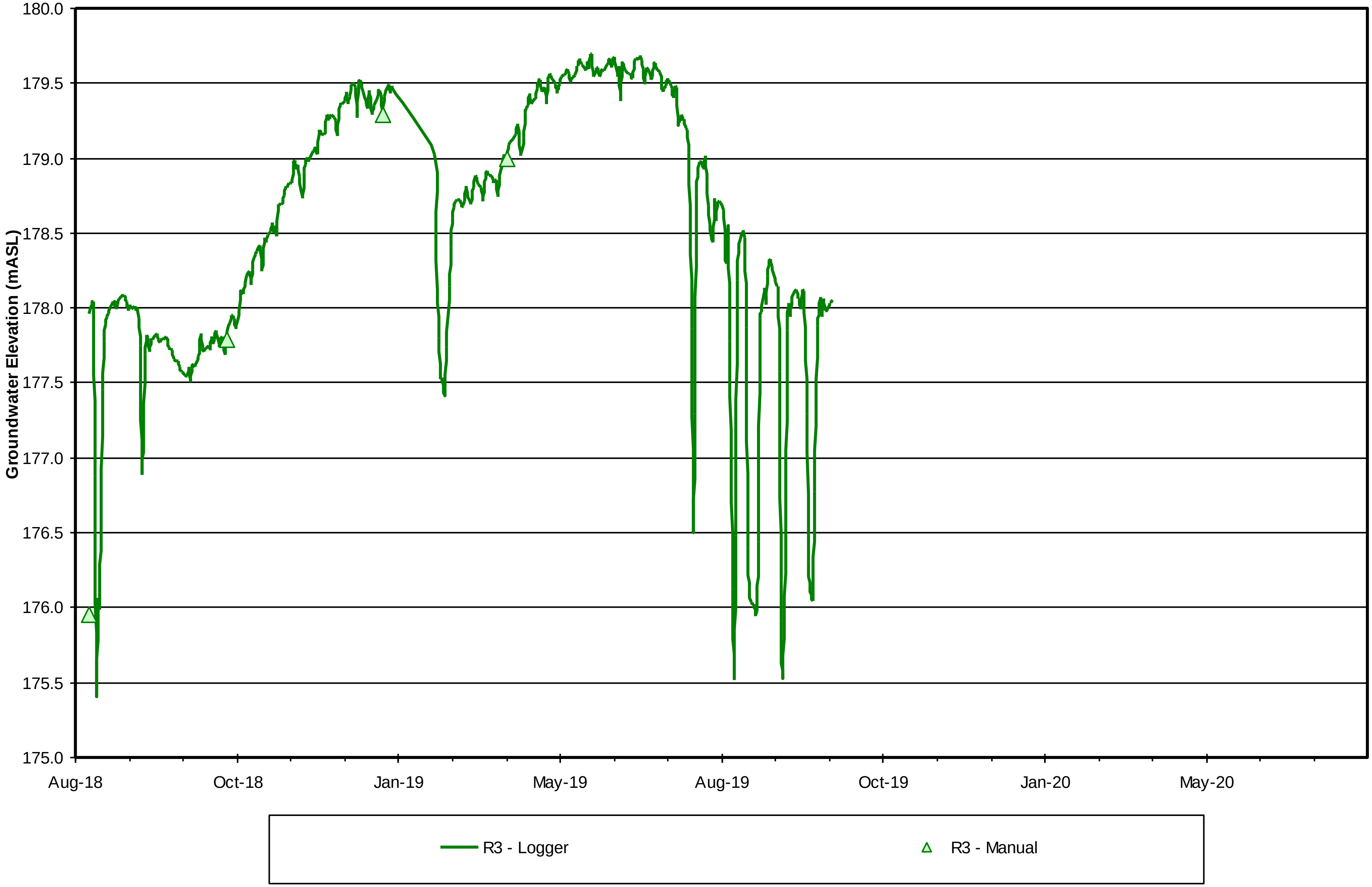
PROPOSED UPPER'S QUARRY
UPPERS_REPORTS.ACCDB

Figure E-41 - Hydrograph for R2 - 5769 Beechwood Road



PROPOSED UPPER'S QUARRY
UPPERS_REPORTS.ACCDB

Figure E-42 - Hydrograph for R3 - 10008 Lundys Lane



PROPOSED UPPER'S QUARRY
UPPERS_REPORTS.ACCDB

Figure E-43 - Hydrograph for R4 - 13011 Highway 20

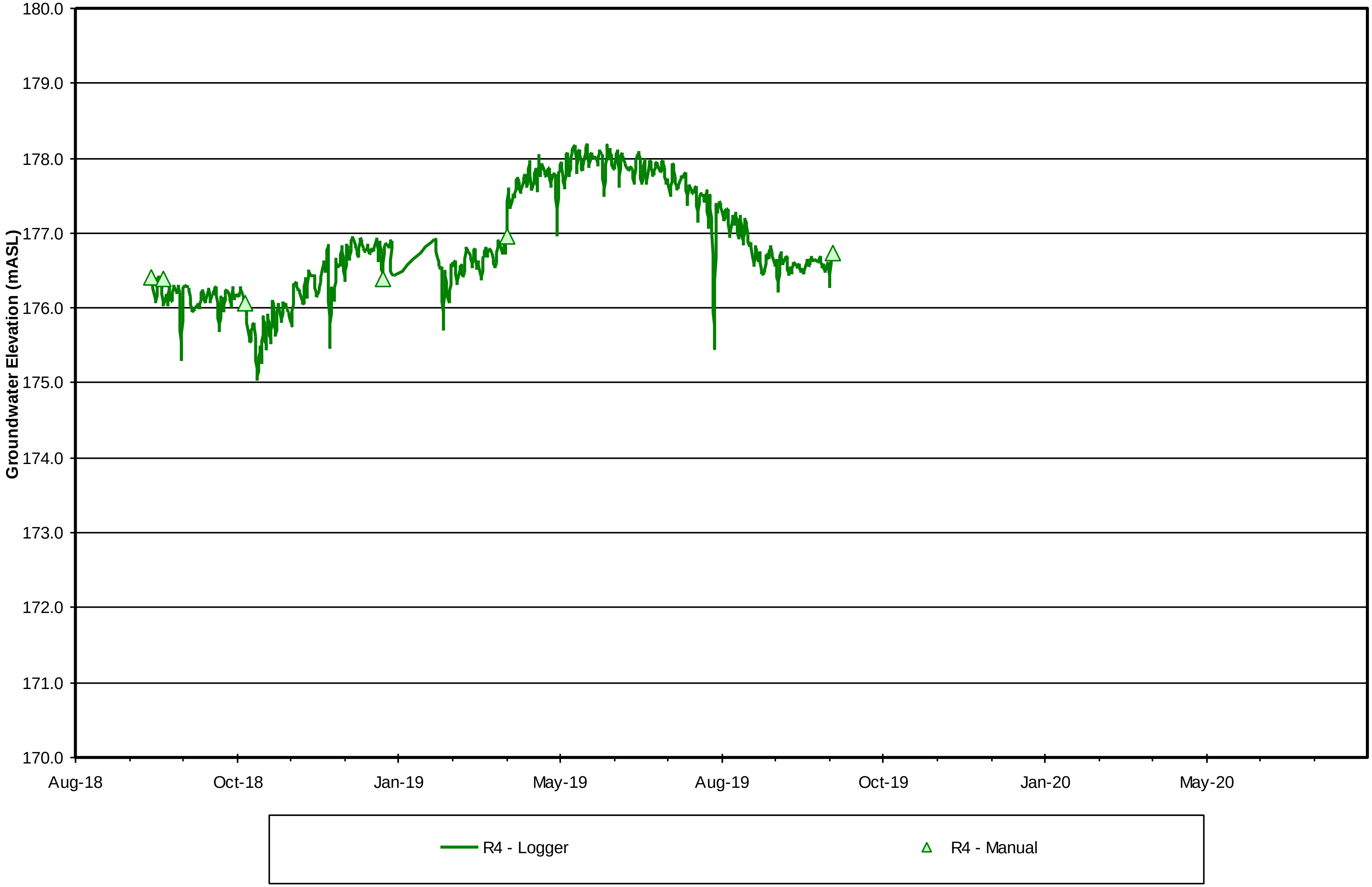


Figure E-44 - Hydrograph for R5 - 5114 Townline Road

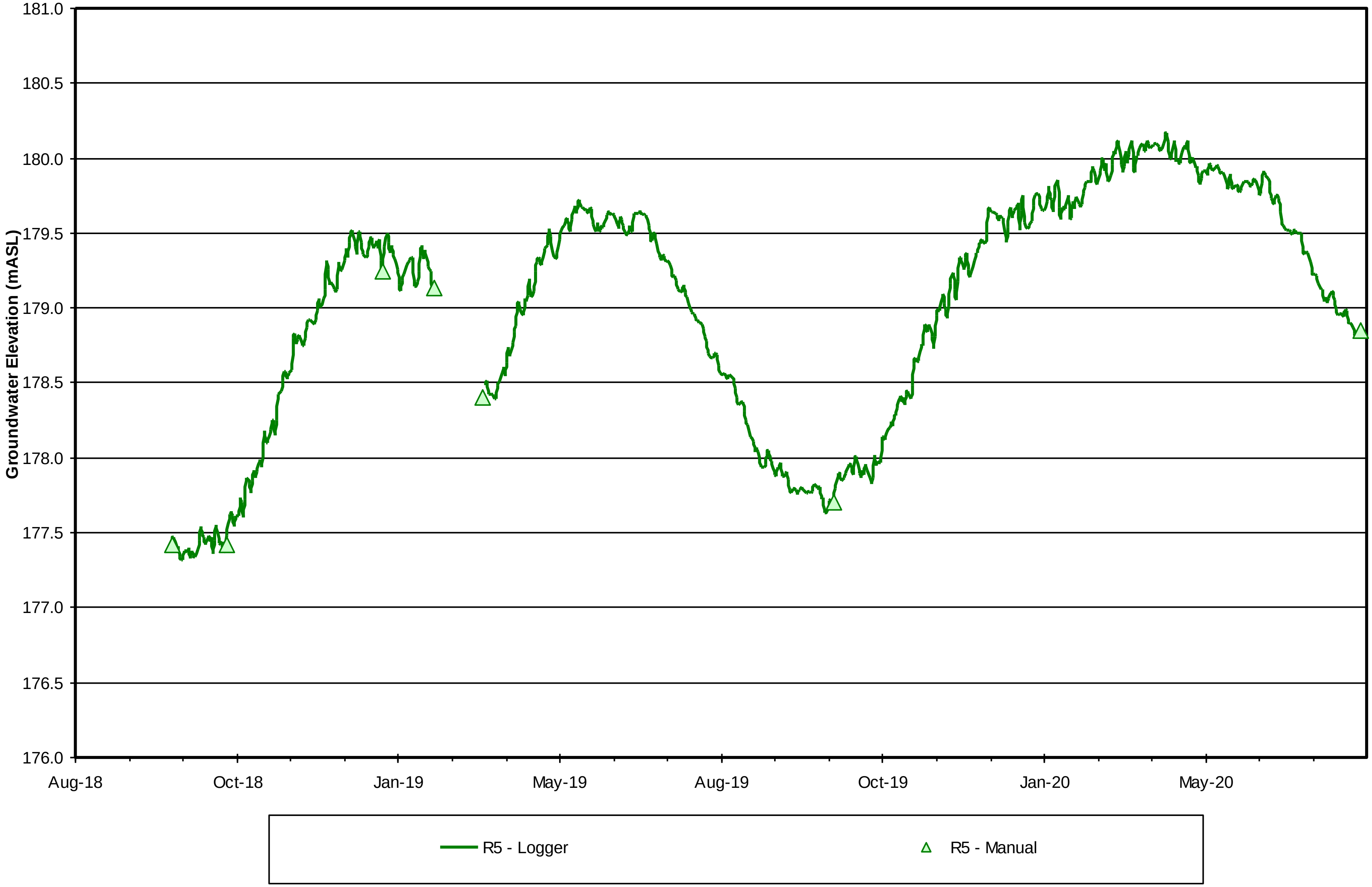


Figure E-45 - Hydrograph for R6 - 4680 Townline Road

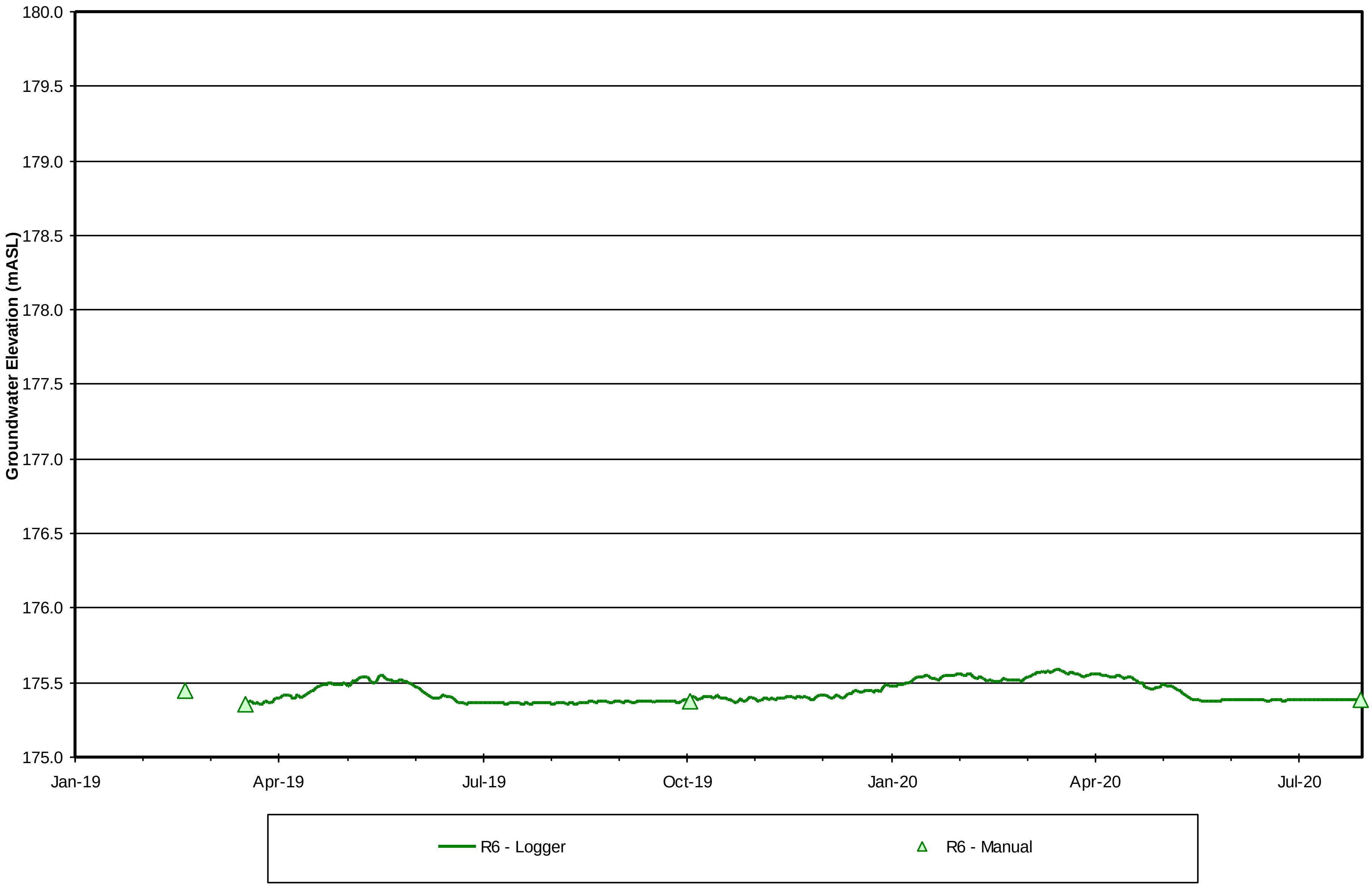


Figure E-46 - Hydrograph for R7 - 9602 Beaverdams Road

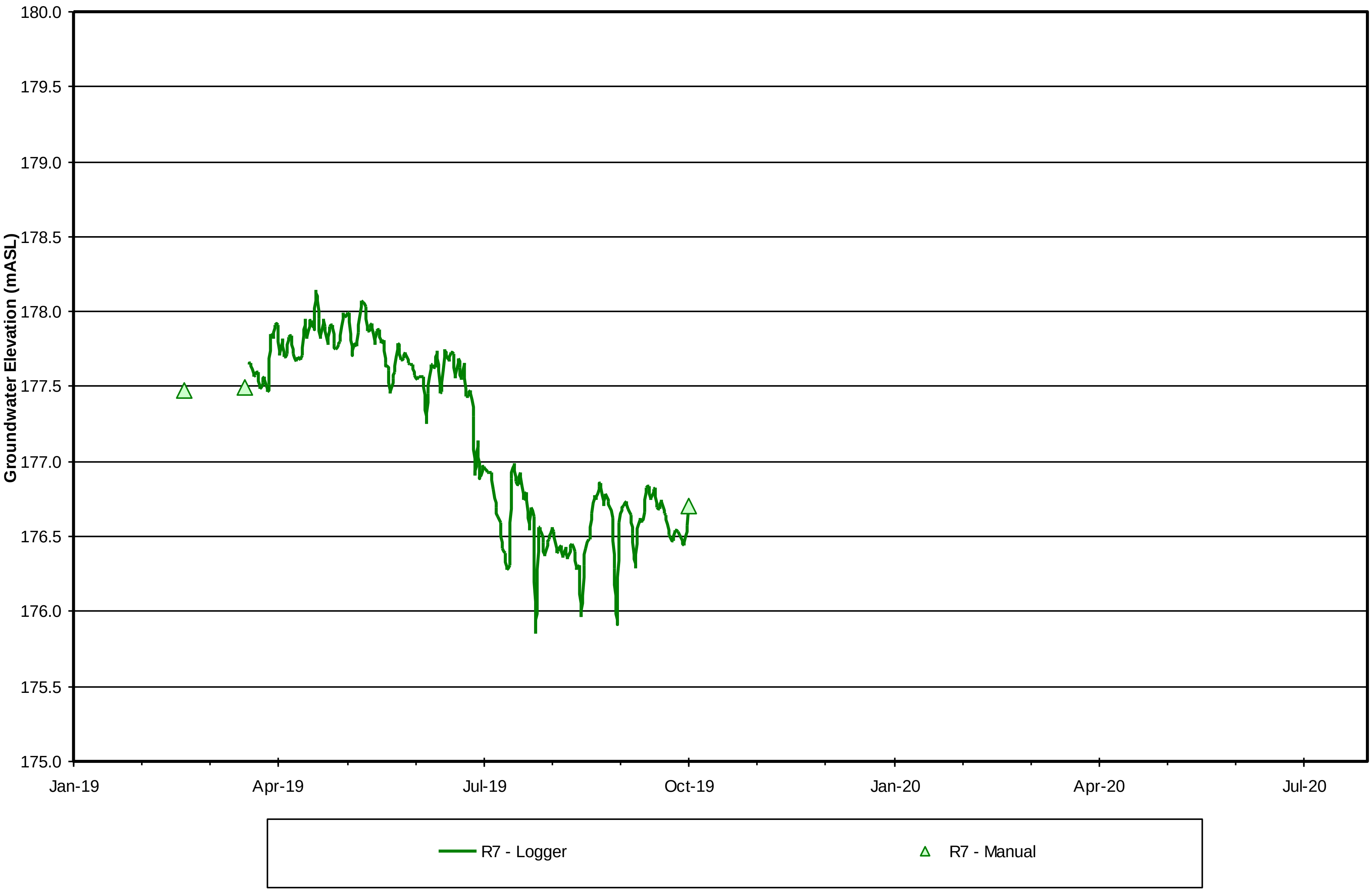


Figure E-47 - Hydrograph for R8 - 9914 Lundys Lane

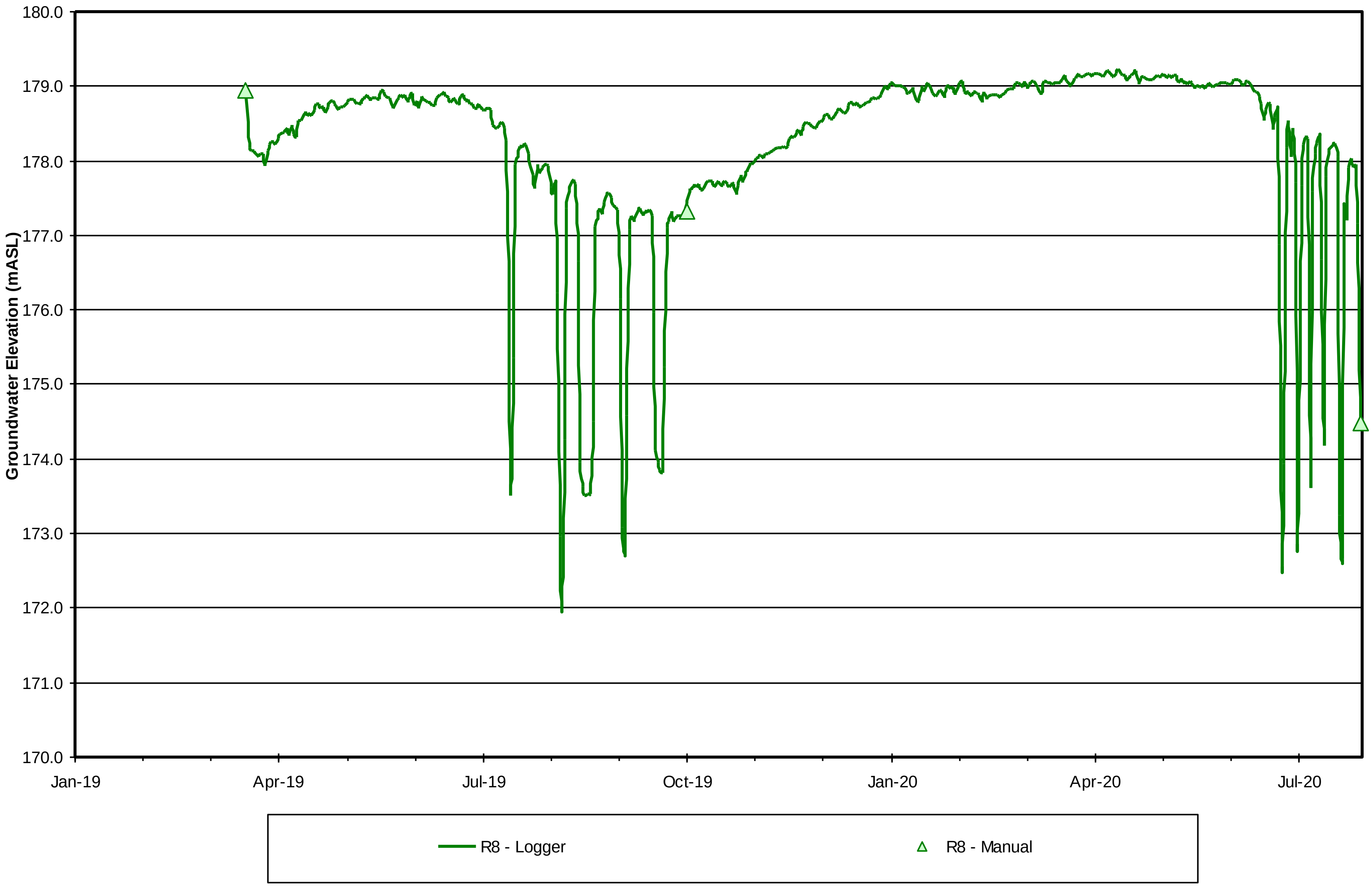
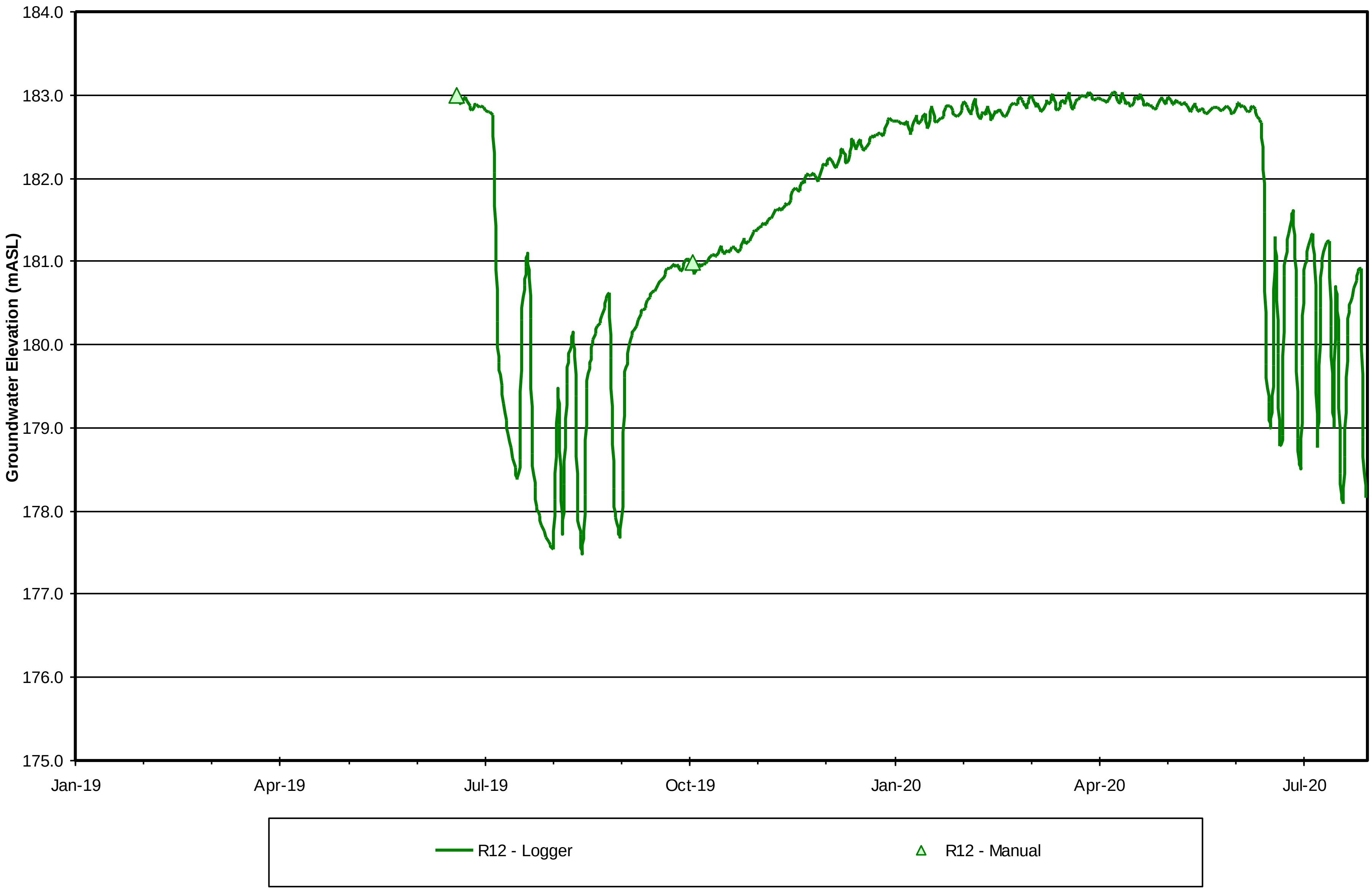


Figure E-48 - Hydrograph for R12 - 6169 Garner Road



PROPOSED UPPER'S QUARRY
UPPERS_REPORTS.ACCDB

Table E-1 Site Well Water Level Data Summary

Well ID	Ground Elevation	Measuring Point Elevation	Hydrostratigraphic Unit	Water Level Elevations				
				Fall		Spring		Water Level Used For Interpolation
	masl			masl	Date	masl	Date	masl
BH03-2B	184.33	184.98	Shallow Bedrock Aquifer	176.6	1-Oct-17	177.5	1-May-18	176.6
MW11-1B	181.04	181.95	Shallow Bedrock Aquifer	176.8	1-Oct-17	177.7	1-May-18	176.8
MW11-1OB	181.02	181.86	Contact Aquifer	179.3	1-Oct-17	180.5	1-May-18	179.3
MW11-2OB	184.22	185.13	Contact Aquifer	182.3	1-Oct-17	183.5	1-May-18	182.3
MW11-2B	184.22	185.06	Shallow Bedrock Aquifer	179.7	1-Oct-17	181.8	1-May-18	179.7
MW11-3BR	178.69	179.76	Shallow Bedrock Aquifer	176.5	1-Oct-17	177.7	1-May-18	176.5
MW11-3OBR	178.64	179.79	Contact Aquifer	176.6	1-Oct-17	177.9	1-May-18	176.6
MW11-4B	181.64	182.45	Shallow Bedrock Aquifer	175.5	1-Oct-17	176.0	1-May-18	175.5
MW11-4OB	181.63	182.56	Contact Aquifer	180.3	1-Oct-17	181.5	1-May-18	180.3
MW16-5B	179.58	180.65	Shallow Bedrock Aquifer	175.3	1-Oct-17	176.0	1-May-18	175.3
MW16-5OB	179.52	180.56	Contact Aquifer	177.4	1-Oct-17	178.4	1-May-18	177.4
MW16-6B	181.51	182.60	Shallow Bedrock Aquifer	179.4	1-Oct-17	180.6	1-May-18	179.4
MW16-6OB	181.56	182.68	Contact Aquifer	180.2	1-Oct-17	181.3	1-May-18	180.2
MW16-7B	180.36	181.34	Shallow Bedrock Aquifer	176.9	1-Oct-17	177.9	1-May-18	176.9
MW16-7OB	180.36	181.36	Contact Aquifer	177.1	1-Oct-17	179.9	1-May-18	177.1
MW16-8B	185.96	186.99	Shallow Bedrock Aquifer	178.3	1-Oct-17	179.3	1-May-18	178.3
MW16-8OB	185.97	186.87	Contact Aquifer	183.3	1-Oct-17	185.5	1-May-18	183.3
MW16-9B	182.06	183.15	Shallow Bedrock Aquifer	176.7	1-Oct-17	177.6	1-May-18	176.7
MW16-9OB	182.08	183.10	Contact Aquifer	177.8	1-Oct-17	179.6	1-May-18	177.8
MW16-10B	181.91	182.96	Shallow Bedrock Aquifer	176.4	1-Oct-17	177.4	1-May-18	176.4
MW16-10OB	181.80	182.96	Contact Aquifer	179.7	1-Oct-17	181.0	1-May-18	179.7
MW16-11	182.85	183.72	Contact Aquifer	179.5	1-Oct-17	181.8	1-May-18	179.5
MW16-12	183.64	184.75	Contact Aquifer	181.8	1-Oct-17	183.4	1-May-18	181.8
MW16-13B	185.23	186.18	Shallow Bedrock Aquifer	176.7	1-Oct-17	177.6	1-May-18	176.7
MW16-13OB	185.22	186.25	Contact Aquifer	182.6	1-Oct-17	184.5	1-May-18	182.6
MW16-14	184.00	184.99	Contact Aquifer	181.2	1-Oct-17	183.2	1-May-18	181.2
MW16-15	182.24	183.05	Contact Aquifer	178.5	1-Oct-17	180.0	1-May-18	178.5
MW16-16	178.78	179.71	Contact Aquifer	177.7	1-Oct-17	178.5	1-May-18	177.7

Notes: • Elevations provided in metres above sea level (masl)

Table E-1 Site Well Water Level Data Summary

Well ID	Ground Elevation	Measuring Point Elevation	Hydrostratigraphic Unit	Water Level Elevations				
				Fall		Spring		Water Level Used For Interpolation
	masl			masl	Date	masl	Date	masl
MW16-17	177.42	178.30	Contact Aquifer	176.5	1-Oct-17	177.0	1-May-18	176.5
MW16-18B	176.23	177.17	Shallow Bedrock Aquifer	176.1	1-Oct-17	176.4	1-May-18	176.1
MW16-18OB	176.36	177.24	Contact Aquifer	175.9	1-Oct-17	176.3	1-May-18	175.9
MW16-19B	176.39	177.45	Shallow Bedrock Aquifer	175.9	1-Oct-17	176.4	1-May-18	175.9
MW16-19OB	176.39	177.38	Contact Aquifer	175.4	1-Oct-17	176.1	1-May-18	175.4
MW17-20B	186.03	187.08	Shallow Bedrock Aquifer	180.4	1-Oct-17	182.9	1-May-18	180.4
MW17-20OB	186.02	187.22	Contact Aquifer			183.1	1-May-18	183.1
MW17-21B	185.69	186.67	Shallow Bedrock Aquifer	178.5	1-Oct-17	179.5	1-May-18	178.5
MW17-21OB	185.73	186.77	Contact Aquifer	183.3	1-Oct-17	185.2	1-May-18	183.3
MW17-22B	183.50	184.46	Shallow Bedrock Aquifer	176.7	1-Oct-17	177.6	1-May-18	176.7
MW17-22OB	183.49	184.53	Contact Aquifer	181.9	1-Oct-17	183.5	1-May-18	181.9
MW17-23B	181.89	182.99	Shallow Bedrock Aquifer	176.5	1-Oct-17	177.1	1-May-18	176.5
MW17-23OB	181.88	183.02	Contact Aquifer	177.7	1-Oct-17	179.2	1-May-18	177.7

Notes: • Elevations provided in metres above sea level (masl)

Table E-2 Other Site Well Water Level Data Summary

Site Name	Well ID	Ground Elevation	Measuring Point Elevation	Hydrostratigraphic Unit	Water Level Elevations				
					Fall		Spring		Water Level Used For Interpolation
		masl			masl	Date	masl	Date	masl
WAI Thorold Site	4-II	--	180.99	Shallow Bedrock Aquifer	169.1	3-Aug-17	169.4	1-Jun-17	169.1
	4-IV	--	181.06	Contact Aquifer	175.4	3-Aug-17	176.2	1-Jun-17	175.4
	19-IIIR	--	184.59	Shallow Bedrock Aquifer	173.5	7-Sep-17	173.5	1-Jun-17	173.5
	19-IVR	--	184.53	Contact Aquifer	179.7	7-Sep-17	181.3	1-Jun-17	179.7
	40-IIr	--	185.09	Shallow Bedrock Aquifer	170.4	7-Sep-17	170.5	1-Jun-17	170.4
	51-III	--	185.11	Shallow Bedrock Aquifer	180.6	1-Sep-17	181.3	1-Jun-17	180.6
	51-IV	--	185.28	Contact Aquifer	180.8	1-Sep-17	181.6	1-Jun-17	180.8
	55-III	--	178.43	Shallow Bedrock Aquifer	170.3	1-Sep-17	170.5	1-Jun-17	170.3
	55-IV	--	178.39	Contact Aquifer	171.2	1-Sep-17	173.1	1-Jun-17	171.2
Brown Road Landfill Site	BH1-I	181.07	181.73	Shallow Bedrock Aquifer	176.3	18-Sep-84			176.3
	BH1-II	181.07	181.72	Contact Aquifer	176.6	18-Sep-84			176.6
	BH2-I	180.16	180.73	Shallow Bedrock Aquifer	175.9	18-Sep-84			175.9
	BH2-II	180.16	180.83	Contact Aquifer	176.7	18-Sep-84			176.7
	BH3-I	178.56	179.18	Shallow Bedrock Aquifer	175.6	18-Sep-84			175.6
	BH3-II	178.56	179.12	Contact Aquifer	175.9	18-Sep-84			175.9
	BH4-I	176.62	177.26	Shallow Bedrock Aquifer	174.4	18-Sep-84			174.4
	BH4-II	176.62	177.21	Contact Aquifer	173.5	19-Oct-84			173.5
	BH5-I	175.95	176.44	Shallow Bedrock Aquifer	174.1	18-Sep-84			174.1
	BH5-II	176.31	176.93	Contact Aquifer	174.0	18-Sep-84			174.0
Thorold Co-Gen Plant	BH6	176.52	--	Contact Aquifer			167.4	11-May-06	167.4
	BH14	179.60	--	Contact Aquifer			164.5	9-May-06	164.5
	BH19	178.13	--	Contact Aquifer			171.4	4-May-06	171.4
Recycling Centre	CRA-11D-09	193.60	193.46	Shallow Bedrock Aquifer	184.9	10-Oct-14	185.7	14-Apr-14	184.9
	IW6	193.16	194.18	Shallow Bedrock Aquifer	184.2	10-Oct-14	185.5	14-Apr-14	184.2
	OW13S	193.12	193.98	Contact Aquifer	185.8	10-Oct-14	187.4	14-Apr-14	185.8
	OW13D	193.07	193.85	Shallow Bedrock Aquifer	184.5	10-Oct-14	186.0	14-Apr-14	184.5

Notes: • Elevations provided in metres above sea level (masl)

Table E-2 Other Site Well Water Level Data Summary

Site Name	Well ID	Ground Elevation	Measuring Point Elevation	Hydrostratigraphic Unit	Water Level Elevations				
					Fall		Spring		Water Level Used For Interpolation
		masl			masl	Date	masl	Date	masl
Mountain Road Landfill Site	OW10(5)r	--	196.59	Contact Aquifer	188.8	14-Oct-16	192.4	9-Apr-18	188.8
	OW30(20)	--	202.88	Contact Aquifer	193.4	14-Oct-16	195.1	9-Apr-18	193.4
	OW54(23)	195.42	196.42	Shallow Bedrock Aquifer			180.4	9-Apr-18	180.4
	CMT3-3(28)	202.00	202.71		182.5	14-Oct-16			182.5
	CMT5-2(7)	174.30	175.04		168.9	14-Oct-16			168.9

Notes: • Elevations provided in metres above sea level (masl)

Table E-3 MECP Water Well Record Water Level Data Summary

Water Well Record No.		Interpolated Ground Elevation	Hydrostratigraphic Unit	Water Level Elevation		
				Static		Water Level Used For Interpolation
		masl		mbgs	Date	masl
1.	6601745	190.5	Contact Aquifer	6.1	8-Aug-52	184.4
2.	6601272	184.5	Contact Aquifer	3.0	15-May-59	181.5
3.	6601785	191.2	Contact Aquifer	9.1	5-Aug-60	182.1
4.	6601781	185.2	Contact Aquifer	7.0	22-Jul-63	178.2
5.	6602725	191.2	Contact Aquifer	5.5	19-Oct-72	185.7
6.	6603214	185.1	Contact Aquifer	4.9	8-Apr-77	180.2
7.	6603302	195.9	Contact Aquifer	4.9	15-Jun-78	191.0
8.	6603353	194.3	Contact Aquifer	13.4	15-Jul-78	180.9
9.	6603308	181.7	Contact Aquifer	4.0	12-Oct-78	177.7
10.	6603400	189.2	Contact Aquifer	4.3	16-Oct-78	184.9
11.	6603382	193.3	Contact Aquifer	7.3	1-Jan-79	186.0
12.	6603324	190.6	Contact Aquifer	10.7	31-Jan-79	179.9
13.	6603342	189.0	Contact Aquifer	3.0	14-May-79	186.0
14.	6603343	179.6	Contact Aquifer	4.9	2-Jun-79	174.7
15.	6603359	186.2	Contact Aquifer	2.1	6-Jun-79	184.1
16.	6603500	190.1	Contact Aquifer	5.5	15-Sep-81	184.6
17.	6603548	186.4	Contact Aquifer	9.8	18-Jan-82	176.6
18.	6604682	185.4	Contact Aquifer	7.6	4-Oct-02	177.8
19.	6604887	194.7	Contact Aquifer	11.3	25-Jul-05	183.4
20.	7048238	192.1	Contact Aquifer	4.9	19-Jul-07	187.2
21.	7128689	186.2	Contact Aquifer	3.6	14-Jan-08	182.6
22.	7105003	191.1	Contact Aquifer	7.3	4-Feb-08	183.8
23.	7105003	187.3	Contact Aquifer	8.2	5-Feb-08	179.1
24.	7105003	193.5	Contact Aquifer	7.9	7-Feb-08	185.6
25.	7105003	185.8	Contact Aquifer	7.3	8-Feb-08	178.5
26.	7105003	182.4	Contact Aquifer	6.0	11-Feb-08	176.4
27.	7105003	178.8	Contact Aquifer	2.1	14-Feb-08	176.7
28.	7126689	182.7	Contact Aquifer	2.4	1-Jan-09	180.3
29.	7126686	190.5	Contact Aquifer	6.4	26-Jun-09	184.1
30.	7135500	179.8	Contact Aquifer	5.1	10-Aug-09	174.7
31.	7135500	184.8	Contact Aquifer	5.1	10-Aug-09	179.7
32.	7135500	182.7	Contact Aquifer	5.1	11-Aug-09	177.6
33.	7133671	184.4	Contact Aquifer	5.3	17-Oct-09	179.1
34.	7184710	202.2	Contact Aquifer	7.0	20-Jul-12	195.2
35.	7203341	185.9	Contact Aquifer	1.6	2-Jun-13	184.3
36.	7206054	195.6	Contact Aquifer	13.1	31-Jul-13	182.5
37.	7209819	199.8	Contact Aquifer	6.3	1-Oct-13	193.5
38.	7226549	185.6	Contact Aquifer	8.4	18-Aug-14	177.2
39.	7251281	189.0	Contact Aquifer	4.6	20-Mar-15	184.4

Notes: • Elevations provided in metres above sea level (masl)

Table E-3 MECP Water Well Record Water Level Data Summary

Water Well Record No.		Interpolated Ground Elevation	Hydrostratigraphic Unit	Water Level Elevation		
				Static		Water Level Used For Interpolation
		masl		mbgs	Date	masl
40.	7245973	207.4	Contact Aquifer	7.0	21-Jul-15	200.4
41.	7248844	182.4	Contact Aquifer	6.1	15-Aug-15	176.3
42.	7258351	204.4	Contact Aquifer	5.0	15-Feb-16	199.4
43.	7278404	189.3	Contact Aquifer	5.0	27-Sep-16	184.3
44.	7277452	203.3	Contact Aquifer	8.9	26-Oct-16	194.4
45.	7279902	189.2	Contact Aquifer	8.1	17-Nov-16	181.1

Notes: • Elevations provided in metres above sea level (masl)

Table E-3 MECP Water Well Record Water Level Data Summary

Water Well Record No.		Interpolated Ground Elevation	Hydrostratigraphic Unit	Water Level Elevation		
				Static		Water Level Used For Interpolation
		masl		mbgs	Date	masl
1.	6601729	187.1	Shallow Bedrock Aquifer	14.6	16-Sep-48	181.0
2.	6601628	180.2	Shallow Bedrock Aquifer	15.2	8-Jul-50	177.2
3.	6601764	182.7	Shallow Bedrock Aquifer	10.7	4-Sep-51	178.1
4.	6601739	181.3	Shallow Bedrock Aquifer	12.2	6-Sep-51	176.7
5.	6601765	180.4	Shallow Bedrock Aquifer	14.0	24-Jan-52	177.4
6.	6601746	183.1	Shallow Bedrock Aquifer	14.6	16-Aug-52	177.6
7.	6601725	195.4	Shallow Bedrock Aquifer	19.5	30-Aug-52	184.7
8.	6601726	195.8	Shallow Bedrock Aquifer	19.5	3-Sep-52	185.1
9.	6601732	187.2	Shallow Bedrock Aquifer	15.2	25-Oct-52	180.2
10.	6601749	180.7	Shallow Bedrock Aquifer	12.5	23-Sep-53	176.7
11.	6601750	183.5	Shallow Bedrock Aquifer	13.1	28-Sep-53	178.3
12.	6601751	176.2	Shallow Bedrock Aquifer	10.4	16-Jun-54	174.7
13.	6601733	182.4	Shallow Bedrock Aquifer	14.3	30-Jul-54	177.8
14.	6601727	190.1	Shallow Bedrock Aquifer	15.2	2-Apr-56	181.0
15.	6601734	185.6	Shallow Bedrock Aquifer	14.6	17-Jul-56	180.1
16.	6601753	190.4	Shallow Bedrock Aquifer	14.0	27-Oct-56	181.9
17.	6601735	194.6	Shallow Bedrock Aquifer	21.9	25-Jun-57	185.5
18.	6601794	196.5	Shallow Bedrock Aquifer	20.1	10-Jul-57	185.8
19.	6601755	188.8	Shallow Bedrock Aquifer	13.1	28-Nov-57	178.1
20.	6601756	189.7	Shallow Bedrock Aquifer	13.1	29-Nov-57	179.0
21.	6601728	187.1	Shallow Bedrock Aquifer	11.0	21-Apr-58	176.4
22.	6601766	184.5	Shallow Bedrock Aquifer	12.2	26-Apr-58	177.8
23.	6601280	199.7	Shallow Bedrock Aquifer	14.3	16-May-58	194.8
24.	6601279	198.0	Shallow Bedrock Aquifer	11.3	1-Jun-58	195.0
25.	6600622	181.6	Shallow Bedrock Aquifer	25.6	9-Jul-58	178.6
26.	6600623	179.7	Shallow Bedrock Aquifer	26.5	12-Jul-58	176.7
27.	6601723	190.6	Shallow Bedrock Aquifer	14.3	30-Jan-59	182.4
28.	6601724	190.5	Shallow Bedrock Aquifer	8.5	11-Mar-59	182.6
29.	6601290	188.1	Shallow Bedrock Aquifer	7.3	23-Mar-59	184.4
30.	6601291	187.3	Shallow Bedrock Aquifer	7.9	2-Jun-59	184.3
31.	6601400	181.6	Shallow Bedrock Aquifer	21.3	23-Jun-59	175.5
32.	6601401	180.9	Shallow Bedrock Aquifer	18.6	14-Jul-59	176.6
33.	6601323	192.7	Shallow Bedrock Aquifer	8.8	18-Aug-59	186.3
34.	6601351	184.2	Shallow Bedrock Aquifer	5.8	22-Aug-59	178.1
35.	6601402	180.0	Shallow Bedrock Aquifer	18.9	22-Mar-60	176.3
36.	6601274	186.3	Shallow Bedrock Aquifer	9.8	5-May-60	184.8
37.	6601304	182.4	Shallow Bedrock Aquifer	8.5	2-Jun-60	181.8
38.	6601625	190.5	Shallow Bedrock Aquifer	9.8	28-Jun-60	180.4
39.	6601394	176.6	Shallow Bedrock Aquifer	21.9	30-Jun-60	174.8

Notes: • Elevations provided in metres above sea level (masl)

Table E-3 MECP Water Well Record Water Level Data Summary

Water Well Record No.		Interpolated Ground Elevation	Hydrostratigraphic Unit	Water Level Elevation		
				Static		Water Level Used For Interpolation
		masl		mbgs	Date	masl
40.	6601848	182.7	Shallow Bedrock Aquifer	25.3	19-Aug-60	178.7
41.	6601277	203.7	Shallow Bedrock Aquifer	16.8	27-Aug-60	195.2
42.	6601267	190.5	Shallow Bedrock Aquifer	10.4	14-Nov-60	185.6
43.	6601269	189.6	Shallow Bedrock Aquifer	8.5	13-Feb-61	184.1
44.	6601281	186.2	Shallow Bedrock Aquifer	7.3	12-May-61	184.4
45.	6601718	191.9	Shallow Bedrock Aquifer	9.1	24-May-61	183.4
46.	6601256	213.5	Shallow Bedrock Aquifer	24.7	19-Jun-61	198.9
47.	6601312	185.6	Shallow Bedrock Aquifer	7.3	23-Jun-61	183.8
48.	6601786	198.6	Shallow Bedrock Aquifer	16.8	23-Jun-61	186.4
49.	6601364	197.5	Shallow Bedrock Aquifer	10.1	25-Jul-61	185.9
50.	6601365	197.9	Shallow Bedrock Aquifer	15.8	25-Aug-61	187.2
51.	6601795	191.8	Shallow Bedrock Aquifer	16.8	29-Aug-61	185.1
52.	6601367	195.4	Shallow Bedrock Aquifer	14.3	30-Sep-61	184.7
53.	6601336	189.6	Shallow Bedrock Aquifer	12.2	7-Oct-61	184.4
54.	6601268	191.8	Shallow Bedrock Aquifer	12.2	1-Mar-62	185.7
55.	6601385	185.8	Shallow Bedrock Aquifer	15.8	28-Mar-62	179.4
56.	6601340	206.6	Shallow Bedrock Aquifer	11.6	28-Apr-62	194.4
57.	6601257	217.6	Shallow Bedrock Aquifer	24.1	31-May-62	199.3
58.	6601382	194.6	Shallow Bedrock Aquifer	14.6	19-Jun-62	183.3
59.	6601779	189.9	Shallow Bedrock Aquifer	15.2	10-Aug-62	180.8
60.	6601261	213.8	Shallow Bedrock Aquifer	16.2	22-Aug-62	200.4
61.	6601760	184.6	Shallow Bedrock Aquifer	13.1	30-Nov-62	179.1
62.	6601354	182.6	Shallow Bedrock Aquifer	4.9	6-Apr-63	177.7
63.	6601352	183.7	Shallow Bedrock Aquifer	7.0	8-Apr-63	179.1
64.	6601353	186.7	Shallow Bedrock Aquifer	4.9	10-Apr-63	181.2
65.	6601626	210.3	Shallow Bedrock Aquifer	10.4	19-Apr-63	182.6
66.	6601226	182.4	Shallow Bedrock Aquifer	18.6	13-May-63	176.9
67.	6601370	196.5	Shallow Bedrock Aquifer	9.1	16-May-63	185.2
68.	6601227	196.3	Shallow Bedrock Aquifer	8.2	4-Jun-63	192.9
69.	6601780	198.3	Shallow Bedrock Aquifer	13.4	10-Jul-63	185.5
70.	6601792	197.6	Shallow Bedrock Aquifer	20.4	31-Jul-63	182.4
71.	6601283	180.3	Shallow Bedrock Aquifer	7.6	31-Jul-63	176.6
72.	6601696	184.3	Shallow Bedrock Aquifer	7.6	2-Aug-63	179.7
73.	6601719	195.0	Shallow Bedrock Aquifer	10.4	13-Sep-63	184.0
74.	6601383	184.9	Shallow Bedrock Aquifer	16.5	21-Nov-63	179.1
75.	6601271	191.6	Shallow Bedrock Aquifer	11.0	23-Dec-63	184.0
76.	6601396	183.4	Shallow Bedrock Aquifer	23.8	10-Apr-64	178.2
77.	6601720	194.1	Shallow Bedrock Aquifer	10.1	25-May-64	184.0
78.	6601721	193.1	Shallow Bedrock Aquifer	9.4	29-May-64	184.0

Notes: • Elevations provided in metres above sea level (masl)

Table E-3 MECP Water Well Record Water Level Data Summary

Water Well Record No.		Interpolated Ground Elevation	Hydrostratigraphic Unit	Water Level Elevation		
				Static		Water Level Used For Interpolation
		masl		mbgs	Date	masl
79.	6601284	183.5	Shallow Bedrock Aquifer	7.6	28-Aug-64	181.1
80.	6601403	180.7	Shallow Bedrock Aquifer	22.9	6-Oct-64	174.0
81.	6601782	196.2	Shallow Bedrock Aquifer	13.7	3-Nov-64	184.9
82.	6601638	184.6	Shallow Bedrock Aquifer	9.8	7-Dec-64	178.5
83.	6601762	186.0	Shallow Bedrock Aquifer	13.4	30-Jun-65	179.9
84.	6601329	190.8	Shallow Bedrock Aquifer	10.1	30-Jun-65	186.2
85.	6601787	189.5	Shallow Bedrock Aquifer	15.8	27-Oct-65	182.2
86.	6601263	200.5	Shallow Bedrock Aquifer	19.2	24-Feb-66	196.5
87.	6601640	184.4	Shallow Bedrock Aquifer	7.9	31-Mar-66	177.7
88.	6601339	202.6	Shallow Bedrock Aquifer	12.2	13-May-66	191.0
89.	6601262	211.3	Shallow Bedrock Aquifer	18.3	25-Jul-66	199.4
90.	6601381	191.9	Shallow Bedrock Aquifer	10.4	14-Feb-67	182.5
91.	6601763	179.1	Shallow Bedrock Aquifer	10.7	25-May-67	175.4
92.	6601326	181.7	Shallow Bedrock Aquifer	9.4	31-May-67	178.0
93.	6601641	179.6	Shallow Bedrock Aquifer	7.0	6-Jul-67	174.7
94.	6601642	184.2	Shallow Bedrock Aquifer	8.8	29-Jul-67	177.5
95.	6601250	181.2	Shallow Bedrock Aquifer	3.4	29-Aug-67	180.3
96.	6601333	181.5	Shallow Bedrock Aquifer	6.7	17-Nov-67	178.5
97.	6602327	202.2	Shallow Bedrock Aquifer	22.6	8-Feb-68	186.0
98.	6602351	196.8	Shallow Bedrock Aquifer	8.2	19-Jul-68	192.5
99.	6602367	187.9	Shallow Bedrock Aquifer	15.5	20-Jul-68	180.0
100.	6602353	199.5	Shallow Bedrock Aquifer	14.6	16-Aug-68	185.8
101.	6602354	184.7	Shallow Bedrock Aquifer	9.4	15-Oct-68	181.0
102.	6602352	185.9	Shallow Bedrock Aquifer	12.8	20-Dec-68	178.3
103.	6602405	196.0	Shallow Bedrock Aquifer	20.4	8-Jan-69	185.3
104.	6602739	183.2	Shallow Bedrock Aquifer	8.5	6-Mar-69	178.9
105.	6602457	205.7	Shallow Bedrock Aquifer	12.2	5-May-69	192.0
106.	6602418	184.9	Shallow Bedrock Aquifer	22.6	8-May-69	177.3
107.	6602456	202.6	Shallow Bedrock Aquifer	11.3	26-Jun-69	193.5
108.	6602454	197.3	Shallow Bedrock Aquifer	14.0	13-Aug-69	184.8
109.	6602455	197.2	Shallow Bedrock Aquifer	13.4	15-Aug-69	184.4
110.	6602459	198.3	Shallow Bedrock Aquifer	13.4	29-Aug-69	183.7
111.	6602471	189.6	Shallow Bedrock Aquifer	10.1	4-Sep-69	184.1
112.	6602469	182.4	Shallow Bedrock Aquifer	12.5	26-Sep-69	177.2
113.	6602468	186.5	Shallow Bedrock Aquifer	13.1	27-Sep-69	179.2
114.	6602492	190.2	Shallow Bedrock Aquifer	6.4	29-Oct-69	184.1
115.	6602515	196.7	Shallow Bedrock Aquifer	20.4	16-Mar-70	185.1
116.	6602512	182.9	Shallow Bedrock Aquifer	12.8	14-Apr-70	177.4
117.	6602619	196.0	Shallow Bedrock Aquifer	17.7	17-Apr-70	183.8

Notes: • Elevations provided in metres above sea level (masl)

Table E-3 MECP Water Well Record Water Level Data Summary

Water Well Record No.		Interpolated Ground Elevation	Hydrostratigraphic Unit	Water Level Elevation		
				Static		Water Level Used For Interpolation
		masl		mbgs	Date	masl
118.	6602520	187.6	Shallow Bedrock Aquifer	6.4	9-Jun-70	180.9
119.	6602547	203.2	Shallow Bedrock Aquifer	11.3	5-Jul-70	193.8
120.	6602538	189.8	Shallow Bedrock Aquifer	17.1	8-Aug-70	181.0
121.	6602549	197.2	Shallow Bedrock Aquifer	10.4	22-Aug-70	184.1
122.	6602554	194.3	Shallow Bedrock Aquifer	10.4	28-Sep-70	183.0
123.	6602598	189.5	Shallow Bedrock Aquifer	14.6	7-May-71	181.0
124.	6602689	202.0	Shallow Bedrock Aquifer	10.1	30-Jun-71	192.9
125.	6602600	194.0	Shallow Bedrock Aquifer	16.5	5-Jul-71	183.0
126.	6602665	202.0	Shallow Bedrock Aquifer	15.2	27-Jul-71	195.9
127.	6602648	182.8	Shallow Bedrock Aquifer	9.8	26-Oct-71	179.1
128.	6602644	183.0	Shallow Bedrock Aquifer	11.6	30-Nov-71	178.7
129.	6602658	208.6	Shallow Bedrock Aquifer	19.5	3-Mar-72	197.9
130.	6602700	185.6	Shallow Bedrock Aquifer	2.4	27-May-72	179.5
131.	6602707	178.2	Shallow Bedrock Aquifer	10.4	15-Sep-72	175.2
132.	6602713	193.8	Shallow Bedrock Aquifer	19.5	19-Oct-72	185.6
133.	6602724	189.3	Shallow Bedrock Aquifer	5.5	20-Oct-72	184.7
134.	6602765	192.0	Shallow Bedrock Aquifer	20.7	18-Jun-73	182.9
135.	6602792	189.2	Shallow Bedrock Aquifer	6.1	27-Sep-73	184.3
136.	6602813	192.9	Shallow Bedrock Aquifer	22.3	23-Nov-73	183.1
137.	6602985	188.2	Shallow Bedrock Aquifer	5.8	1-Aug-74	181.5
138.	6603017	182.2	Shallow Bedrock Aquifer	11.6	28-Aug-74	178.5
139.	6602986	192.9	Shallow Bedrock Aquifer	15.5	30-Aug-74	186.8
140.	6603043	182.3	Shallow Bedrock Aquifer	10.4	1-Sep-74	179.6
141.	6603030	188.5	Shallow Bedrock Aquifer	5.8	14-Dec-74	181.8
142.	6603110	190.0	Shallow Bedrock Aquifer	18.3	14-Nov-75	182.7
143.	6603118	184.3	Shallow Bedrock Aquifer	12.8	23-Jan-76	177.6
144.	6603121	191.3	Shallow Bedrock Aquifer	10.1	15-Apr-76	182.8
145.	6603146	199.7	Shallow Bedrock Aquifer	21.0	7-Jul-76	186.0
146.	6603169	188.6	Shallow Bedrock Aquifer	11.3	12-Jul-76	182.5
147.	6603168	189.9	Shallow Bedrock Aquifer	9.4	14-Jul-76	185.0
148.	6603167	189.8	Shallow Bedrock Aquifer	12.5	19-Jul-76	186.1
149.	6603166	204.1	Shallow Bedrock Aquifer	10.7	19-Aug-76	194.0
150.	6603171	188.0	Shallow Bedrock Aquifer	12.5	1-Sep-76	181.0
151.	6603203	184.9	Shallow Bedrock Aquifer	11.0	8-Dec-76	180.3
152.	6603255	184.7	Shallow Bedrock Aquifer	9.8	15-Jul-77	178.3
153.	6603248	189.2	Shallow Bedrock Aquifer	10.7	28-Sep-77	182.8
154.	6603240	187.9	Shallow Bedrock Aquifer	17.4	30-Sep-77	180.9
155.	6603250	183.4	Shallow Bedrock Aquifer	10.4	29-Oct-77	179.7
156.	6603243	195.6	Shallow Bedrock Aquifer	18.3	16-Nov-77	184.6

Notes: • Elevations provided in metres above sea level (masl)

Table E-3 MECP Water Well Record Water Level Data Summary

Water Well Record No.		Interpolated Ground Elevation	Hydrostratigraphic Unit	Water Level Elevation		
				Static		Water Level Used For Interpolation
		masl		mbgs	Date	masl
157.	6603314	195.3	Shallow Bedrock Aquifer	36.6	3-Mar-78	183.7
158.	6603315	194.5	Shallow Bedrock Aquifer	17.4	15-Mar-78	183.2
159.	6603262	182.9	Shallow Bedrock Aquifer	9.1	29-Mar-78	178.3
160.	6603316	198.4	Shallow Bedrock Aquifer	17.4	10-Apr-78	187.1
161.	6603317	194.2	Shallow Bedrock Aquifer	17.1	1-May-78	182.9
162.	6603266	188.2	Shallow Bedrock Aquifer	10.1	10-May-78	182.1
163.	6603264	199.8	Shallow Bedrock Aquifer	14.6	11-May-78	187.0
164.	6603269	193.1	Shallow Bedrock Aquifer	20.1	19-May-78	182.4
165.	6603273	195.8	Shallow Bedrock Aquifer	18.9	26-May-78	185.1
166.	6603268	189.1	Shallow Bedrock Aquifer	17.7	31-May-78	181.2
167.	6603271	187.7	Shallow Bedrock Aquifer	24.7	14-Jun-78	181.0
168.	6603318	195.3	Shallow Bedrock Aquifer	21.3	15-Sep-78	184.6
169.	6603285	181.8	Shallow Bedrock Aquifer	7.3	29-Sep-78	173.3
170.	6603286	181.7	Shallow Bedrock Aquifer	7.9	19-Oct-78	178.3
171.	6603287	183.0	Shallow Bedrock Aquifer	9.4	21-Oct-78	178.7
172.	6603313	187.9	Shallow Bedrock Aquifer	11.0	30-Nov-78	183.6
173.	6603388	182.5	Shallow Bedrock Aquifer	9.8	15-May-80	178.2
174.	6603426	186.7	Shallow Bedrock Aquifer	16.2	12-Nov-80	177.6
175.	6603499	186.4	Shallow Bedrock Aquifer	16.2	10-Sep-81	179.7
176.	6603525	185.1	Shallow Bedrock Aquifer	12.5	17-Sep-82	178.1
177.	6603647	187.0	Shallow Bedrock Aquifer	23.5	9-Apr-85	180.3
178.	6603646	186.4	Shallow Bedrock Aquifer	19.5	18-Apr-85	181.5
179.	6604653	186.4	Shallow Bedrock Aquifer	10.4	8-May-02	181.8
180.	6604658	185.8	Shallow Bedrock Aquifer	5.8	31-May-02	183.4
181.	6604664	190.4	Shallow Bedrock Aquifer	23.5	13-Jul-02	183.1
182.	6604678	191.9	Shallow Bedrock Aquifer	14.0	14-Aug-02	183.4
183.	6604702	188.5	Shallow Bedrock Aquifer	18.0	8-Nov-02	180.9
184.	6604805	190.7	Shallow Bedrock Aquifer	6.1	17-Aug-04	188.4
185.	6604861	186.0	Shallow Bedrock Aquifer	25.0	22-Apr-05	180.0
186.	6604868	191.6	Shallow Bedrock Aquifer	20.7	13-May-05	184.9

Notes: • Elevations provided in metres above sea level (masl)

APPENDIX

F

GROUNDWATER CHEMICAL RESULTS

Appendix F Table Notation for Groundwater Chemical Results

Notation	*Description*		
mg/L	milligrams per Litre	T D S	Total Dissolved Solids
	• values in mg/L unless otherwise noted	T K N	Total Kjehldahl Nitrogen
µg/L	micrograms per Litre	D O C	Dissolved Organic Carbon
pH	provided in Scientific Units	SP	Shallow Weathered Overburden
E C	Electrical Conductivity	OB	Contact Aquifer
	provided in microSiemens per centimetre	ER	Shallow Bedrock (Eramosa Mb) Aquifer
T	Temperature	GP	Deep Bedrock (Gasport Mb) Aquifer
	provided in degrees Celsius	DC	DeCew / Rochester Formation Aquitard
VOCs	Volatile Organic Compounds	RO	
	VOC results provided in ug/L		
QA / QC			
RDL	laboratory reported detection limit		
RPD	relative percent difference, provided in %		
	bold and shading indicates RPD greater than 20% or >2 RDL		
ODWQS	Ontario Drinking Water Quality Standards (June 2003 and updates)		
MAC	Maximum Acceptable Concentration		
IMAC	Interim Maximum Acceptable Concentration		
AO	Aesthetic objective		
OG	Operational Guideline		
nc	no OWDQS criteria		
	shading indicates an exceedance of the ODWQS criteria		
(1)	NSD - well dry		
(2)	NSI - insufficient volume for sample		
(3)	INX - well inaccessible		
blank	data not available		
< value	parameter not detected above associated laboratory reported detection limit		

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Field pH	Field E C	Field T	General Chemistry pH	General Chemistry E C	General Chemistry T D S	General Chemistry Hardness	Major Ions Chloride	Major Ions Sulphate	Major Ions Alkalinity	Major Ions Calcium	Major Ions Magnesium	Major Ions Sodium	Major Ions Potassium
		Units	S U	µS/cm	°C	S U	µS/cm									
		ODWQS	6.5 - 8.5 OG	nc	15 AO	6.5 - 8.5 OG	nc	500 AO	80 - 100 OG	250 AO	500 AO	30 - 500 OG	nc	nc	200 AO	nc
BH03-2A	**GP**	5-Dec-16	8.8	2,870	8.8	8.11	4,000	1,790	82	1,000	150	200	21	8	700	4
		2-May-17	7.6	4,560	9.7	7.55	7,400	3,860	880	2,000	360	370	210	89	870	16
		22-Mar-18	7.5	11,770	7.7	7.79	13,000	5,640	1,800	3,900	360	420	440	170	1,800	29
		30-Jul-20	7.0	20,000	15.5	7.47	25,000	16,400	4,600	7,900	250	300	1,100	470	3,900	39
BH03-2B	**ER**	5-Dec-16	6.9	2,210	10.4	7.59	2,000	1,220	810	270	270	440	150	110	120	1.9
		2-May-17	7.4	1,529	10.4	7.66	1,600	990	690	140	240	430	120	96	59	2.4
		22-Mar-18	7.1	1,372	10.4	7.59	1,500	880	640	110	240	460	110	88	49	2.4
		30-Jul-20	7.5	1,440	11.8	7.55	1,500	915	720	140	240	430	130	94	65	2.8
MW11-1A	**DC**	2-May-17	6.3	20,000	10.4	6.95	140,000	126,000	38,000	71,000	1,200	130	8,700	4,000	28,000	390
		21-Mar-18	6.0	20,000	8.1	6.74	100,000	125,000	37,000	69,000	1,300	130	8,400	3,900	26,000	400
		30-Jul-20	5.8	20,000	12.6	6.76	100,000	132,000	40,000	75,000	1,300	120	9,300	4,100	28,000	400
MW11-1B	**ER**	6-Dec-16	7.4	1,480	9.1	7.70	1,500	990	760	63	360	410	150	90	41	3.5
		2-May-17	7.4	1,466	10.4	7.68	1,700	948	820	140	350	370	190	84	140	5.2
		21-Mar-18	7.2	1,723	9.1	7.25	1,600	1,020	850	48	390	370	200	83	39	3.9
		30-Jul-20	8.1	1,540	13.6	7.65	1,500	1,010	760	74	330	400	170	79	41	3.9
MW11-1OB	**OB**	6-Dec-16	8.0	1,230	10.1	8.14	1,400	790	360	40	210	510	53	55	200	2.8
		2-May-17	7.7	1,355	9.6	7.97	1,500	838	510	56	250	470	67	83	160	2.9
		21-Mar-18	7.5	1,656	7.5	7.89	1,500	855	560	94	240	470	70	93	110	2.5
		30-Jul-20	8.2	1,168	13.0	7.68	4,100	2,440	1,600	1,100	250	400	170	280	270	4
MW11-2A	**RO**	4-May-17	6.3	20,000	9.6	6.57	100,000	172,000	52,000	96,000	1,000	54	11,000	6,100	37,000	580
		21-Mar-18	6.0	20,000	6.7	6.49	100,000	129,000	47,000	87,000	1,000	57	9,600	5,400	33,000	470
		30-Jul-20	6.3	20,000	16.4	6.46	100,000	176,000	54,000	96,000	1,100	60	11,000	6,100	35,000	540
MW11-2B	**ER**	6-Dec-16	7.6	1,374	7.6	7.79	1,300	838	630	93	230	400	120	81	51	2.9
		4-May-17	7.3	1,310	9.7	7.67	1,300	748	560	88	190	400	100	74	47	2.4
		21-Mar-18	7.3	1,426	7.3	7.71	1,200	730	600	79	150	420	110	78	52	2.6
		30-Jul-20	7.4	1,330	11.5	7.64	1,300	750	630	74	210	400	110	82	48	2.7
MW11-2OB	**OB**	5-Dec-16 (2)														
		4-May-17	8.0	1,359	8.0	7.88	1,400	874	660	4	330	440	82	110	48	2.1
		21-Mar-18	7.5	1,570	6.5	7.97	1,400	810	640	4	310	490	73	110	47	1.9
		29-Jul-20	8.6	1,490	15.0	7.81	1,400	960	690	13	300	500	77	120	56	1.9
MW11-3AR	**GP**	5-Dec-16	7.6	20,000	9.1	6.87	100,000	55,600	39,000	70,000	670	76	8,900	4,100	25,000	370
		4-May-17	6.5	20,000	10.4	6.85	160,000	149,000	45,000	84,000	790	67	9,900	5,000	31,000	410
		20-Mar-18	6.8	20,000	7.8	7.06	110,000	110,000	28,000	52,000	1,400	340	6,300	3,000	21,000	260
		29-Jul-20	6.0	20,000	19.5	6.58	100,000	188,000	62,000	110,000	900	55	14,000	6,700	43,000	590

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Nitrate	Nitrite	T K N	Ammonia	Total Phosphorus	D O C	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium
			Nutrients and Organic Indicators						*Dissolved Metals*						
		Units													
		ODWQS	10.0 MAC	1.0 MAC	nc	nc	nc	5 AO	0.10 OG	0.006 IMAC	0.025 IMAC	1 MAC	nc	5 IMAC	0.005 MAC
BH03-2A	**GP**	5-Dec-16	<0.1	<0.01	1.4	1.2	2.4	5.4	0.0073	0.0038	0.0016	0.15	<0.0005	0.37	<0.0001
		2-May-17	<0.1	<0.01	2.9	2.2	0.76	23.0	0.012	0.0025	0.0027	0.18	<0.0005	0.34	<0.0001
		22-Mar-18	<0.1	<0.01	4.7	3.8	1.8	30.0	0.031	<0.0025	<0.005	0.27	<0.0025	0.43	<0.0005
		30-Jul-20	<0.1	<0.01	5.3	4.9	0.32	12.0	0.19	<0.0025	<0.005	0.27	<0.002	0.25	<0.0005
BH03-2B	**ER**	5-Dec-16	<0.1	<0.01	0.5	0.28	2.0	1.9	0.0099	<0.0005	0.0011	0.092	<0.0005	0.091	<0.0001
		2-May-17	<0.1	<0.01	0.41	0.17	0.64	1.9	<0.005	<0.0005	0.0017	0.18	<0.0005	0.053	<0.0001
		22-Mar-18	<0.1	<0.01	0.28	0.23	0.44	6.7	<0.005	<0.0005	<0.001	0.2	<0.0005	0.043	<0.0001
		30-Jul-20	<0.1	<0.01	0.16	0.23	0.087	1.6	<0.0049	<0.0005	<0.001	0.23	<0.0004	0.057	<0.0001
MW11-1A	**DC**	2-May-17	<1.0	<0.1	34.0	37.0	<0.1	1.4	<0.25	<0.025	<0.05	0.14	<0.025	3.9	<0.005
		21-Mar-18	<0.5	<0.05	41.0	30.0	0.36	8.2	<0.05	<0.005	<0.01	0.12	<0.005	3.9	<0.001
		30-Jul-20	<1.0	<0.1	38.0	41.0	<0.2	1.1	<0.25	<0.025	<0.05	0.13	<0.02	3.8	<0.0045
MW11-1B	**ER**	6-Dec-16	<0.1	<0.01	0.15	<0.05	0.12	2.0	0.0059	<0.0005	<0.001	0.071	<0.0005	0.059	<0.0001
		2-May-17	<0.1	<0.01	0.53	0.13	0.3	1.7	0.014	<0.0005	<0.001	0.042	<0.0005	0.092	<0.0001
		21-Mar-18	<0.1	<0.01	0.27	0.21	0.084	9.5	<0.005	<0.0005	<0.001	0.029	<0.0005	0.088	<0.0001
		30-Jul-20	<0.1	<0.01	0.27	0.17	0.14	1.9	0.074	<0.0005	<0.001	0.037	<0.0004	0.07	<0.0001
MW11-1OB	**OB**	6-Dec-16	0.19	0.45	0.95	0.71	280.0	2.4	0.071	0.0011	0.0015	0.1	<0.0005	0.12	<0.0001
		2-May-17	0.31	<0.01	1.3	0.068	31.0	1.5	0.0079	0.0013	0.0021	0.049	<0.0005	0.096	<0.0001
		21-Mar-18	0.5	0.012	0.45	0.19	37.0	9.9	0.0076	0.0007	0.0013	0.039	<0.0005	0.077	<0.0001
		30-Jul-20	0.71	<0.01	0.35	0.098	23.0	1.6	0.0061	<0.0005	<0.001	0.073	<0.0004	0.076	0.0002
MW11-2A	**RO**	4-May-17	<2.0	<0.2	65.0	53.0	0.43	5.0	<0.1	<0.01	<0.02	0.33	<0.01	3.4	<0.002
		21-Mar-18	<1.0	<0.1	58.0	52.0	<0.4	5.6	<0.5	<0.05	<0.1	0.2	<0.05	3.0	<0.01
		30-Jul-20	<0.1	<0.01	48.0	56.0	0.27	8.7	<0.25	<0.025	<0.05	0.2	<0.02	3.6	<0.0045
MW11-2B	**ER**	6-Dec-16	<0.1	<0.01	0.16	<0.05	1.4	1.4	<0.005	<0.0005	0.0015	0.069	<0.0005	0.047	<0.0001
		4-May-17	0.23	<0.01	0.19	<0.05	0.14	0.99	<0.005	<0.0005	<0.001	0.13	<0.0005	0.036	<0.0001
		21-Mar-18	0.5	<0.01	0.18	0.096	0.59	3.5	<0.005	<0.0005	<0.001	0.12	<0.0005	0.033	<0.0001
		30-Jul-20	0.22	<0.01	0.14	0.092	0.1	1.1	0.0056	<0.0005	<0.001	0.12	<0.0004	0.036	0.0001
MW11-2OB	**OB**	5-Dec-16 (2)													
		4-May-17	1.27	<0.01	<0.1	<0.05	0.089	0.96	<0.005	<0.0005	<0.001	0.018	<0.0005	0.044	<0.0001
		21-Mar-18	1.12	<0.01	0.17	<0.05	1.2	1.8	<0.005	<0.0005	<0.001	0.019	<0.0005	0.034	<0.0001
		29-Jul-20	4.63	<0.01	0.42	0.07	0.48	1.0	0.0052	<0.0005	<0.001	0.021	<0.0004	0.035	<0.0001
MW11-3AR	**GP**	5-Dec-16	<1.0	<0.1	7.7	7.4	0.23	5.0	<0.25	<0.025	<0.05	0.18	<0.025	2.3	<0.005
		4-May-17	<2.0	<0.2	50.0	40.0	0.42	31.0	<0.5	<0.05	<0.1	0.21	<0.05	2.7	<0.01
		20-Mar-18	<0.5	<0.05	39.0	27.0	<1.0	97.0	<0.25	<0.025	<0.05	0.11	<0.025	2.7	<0.005
		29-Jul-20	<1.0	<0.1	51.0	54.0	1.8	3.6	<0.25	<0.025	<0.05	0.2	<0.02	3.0	<0.0045

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Chromium	Cobalt	Copper	Fluoride	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium
			Dissolved Metals												
		Units													
		ODWQS	0.05 MAC	nc	1 AO	1.5 MAC	0.30 AO	0.01 MAC	0.05 AO	0.001 MAC	nc	nc	0.01 MAC	nc	nc
BH03-2A	GP	5-Dec-16	<0.005	<0.0005	0.0011	0.73	<0.1	<0.0005	0.0031	0.0001	0.082	0.0018	<0.002	<0.0001	0.38
		2-May-17	<0.005	0.0005	<0.001	0.64	1.8	<0.0005	0.13	<0.0001	0.024	0.0024	<0.002	<0.0001	2.3
		22-Mar-18	<0.025	<0.0025	<0.005	0.58	<0.5	<0.0025	0.32	<0.0001	<0.0025	<0.005	<0.01	<0.0005	9.6
		30-Jul-20	<0.025	<0.0025	<0.0045	0.38	<0.5	<0.0025	0.32	<0.0001	<0.0025	0.013	<0.01	<0.0005	22.0
BH03-2B	ER	5-Dec-16	<0.005	<0.0005	0.0013	0.67	5.1	<0.0005	0.085	<0.0001	0.0032	<0.001	<0.002	<0.0001	1.1
		2-May-17	<0.005	<0.0005	<0.001	0.61	3.7	<0.0005	0.05	<0.0001	0.0012	<0.001	<0.002	<0.0001	0.68
		22-Mar-18	<0.005	<0.0005	<0.001	0.68	2.3	<0.0005	0.046	<0.0001	0.0012	<0.001	<0.002	<0.0001	0.62
		30-Jul-20	<0.005	<0.0005	<0.0009	0.73	2.6	<0.0005	0.045	<0.0001	0.0013	<0.001	<0.002	<0.0001	0.74
MW11-1A	DC	2-May-17	<0.25	<0.025	<0.05	0.22	<5.0	<0.025	0.36	<0.0001	<0.025	<0.05	<0.1	<0.005	170.0
		21-Mar-18	<0.05	<0.005	<0.01	0.22	<1.0	<0.005	0.37	<0.0001	<0.005	<0.01	<0.02	<0.001	170.0
		30-Jul-20	<0.25	<0.025	<0.045	0.24	<5.0	<0.025	0.4	<0.0001	<0.025	<0.05	<0.1	<0.0045	180.0
MW11-1B	ER	6-Dec-16	<0.005	<0.0005	<0.001	1.1	0.11	<0.0005	0.037	<0.0001	<0.0005	<0.001	<0.002	<0.0001	0.98
		2-May-17	<0.005	<0.0005	<0.001	1.2	<0.1	<0.0005	0.016	<0.0001	<0.0005	<0.001	<0.002	<0.0001	1.8
		21-Mar-18	<0.005	<0.0005	<0.001	1.3	<0.1	<0.0005	0.016	<0.0001	<0.0005	<0.001	0.0071	<0.0001	1.6
		30-Jul-20	<0.005	<0.0005	<0.0009	1.3	<0.1	<0.0005	0.022	<0.0001	<0.0005	<0.001	<0.002	<0.0001	1.3
MW11-1OB	OB	6-Dec-16	<0.005	<0.0005	0.0023	1.6	0.12	<0.0005	0.035	<0.002	0.024	0.0011	<0.002	<0.0001	0.56
		2-May-17	<0.005	<0.0005	<0.001	1.1	<0.1	<0.0005	0.045	<0.0001	0.018	0.0017	<0.002	<0.0001	0.78
		21-Mar-18	<0.005	<0.0005	<0.001	1.0	<0.1	<0.0005	0.028	<0.0001	0.0099	0.0014	<0.002	<0.0001	0.81
		30-Jul-20	<0.005	<0.0005	0.0027	0.76	<0.1	<0.0005	0.028	<0.0001	0.0053	0.0022	<0.002	<0.0001	2.6
MW11-2A	RO	4-May-17	<0.1	<0.01	<0.02	<0.1	3.6	<0.01	0.7	<0.0001	<0.01	<0.02	<0.04	<0.002	250.0
		21-Mar-18	<0.5	<0.05	<0.1	0.14	<10.0	<0.05	0.59	<0.0002	<0.05	<0.1	<0.2	<0.01	210.0
		30-Jul-20	<0.25	<0.025	<0.045	0.17	<5.0	<0.025	0.7	<0.0001	<0.025	<0.05	<0.1	<0.0045	240.0
MW11-2B	ER	6-Dec-16	<0.005	<0.0005	<0.001	0.79	0.2	<0.0005	0.042	<0.0001	0.0016	<0.001	<0.002	<0.0001	0.58
		4-May-17	<0.005	<0.0005	<0.001	0.69	<0.1	<0.0005	0.011	<0.0001	0.0018	0.0019	<0.002	<0.0001	0.42
		21-Mar-18	<0.005	<0.0005	<0.001	0.63	<0.1	<0.0005	0.015	<0.0001	0.0024	0.0017	<0.002	<0.0001	0.47
		30-Jul-20	<0.005	<0.0005	0.0029	0.71	<0.1	<0.0005	0.025	<0.0001	0.0011	0.0011	<0.002	<0.0001	0.48
MW11-2OB	OB	5-Dec-16 (2)													
		4-May-17	<0.005	<0.0005	<0.001	0.62	<0.1	<0.0005	<0.002	<0.0001	0.0045	0.0017	0.0021	<0.0001	0.58
		21-Mar-18	<0.005	<0.0005	0.0015	0.61	<0.1	<0.0005	<0.002	<0.0001	0.0037	<0.001	<0.002	<0.0001	0.61
		29-Jul-20	<0.005	<0.0005	0.0029	0.64	<0.1	<0.0005	<0.002	<0.0001	0.003	0.0012	0.0022	<0.0001	0.63
MW11-3AR	GP	5-Dec-16	<0.25	<0.025	<0.05	0.23	<5.0	<0.025	0.65	<0.0001	<0.025	<0.05	<0.1	<0.005	190.0
		4-May-17	<0.5	<0.05	<0.1	0.16	<10.0	<0.05	0.67	<0.0001	<0.05	<0.1	<0.2	<0.01	210.0
		20-Mar-18	<0.25	<0.025	<0.05	0.33	<5.0	<0.025	0.55	<0.0001	<0.025	<0.05	<0.1	<0.005	140.0
		29-Jul-20	<0.25	<0.025	<0.045	0.18	<5.0	<0.025	0.77	<0.0001	<0.025	<0.05	<0.1	<0.0045	280.0

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Sulphide	Tungsten	Uranium	Vanadium	Zinc	Zirconium
			Dissolved Metals					
		Units						
		ODWQS	0.05 AO	nc	0.02 MAC	nc	5 AO	nc
BH03-2A	GP	5-Dec-16	<0.02	0.003	0.018	0.0005	<0.005	<0.001
		2-May-17	0.22	<0.001	0.018	<0.0005	0.025	<0.001
		22-Mar-18	6.2	<0.005	0.012	<0.0025	<0.025	<0.005
		30-Jul-20	1.9	<0.005	0.0012	<0.0025	<0.025	<0.005
BH03-2B	ER	5-Dec-16	0.084	<0.001	0.0057	<0.0005	0.028	<0.001
		2-May-17	0.86	<0.001	0.002	<0.0005	<0.005	<0.001
		22-Mar-18	0.51	<0.001	0.0018	<0.0005	<0.005	<0.001
		30-Jul-20	0.95	<0.001	0.0021	<0.0005	<0.005	<0.001
MW11-1A	DC	2-May-17	15.0	<0.05	<0.005	<0.025	<0.25	<0.05
		21-Mar-18	5.5	<0.01	<0.001	<0.005	<0.05	<0.01
		30-Jul-20	16.0	<0.05	<0.005	<0.025	<0.25	<0.05
MW11-1B	ER	6-Dec-16	3.2	<0.001	0.0018	<0.0005	<0.005	<0.001
		2-May-17	7.0	<0.001	0.0009	<0.0005	<0.005	<0.001
		21-Mar-18	9.4	<0.001	0.0011	<0.0005	<0.005	<0.001
		30-Jul-20	6.5	<0.001	0.0013	<0.0005	0.024	<0.001
MW11-1OB	OB	6-Dec-16	<0.02	<0.001	0.015	0.001	0.014	<0.001
		2-May-17	0.051	<0.001	0.017	0.0006	0.023	<0.001
		21-Mar-18	0.062	<0.001	0.013	<0.0005	0.041	<0.001
		30-Jul-20	<0.02	<0.001	0.014	<0.0005	0.1	<0.001
MW11-2A	RO	4-May-17	0.046	<0.02	<0.002	<0.01	<0.1	<0.02
		21-Mar-18	0.074	<0.1	<0.01	<0.05	<0.5	<0.1
		30-Jul-20	0.32	<0.05	<0.005	<0.025	<0.25	<0.05
MW11-2B	ER	6-Dec-16	0.55	<0.001	0.0059	<0.0005	0.055	<0.001
		4-May-17	0.23	<0.001	0.0066	<0.0005	0.36	<0.001
		21-Mar-18	0.53	<0.001	0.0071	<0.0005	0.15	<0.001
		30-Jul-20	0.47	<0.001	0.0058	<0.0005	0.37	<0.001
MW11-2OB	OB	5-Dec-16 (2)						
		4-May-17	<0.02	<0.001	0.012	<0.0005	<0.005	<0.001
		21-Mar-18	<0.02	<0.001	0.012	<0.0005	<0.005	<0.001
		29-Jul-20	<0.02	<0.001	0.014	<0.0005	<0.005	<0.001
MW11-3AR	GP	5-Dec-16	3.0	<0.05	0.011	<0.13	<0.25	<0.05
		4-May-17	1.2	<0.1	<0.01	<0.05	<0.5	<0.1
		20-Mar-18	3.1	<0.05	0.056	<0.025	<0.25	<0.05
		29-Jul-20	0.88	<0.05	<0.005	<0.025	<0.25	<0.05

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Field pH	Field E C	Field T	General Chemistry pH	General Chemistry E C	T D S	Hardness	Chloride	Sulphate	Alkalinity	Calcium	Magnesium	Sodium	Potassium
		Units	S U	µS/cm	°C	S U	µS/cm									
		ODWQS	6.5 - 8.5 OG	nc	15 AO	6.5 - 8.5 OG	nc	500 AO	80 - 100 OG	250 AO	500 AO	30 - 500 OG	nc	nc	200 AO	nc
MW11-3BR	ER	5-Dec-16	7.7	2,790	10.3	7.62	2,800	2,580	1,800	44	1,500	320	500	120	42	8.6
		4-May-17	7.0	2,760	9.8	7.59	2,800	2,440	1,600	44	1,300	290	470	110	36	7.9
		20-Mar-18	7.1	2,910	8.5	7.41	2,900	2,500	1,800	47	1,500	300	510	120	41	8
		29-Jul-20	7.3	2,600	11.4	7.42	2,500	2,220	1,700	36	1,200	310	510	110	42	8.1
MW11-3OBR	OB	5-Dec-16	8.1	1,820	11.0	7.71	1,800	1,040	840	210	170	500	110	140	60	2.6
		4-May-17	7.6	1,412	8.6	7.74	1,600	678	710	160	120	450	81	120	62	1.8
		20-Mar-18	7.7	1,742	7.0	7.75	1,400	675	570	140	99	440	68	97	37	0.92
		29-Jul-20	7.9	1,230	14.0	7.67	1,300	905	620	120	110	430	81	100	44	1.4
MW11-4A	RO	2-May-17	6.5	20,000	9.5	6.62	150,000	144,000	48,000	80,000	800	67	11,000	5,300	31,000	470
		22-Mar-18	6.7	20,000	9.7	6.94	100,000	88,100	41,000	62,000	850	200	9,100	4,400	25,000	350
		30-Jul-20	6.9	20,000	13.6	7.33	36,000	123,000	54,000	12,000	370	500	12,000	6,000	34,000	500
MW11-4B	ER	6-Dec-16	7.2	3,350	10.3	7.63	2,500	1,650	1,100	380	380	410	230	120	180	5.9
		2-May-17	7.2	2,080	10.4	7.68	2,200	1,400	940	250	340	450	150	140	110	3.8
		22-Mar-18	7.4	3,150	10.0	7.50	2,300	2,100	2,000	310	360	460	410	230	580	14
		30-Jul-20	7.0	3,660	13.4	7.45	3,300	1,880	1,200	640	330	430	220	160	230	6.4
MW11-4OB	OB	6-Dec-16	7.8	1,800	12.0	7.86	1,800	1,150	820	170	360	320	97	140	68	2.1
		2-May-17	7.8	1,760	8.1	7.88	1,800	1,170	860	170	390	340	92	150	62	1.8
		22-Mar-18	7.6	1,804	6.0	7.98	2,000	1,120	920	200	380	360	99	160	63	1.8
		28-Jul-20	7.2	2,230	15.7	7.73	2,100	1,560	1,000	250	360	360	100	180	83	1.9
MW16-5A	GP	5-Dec-16	6.7		8.4	6.70	100,000	181,000	60,000	99,000	830	63	13,000	6,400	38,000	540
		3-May-17	6.5	20,000	13.1	6.69	180,000	199,000	66,000	110,000	790	50	15,000	7,200	45,000	580
		20-Mar-18	6.2	20,000	7.8	6.60	100,000	194,000	64,000	97,000	810	51	14,000	7,000	41,000	530
		29-Jul-20	5.0	20,000	18.0	6.56	100,000	198,000	65,000	120,000	820	44	15,000	6,800	40,000	630
MW16-5AR	GP	20-Mar-18	6.7	20,000	8.3	6.61	100,000	176,000	63,000	96,000	830	53	14,000	6,900	42,000	540
		29-Jul-20	6.0	20,000	18.2	6.58	100,000	191,000	63,000	110,000	840	46	14,000	6,500	39,000	630
MW16-5B	ER	5-Dec-16	7.3	3,750	10.1	7.55	3,100	2,730	1,600	220	1,200	370	380	160	240	11
		3-May-17	7.1	3,720	10.1	7.64	3,800	2,700	1,600	480	910	440	380	160	180	9.5
		20-Mar-18	7.4	8,810	8.5	7.60	2,200	1,620	1,100	80	750	430	230	130	70	6.2
		29-Jul-20	7.1	3,260	11.1	7.56	2,700	2,140	1,600	220	790	450	350	170	210	12
MW16-5OB	OB	5-Dec-16	7.6	1,150	9.9	7.70	990	564	400	41	170	300	74	53	40	8.4
		3-May-17	7.6	821	8.5	7.95	830	470	420	18	74	340	52	69	9	2.5
		20-Mar-18	7.9	936	6.6	7.96	900	410	470	29	68	380	58	78	9	1.3
		29-Jul-20	7.7	1,140	14.0	7.82	990	770	530	56	88	350	72	86	10	1.5

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Nitrate	Nitrite	T K N	Ammonia	Total Phosphorus	D O C	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium
			Nutrients and Organic Indicators						Dissolved Metals						
		Units													
		ODWQS	10.0 MAC	1.0 MAC	nc	nc	nc	5 AO	0.10 OG	0.006 IMAC	0.025 IMAC	1 MAC	nc	5 IMAC	0.005 MAC
MW11-3BR	ER	5-Dec-16	<0.1	<0.01	0.61	0.62	0.14	0.84	<0.005	<0.0005	0.001	0.015	<0.0005	0.58	<0.0001
		4-May-17	<0.1	<0.01	1.0	0.58	0.035	0.49	0.0059	<0.0005	<0.001	0.0068	<0.0005	0.48	<0.0001
		20-Mar-18	<0.1	<0.01	0.82	0.71	<0.1	0.96	<0.005	<0.0005	<0.001	0.0078	<0.0005	0.51	<0.0001
		29-Jul-20	<0.1	<0.01	0.57	0.61	0.11	0.71	0.012	<0.0005	<0.001	0.0091	<0.0004	0.51	<0.0001
MW11-3OBR	OB	5-Dec-16	1.18	<0.01	<0.1	<0.05	3.7	1.5	0.018	<0.0005	<0.001	0.049	<0.0005	0.053	0.0001
		4-May-17	2.45	<0.01	0.31	<0.05	0.33	1.5	0.01	<0.0005	<0.001	0.031	<0.0005	0.03	<0.0001
		20-Mar-18	3.05	<0.01	0.23	0.069	0.24	3.0	<0.005	<0.0005	<0.001	0.036	<0.0005	0.023	<0.0001
		29-Jul-20	5.5	<0.01	0.54	0.54	1.5	1.1	0.023	<0.0005	<0.001	0.032	<0.0004	0.036	<0.0001
MW11-4A	RO	2-May-17	<2.0	<0.2	45.0	35.0	1.6	5.6	<0.025	<0.0025	<0.005	0.6	<0.0025	2.5	<0.0005
		22-Mar-18	<0.5	<0.05	26.0	19.0	0.52	17.0	<0.25	<0.025	<0.05	0.44	<0.025	2.8	<0.005
		30-Jul-20	<0.1	<0.01	4.7	4.1	0.2	4.0	0.067	<0.005	<0.01	0.37	<0.004	2.7	<0.0009
MW11-4B	ER	6-Dec-16	<0.1	<0.01	0.42	0.37	0.17	1.7	<0.005	<0.0005	<0.001	0.067	<0.0005	0.3	<0.0001
		2-May-17	<0.1	<0.01	0.46	0.24	0.059	2.1	<0.005	<0.0005	<0.001	0.069	<0.0005	0.1	<0.0001
		22-Mar-18	<0.1	<0.01	0.32	0.3	<0.1	5.4	0.0062	<0.0005	0.0012	0.056	<0.0005	1.1	<0.0001
		30-Jul-20	<0.1	<0.01	0.43	0.43	<0.04	1.8	<0.0049	<0.0005	<0.001	0.078	<0.0004	0.33	<0.0001
MW11-4OB	OB	6-Dec-16	11.9	<0.01	<0.5	0.087	7.1	2.3	0.0073	<0.0005	<0.001	0.041	<0.0005	0.031	<0.0001
		2-May-17	6.4	<0.01	1.8	0.11	12.0	1.8	<0.005	<0.0005	<0.001	0.034	<0.0005	0.023	<0.0001
		22-Mar-18	4.7	<0.01	0.4	0.14	1.4	3.0	<0.005	<0.0005	<0.001	0.032	<0.0005	0.022	0.0003
		28-Jul-20	6.8	<0.01	0.67	<0.05	1.4	1.7	<0.0049	<0.0005	<0.001	0.041	<0.0004	0.031	<0.0001
MW16-5A	GP	5-Dec-16	<1.0	<0.1	51.0	47.0	1.1	3.9	<0.5	<0.05	<0.1	0.34	<0.05	3.0	<0.01
		3-May-17	<5.0	<0.5	66.0	51.0	0.9	3.1	<0.25	<0.025	<0.05	0.19	<0.025	3.7	<0.005
		20-Mar-18	<1.0	<0.1	57.0	51.0	1.0	7.8	<0.5	<0.05	<0.1	0.21	<0.05	3.5	<0.01
		29-Jul-20	<0.1	<0.01	50.0	55.0	0.31	2.5	<0.049	<0.005	<0.01	0.21	<0.004	2.6	<0.0009
MW16-5AR	GP	20-Mar-18	<1.0	<0.1	61.0	50.0	<1.0	6.8	<0.25	<0.025	<0.05	0.19	<0.025	3.3	<0.005
		29-Jul-20	<1.0	<0.1	54.0	54.0	0.25	2.6	0.057	<0.005	<0.01	0.19	<0.004	2.5	<0.0009
MW16-5B	ER	5-Dec-16	<0.1	<0.01	0.76	0.7	0.074	1.5	<0.005	<0.0005	<0.001	0.083	<0.0005	0.84	<0.0001
		3-May-17	<0.1	<0.01	1.4	0.55	0.042	1.6	0.0058	<0.0005	<0.001	0.064	<0.0005	0.66	<0.0001
		20-Mar-18	<0.1	<0.01	0.53	0.52	<0.1	4.8	0.013	<0.0005	<0.001	0.031	<0.0005	0.31	<0.0001
		29-Jul-20	<0.1	<0.01	0.77	0.76	1.1	1.6	0.013	<0.0005	0.0012	0.036	<0.0004	0.84	<0.0001
MW16-5OB	OB	5-Dec-16	0.1	0.016	0.5	0.24	0.82	3.5	0.0086	0.0011	0.0012	0.13	<0.0005	0.049	<0.0001
		3-May-17	2.07	<0.01	0.38	0.11	1.3	0.92	0.0069	<0.0005	<0.001	0.065	<0.0005	0.029	<0.0001
		20-Mar-18	3.86	<0.01	<0.2	<0.05	0.54	4.0	0.0051	<0.0005	<0.001	0.071	<0.0005	0.026	<0.0001
		29-Jul-20	9.24	<0.01	0.57	<0.05	0.19	1.0	0.012	<0.0005	<0.001	0.086	<0.0004	0.029	<0.0001

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Dissolved Metals												
		Units	Chromium	Cobalt	Copper	Fluoride	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium
		ODWQS	0.05 MAC	nc	1 AO	1.5 MAC	0.30 AO	0.01 MAC	0.05 AO	0.001 MAC	nc	nc	0.01 MAC	nc	nc
MW11-3BR	ER	5-Dec-16	<0.005	<0.001	<0.001	1.0	<0.1	<0.0005	0.035	<0.0001	<0.0005	<0.002	<0.002	<0.0001	6.4
		4-May-17	<0.005	<0.0005	<0.001	1.2	<0.1	<0.0005	0.022	<0.0001	<0.0005	<0.001	<0.002	<0.0001	5.9
		20-Mar-18	<0.005	<0.0005	<0.001	1.2	<0.1	<0.0005	0.023	<0.0001	<0.0005	<0.001	0.0084	<0.0001	7.0
		29-Jul-20	<0.005	<0.0005	<0.0009	1.2	<0.1	<0.0005	0.021	<0.0001	<0.0005	<0.001	0.0028	<0.0001	5.9
MW11-3OBR	OB	5-Dec-16	<0.005	<0.0005	<0.001	0.66	<0.1	<0.0005	0.0088	0.0001	0.0012	<0.001	<0.002	<0.0001	1.2
		4-May-17	<0.005	<0.0005	0.0011	0.69	<0.1	<0.0005	<0.002	<0.0001	0.0009	<0.001	<0.002	<0.0001	1.1
		20-Mar-18	<0.005	<0.0005	<0.001	0.69	<0.1	<0.0005	<0.002	<0.0001	0.0009	<0.001	<0.002	<0.0001	0.87
		29-Jul-20	<0.005	<0.0005	<0.0009	0.71	<0.1	<0.0005	0.0071	<0.0001	0.001	<0.001	<0.002	<0.0001	0.95
MW11-4A	RO	2-May-17	<0.025	<0.0025	<0.005	0.12	11.0	<0.0025	3.7	<0.0001	0.0036	<0.005	<0.01	<0.0005	230.0
		22-Mar-18	<0.25	<0.025	<0.05	0.21	9.6	<0.025	4.1	<0.0001	<0.025	<0.05	<0.1	<0.005	180.0
		30-Jul-20	<0.05	<0.005	<0.009	0.39	8.6	<0.005	5.2	<0.0001	<0.005	<0.01	<0.02	<0.0009	250.0
MW11-4B	ER	6-Dec-16	<0.005	<0.0005	<0.001	0.89	<0.1	<0.0005	0.038	<0.0001	<0.0005	<0.001	<0.002	<0.0001	2.6
		2-May-17	<0.005	<0.0005	<0.001	0.73	0.39	<0.0005	0.047	<0.0001	<0.0005	0.014	<0.002	<0.0001	1.4
		22-Mar-18	<0.005	<0.0005	<0.001	0.7	0.32	<0.0005	0.054	<0.0001	<0.0005	<0.001	0.0023	<0.0001	6.3
		30-Jul-20	<0.005	<0.0005	<0.0009	0.75	0.59	<0.0005	0.045	<0.0001	<0.0005	<0.001	<0.002	<0.0001	2.5
MW11-4OB	OB	6-Dec-16	<0.005	<0.0005	0.0024	0.45	<0.1	<0.0005	<0.002	0.0002	0.0023	<0.001	0.0024	<0.0001	0.85
		2-May-17	<0.005	<0.0005	0.001	0.39	<0.1	<0.0005	<0.002	<0.0001	0.0018	<0.001	0.0022	<0.0001	0.9
		22-Mar-18	<0.005	<0.0005	0.0011	0.4	<0.1	<0.0005	<0.002	<0.0001	0.0018	<0.001	<0.002	<0.0001	0.87
		28-Jul-20	<0.005	<0.0005	0.003	0.43	<0.1	<0.0005	<0.002	<0.0001	0.0021	<0.001	<0.002	<0.0001	1.0
MW16-5A	GP	5-Dec-16	<0.5	<0.05	<0.1	0.17	<10.0	<0.05	0.88	<0.0001	<0.05	<0.1	<0.2	<0.01	270.0
		3-May-17	<0.25	<0.025	<0.05	0.13	<5.0	<0.025	0.79	<0.0001	<0.025	<0.05	<0.1	<0.005	290.0
		20-Mar-18	<0.5	<0.05	<0.1	0.15	<10.0	<0.05	0.78	<0.0001	<0.05	<0.1	<0.2	<0.01	300.0
		29-Jul-20	<0.05	<0.005	<0.009	0.16	<1.0	<0.005	0.81	<0.0001	<0.005	<0.01	<0.02	<0.0009	290.0
MW16-5AR	GP	20-Mar-18	<0.25	<0.025	<0.05	0.14	<5.0	<0.025	0.79	<0.0002	<0.025	<0.05	<0.1	<0.005	300.0
		29-Jul-20	<0.05	<0.005	<0.009	0.16	<1.0	<0.005	0.81	<0.0001	<0.005	<0.01	<0.02	<0.0009	290.0
MW16-5B	ER	5-Dec-16	<0.005	<0.001	<0.001	0.99	<0.1	<0.0005	0.054	<0.0001	<0.0005	<0.002	<0.002	<0.0001	4.6
		3-May-17	<0.005	<0.0005	<0.001	0.62	<0.1	<0.0005	0.058	<0.0001	<0.0005	<0.001	<0.002	<0.0001	4.5
		20-Mar-18	<0.005	<0.0005	<0.001	1.1	0.1	<0.0005	0.046	<0.0001	<0.0005	<0.001	0.0024	<0.0001	2.5
		29-Jul-20	<0.005	<0.0005	<0.0009	0.97	<0.1	<0.0005	0.046	<0.0001	<0.0005	<0.001	<0.002	<0.0001	4.5
MW16-5OB	OB	5-Dec-16	<0.005	0.0007	0.0014	0.32	0.38	<0.0005	0.31	<0.0001	0.02	0.0011	<0.002	<0.0001	0.46
		3-May-17	<0.005	<0.0005	0.0012	0.72	<0.1	<0.0005	0.013	<0.0001	0.0043	<0.001	<0.002	<0.0001	0.69
		20-Mar-18	<0.005	<0.0005	<0.001	0.82	<0.1	<0.0005	<0.002	<0.0001	0.0025	<0.001	<0.002	<0.0001	0.94
		29-Jul-20	<0.005	<0.0005	0.0027	0.72	<0.1	<0.0005	0.0033	<0.0001	0.0024	<0.001	<0.002	<0.0001	1.1

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Sulphide	Tungsten	Uranium	Vanadium	Zinc	Zirconium
			Dissolved Metals					
		Units						
		ODWQS	0.05 AO	nc	0.02 MAC	nc	5 AO	nc
MW11-3BR	**ER**	5-Dec-16	3.2	0.0031	0.0002	<0.0005	<0.01	<0.001
		4-May-17	17.0	<0.001	<0.0001	<0.0005	<0.005	<0.001
		20-Mar-18	5.1	<0.001	<0.0001	<0.0005	<0.005	<0.001
		29-Jul-20	6.8	<0.001	<0.0001	<0.0005	<0.005	<0.001
MW11-3OBR	**OB**	5-Dec-16	<0.02	<0.001	0.0058	0.0006	0.074	<0.001
		4-May-17	<0.02	<0.001	0.0042	<0.0005	0.024	<0.001
		20-Mar-18	<0.02	<0.001	0.0046	0.0006	<0.005	<0.001
		29-Jul-20	0.2	<0.001	0.0045	<0.0005	<0.005	<0.001
MW11-4A	**RO**	2-May-17	0.065	<0.005	0.0031	<0.0025	<0.025	<0.005
		22-Mar-18	4.7	<0.05	0.017	<0.025	<0.25	<0.05
		30-Jul-20	2.3	<0.01	<0.001	<0.005	<0.05	<0.01
MW11-4B	**ER**	6-Dec-16	2.2	<0.001	0.0003	<0.0005	<0.005	<0.001
		2-May-17	2.1	<0.001	0.0007	<0.0005	<0.005	<0.001
		22-Mar-18	1.4	<0.001	0.0006	<0.0005	<0.005	<0.001
		30-Jul-20	5.6	<0.001	0.0006	<0.0005	<0.005	<0.001
MW11-4OB	**OB**	6-Dec-16	<0.02	<0.001	0.0089	<0.0005	0.0071	<0.001
		2-May-17	<0.02	<0.001	0.0089	<0.0005	0.0066	<0.001
		22-Mar-18	<0.02	<0.001	0.01	<0.0005	0.011	<0.001
		28-Jul-20	<0.02	<0.001	0.01	<0.0005	0.0064	<0.001
MW16-5A	**GP**	5-Dec-16	0.075	<0.1	<0.01	<0.1	<0.5	<0.1
		3-May-17	1.2	<0.05	<0.005	<0.025	<0.25	<0.05
		20-Mar-18	0.73	<0.1	<0.01	<0.05	<0.5	<0.1
		29-Jul-20	0.4	<0.01	<0.001	<0.005	<0.05	<0.01
MW16-5AR	**GP**	20-Mar-18	0.57	<0.05	<0.005	<0.025	<0.25	<0.05
		29-Jul-20	0.56	<0.01	<0.001	<0.005	<0.05	<0.01
MW16-5B	**ER**	5-Dec-16	5.0	<0.001	0.0007	<0.0005	<0.01	<0.001
		3-May-17	17.0	<0.001	0.0011	<0.0005	<0.005	<0.001
		20-Mar-18	5.7	<0.001	0.0035	<0.0005	<0.005	<0.001
		29-Jul-20	2.9	<0.001	0.004	0.001	0.046	<0.001
MW16-5OB	**OB**	5-Dec-16	0.032	<0.001	0.0085	0.0016	0.026	<0.001
		3-May-17	<0.02	<0.001	0.0068	0.0026	<0.005	<0.001
		20-Mar-18	<0.02	<0.001	0.0067	0.0014	0.0062	<0.001
		29-Jul-20	<0.02	<0.001	0.007	0.001	<0.005	<0.001

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Field pH	Field E C	Field T	General Chemistry pH	General Chemistry E C	T D S	Hardness	Chloride	Sulphate	Alkalinity	Calcium	Magnesium	Sodium	Potassium
		Units	S U	µS/cm	°C	S U	µS/cm									
		ODWQS	6.5 - 8.5 OG	nc	15 AO	6.5 - 8.5 OG	nc	500 AO	80 - 100 OG	250 AO	500 AO	30 - 500 OG	nc	nc	200 AO	nc
MW16-6A	GP	5-Dec-16	7.9	1,090	8.0	7.90	1,200	622	210	220	57	140	51	20	150	7
		2-May-17	7.0	1,949	10.7	7.33	28,000	13,200	3,700	9,200	1,500	470	1,000	270	6,300	47
		20-Mar-18	6.0	20,000	6.2	6.77	100,000	81,900	30,000	53,000	1,500	300	6,900	3,000	22,000	160
		29-Jul-20	6.3	20,000	21.4	6.71	100,000	126,000	41,000	65,000	1,500	370	9,400	4,300	27,000	320
MW16-6B	ER	5-Dec-16	7.1	1,670	10.7	7.63	1,900	1,110	780	200	250	450	130	110	75	3.7
		2-May-17	7.8	1,515	9.2	7.77	1,600	950	700	130	220	440	120	98	61	3.1
		20-Mar-18	7.4	1,432	8.5	7.76	1,400	750	650	96	210	460	110	91	55	2.9
		29-Jul-20	8.2	1,490	12.2	7.64	1,500	995	680	100	240	450	120	92	51	2.9
MW16-6OB	OB	5-Dec-16				7.83	1,900			150	440	360	130	120	100	13
		2-May-17	7.7	1,959	8.6	7.81	2,100	1,220	900	210	310	470	120	150	100	4.9
		20-Mar-18	7.9	2,340	6.2	7.82	2,000	1,110	830	260	250	470	98	140	110	3.2
		29-Jul-20	7.6	2,250	15.8	7.79	2,100	1,480	820	310	220	430	77	150	140	2.1
MW16-7A	GP	6-Dec-16	8.1	5,530	9.0	7.95	4,000	2,750	1,000	1,100	280	140	290	70	540	16
		3-May-17	7.3	20,000	13.0	7.83	19,000	11,200	2,400	6,100	780	230	640	200	2,500	43
		21-Mar-18	6.8	20,000	8.5	7.41	26,000	11,500	4,000	8,600	1,100	280	1,000	350	3,600	99
		29-Jul-20	5.9	20,000	20.4	7.17	84,000	79,700	25,000	39,000	1,100	290	5,800	2,600	17,000	240
MW16-7B	ER	6-Dec-16	7.6	2,950	9.7	7.79	2,500	1,700	930	400	360	350	210	100	190	7.5
		3-May-17	7.4	1,984	10.7	7.77	2,100	1,230	760	260	300	390	170	82	130	4.1
		21-Mar-18	7.1	1,650	9.2	7.64	1,500	900	630	100	290	400	140	69	57	3
		29-Jul-20	7.6	3,060	13.0	7.60	2,900	2,150	930	590	320	390	220	95	200	5.2
MW16-7OB	OB	6-Dec-16	7.4	2,420	9.9	7.71	2,400	2,030	1,400	6	1,100	470	240	200	76	7.4
		3-May-17	7.9	3,250	9.7	7.64	3,000	2,550	1,700	4	1,400	530	210	280	93	4.6
		21-Mar-18	7.2	3,490	7.6	7.66	3,100	2,460	1,700	4	1,400	560	200	310	92	4.1
		29-Jul-20	8.0	3,370	13.2	7.63	3,200	2,850	2,000	7	1,600	550	170	390	120	3.2
MW16-8A	GP	6-Dec-16	8.1	2,520	9.1	7.87	2,300	1,480	420	590	140	96	110	34	250	8.4
		3-May-17	7.3	20,000	9.2	7.59	28,000	20,400	4,100	9,000	1,500	520	1,000	360	4,100	69
		21-Mar-18	6.6	20,000	8.4	7.77	30,000	18,600	3,500	9,400	1,900	730	950	270	5,400	52
		28-Jul-20	7.9	11,860	23.6	7.64	17,000	40,300	7,500	4,800	930	540	2,000	600	5,900	100
MW16-8B	ER	6-Dec-16	7.5	1,410	9.4	7.81	1,400	906	580	110	270	360	140	57	26	2.3
		3-May-17	7.3	1,201	9.2	7.68	1,100	708	560	20	220	380	130	56	19	2.2
		21-Mar-18	7.1	1,294	8.8	7.37	1,100	700	580	25	240	380	140	57	19	2.4
		28-Jul-20	7.6	1,160	11.6	7.62	1,100	715	570	19	210	360	140	56	20	2.4

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Nutrients and Organic Indicators						Dissolved Metals						
		Units	Nitrate	Nitrite	T K N	Ammonia	Total Phosphorus	D O C	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium
		ODWQS	10.0 MAC	1.0 MAC	nc	nc	nc	5 AO	0.10 OG	0.006 IMAC	0.025 IMAC	1 MAC	nc	5 IMAC	0.005 MAC
MW16-6A	**GP**	5-Dec-16	<0.1	<0.01	0.54	0.39	0.49	3.2	0.0052	<0.0005	0.0011	0.056	<0.0005	0.11	<0.0001
		2-May-17	<0.1	<0.01	4.7	3.1	0.12	250.0	<0.05	<0.005	<0.01	0.18	<0.005	0.88	<0.001
		20-Mar-18	<0.5	<0.05	11.0	8.7	0.47	230.0	<0.25	<0.025	<0.05	0.31	<0.025	1.9	<0.005
		29-Jul-20	<1.0	<0.1	22.0	21.0	0.42	260.0	0.07	<0.005	0.013	0.41	<0.004	1.8	<0.0009
MW16-6B	**ER**	5-Dec-16	<0.1	<0.01	0.17	0.058	0.48	1.9	<0.005	<0.0005	0.0028	0.16	<0.0005	0.058	<0.0001
		2-May-17	<0.1	<0.01	0.3	<0.05	0.031	1.6	<0.005	<0.0005	0.002	0.16	<0.0005	0.05	<0.0001
		20-Mar-18	<0.1	<0.01	<0.1	0.088	0.025	4.7	<0.005	<0.0005	0.0015	0.15	<0.0005	0.047	<0.0001
		29-Jul-20	<0.1	<0.01	0.17	0.091	0.25	1.4	0.006	<0.0005	0.0017	0.14	<0.0004	0.048	<0.0001
MW16-6OB	**OB**	5-Dec-16			0.35	0.068	2.3		0.0063	0.0015	<0.001	0.13	<0.0005	0.11	0.0002
		2-May-17	0.29	<0.01	0.2	<0.05	0.26	1.4	0.0083	<0.0005	<0.001	0.052	<0.0005	0.045	<0.0001
		20-Mar-18	0.41	<0.01	0.14	0.099	1.0	3.4	0.0052	<0.0005	<0.001	0.038	<0.0005	0.032	<0.0001
		29-Jul-20	1.83	<0.01	<0.1	<0.05	0.24	1.7	0.01	<0.0005	<0.001	0.033	<0.0004	0.033	<0.0001
MW16-7A	**GP**	6-Dec-16	<0.1	<0.01	1.4	1.2	0.29	7.8	0.02	<0.0005	0.0046	0.099	<0.0005	0.14	<0.0001
		3-May-17	<0.5	<0.05	7.9	6.0	0.061	150.0	0.036	<0.0025	<0.005	0.14	<0.0025	0.48	<0.0005
		21-Mar-18	<0.1	<0.01	15.0	15.0	<0.4	64.0	<0.05	<0.005	0.01	0.096	<0.005	0.92	<0.001
		29-Jul-20	<1.0	<0.1	25.0	26.0	0.52	57.0	0.065	<0.005	<0.01	0.16	<0.004	1.9	<0.0009
MW16-7B	**ER**	6-Dec-16	<0.1	<0.01	0.52	0.45	0.071	1.5	0.0092	<0.0005	0.0013	0.029	<0.0005	0.19	<0.0001
		3-May-17	<0.1	<0.01	0.57	0.31	0.16	1.4	<0.005	<0.0005	<0.001	0.015	<0.0005	0.13	<0.0001
		21-Mar-18	<0.1	<0.01	0.27	0.29	<0.4	2.2	0.0061	<0.0005	<0.001	0.013	<0.0005	0.088	<0.0001
		29-Jul-20	<0.1	<0.01	0.51	0.51	0.022	1.2	0.029	<0.0005	<0.001	0.017	<0.0004	0.15	<0.0001
MW16-7OB	**OB**	6-Dec-16	<0.1	<0.01	0.22	0.12	0.39	2.8	0.0066	<0.0005	<0.001	0.039	<0.0005	0.065	<0.0001
		3-May-17	0.19	<0.01	0.83	<0.05	0.72	1.8	0.0066	<0.0005	<0.001	0.021	<0.0005	0.074	<0.0001
		21-Mar-18	0.29	<0.01	0.16	0.097	1.1	2.3	<0.005	<0.0005	<0.001	0.012	<0.0005	0.067	<0.0001
		29-Jul-20	1.86	<0.01	0.46	<0.05	0.42	2.4	0.01	<0.0005	<0.001	0.011	<0.0004	0.088	<0.0001
MW16-8A	**GP**	6-Dec-16	<0.1	<0.01	1.4	1.4	0.35	3.7	0.0074	0.0006	<0.001	0.05	<0.0005	0.11	<0.0001
		3-May-17	0.11	0.045	5.1	4.0	0.12	430.0	0.014	<0.0005	0.013	0.12	<0.0005	0.94	<0.0001
		21-Mar-18	<0.1	<0.01	2.0	1.9	0.26	300.0	0.026	<0.0025	<0.005	0.11	<0.0025	1.2	<0.0005
		28-Jul-20	<0.1	<0.01	13.0	14.0	0.15	80.0	<0.025	<0.0025	0.0052	0.11	<0.002	2.1	<0.0005
MW16-8B	**ER**	6-Dec-16	<0.1	<0.01	0.3	0.11	<0.02	1.2	0.0057	<0.0005	<0.001	0.043	<0.0005	0.046	<0.0001
		3-May-17	<0.1	<0.01	0.29	<0.05	<0.02	1.1	0.016	<0.0005	<0.001	0.04	<0.0005	0.039	<0.0001
		21-Mar-18	<0.1	<0.01	0.27	0.095	<0.02	4.0	0.019	<0.0005	<0.001	0.038	<0.0005	0.038	0.0002
		28-Jul-20	<0.1	<0.01	0.13	0.1	<0.02	1.1	<0.0049	<0.0005	<0.001	0.045	<0.0004	0.041	<0.0001

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone	Date	Dissolved Metals												
	Units	Chromium	Cobalt	Copper	Fluoride	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium
	ODWQS	0.05 MAC	nc	1 AO	1.5 MAC	0.30 AO	0.01 MAC	0.05 AO	0.001 MAC	nc	nc	0.01 MAC	nc	nc
MW16-6A GP	5-Dec-16	<0.005	<0.0005	<0.001	0.3	0.66	<0.0005	0.12	<0.0001	0.005	<0.001	<0.002	<0.0001	0.5
	2-May-17	<0.05	<0.005	<0.01	0.22	<1.0	<0.005	1.4	<0.0001	<0.005	<0.01	<0.02	<0.001	22.0
	20-Mar-18	<0.25	<0.025	<0.05	<0.1	5.4	<0.025	4.4	<0.0001	<0.025	<0.05	<0.1	<0.005	150.0
	29-Jul-20	<0.05	<0.005	<0.009	0.1	2.0	<0.005	2.6	<0.0001	<0.005	<0.01	<0.02	<0.0009	180.0
MW16-6B ER	5-Dec-16	<0.005	0.0006	<0.001	0.83	0.32	<0.0005	0.12	0.0005	0.0011	0.0012	<0.002	<0.0001	0.91
	2-May-17	<0.005	<0.0005	<0.001	0.58	0.34	<0.0005	0.09	<0.0001	0.0007	<0.001	<0.002	<0.0001	0.78
	20-Mar-18	<0.005	<0.0005	<0.001	0.73	0.19	<0.0005	0.084	<0.0001	0.0008	<0.001	<0.002	<0.0001	0.74
	29-Jul-20	<0.005	<0.0005	<0.0009	0.84	0.25	<0.0005	0.08	<0.0001	0.0007	<0.001	<0.002	<0.0001	0.72
MW16-6OB OB	5-Dec-16	<0.005	0.0005	0.0014	0.48	<0.1	<0.0005	0.14		0.025	0.0023	0.014	<0.0001	0.65
	2-May-17	<0.005	<0.0005	<0.001	0.5	<0.1	<0.0005	0.15	<0.0001	0.0028	0.0011	<0.002	<0.0001	0.79
	20-Mar-18	<0.005	<0.0005	0.0015	0.66	<0.1	<0.0005	0.017	<0.0001	0.0022	<0.001	<0.002	<0.0001	0.76
	29-Jul-20	<0.005	<0.0005	0.0018	0.8	<0.1	<0.0005	0.0022	<0.0001	0.0023	<0.001	<0.002	<0.0001	0.78
MW16-7A GP	6-Dec-16	<0.005	<0.0005	<0.001	0.2	<0.1	<0.0005	0.12	<0.0001	<0.0005	<0.001	<0.002	<0.0001	2.9
	3-May-17	<0.025	<0.0025	<0.005	0.25	<0.5	<0.0025	0.3	<0.0001	<0.0025	<0.005	<0.01	<0.0005	10.0
	21-Mar-18	<0.05	<0.005	<0.01	0.25	<1.0	<0.005	0.38	<0.0001	<0.005	<0.01	<0.02	<0.001	19.0
	29-Jul-20	<0.05	<0.005	<0.009	0.24	<1.0	<0.005	1.1	<0.0001	<0.005	<0.01	<0.02	<0.0009	120.0
MW16-7B ER	6-Dec-16	<0.005	<0.0005	<0.001	0.82	0.18	<0.0005	0.029	<0.0001	0.0022	<0.001	<0.002	<0.0001	2.7
	3-May-17	<0.005	<0.0005	<0.001	1.1	<0.1	<0.0005	0.028	<0.0001	<0.0005	<0.001	<0.002	<0.0001	2.0
	21-Mar-18	<0.005	<0.0005	<0.001	1.1	<0.1	<0.0005	0.03	<0.0001	<0.0005	<0.001	0.0027	<0.0001	1.5
	29-Jul-20	<0.005	<0.0005	<0.0009	1.1	0.19	<0.0005	0.033	<0.0001	<0.0005	<0.001	<0.002	<0.0001	2.7
MW16-7OB OB	6-Dec-16	<0.005	0.0017	0.0014	0.65	0.15	<0.0005	0.41	<0.0001	0.0032	0.0021	<0.002	<0.0001	1.4
	3-May-17	<0.005	0.0022	<0.001	0.98	0.11	<0.0005	0.83	<0.0001	0.0023	0.0023	<0.002	<0.0001	1.5
	21-Mar-18	<0.005	0.0015	<0.001	1.0	<0.1	<0.0005	0.83	<0.0001	0.0015	0.0018	<0.002	<0.0001	1.7
	29-Jul-20	<0.005	<0.0005	0.0033	1.1	<0.1	<0.0005	0.22	<0.0001	0.002	<0.001	0.0035	<0.0001	2.3
MW16-8A GP	6-Dec-16	<0.005	<0.0005	<0.001	0.19	0.15	<0.0005	0.19	<0.0001	0.027	0.003	<0.002	<0.0001	1.3
	3-May-17	<0.005	0.0005	<0.001	0.27	1.1	<0.0005	0.49	<0.0001	0.007	0.0015	<0.002	<0.0001	19.0
	21-Mar-18	<0.025	<0.0025	<0.005	0.34	<0.5	<0.0025	0.9	<0.0001	<0.0025	<0.005	0.05	<0.0005	17.0
	28-Jul-20	<0.025	<0.0025	<0.0045	0.5	<0.5	<0.0025	1.0	<0.0001	<0.0025	<0.005	<0.01	<0.0005	32.0
MW16-8B ER	6-Dec-16	<0.005	<0.0005	<0.001	1.1	<0.1	<0.0005	0.0086	<0.0001	<0.0005	<0.001	<0.002	<0.0001	0.91
	3-May-17	<0.005	<0.0005	<0.001	1.0	<0.1	<0.0005	0.0084	<0.0001	<0.0005	<0.001	<0.002	<0.0001	0.89
	21-Mar-18	<0.005	<0.0005	<0.001	1.1	<0.1	<0.0005	0.0091	<0.0001	<0.0005	<0.001	<0.002	<0.0001	0.89
	28-Jul-20	<0.005	<0.0005	<0.0009	0.99	<0.1	<0.0005	0.007	<0.0001	<0.0005	<0.001	<0.002	<0.0001	0.88

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Dissolved Metals					
			Sulphide	Tungsten	Uranium	Vanadium	Zinc	Zirconium
		Units						
		ODWQS	0.05 AO	nc	0.02 MAC	nc	5 AO	nc
MW16-6A	GP	5-Dec-16	0.3	0.0015	0.0014	0.0006	<0.005	<0.001
		2-May-17	20.0	<0.01	0.0013	0.016	<0.05	<0.01
		20-Mar-18	1.9	<0.05	0.0066	<0.025	<0.25	<0.05
		29-Jul-20	1.7	<0.01	0.0014	0.025	<0.05	<0.01
MW16-6B	ER	5-Dec-16	0.022	<0.001	0.0052	<0.0005	0.049	<0.001
		2-May-17	0.075	<0.001	0.0039	<0.0005	0.094	<0.001
		20-Mar-18	0.042	<0.001	0.0041	<0.0005	0.067	<0.001
		29-Jul-20	0.092	<0.001	0.0034	<0.0005	0.0063	<0.001
MW16-6OB	OB	5-Dec-16		0.0013	0.014	0.0008	0.79	<0.001
		2-May-17	<0.02	<0.001	0.011	0.0045	<0.005	<0.001
		20-Mar-18	<0.02	<0.001	0.0091	0.0025	<0.005	<0.001
		29-Jul-20	<0.02	<0.001	0.0091	0.002	<0.005	<0.001
MW16-7A	GP	6-Dec-16	5.2	0.0035	0.0018	<0.001	<0.005	<0.001
		3-May-17	0.52	<0.005	0.029	0.0026	<0.025	<0.005
		21-Mar-18	4.4	<0.01	0.028	<0.005	<0.05	<0.01
		29-Jul-20	1.6	<0.01	0.027	<0.005	<0.05	<0.01
MW16-7B	ER	6-Dec-16	5.2	0.016	0.0028	<0.0005	<0.005	<0.001
		3-May-17	5.0	0.0015	0.0002	<0.0005	<0.005	<0.001
		21-Mar-18	3.9	<0.001	0.0001	<0.0005	<0.005	<0.001
		29-Jul-20	3.2	<0.001	<0.0001	<0.0005	<0.005	<0.001
MW16-7OB	OB	6-Dec-16	<0.02	<0.001	0.013	0.0024	0.1	<0.001
		3-May-17	<0.02	<0.001	0.014	0.0011	0.023	<0.001
		21-Mar-18	<0.02	<0.001	0.016	0.0005	0.014	<0.001
		29-Jul-20	<0.02	<0.001	0.024	<0.0005	<0.005	<0.001
MW16-8A	GP	6-Dec-16	0.094	0.0012	0.0009	<0.0005	0.0074	<0.001
		3-May-17	7.6	0.01	0.012	0.0078	0.0066	0.0043
		21-Mar-18	2.5	0.0077	0.12	0.0044	<0.025	0.0055
		28-Jul-20	2.4	0.0063	0.025	0.003	<0.025	<0.005
MW16-8B	ER	6-Dec-16	5.2	0.0021	0.0004	<0.0005	<0.005	<0.001
		3-May-17	9.9	<0.001	0.0002	<0.0005	<0.005	<0.001
		21-Mar-18	8.2	<0.001	0.0001	<0.0005	<0.005	<0.001
		28-Jul-20	5.3	<0.001	0.0002	<0.0005	<0.005	<0.001

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Field			General Chemistry				Major Ions						
			pH	E C	T	pH	E C	T D S	Hardness	Chloride	Sulphate	Alkalinity	Calcium	Magnesium	Sodium	Potassium
		Units	S U	µS/cm	°C	S U	µS/cm									
		ODWQS	6.5 - 8.5 OG	nc	15 AO	6.5 - 8.5 OG	nc	500 AO	80 - 100 OG	250 AO	500 AO	30 - 500 OG	nc	nc	200 AO	nc
MW16-8OB	OB	6-Dec-16	7.9	380	10.1	7.91	740	402	380	7	96	300	76	45	9	4.4
		3-May-17	7.5	725	9.5	7.91	750	420	370	5	73	300	76	44	9	1.5
		21-Mar-18	7.4	831	8.4	7.74	750	410	380	5	80	310	78	44	9	1.5
		28-Jul-20	8.3	900	11.5	7.81	750	475	400	5	71	310	84	46	12	1.4
MW16-9A	GP	7-Dec-16	8.1	2,060	8.5	7.83	6,100	3,360	1,500	1,700	400	300	280	180	660	19
		3-May-17	7.3	20,000	11.9	7.24	61,000	41,200	1,900	24,000	700	200	390	230	1,200	30
		22-Mar-18	7.1	20,000	8.8	7.52	46,000	27,600	8,300	16,000	1,300	470	1,800	920	6,100	100
		28-Jul-20	7.0	20,000	12.6	6.84	100,000	104,000	13,000	64,000	1,300	150	3,200	1,100	11,000	130
MW16-9B	ER	7-Dec-16	7.9	1,560	8.7	7.30	13,000	1,350	3,400	3,700	1,300	410	910	280	1,500	35
		3-May-17	7.3	1,480	10.5	7.81	1,500	952	680	57	320	420	140	82	50	3
		22-Mar-18	7.4	1,977	9.3	7.70	1,500	935	720	39	370	440	140	91	47	3.1
		28-Jul-20	7.8	1,710	13.6	7.44	1,700	1,020	810	120	330	380	180	89	68	3.8
MW16-9OB	OB	7-Dec-16	7.7	1,400	8.9	7.94	1,400	924	580	29	360	420	79	94	89	9.4
		3-May-17	7.7	1,880	9.7	7.77	1,800	1,250	910	10	480	490	110	150	69	4.5
		22-Mar-18	7.6	1,765	9.2	7.81	1,700	1,030	710	9	420	530	75	130	76	4.9
		28-Jul-20	7.5	1,700	12.8	7.59	1,700	1,100	730	6	400	520	78	130	85	4.5
MW16-9SP	SO	22-Mar-18	8.1	880	4.6	8.06	920	485	380	11	71	440	33	71	47	2.1
		28-Jul-20				8.26	960	565	480	7	93	450	29	100	54	2.5
MW16-10A	GP	7-Dec-16	7.8	1,110	8.3	7.90	1,300	694	420	130	140	320	88	48	95	3.8
		3-May-17	7.8	1,230	10.4	7.64	12,000	8,010	1,400	3,200	690	450	340	130	2,400	44
		22-Mar-18	7.0	20,000	3.8	7.78	23,000	10,400	2,100	6,900	1,300	660	560	170	3,200	51
		28-Jul-20	6.7	20,000	12.3	6.73	83,000	50,400	12,000	34,000	1,200	270	3,300	1,000	7,600	120
MW16-10B	ER	7-Dec-16	7.5	1,270	9.2	7.64	1,300	802	690	7	260	480	100	100	39	3.4
		3-May-17	7.6	1,482	10.2	7.59	1,300	902	690	10	230	470	99	110	40	3.3
		22-Mar-18	7.2	1,306	9.8	7.84	1,300	635	670	8	250	480	97	110	36	3.3
		28-Jul-20	7.9	1,500	13.8	7.62	1,300	895	720	8	270	460	110	110	37	3.3
MW16-10OB	OB	7-Dec-16	7.5	1,660	7.3	7.65	1,600	1,010	830	46	300	590	110	140	55	7.3
		3-May-17	7.5	1,962	9.0	7.79	1,700	1,150	980	46	320	620	110	170	53	3.2
		22-Mar-18	7.5	1,747	6.9	7.70	1,800	1,090	960	49	330	680	110	170	49	3.1
		28-Jul-20	7.5	1,850	12.5	7.59	1,800	1,170	1,000	61	320	660	120	180	51	2.9
MW16-11	OB	5-Dec-16	7.3	5,400	11.7	7.61	5,300	3,010	1,500	1,400	260	330	280	210	510	8.2
		2-May-17	7.3	5,310	9.5	7.63	5,600	3,410	1,500	1,400	230	320	270	190	570	3.9
		22-Mar-18	7.1	4,890	9.1	7.71	5,400	2,950	1,400	1,400	240	320	260	180	470	3.7
		30-Jul-20	7.3	5,310	11.0	7.46	5,400	3,240	1,500	1,500	240	310	280	200	550	4.8

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Nitrate	Nitrite	T K N	Ammonia	Total Phosphorus	D O C	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium
			Nutrients and Organic Indicators						*Dissolved Metals*						
		Units													
		ODWQS	10.0 MAC	1.0 MAC	nc	nc	nc	5 AO	0.10 OG	0.006 IMAC	0.025 IMAC	1 MAC	nc	5 IMAC	0.005 MAC
MW16-8OB	**OB**	6-Dec-16	2.21	<0.01	0.36	0.068	8.9	1.0	0.01	<0.0005	<0.001	0.059	<0.0005	0.025	<0.0001
		3-May-17	4.94	<0.01	1.3	<0.05	140.0	0.82	<0.005	<0.0005	<0.001	0.053	<0.0005	<0.01	<0.0001
		21-Mar-18	3.65	<0.01	1.1	0.11	3.5	4.3	<0.005	<0.0005	<0.001	0.059	<0.0005	0.012	<0.0001
		28-Jul-20	6.63	0.026	0.8	<0.05	3.2	1.5	0.01	<0.0005	<0.001	0.072	<0.0004	0.015	<0.0001
MW16-9A	**GP**	7-Dec-16	<0.1	<0.01	0.41	0.33	0.039	2.7	0.0064	0.0014	0.0011	0.11	<0.0005	0.22	<0.0001
		3-May-17	<1.0	<0.1	12.0	9.9	0.11	5.9	<0.005	0.0006	0.0012	0.11	<0.0005	0.38	<0.0001
		22-Mar-18	<0.1	<0.01	11.0	9.3	0.086	140.0	0.21	<0.005	<0.01	0.23	<0.005	1.2	<0.001
		28-Jul-20	<1.0	<0.1	14.0	15.0	1.1	140.0	<0.025	<0.0025	0.0055	0.15	<0.002	2.2	<0.0005
MW16-9B	**ER**	7-Dec-16	<0.1	<0.01	0.37	0.25	<0.02	1.7	0.019	<0.0005	0.001	0.069	<0.0005	1.5	<0.0001
		3-May-17	<0.1	<0.01	0.48	0.18	0.075	1.8	0.0083	<0.0005	<0.001	0.066	<0.0005	0.076	0.0002
		22-Mar-18	<0.1	<0.01	0.29	0.35	0.042	5.0	0.0052	<0.0005	<0.001	0.072	<0.0005	0.066	<0.0001
		28-Jul-20	<0.1	<0.01	0.34	0.27	0.027	1.5	<0.0049	<0.0005	<0.001	0.064	<0.0004	0.14	<0.0001
MW16-9OB	**OB**	7-Dec-16	<0.1	0.022	0.2	0.14	5.8	3.3	0.008	0.0012	0.0031	0.091	<0.0005	0.08	<0.0001
		3-May-17	<0.1	<0.01	0.31	0.11	0.25	2.0	<0.005	<0.0005	0.0077	0.034	<0.0005	0.078	<0.0001
		22-Mar-18	<0.1	<0.01	0.27	0.25	1.7	2.5	0.0051	<0.0005	0.0048	0.037	<0.0005	0.1	<0.0001
		28-Jul-20	<0.1	<0.01	0.13	0.15	0.37	1.4	0.0084	<0.0005	0.0019	0.031	<0.0004	0.12	<0.0001
MW16-9SP	**SO**	22-Mar-18	1.33	<0.01	0.24	0.088	0.31	10.0	0.0062	<0.0005	0.0011	0.061	<0.0005	0.043	<0.0001
		28-Jul-20	1.74	<0.01	0.32	0.07	1.9	1.8	0.019	<0.0005	0.0013	0.056	<0.0004	0.064	0.0002
MW16-10A	**GP**	7-Dec-16	2.61	0.379	0.37	0.3	0.27	2.5	<0.005	0.0005	<0.001	0.081	<0.0005	0.076	<0.0001
		3-May-17	0.14	0.024	4.7	3.6	0.58	150.0	<0.025	<0.0025	0.012	0.13	<0.0025	0.84	<0.0005
		22-Mar-18	<0.5	<0.05	4.7	4.3	0.26	170.0	<0.025	<0.0025	0.019	0.15	<0.0025	1.1	<0.0005
		28-Jul-20	<1.0	<0.1	22.0	23.0	0.26	30.0	0.027	<0.0025	0.006	0.19	<0.002	2.2	<0.0005
MW16-10B	**ER**	7-Dec-16	<0.1	<0.01	<0.1	0.073	0.16	1.3	<0.005	<0.0005	<0.001	0.036	<0.0005	0.057	<0.0001
		3-May-17	<0.1	<0.01	0.21	<0.05	0.038	1.6	0.0059	<0.0005	<0.001	0.028	<0.0005	0.056	<0.0001
		22-Mar-18	<0.1	<0.01	0.31	0.17	0.16	2.0	<0.005	<0.0005	0.0012	0.027	<0.0005	0.049	<0.0001
		28-Jul-20	<0.1	<0.01	0.15	0.065	0.051	1.0	<0.0049	<0.0005	0.0011	0.033	<0.0004	0.056	<0.0001
MW16-10OB	**OB**	7-Dec-16	0.28	0.011	0.18	<0.05	0.9	4.1	0.0079	0.0006	0.001	0.13	<0.0005	0.04	<0.0001
		3-May-17	1.17	<0.01	0.27	0.061	1.9	2.9	0.0055	<0.0005	<0.001	0.054	<0.0005	0.035	<0.0001
		22-Mar-18	0.22	<0.01	0.16	0.14	1.6	3.1	<0.005	<0.0005	0.0013	0.046	<0.0005	0.032	<0.0001
		28-Jul-20	0.26	<0.01	0.22	<0.05	0.51	2.5	0.018	<0.0005	<0.001	0.041	<0.0004	0.029	<0.0001
MW16-11	**OB**	5-Dec-16	0.48	<0.01	0.17	<0.05	0.15	2.8	0.0051	<0.0005	<0.001	0.16	<0.0005	0.045	<0.0001
		2-May-17	1.71	<0.01	0.42	<0.05	0.12	2.5	<0.005	<0.0005	<0.001	0.098	<0.0005	0.023	<0.0001
		22-Mar-18	2.75	<0.01	0.77	0.07	0.086	2.9	0.0075	<0.0005	<0.001	0.092	<0.0005	0.021	0.0002
		30-Jul-20	3.12	<0.01	0.68	0.13	0.05	2.2	0.005	<0.0005	<0.001	0.098	<0.0004	0.031	<0.0001

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Chromium	Cobalt	Copper	Fluoride	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium
			Dissolved Metals												
		Units													
		ODWQS	0.05 MAC	nc	1 AO	1.5 MAC	0.30 AO	0.01 MAC	0.05 AO	0.001 MAC	nc	nc	0.01 MAC	nc	nc
MW16-8OB	**OB**	6-Dec-16	<0.005	<0.0005	0.002	0.18	<0.1	<0.0005	0.11	0.0001	0.0049	0.0012	<0.002	<0.0001	0.16
		3-May-17	<0.005	<0.0005	<0.001	0.2	<0.1	<0.0005	0.009	<0.0001	0.0014	<0.001	<0.002	<0.0001	0.12
		21-Mar-18	<0.005	<0.0005	0.0016	0.2	<0.1	<0.0005	0.0075	<0.0001	0.0017	<0.001	<0.002	<0.0001	0.12
		28-Jul-20	<0.005	<0.0005	0.0029	0.21	<0.1	<0.0005	0.0032	<0.0001	0.0013	<0.001	<0.002	<0.0001	0.13
MW16-9A	**GP**	7-Dec-16	<0.005	0.0006	<0.005	0.46	<0.1	<0.0005	0.076	<0.0001	0.017	0.0025	<0.002	<0.0001	4.8
		3-May-17	<0.005	<0.0005	<0.001	0.26	0.39	<0.0005	0.1	<0.0001	0.015	0.0011	<0.002	<0.0001	6.3
		22-Mar-18	<0.05	<0.005	<0.01	0.27	<1.0	<0.005	0.38	<0.0001	<0.005	<0.01	<0.02	<0.001	37.0
		28-Jul-20	<0.025	<0.0025	<0.0045	0.17	<0.5	<0.0025	2.8	<0.0001	<0.0025	<0.005	<0.01	<0.0005	59.0
MW16-9B	**ER**	7-Dec-16	<0.005	<0.0025	<0.001	0.57	<0.1	<0.0005	0.11	<0.0001	<0.0005	<0.005	<0.002	<0.0001	16.0
		3-May-17	<0.005	<0.0005	<0.001	0.79	<0.1	<0.0005	0.029	<0.0001	<0.0005	<0.001	<0.002	<0.0001	1.3
		22-Mar-18	<0.005	<0.0005	<0.001	0.83	<0.1	<0.0005	0.038	<0.0001	<0.0005	<0.001	<0.002	<0.0001	1.3
		28-Jul-20	<0.005	<0.0005	<0.0009	0.88	<0.1	<0.0005	0.036	<0.0001	<0.0005	<0.001	0.0021	<0.0001	1.7
MW16-9OB	**OB**	7-Dec-16	<0.005	0.0005	0.001	0.47	<0.1	<0.0005	0.082	0.0002	0.026	0.0012	<0.002	<0.0001	0.78
		3-May-17	<0.005	<0.0005	<0.001	0.71	1.3	<0.0005	0.04	<0.0001	0.0041	<0.001	<0.002	<0.0001	1.4
		22-Mar-18	<0.005	0.0006	<0.001	0.67	0.89	<0.0005	0.13	<0.0001	0.006	<0.001	<0.002	<0.0001	1.0
		28-Jul-20	<0.005	0.0009	<0.0009	0.6	0.53	<0.0005	0.042	<0.0001	0.0047	<0.001	<0.002	<0.0001	1.1
MW16-9SP	**SO**	22-Mar-18	<0.005	<0.0005	<0.001	0.6	<0.1	<0.0005	0.023	<0.0001	0.0086	<0.001	<0.002	<0.0001	0.54
		28-Jul-20	<0.005	<0.0005	0.0034	0.65	<0.1	<0.0005	<0.002	<0.0001	0.0062	<0.001	0.0021	<0.0001	0.65
MW16-10A	**GP**	7-Dec-16	<0.005	<0.0005	0.0014	0.53	<0.1	<0.0005	0.057	<0.0001	0.0075	0.0025	<0.002	<0.0001	0.71
		3-May-17	<0.025	<0.0025	<0.005	0.47	<0.5	<0.0025	0.22	<0.0001	<0.0025	<0.005	<0.01	<0.0005	7.0
		22-Mar-18	<0.025	<0.0025	<0.005	0.4	<0.5	<0.0025	0.71	<0.0001	<0.0025	<0.005	<0.01	<0.0005	10.0
		28-Jul-20	<0.025	<0.0025	<0.0045	0.17	0.65	<0.0025	4.3	<0.0001	<0.0025	<0.005	<0.01	<0.0005	57.0
MW16-10B	**ER**	7-Dec-16	<0.005	<0.0005	<0.001	1.1	<0.1	<0.0005	0.035	<0.0001	0.0006	<0.001	<0.002	<0.0001	1.0
		3-May-17	<0.005	<0.0005	<0.001	1.0	0.27	<0.0005	0.036	<0.0001	0.0011	<0.001	<0.002	<0.0001	0.96
		22-Mar-18	<0.005	<0.0005	<0.001	0.91	0.3	<0.0005	0.044	<0.0001	0.0017	<0.001	<0.002	<0.0001	0.94
		28-Jul-20	<0.005	<0.0005	<0.0009	0.99	0.17	<0.0005	0.036	<0.0001	0.0019	0.0015	<0.002	<0.0001	0.99
MW16-10OB	**OB**	7-Dec-16	<0.005	<0.0005	0.0022	0.14	<0.1	<0.0005	0.088	<0.0001	0.0087	0.0014	<0.002	<0.0001	0.88
		3-May-17	<0.005	0.0005	<0.001	0.1	<0.1	<0.0005	0.11	<0.0001	0.002	0.0014	<0.002	<0.0001	0.99
		22-Mar-18	<0.005	0.0007	0.0013	0.26	1.0	<0.0005	0.15	<0.0001	0.0015	0.0015	<0.002	<0.0001	1.0
		28-Jul-20	<0.005	<0.0005	<0.0009	0.25	0.33	<0.0005	0.059	<0.0001	0.0013	<0.001	<0.002	<0.0001	1.0
MW16-11	**OB**	5-Dec-16	<0.005	0.0012	0.0026	0.16	<0.1	<0.0005	0.077	<0.0001	0.0027	0.0021	<0.002	<0.0001	2.3
		2-May-17	<0.005	<0.0005	<0.001	0.17	<0.1	<0.0005	0.014	<0.0001	0.0011	0.0062	<0.002	<0.0001	2.1
		22-Mar-18	<0.005	<0.0005	0.0014	0.2	<0.1	<0.0005	0.0099	<0.0001	0.001	0.0018	<0.002	<0.0001	1.9
		30-Jul-20	<0.005	<0.0005	0.0028	0.21	<0.1	<0.0005	0.0027	<0.0001	0.0009	0.0017	<0.002	<0.0001	2.1

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Dissolved Metals					
			Sulphide	Tungsten	Uranium	Vanadium	Zinc	Zirconium
		Units						
		ODWQS	0.05 AO	nc	0.02 MAC	nc	5 AO	nc
MW16-8OB	OB	6-Dec-16	<0.02	<0.001	0.0062	0.001	<0.005	<0.001
		3-May-17	<0.02	<0.001	0.0054	0.002	<0.005	<0.001
		21-Mar-18	<0.02	<0.001	0.009	0.0011	<0.005	<0.001
		28-Jul-20	<0.02	<0.001	0.0054	0.0007	<0.005	<0.001
MW16-9A	GP	7-Dec-16	<0.02	0.0051	0.008	<0.0025	0.01	<0.001
		3-May-17	0.094	0.0038	0.0086	<0.0005	0.009	<0.001
		22-Mar-18	5.1	<0.01	0.0038	<0.005	<0.05	<0.01
		28-Jul-20	4.3	<0.005	0.25	0.0034	<0.025	<0.005
MW16-9B	ER	7-Dec-16	3.4	0.012	0.0043	0.0021	<0.025	0.0012
		3-May-17	4.8	0.0021	0.001	<0.0005	0.012	<0.001
		22-Mar-18	4.3	<0.001	0.0004	<0.0005	<0.005	<0.001
		28-Jul-20	4.6	<0.001	0.0002	<0.0005	<0.005	<0.001
MW16-9OB	OB	7-Dec-16	<0.02	0.003	0.0098	0.0018	0.013	<0.001
		3-May-17	<0.02	<0.001	0.0026	<0.0005	0.02	<0.001
		22-Mar-18	0.042	<0.001	0.009	0.0009	0.0056	<0.001
		28-Jul-20	0.092	<0.001	0.0079	0.001	<0.005	<0.001
MW16-9SP	SO	22-Mar-18	<0.02	<0.001	0.0046	0.0026	0.1	<0.001
		28-Jul-20		<0.001	0.0074	0.0032	0.025	<0.001
MW16-10A	GP	7-Dec-16	0.034	0.003	0.0064	<0.0005	0.017	<0.001
		3-May-17	7.6	<0.005	0.019	0.0063	<0.025	<0.005
		22-Mar-18	6.5	<0.005	0.034	0.0032	<0.025	<0.005
		28-Jul-20	1.9	<0.005	0.24	<0.0025	<0.025	<0.005
MW16-10B	ER	7-Dec-16	0.51	<0.001	0.0031	<0.0005	<0.005	<0.001
		3-May-17	3.8	<0.001	0.0057	<0.0005	0.0067	<0.001
		22-Mar-18	0.99	<0.001	0.0078	<0.0005	<0.005	<0.001
		28-Jul-20	0.13	<0.001	0.0085	<0.0005	0.019	<0.001
MW16-10OB	OB	7-Dec-16	<0.02	0.0015	0.014	0.0028	0.025	0.001
		3-May-17	<0.02	<0.001	0.018	0.0021	0.011	<0.001
		22-Mar-18	0.11	<0.001	0.018	<0.0005	<0.005	<0.001
		28-Jul-20	0.061	<0.001	0.018	0.0009	<0.005	<0.001
MW16-11	OB	5-Dec-16	<0.02	<0.001	0.014	0.0022	0.014	<0.001
		2-May-17	<0.02	<0.001	0.012	0.001	<0.005	<0.001
		22-Mar-18	<0.02	<0.001	0.011	0.0009	<0.005	<0.001
		30-Jul-20	<0.02	<0.001	0.011	0.0005	<0.005	<0.001

Table F-1 Groundwater Chemical Results

Monitor / Flow	Zone	Date	Field			General Chemistry				Major Ions						
			pH	E C	T	pH	E C	T D S	Hardness	Chloride	Sulphate	Alkalinity	Calcium	Magnesium	Sodium	Potassium
		Units	S U	µS/cm	°C	S U	µS/cm									
		ODWQS	6.5 - 8.5 OG	nc	15 AO	6.5 - 8.5 OG	nc	500 AO	80 - 100 OG	250 AO	500 AO	30 - 500 OG	nc	nc	200 AO	nc
MW16-12	OB	5-Dec-16	7.6	1,800	11.2	7.75	1,700	982	710	170	210	440	110	110	77	16
		2-May-17	7.9	2,230	8.7	7.87	2,200	1,340	990	270	290	450	110	180	65	5.1
		22-Mar-18	7.6	2,010	6.5	7.97	2,100	1,200	870	300	270	410	90	160	82	3.2
		30-Jul-20	7.6	2,950	14.9	7.67	2,800	1,960	1,400	560	350	400	130	250	89	3.2
MW16-13A	GP	5-Dec-16	7.5	5,310	8.5	7.77	5,200	3,030	1,300	1,300	330	310	310	140	500	11
		2-May-17	7.3	20,000	9.3	7.13	63,000	50,000	13,000	25,000	780	170	2,700	1,400	8,900	150
		23-Mar-18	6.3	20,000	5.0	6.65	100,000	129,000	39,000	57,000	1,800	150	8,800	4,200	28,000	370
		28-Jul-20	6.1	20,000	13.8	6.59	100,000	159,000	33,000	67,000	1,500	110	7,500	3,500	24,000	340
MW16-13B	ER	5-Dec-16	7.8	1,510	9.2	7.75	1,500	980	740	72	330	420	150	91	46	3.8
		2-May-17	7.6	1,836	9.2	7.32	1,800	1,330	880	130	440	370	210	85	52	3.6
		23-Mar-18	7.3	1,531	7.6	7.30	1,600	1,050	820	75	360	410	190	83	38	3.1
		28-Jul-20	7.8	1,860	14.7	7.56	1,400	995	730	74	310	390	170	74	39	3.2
MW16-13OB	OB	5-Dec-16 (1)														
		2-May-17	7.5	3,220	8.2	7.76	3,300	2,210	1,300	740	170	370	180	210	120	4.1
		23-Mar-18	7.4	3,300	6.8	7.71	3,400	1,910	1,300	800	140	410	220	190	110	3.2
		28-Jul-20	7.6	3,410	13.2	7.50	3,500	2,270	1,500	840	140	390	230	220	130	3.2
MW16-14	OB	6-Dec-16				8.42	740			44	91	230	10	2	150	5.6
		2-May-17	7.8	1,397	8.2	7.88	1,600	924	560	250	75	330	100	72	73	1.6
		23-Mar-18	7.6	1,695	6.9	7.86	2,100	1,090	720	350	110	440	120	100	75	1.2
		28-Jul-20	8.3	1,750	14.1	7.72	1,700	1,150	690	230	75	440	110	100	100	1.3
MW16-15	OB	5-Dec-16 (1)														
		2-May-17	7.4	8,560	9.5	7.45	8,600	6,260	3,100	2,500	560	430	440	490	620	5.6
		21-Mar-18	6.8	9,470	9.1	7.37	9,100	5,690	3,200	2,600	580	530	370	570	840	4.4
		28-Jul-20	7.4	8,180	14.3	7.47	8,500	5,890	3,000	2,400	530	460	440	470	720	5.4
MW16-16	OB	6-Dec-16	7.8	1,730	10.4	7.78	1,800	1,410	950	36	700	280	210	100	65	6
		2-May-17	7.7	1,793	9.3	7.72	1,800	1,370	860	32	610	300	170	100	59	4.5
		21-Mar-18	7.4	2,060	9.2	7.96	1,900	1,330	900	35	730	290	200	98	50	4
		30-Jul-20	8.4	1,610	11.3	7.49	1,800	1,360	960	35	680	260	210	100	51	3.7
MW16-17	OB	6-Dec-16	7.7	1,110	11.3	7.92	1,100	682	510	9	190	470	74	78	59	5.2
		3-May-17	7.8	1,113	9.5	7.92	1,000	600	490	7	130	450	58	83	40	3
		23-Mar-18	7.7	985	7.0	7.99	1,000	490	490	7	130	460	60	84	36	2.7
		29-Jul-20	8.2	1,170	11.5	7.77	1,100	630	530	7	180	460	72	85	40	3.1

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date		Nutrients and Organic Indicators						Dissolved Metals						
		Units		Nitrate	Nitrite	T K N	Ammonia	Total Phosphorus	D O C	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium
		ODWQS		10.0 MAC	1.0 MAC	nc	nc	nc	5 AO	0.10 OG	0.006 IMAC	0.025 IMAC	1 MAC	nc	5 IMAC	0.005 MAC
MW16-12	OB	5-Dec-16		0.66	0.056	0.33	0.11	0.52	3.6	0.0062	0.0005	<0.001	0.11	<0.0005	0.1	<0.0001
		2-May-17		2.48	<0.01	0.67	<0.05	0.54	2.2	<0.005	<0.0005	<0.001	0.059	<0.0005	0.05	<0.0001
		22-Mar-18		3.16	<0.01	0.59	0.086	0.71	2.9	0.0067	<0.0005	<0.001	0.048	<0.0005	0.033	0.0001
		30-Jul-20		5.42	<0.01	<0.2	<0.05	0.25	1.7	<0.0049	<0.0005	<0.001	0.049	<0.0004	0.034	0.0002
MW16-13A	GP	5-Dec-16		<0.1	<0.01	0.73	0.67	0.021	2.4	0.0067	0.0006	0.0016	0.14	<0.0005	0.13	<0.0001
		2-May-17		<1.0	<0.1	23.0	18.0	0.15	30.0	<0.025	<0.0025	<0.005	0.28	<0.0025	1.3	<0.0005
		23-Mar-18		<0.5	<0.05	48.0	40.0	0.37	150.0	<0.1	<0.01	<0.02	0.23	<0.01	3.0	<0.002
		28-Jul-20		<1.0	<0.1	47.0	50.0	0.3	25.0	0.065	<0.005	<0.01	0.28	<0.004	2.9	0.0026
MW16-13B	ER	5-Dec-16		<0.1	<0.01	0.46	0.28	0.053	1.8	0.0051	<0.0005	0.0014	0.13	<0.0005	0.098	<0.0001
		2-May-17		<0.1	<0.01	<0.5	0.2	0.026	1.5	<0.005	<0.0005	<0.001	0.035	<0.0005	0.1	<0.0001
		23-Mar-18		<0.1	<0.01	0.3	0.27	0.042	1.8	<0.005	<0.0005	<0.001	0.093	<0.0005	0.068	<0.0001
		28-Jul-20		<0.1	<0.01	0.29	0.27	<0.02	1.3	<0.0049	<0.0005	<0.001	0.1	<0.0004	0.088	<0.0001
MW16-13OB	OB	5-Dec-16	(1)													
		2-May-17		0.2	<0.01	0.21	<0.05	0.043	2.2	<0.005	<0.0005	<0.001	0.12	<0.0005	0.029	0.0004
		23-Mar-18		0.14	<0.01	0.11	0.053	0.054	3.5	0.0077	<0.0005	<0.001	0.15	<0.0005	0.019	0.0002
		28-Jul-20		0.11	<0.01	0.12	<0.05	0.048	1.1	0.0095	<0.0005	<0.001	0.13	<0.0004	0.024	0.0003
MW16-14	OB	6-Dec-16				1.6	0.99	4.1		0.091	0.0025	0.0062	0.075	<0.0005	0.2	<0.0001
		2-May-17		<0.1	<0.01	0.23	<0.05	0.16	2.1	0.01	<0.0005	<0.001	0.096	<0.0005	0.013	<0.0001
		23-Mar-18		0.2	<0.01	0.14	0.068	0.15	2.9	<0.005	<0.0005	<0.001	0.089	<0.0005	<0.01	0.0003
		28-Jul-20		<0.1	<0.01	0.15	<0.05	0.11	1.7	<0.0049	<0.0005	<0.001	0.095	<0.0004	<0.01	0.0001
MW16-15	OB	5-Dec-16	(1)													
		2-May-17		0.13	<0.01	0.23	<0.05	0.85	2.9	<0.005	<0.0005	<0.001	0.046	<0.0005	0.032	<0.0001
		21-Mar-18		<0.1	<0.01	0.17	0.12	0.33	6.3	0.023	<0.0005	<0.001	0.035	<0.0005	0.034	<0.0001
		28-Jul-20		<0.1	<0.01	0.21	0.14	0.37	2.8	<0.0049	<0.0005	<0.001	0.034	<0.0004	0.033	<0.0001
MW16-16	OB	6-Dec-16		0.33	0.022	0.16	0.13	13.0	1.7	0.014	0.0009	<0.001	0.037	<0.0005	0.22	<0.0001
		2-May-17		<0.1	<0.01	0.27	<0.05	0.19	1.2	<0.005	0.001	0.0015	0.03	<0.0005	0.22	0.0002
		21-Mar-18		<0.1	<0.01	0.25	0.28	7.7	2.3	<0.005	<0.0005	0.0019	0.026	<0.0005	0.21	<0.0001
		30-Jul-20		<0.1	<0.01	0.23	0.25	5.7	0.81	<0.0049	<0.0005	0.0058	0.023	<0.0004	0.21	<0.0001
MW16-17	OB	6-Dec-16		<0.1	<0.01	0.15	<0.05	0.36	1.5	0.011	0.0007	<0.001	0.11	<0.0005	0.15	<0.0001
		3-May-17		0.29	<0.01	0.1	<0.05	0.29	0.89	<0.005	<0.0005	<0.001	0.057	<0.0005	0.12	<0.0001
		23-Mar-18		1.19	0.025	<0.1	0.14	0.66	8.6	<0.005	<0.0005	<0.001	0.048	<0.0005	0.1	<0.0001
		29-Jul-20		0.42	<0.01	<0.1	<0.05	0.24	0.7	0.0065	<0.0005	<0.001	0.043	<0.0004	0.13	<0.0001

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Chromium	Cobalt	Copper	Fluoride	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium
			Dissolved Metals												
		Units													
		ODWQS	0.05 MAC	nc	1 AO	1.5 MAC	0.30 AO	0.01 MAC	0.05 AO	0.001 MAC	nc	nc	0.01 MAC	nc	nc
MW16-12	OB	5-Dec-16	<0.005	<0.0005	0.0016	0.28	<0.1	<0.0005	0.18	<0.0001	0.015	0.0016	0.003	<0.0001	0.46
		2-May-17	<0.005	<0.0005	0.001	0.28	<0.1	<0.0005	0.051	<0.0001	0.0044	<0.001	0.0078	<0.0001	0.67
		22-Mar-18	<0.005	<0.0005	0.0016	0.39	<0.1	<0.0005	<0.002	<0.0001	0.0026	<0.001	0.0022	<0.0001	0.66
		30-Jul-20	<0.005	<0.0005	<0.0009	0.41	<0.1	<0.0005	<0.002	<0.0001	0.0018	<0.001	0.0067	<0.0001	0.99
MW16-13A	GP	5-Dec-16	<0.005	<0.001	0.0016	0.41	0.13	<0.0005	0.084	<0.0001	0.0034	0.0026	<0.002	<0.0001	3.4
		2-May-17	<0.025	<0.0025	<0.005	0.13	3.3	<0.0025	0.34	<0.0001	0.0066	<0.005	<0.01	<0.0005	60.0
		23-Mar-18	<0.1	<0.01	<0.02	0.15	7.3	<0.01	0.87	<0.0001	<0.01	<0.02	<0.04	<0.002	170.0
		28-Jul-20	<0.05	<0.005	<0.009	0.17	9.3	<0.005	1.2	<0.0001	0.0082	<0.01	<0.02	<0.0009	170.0
MW16-13B	ER	5-Dec-16	<0.005	<0.0005	<0.001	0.86	<0.1	<0.0005	0.031	<0.0001	<0.0005	<0.001	<0.002	<0.0001	1.7
		2-May-17	<0.005	<0.0005	<0.001	0.95	0.23	<0.0005	0.028	<0.0001	<0.0005	<0.001	<0.002	<0.0001	2.1
		23-Mar-18	<0.005	<0.0005	<0.001	0.97	0.65	<0.0005	0.033	<0.0001	<0.0005	<0.001	<0.002	<0.0001	1.7
		28-Jul-20	<0.005	<0.0005	<0.0009	0.96	0.58	<0.0005	0.029	<0.0001	<0.0005	<0.001	<0.002	<0.0001	1.4
MW16-13OB	OB	5-Dec-16 (1)													
		2-May-17	<0.005	<0.0005	0.0013	0.28	<0.1	<0.0005	0.088	<0.0001	0.0069	<0.001	<0.002	<0.0001	0.75
		23-Mar-18	<0.005	<0.0005	0.0013	0.38	<0.1	<0.0005	0.12	<0.0001	0.001	<0.001	<0.002	<0.0001	0.72
		28-Jul-20	<0.005	<0.0005	0.0023	0.39	<0.1	<0.0005	0.0063	<0.0001	0.001	<0.001	<0.002	<0.0001	0.81
MW16-14	OB	6-Dec-16	0.023	<0.0005	0.0018	0.77	<0.1	<0.0005	<0.002		0.049	0.001	<0.002	<0.0001	0.13
		2-May-17	<0.005	<0.0005	<0.001	0.28	<0.1	<0.0005	0.0034	<0.0001	0.0018	<0.001	<0.002	<0.0001	0.62
		23-Mar-18	<0.005	<0.0005	<0.001	0.38	<0.1	<0.0005	<0.002	<0.0001	0.0007	<0.001	<0.002	<0.0001	0.69
		28-Jul-20	<0.005	<0.0005	0.0012	0.4	<0.1	<0.0005	0.0042	<0.0001	0.0006	<0.001	<0.002	<0.0001	0.61
MW16-15	OB	5-Dec-16 (1)													
		2-May-17	<0.005	0.0028	0.0012	0.5	0.57	<0.0005	0.4	<0.0001	0.0014	0.0042	<0.002	<0.0001	1.7
		21-Mar-18	<0.005	0.0007	0.0015	0.68	0.42	<0.0005	0.14	<0.0001	0.0013	0.0015	<0.002	<0.0001	1.9
		28-Jul-20	<0.005	0.0024	0.0016	0.65	1.7	<0.0005	0.56	<0.0001	0.0011	0.0019	<0.002	<0.0001	1.8
MW16-16	OB	6-Dec-16	<0.005	0.0006	0.0028	0.56	<0.1	<0.0005	0.099	<0.0001	0.01	0.0012	<0.002	<0.0001	2.6
		2-May-17	<0.005	0.0008	<0.001	0.7	0.1	<0.0005	0.12	<0.0001	0.0099	<0.001	<0.002	<0.0001	2.8
		21-Mar-18	<0.005	0.0006	<0.001	0.96	0.58	<0.0005	0.12	<0.0001	0.0034	0.0011	<0.002	<0.0001	2.8
		30-Jul-20	<0.005	<0.0005	0.0013	0.97	15.0	<0.0005	0.11	<0.0001	0.0024	<0.001	<0.002	<0.0001	3.0
MW16-17	OB	6-Dec-16	<0.005	<0.0005	0.0025	0.69	<0.1	<0.0005	0.09	<0.0001	0.01	<0.001	<0.002	<0.0001	1.1
		3-May-17	<0.005	<0.0005	<0.001	0.6	<0.1	<0.0005	0.047	<0.0001	0.0033	<0.001	<0.002	<0.0001	1.1
		23-Mar-18	<0.005	<0.0005	<0.001	0.95	0.14	<0.0005	0.042	<0.0001	0.0026	<0.001	<0.002	<0.0001	1.1
		29-Jul-20	<0.005	<0.0005	<0.0009	1.0	0.4	<0.0005	0.059	<0.0001	0.0022	<0.001	<0.002	<0.0001	1.2

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date		Dissolved Metals					
		Units		Sulphide	Tungsten	Uranium	Vanadium	Zinc	Zirconium
		ODWQS		0.05 AO	nc	0.02 MAC	nc	5 AO	nc
MW16-12	OB	5-Dec-16		<0.02	<0.001	0.0097	0.0023	0.62	<0.001
		2-May-17		<0.02	<0.001	0.014	0.003	0.0092	<0.001
		22-Mar-18		<0.02	<0.001	0.012	0.0019	<0.005	<0.001
		30-Jul-20		<0.02	<0.001	0.017	0.0015	<0.005	<0.001
MW16-13A	GP	5-Dec-16		0.022	0.012	0.0027	<0.001	0.025	<0.001
		2-May-17		0.078	<0.005	0.019	<0.0025	<0.025	<0.005
		23-Mar-18		0.63	<0.02	0.05	<0.01	<0.1	<0.02
		28-Jul-20		0.58	<0.01	0.098	<0.005	<0.05	<0.01
MW16-13B	ER	5-Dec-16		5.4	0.0063	0.0021	<0.0005	0.0068	<0.001
		2-May-17		17.0	0.0013	0.0004	<0.0005	<0.005	<0.001
		23-Mar-18		13.0	<0.001	0.0007	<0.0005	<0.005	<0.001
		28-Jul-20		6.0	<0.001	0.0006	<0.0005	<0.005	<0.001
MW16-13OB	OB	5-Dec-16	(1)						
		2-May-17		<0.02	<0.001	0.0099	0.0029	0.026	<0.001
		23-Mar-18		<0.02	<0.001	0.0074	0.002	0.0066	<0.001
		28-Jul-20		<0.02	<0.001	0.008	0.0011	0.0066	<0.001
MW16-14	OB	6-Dec-16			<0.001	0.0023	0.012	<0.005	<0.001
		2-May-17		<0.02	<0.001	0.0056	0.0033	0.015	<0.001
		23-Mar-18		<0.02	<0.001	0.0061	0.0029	0.0063	<0.001
		28-Jul-20		<0.02	<0.001	0.0053	0.0013	<0.005	<0.001
MW16-15	OB	5-Dec-16	(1)						
		2-May-17		<0.02	<0.001	0.011	0.0009	0.048	<0.001
		21-Mar-18		<0.02	<0.001	0.014	<0.0005	0.013	<0.001
		28-Jul-20		<0.02	<0.001	0.0077	<0.0005	0.0059	<0.001
MW16-16	OB	6-Dec-16		<0.02	<0.001	0.014	0.0029	0.047	<0.001
		2-May-17		<0.02	<0.001	0.0099	0.0022	0.38	<0.001
		21-Mar-18		0.078	<0.001	0.0056	0.0005	0.0064	<0.001
		30-Jul-20		0.073	<0.001	0.0036	<0.0005	<0.005	<0.001
MW16-17	OB	6-Dec-16		<0.02	<0.001	0.0077	0.004	0.012	<0.001
		3-May-17		<0.02	<0.001	0.006	0.0033	<0.005	<0.001
		23-Mar-18		0.044	<0.001	0.0051	0.0026	<0.005	<0.001
		29-Jul-20		<0.02	<0.001	0.0052	0.001	<0.005	<0.001

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Field			General Chemistry				Major Ions						
			pH	E C	T	pH	E C	T D S	Hardness	Chloride	Sulphate	Alkalinity	Calcium	Magnesium	Sodium	Potassium
		Units	S U	µS/cm	°C	S U	µS/cm									
		ODWQS	6.5 - 8.5 OG	nc	15 AO	6.5 - 8.5 OG	nc	500 AO	80 - 100 OG	250 AO	500 AO	30 - 500 OG	nc	nc	200 AO	nc
MW16-18B	ER	5-Dec-16	8.0	1,000	10.3	7.70	1,000	584	520	23	110	430	98	67	28	2
		3-May-17	7.4	1,148	9.0	7.59	1,000	632	540	18	150	430	87	79	31	2
		22-Mar-18	7.5	1,168	7.1	7.89	1,000	555	530	9	130	460	80	80	27	1.9
		29-Jul-20	7.9	1,240	12.0	7.71	1,100	670	600	10	170	450	98	86	33	2.3
MW16-18OB	OB	5-Dec-16		1,230	7.9	10.80	1,100	632	250	81	270	100	99	1	100	3.5
		3-May-17	8.7	1,044	10.6	8.39	1,000	664	360	72	240	180	87	36	63	2
		22-Mar-18	7.9	1,496	4.2	7.94	1,300	755	600	48	210	460	140	58	55	0.83
		29-Jul-20 (3)														
MW16-19B	ER	5-Dec-16	7.2	1,390	10.8	7.60	1,400	954	730	29	360	430	130	100	39	2.8
		3-May-17	7.7	1,445	8.8	7.68	1,500	984	730	32	360	450	120	110	38	2.4
		20-Mar-18	7.6	1,370	5.6	7.60	1,400	855	750	29	300	470	120	110	35	2.3
		29-Jul-20	7.7	1,460	14.5	7.63	1,300	915	740	25	270	470	120	100	33	2.9
MW16-19OB	OB	5-Dec-16 (1)														
		3-May-17	7.7	911	11.8	8.05	760	466	330	14	84	260	90	27	23	1.7
		20-Mar-18	7.8	1,424	3.0	7.91	1,200	765	290	24	210	470	81	20	190	1.5
		29-Jul-20 (3)														
MW17-20A	GP	20-Mar-18	7.4	13,700	10.1	7.49	12,000	5,710	2,100	3,900	110	120	490	210	1,400	24
		29-Jul-20	7.6	20,000	14.5	6.94	87,000	62,200	22,000	40,000	500	93	5,000	2,300	15,000	220
MW17-20B	ER	20-Mar-18	7.3	1,215	10.4	7.83	1,100	605	540	13	170	420	92	76	33	2.5
		29-Jul-20	8.0	1,140	11.3	7.77	1,000	645	560	13	170	390	100	76	32	2.6
MW17-20OB	OB	20-Mar-18	8.0	678	7.9	7.88	660	270	320	2	39	330	69	37	18	1.4
		29-Jul-20 (2)														
MW17-20SP	SO	20-Mar-18	8.4	1,636	6.2	8.00	520	225	240	10	34	230	58	23	18	1.4
		29-Jul-20 (1)														
MW17-21B	ER	21-Mar-18	7.2	1,240	8.6	7.64	1,100	605	590	24	160	430	110	79	29	2.3
		28-Jul-20	7.5	1,053	14.5	7.59	1,000	675	550	22	160	400	120	63	24	2.2
MW17-21OB	OB	21-Mar-18	7.3	1,058	7.9	7.51	970	510	480	10	150	400	90	62	26	3.3
		28-Jul-20	8.2	1,120	14.0	7.71	960	605	500	11	150	380	93	65	29	2.8
MW17-21SP	SO	21-Mar-18	7.6	866	4.5	8.00	780	375	390	7	37	400	64	56	18	2.2
		28-Jul-20	8.3	870	21.1	7.79	730	520	310	3	41	350	76	30	50	1.3
MW17-22B	ER	22-Mar-18	7.1	1,240	9.2	7.70	1,300	910	730	31	350	390	190	61	17	2.7
		28-Jul-20	7.7	1,260	11.2	7.63	1,200	905	690	31	300	370	180	57	21	2.9
MW17-22OB	OB	22-Mar-18				7.92	1,300	700	410	27	170	500	56	66	110	3.2
		28-Jul-20	8.0	1,530	20.1	7.95	1,400	830	600	16	220	530	77	98	92	2.8

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Nitrate	Nitrite	T K N	Ammonia	Total Phosphorus	D O C	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium
			Nutrients and Organic Indicators						*Dissolved Metals*						
		Units													
		ODWQS	10.0 MAC	1.0 MAC	nc	nc	nc	5 AO	0.10 OG	0.006 IMAC	0.025 IMAC	1 MAC	nc	5 IMAC	0.005 MAC
MW16-18B	ER	5-Dec-16	0.16	<0.01	0.14	<0.05	0.22	1.2	0.074	<0.0005	0.0024	0.048	<0.0005	0.035	<0.0001
		3-May-17	<0.1	<0.01	0.15	<0.05	0.16	1.2	<0.005	<0.0005	0.0029	0.036	<0.0005	0.045	<0.0001
		22-Mar-18	<0.1	<0.01	0.15	0.1	0.3	1.8	0.019	<0.0005	0.0016	0.029	<0.0005	0.033	<0.0001
		29-Jul-20	<0.1	<0.01	0.17	0.077	0.12	1.1	0.0063	<0.0005	0.0087	0.046	<0.0004	0.044	<0.0001
MW16-18OB	OB	5-Dec-16	0.33	0.105	0.44	0.12	0.37	6.8	0.21	0.0007	0.005	0.047	<0.0005	0.057	<0.0001
		3-May-17	<0.1	<0.01	0.91	0.15	1.3	4.0	0.0088	<0.0005	0.0034	0.053	<0.0005	0.059	<0.0001
		22-Mar-18	<0.1	<0.01	0.26	0.15	0.7	3.2	0.018	<0.0005	0.0013	0.062	<0.0005	0.032	<0.0001
		29-Jul-20 (3)													
MW16-19B	ER	5-Dec-16	<0.1	<0.01	0.15	0.077	0.094	2.1	0.021	<0.0005	0.0026	0.072	<0.0005	0.04	<0.0001
		3-May-17	<0.1	<0.01	0.26	0.05	0.11	1.7	0.022	<0.0005	0.0019	0.076	<0.0005	0.032	<0.0001
		20-Mar-18	0.43	0.018	0.12	0.1	0.31	2.3	<0.005	<0.0005	<0.001	0.063	<0.0005	0.028	<0.0001
		29-Jul-20	<0.1	<0.01	<0.1	0.061	0.12	1.1	<0.0049	<0.0005	0.0034	0.072	<0.0004	0.035	<0.0001
MW16-19OB	OB	5-Dec-16 (1)													
		3-May-17	6.09	<0.01	<0.5	<0.05	0.12	2.5	0.0059	<0.0005	<0.001	0.068	<0.0005	0.031	0.0005
		20-Mar-18	<0.5	<0.05	<1.0	0.21	1.4	19.0	0.036	0.0008	<0.001	0.12	<0.0005	0.091	<0.0001
		29-Jul-20 (3)													
MW17-20A	GP	20-Mar-18	<0.1	<0.01	2.3	2.2	0.025	8.5	<0.005	<0.0005	<0.001	0.046	<0.0005	0.16	<0.0001
		29-Jul-20	<1.0	<0.1	18.0	20.0	0.15	7.0	<0.049	<0.005	<0.01	0.16	<0.004	1.1	<0.0009
MW17-20B	ER	20-Mar-18	2.5	<0.01	<0.1	<0.05	0.022	2.2	<0.005	<0.0005	<0.001	0.042	<0.0005	0.042	<0.0001
		29-Jul-20	1.97	<0.01	<0.1	<0.05	<0.02	0.88	0.0083	<0.0005	<0.001	0.044	<0.0004	0.046	0.0002
MW17-20OB	OB	20-Mar-18	0.26	<0.01	<0.2	0.076	0.62	0.94	<0.005	<0.0005	<0.001	0.073	<0.0005	0.011	<0.0001
		29-Jul-20 (2)													
MW17-20SP	SO	20-Mar-18	1.15	<0.01	<0.1	0.062	0.18	1.7	0.012	<0.0005	0.001	0.052	<0.0005	0.016	<0.0001
		29-Jul-20 (1)													
MW17-21B	ER	21-Mar-18	<0.1	<0.01	0.16	0.13	0.027	1.9	<0.005	<0.0005	<0.001	0.1	<0.0005	0.036	<0.0001
		28-Jul-20	<0.1	<0.01	0.18	0.12	<0.02	1.4	<0.0049	<0.0005	<0.001	0.12	<0.0004	0.03	<0.0001
MW17-21OB	OB	21-Mar-18	0.64	<0.01	0.39	0.18	21.0	7.1	<0.005	<0.0005	<0.001	0.051	<0.0005	0.03	<0.0001
		28-Jul-20	0.9	<0.01	0.31	<0.05	11.0	0.77	0.012	<0.0005	<0.001	0.083	<0.0004	0.03	<0.0001
MW17-21SP	SO	21-Mar-18	1.13	<0.01	0.1	0.07	0.3	4.5	<0.005	<0.0005	<0.001	0.092	<0.0005	0.024	<0.0001
		28-Jul-20	0.5	<0.01	0.39	0.06	1.2	4.9	0.06	0.0011	<0.001	0.07	<0.0004	0.027	<0.0001
MW17-22B	ER	22-Mar-18	<0.1	<0.01	0.27	0.21	<0.02	1.6	<0.005	<0.0005	<0.001	0.016	<0.0005	0.05	<0.0001
		28-Jul-20	<0.1	<0.01	0.3	0.14	<0.02	1.3	<0.0049	<0.0005	<0.001	0.018	<0.0004	0.062	<0.0001
MW17-22OB	OB	22-Mar-18	<0.1	<0.01	0.19	0.11	0.36	2.6	0.014	0.0006	<0.001	0.085	<0.0005	0.045	<0.0001
		28-Jul-20	0.47	<0.01	0.19	<0.05	0.1	1.5	<0.0049	<0.0005	<0.001	0.068	<0.0004	0.035	<0.0001

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Dissolved Metals												
			Chromium	Cobalt	Copper	Fluoride	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium
		Units													
		ODWQS	0.05 MAC	nc	1 AO	1.5 MAC	0.30 AO	0.01 MAC	0.05 AO	0.001 MAC	nc	nc	0.01 MAC	nc	nc
MW16-18B	ER	5-Dec-16	<0.005	<0.0005	<0.001	0.82	0.17	0.0028	0.042	<0.0001	0.0012	<0.001	<0.002	<0.0001	0.59
		3-May-17	<0.005	<0.0005	<0.001	0.82	0.26	<0.0005	0.032	<0.0001	0.0022	<0.001	<0.002	<0.0001	0.77
		22-Mar-18	<0.005	<0.0005	0.0011	0.78	0.19	<0.0005	0.024	<0.0001	0.0023	<0.001	<0.002	<0.0001	0.63
		29-Jul-20	<0.005	<0.0005	<0.0009	0.76	1.3	<0.0005	0.028	<0.0001	0.0012	<0.001	<0.002	<0.0001	0.68
MW16-18OB	OB	5-Dec-16	0.13	<0.0005	0.0048	1.0	<0.1	<0.0005	<0.002	<0.0001	0.026	0.0014	<0.002	<0.0001	0.46
		3-May-17	0.0053	<0.0005	<0.001	0.41	<0.1	<0.0005	0.14	<0.0001	0.0053	0.0015	<0.002	<0.0001	0.46
		22-Mar-18	<0.005	0.0005	0.001	0.27	0.43	<0.0005	0.83	<0.0001	0.0014	0.0018	<0.002	<0.0001	0.6
		29-Jul-20 (3)													
MW16-19B	ER	5-Dec-16	<0.005	<0.0005	<0.001	0.87	0.18	0.001	0.047	<0.0001	0.0012	<0.001	<0.002	<0.0001	0.63
		3-May-17	<0.005	<0.0005	<0.001	0.83	0.27	0.0036	0.045	<0.0001	0.0013	<0.001	<0.002	<0.0001	0.61
		20-Mar-18	<0.005	<0.0005	0.0019	0.78	<0.1	<0.0005	0.042	<0.0001	0.0015	0.0012	<0.002	<0.0001	0.63
		29-Jul-20	<0.005	<0.0005	<0.0009	0.81	0.56	<0.0005	0.03	<0.0001	0.0025	0.0014	<0.002	<0.0001	0.66
MW16-19OB	OB	5-Dec-16 (1)													
		3-May-17	<0.005	<0.0005	0.002	0.32	<0.1	<0.0005	0.0089	<0.0001	0.0064	<0.001	<0.002	<0.0001	0.34
		20-Mar-18	<0.005	<0.0005	<0.001	0.41	0.24	<0.0005	0.24	<0.0001	0.022	0.0021	<0.002	<0.0001	0.33
		29-Jul-20 (3)													
MW17-20A	GP	20-Mar-18	<0.005	<0.0005	<0.001	0.18	0.37	<0.0005	0.096	<0.0001	0.0032	<0.001	0.0022	<0.0001	9.2
		29-Jul-20	<0.05	<0.005	<0.009	0.24	<1.0	<0.005	0.76	<0.0001	<0.005	<0.01	<0.02	<0.0009	100.0
MW17-20B	ER	20-Mar-18	<0.005	<0.0005	<0.001	1.0	<0.1	0.0009	<0.002	<0.0001	0.0019	<0.001	<0.002	<0.0001	0.56
		29-Jul-20	<0.005	<0.0005	<0.0009	1.1	<0.1	0.0005	0.0024	<0.0001	0.0011	<0.001	<0.002	<0.0001	0.56
MW17-20OB	OB	20-Mar-18	<0.005	<0.0005	<0.001	0.32	<0.1	<0.0005	<0.002	<0.0001	0.0011	<0.001	<0.002	<0.0001	0.27
		29-Jul-20 (2)													
MW17-20SP	SO	20-Mar-18	<0.005	<0.0005	<0.001	0.31	<0.1	<0.0005	0.0023	<0.0001	0.0057	<0.001	<0.002	<0.0001	0.18
		29-Jul-20 (1)													
MW17-21B	ER	21-Mar-18	<0.005	<0.0005	<0.001	0.87	0.25	<0.0005	0.017	<0.0001	0.013	<0.001	<0.002	<0.0001	0.58
		28-Jul-20	<0.005	<0.0005	<0.0009	0.89	<0.1	<0.0005	0.023	<0.0001	<0.0005	<0.001	<0.002	<0.0001	0.64
MW17-21OB	OB	21-Mar-18	<0.005	<0.0005	<0.001	0.57	<0.1	<0.0005	0.079	<0.0001	0.002	<0.001	<0.002	<0.0001	0.32
		28-Jul-20	<0.005	<0.0005	0.0011	0.59	<0.1	<0.0005	0.03	0.0001	0.0014	<0.001	<0.002	<0.0001	0.36
MW17-21SP	SO	21-Mar-18	<0.005	<0.0005	0.0024	0.32	<0.1	<0.0005	0.062	<0.0001	0.0044	<0.001	<0.002	<0.0001	0.31
		28-Jul-20	<0.005	<0.0005	0.0035	0.42	<0.1	<0.0005	0.008	<0.0001	0.0064	0.0013	<0.002	<0.0001	0.33
MW17-22B	ER	22-Mar-18	<0.005	<0.0005	<0.001	1.0	<0.1	<0.0005	0.018	<0.0001	<0.0005	<0.001	<0.002	<0.0001	1.6
		28-Jul-20	<0.005	<0.0005	<0.0009	0.95	<0.1	<0.0005	0.016	<0.0001	<0.0005	<0.001	<0.002	<0.0001	1.6
MW17-22OB	OB	22-Mar-18	<0.005	<0.0005	0.0047	0.58	<0.1	<0.0005	0.061	<0.0001	0.029	0.001	<0.002	<0.0001	0.24
		28-Jul-20	<0.005	<0.0005	<0.0009	0.6	<0.1	<0.0005	0.024	<0.0001	0.0058	<0.001	<0.002	<0.0001	0.23

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date		Sulphide	Tungsten	Uranium	Vanadium	Zinc	Zirconium
				Dissolved Metals					
		Units							
		ODWQS		0.05 AO	nc	0.02 MAC	nc	5 AO	nc
MW16-18B	ER	5-Dec-16		<0.02	<0.001	0.0041	<0.0005	0.02	<0.001
		3-May-17		0.025	<0.001	0.005	<0.0005	0.015	<0.001
		22-Mar-18		0.023	<0.001	0.0047	<0.0005	0.014	<0.001
		29-Jul-20		0.061	<0.001	0.0035	<0.0005	0.0076	<0.001
MW16-18OB	OB	5-Dec-16		<0.02	0.0011	<0.0001	0.066	<0.005	<0.001
		3-May-17		<0.02	<0.001	0.0068	0.01	0.023	<0.001
		22-Mar-18		0.14	<0.001	0.0048	0.0009	0.25	<0.001
		29-Jul-20	(3)						
MW16-19B	ER	5-Dec-16		0.13	<0.001	0.0019	<0.0005	0.0083	<0.001
		3-May-17		0.055	<0.001	0.0039	<0.0005	0.043	<0.001
		20-Mar-18		0.3	<0.001	0.0055	<0.0005	0.14	<0.001
		29-Jul-20		<0.02	<0.001	0.0085	<0.0005	0.24	<0.001
MW16-19OB	OB	5-Dec-16	(1)						
		3-May-17		<0.02	<0.001	0.0073	0.0037	0.56	<0.001
		20-Mar-18		0.25	<0.001	0.021	0.0009	<0.005	<0.001
		29-Jul-20	(3)						
MW17-20A	GP	20-Mar-18		1.5	0.0023	0.0023	<0.0005	<0.005	<0.001
		29-Jul-20		2.2	<0.01	0.0015	<0.005	<0.05	<0.01
MW17-20B	ER	20-Mar-18		0.67	<0.001	0.0056	<0.0005	1.4	<0.001
		29-Jul-20		<0.02	<0.001	0.0049	<0.0005	0.74	<0.001
MW17-20OB	OB	20-Mar-18		<0.02	<0.001	0.0033	0.0014	0.0077	<0.001
		29-Jul-20	(2)						
MW17-20SP	SO	20-Mar-18		<0.02	<0.001	0.0026	0.0017	0.18	<0.001
		29-Jul-20	(1)						
MW17-21B	ER	21-Mar-18		0.49	0.002	0.0017	<0.0005	<0.005	<0.001
		28-Jul-20		1.3	<0.001	0.0001	<0.0005	<0.005	<0.001
MW17-21OB	OB	21-Mar-18		0.024	<0.001	0.0072	<0.0005	<0.005	<0.001
		28-Jul-20		<0.02	<0.001	0.0073	<0.0005	0.0079	<0.001
MW17-21SP	SO	21-Mar-18		<0.02	<0.001	0.0034	0.0017	0.12	<0.001
		28-Jul-20		<0.02	<0.001	0.0096	0.0008	<0.005	<0.001
MW17-22B	ER	22-Mar-18		13.0	<0.001	0.0001	<0.0005	<0.005	<0.001
		28-Jul-20		6.4	<0.001	0.0001	<0.0005	<0.005	<0.001
MW17-22OB	OB	22-Mar-18		<0.02	<0.001	0.0081	0.0017	0.081	<0.001
		28-Jul-20		0.039	<0.001	0.0075	0.0018	0.0071	<0.001

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Field pH	Field E C	Field T	General Chemistry pH	General Chemistry E C	T D S	Hardness	Chloride	Sulphate	Alkalinity	Calcium	Magnesium	Sodium	Potassium
		Units	S U	µS/cm	°C	S U	µS/cm									
		ODWQS	6.5 - 8.5 OG	nc	15 AO	6.5 - 8.5 OG	nc	500 AO	80 - 100 OG	250 AO	500 AO	30 - 500 OG	nc	nc	200 AO	nc
MW17-22SP	SO	22-Mar-18	7.9	1,130	3.3	8.15	1,200	650	540	12	160	510	44	100	43	1
		28-Jul-20	8.0	1,310	22.8	7.96	1,200	655	610	12	200	480	45	120	53	1
MW17-23B	ER	22-Mar-18	7.1	1,369	9.2	7.38	1,500	910	730	17	360	460	130	98	39	2.8
		28-Jul-20	7.5	2,070	14.5	7.56	2,000	1,460	1,100	77	650	390	280	95	67	4.3
MW17-23OB	OB	22-Mar-18	7.4	1,734	9.4	7.73	1,500	980	800	9	370	510	110	130	47	4.2
		28-Jul-20	7.8	1,533	11.6	7.72	1,500	1,080	820	8	390	470	110	130	46	4.1
MW17-23SP	SO	22-Mar-18	7.7	947	5.5	7.93	990	515	450	23	170	370	87	56	32	1.4
		28-Jul-20	8.0	1,060	16.2	7.91	1,000	600	510	21	150	480	85	71	32	1.6
R2		8-Aug-18	7.5	1,134	12.4	7.80	1,100	610	620	63	77	460	74	100	42	3.6
R3		9-Aug-18	7.8	1,059	11.8	8.11	1,600	940	7	16	380	360	1	1	360	1.9
R11		25-Jun-19	7.1	2,690	18.3	7.73	3,250	2,440	1,210	522	688	405	308	106	250	23

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Nitrate	Nitrite	T K N	Ammonia	Total Phosphorus	D O C	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium
			Nutrients and Organic Indicators						*Dissolved Metals*						
		Units													
		ODWQS	10.0 MAC	1.0 MAC	nc	nc	nc	5 AO	0.10 OG	0.006 IMAC	0.025 IMAC	1 MAC	nc	5 IMAC	0.005 MAC
MW17-22SP	**SO**	22-Mar-18	0.57	0.011	0.29	0.23	1.9	7.1	0.0075	<0.0005	<0.001	0.056	<0.0005	0.013	<0.0001
		28-Jul-20	0.25	<0.01	0.26	<0.05	0.31	2.1	0.095	0.0006	<0.001	0.064	<0.0004	0.021	<0.0001
MW17-23B	**ER**	22-Mar-18	<0.1	<0.01	0.23	0.17	0.079	2.3	0.012	<0.0005	<0.001	0.045	<0.0005	0.045	<0.0001
		28-Jul-20	<0.1	<0.01	0.42	0.34	<0.4	1.4	0.012	<0.0005	<0.001	0.027	<0.0004	0.12	<0.0001
MW17-23OB	**OB**	22-Mar-18	0.28	<0.01	0.29	0.23	15.0	5.4	0.0052	<0.0005	<0.001	0.031	<0.0005	0.054	0.0001
		28-Jul-20	0.24	<0.01	0.11	<0.05	1.2	0.96	<0.0049	<0.0005	<0.001	0.032	<0.0004	0.06	0.0003
MW17-23SP	**SO**	22-Mar-18	0.82	<0.01	<0.2	0.093	0.3	2.6	0.0076	<0.0005	<0.001	0.066	<0.0005	0.017	<0.0001
		28-Jul-20	<0.1	<0.01	<0.5	0.099	1.2	1.5	0.02	<0.0005	<0.001	0.068	<0.0004	0.021	<0.0001
R2		8-Aug-18	<0.1	<0.01	0.12	0.13	0.053	1.2	<0.005	<0.0005	0.017	0.069	<0.0005	0.11	<0.0001
R3		9-Aug-18	<0.1	<0.01	0.16	0.17	0.02	1.3	<0.005	<0.0005	0.0015	<0.002	<0.0005	0.17	<0.0001
R11		25-Jun-19	<0.1	<0.1	1.14	0.9	0.07	1.4	<0.1	<0.005	<0.01	<0.1	<0.005	0.7	<0.001

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Chromium	Cobalt	Copper	Fluoride	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium
			Dissolved Metals												
		Units													
		ODWQS	0.05 MAC	nc	1 AO	1.5 MAC	0.30 AO	0.01 MAC	0.05 AO	0.001 MAC	nc	nc	0.01 MAC	nc	nc
MW17-22SP	SO	22-Mar-18	<0.005	<0.0005	0.001	0.86	<0.1	<0.0005	0.12	<0.0001	0.0057	<0.001	<0.002	<0.0001	0.41
		28-Jul-20	<0.005	<0.0005	0.0036	1.0	0.13	<0.0005	0.0074	<0.0001	0.0038	<0.001	<0.002	<0.0001	0.48
MW17-23B	ER	22-Mar-18	<0.005	<0.0005	<0.001	0.79	0.97	<0.0005	0.042	<0.0001	0.0007	<0.001	<0.002	<0.0001	0.9
		28-Jul-20	<0.005	<0.0005	<0.0009	0.96	<0.1	<0.0005	0.03	<0.0001	<0.0005	<0.001	<0.002	<0.0001	2.2
MW17-23OB	OB	22-Mar-18	<0.005	0.0009	0.0015	0.6	<0.1	<0.0005	0.11	<0.0001	0.0034	0.0026	<0.002	<0.0001	0.82
		28-Jul-20	<0.005	0.0008	0.0013	0.75	<0.1	<0.0005	0.11	<0.0001	0.0026	0.0034	<0.002	<0.0001	0.86
MW17-23SP	SO	22-Mar-18	<0.005	<0.0005	<0.001	0.28	<0.1	<0.0005	0.0039	<0.0001	0.0043	<0.001	<0.002	<0.0001	0.51
		28-Jul-20	<0.005	<0.0005	0.0017	0.25	0.37	<0.0005	0.055	<0.0001	0.0022	<0.001	<0.002	<0.0001	0.57
R2		8-Aug-18	0.0057	0.0007	<0.001	0.42	1.3	<0.0005	0.065	<0.0001	0.0025	0.01	<0.002	<0.0001	1.1
R3		9-Aug-18	<0.005	<0.0005	0.004	1.0	<0.1	<0.0005	<0.002	<0.0001	0.0024	<0.001	<0.002	<0.0001	0.013
R11		25-Jun-19	<0.01	<0.002	<0.01	0.79	1.0	<0.01	<0.1	<0.0001	<0.05	<0.05	<0.01	<0.001	3.95

Table F-1 Groundwater Chemical Results

Monitor / Flow Zone		Date	Sulphide	Tungsten	Uranium	Vanadium	Zinc	Zirconium
			Dissolved Metals					
		Units						
		ODWQS	0.05 AO	nc	0.02 MAC	nc	5 AO	nc
MW17-22SP	**SO**	22-Mar-18	<0.02	<0.001	0.0092	0.0021	0.1	<0.001
		28-Jul-20	0.021	<0.001	0.013	0.0021	0.021	<0.001
MW17-23B	**ER**	22-Mar-18	0.19	<0.001	0.0016	<0.0005	<0.005	<0.001
		28-Jul-20	5.1	<0.001	0.0008	<0.0005	<0.005	<0.001
MW17-23OB	**OB**	22-Mar-18	0.043	<0.001	0.015	<0.0005	0.24	<0.001
		28-Jul-20	<0.02	<0.001	0.013	<0.0005	0.53	<0.001
MW17-23SP	**SO**	22-Mar-18	<0.02	<0.001	0.0068	0.0021	0.048	<0.001
		28-Jul-20	0.11	<0.001	0.0058	<0.0005	0.0066	<0.001
R2		8-Aug-18	<0.02	<0.001	0.0035	<0.0005	<0.005	<0.001
R3		9-Aug-18	<0.02	<0.001	0.0004	<0.0005	0.0085	<0.001
R11		25-Jun-19	<0.01	<0.02	<0.01	<0.01	0.2	<0.02

Table F-2 Groundwater VOC Results

Monitor / Flow Zone		Date	Benzene	Toluene	Ethylbenzene	Total Xylenes
		ODWQS	1 MAC	24 AO	2.4 AO	300 AO
BH03-2A	GP	22-Mar-18	4.0	0.6	0.64	3.6
BH03-2B	ER	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW11-1A	DC	21-Mar-18	0.91	1.7	1.9	1.3
MW11-1B	ER	21-Mar-18	0.26	<0.2	<0.2	<0.4
MW11-1OB	OB	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW11-2A	RO	21-Mar-18	6.3	5.1	1.7	2.9
MW11-2B	ER	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW11-2OB	OB	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW11-3AR	GP	20-Mar-18	30.0	18.0	1.3	8.2
MW11-3BR	ER	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW11-3OBR	OB	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW11-4A	RO	22-Mar-18	35.0	19.0	1.8	13.0
MW11-4B	ER	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW11-4OB	OB	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-5A	GP	20-Mar-18	84.0	53.0	3.3	23.0
MW16-5AR	GP	20-Mar-18	77.0	47.0	2.9	20.0
MW16-5B	ER	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-5OB	OB	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-6A	GP	20-Mar-18	12.0	3.8	<0.2	1.1
MW16-6B	ER	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-6OB	OB	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-7A	GP	21-Mar-18	16.0	21.0	2.9	23.0
MW16-7B	ER	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-7OB	OB	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-8A	GP	21-Mar-18	0.59	0.52	<0.2	0.94
MW16-8B	ER	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-8OB	OB	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-9A	GP	22-Mar-18	13.0	4.3	0.47	3.3
MW16-9B	ER	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-9OB	OB	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-9SP	SO	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-10A	GP	22-Mar-18	14.0	2.3	0.32	2.6
MW16-10B	ER	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-10OB	OB	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-11	OB	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-12	OB	22-Mar-18	<0.2	<0.2	<0.2	<0.4

Table F-2 Groundwater VOC Results

Monitor / Flow Zone		Date	Benzene	Toluene	Ethylbenzene	Total Xylenes
		ODWQS	1 MAC	24 AO	2.4 AO	300 AO
MW16-13A	GP	23-Mar-18	37.0	22.0	1.9	14.0
MW16-13B	ER	23-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-13OB	OB	23-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-14	OB	23-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-15	OB	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-16	OB	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-17	OB	23-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-18B	ER	22-Mar-18	<0.2	0.22	<0.2	<0.4
MW16-18OB	OB	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-19B	ER	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW16-19OB	OB	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-20A	GP	20-Mar-18	11.0	8.5	0.82	5.7
MW17-20B	ER	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-20OB	OB	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-20SP	SO	20-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-21B	ER	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-21OB	OB	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-21SP	SO	21-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-22B	ER	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-22OB	OB	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-22SP	SO	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-23B	ER	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-23OB	OB	22-Mar-18	<0.2	<0.2	<0.2	<0.4
MW17-23SP	SO	22-Mar-18	<0.2	<0.2	<0.2	<0.4

Table F-3 Groundwater QA/QC Results

05-Dec-16

Parameter	RDL	Original MW16-19B	Duplicate OW100	RPD
E C	1	1400	1400	<1
T D S	10	954	934	2
Hardness	1	730	750	3
Chloride	1	29	29	<1
Sulphate	1	360	320	12
Alkalinity	1	430	430	<1
Calcium	0.2	130	130	<1
Magnesium	0.05	100	100	<1
Sodium	0.1	39	41	5
Potassium	0.2	2.8	2.9	4
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.15	0.15	<2 RDL
Ammonia	0.05	0.077	0.076	<2 RDL
Total Phosphorus	0.02	0.094	0.088	<2 RDL
D O C	0.2	2.1	2	5
Aluminum	0.005	0.021	0.028	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	0.0026	0.003	<2 RDL
Barium	0.002	0.072	0.071	1
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.04	0.039	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	0.87	0.87	<1
Iron	0.1	0.18	0.19	<2 RDL
Lead	0.0005	0.00096	0.00096	<2 RDL
Manganese	0.002	0.047	0.048	2
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0012	0.0012	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.63	0.63	<1
Sulphide	0.02	0.13	0.12	8
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0019	0.0018	5
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	0.0083	0.01	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

06-Dec-16

Parameter	RDL	Original MW11-2B	Duplicate OW200	RPD
E C	1	1300	1300	<1
T D S	10	838	792	6
Hardness	1	630	620	2
Chloride	1	93	90	3
Sulphate	1	230	220	4
Alkalinity	1	400	400	<1
Calcium	0.2	120	120	<1
Magnesium	0.05	81	79	3
Sodium	0.1	51	49	4
Potassium	0.2	2.9	2.8	4
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.16	0.15	<2 RDL
Ammonia	0.05	< 0.05	< 0.05	<2 RDL
Total Phosphorus	0.04	1.4	1.5	7
D O C	0.2	1.4	1.3	7
Aluminum	0.005	< 0.005	< 0.005	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	0.0015	0.0017	<2 RDL
Barium	0.002	0.069	0.067	3
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.047	0.048	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	0.79	0.78	1
Iron	0.1	0.2	0.2	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.042	0.043	2
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0016	0.0016	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.58	0.58	<1
Sulphide	0.02	0.55	0.6	9
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0059	0.0056	5
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	0.055	0.06	9
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table F-3 Groundwater QA/QC Results

06-Dec-16

Parameter	RDL	Original MW16-17	Duplicate OW300	RPD
E C	1	1100	1100	<1
T D S	10	682	672	1
Hardness	1	510	520	2
Chloride	1	8.6	8.6	<1
Sulphate	1	190	190	<1
Alkalinity	1	470	460	2
Calcium	0.2	74	75	1
Magnesium	0.05	78	81	4
Sodium	0.1	59	59	<1
Potassium	0.2	5.2	5	4
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.15	0.14	<2 RDL
Ammonia	0.05	< 0.05	< 0.05	<2 RDL
Total Phosphorus	0.2	0.36	0.39	<2 RDL
D O C	0.2	1.5	1.5	<1
Aluminum	0.005	0.011	0.0082	<2 RDL
Antimony	0.0005	0.00066	0.00073	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.11	0.11	<1
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.15	0.15	<1
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	0.0025	< 0.001	<2 RDL
Fluoride	0.1	0.69	0.7	1
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.09	0.09	<1
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.01	0.011	10
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	1.1	1.1	<1
Sulphide	0.02	< 0.02	< 0.02	<2 RDL
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0077	0.0077	<1
Vanadium	0.0005	0.004	0.0043	7
Zinc	0.005	0.012	0.0081	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

07-Dec-16

Parameter	RDL	Original MW16-10B	Duplicate OW400	RPD
E C	1	1300	1300	<1
T D S	10	802	792	1
Hardness	1	690	690	<1
Chloride	1	7.1	7.5	5
Sulphate	1	260	270	4
Alkalinity	1	480	480	<1
Calcium	0.2	100	100	<1
Magnesium	0.05	100	100	<1
Sodium	0.1	39	39	<1
Potassium	0.2	3.4	3.3	3
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	0.01	<2 RDL
T K N	0.1	< 0.1	0.13	<2 RDL
Ammonia	0.05	0.073	0.067	<2 RDL
Total Phosphorus	0.02	0.16	0.15	6
D O C	0.2	1.3	1.3	<1
Aluminum	0.005	< 0.005	0.0069	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.036	0.037	3
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.057	0.059	3
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	1.1	1	10
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.035	0.035	<1
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.00058	0.00074	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	1	1	<1
Sulphide	0.02	0.51	0.46	10
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0031	0.0031	<1
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table F-3 Groundwater QA/QC Results

02-May-17

Parameter	RDL	Original MW11-1B	Duplicate OW300	RPD
E C	1	1700	1700	<1
T D S	10	948	972	3
Hardness	1	820	790	4
Chloride	2	140	140	<1
Sulphate	1	350	340	3
Alkalinity	1	370	370	<1
Calcium	0.2	190	180	5
Magnesium	0.05	84	83	1
Sodium	0.1	140	130	7
Potassium	0.2	5.2	4.9	6
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.5	0.53	< 0.5	<2 RDL
Ammonia	0.05	0.13	0.14	<2 RDL
Total Phosphorus	0.1	0.3	0.31	<2 RDL
D O C	0.2	1.7	1.5	13
Aluminum	0.005	0.014	< 0.005	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.042	0.04	5
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.092	0.083	10
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	1.2	1.2	<1
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.016	0.015	6
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	< 0.0005	< 0.0005	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	1.8	1.9	5
Sulphide	0.02	7	7.3	4
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0009	0.0011	20
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

03-May-17

Parameter	RDL	Original MW16-8B	Duplicate OW100	RPD
E C	1	1100	1100	<1
T D S	10	708	732	3
Hardness	1	560	540	4
Chloride	1	20	20	<1
Sulphate	1	220	220	<1
Alkalinity	1	380	380	<1
Calcium	0.2	130	130	<1
Magnesium	0.05	56	55	2
Sodium	0.1	19	19	<1
Potassium	0.2	2.2	2.2	<1
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.2	0.29	0.34	<2 RDL
Ammonia	0.05	< 0.05	< 0.05	<2 RDL
Total Phosphorus	0.02	< 0.02	< 0.02	<2 RDL
D O C	0.2	1.1	1.1	<1
Aluminum	0.005	0.016	0.026	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.04	0.039	3
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.039	0.034	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	1	1.1	10
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.0084	0.01	<2 RDL
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	< 0.0005	< 0.0005	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.89	1	12
Sulphide	0.02	9.9	10	1
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0002	0.00018	<2 RDL
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table F-3 Groundwater QA/QC Results

03-May-17

Parameter	RDL	Original MW16-17	Duplicate OW200	RPD
E C	1	1000	1100	10
T D S	10	600	604	<1
Hardness	1	490	470	4
Chloride	1	7	7.2	3
Sulphate	1	130	130	<1
Alkalinity	1	450	450	<1
Calcium	0.2	58	55	5
Magnesium	0.05	83	81	2
Sodium	0.1	40	39	3
Potassium	0.2	3	2.9	3
Nitrate	0.1	0.29	0.29	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.1	< 0.1	<2 RDL
Ammonia	0.05	< 0.05	< 0.05	<2 RDL
Total Phosphorus	0.1	0.29	0.3	<2 RDL
D O C	0.2	0.89	0.83	<2 RDL
Aluminum	0.005	< 0.005	0.015	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.057	0.054	5
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.12	0.1	18
Cadmium	0.0001	< 0.0001	0.00011	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	0.6	0.96	**46**
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.047	0.046	2
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0033	0.0032	3
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	1.1	1.2	9
Sulphide	0.02	< 0.02	0.028	<2 RDL
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.006	0.0055	9
Vanadium	0.0005	0.0033	0.0032	3
Zinc	0.005	< 0.005	0.0068	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

04-May-17

Parameter	RDL	Original MW11-3BR	Duplicate OW400	RPD
E C	1	2800	2800	<1
T D S	10	2440	2440	<1
Hardness	1	1600	1600	<1
Chloride	1	44	44	<1
Sulphate	5	1300	1300	<1
Alkalinity	1	290	290	<1
Calcium	0.4	470	470	<1
Magnesium	0.05	110	110	<1
Sodium	0.1	36	36	<1
Potassium	0.2	7.9	7.5	5
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.5	1	1.2	<2 RDL
Ammonia	0.05	0.58	0.55	5
Total Phosphorus	0.02	0.035	0.032	<2 RDL
D O C	0.2	0.49	0.48	<2 RDL
Aluminum	0.005	0.0059	0.0056	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.0068	0.0068	<2 RDL
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.48	0.52	8
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	1.2	1.2	<1
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.022	0.021	5
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	< 0.0005	< 0.0005	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	5.9	6.1	3
Sulphide	0.04	17	19	11
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	< 0.0001	< 0.0001	<2 RDL
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table F-3 Groundwater QA/QC Results

20-Mar-18

Parameter	RDL	Original MW16-5OB	Duplicate MW100	RPD
E C	1	900	890	1
T D S	10	410	390	5
Hardness	1	470	470	<1
Chloride	1	29	30	3
Sulphate	1	68	67	1
Alkalinity	1	380	380	<1
Calcium	0.2	58	58	<1
Magnesium	0.05	78	79	1
Sodium	0.1	8.7	8.9	2
Potassium	0.2	1.3	1.3	<1
Nitrate	0.1	3.86	3.82	1
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.2	< 0.2	0.25	<2 RDL
Ammonia	0.05	< 0.05	0.098	<2 RDL
Total Phosphorus	0.1	0.54	0.79	**38**
D O C	0.5	4	10	**86**
Aluminum	0.005	0.0051	0.057	**>2 RDL**
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.071	0.071	<1
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.026	0.027	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	0.82	0.74	10
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	< 0.002	< 0.002	<2 RDL
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0025	0.0025	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.94	0.93	1
Sulphide	0.02	< 0.02	< 0.02	<2 RDL
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0067	0.0066	2
Vanadium	0.0005	0.0014	0.0014	<2 RDL
Zinc	0.005	0.0062	0.0065	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

20-Mar-18

Parameter	RDL	Original MW11-3OBR	Duplicate MW200	RPD
E C	1	1400	1400	<1
T D S	10	675	650	4
Hardness	1	570	560	2
Chloride	1	140	130	7
Sulphate	1	99	98	1
Alkalinity	1	440	450	2
Calcium	0.2	68	68	<1
Magnesium	0.05	97	95	2
Sodium	0.1	37	37	<1
Potassium	0.2	0.92	0.92	<2 RDL
Nitrate	0.1	3.05	2.98	2
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.23	0.16	<2 RDL
Ammonia	0.05	0.069	0.073	<2 RDL
Total Phosphorus	0.1	0.24	0.27	<2 RDL
D O C	0.5	3	3	<1
Aluminum	0.005	< 0.005	< 0.005	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.036	0.036	<1
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.023	0.025	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	0.69	0.66	4
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	< 0.002	< 0.002	<2 RDL
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.00091	0.00095	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.87	0.86	1
Sulphide	0.02	< 0.02	< 0.02	<2 RDL
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0046	0.0046	<1
Vanadium	0.0005	0.00061	0.00065	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table F-3 Groundwater QA/QC Results

21-Mar-18

Parameter	RDL	Original MW11-2OB	Duplicate MW300	RPD
E C	1	1400	1400	<1
T D S	10	810	480	**51**
Hardness	1	640	640	<1
Chloride	1	3.8	4	<2 RDL
Sulphate	1	310	320	3
Alkalinity	1	490	500	2
Calcium	0.2	73	72	1
Magnesium	0.05	110	110	<1
Sodium	0.1	47	48	2
Potassium	0.2	1.9	1.9	<1
Nitrate	0.1	1.12	1.1	2
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.17	< 0.1	<2 RDL
Ammonia	0.05	< 0.05	0.07	<2 RDL
Total Phosphorus	0.4	1.2	1.2	<2 RDL
D O C	0.5	1.8	3.2	**>2 RDL**
Aluminum	0.005	< 0.005	< 0.005	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.019	0.018	5
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.034	0.033	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	0.0015	< 0.001	<2 RDL
Fluoride	0.1	0.61	0.59	3
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	< 0.002	< 0.002	<2 RDL
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0037	0.0036	3
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.61	0.61	<1
Sulphide	0.02	< 0.02	< 0.02	<2 RDL
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.012	0.012	<1
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

22-Mar-18

Parameter	RDL	Original MW16-10B	Duplicate MW400	RPD
E C	1	1300	1200	8
T D S	10	635	670	5
Hardness	1	670	730	9
Chloride	1	8.2	8.6	5
Sulphate	1	250	240	4
Alkalinity	1	480	490	2
Calcium	0.2	97	100	3
Magnesium	0.05	110	110	<1
Sodium	0.1	36	39	8
Potassium	0.2	3.3	3.4	3
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	0.021	<2 RDL
T K N	0.1	0.31	0.33	<2 RDL
Ammonia	0.05	0.17	0.2	<2 RDL
Total Phosphorus	0.02	0.16	0.14	13
D O C	0.5	2	2	<2 RDL
Aluminum	0.005	< 0.005	0.012	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	0.0012	0.0013	<2 RDL
Barium	0.002	0.027	0.029	7
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.049	0.049	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	0.91	0.93	2
Iron	0.1	0.3	0.33	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.044	0.048	9
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0017	0.0016	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.94	0.99	5
Sulphide	0.02	0.99	0.95	4
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0078	0.0085	9
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table F-3 Groundwater QA/QC Results

22-Mar-18

Parameter	RDL	*Original* MW17-22B	*Duplicate* MW500	RPD
E C	1	1300	1300	<1
T D S	10	910	895	2
Hardness	1	730	680	7
Chloride	1	31	27	14
Sulphate	1	350	360	3
Alkalinity	1	390	380	3
Calcium	0.2	190	180	5
Magnesium	0.05	61	57	7
Sodium	0.1	17	16	6
Potassium	0.2	2.7	2.7	<1
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.27	0.28	<2 RDL
Ammonia	0.05	0.21	0.23	<2 RDL
Total Phosphorus	0.02	< 0.02	0.021	<2 RDL
D O C	0.5	1.6	1.6	<2 RDL
Aluminum	0.005	< 0.005	0.013	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.016	0.015	6
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.05	0.047	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	1	0.99	1
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.018	0.018	<1
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	< 0.0005	< 0.0005	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	1.6	1.6	<1
Sulphide	0.04	13	6.2	**71**
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.00011	0.00012	<2 RDL
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

23-Mar-18

Parameter	RDL	*Original* MW16-17	*Duplicate* MW600	RPD
E C	1	1000	1000	<1
T D S	10	490	510	4
Hardness	1	490	510	4
Chloride	1	6.9	7.3	6
Sulphate	1	130	120	8
Alkalinity	1	460	460	<1
Calcium	0.2	60	62	3
Magnesium	0.05	84	86	2
Sodium	0.1	36	37	3
Potassium	0.2	2.7	2.8	4
Nitrate	0.1	1.19	1.15	3
Nitrite	0.01	0.025	0.024	<2 RDL
T K N	0.1	< 0.1	0.17	<2 RDL
Ammonia	0.05	0.14	0.11	<2 RDL
Total Phosphorus	0.1	0.66	0.7	6
D O C	0.5	8.6	4	**73**
Aluminum	0.005	< 0.005	< 0.005	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.048	0.049	2
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.1	0.11	10
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	< 0.001	< 0.001	<2 RDL
Fluoride	0.1	0.95	0.95	<1
Iron	0.1	0.14	0.17	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.042	0.044	5
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0026	0.0028	7
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	1.1	1.1	<1
Sulphide	0.02	0.044	< 0.02	<2 RDL
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0051	0.0051	<1
Vanadium	0.0005	0.0026	0.0025	<2 RDL
Zinc	0.005	< 0.005	0.0051	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table F-3 Groundwater QA/QC Results

28-Jul-20

Parameter	RDL	Original MW17-22B	Duplicate MW200	RPD
E C	1	1200	1200	<1
T D S	10	905	855	6
Hardness	1	690	680	1
Chloride	1	31	30	3
Sulphate	1	300	300	<1
Alkalinity	1	370	370	<1
Calcium	0.2	180	180	<1
Magnesium	0.05	57	57	<1
Sodium	0.1	21	20	5
Potassium	0.2	2.9	2.9	<1
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.3	0.26	<2 RDL
Ammonia	0.05	0.14	0.12	<2 RDL
Total Phosphorus	0.02	< 0.02	< 0.02	<2 RDL
D O C	0.4	1.3	1.3	<2 RDL
Aluminum	0.0049	< 0.0049	< 0.0049	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.018	0.017	6
Beryllium	0.0004	< 0.0004	< 0.0004	<2 RDL
Boron	0.01	0.062	0.054	14
Cadmium	0.00009	< 0.00009	< 0.00009	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.0009	< 0.0009	< 0.0009	<2 RDL
Fluoride	0.1	0.95	0.95	<1
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.016	0.016	<1
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	< 0.0005	< 0.0005	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.00009	< 0.00009	< 0.00009	<2 RDL
Strontium	0.001	1.6	1.5	6
Sulphide	0.02	6.4	5.1	**23**
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.00011	0.00012	<2 RDL
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

28-Jul-20

Parameter	RDL	Original MW16-10B	Duplicate OW100	RPD
E C	1	1300	1300	<1
T D S	10	895	900	<1
Hardness	1	720	710	1
Chloride	1	7.9	8	1
Sulphate	1	270	260	4
Alkalinity	1	460	460	<1
Calcium	0.2	110	110	<1
Magnesium	0.05	110	110	<1
Sodium	0.1	37	37	<1
Potassium	0.2	3.3	3.3	<1
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.15	0.14	<2 RDL
Ammonia	0.05	0.065	0.052	<2 RDL
Total Phosphorus	0.02	0.051	0.036	<2 RDL
D O C	0.4	1	1	<2 RDL
Aluminum	0.0049	< 0.0049	< 0.0049	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	0.0011	0.001	<2 RDL
Barium	0.002	0.033	0.032	3
Beryllium	0.0004	< 0.0004	< 0.0004	<2 RDL
Boron	0.01	0.056	0.057	2
Cadmium	0.00009	< 0.00009	< 0.00009	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.0009	< 0.0009	< 0.0009	<2 RDL
Fluoride	0.1	0.99	0.99	<1
Iron	0.1	0.17	0.17	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.036	0.035	3
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0019	0.0019	<2 RDL
Nickel	0.001	0.0015	0.0015	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.00009	< 0.00009	< 0.00009	<2 RDL
Strontium	0.001	0.99	1	1
Sulphide	0.02	0.13	0.13	<1
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0085	0.0085	<1
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	0.019	0.014	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table F-3 Groundwater QA/QC Results

29-Jul-20

Parameter	RDL	Original MW16-6B	Duplicate OW300	RPD
E C	1	1500	1400	7
T D S	10	995	990	<1
Hardness	1	680	720	6
Chloride	1	100	100	<1
Sulphate	1	240	240	<1
Alkalinity	1	450	450	<1
Calcium	0.2	120	130	8
Magnesium	0.05	92	99	7
Sodium	0.1	51	55	8
Potassium	0.2	2.9	3.2	10
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.17	0.18	<2 RDL
Ammonia	0.05	0.091	0.06	<2 RDL
Total Phosphorus	0.04	0.25	0.25	<1
D O C	0.4	1.4	1.4	<2 RDL
Aluminum	0.0049	0.006	< 0.0049	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	0.0017	0.0019	<2 RDL
Barium	0.002	0.14	0.15	7
Beryllium	0.0004	< 0.0004	< 0.0004	<2 RDL
Boron	0.01	0.048	0.052	<2 RDL
Cadmium	0.00009	< 0.00009	< 0.00009	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.0009	< 0.0009	< 0.0009	<2 RDL
Fluoride	0.1	0.84	0.82	2
Iron	0.1	0.25	0.26	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.08	0.085	6
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.00072	0.0008	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.00009	< 0.00009	< 0.00009	<2 RDL
Strontium	0.001	0.72	0.75	4
Sulphide	0.02	0.092	0.085	<2 RDL
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0034	0.0033	3
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	0.0063	0.0075	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

29-Jul-20

Parameter	RDL	Original MW17-20B	Duplicate OW400	RPD
E C	1	1000	1000	<1
T D S	10	645	645	<1
Hardness	1	560	540	4
Chloride	1	13	13	<1
Sulphate	1	170	170	<1
Alkalinity	1	390	390	<1
Calcium	0.2	100	94	6
Magnesium	0.05	76	74	3
Sodium	0.1	32	31	3
Potassium	0.2	2.6	2.5	4
Nitrate	0.1	1.97	1.94	2
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	< 0.1	< 0.1	<2 RDL
Ammonia	0.05	< 0.05	< 0.05	<2 RDL
Total Phosphorus	0.02	< 0.02	< 0.02	<2 RDL
D O C	0.4	0.88	0.77	<2 RDL
Aluminum	0.0049	0.0083	0.0088	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.044	0.04	10
Beryllium	0.0004	< 0.0004	< 0.0004	<2 RDL
Boron	0.01	0.046	0.041	<2 RDL
Cadmium	0.00009	0.00018	0.00021	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.0009	< 0.0009	0.0011	<2 RDL
Fluoride	0.1	1.1	1	10
Iron	0.1	< 0.1	< 0.1	<2 RDL
Lead	0.0005	0.00051	0.00059	<2 RDL
Manganese	0.002	0.0024	0.0025	<2 RDL
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0011	0.001	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.00009	< 0.00009	< 0.00009	<2 RDL
Strontium	0.001	0.56	0.55	2
Sulphide	0.02	< 0.02	< 0.02	<2 RDL
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0049	0.0052	6
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	0.74	0.78	5
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table F-3 Groundwater QA/QC Results

29-Jul-20

Parameter	RDL	Original MW16-17	Duplicate OW500	RPD
E C	1	1100	1100	<1
T D S	10	630	675	7
Hardness	1	530	580	9
Chloride	1	7	7.2	3
Sulphate	1	180	160	12
Alkalinity	1	460	460	<1
Calcium	0.2	72	77	7
Magnesium	0.05	85	94	10
Sodium	0.1	40	45	12
Potassium	0.2	3.1	3.3	6
Nitrate	0.1	0.42	0.5	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	< 0.1	< 0.1	<2 RDL
Ammonia	0.05	< 0.05	< 0.05	<2 RDL
Total Phosphorus	0.2	0.24	0.2	<2 RDL
D O C	0.4	0.7	0.72	<2 RDL
Aluminum	0.0049	0.0065	0.009	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.043	0.045	5
Beryllium	0.0004	< 0.0004	< 0.0004	<2 RDL
Boron	0.01	0.13	0.14	7
Cadmium	0.00009	< 0.00009	< 0.00009	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.0009	< 0.0009	< 0.0009	<2 RDL
Fluoride	0.1	1	1.1	10
Iron	0.1	0.4	0.39	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.059	0.061	3
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0022	0.0022	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.00009	< 0.00009	< 0.00009	<2 RDL
Strontium	0.001	1.2	1.2	<1
Sulphide	0.02	< 0.02	< 0.02	<2 RDL
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0052	0.005	4
Vanadium	0.0005	0.001	0.001	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

30-Jul-20

Parameter	RDL	Original BH03-2B	Duplicate OW600	RPD
E C	1	1500	1500	<1
T D S	10	915	905	1
Hardness	1	720	710	1
Chloride	1	140	140	<1
Sulphate	1	240	230	4
Alkalinity	1	430	430	<1
Calcium	0.2	130	130	<1
Magnesium	0.05	94	94	<1
Sodium	0.1	65	65	<1
Potassium	0.2	2.8	2.8	<1
Nitrate	0.1	< 0.1	< 0.1	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.16	0.16	<2 RDL
Ammonia	0.05	0.23	0.21	<2 RDL
Total Phosphorus	0.04	0.087	0.08	<2 RDL
D O C	0.4	1.6	1.6	<2 RDL
Aluminum	0.0049	< 0.0049	< 0.0049	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.23	0.24	4
Beryllium	0.0004	< 0.0004	< 0.0004	<2 RDL
Boron	0.01	0.057	0.058	2
Cadmium	0.00009	< 0.00009	< 0.00009	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.0009	< 0.0009	< 0.0009	<2 RDL
Fluoride	0.1	0.73	0.73	<1
Iron	0.1	2.6	2.6	<1
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.045	0.045	<1
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0013	0.0012	<2 RDL
Nickel	0.001	< 0.001	< 0.001	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.00009	< 0.00009	< 0.00009	<2 RDL
Strontium	0.001	0.74	0.74	<1
Sulphide	0.02	0.95	0.85	11
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.0021	0.0021	<1
Vanadium	0.0005	< 0.0005	< 0.0005	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

APPENDIX

G SURFACE WATER CHEMICAL RESULTS

Appendix G   Table Notation for Surface Water Chemical Results

Notation	Description		
mg/L	milligrams per Litre	D O	Dissolved Oxygen
	• values in mg/L unless otherwise noted	T D S	Total Dissolved Solids
pH	provided in Scientific Units	T S S	Total Suspended Solids
E C	Electrical Conductivity	T K N	Total Kjeldahl Nitrogren
	provided in microSiemens per centimetre	T O C	Total Organic Carbon
T	Temperature		
	provided in degrees Celsius		
QA / QC			
RDL	laboratory reported detection limit		
RPD	relative percent difference, provided in %		
	bold and shading indicates RPD greater than 20% or >2 RDL		
PWQO	Provincial Water Quality Objectives (1994)		
( )	interim PWQO		
nc	no PWQO criteria		
(grey shading)	shading indicates an exceedance of the PWQO criteria		
(a)	**dissolved oxygen** is temperature dependent: value should not be less than the range of 4 mg/L (0 °C) to 7 mg/L (25 °C) for warm water biota		
(b)	**turbidity** does not have a firm objective: Suspended matter should not be added to surface water in concentrations that will change the natural Secchi disc reading by more than 10%		
(c)	**oil & grease** does not have a firm objective: Oil or petrochemicals should not be present in concentrations that: • can be detected as visible film, sheen or discolouration on the surface; • can be detected by odour; • can cause tainting of edible aquatic organisms; • can form deposits on shorelines and bottom sediments that are detectable by sight or odour, or are deleterious to resident aquatic organisms		
(d)	**alkalinity** should not decrease by more than 25% of the natural concentration		
(e)	**un-ionized ammonia** value calculated value using the fraction (*f*) of NH_3 from: $f = 1 \div (10^{pKa-pH}+1)$ *where:* pKa = 0.09018 + 2729.92 ÷ T; T = ambient water temperature in Kelvin (K); K = °C + 273.16; Field pH and temperature values and laboratory total ammonia results are used in the equation		
(f)	**total phosphorus** does not have a firm objective: excessive plant growth in rivers and streams should be eliminated at a concenctration below 0.03 mg/L		
(1)	NSD - station dry		
(2)	NSF - frozen		
blank	parameter not analysed during sampling event		
< value	parameter not detected above associated laboratory reported detection limit		

Table G-1 Surface Water Chemical Results

		Field				General Chemistry							Major Ions						
Station	Date	pH	E C	T	D O	pH	E C	T D S	T S S	Hardness	Turbidity	Total Oil & Grease	Chloride	Sulphate	Alkalinity	Calcium	Magnesium	Sodium	Potassium
	Units	S U	µS/cm	°C		S U	µS/cm												
	PWQO	6.5 - 8.5	nc	nc	(a)	6.5 - 8.5	nc	nc	nc	nc	(b)	(c)	nc	nc	(d)	nc	nc	nc	nc
SW1	7-Dec-16	8.3	960	4.1	3.3	8.09	870	518	5	340	4.6	<0.5	93	120	200	76	26	57	3.3
	1-May-17	7.5	327	9.9	13.5	7.77	330	178	61	120	130	<0.5	26	31	91	31	11	23	3.1
	19-Mar-18	7.9	796	1.1	13.9	8.00	780	235	16	270	43	0.5	100	67	160	57	21	56	3.3
SW2	7-Dec-16	8.6	480	4.3	2.7	8.06	460	270	7	160	18	<0.5	37	44	120	39	11	33	2.4
	1-May-17	7.4	210	10.5	13	7.62	200	168	77	81	84	<0.5	8.5	<5.0	82	23	8	11	2
	19-Mar-18	8.5	239	1.1	13.4	7.84	250	120	250	95	170	0.7	23	25	59	28	10	9.4	4.1
SW3	7-Dec-16	8.2	820	5.1	3.6	7.99	810	454	9	300	13	<0.5	81	120	160	73	18	50	4
	1-May-17	7.7	341	12.3	12.3	7.76	360	262	67	130	130	<0.5	27	37	100	34	10	20	4
	21-Mar-18	7.7	1,213	0.1	11.7	7.98	1100	450	18	290	14	1.8	160	97	160	72	21	100	5
SW4	7-Dec-16	8.4	920	4.2	4.4	8.00	880	494	17	320	9.1	<0.5	97	140	160	72	21	59	3.6
	1-May-17	7.8	292	9.8	11.1	7.68	280	232	76	96	180	<0.5	23	25	78	27	8	18	3.7
	19-Mar-18	8.3	699	0.1	13	7.99	750	410	17	220	21	2.6	110	73	130	54	15	62	5.1
DP1	7-Dec-16	8.3	1,750	4.5	3.1	8.15	1400	758	98	240	26	<0.5	250	95	170	67	18	220	3.3
	1-May-17	7.7	374	12.4	12.5	7.79	330	352	830	77	690	<0.5	33	24	87	33	17	32	5.3
	21-Mar-18	7.6	1,024	0	11.6	8.10	850	440	29	260	31	<0.5	110	89	160	65	22	67	4.4
DP2	7-Dec-16	8.1	1,130	3.8	3.4	7.60	1100	676	13	410	14	<0.5	110	150	240	94	31	67	4.3
	1-May-17	7.7	281	9.6	12.7	7.71	280	232	120	96	180	<0.5	25	24	78	27	8.5	19	4.2
	19-Mar-18	8.0	676	0.6	13	7.98	690	185	79	210	32	1.6	95	69	120	55	18	56	6.3
DP3	7-Dec-16	8.2	870	4.9	3.8	8.07	850	486	3	290	6.5	<0.5	88	130	160	71	19	57	4
	1-May-17	7.6	344	12.1	12.2	7.75	350	270	77	120	160	<0.5	32	32	91	33	9.9	25	4
	19-Mar-18	7.8	797	2.4	13.2	8.05	830	275	17	230	15	0.8	120	82	140	62	16	71	5.1
DP4	5-Dec-16 (1)																		
	19-Mar-18	7.9	222	1.3	13.9	7.83	230	45	24	92	74	2.4	14	31	60	21	7.3	8.3	3.1
DP5	22-Mar-18 (2)																		

Table G-1 Surface Water Chemical Results

		Nutrients and Organic Indicators								Total Metals						
Station	Date	Nitrate	Nitrite	T K N	Ammonia	Un-ionized Ammonia	Total Phosphorus	T O C	Phenols	Aluminum (dissolved)	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium
	Units															
	PWQO	nc	nc	nc	nc	0.02 (e)	0.03 (f)	nc	0.001	0.075	(0.02)	0.1	nc	0.011	(0.2)	0.0002
SW1	7-Dec-16	0.46	<0.01	0.37	<0.05	<0.001	0.061	5.7	<0.001	<0.005	<0.0005	<0.001	0.035	<0.0005	0.051	<0.0001
	1-May-17	1.5	0.016	0.5	<0.05	<0.001	0.16	7.8	<0.001	0.016	<0.0005	0.0015	0.037	<0.0005	0.039	<0.0001
	19-Mar-18	0.56	<0.01	0.3	0.081	<0.001	0.12		<0.001	0.008	<0.0005	<0.001	0.035	<0.0005	0.026	<0.0001
SW2	7-Dec-16	0.27	0.023	0.85	<0.05	<0.0024	0.075	13	<0.001	0.017	<0.0005	<0.001	0.014	<0.0005	0.017	<0.0001
	1-May-17	1.3	0.017	0.69	<0.05	<0.001	0.2	13	<0.001	0.029	<0.0005	0.0013	0.03	<0.0005	0.029	<0.0001
	19-Mar-18	0.66	<0.01	0.37	<0.05	<0.001	0.37		<0.001	0.031	<0.0005	0.0029	0.08	0.00053	0.012	<0.0001
SW3	7-Dec-16	0.74	0.018	0.36	<0.05	<0.001	0.048	7	<0.001	<0.005	<0.0005	<0.001	0.032	<0.0005	0.035	<0.0001
	1-May-17	0.3	<0.01	0.67	<0.05	<0.001	0.2	11	<0.001	0.017	<0.0005	0.0015	0.041	<0.0005	0.032	<0.0001
	21-Mar-18	0.19	<0.01	1	0.15	<0.001	0.16		<0.001	0.007	<0.0005	<0.001	0.032	<0.0005	0.022	<0.0001
SW4	7-Dec-16	0.34	<0.01	0.4	<0.05	<0.0015	0.032	7.6	<0.001	<0.005	<0.0005	<0.001	0.024	<0.0005	0.028	<0.0001
	1-May-17	0.6	0.013	0.66	<0.05	<0.001	0.25	9.9	<0.001	0.019	<0.0005	0.0011	0.037	<0.0005	0.024	<0.0001
	19-Mar-18	0.36	<0.01	0.52	0.067	0.0011	0.076		<0.001	0.008	<0.0005	<0.001	0.026	<0.0005	0.014	<0.0001
DP1	7-Dec-16	0.28	<0.01	0.31	<0.05	<0.001	0.075	5.2	<0.001	0.008	<0.0005	0.0012	0.051	<0.0005	0.029	<0.0001
	1-May-17	1.44	<0.05	0.46	<0.05	<0.001	0.58	10	<0.001	0.02	<0.0005	0.0054	0.12	0.0009	0.037	0.00025
	21-Mar-18	0.12	<0.01	0.37	0.088	<0.001	0.08		<0.001	0.009	<0.0005	<0.001	0.032	<0.0005	0.028	<0.0001
DP2	7-Dec-16	<0.1	<0.01	0.72	0.11	0.0015	0.12	13	<0.001	0.005	<0.0005	0.0013	0.034	<0.0005	0.024	<0.0001
	1-May-17	0.26	<0.01	0.68	<0.05	<0.001	0.28	10	0.0014	0.021	<0.0005	0.0019	0.045	<0.0005	0.026	<0.0001
	19-Mar-18	0.39	<0.01	0.51	0.05	<0.001	0.18		<0.001	0.009	<0.0005	0.0031	0.094	0.00055	0.016	0.00037
DP3	7-Dec-16	0.42	<0.01	0.43	<0.05	<0.001	0.034	7.3	<0.001	0.005	<0.0005	<0.001	0.024	<0.0005	0.029	<0.0001
	1-May-17	0.33	0.011	0.6	<0.05	<0.001	0.2	11	<0.001	0.02	<0.0005	0.0017	0.044	<0.0005	0.029	<0.0001
	19-Mar-18	0.35	<0.01	0.49	0.059	<0.001	0.073			0.007	<0.0005	<0.001	0.028	<0.0005	0.016	<0.0001
DP4	5-Dec-16 (1)															
	19-Mar-18	<0.1	<0.01	0.33	<0.05	<0.001	0.16		<0.001	0.024	<0.0005	<0.001	0.029	<0.0005	0.01	<0.0001
DP5	22-Mar-18 (2)															

Table G-1 Surface Water Chemical Results

Station	Date	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel
		Total Metals								
	Units									
	PWQO	0.0089	0.0009	0.005	0.3	0.025	nc	0.0002	(0.04)	nc
SW1	7-Dec-16	<0.005	<0.0005	0.0015	0.22	<0.0005	0.032	<0.0001	0.0007	0.0015
	1-May-17	0.0056	0.0017	0.0065	5	0.0031	0.065	<0.0001	0.00083	0.0055
	19-Mar-18	<0.005	0.00074	0.0033	2.3	0.001	0.053	<0.0001	0.00071	0.0027
SW2	7-Dec-16	<0.005	<0.0005	0.0045	0.66	0.00054	0.012	<0.0001	<0.0005	0.0016
	1-May-17	<0.005	0.0014	0.0062	4.2	0.0028	0.059	<0.0001	<0.0005	0.0048
	19-Mar-18	0.013	0.005	0.013	15	0.0075	0.22	<0.0001	0.00053	0.014
SW3	7-Dec-16	<0.005	<0.0005	0.003	0.53	0.0006	0.072	<0.0001	0.00097	0.0018
	1-May-17	0.0054	0.0017	0.008	5	0.003	0.082	<0.0001	0.00083	0.0058
	21-Mar-18	<0.005	<0.0005	0.0041	0.82	0.00069	0.082		0.0012	0.0021
SW4	7-Dec-16	<0.005	<0.0005	0.0024	0.62	<0.0005	0.05	<0.0001	0.00075	0.002
	1-May-17	<0.005	0.0013	0.0063	3	0.0034	0.088	<0.0001	<0.0005	0.0041
	19-Mar-18	<0.005	0.00053	0.0064	1.2	0.00069	0.054	<0.0001	0.0011	0.0027
DP1	7-Dec-16	<0.005	0.00084	0.0033	1.9	0.0016	0.065	<0.0001	0.001	0.0028
	1-May-17	0.024	0.0097	0.022	25	0.012	0.35	<0.0001	0.0015	0.028
	21-Mar-18	<0.005	0.00066	0.0038	2	0.00097	0.082	<0.0001	0.00087	0.003
DP2	7-Dec-16	<0.005	0.0011	0.0018	1.3	<0.0005	2.3	<0.0001	0.00082	0.0051
	1-May-17	0.0075	0.0025	0.0089	7.2	0.0044	0.12	<0.0001	0.00078	0.0078
	19-Mar-18	0.015	0.0061	0.018	15	0.012	0.61	<0.0001	0.0014	0.017
DP3	7-Dec-16	<0.005	<0.0005	0.0015	0.34	<0.0005	0.076	<0.0001	0.00068	0.0027
	1-May-17	0.0066	0.0022	0.0078	6.4	0.0033	0.1	<0.0001	0.00078	0.007
	19-Mar-18	<0.005	0.00057	0.0062	1.1	0.00071	0.061	<0.0001	0.0011	0.0028
DP4	5-Dec-16 (1)									
	19-Mar-18	<0.005	0.00096	0.0035	3.7	0.0018	0.03	<0.0001	<0.0005	0.004
DP5	22-Mar-18 (2)									

Table G-1 Surface Water Chemical Results

Station	Date	Selenium	Silver	Strontium	Tungsten	Uranium	Vanadium	Zinc	Zirconium
		Total Metals							
	Units								
	PWQO	0.1	0.0001	nc	(0.03)	(0.005)	(0.006)	0.03	(0.004)
SW1	7-Dec-16	<0.002	<0.0001	0.49	<0.001	0.0021	0.00091	<0.005	<0.001
	1-May-17	<0.002	<0.0001	0.18	<0.001	0.00058	0.0077	0.023	<0.001
	19-Mar-18	<0.002	<0.0001	0.35	<0.001	0.0016	0.0036	0.0099	<0.001
SW2	7-Dec-16	<0.002	<0.0001	0.12	<0.001	0.00025	0.0017	0.0055	<0.001
	1-May-17	<0.002	<0.0001	0.09	<0.001	0.00016	0.0069	0.019	<0.001
	19-Mar-18	<0.002	<0.0001	0.19	<0.001	0.00047	0.018	0.051	0.0012
SW3	7-Dec-16	<0.002	<0.0001	0.47	<0.001	0.0009	0.001	0.0085	<0.001
	1-May-17	<0.002	<0.0001	0.21	<0.001	0.00054	0.0076	0.026	<0.001
	21-Mar-18	<0.002	<0.0001	0.51	<0.001	0.0013	0.0016	0.0081	<0.001
SW4	7-Dec-16	<0.002	<0.0001	0.42	<0.001	0.00075	0.0012	<0.005	<0.001
	1-May-17	<0.002	<0.0001	0.15	<0.001	0.00037	0.0053	0.02	<0.001
	19-Mar-18	<0.002	<0.0001	0.31	<0.001	0.00089	0.0019	0.0077	<0.001
DP1	7-Dec-16	<0.002	<0.0001	0.38	<0.001	0.0012	0.0029	0.01	<0.001
	1-May-17	<0.002	0.00012	0.17	<0.001	0.00092	0.031	0.094	0.0017
	21-Mar-18	<0.002	<0.0001	0.41	<0.001	0.0013	0.0029	0.0083	<0.001
DP2	7-Dec-16	<0.002	<0.0001	0.42	<0.001	0.00093	0.0013	0.0059	<0.001
	1-May-17	<0.002	<0.0001	0.15	<0.001	0.0005	0.01	0.032	<0.001
	19-Mar-18	<0.002	<0.0001	0.31	<0.001	0.0014	0.017	0.085	0.0012
DP3	7-Dec-16	<0.002	<0.0001	0.42	<0.001	0.0008	0.00089	<0.005	<0.001
	1-May-17	<0.002	<0.0001	0.2	<0.001	0.00043	0.0092	0.028	0.001
	19-Mar-18	<0.002	<0.0001	0.36	<0.001	0.00099	0.0018	0.006	<0.001
DP4	5-Dec-16 (1)								
	19-Mar-18	<0.002	<0.0001	0.096	<0.001	0.00032	0.0061	0.019	<0.001
DP5	22-Mar-18 (2)								

Table G-2 Surface Water VOC Results

Station	Date	Benzene	Toluene	Ethylbenzene	Total Xylenes
	PWQO	(100)	(8)	(0.8)	
SW1	1-May-17	<0.2	<0.2	<0.2	<0.4
	19-Mar-18	<0.2	<0.2	<0.2	<0.4
	7-Dec-16	<0.2	<0.2	<0.2	<0.4
SW2	1-May-17	<0.2	<0.2	<0.2	<0.4
	19-Mar-18	<0.2	<0.2	<0.2	<0.4
	7-Dec-16	<0.2	<0.2	<0.2	<0.4
SW3	21-Mar-18	<0.2	<0.2	<0.2	<0.4
	1-May-17	<0.2	<0.2	<0.2	<0.4
	7-Dec-16	<0.2	<0.2	<0.2	<0.4
SW4	1-May-17	<0.2	<0.2	<0.2	<0.4
	19-Mar-18	<0.2	<0.2	<0.2	<0.4
	7-Dec-16	<0.2	<0.2	<0.2	<0.4
DP1	21-Mar-18	<0.2	<0.2	<0.2	<0.4
	1-May-17	<0.2	<0.2	<0.2	<0.4
	7-Dec-16	<0.2	<0.2	<0.2	<0.4
DP2	1-May-17	<0.2	<0.2	<0.2	<0.4
	19-Mar-18	<0.2	<0.2	<0.2	<0.4
	7-Dec-16	<0.2	<0.2	<0.2	<0.4
DP3	1-May-17	<0.2	<0.2	<0.2	<0.4
	19-Mar-18	<0.2	<0.2	<0.2	<0.4
	7-Dec-16	<0.2	<0.2	<0.2	<0.4
DP4	19-Mar-18	<0.2	<0.2	<0.2	<0.4

Table G-3 Surface Water QA/QC Results

07-Dec-16

Parameter	RDL	*Original* SW4	*Duplicate* SW100	RPD
E C	1	880	880	<1
T D S	10	494	496	<1
T S S	1	17	13	**27**
Hardness	1	320	320	<1
Turbidity	0.1	9.1	8	13
Total Oil & Grease	0.5	< 0.5	< 0.5	<2 RDL
Chloride	1	97	99	2
Sulphate	1	140	140	<1
Alkalinity	1	160	160	<1
Calcium	0.2	72	74	3
Magnesium	0.05	21	22	5
Sodium	0.1	59	61	3
Potassium	0.2	3.6	3.8	5
Nitrate	0.1	0.34	0.35	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.4	0.41	<2 RDL
Ammonia	0.05	< 0.05	< 0.05	<2 RDL
Total Phosphorus	0.02	0.032	0.032	<2 RDL
T O C	0.2	7.6	7.4	3
Phenols	0.001	< 0.001	< 0.001	<2 RDL
Aluminum (dissolve	0.005	< 0.005	< 0.005	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.024	0.025	4
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.028	0.028	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	< 0.0005	< 0.0005	<2 RDL
Copper	0.001	0.0024	0.0019	<2 RDL
Iron	0.1	0.62	0.43	<2 RDL
Lead	0.0005	< 0.0005	< 0.0005	<2 RDL
Manganese	0.002	0.05	0.06	18
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.00075	0.00067	<2 RDL
Nickel	0.001	0.002	0.0018	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.42	0.44	5
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.00075	0.00076	1
Vanadium	0.0005	0.0012	0.0012	<2 RDL
Zinc	0.005	< 0.005	< 0.005	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

01-May-17

Parameter	RDL	*Original* SW4	*Duplicate* SW100	RPD
E C	1	280	280	<1
T D S	10	232	244	5
T S S	2	76	110	**37**
Hardness	1	96	96	<1
Turbidity	0.1	180	190	5
Total Oil & Grease	0.5	< 0.5	< 0.5	<2 RDL
Chloride	1	23	23	<1
Sulphate	1	25	25	<1
Alkalinity	1	78	78	<1
Calcium	0.2	27	27	<1
Magnesium	0.05	8	8.7	8
Sodium	0.1	18	18	<1
Potassium	0.2	3.7	4.3	15
Nitrate	0.1	0.6	0.61	2
Nitrite	0.01	0.013	0.016	<2 RDL
T K N	0.1	0.66	0.66	<1
Ammonia	0.05	< 0.05	< 0.05	<2 RDL
Total Phosphorus	0.1	0.25	0.27	<2 RDL
T O C	0.2	9.9	10	1
Phenols	0.001	< 0.001	< 0.001	<2 RDL
Aluminum (dissolve	0.005	0.019	0.018	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	0.0011	0.0018	<2 RDL
Barium	0.002	0.037	0.046	**22**
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.024	0.025	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	0.0075	<2 RDL
Cobalt	0.0005	0.0013	0.0025	**>2 RDL**
Copper	0.001	0.0063	0.0084	**29**
Iron	0.1	3	7.2	**82**
Lead	0.0005	0.0034	0.0041	19
Manganese	0.002	0.088	0.11	**22**
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	< 0.0005	0.00074	<2 RDL
Nickel	0.001	0.0041	0.0077	**>2 RDL**
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.15	0.15	<1
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.00037	0.00038	<2 RDL
Vanadium	0.0005	0.0053	0.01	**61**
Zinc	0.005	0.02	0.032	**>2 RDL**
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table G-3 Surface Water QA/QC Results

Parameter	RDL	19-Mar-18 Original SW4	Duplicate SW100	RPD
E C	1	750	750	<1
T D S	10	410	255	**47**
T S S	1	17	15	13
Hardness	1	220	210	5
Turbidity	0.1	21	21	<1
Total Oil & Grease	0.5	2.6	2.7	4
Chloride	1	110	110	<1
Sulphate	1	73	72	1
Alkalinity	1	130	130	<1
Calcium	0.2	54	55	2
Magnesium	0.05	15	15	<1
Sodium	0.1	62	63	2
Potassium	0.2	5.1	5.2	2
Nitrate	0.1	0.36	0.36	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.52	0.45	<2 RDL
Ammonia	0.05	0.067	0.077	<2 RDL
Total Phosphorus	0.02	0.076	0.079	<2 RDL
Phenols	0.001	< 0.001	< 0.001	<2 RDL
Aluminum (dissolve	0.005	0.008	0.01	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.026	0.026	<1
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.014	0.013	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	0.00053	0.0006	<2 RDL
Copper	0.001	0.0064	0.0063	2
Iron	0.1	1.2	1.3	8
Lead	0.0005	0.00069	0.00073	<2 RDL
Manganese	0.002	0.054	0.054	<1
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0011	0.0011	<2 RDL
Nickel	0.001	0.0027	0.0028	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.31	0.32	3
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.00089	0.00092	3
Vanadium	0.0005	0.0019	0.0021	<2 RDL
Zinc	0.005	0.0077	0.0083	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

Table G-3 Surface Water QA/QC Results

Parameter	RDL	19-Mar-18 Original SW4	19-Mar-18 Duplicate SW100	RPD
E C	1	750	750	<1
T D S	10	410	255	**47**
T S S	1	17	15	13
Hardness	1	220	210	5
Turbidity	0.1	21	21	<1
Total Oil & Grease	0.5	2.6	2.7	4
Chloride	1	110	110	<1
Sulphate	1	73	72	1
Alkalinity	1	130	130	<1
Calcium	0.2	54	55	2
Magnesium	0.05	15	15	<1
Sodium	0.1	62	63	2
Potassium	0.2	5.1	5.2	2
Nitrate	0.1	0.36	0.36	<2 RDL
Nitrite	0.01	< 0.01	< 0.01	<2 RDL
T K N	0.1	0.52	0.45	<2 RDL
Ammonia	0.05	0.067	0.077	<2 RDL
Total Phosphorus	0.02	0.076	0.079	<2 RDL
Phenols	0.001	< 0.001	< 0.001	<2 RDL
Aluminum (dissolve	0.005	0.008	0.01	<2 RDL
Antimony	0.0005	< 0.0005	< 0.0005	<2 RDL
Arsenic	0.001	< 0.001	< 0.001	<2 RDL
Barium	0.002	0.026	0.026	<1
Beryllium	0.0005	< 0.0005	< 0.0005	<2 RDL
Boron	0.01	0.014	0.013	<2 RDL
Cadmium	0.0001	< 0.0001	< 0.0001	<2 RDL
Chromium	0.005	< 0.005	< 0.005	<2 RDL
Cobalt	0.0005	0.00053	0.0006	<2 RDL
Copper	0.001	0.0064	0.0063	2
Iron	0.1	1.2	1.3	8
Lead	0.0005	0.00069	0.00073	<2 RDL
Manganese	0.002	0.054	0.054	<1
Mercury	0.0001	< 0.0001	< 0.0001	<2 RDL
Molybdenum	0.0005	0.0011	0.0011	<2 RDL
Nickel	0.001	0.0027	0.0028	<2 RDL
Selenium	0.002	< 0.002	< 0.002	<2 RDL
Silver	0.0001	< 0.0001	< 0.0001	<2 RDL
Strontium	0.001	0.31	0.32	3
Tungsten	0.001	< 0.001	< 0.001	<2 RDL
Uranium	0.0001	0.00089	0.00092	3
Vanadium	0.0005	0.0019	0.0021	<2 RDL
Zinc	0.005	0.0077	0.0083	<2 RDL
Zirconium	0.001	< 0.001	< 0.001	<2 RDL

APPENDIX

H

NUMERICAL GROUNDWATER MODEL REPORT

TABLE OF CONTENTS

TABLES

FIGURES

H.1 INTRODUCTION

This report summarizes the numerical groundwater modeling activities undertaken as part of the Level 2 Hydrogeological Study report prepared in support of the Category 2 Class A licence application for the proposed Upper's Quarry under the Aggregate Resources Act (R.S.O., 1990). The purpose of the groundwater modeling is to predict the potential effects of the quarry during the operational phase and final rehabilitation to a lake on the local groundwater users and surface water features.

The calibrated baseline model incorporates an extensive data set consisting of borehole stratigraphy, hydraulic testing results, groundwater elevations and quality, and surface water flows and quality. The work program for this study was completed between 2016 and 2019, and data collection is on-going. Climatic data from local Environment Canada and Vine and Tree Fruit Innovations stations were used to estimate recharge to the groundwater system from infiltration of water surplus (precipitation less evapotranspiration).

A steady-state baseline model was constructed for this study, representing average October baseline conditions observed at the Site. Calibration targets include Site groundwater elevation data, as well as additional groundwater elevation data from other known sites within the model domain where groundwater monitoring data is available. Water level data from Ministry of the Environment, Conservation and Parks (MECP) water well records were also included. Interpreted groundwater elevations at mapped wetland features were also incorporated as calibration targets. Finally, flow rate targets were used for the Existing Watercourse staff gauges at the Site, as well as annual dewatering flow rates from Walker Brothers Quarry and the Closed West Landfill north of the Site.

H.1.1 MODEL OBJECTIVES

The primary objectives of the numerical groundwater modeling are as follows.

- ➔ Formulate the conceptual hydrogeologic setting of the Site and construct a steady-state numerical groundwater flow model representing the conceptualization. Calibrate the model to observed baseline groundwater conditions.
- ➔ Complete an analysis of uncertainty and sensitivity of the calibrated baseline model parameters in order to aid in the calibration and determine if the model is significantly robust to generate reliable predictions.
- ➔ Modify the baseline model to simulate full quarry development to simulate the maximum radius of influence of the proposed quarry, the contribution of groundwater inflows to quarry dewatering and assess any changes to the water balance during the operational phase.
- ➔ Use the modified model to simulate conditions under final rehabilitation to a lake to assess any long-term changes to the water balance.

H.1.2 PREVIOUS INVESTIGATIONS

South Welland Canal Re-alignment

During the 1960's, the Welland Canal was re-aligned between Port Robinson and Port Colborne, south of the model domain for the current study. As part of the re-alignment, dewatering of the shallow bedrock (Salina Formation) was required on a temporary basis for construction, and continued on a permanent basis to prevent the flooding of the East Main Street and Townline Road tunnels which underpass the canal. These two dewatering systems are still in operation today; however, little data is available as there is no PTTW for either system since they are operated by a Federal entity not subject to provincial permitting requirements.

A significant hydrogeological investigation was undertaken prior to the re-alignment to estimate the hydrogeological properties of the bedrock, as summarized in the research paper by Farvolden and Nunan (1970). A numerical model was also completed as outlined in the companion paper by Frind (1970), one of the first numerical models completed for a site in Canada.

Long-term constant rate pumping tests were completed on several pumping wells situated along the canal re-alignment, with pumping rates varying between 155 L/min (34 Igpm) and 1,137 L/min (250 Igpm). Estimates of the shallow bedrock transmissivity ranged between approximately 30 m^2/day to 1,300 m^2/day. Groundwater elevations in a number of observation wells installed for monitoring of the construction dewatering suggests that the radius of influence extended up to 15 km away from the pumping wells once the dewatering system became operational.

To construct the model, it was assumed that horizontal groundwater flow primarily occurred in the upper (weathered) portion of the bedrock, while the underlying intact bedrock was assumed to act as a lower impermeable boundary. The bedrock aquifer was assumed to be confined due to the significant thickness of overlying low-permeability silt and clay overburden, with leakage from the water table through the confining layer at a rate proportional to the hydraulic conductivity of the silt and clay. A relatively simple two-dimensional model of the bedrock aquifer was simulated, with leakage from an overlying confining layer. It was assumed that when the pumping wells were simulated in the model, a cone of depression would form within the bedrock aquifer, expanding radially outward from the pumping wells to an extent such that the leakage (recharge) from the confining layer would balance with the water withdrawn from the pumping wells and a new equilibrium would be established. The model extent was selected such that the boundaries would not interfere with the simulation of the expanding cone of depression at equilibrium (steady-state). The calibrated model transmissivity of the bedrock aquifer ranged between approximately 15 m^2/day to 120 m^2/day.

Niagara Falls, New York State

A numerical model was created as part of a USGS study to simulate groundwater flow within the Lockport Group sub-members for a study area east of the Niagara River in Niagara Falls, New York, roughly spanning the same latitude as the model domain for the current study (Yager, 1996). The purpose of the model was to estimate seepage from the numerous "super-fund" sites within the study area to the groundwater system.

The model consisted of 10 layers representing the overburden, weathered bedrock, Salina Formation and interpreted regional water bearing zones within the Lockport Group sub-members. The lower Lockport Group contact was assumed to act as a lower impermeable boundary. The fracture network was assumed to act as an equivalent porous medium at the scale of the model. The lower model layers "pinched out" at the inferred subcrop with the weathered bedrock layer.

Natural groundwater features (i.e., the Niagara Escarpment and Niagara River Gorge) were chosen as the lateral model boundaries where possible. Where no natural boundary existed, no-flow or constant-head boundaries were used to represent inferred groundwater flowlines or potentiometric contours. Anthropogenic excavations were represented using drain boundaries, with conductance values computed using the transmissivity of the lower Lockport Group bedrock. Constant-head boundaries were used to represent the New York Power Authority Reservoir and forebay canal (the American equivalent of the OPG Pump Generating Station reservoir and Queenston-Chippewa Power Canal). A recharge boundary rate of 13 mm/year (1.2×10^{-4} ft/day) was used for the model domain outside of urbanized areas.

The hydrogeological properties of the weathered bedrock were estimated from the results of hydraulic testing completed for the various super-fund sites. The hydraulic conductivity for the weathered bedrock was reported to range between approximately 0.3 m/day (1 ft/day) to 60 m/day (200 ft/day). For the underlying water bearing zones in the Lockport Group bedrock, transmissivities ranging between 9 m^2/day (30 ft^2/day) and 210 m^2/day (700 ft^2/day) were reported. Packer testing was completed near the Niagara Falls Quarry to estimate the vertical anisotropy of the Lockport Group bedrock. Numerical modeling of the packer test results suggests a vertical anisotropy of 0.01. It was inferred that vertical anisotropy could be much lower elsewhere as the quarry is situated within a suspected regional fracture zone with enhanced vertical fracture density.

Walker Brothers Quarry

More recently, S.S. Papadopulos & Associates Inc. (SSPA) completed modeling of the current study area (SSPA, 2006). The purpose of the previous work was to evaluate potential impacts from changes in the water management operations at the Walker Brothers Quarry. Although completed for a different purpose, the previous model domain covers a large portion of the current study area. The SSPA report and conclusions were considered when determining appropriate boundary conditions and hydraulic properties of the current modeling effort.

H.2 CONCEPTUAL MODEL

The first step in constructing a numerical groundwater model is to create a “conceptual model” that describes in general terms the hydrogeologic conditions and water budget of the natural system to be simulated and other physical elements of the undertaking to be considered. Some components of the conceptual model include:

- ➔ A decision on the areal extent to be studied;
- ➔ Identification of the geologic framework and hydrogeologic properties of the subsurface;
- ➔ Derivation of hydrostratigraphic units (aquifers and aquitards) in the subsurface;
- ➔ An understanding of the regional movement of groundwater, including groundwater elevations and trends as well as hydraulic gradients;
- ➔ Identification of hydrologic features, such as watershed divides, groundwater seeps and springs and watercourses; and
- ➔ A basic understanding of water budget components that include recharge and discharge conditions and controls.

The conceptual understanding is used to make decisions regarding the construction of the numerical model to provide adequately representative simulations. The initial decision relates to the extent of the overall model domain and the scale to be used in representing the hydrogeologic systems in both the horizontal and vertical dimensions.

In formulating the conceptual model there are three key steps (Anderson and Woessner, 1992):

- ➔ Defining hydrostratigraphic units;
- ➔ Defining the groundwater and surface water system; and
- ➔ Analyzing elements of the water budget.

The conceptual model and the subsequent construction of the computer model involve some simplification and categorization of the data to represent the groundwater system in sufficient detail to provide reasonably representative results. Ultimately, model accuracy depends on the ability of the conceptual model to approximate observed conditions. Calibration statistics show how well the numerical model simulates these observed conditions.

The conceptual model for the Site is based on the topography, physiography, geology, hydrogeology and water budget outlined in **Section 2** of the main report and is depicted in the schematic section on **Figure 2A**.

H.3 SIMULATION CODE SELECTION

The numerical simulation code selected for this study was MODFLOW-USG (**U**n-**S**tructured **G**rid) developed and maintained by the United States Geological Survey (USGS) (Panday, S., et al, 2013). Like previous versions of MODFLOW (USGS 1988-2005), MODFLOW-USG is a modular numerical groundwater flow simulator capable of representing the complex three-dimensional multi-layer systems for steady-state conditions in the confined and unconfined aquifers within the study area using the finite-difference method. However, MODFLOW-USG allows for more robust grid refinement in areas of increased interest. The MODFLOW family of software is the most widely used groundwater modeling code in the world and has been extensively tested and applied in the research and consulting communities. The MODFLOW-USG code is public domain and freely distributed. For this study, version 1.4.0 of the MODFLOW-USG code (released in 2017) was used.

Model input datasets include the physical geometry of the system, boundary conditions (no-flow, recharge or discharge) and aquifer properties (hydraulic conductivity). Groundwater flow can be modeled for many different types of sources or sinks, including lakes, rivers, drains, recharge from infiltration of precipitation, and pumping wells, among others. The code is flexible when modeling aquifer properties, allowing heterogeneity and anisotropy in three dimensions.

The flow system being modeled is split up into layers comprised of many smaller blocks referred to as nodes (or cells for previous versions of MODFLOW) based on the conceptual hydrogeological understanding of the model domain. The MODFLOW-USG code solves the groundwater flow mass balance equation for each node using the model input parameters. The general mass balance equation can be expressed as:

Sum of Boundary Inflows	+	Sum of Internal Sources of Water	=	Sum of Boundary Outflows	+	Sum of Internal Sinks of Water

The mass balance equation for an unconfined aquifer with recharge, discharge and leakage (Bear, 1979) can be written as:

$$\frac{\partial}{\partial x}\left[(h-b)\left(K_{xx}\frac{\partial h}{\partial x}\right)\right]+\frac{\partial}{\partial y}\left[(h-b)\left(K_{yy}\frac{\partial h}{\partial y}\right)\right]+\frac{K'}{B'}(H_0-h)+N-W=0$$

Where:

Where:	K_{xx}	=	hydraulic conductivity in the x-direction;
	K_{yy}	=	hydraulic conductivity in the y-direction;
	h	=	hydraulic head;
	b	=	elevation of the unit bottom;
	K'	=	vertical hydraulic conductivity of an underlying confining unit;
	B'	=	thickness of the confining unit;
	H_0	=	head in the aquifer underlying the confining unit;

N	=	a general source term representing groundwater recharge; and
W	=	a general sink term representing groundwater discharge.

Similar equations can be written for each aquifer in a layered sequence of aquifers / aquitards. When an aquifer is confined, the saturated thickness (h-b) is replaced with the total aquifer thickness.

MODFLOW-USG computes a mass balance for each time step specified by the model input, as well as cumulative flow volumes for each type of source / sink included in the model.

The solution to the mass balance equation is obtained by iteratively solving the system of equations for each model node. Initial conditions for the hydraulic head in each node are specified in the model input. A calculation procedure is used to adjust the initial head estimates and produce a new estimate of the heads which are closer to the solution of the system of equations. The procedure is repeated until the maximum head change in a model node between successive iterations falls below a closure criterion which is user specified. MODFLOW-USG provides two solver modules to obtain the model solution. For this study, the χMD solver was used with a closure criterion of 0.001 m.

MODFLOW-USG is accompanied by a utility program called ZONBUDUSG, a water budget calculator which sums the flow volumes from the various groundwater sources / sinks over a zone of interest. The program was modified from the earlier ZoneBudget version 3.01 (Harbaugh, 1990) to work with un-structured grid models. ZONBUDUSG was used in this study to calculate the water balance components of the study area, as well as predicting the discharge volume due to proposed quarry dewatering.

The model construction and calibration process were completed using Groundwater Vistas version 7.20 (Environmental Simulations Inc., 2017). Groundwater Vistas is a pre- and post-processor that is capable of creating MODFLOW-USG input files as well as reading output files in a user-friendly graphical user interface. Groundwater Vistas is also capable of importing model input datasets created by third-party software, including ArcGIS (ESRI, 2017). Both of these software programs were used to interactively prepare, edit and manage the information needed for model development.

To calibrate the baseline model, PEST (**P**arameter **EST**imation) version 15.0 (Doherty, 2016) software was used. PEST facilitates computer-assisted calibration of MODFLOW-USG models by back-calculating model parameters to match observation data such as groundwater elevation data, surface watercourse baseflow rates and horizontal and vertical hydraulic gradients. This procedure is referred to as “inverse modeling”. Additional utilities included in the Groundwater Data Utilities suite (Doherty, 2015b) were also used in tandem with PEST during the calibration process.

Particle tracking analysis was completed using mod-PATH3DU (Muffels et al, 2018), a particle-tracking model that uses MODFLOW-USG groundwater flow velocity vector output to delineate the travel path and time-of-travel for unstructured model grids.

H.3.1 EQUIVALENT POROUS MEDIA APPROACH

Numerical modeling of groundwater flow through saturated porous media typically simulates water movement through a continuous fully saturated medium such as sand and gravel with assigned distributions of porosity and hydraulic conductivity. Within fractured bedrock, the groundwater movement is typically greater within the fractures than within the surrounding matrix. **Photo 1** below shows the fracture density and continuous nature of the fractures at the existing Walker Brothers Quarry face while

Photo 2 below shows the Eramosa member and Goat Island member at the Spring Creek Quarry west of the Site near Beamsville. These photos demonstrate that the fractured rock can be simulated as an "equivalent porous media" using a model constructed to simulate flow through porous media with appropriate hydraulic properties. On a small scale, actual groundwater movement and simulated groundwater movement can be different. With simulations at a larger scale, the equivalent porous media approach provides a reasonable representation of groundwater flow patterns that is accepted by industry.

Photo 1 Quarry Face at Existing Walker Brothers Quarry

Photo 2 **Quarry Face at Spring Creek Quarry (near Beamsville)**

H.4 MODEL CONSTRUCTION

The groundwater model construction consisted of the following five phases:

- Spatial domain and grid discretization;
- Input of model layers;
- Boundary condition implementation; and
- Selection and input of hydraulic properties.

The following sub-sections describe each stage of the groundwater model construction.

H.4.1 SPATIAL DOMAIN AND GRID DISCRETIZATION

The model domain was set to encompass approximately 18,724 ha, with the proposed quarry excavation footprint located in the approximate centre of the domain, as shown in **Figure H-1**. The dimensions of the model are 12,400 metres on the north and south sides, and 15,100 metres on the east and west sides. The lower left corner of the model is located at UTM coordinates 644,500 E and 4,764,900 N (NAD83 Zone 17N).

The size of the domain was set to incorporate regional “boundaries”, including the Niagara Escarpment to the north, the OPG canal to the east, the Welland River to the south and the Welland Canal to the west. This is consistent with the local study area, as defined in **Section 1.3** of the main report. These features generally represent natural groundwater boundary conditions for the model domain and are sufficiently distant from the proposed quarry excavation footprint such that edge effects of the model boundaries do not have a direct influence on the groundwater flow patterns in the vicinity of the Site. Outside of these boundaries, the model cells were set as no-flow boundaries (inactive). Groundwater Vistas was set to remove inactive model cells from the MODFLOW-USG input files to reduce the model numerical burden.

Quadtree grid refinement was used at the Site and for other features of interest as shown in **Figure H-1**. Quadtree grid refinement is compatible with MODFLOW-USG and is implemented in Groundwater Vistas. For a quadtree-refined grid, parent grid cells are divided into smaller cells by powers of 2 (i.e., 2^x where x is the order of the desired refinement). The grid is then “smoothed” around the refined cells, such that no cell is refined by more than a factor of 2 compared to any adjacent cell. The quadtree approach provides numerical stability and reduces the number of unnecessary grid cells that are typically present in more traditional grid refinement methods.

Initially, a uniform grid of 151 rows by 124 columns was set up, resulting in grid spacing of 100 m in the x- and y-directions. Third order refinement (i.e., 8x8 sub-divided cells) was used for the model cells at the Site, resulting in a local grid spacing of 12.5 m square at the Site as shown in **Figure H-1A**. Second order refinement was used for cells coincident with watercourses and wetland features.

H.4.2 MODEL LAYERS

Ten (10) hydrostratigraphic layers were established in the model, representing the overburden, contact aquifer and bedrock stratigraphy outlined in **Section 2.4** of the main report, as summarized in **Table H.4.1** below.

Table H.4.1 Model Layer Thicknesses

Model Layer	Description	Layer Thickness (m)	Layer Type
1	Surficial Soils	1	Unconfined
2	Clayey Silt Overburden	Varies	
3	Contact Aquifer Till	10% of total overburden thickness	Confined
4	Weathered Bedrock	1	
5	Guelph Formation Bedrock	Up to 13.2	
6	Eramosa Member Bedrock	Up to 17.4	
7	Goat Island Member Bedrock	Up to 10.2	
8	Gasport Member Bedrock	Up to 11.4	
9	DeCew Formation Bedrock	Up to 3.5	
10	Rochester Formation Bedrock	Up to 18.0	

Layers 4, 5 and 6 represent the shallow bedrock aquifer at the Site, while layers 7 and 8 represent the deep bedrock aquifer.

Layer 10 of the model represents the Rochester formation shale, a lower no-flow boundary. This bedrock unit was included in the simulation as there are regional features which have an effect on the groundwater levels in this layer (for example, the groundwater collection trench at the Walker Brothers Quarry). Layers 1 (surficial soils) and 2 (clayey silt overburden) were set as unconfined, while the remaining layers 3 through 10 were set as confined. The conductivity of the model cells in layers 1 and 2 is computed using the upstream weighting method included in MODFLOW-USG (layer type 4).

The ground surface elevation (top of layer 1) is based on the 1 m Digital Elevation Model (DEM) released in 2013 and by the Niagara Peninsula Conservation Authority (NPCA). The contours were used to interpolate a raster data set using ArcGIS Desktop (ESRI, 2017). The interpolation at the Site was verified using ground surface spot elevation data acquired during the monitoring well surveys.

As noted in **Section 2.4.1** of the main report, the top of bedrock (top of layer 4) was interpolated using Site data, high-quality data from other Sites within the model domain and the MECP water well database. The raster calculator tool included in ArcGIS Desktop was used to ensure the interpolated top of bedrock was below the ground surface elevation. The closest area to the Site where bedrock is near ground surface occurs is in the vicinity of Beaverdams Creek to the north and northwest of the Site, where the data suggest that minimal overburden is present.

It is interpreted that the surficial soils mapping applies to the upper 1 m of overburden, as such the conductivity zones corresponding to surficial soil types is only present in layer 1. As noted in **Section 2.5.1** of the main report, the contact aquifer is discontinuous in the study area. The top of the contact aquifer (top of layer 3) was calculated by adding 10% of the total overburden thickness to the interpolated top of bedrock. This simplification was used due to the lack of data to ensure that in areas of thin overburden thickness the contact aquifer thickness is minimal.

The Eramosa member upper contact with the overburden is variable owing to the irregular upper erosional surface. For the underlying bedrock units, it is understood that the stratigraphic contact surfaces are not perfectly planar over Site specific distances, but planar surfaces are inferred to be a reasonable approximation over larger regional study areas. In the conceptual (and numerical) hydrogeological model for the study area, flat planar surfaces were interpolated from the Site borehole data to represent the stratigraphic contacts between bedrock units, and then extrapolated over the study area. A summary of the Site borehole stratigraphic details is provided on **Table C-3**, **Appendix C** of the main report.

The “trend” tool in ArcGIS was used to calculate a best-fit, flat (polynomial order 1) planar surface by performing a linear regression analysis in two dimensions (latitude and longitude). The Eramosa / Goat Island contact from 21 Site boreholes (including the Rolling Meadows study (JHL, 2004)) was used to perform the linear regression analysis, since it is among the most distinct contacts to pick at the Site and is inferred to most closely approximate a flat planar surface. An equation for the best-fit planar surface was calculated, and then the predicted contact elevations for each of the Site boreholes was compared to the actual values to determine the error at each point, and the overall root-mean-square error (RMSE), a measure of the plane’s fit to the available data. The results of the analysis yield a planar surface for the contact of the Goat Island member that dips at an orientation of 18º east of true north, with a slope of 0.64%. These results compare favourably to the generally accepted interpretation of the Niagara Peninsula stratigraphy published in the literature (e.g., NPCA, 2013). The RMSE of the best-fit plane is 1.4 m, which indicates that approximately two-thirds of the interpreted contact elevations from the bedrock core fall within ±1.4 m of this best-fit plane. Another useful measure of fit is normalized RMSE (NRMS), which divides the RMSE by the range of observed values. In this case, the NRMS is approximately 8%, indicating the planar surface is a good fit to the data.

To simplify the conceptual model, it is assumed that the stratigraphic contacts for the other underlying bedrock units fall along planar surfaces which are parallel (i.e., have the same slope and dip angle) to the Goat Island member contact as described above. To accomplish this, the z-axis coefficient of the equation of the best-fit Goat Island contact planar surface was modified to fit the observed contact data for the other bedrock units at the Site. Supplemental data from the other studies were also used to compute the measure of fit between the planar surfaces and the data. Relevant stratigraphic contact details from the supplemental boreholes are summarized in **Table C-2**, **Appendix C**. Borehole logs are also included in **Appendix C**.

A summary of the stratigraphic interpretation is provided in the table below.

Of note, there are no boreholes at the Site which are completed through the Rochester Formation from which to estimate its thickness. Therefore, a thickness of 18.0 m was assumed, based on the unit thicknesses calculated for more recent boreholes completed at the Walker Brothers Quarry to the north and the Ontario Power Generation Niagara Sir Adam Beck 3 Tunnel Project to the east. The best-fit NRMS was calculated using the contact values from all the boreholes within the study area with associated Irondequoit formation picks, including Bolton (1957) and the Ontario Oil, Gas & Salt Resources (OGSR) library.

Stratigraphic Layer	Calculated NRMS (%)		Interpolated Thickness (m)
	Site Boreholes	All Boreholes	
Eramosa Member	6.7	87.1	17.3
Goat Island Member	7.9	31.1	10.2
Gasport Member	12.7	32.5	11.4
DeCew Formation	6.9	27.9	3.5
Rochester Formation	6.4	17.1	18.0
Irondequoit Formation	--	24.4	--

The NRMS using data from all boreholes within the study area is notably higher than the others, at 87%. It is noted that the interpolation of the intact Eramosa member contact is highly reliant on data from boreholes completed along the western shoreline of the Niagara River (Bolton, 1957). This older data is subject to elevation errors due to the limited accurate information on the borehole locations but was included in the analysis as there is very little data available on the Eramosa member within the greater study area beyond the Site itself.

Layer 4 in the model represents the upper weathered bedrock. A thickness of 1 m was chosen to represent this layer. Layer 4 is continuous across the entire model domain; however, two separate conductivity zones were used to represent this layer north and south of the inferred Eramosa member subcrop. The underlying bedrock unit layer thicknesses and dip angle were set using the stratigraphic interpolation outlined above. Where an underlying bedrock layer intersected the bottom of layer 4, the layer thickness was set at a nominal value of 0.1 m. Groundwater Vistas was set to pinch-out model cells less than a thickness of 0.2 m, and set them as inactive. As such, layer 5 through 10 model cells north of their respective sub-crops were inactive.

A 3-dimensional oblique view of the model domain showing the model layers and hydraulic conductivity zones is provided in **Figure H-2**. This figure illustrates how the lower bedrock layers 5 through 10 pinch out where they intersect the weathered bedrock layer 4.

H.4.3 BOUNDARY CONDITIONS

The boundary conditions assigned to the model are shown in **Figure H-3**. The boundary conditions in the vicinity of the Site are shown in **Figure H-3A**.

The active model domain is consistent with the local study area as defined in **Section 1.3** of the main report. As noted above, all model cells outside of this lateral extent are set as no-flow boundaries (inactive). Additional no-flow boundary cells were simulated within the WAI East Landfill footprint (shown in **Figure H-3**). This landfill is lined and the internal flow processes within the landfill are not relevant to the current study.

H.4.3.1 CONSTANT HEAD BOUNDARIES

Constant head boundaries were used to represent the Welland Canal and turn basins and the Queenston Chippewa Power Canal. The 3,322 constant head boundaries used in the model are summarized in **Table H.4.2** below.

Table H.4.2 Constant Head Boundary Parameter Values

Reach	Description	No. of Cells	Layer	Stage Elevation (masl)
0	Welland Canal (below Lock 7)	12	1 – 4	161
1	Welland Canal (above Lock 7)	1,069	1 – 7	173.4
2	Welland Canal Central Turn Basin	328	1 – 4	173.4
3	Welland Canal South Turn Basin	1,722	1 – 4	173.4
4	Queenston-Chippewa Canal	191	6 – 9	165.5

Constant head boundaries are used for model cells for which the head is specified in advance of the simulation and held at the specified value through all model time steps.

The Welland Canal is located west of the Site and is shown on the conceptual east-west cross section (**Figure 8** of the main report). The published depth of the canal is approximately 8.2 m. Based on information provided by NPCA, the canal is completed into bedrock from approximately Hurricane Road in Thorold to Glendale Road in St. Catharines (i.e., essentially along the entire route within the study area). The water levels in this reach of the canal are 1 m to 2 m below the average Lake Erie water level elevation of 175 masl, governed by the outlet elevation at Lock 7 (shown on **Figure 3** in the main report). North of Lock 7, the canal water level is maintained at approximately 161 masl upstream of Lock 6 situated at the north end of the study area.

The Queenston-Chippewa Power Canal is located east of the Site and is shown on the conceptual east-west cross section (**Figure 9** of the main report). The channel is reportedly concrete lined north of Oldfield Road (i.e., along the entire length of the canal within the study area). The reported maximum depth (including soil and rock cut) of the canal is approximately 43.5 mbgs. It is inferred that this maximum depth occurs at the point of highest ground surface elevation along the canal route. Based on the 2010 DEM released by NPCA, this point is located south of the east-west regional section line near Lundy's Lane. An assumed depth of 43.5 m places the base of the canal at approximately the top of the DeCew Formation. There is reportedly very minimal bottom depth vertical declination along the canal route from the inlet at the Welland River to the outlet at Sir Adam Beck generating station. Canal water level hourly data from 2008 to 2012 suggests a relatively narrow range of fluctuation between 164 masl and 170 masl, with an assumed mean value of 165.5 masl.

H.4.3.2 RIVERS

River boundary cells were used to represent waterbodies and major watercourses. The 234 river boundaries used in the model are summarized in **Table H.4.3** below.

Table H.4.3 River Boundary Parameter Values

Reach	Description	No. of Cells	Layer	Stage Elevation (masl)	Bottom Elevation (masl)	Conductance (m^2/day)
0	Undifferentiated Waterbodies	90	1	GS – 0.5 m	GS – 1.0 m	0.1
1	Welland River	144	1	171.3	166	0.1

Notes: GS – Ground surface

River boundaries are capable of simulating both discharge from and recharge to the groundwater system (i.e., groundwater sinks or sources) depending on the specified stage elevation of the boundary. Each river boundary requires three parameters which must be specified in the MODFLOW-USG input file: stage elevation, bottom elevation and conductance. As noted above, the stage elevation determines the gradient between the boundary condition and the adjacent model cell. The bottom elevation dictates which layer the boundary condition is placed in. Finally, the conductance of the river boundary governs the rate of flux to or from the groundwater system. River conductance is an aggregate of several parameters including stream width, bed thickness and vertical hydraulic conductivity of the streambed the river boundary represents. In Groundwater Vistas, river boundaries may be grouped together into reaches to represent different features of interest. The parameters for each reach included in the model are provided in **Table H.4.3** above.

The small waterbodies scattered sparsely throughout the domain were simulated as Reach 0. These boundaries were assigned a stage elevation equivalent to the interpolated ground surface minus 0.5 m, with a bottom elevation equal to 1.0 m below the interpolated ground surface. The Welland River was simulated as Reach 1, with stage elevation and bottom depths based on cross-sections provided by NPCA.

H.4.3.3 DRAINS

Drain boundary cells were used to represent ephemeral watercourses, seepage along the escarpment face, wetlands, the Walker Brothers Quarry active dewatering sump, drainage of the unconstructed portion of the South Landfill, and the Groundwater Collection System (GWCS) within the Rochester Formation (layer 10) and the leachate collection system (LCS) at the landfills west of Walker Brothers Quarry. The 6,395 drain boundaries used in the model are summarized in **Table H.4.4** below.

Table H.4.4 Drain Boundary Parameter Values

Reach	Description	Layer	No. of Cells	Stage Elevation (masl)	Conductance (m^2/day)
0	Escarpment Seeps	1 – 4	447	Bot of layer	10
1	Undifferentiated Watercourses	1	511	GS - 0.5 m	0.004
2	Thompsons Creek	1	307	GS - 0.5 m	
3	Beaverdams Creek (below SW1)	1	485	GS - 0.5 m	
4	Shriners Creek	1	517	GS - 0.5 m	

5	10 Mile Creek	1	117	GS - 0.5 m	
6	Beaverdams Creek (above SW1)	1	188	GS - 0.5 m	
7	Existing Watercourse (above SW3)	1	185	GS - 0.5 m	0.001
8	Existing Watercourse (above SW4)	1	425	GS - 0.5 m	
9	Existing Watercourse (below SW4)	1	82	GS - 0.5 m	
10	West Landfill LCS	8	61	166	10
11	South Landfill sump	8	173	L8 Bot	1,000
12	Walker Brothers Quarry sump	8	83	L8 Bot	1,000
13	GWCS	10	28	159	0.3
14	East Landfill LCS	1 – 8	426	Bot of layer	10
15	Wetlands	1	2,054	GS - 0.5 m	0.1
16	Queenston-Chippewa Canal Seeps	1 – 8	306	Bot of layer	10

Notes: GS = Ground surface, L3 Bot = Layer 3 bottom elevation, L8 Bot = Layer 8 bottom elevation

Drain boundaries are only capable of simulating discharge from the groundwater system (i.e., groundwater sinks). Each drain boundary requires two parameters which must be specified in the MODFLOW-USG input file: stage elevation and conductance. As noted above, the stage elevation determines the gradient between the boundary condition and the adjacent model cell. Finally, the conductance of the drain boundary serves the same purpose as that of river boundaries. Similar to river boundaries, drain boundaries may be grouped together into reaches to represent different features of interest. The parameters for each reach included in the model are provided in **Table H.4.4**.

The stage elevation of the ephemeral streams (reaches 1 through 9) and wetlands (reach 15) were estimated as 0.5 m below ground surface. The escarpment seep elevation was assumed equivalent to the bottom of layers 1 through 4. Of note, portions of Beaverdams Creek and the Existing Watercourse were separated into different reaches to allow calibration of the model to estimated baseflows at the staff gauges at the Site.

The Walker Brothers Quarry and West, East and South Landfills are located north of the Site. Active dewatering is occurring at the quarry and unfinished portion of the South Landfill, as well as localized drawdown within the Rochester Formation shale by the Groundwater Collection System (GWCS). The West Landfill LCS and GWCS elevations were set based on values provided in previous studies (SSPA, 2006). The South Landfill and Walker Brothers Quarry sump drains were placed in layer 8 with the stage elevation set at the top of the DeCew formation (bottom of layer 8). Finally, drains were added within the East Landfill footprint and along the Queenston-Chippewa Canal to remove excess water collecting within adjacent model cells due to the low-conductivity liner / no-flow boundaries used in the simulation.

H.4.3.4 GENERAL HEAD BOUNDARIES

The southern model boundary terminates along the Welland River, a surface watercourse which is interpreted to receive very little baseflow due to discharge of groundwater in the *Updated Assessment Report, Niagara Peninsula Source Protection Area* (NPCA, November 2013). Rather, flow within this watercourse is predominately the result of runoff from precipitation events. As such, the Welland River is not a natural boundary for the groundwater system, as there is the potential for groundwater inflow from outside of the model domain within the contact aquifer and shallow bedrock aquifer (layers 3 through 6) underlying the upper aquitard. For this reason, general head boundary cells were used along the southern model no-flow boundary from layers 3 through 6.

Similar to river boundaries, general head boundaries are capable of simulating both discharge from and recharge to the groundwater system (i.e., groundwater sinks or sources). However, flow into or out of the model domain is dependent on the groundwater elevation in the adjacent model cell within the active model domain and the specified elevation of the apparent recharge boundary outside of the model domain. Each general head boundary requires two parameters which must be specified in the MODFLOW-USG input file: recharge boundary elevation and conductance. As noted above, the recharge boundary elevation determines the gradient between the apparent recharge boundary outside of the active model domain and the adjacent model cell. The conductance of the general head boundary governs the rate of flux to or from the groundwater system and is related to the hydraulic conductivity of the hydrostratigraphic layer. The 399 general head boundaries used in the model were set as reach 0. The elevation of the apparent recharge boundary was set as 175 masl, and a conductance of 10 m^2/day was specified.

H.4.3.5 RECHARGE

Recharge boundaries were used in the uppermost active model cell to represent infiltration to the groundwater system. It is noted that for this study, infiltration to the groundwater system is defined as total precipitation less evapotranspiration and runoff to surface water features. In the model, the recharge boundaries were applied to the uppermost active cell in the vertical column (i.e., NRCHOP = 3)

Seven (7) zones were used to define areas of similar surficial soil types based on the surficial geology mapping provided in **Figure 4** of the main report. The recharge zones are shown in **Figure H-4**, and the calibrated baseline model parameter values are summarized in **Table H.4.5** below.

Table H.4.5 Recharge Zone Parameter Values

Zone	Description	Recharge	
		mm/year	m/day
1	Glaciolacustrine Silt and Clay (8a)	23	$6.3x10^{-5}$
2	Glaciolacustrine Sand and Gravel (9)	60	$1.6x10^{-4}$
3	Anthropogenic Deposits (21)	10	$2.7x10^{-5}$
4	Modern Alluvial Deposits (19)	20	$5.5x10^{-5}$
5	Active Quarry Excavation	330	$9.0x10^{-4}$
6	Unlined Landfill	20	$5.5x10^{-5}$
7	Landfill with LCS	0	0

As noted in **Section 2.3.1** of the main report, the recharge rate for the general study area was estimated to be 50 mm/year by the NPCA. However, the hydraulic conductivity estimates from the single well response tests indicate that the maximum recharge through the upper aquitard to the aquifer is much lower and was estimated to be 23 mm/year in the model. Higher recharge rates were assumed for the glaciolacustrine sand and gravel in the northeast portion of the model domain, while lower recharge rates were estimated for anthropogenic deposits (e.g., spoil from historic canal construction, etc.), modern alluvial deposits and unlined landfills. For landfills with a leachate collection system (LCS), no recharge was assumed to reach the aquifer. It should be noted that the glaciolacustrine silt and clay overburden covers the majority of the study area; the other overburden types cover much smaller areas and therefore have much less of an influence on the model results.

The recharge for the active quarry excavation was calculated by subtracting the estimated mean annual lake evaporation of 800 mm/year (Map 17 – Mean Annual Lake Evaporation, Hydrogeologic Atlas of Canada, 1975) from the 2017 annual precipitation within the study area, estimated as approximately 1,130 mm/year.

H.4.3.6 WELLS

Well boundaries were used to represent known major groundwater users within the model domain, as summarized in **Section 2.5.4.4** of the main report. The thirteen (13) wells included in the model are summarized in **Table H.4.6** below.

It is noted that for the calibration process, these well boundaries were deactivated. Most of the water level data (i.e., low-quality calibration targets, refer to **Section H.5.2** below) from the MECP water well records pre-date the inferred start-up date for these wells. Activation of these wells during the calibration process could potentially lead to errors in the calibrated baseline model parameter values. The well boundaries were activated in the post-calibration baseline model and predictive models to allow a cumulative assessment of impacts.

The “auto flow reduction” feature of Groundwater Vistas was used to automatically reduce the modeled discharge rates from the maximum permitted rates shown in the table above to speed model convergence. It is not likely that all of these wells pump at the maximum permitted rate for long periods of time, therefore the use of slightly lower rates in the calibrated model is appropriate.

Based on what is known about all of these Sites, the wells were assumed to be screened within model layer 4 (weathered bedrock).

Table H.4.6 Well Boundary Parameter Values

No.	Description	Site	UTM Coordinates		Model Layer	Discharge	
			Easting	Northing		L/s	m^3/day
1	Well No 1	Niagara Falls Golf Club	650650	4771750	4	3.8	327
2	Well No 2		650525	4771750		6.8	589
3	PW2	Mountain Road Landfill Site	652450	4778350		0.3	25.9
4	PW3		652450	4777550		0.8	64.8
5	PW4		652450	4777950		1.8	159.8
6	PW5		652650	4778450		0.8	71.3
7	PW7 / 13 / 14		652450	4778450		0.5	43.9

8	PW12		652550	4778450		0.05	4.3
9	PW16		652450	4778150		0.06	5.0
10	PW17		652650	4778350		0.3	21.6
11	PW18		652750	4778350		0.5	43.2
12	PW19		652450	4777450		0.7	64.8
13	RC	Recycling Centre	652950	4773750		0.3	25

H.4.4 HYDRAULIC PROPERTIES

Zones were used to represent hydraulic conductivity and vertical anisotropy for the various hydrostratigraphic units present within the study area. The calibrated model values for each of the nineteen (19) zones used in the model are summarized below in **Table H.4.7** below.

Table H.4.7 Hydraulic Conductivity Parameter Values

Layer	Description	Zone	Horizontal Hydraulic Conductivity (K_H) (m/day)	Vertical Anisotropy (K_Z / K_H) (Unitless)
1	*Weathered* Glaciolacustrine Silt and Clay (8a)	11	0.53	1.0
	Glaciolacustrine Sand and Gravel (9)	12	5.2x10^{-2}	0.2
	Anthropogenic Deposits (21)	13	0.1	1.0
	Modern Alluvial Deposits (19)	14	1.0	0.1
2	*Unweathered* Glaciolacustrine Silt and Clay	10	0.12	0.002
	Glaciolacustrine Sand and Gravel (9)	12	5.2x10^{-2}	0.2
3	Contact Aquifer Till	9	8.8x10^{-4}	0.06
	Glaciolacustrine Sand and Gravel (9)	12	5.2x10^{-2}	0.2
4	Weathered Eramosa / Guelph	7	1.3x10^{-2}	0.0015
	Weathered Goat Is / Gasport	8	3.6x10^{-5}	1.0
	Confining Bed “Window”	18	74	1.0
5	Guelph Formation	6	45	0.003
6	Eramosa Member	5	0.8	0.005
	High-permeability zone around PW1	19	137	0.5
7	Goat Island Member	4	0.8	0.009
8	Gasport Member	3	5.0x10^{-3}	0.3
9	DeCew Formation	2	1.0x10^{-4}	0.3

10	Rochester Formation	1	5.7	0.0003
--	Active Quarry Excavation	15	$1x10^{5}$	1.0
--	Unlined Landfill	16	0.1	1.0
--	Landfill with LCS	17	$2.6x10^{-5}$	1.0

At the Site, the shallow bedrock aquifer consists of model layers 4, 5 and 6, while the deep bedrock aquifer consists of layers 7 and 8.

Four zones (zones 11 – 14) were used to represent hydraulic conductivity and vertical anisotropy of similar surficial soil types in model layer 1 based on the surficial geology mapping provided in **Figure 4** of the main report. The zones in layer 1 are shown in **Figure H-5**. Based on MECP water well record information, the surficial sand and gravel (zone 12) was included in layers 1 through 3 in the calibrated baseline model. The weathered bedrock (model layer 4) was broken up into two zones (zones 7 and 8), separated by the inferred Eramosa member subcrop, as shown in **Figure H-6**. A low anisotropy value was used to simulate the inferred confining bed between the contact and shallow bedrock aquifers. An additional zone (zone 18) was added to represent an inferred “window” in the confining layer along the reach of the Existing Watercourse north of Upper’s Lane and the reservoir on Beaverdams Creek north of the SIte. The remaining layers are generally simulated using a single zone, with the exception of the Eramosa member (model layer 6). A high-permeability zone (zone 19) was simulated around pumping well PW1 based on the results of the constant rate pumping tests completed in 2017 and 2019 (refer to **Appendix D**). Three additional zones (zones 15 – 17) were added to represent anthropogenic features (i.e., the Walker Brothers Quarry and nearby landfills), also shown in **Figure H-5**.

Initial horizontal hydraulic conductivity and anisotropy values were set based on the discussion provided in **Section 2.5.2** of the main report and published ranges available in the literature. Zone properties were adjusted during the course of the model calibration to improve the fit with observation data.

H.5 MODEL CALIBRATION

H.5.1 OBJECTIVES AND METHODOLOGY

The objective of the groundwater flow model calibration is to achieve an acceptable approximation of the observed baseline groundwater elevation and flow patterns within the study area. The quantification of the model fit to calibration targets is evaluated using “residuals”. Residuals are calculated as the difference between the calibration target values and the simulated model output (i.e., observed minus simulated).

Model calibration statistics typically include max / min residual values, residual mean, absolute residual mean, sum of squared error (SSE), root mean square error (RMSE), and normalized root mean sum of squares (NRMS). The residual mean is an average of the residuals; a value approaching zero is desired (i.e., there is a balance of over-prediction and under-prediction occurring in the model). The spatial distribution of residuals is also considered; randomly distributed positive and negative residuals are desired. The mean of the absolute value of residuals provides an estimate of the total error of the model output. The SSE is calculated by summing the squares of the residuals. RMSE is calculated by taking the square root of the SSE divided by the total number of calibration targets. Another indicator of a successful model calibration is if the RMSE is comparable to the variance of the calibration target values. Finally, NRMS is calculated by dividing the RMSE by the total range in the calibration target values. An industry accepted target for the NRMS is less than or equal to 10% (Spitz and Moreno, 1996).

The model calibration was also evaluated using the volumetric water budget output summarized by MODFLOW-USG at the end of each simulation. The volumetric water budget provides the simulated water balance (groundwater flow into and out of the model domain) broken down by boundary condition type. An acceptable water balance error is less than 0.1%.

As noted in **Section 2.5.2** of the main report, natural fluctuations in groundwater elevations occur as a result of seasonal climatic conditions. However, the potential impacts on the from dewatering of the proposed quarry on the available drawdown are inferred to be greatest during the drier period of the year (i.e., September to November). Therefore, the study area is simulated using a single steady-state stress period representing average conditions in the month of October. The mean and variance of the baseline water level data for the month of October was used as the calibration targets for the Site wells. For high-quality data from other site wells, representative autumn water level data were used as the calibration targets, where available.

As noted above, PEST was used to assist in the model calibration, along with various utility programs developed by Watermark Numerical Computing. Groundwater Vistas was used to import calibration targets into the model in order to provide PEST with the observation data required to perform the inverse modeling. Sensitivity analyses of the model parameters were completed throughout the calibration process to determine which parameters were most sensitive to the model output.

The following sections describe the calibration target data and model parameters used in the PEST calibration.

H.5.2 CALIBRATED PARAMETERS

Where used, the PEST automated calibration process was allowed to modify the hydraulic conductivity and vertical anisotropy values for 12 of the 19 zones identified in **Table H.4.7** above, or up to 24 model parameters. Zones 13 through 19 were not included in the automated parameter calibration process, as they either (1) represented relatively small areas of the model domain and were insensitive to the model calibration, or (2) have values which represent anthropogenic features. The baseline model calibration was also sensitive to the value of the recharge zone corresponding to the weathered silt and clay overburden (recharge zone 1); as such, it was also included in the automated calibration process.

The remaining recharge zones and boundary conductances were relatively insensitive to the model calibration. In some cases, there were relatively sparse data with which to estimate model parameter values directly. For these parameters, physically realistic values were adopted, based either on Site-specific data or from published ranges.

H.5.3 CALIBRATION TARGETS

For this study, a total of 810 targets were used to calibrate the model to baseline conditions, described in the sections below. Summary tables of the target values and calibrated residuals are provided in **Section H.5.4** below.

H.5.3.1 SITE OBSERVATION DATA

A statistical analysis was completed on the baseline water level data for the Site monitoring wells to calculate the mean groundwater elevation and associated variance for the month of October. These elevations were imported to Groundwater Vistas as head targets, designated as Group 1. There are a total of sixty (60) groundwater monitoring wells / standpipes in the Site monitoring network; however, there are only forty-five (45) head targets included in Group 1. Water level data from the eleven (11) monitoring wells screened in the Gasport member (BH03-2A, MW11-3AR, MW16-5A, MW16-5AR, MW16-6A, MW16-7A, MW16-8A, MW16-9A, MW16-10A, MW16-13A and MW17-20A) were not included in the Group 1 head targets as the water levels were deemed unreliable due to interference from the gas present in these wells and slow recovery from drilling. The water levels from Rochester / DeCew wells MW11-1A, MW11-2A and MW11-4A were also excluded for this reason. Also, a target is not available for MW17-20SP as this well was dry during the late summer / fall throughout the baseline monitoring period. The overall variance (σ^2) for all of the October baseline water level data is calculated as 8.05 m^2 (standard deviation s = 2.84 m).

The mean water level data from nested Site wells were also used to calculate vertical hydraulic gradients between the contact aquifer (model layer 3) and the shallow bedrock aquifer (model layers 4 and 6). Hydraulic gradients between the Gasport member and other layers were interpreted to be unreliable due to the interference caused by the natural gas. A total of twenty-five (25) vertical hydraulic gradient (head difference) targets were imported to Groundwater Vistas, designated as Group 5.

Finally, baseflow (flux) targets were assigned for the reaches of Beaverdams Creek and the Existing Watercourse upstream of staff gauges SW1, SW3 and SW4, designated as Group 6. As noted in **Section 2.3.1** of the main report, flow is observed at these staff gauges only following precipitation or melt events. As such, the baseflow from groundwater discharge appears to be minimal, and a flux target of 0 m^3/day was assigned for these stream reaches.

H.5.3.2 OTHER HIGH-QUALITY OBSERVATION DATA

High-quality autumn water level data (where available) from monitoring wells at other sites within the study area were imported to Groundwater Vistas as head targets, designated as Group 2. Data from a total of forty-two (42) off-site monitoring wells is included in Group 2. It is noted that autumn water level data was not available for all of the off-site high-quality wells. A summary of the dates of the available data is provided in **Table E-2**, **Appendix E** of the main report.

Where possible, autumn water level data from off-site nested monitoring wells were also used to calculate vertical hydraulic gradients between the various layers. A total of thirty-two (32) off-site head difference targets were imported to Groundwater Vistas and added to Group 5.

A flux target of 265 m^3/day (approximately 96.7 ML/year) was assigned to the Walker Brothers Quarry (drain reach 12), and also designated Group 6. Since the 2010 DEM was used to interpolate the ground surface in the model, the excavation footprint in the model is similar to the 2010 configuration. Therefore, the October 2010 pumping records were used to estimate the flux target. It is noted that this total includes precipitation less evaporation, which is consistent with parameter value for recharge zone 5.

An additional flux target of 45 m^3/day (approximately 16.4 ML/year) was assigned to the closed West Landfill LCS (drain reach 10), and also designated as Group 6. An analysis of the West Landfill LCS yearly discharge volumes from 1995 through 2018 shows that the discharge is highly correlated with the observed annual precipitation. A representative target of 45 m^3/day was selected to simulate average October conditions in any given year.

H.5.3.3 WATER WELL RECORDS

Lower-quality water level data from MECP water well records within the study area were imported to Groundwater Vistas as head targets, designated as Group 3. The water well record data was parsed to remove data of low reliability as summarized in **Section 2.5.1** of the main report. A total of 224 water levels were included in Group 3, as summarized in **Table E-3**, **Appendix E**, of the main report. The dates the water levels were obtained are also given on **Table E-3**.

It is noted that the MECP water well record target data represent a single “snapshot” in time. Calculated residuals of up to ± 5 m between the model simulated head and water level reported on the record are not unexpected. The reasons for such a relatively large discrepancy include, among others, (1) seasonal variance at the well during the period in which the level was measured, (2) incomplete recovery after the well was installed, (3) poor (or no) elevation control on the data and (4) inaccuracy in the reported well location.

H.5.3.4 WETLAND FEATURES

In order to increase the observation data in the model, artificial head targets were assigned as the interpolated ground surface in the vicinity of the mapped wetland features in the study area. This implies that the water table in the shallow overburden (model layer 1) intersects the ground surface in these areas, which is a reasonable assumption. A total of 437 head targets associated with the wetland features were imported to Groundwater Vistas, designated as Group 4.

H.5.4 CALIBRATION RESULTS

H.5.4.1 CALCULATED RESIDUALS

Group 1 Head Targets

The Group 1 (Site data) head targets and calculated residuals from the calibrated baseline model are summarized in **Table H.5.1** below.

Table H.5.1 Group 1 Head Targets Calculated Residuals

No.	Description	Easting	Northing	Model Layer	Head Target			Calculated Residual (m)
					October Baseline Data		Simulated (masl)	
					Mean (masl)	Standard Deviation (m)		
1	BH03-2B	648519	4772919	6	176.45	0.55	178.49	-2.04
2	MW11-1B	648540	4772243	6	176.59	0.64	178.84	-2.25
3	MW11-1OB	648542	4772243	3	179.04	0.59	181.72	-2.68
4	MW11-2B	649458	4772697	6	179.43	1.33	180.43	-1.00
5	MW11-2OB	649457	4772697	3	180.84	0.94	183.57	-2.73
6	MW11-3BR	649515	4773488	4	176.32	0.57	180.33	-4.01
7	MW11-3OBR	649515	4773486	3	176.49	0.73	182.32	-6.00
8	MW11-4B	648503	4773352	6	174.94	0.66	177.39	-2.45
9	MW11-4OB	648505	4773352	3	179.88	1.06	180.05	-0.17
10	MW16-5B	649015	4773470	6	175.21	0.40	178.14	-2.93
11	MW16-5OB	649014	4773470	3	177.19	1.01	180.02	-2.83
12	MW16-6B	649413	4773168	6	178.70	1.14	180.19	-1.49
13	MW16-6OB	649412	4773167	3	179.85	1.02	182.92	-3.07
14	MW16-7B	649148	4772487	6	176.78	0.64	179.82	-3.04
15	MW16-7OB	649150	4772488	3	177.81	0.89	182.07	-4.26
16	MW16-8B	648270	4772003	6	177.91	0.74	178.39	-0.48
17	MW16-8OB	648269	4772003	3	181.88	2.24	181.83	0.05
18	MW16-9B	648260	4773006	6	176.55	0.56	178.33	-1.78
19	MW16-9OB	648261	4773005	3	177.68	0.65	181.29	-3.61
20	MW16-9SP	648263	4773003	1	180.22	0.44	182.91	-2.69
21	MW16-10B	648212	4773547	6	176.32	0.44	176.50	-0.18
22	MW16-10OB	648212	4773550	3	179.76	0.83	179.05	0.71

23	MW16-11	648503	4773178	3	180.35	1.16	180.76	-0.41
24	MW16-12	648507	4772982	3	181.76	0.88	181.43	0.33
25	MW16-13B	648513	4772783	6	176.53	0.56	178.49	-1.96
26	MW16-13OB	648513	4772782	3	181.92	1.17	181.68	0.24
27	MW16-14	648520	4772609	3	180.81	0.84	181.67	-0.86
28	MW16-15	648524	4772421	3	177.97	0.88	181.71	-3.74
29	MW16-16	648806	4772274	3	177.57	0.45	181.00	-3.43
30	MW16-17	648996	4772677	3	176.54	0.35	179.95	-3.41
31	MW16-18B	648816	4773300	4	176.00	0.42	176.88	-0.88
32	MW16-18OB	648815	4773302	3	175.83	0.34	177.65	-1.82
33	MW16-19B	648826	4773443	4	175.79	0.47	176.58	-0.79
34	MW16-19OB	648826	4773445	3	175.63	0.21	177.45	-1.82
35	MW17-20B	649805	4772731	6	179.61	1.84	181.02	-1.41
36	MW17-20OB	649804	4772730	3	181.52	0.27	184.46	-2.94
37	MW17-21B	648250	4772587	6	178.07	0.76	178.55	-0.48
38	MW17-21OB	648247	4772587	3	182.93	0.67	182.11	0.82
39	MW17-21SP	648249	4772587	1	183.89	0.05	183.61	0.28
40	MW17-22B	648409	4772965	6	176.52	0.57	178.49	-1.97
41	MW17-22OB	648411	4772964	3	182.18	0.27	181.73	0.45
42	MW17-22SP	648412	4772963	1	182.15	0.30	182.75	-0.60
43	MW17-23B	648239	4773134	6	176.19	0.59	178.03	-1.84
44	MW17-23OB	648239	4773131	3	177.48	0.66	181.02	-3.54
45	MW17-23SP	648239	4773130	1	180.62	0.11	182.57	-1.95

Group 2 Head Targets

The Group 2 (other site high-quality data) head targets and calculated residuals from the calibrated baseline model are summarized in **Table H.5.2** below.

Table H.5.2 Group 2 Head Targets Calculated Residuals

No.	Description	Location	Easting	Northing	Model Layer	Head Target (masl)		Calculated Residual (m)
						Representative Fall Groundwater Elevation	Simulated	
1	BH1-I	Brown Line Landfill	648683	4768945	4	176.31	175.87	0.44
2	BH1-II		648683	4768945	3	176.64	179.34	-2.70
3	BH1-III		648683	4768945	1	179.39	181.66	-2.27
4	BH2-I		650424	4768922	4	175.88	177.91	-2.03
5	BH2-II		650424	4768922	3	176.65	179.59	-2.94
6	BH2-III		650424	4768922	1	179.83	181.33	-1.50
7	BH3-I		649591	4768335	4	175.61	175.88	-0.27
8	BH3-II		649591	4768335	3	175.86	179.19	-3.33
9	BH3-III		649591	4768335	1	177.53	181.66	-4.13
10	BH4-I		649254	4767269	4	174.42	175.36	-0.94
11	BH4-II		649254	4767269	3	173.53	176.83	-3.30
12	BH4-III		649254	4767269	1	175.80	178.01	-2.21
13	BH5-I		650353	4767364	4	174.11	175.48	-1.37
14	BH5-II		650353	4767364	3	173.97	177.52	-3.55
15	BH5-III		650353	4767364	1	174.24	179.33	-5.09
16	CMT3-3(28)	Mountain Road Landfill	652741	4777578	4	182.50	185.66	-3.16
17	CMT3-6(37)		652741	4777578	10	177.66	181.62	-3.96
18	CMT5-2(7)		652386	4778554	4	168.93	179.63	-10.70
19	CMT5-5(13)		652386	4778554	4	166.28	180.86	-14.58
20	OW10(5)r		652517	4777526	3	188.75	186.83	1.92
21	OW30(20)		652741	4777578	3	193.43	187.11	6.32
22	OW54(23)		652517	4777526	4	180.41	185.07	-4.66
23	CRA-11D-09	Recycling Centre	652979	4773743	4	184.90	181.06	3.84
24	IW6		652985	4773843	4	184.21	181.90	2.31
25	OW13D		652871	4773896	4	184.53	182.51	2.02

26	OW13S		652871	4773896	3	185.79	186.76	-0.97
27	BH14	Thorold Co-Gen Plant	646579	4774238	3	164.46	174.56	-10.10
28	BH19		646580	4774177	3	171.40	174.72	-3.32
29	BH6		646640	4774257	3	167.40	174.94	-7.54
30	19-IIIR	Walker Brothers Quarry	649320	4777011	4	173.47	174.97	-1.50
31	19-IR2		649320	4777011	10	172.70	177.07	-4.37
32	19-IVR		649320	4777011	3	179.71	176.22	3.49
33	40-IIr		649322	4776674	4	170.42	164.68	5.74
34	4-I		647826	4776540	10	168.62	175.93	-7.31
35	4-II		647826	4776540	4	169.08	169.27	-0.19
36	4-IV		647826	4776540	3	175.43	169.59	5.84
37	51-I		650403	4776402	10	180.08	179.04	1.04
38	51-III		650403	4776402	4	180.57	184.54	-3.97
39	51-IV		650403	4776402	1	180.83	187.43	-6.60
40	55-I		648943	4775340	10	168.80	177.33	-8.53
41	55-III		648943	4775340	4	170.31	179.15	-8.84
42	55-IV		648943	4775340	3	171.21	179.77	-8.56

Group 3 and 4 Head Targets

Due to the large number of targets in Group 3 (water well record data) and Group 4 (wetlands), the summary table of residuals is not included in the report. Only the calibration statistics are presented below in **Section H.5.4.2**.

Group 5 Head Difference Targets

The Group 5 head difference targets and calculated residuals from the calibrated baseline model are summarized in **Table H.5.3** below.

Table H.5.3 Group 5 Head Difference Targets Calculated Residuals

No.	Description	Location	Easting	Northing	Model Layers	Head Difference Target (m)		Residual (m)
						Observed	Simulated	
1	MW11-1OB/B	Site	648542	4772243	3 / 6	2.45	2.87	-0.42
2	MW11-2OB/B		649457	4772697	3 / 6	1.41	3.14	-1.73
3	MW11-3ROB/B		649515	4773486	3 / 6	0.17	1.99	-1.82
4	MW11-4OB/B		648505	4773352	3 / 6	4.94	2.66	2.28
5	MW16-5OB/B		649014	4773470	3 / 6	1.98	1.89	0.09
6	MW16-6OB/B		649412	4773167	3 / 6	1.15	2.74	-1.59
7	MW16-7OB/B		649150	4772488	3 / 6	1.03	2.25	-1.22
8	MW16-8OB/B		648269	4772003	3 / 6	3.97	3.44	0.53
9	MW16-9SP/OB		648263	4773003	1 / 3	2.54	1.62	0.92
10	MW16-9SP/B		648263	4773003	1 / 6	3.67	4.57	-0.90
11	MW16-9OB/B		648261	4773005	3 / 6	1.13	2.95	-1.82
12	MW16-10OB/B		648212	4773550	3 / 6	3.44	2.56	0.88
13	MW16-13OB/B		648513	4772782	3 / 6	5.36	3.19	2.17
14	MW16-18OB/B		648815	4773302	3 / 4	-0.17	0.92	-1.09
15	MW16-19OB/B		648826	4773445	3 / 4	-0.16	0.87	-1.03
16	MW17-20OB/B		649804	4772730	3 / 6	0.00	3.45	-3.45
17	MW17-21SP/OB		648249	4772587	1 / 3	0.96	1.49	-0.53
18	MW17-21SP/B		648249	4772587	1 / 6	5.82	5.05	0.77
19	MW17-21OB/B		648247	4772587	3 / 6	4.86	3.56	1.30
20	MW17-22SP/OB		648412	4772963	1 / 3	-0.03	1.03	-1.06
21	MW17-22SP/B		648412	4772963	1 / 6	5.63	4.27	1.36
22	MW17-22OB/B		648411	4772964	3 / 6	5.66	3.24	2.42
23	MW17-23SP/OB		648239	4773130	1 / 3	3.14	1.54	1.60
24	MW17-23SP/B		648239	4773130	1 / 6	4.43	4.52	-0.09
25	MW17-23OB/B		648239	4773131	3 / 6	1.29	2.98	-1.69
26	BH1-III/II	Brown Line Landfill	648683	4768945	1 / 3	2.75	2.32	0.43
27	BH1-III/I		648683	4768945	1 / 4	3.08	5.79	-2.71

28	BH1-II/I		648683	4768945	3 / 4	0.33	3.47	-3.14
29	BH2-III/II		650424	4768922	1 / 3	3.18	1.74	1.44
30	BH2-III/I		650424	4768922	1 / 4	3.95	3.42	0.53
31	BH2-II/I		650424	4768922	3 / 4	0.77	1.68	-0.91
32	BH3-III/II		649591	4768335	1 / 3	1.67	2.47	-0.80
33	BH3-III/I		649591	4768335	1 / 4	1.92	5.78	-3.86
34	BH3-II/I		649591	4768335	3 / 4	0.25	3.31	-3.06
35	BH4-III/II		649254	4767269	1 / 3	2.27	1.18	1.09
36	BH4-III/I		649254	4767269	1 / 4	1.38	2.65	-1.27
37	BH4-II/I		649254	4767269	3 / 4	-0.89	1.47	-2.36
38	BH5-III/II		650353	4767364	1 / 3	0.27	1.81	-1.54
39	BH5-III/I		650353	4767364	1 / 4	0.13	3.85	-3.72
40	BH5-II/I		650353	4767364	3 / 4	-0.14	2.03	-2.17
41	OW10/54	Mountain Road Landfill	652517	4777526	3 / 4	8.34	1.75	6.59
42	OW30/CMT3-3		652741	4777578	3 / 4	10.93	1.45	9.48
43	OW30/CMT3-6		652741	4777578	3 / 10	15.77	5.49	10.28
44	CMT3-3/6		652741	4777578	4 / 10	4.84	4.04	0.80
45	OW13S/D	Recycling Centre	652871	4773896	3 / 4	1.26	4.25	-2.99
46	4-IV/II	Walker Brothers Quarry	647826	4776540	3 / 4	6.35	0.32	6.03
47	4-IV/I		647826	4776540	3 / 10	6.81	-6.34	13.15
48	4-II/I		647826	4776540	4 / 10	0.46	-6.66	7.12
49	19R-IV/III		649320	4777011	3 / 4	6.24	1.25	4.99
50	19R-IV/I		649320	4777011	3 / 10	7.01	-0.85	7.86
51	19R-III/I		649320	4777011	4 / 10	0.77	-2.10	2.87
52	51-IV/III		650403	4776402	1 / 4	0.26	2.89	-2.63
53	51-IV/I		650403	4776402	1 / 10	0.75	8.39	-7.64
54	51-III/I		650403	4776402	4 / 10	0.49	5.50	-5.01
55	55-IV/III		648943	4775340	3 / 4	0.90	0.62	0.28
56	55-IV/I		648943	4775340	3 / 10	2.41	2.43	-0.02
57	55-III/I		648943	4775340	4 / 10	1.51	1.81	-0.30

Group 6 Flux Targets

The Group 6 flux targets for the calibrated baseline model are summarized in **Table H.5.4** below.

Table H.5.4 Group 6 Flux Targets

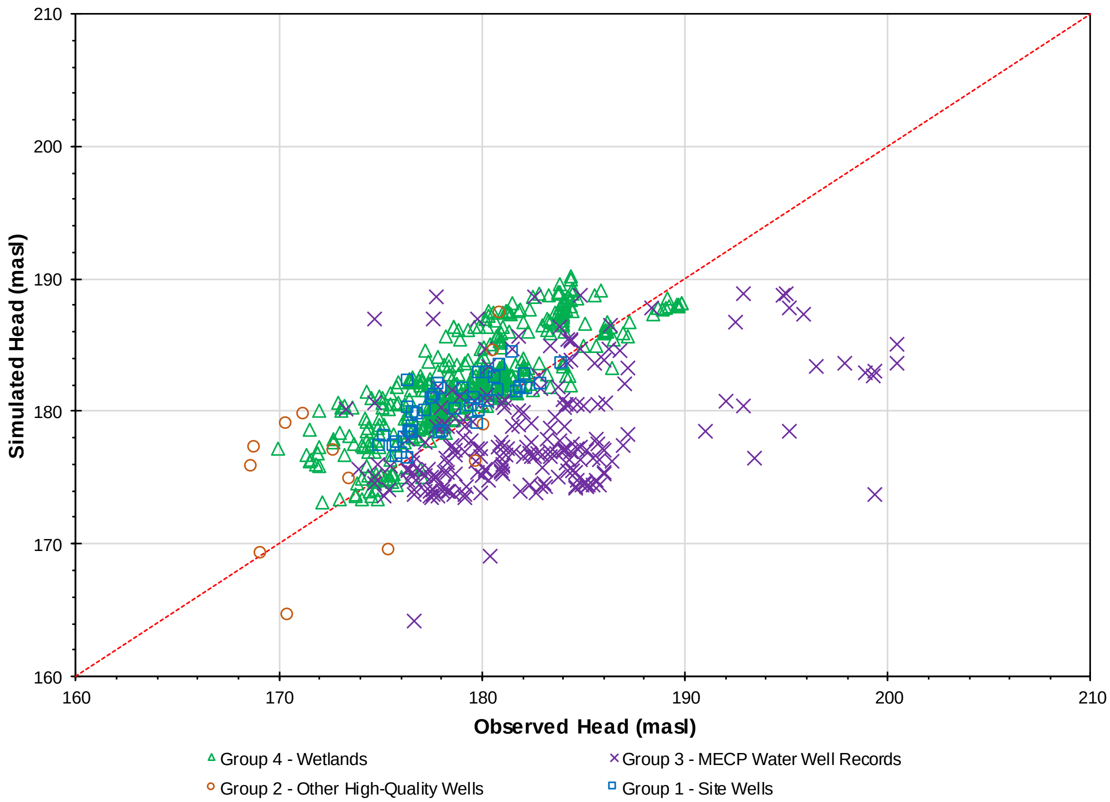
No.	Description	Drain Boundary Reach No.	Flux Target (m^3/day)	
			Observed	Simulated
1	Beaverdams Creek (above SW1)	6	0	4
2	Existing Watercourse (above SW3)	7	0	0.7
3	Existing Watercourse (above SW4)	8	0	1
4	Walker Brothers Quarry 2010 Sump Discharge	12	265	308
5	Closed West Landfill LCS Discharge	10	45	43

As shown in the table, the calibrated baseline model is a balance of over- and under-prediction of the observed flux targets.

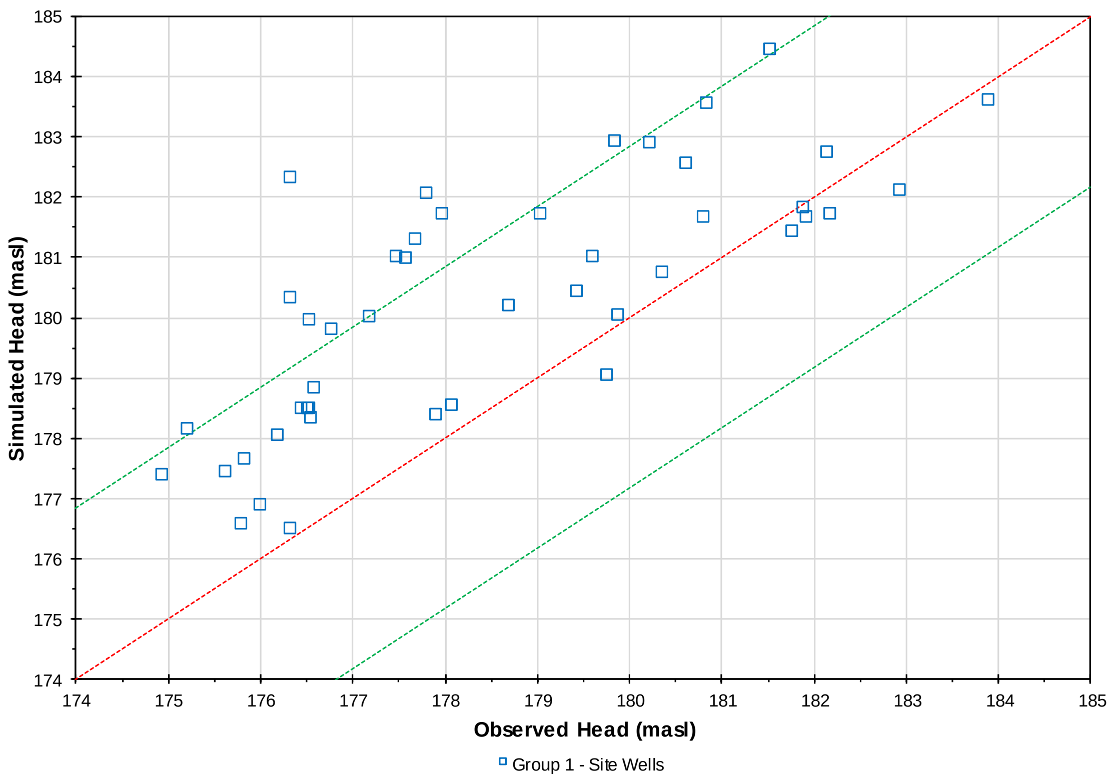
H.5.4.2 DIAGNOSTIC RESIDUAL PLOTS

A scatterplot of the observed and simulated heads for the calibrated baseline model is shown below, with different symbols representing the different head target groups discussed above. A scatterplot of the observed and simulated heads for the calibrated baseline model for the Site well data only is also shown below.

If a model were perfectly calibrated to fit the observation data, all of the points on the scatterplot would fall along the 45º line (i.e., the dotted red line on the plot). The scatterplot of all of the head targets (Groups 1 through 4) indicates that there is a reasonable balance between over- and underprediction in the calibrated baseline model. The scatterplot for the Site wells (Group 1) only indicates that the residuals follow the trend of the 45º line; however, a degree of over-prediction at the Site is occurring. Some of the over-prediction may be attributed to longer-term seasonal trends within the October data, or short-duration trends within the October data itself. The standard deviation of the October data is also shown on the scatterplot (i.e., the upper and lower dotted green lines). The majority of the Site well observation falls within this range.



Simulated Head (masl)
Observed Head (masl)
160
170
180
190
200
210
Group 4 - Wetlands
Group 3 - MECP Water Well Records
Group 2 - Other High-Quality Wells
Group 1 - Site Wells

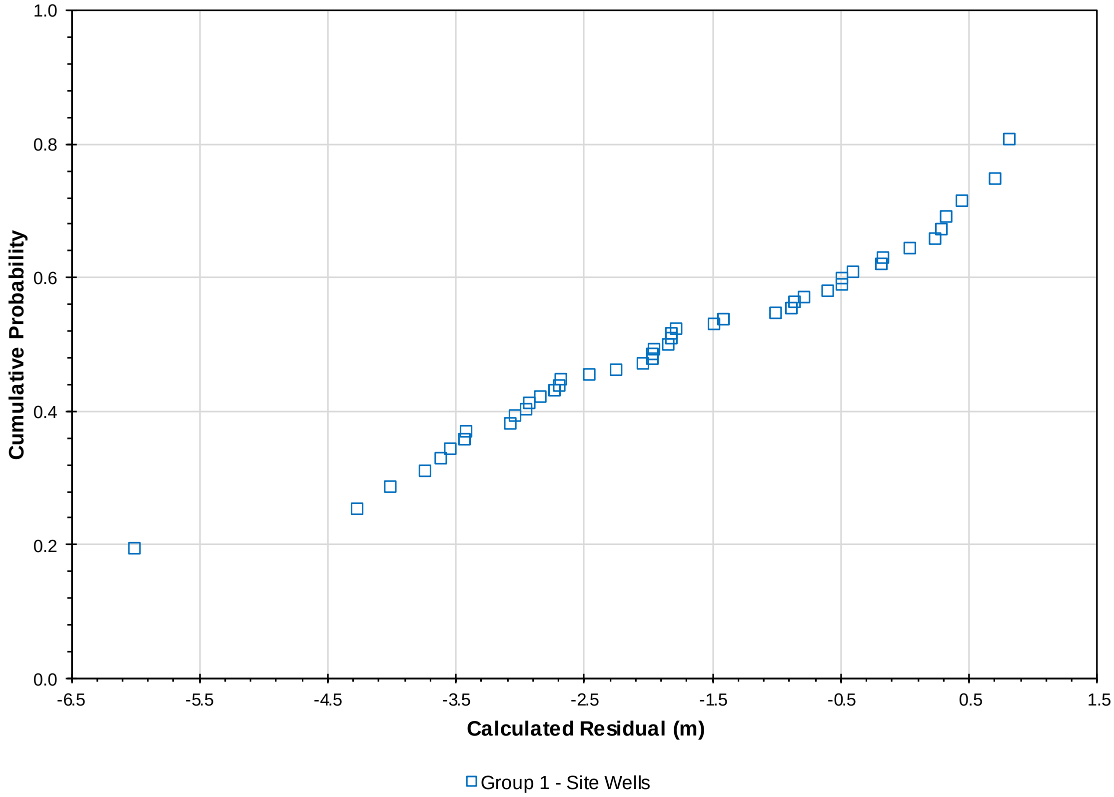


Simulated Head (masl)
Observed Head (masl)
174
175
176
177
178
179
180
181
182
183
184
185
Group 1 - Site Wells

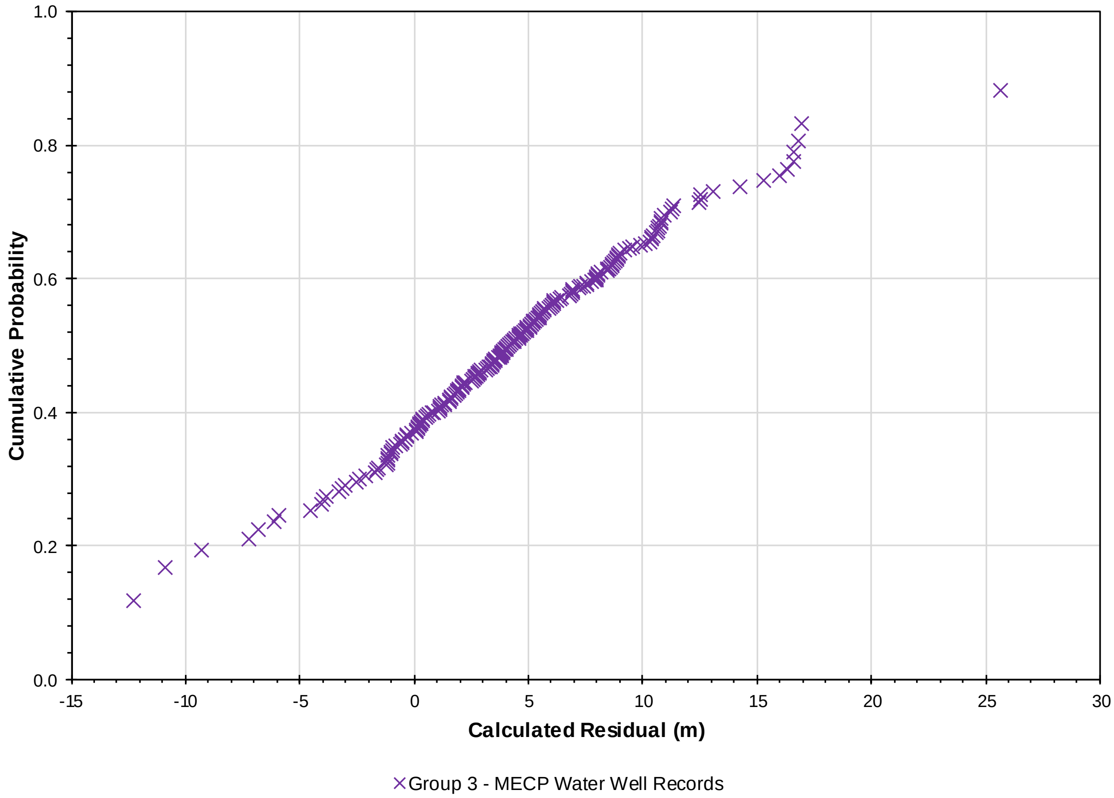
Cumulative probability plots for Group 1 (Site data) and Group 3 (water well record data) for the calibrated baseline model are provided below.

In practice, error is inherent in all numerical models due to various factors. However, it is desirable that the model error is not biased to one extreme. Cumulative probability plots are an indication of whether the error in the model simulated groundwater elevation is randomly distributed. If this is the case, all of the calibration targets tend to plot along a straight line. For this study, the majority of head target residuals in the cumulative probability plots for these two groups generally plot along a straight line, which indicates that the model error is generally randomly distributed.

At the two extremes of the cumulative probability plot, outlier targets (i.e., targets with extreme residual values which a reasonably calibrated model may not be capable of reproducing) tend to plot off of the straight line. For the plot of Group 1 targets, the residual for MW11-3OBR (approximately -6.0 m) is the largest absolute residual for the Site well data, and it plots off of the lower end of the straight line. The baseline data indicate that at this monitoring well nest, the groundwater elevation in the contact aquifer (MW11-3OBR) and shallow bedrock aquifer (MW11-3BR) are nearly identical. At nearly every other well nest, a consistent separation between the contact aquifer and shallow bedrock aquifer groundwater elevation was observed. This likely explains why this well appears to be an outlier on the cumulative probability plot, as the deliberately simplified model of the hydrogeological conditions at the Site is incapable of reproducing the unique conditions at this well nest. For the plot of Group 3 targets, calculated residuals of less than -5 m and more than +10 m deviate marginally from the straight line. This is not unexpected, given the potential error associated with MECP water well record data previously discussed in **Section H.5.3.3** above. A reasonably calibrated model would be expected to have difficulty reproducing anomalous head targets. Of note, the residual for well record no. 7258351 (approximately +25.7 m) is the largest absolute residual for the MECP water well record data, and it plots off of the upper end of the straight line. The well record indicates a street address of 1024 Beaverdams Road; however, this contradicts the findings of the water well survey (refer to **Appendix B** of the main report), in which the well at 1024 Beaverdams Road was confirmed to correspond to MECP water well record no. 7278404. The address / location of well record no. 7258351 is likely in error; however, there is no additional data to verify its accuracy.



1.0
0.8
0.6
0.4
0.2
0.0
Cumulative Probability
-6.5
-5.5
-4.5
-3.5
-2.5
-1.5
-0.5
0.5
1.5
Calculated Residual (m)
Group 1 - Site Wells



1.0
0.8
0.6
0.4
0.2
0.0
Cumulative Probability
-15
-10
-5
0
5
10
15
20
25
30
Calculated Residual (m)
Group 3 - MECP Water Well Records

The spatial distributions of head target residuals are shown in **Figures H-7 and H-8** for the contact aquifer (model layer 3) and shallow bedrock aquifer (model layers 4 through 6), respectively. The simulated groundwater elevation contours are also shown. The simulated flow patterns in each of these aquifers are similar to those shown in **Figures 14 and 15** of the main report. Model over- and under-predictions are generally not spatially correlated. The exception is for the shallow bedrock aquifer, in which the groundwater elevation in the southwestern portion of the model domain is largely under-predicted in the calibrated baseline model. It is noted that these head targets are mostly situated within model layer 5 (Guelph Formation), for which little high-quality data exists. During the calibration process, the hydraulic properties of this layer were found to be relatively insensitive to the overall model calibration, as well as the predicted drawdown from the full-development quarry (further discussion is provided below).

H.5.4.3 CALIBRATION STATISTICS

The calibration statistics for the various target groups in the calibrated baseline model are summarized in **Table H.5.5** below.

Table H.5.5 Calibration Statistics

Statistical Measurement	Unit	Head Targets					Head Difference Targets
		Overall	Group 1	Group 2	Group 3	Group 4	Group 5
Number of Observations	**--**	748	45	42	224	437	57
Min Residual	**m**	-14.6	-6.0	-14.6	-12.3	-8.1	-7.6
Max Residual	**m**	25.7	0.8	6.3	25.7	3.1	13.2
Residual Mean	**m**	-0.5	-1.8	-2.7	4.4	-2.7	0.4
Absolute Residual Mean	**m**	3.6	1.9	4.2	5.3	2.9	2.6
SSE	**m^2**	16,800	250	1,200	10,100	5,300	830
RMSE	**m**	4.7	2.4	5.3	6.7	3.5	3.8
Range of Observations	**m**	35.95	8.95	28.97	27.08	19.91	16.66
NRMS	**%**	**13.2**	**26.3**	**18.2**	**24.8**	**17.5**	**22.9**

The overall statistics for the head targets show that the model NRMS of about 13%. The residual mean error of -0.5 m indicates that there is a reasonable balance of over- and under-prediction of groundwater elevation within the model. The NRMS for the individual groups of targets is higher than the overall model NRMS, which demonstrates the difficulty with fitting a deliberately simplified regional model to different collections of target data. In this case, it was more desirable to obtain a satisfactory balance between over- and under-prediction in the simulated groundwater elevation. Of note, the RMSE for the Site well head targets (Group 1) is approximately
2.4 m, which is comparable to the standard deviation of the October baseline water level data (approximately 2.8 m).

H.5.4.4 MASS BALANCE ERROR

The mass balance for the calibrated baseline model is shown in **Table H.5.6** below.

Table H.5.6 Baseline Calibrated Model Mass Balance

Boundary Type	Mass Balance (m^3/day)		
	Inflows	Outflows	Outflow – Inflow
Recharge (RCH)	6,466	0	-6,466
Constant Head (CHD)	74	4,018	3,944
General Head (GHB)	479	251	-228
River (RIV)	7	155	148
Drain (DRN)	0	2,538	2,538
Well (WEL)	0	64	64
TOTAL	**7,026**	**7,026**	**0**
Discrepancy (%)	**--**	**--**	**0.02**

The mass balance error for the calibrated baseline model is approximately 0.02%, which indicates that there are no major mass-balance issues in the calibrated model.

H.5.5 CALIBRATED BASELINE MODEL SENSITIVITY ANALYSIS

PEST was used to complete a sensitivity analysis to estimate the calibrated baseline model parameter correlation and sensitivity (i.e., NOPTMAX set to -1). The purpose of the sensitivity analysis was to identify parameters which are highly correlated (i.e., different combinations of the correlated parameters may result in similar model predictions), and to quantify the sensitivity of the different parameters to the model calibration.

Parameter Correlation

Parameter correlation coefficients (PCCs) are used to evaluate whether parameter values can be estimated uniquely and are calculated for each parameter pair. PCCs can be expressed as the covariance of a parameter pair divided by the product of the square roots of the variances of the parameters. The calibrated baseline model PCC matrix for horizontal hydraulic conductivity is shown in **Table H.5.7**, while the PCC matrix for vertical anisotropy is shown in **Table H.5.8**.

Generally, a correlation coefficient with an absolute value greater than about 0.95 indicates that the two parameters involved likely cannot be estimated uniquely with the available data. **Tables H.5.7 and H.5.8** indicate that in general, most model parameters are not correlated to a high degree. The exceptions are the horizontal hydraulic conductivity / vertical anisotropy pairs for zones 2 (DeCew Formation), 7 (weathered Eramosa member), 8 (weathered Goat Island member) and 9 (contact aquifer) where a perfect correlation (i.e., a correlation coefficient of +1.0) is observed. For these zones, different combinations of these pairs of parameter values may result in similar model predictions (i.e., a nonunique solution). Because of this, the vertical anisotropy parameters for these layers were fixed at physically realistic values during the automated calibration process; only the horizontal hydraulic conductivity parameters were allowed to vary.

Composite Scaled Sensitivity

Composite scaled sensitivity (CSS) values are used to evaluate the overall sensitivity of a parameter and are calculated as the sum of the square roots of the dimensionless scaled sensitivity (DSS) divided by the number of observations. The DSS is the partial derivative of the simulated observation with respect to the parameter, multiplied by the square root of the weight assigned to the observation. DSS is used to evaluate the importance of an observation relative to the estimation of a single parameter.

The CSS typically is a good measure of the information that observations contribute to the estimation of parameters. The relative size of CSS values can be used to assess whether additional parameters can be estimated. A relatively large CSS value indicates that observations contain enough information to represent that aspect of the system. A relatively small CSS value (about two orders of magnitude less than the largest CSS value) indicates that the observations provide insufficient information with which to estimate the parameter. CSS values are useful in identifying those parameters which may be degrading, or are likely to degrade, the performance of the parameter estimation process through lack of sensitivity to model outcomes.

It is noted that some hydrogeological model parameters, such as hydraulic conductivity, are log transformed in PEST for easier processing. Therefore, sensitivity is expressed with respect to the log of the parameter. The relative composite sensitivity of a log-transformed parameter is determined by multiplying the composite sensitivity of that parameter by the absolute log of the value of that parameter. The CSS values for model parameters included in the calibration process are shown in **Table H.5.9** below.

The most sensitive parameters for the overall model calibration are the recharge in the silt and clay overburden (recharge zone 1), followed by the horizontal hydraulic conductivity / vertical anisotropy of the DeCew member (zone 2), the unweathered silt and clay (zone 10), the weathered Eramosa member (zone 7) and the Goat Island member hydraulic conductivity only (zone 4). For the Site wells, the most sensitive parameters are the recharge in the silt and clay overburden (recharge zone 1), followed by the horizontal hydraulic conductivity / vertical anisotropy of the weathered Eramosa member (zone 7), and the hydraulic conductivity of the Goat Island member (zone 4) and Eramosa member (zone 5).

For both target groups, the vertical anisotropy of the Goat Island member (zone 4), Guelph Formation (zone 6), the weathered silt and clay (zone 11) and the sand and gravel overburden (zone 12) were relatively insensitive to the model calibration.

Table H.5.7 Horizontal Hydraulic Conductivity Correlation Coefficients

		Horizontal Hydraulic Conductivity Zone											
		1	2	3	4	5	6	7	8	9	10	11	12
		Rochester Fm	DeCew Fm	Gasport Mb	Goat Island Mb	Eramosa Mb	Guelph Fm	Weathered Eramosa Mb	Weathered Goat Island	Contact Aquifer	Unweathered Silt and Clay	Weathered Silt and Clay	Sand and Gravel
Rch. Zn	**1**	-0.16	-0.33	0.24	-0.23	0.30	0.27	0.10	0.42	-0.23	0.30	-0.12	-0.16
Vertical Anisotropy Zone	**12**	-0.36	0.13	0.07	0.06	0.06	-0.19	0.06	-0.18	-0.15	0.02	-0.03	0.75
	11	0.22	0.37	-0.07	0.22	-0.17	0.15	0.001	-0.74	-0.004	-0.04	0.01	0.04
	10	0.10	-0.06	0.00	-0.06	0.11	-0.02	-0.06	0.05	-0.19	0.83	-0.43	0.03
	9	0.02	0.04	-0.63	-0.04	-0.002	-0.02	-0.68	-0.25	**1.00**	-0.31	0.13	-0.10
	8	-0.07	-0.40	0.18	-0.01	-0.03	-0.13	0.08	**1.00**	-0.24	0.16	-0.04	-0.22
	7	-0.004	-0.03	0.46	0.04	-0.02	-0.05	**1.00**	0.08	-0.67	-0.04	0.06	0.05
	6	0.23	0.17	0.01	-0.14	0.06	0.17	-0.03	-0.34	-0.04	-0.02	-0.07	-0.30
	5	-0.07	-0.02	-0.10	-0.40	0.54	-0.07	-0.28	0.10	0.16	0.08	-0.02	0.06
	4	0.09	0.30	0.10	0.40	-0.29	-0.09	0.30	-0.04	-0.24	-0.12	0.03	-0.10
	3	-0.25	-0.13	0.03	0.66	-0.42	-0.13	0.07	0.11	-0.03	-0.20	0.05	0.12
	2	0.03	**1.00**	-0.10	0.002	-0.06	-0.13	-0.04	-0.41	0.04	-0.16	0.12	0.04
	1	-0.17	-0.37	0.05	0.25	-0.12	-0.10	0.04	0.54	-0.10	0.11	0.02	0.27
Horizontal Hydraulic Conductivity Zone	**12**	-0.59	0.05	0.06	0.04	0.04	-0.16	0.05	-0.21	-0.10	-0.02	-0.02	
	11	0.09	0.12	-0.05	0.01	-0.04	-0.05	0.06	-0.04	0.13	-0.59		
	10	0.06	-0.16	0.08	-0.11	0.17	0.08	-0.04	0.16	-0.30			
	9	0.02	0.04	-0.63	-0.04	0.001	-0.02	-0.68	-0.24				
	8	-0.07	-0.40	0.18	-0.01	-0.03	-0.13	0.08					
	7	-0.01	-0.03	0.46	0.03	-0.02	-0.04						
	6	0.16	-0.13	0.03	0.06	-0.14							
	5	-0.01	-0.06	0.07	-0.85								
	4	-0.09	0.01	-0.06									
	3	-0.12	-0.10										
	2	0.02											

Table H.5.8 Vertical Anisotropy Correlation Coefficients

		Vertical Anisotropy Zone											
		1	2	3	4	5	6	7	8	9	10	11	12
		Rochester Fm	DeCew Fm	Gasport Mb	Goat Island Mb	Eramosa Mb	Guelph Fm	Weathered Eramosa Mb	Weathered Goat Island	Contact Aquifer	Unweathered Silt and Clay	Weathered Silt and Clay	Sand and Gravel
Rch. Zn	**1**	0.08	-0.33	-0.22	-0.28	0.04	-0.14	0.09	0.41	-0.23	0.02	-0.38	-0.17
Horizontal Hydraulic Conductivity Zone	**12**	0.27	0.04	0.12	-0.10	0.06	-0.30	0.05	-0.22	-0.10	0.03	0.04	0.75
	11	0.02	0.12	0.05	0.03	-0.02	-0.07	0.06	-0.04	0.13	-0.43	0.01	-0.03
	10	0.11	-0.16	-0.20	-0.12	0.08	-0.02	-0.04	0.16	-0.31	0.83	-0.04	0.02
	9	-0.10	0.04	-0.03	-0.24	0.16	-0.04	-0.67	-0.24	**1.00**	-0.19	-0.004	-0.15
	8	0.54	-0.41	0.11	-0.04	0.10	-0.34	0.08	**1.00**	-0.25	0.05	-0.74	-0.18
	7	0.04	-0.04	0.07	0.30	-0.28	-0.03	**1.00**	0.08	-0.68	-0.06	0.001	0.06
	6	-0.10	-0.13	-0.13	-0.09	-0.07	0.17	-0.05	-0.13	-0.02	-0.02	0.15	-0.19
	5	-0.12	-0.06	-0.42	-0.29	0.54	0.06	-0.02	-0.03	-0.002	0.11	-0.17	0.06
	4	0.25	0.002	0.66	0.40	-0.40	-0.14	0.04	-0.01	-0.04	-0.06	0.22	0.06
	3	0.05	-0.10	0.03	0.10	-0.10	0.01	0.46	0.18	-0.63	0.002	-0.07	0.07
	2	-0.37	**1.00**	-0.13	0.30	-0.02	0.17	-0.03	-0.40	0.04	-0.06	0.37	0.13
	1	-0.17	0.03	-0.25	0.09	-0.07	0.23	-0.004	-0.07	0.02	0.10	0.22	-0.36
Vertical Anisotropy Zone	**12**	0.19	0.12	0.13	-0.14	0.10	-0.46	0.06	-0.18	-0.15	0.07	-0.02	
	11	-0.46	0.38	0.00	0.25	-0.15	0.10	0.001	-0.74	0.002	0.01		
	10	0.04	-0.06	-0.13	-0.04	0.05	-0.01	-0.05	0.05	-0.21			
	9	-0.10	0.04	-0.03	-0.24	0.16	-0.04	-0.67	-0.25				
	8	0.54	-0.41	0.10	-0.04	0.10	-0.34	0.08					
	7	0.05	-0.04	0.07	0.31	-0.28	-0.04						
	6	-0.23	0.17	-0.16	0.04	0.03							
	5	0.06	-0.02	-0.09	-0.52								
	4	0.10	0.30	0.17									
	3	0.37	-0.14										
	2	-0.38											

Table H.5.9 Composite Scaled Sensitivies for Calibrated Parameters

			All Targets	Group 1 Targets Only
Recharge Zone 1 – Silt and Clay			0.51	1.87
Horizontal Hydraulic Conductivity Zone	1	Rochester Fm	0.06	0.05
	2	DeCew Fm	0.13	0.26
	3	Gasport Mb	0.02	0.03
	4	Goat Island Mb	0.08	0.39
	5	Eramosa Mb	0.06	0.39
	6	Guelph Fm	0.04	0.18
	7	Weathered Eramosa Mb	0.07	0.46
	8	Weathered Goat Island Mb	0.06	0.08
	9	Contact Aquifer	0.03	0.06
	10	Unweathered Silt and Clay	0.11	0.15
	11	Weathered Silt and Clay	0.03	0.10
	12	Sand and Gravel	0.01	0.02
Vertical Anisotropy Zone	1	Rochester Fm	0.01	0.03
	2	DeCew Fm	0.13	0.26
	3	Gasport Mb	0.01	0.02
	4	Goat Island Mb	0.005	0.03
	5	Eramosa Mb	0.01	0.07
	6	Guelph Fm	0.001	0.002
	7	Weathered Eramosa Mb	0.08	0.46
	8	Weathered Goat Island Mb	0.06	0.07
	9	Contact Aquifer	0.03	0.06
	10	Unweathered Silt and Clay	0.08	0.12
	11	Weathered Silt and Clay	0.001	0.003
	12	Sand and Gravel	0.001	0.002

H.5.6 CALIBRATION SUMMARY

A number of calibration targets and statistics related to different aspects of the conceptual understanding of the study area have been provided above. The objective of the calibration process for this study was to achieve a reasonable balance of these various targets.

Like many fractured-bedrock settings in southern Ontario, there are many variables to consider in understanding the hydrogeological setting of the study area. The numerical model is a deliberate simplification of a natural system and has been calibrated to achieve a reasonable representation with the available data at the time this report was published. The objective of the calibration process is not to capture every detail of the hydrogeological setting and match every observation. Instead, the goal is to achieve a reasonable balance between over- and under-prediction of the simulated groundwater elevations. In practice, all models have some degree of error; however, ensuring that model error is randomly distributed helps to reduce the possibility of bias in the model predictions.

The calibrated baseline model represents a reasonable representation of the autumn (October) data, with a balance between over- and under-prediction of the simulated groundwater elevations and a random distribution of error. The parameters that are most sensitive to the model calibration are physically realistic values based on the available data. Parameters which cannot be inferred through the model calibration process (i.e., there are insufficient observation data for estimation) have been assigned values which are physically realistic and within the ranges of published data. As such, the calibrated baseline model can be used to simulate the predicted effects of the proposed quarry during the drier months of the year when impacts to the available drawdown are greatest with a high degree of confidence in the results.

H.6 CALIBRATED BASELINE MODEL

The baseline Site water balance is shown in **Table H.6.1** below. Flow terms are shown both in the model units (m^3/day), as well as values normalized by the Site area (approximately 1.1 km^2) in mm/year. The Site area is equivalent to the proposed Licence boundary shown on the Site Plan (**Figure 2** in the main report).

Table H.6.1 Site Water Balance – Baseline Conditions

Boundary Type	Inflows		Outflows		Outflow – Inflow	
	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)
Recharge (RCH)	67	23	0	0	-67	-23
Drain (DRN)	0	0	37	13	37	13
Lateral GW Flow	63	22	93	32	30	10
TOTAL	**131**	**45**	**131**	**45**	**<0.01**	
				Discrepancy (%)	**0.08**	

The baseline water balance for the Site for autumn (October) conditions indicates that just over half of the total inflow to the Site originates as recharge, with the remainder originating as lateral groundwater inflow from the surrounding areas. Approximately 28% of the total outflow from the Site discharges to the Existing Watercourse and associated wetland complex, equivalent to a rate of 13 mm/year (0.4 L/s), which would not be detectable within the downstream standing water near DP2. The remainder or the outflow discharges as lateral groundwater outflow to the surrounding areas. There is an overall net outflow of groundwater from the Site to the surrounding areas, at a rate of approximately 30 m^3/day, or 10 mm/year.

The water balance for the Beaverdams Creek subwatershed for the calibrated baseline model is shown in **Table H.6.2** below. Flow terms are shown both in the model units (m^3/day), as well as values normalized by the subwatershed area (approximately 15.5 km^2) in mm/year.

Table H.6.2 Beaverdams Creek Subwatershed Water Balance – Baseline Conditions

Boundary Type	Inflows		Outflows		Outflow – Inflow	
	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)
Recharge (RCH)	990	23	0	0	-990	-23
Constant Head (CHD)	<1	<0.1	299	7	299	7
River (RIV)	6	~0.1	13	~0.3	7	0.2
Drain (DRN)	0	0	74	2	74	2
Well (WEL)	0	0	6	~0.1	6	0.1

Lateral GW Flow	676	16	1,280	30	604	14
TOTAL	**1,672**	**39**	**1,672**	**39**	**<0.01**	
				Discrepancy (%)	**-0.005**	

The baseline water balance for the Beaverdams Creek subwatershed indicates that approximately 60% of the total inflow to the subwatershed originates as recharge (infiltration through the silt and clay overburden), with virtually no contribution from the Welland Canal South Turn Basin (simulated as a constant head boundary in the model) or the small surficial waterbodies (simulated as river boundaries). Approximately 18% of the total outflow from the subwatershed discharges to the Welland Canal South Turn Basin, equivalent to a rate of 7 mm/year. An additional 4% of the total outflow discharges to the surficial watercourses (simulated as drain boundaries), equivalent to a rate of 2 mm/year (0.9 L/s), which would not be detectable within the downstream standing water near DP1. There would be negligible discharge to the small surficial waterbodies.

The two irrigation supply wells for the Niagara Falls Golf Club are situated within the subwatershed. As noted previously, the "auto flow reduce" feature of Groundwater Vistas was used during the model calibration process. This feature reduces the flow in well boundaries such that the simulated head in the model cell does not fall below the base of the cell (which causes model convergence issues). In the calibrated model, the wells withdraw groundwater at a rate of 6 m^3/day; this represents a negligible amount relative to the total outflow from the subwatershed. It is noted that because the model represents steady-state conditions, the well is implicitly assumed to be operating continuously. In reality, this is not the case. Based on the information obtained during the water well survey, these wells are only used sporadically to augment irrigation pond storage during dry periods. The assumption of continuous operation is therefore very conservative, and likely the reason for the discrepancy between the calibrated model flow rate and maximum permitted flow rate.

Finally, it is noted that there is an overall net outflow of groundwater from the subwatershed to the surrounding areas, at a rate of approximately 604 m^3/day, or 14 mm/year.

H.7 FULL DEVELOPMENT MODEL

Dewatering of the proposed quarry is required to maintain dry working conditions in the excavation. Groundwater will percolate through fractures in the quarry working face and drain by gravity through an internal network of ditches to the quarry sump. Direct precipitation on the quarry floor (less evaporation) will also accumulate in the sump. A dewatering pump will operate within the sump to remove excess water as needed, with discharge to the Existing or Realigned Watercourse.

The dewatering operation described above will manifest as an additional ‘stress’ to the baseline subwatershed water balance. The available drawdown within the shallow and deep bedrock aquifers will be lowered as a result of the additional stress, and a cone of depression (i.e., area that will exhibit a lowering of the available drawdown) will expand radially from the quarry excavation to reach a new equilibrium. The ultimate size of the cone of depression (i.e., the radius of influence) and the annual dewatering rate are dependant on the properties of the hydrostratigraphic layers present within the study area. The cone of depression will continue to expand away from the quarry dewatering until the total groundwater inflow and recharge over the radius of influence will be equal to the rate of groundwater withdrawal (i.e., outflow) by the quarry dewatering sump.

The proposed quarry design is described in **Section 3.0** of the main report. Numerical groundwater modeling was completed to predict the long-term steady-state effects of the proposed quarry dewatering at full development. The calibrated baseline model was adapted to simulate full quarry development at the Site, when the radius of influence will be the largest. The Realigned Watercourse was not included in the predictive model since it will be lined with a low-permeability material. Adaptation of the calibrated baseline model to simulate full quarry development conditions included the following modifications:

- ➔ Removal of the drain boundary conditions (i.e., Existing Watercourse tributaries) within the proposed quarry footprint.
- ➔ Additional hydraulic conductivity zone 20 was specified in model layers 1 through 8 within the proposed quarry footprint to simulate the removal of overburden and extraction of the bedrock resource. The hydrogeological properties for zone 20 are equivalent to those of zone 15 in the calibrated baseline model, which is used to simulate the effects of bedrock resource extraction at the Walker Brothers Quarry.
- ➔ Additional recharge zone 8 was specified within the proposed quarry footprint, with an equivalent rate of recharge to that of zone 5 in the calibrated baseline model, which is used to simulate the water surplus (i.e., precipitation less evaporation) at the Walker Brothers Quarry.
- ➔ A total of 4,909 model cells are situated within the proposed quarry footprint. Drain boundaries were set within each of these cells in model layer 8 (Gasport member), with a specified elevation of 0.1 m above the cell bottom to represent the quarry dewatering sumps. High conductance values were used such that there was no simulated hydraulic gradient across the proposed quarry footprint. The additional drain boundaries were specified as Reach 20 to facilitate estimation of the predicted annual water takings for dewatering the proposed quarry excavation.
- ➔ The simulated groundwater elevations from the calibrated baseline model were used as the initial head values in the full development model. This was implemented to allow the predicted drawdown

from the proposed quarry dewatering to be calculated directly by the MODFLOW code (i.e., the 'DDN' output file).

H.7.1 PREDICTED QUARRY EFFECTS

The shallow and deep bedrock aquifer predicted available drawdown at full quarry development is shown on **Figure H-9**. The existing water system extent per the Niagara Region Master Servicing Plan (2016) and the City of Niagara Falls and City of Thorold Official Plans are also shown on the figure.

Impacts to groundwater users due to quarry development are limited as only a relatively small portion of the currently un-serviced area between the urban boundaries of the City of Niagara Falls and City of Thorold is predicted to have an available drawdown of less than 3 m. It is also noted that the majority of the un-serviced land parcels north of Thorold Stone Road are currently monitored as part of the environmental monitoring program for the Walker Brothers Quarry.

The orientation of the predicted available drawdown 3 m contour towards the sand and gravel overburden in the northeast portion of the model domain is consistent with the conceptual interpretation that this area acts as a regional groundwater recharge zone.

The predicted dewatering rate for the sumps during the drier summer and autumn months is approximately 1.6 Mm^3/year (4,300 m^3/day). This value includes both groundwater inflow and runoff from direct precipitation (less evaporation). Using the proposed quarry excavation footprint area of approximately 681,600 m^2 and an estimated water surplus of 330 mm/year, direct precipitation accounts for approximately 14% of the total annual dewatering rate. The remaining 1.3 Mm^3/year (approximately 3,700 m^3/day) is due to predicted groundwater influx to the quarry excavation. Refer to **Section H.7.2** below for further discussion.

H.7.1.1 SENSITIVITY ANALYSIS

The impacted area of the predicted available drawdown and annual dewatering rate is not unexpected, given the study area hydrogeological setting:

- ➔ The proposed quarry excavation is relatively deep in comparison to the existing Walker Brothers Quarry, where the observed cone of depression is smaller and the annual dewatering rate is lower.
- ➔ The thick silt and clay overburden encountered at the Site is of relatively low permeability and is interpreted to restrict the recharge to the underlying aquifers, except immediately north of the Site. The overburden at the Walker Brothers Quarry is thinner and absent altogether in some areas closer to the Escarpment, facilitating recharge to the shallow bedrock aquifer.
- ➔ The Eramosa member bedrock in the vicinity of the Site is permeable and is interpreted to act as a relatively productive aquifer. This interpretation is consistent with the findings of the Welland Canal and Niagara Falls, New York studies summarized in **Section H.1.2**. The productive Eramosa member bedrock does not exist at the Walker Brothers Quarry, where the extraction of less permeable Goat Island and Gasport member bedrock is occurring.

A sensitivity analysis of the drawdown within the shallow bedrock aquifer was completed using the full development model, by placing artificial targets to the northeast and southwest of the Site in model layer 4. Not surprisingly, the overall most sensitive parameter for the predicted drawdown is the recharge through the silt and clay overburden, followed by the horizontal hydraulic conductivity / vertical anisotropy of the unweathered silt and clay. Northeast of the Site, the predicted drawdown is also sensitive to the hydraulic conductivity of the Goat Island member and the recharge through the sand and gravel overburden. Southwest of the Site, the predicted drawdown is also sensitive to the hydraulic conductivity of the weathered / unweathered Eramosa member bedrock.

A sensitivity analysis of the predicted dewatering rate was also completed using the full development model. The most sensitive parameters are the horizontal hydraulic conductivity / vertical anisotropy of the Eramosa and Goat Island member bedrock units, and the recharge in the silt and clay and to a lesser extent, the sand and gravel overburden. The remaining model parameters are relatively insensitive to the prediction of the dewatering rate.

H.7.2 FULL DEVELOPMENT WATER BALANCE

The full development Site water balance during dry summer / autumn conditions is shown in **Table H.7.1** below.

Table H.7.1 Site Water Balance - Full Development

Boundary Type	Inflows		Outflows		Outflow – Inflow	
	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)
Recharge (RCH)	712	244.4	0	0	-712	-244.4
Drain (DRN)	0	0	4,268	1,465.2	4,268	1,465.2
Lateral GW Flow	3,623	1,243.7	67	23.0	-3,556	-1,220.7
TOTAL	**4,335**	**1,488.1**	**4,335**	**1,488.2**	**0.2**	
				Discrepancy (%)	**-0.005**	

The full development Site water balance indicates that the predicted autumn (October) dewatering rate at full quarry development is approximately 4,268 m^3/day (approximately 1.6 Mm^3/year), as noted previously. The total inflow from recharge also increases to about 244 mm/year due to the removal of the overburden within the quarry excavation footprint. However, the increase in total inflow from recharge is insufficient to equilibrate with the total outflow due to dewatering. As a result, the net lateral groundwater flow switches from marginally net outward flow to a net inward flow, and accounts for approximately 86% of the predicted annual dewatering rate.

The water balance for the Beaverdams Creek subwatershed for the full development model is shown in **Table H.7.2** below.

Two main changes to the Beaverdams Creek subwatershed water balance for the fully developed quarry are (1) an increase in the inflow due to enhanced recharge within the quarry excavation footprint, and (2) an increase in the outflow for drain boundary conditions, over 99% of which is due to the simulated quarry dewatering sump.

Table H.7.2 Beaverdams Creek Subwatershed Water Balance - Full Development

Boundary Type	Inflows		Outflows		Outflow – Inflow	
	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)
Recharge (RCH)	1,635	38.5	0	0	-1,635	-38.5
Constant Head (CHD)	776	18.3	15	0.4	-761	-17.9
River (RIV)	12	0.3	0.1	<0.01	-12	-0.3
Drain (DRN)	0	0	4,270	100.6	4,270	100.6
Lateral GW Flow	2,540	59.9	678	16.0	-1,862	-43.9
TOTAL	**4,963**	**117.0**	**4,963**	**117.0**	**0.3**	
Discrepancy (%)					**0.005**	

In response to the dewatering, two notable changes to the water balance occur:

- The Beaverdams Creek subwatershed net lateral groundwater flow switches from a net outflow of about 14 mm/year under baseline conditions, to a net inflow of about 44 mm/year at full quarry development.
- The Welland Canal South Turn Basin (simulated using constant head boundaries), a net gaining surface water feature under baseline conditions (about 7 mm/year), switches to a net losing surface water feature at full quarry development, at a rate of about 18 mm/year. This results in a net change of about 12 L/s. It is expected that this rate would be lower in the spring when groundwater levels are seasonally highest, and the downward gradient is lowest.

The predicted subwatershed water balance under full quarry development results in a negligible change in net flow from the river boundaries, which represent surface water body features in the model. Under baseline conditions, the model simulated a net gain of about 0.2 mm/year for these features. Under the full quarry development, these features are predicted to switch from marginally net gaining to marginally net losing, at a rate of about 0.3 mm/year. This results in a net change of about 0.2 L/s. It is expected that this rate would be lower in the spring when groundwater levels are seasonally highest. This prediction is consistent with the interpretation that the surface water features are isolated from the underlying aquifers such that even under full quarry development, there is a negligible change in the water balance.

H.7.3 CUMULATIVE IMPACT ASSESSMENT

As noted previously in **Section H.4.3.6**, known permitted groundwater users (i.e., the Walker Brothers Quarry) are included in the calibrated baseline model. These users have also been included in the full development model to assess the cumulative impacts from the proposed quarry and existing permitted groundwater users.

Additional non-permitted users have not been included in the analysis to this point. Non-permitted groundwater users of significance include private domestic well users, and wells used for livestock watering or crop irrigation. Estimates of the annual demand for these non-permitted groundwater users are provided in the NPCA source protection report (NPCA, 2013). It is noted that the estimates were given for the combined subwatersheds shown on **Figure 3** of the main report, which have a combined area of approximately 75.8 km^2. The estimated average annual groundwater takings from these three groups of non-permitted users is summarized in **Table H.7.3**.

Table H.7.3 Estimated Non-Permitted Groundwater Use

Use	Annual Demand	
	(m^3/year)	(mm/year)
Private Domestic Wells	4,213	0.06
Livestock Watering	3,798	0.05
Crop Irrigation	62,689	0.8
TOTAL	**70,700**	**<1**

As shown in **Table H.7.3**, the estimated annual demand from non-permitted groundwater users is less than 1 mm/year. As such, the cumulative impact from these additional takings on the predicted subwatershed water balance at full quarry development is interpreted to be negligible.

H.7.4 ALTERNATE QUARRY DESIGN

Additional numerical groundwater modeling was completed to predict the long-term steady-state effects of an alternate quarry design with the internal road allowances removed as part of the excavation, as outlined in **Section 3.0** of the main report.

The shallow and deep bedrock aquifer predicted available drawdown for the alternate quarry design is shown on **Figure H-9A**. The extent of the drawdown for the alternate quarry scenario is nearly identical to the full quarry design presented on **Figure H-9**.

The predicted dry season dewatering rate for the alternate scenario is approximately 1.6 Mm^3/year (4,400 m^3/day), or about 4% higher than the full quarry scenario presented above.

The Site water balance and Beaverdams Creek subwatershed water balance for the alternate quarry design are shown in **Tables H.7.4 and H.7.5** below.

Table H.7.4 Site Water Balance – Alternate Quarry Design

Boundary Type	Inflows		Outflows		Outflow – Inflow	
	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)
Recharge (RCH)	749	257.1	0	0	-749	-257.1
Drain (DRN)	0	0	4,433	1,521.8	4,433	1,521.8

Lateral GW Flow	3,738	1,283.2	53	18.2	-3,685	-1,265.0
TOTAL	**4,487**	**1,540.3**	**4,486**	**1,540.0**	**-0.02**	
				Discrepancy (%)	**0.0005**	

Table H.7.5 Beaverdams Creek Subwatershed Water Balance – Alternate Quarry Design

Boundary Type	**Inflows**		**Outflows**		**Outflow – Inflow**	
	(m^3/day)	**(mm/year)**	**(m^3/day)**	**(mm/year)**	**(m^3/day)**	**(mm/year)**
Recharge (RCH)	1,672	39.4	0	0	-1,672	-39.4
Constant Head (CHD)	840	19.8	14	0.3	-826	-19.5
River (RIV)	12	0.3	0.1	<0.01	-12	-0.3
Drain (DRN)	0	0	4,435	104.5	4,435	104.5
Lateral GW Flow	2,604	61.4	679	16.0	-1,925	-45.4
TOTAL	**5,128**	**120.9**	**5,128**	**120.8**	**-0.05**	
				Discrepancy (%)	**-0.001**	

These results indicate that there is not a substantial difference in water budget components at either the Site level or the subwatershed level if the internal road allowances are excavated as part of the alternate quarry design.

H.8 REHABILITATED MODEL

During the operational phase, the quarry excavations will be progressively rehabilitated by backfilling surplus overburden against the quarry walls with a suitable side-slope. Once the quarry excavations are complete, the dewatering sumps will be decommissioned, and the excavations will be allowed to fill naturally with precipitation and groundwater discharge. As such, the proposed end use of the quarry is a series of lakes, with a long-term average stage elevation of ±175.15 masl. Discharge from the lakes to the Realigned Watercourse will be governed by gravity through a constructed outlet.

Numerical groundwater modeling was completed to predict the long-term steady-state effects of the proposed end use. The full development model was adapted to simulate the final rehabilitation of the Site to a series of lakes. Adaptation of the full development model included the following modifications:

- ➔ The drain boundaries representing the quarry dewatering sump (Reach 20) were given a conductance of ‘0’ to simulate the predicted stage elevation in the lake assuming that no flow outlets were present. The final lakes elevations under this scenario was predicted to be higher than the long-term average stage elevation of 175.15 masl.
- ➔ These results suggest that the final lakes constructed outlet will be the controlling feature which dictates the stage in the lake. As such, a final lake stage elevation of 175.15 masl was adopted in the rehabilitated model.
- ➔ To simulate the predicted effects of the final lakes on the local groundwater potentiometric surface and water balance, the drain boundaries representing the quarry dewatering sump in model layer 8 were converted to constant head boundaries, with a specified head elevation of 175.15 masl.

H.8.1 PREDICTED FINAL LAKE EFFECTS

Because the predicted average stage elevation of the final lakes (171.15 masl) is marginally lower than the existing groundwater potentiometric surface for the shallow bedrock aquifer (between 175 masl and 180 masl southeast and southwest of the proposed quarry footprint), the lakes will receive future groundwater discharge from the shallow bedrock aquifer. The shallow and deep bedrock aquifer predicted available drawdown at final rehabilitation is shown on **Figure H-10**.

Both the area and magnitude of the drawdown under final rehabilitation conditions are significantly less than those predicted for the full development conditions, and the predicted available drawdown is nearly identical to baseline conditions.

H.8.2 REHABILITATED WATER BALANCE

The rehabilitated model Site water balance is shown in **Table H.8.1** below.

Table H.8.1 Site Water Balance – Rehabilitated Conditions

Boundary Type	Inflows		Outflows		Outflow – Inflow	
	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)
Recharge (RCH)	712	244.4	0	0	-712	-244.4
Constant Head (CHD)	6	2.1	1,050	360.5	1,044	358.4
Drain (DRN)	0	0	<0.01	<0.01	<0.01	<0.01
Lateral GW Flow	430	147.6	98	33.6	-332	-114.0
TOTAL	**1,148**	**394.1**	**1,148**	**394.1**	**0.003**	
				Discrepancy (%)	**-0.0002**	

At final rehabilitation, about two thirds of the total inflow to the Site originates as recharge. Net groundwater discharge to the final lake (simulated as a constant head boundary) is predicted to average approximately 1,044 m^3/day. Because the predicted stage elevations of the final lakes are marginally lower than the existing groundwater potentiometric surface, groundwater flow will be induced towards the lakes (i.e., there is a net inflow of lateral groundwater to the Site). This differs from baseline conditions, where the Site was simulated with a marginal net outflow of groundwater to the surrounding areas.

The water balance for the Beaverdams Creek subwatershed for the rehabilitated model is shown in **Table H.8.2** below.

Table H.8.2 Beaverdams Creek Subwatershed Water Balance – Rehabilitated Conditions

Boundary Type	Inflows		Outflows		Outflow – Inflow	
	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)
Recharge (RCH)	1,635	38.5	0	0	-1,635	-38.5
Constant Head (CHD)	6	0.1	1,268	29.9	1,262	29.8
River (RIV)	6	0.1	7	0.2	1	0.01
Drain (DRN)	0	0	19	0.5	19	0.5
Well (WEL)	0	0	6	0.1	6	0.1
Lateral GW Flow	722	17.0	1,068	25.2	346	8.2
TOTAL	**2,369**	**55.7**	**2,368**	**55.9**	**0.01**	
				Discrepancy (%)	**0.0006**	

After rehabilitation to the final lakes, the total inflow from recharge remains elevated above baseline conditions due to the permanent removal of overburden from the quarry excavation footprint and represents nearly 70% of the total inflow to the subwatershed. Surface waterbody features (simulated as river boundaries), which were marginally net losing at full quarry development, revert to marginally net gaining, which is similar to baseline conditions. There is a marginal reduction in baseflow to surface watercourses (simulated as drain boundaries), from about 2 mm/year under baseline conditions to about

0.4 mm/year at final rehabilitation. This results in a net change of about 0.8 L/s. It is expected that this rate would be lower in the spring when groundwater levels are seasonally highest. Also, the subwatershed reverts to a net outflow of lateral groundwater flow to the surrounding areas, albeit at a reduced rate.

In the rehabilitation model, constant head boundaries are used to simulate two features: the Welland Canal South Turn Basin and groundwater inflows to the final lake (assuming an average lake elevation of 175.15 masl). At full development, the Welland Canal South Turn Basin (simulated as a constant head boundary) is predicted to function as a net losing feature; however, at final rehabilitation, it reverts to a net gaining feature similar to baseline conditions. The portion of the simulated constant head outflow related to the turn basin is approximately 224 m^3/day with the net groundwater discharge to the turn basin predicted to be approximately 218 m^3/day (when the minor inflow of 6 m^3/day is considered). This is a reduction of approximately 25% in comparison to baseline conditions. However, the remaining portion of the simulated constant head outflow (approximately 1,044 m^3/day or 12 L/s) represents the steady flow that would permanently discharge from the final lakes to the reach of the Existing Watercourse (and the Welland Canal South Turn Basin) north of the Site.

H.8.3 ALTERNATE QUARRY DESIGN

Additional numerical groundwater modeling was completed to predict the long-term steady-state effects of the rehabilitated alternate quarry design with the internal road allowances removed as part of the excavation, as outlined in **Section 3.0** of the main report.

The shallow and deep bedrock aquifer predicted available drawdown for the rehabilitated alternate quarry design is shown on **Figure H-10A**. The extent of the drawdown for the alternate quarry scenario is nearly identical to the full quarry design presented on **Figure H-10**.

The Site water balance and Beaverdams Creek subwatershed water balance for the alternate quarry design are shown in **Tables H.8.3 and H.8.4** below.

Table H.8.3 Site Water Balance – Alternate Quarry Design Rehabilitated Conditions

Boundary Type	Inflows		Outflows		Outflow – Inflow	
	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)
Recharge (RCH)	749	257	0	0	-749	-257
Constant Head (CHD)	7	2	1,084	372	1,077	370
Drain (DRN)	0	0	0	0	0	0
Lateral GW Flow	426	146	98	34	-328	113
TOTAL	**1,182**	**406**	**1,182**	**406**	**-0.002**	
				Discrepancy (%)	**0.0002**	

Table H.8.4 Beaverdams Creek Subwatershed Water Balance – Alternate Quarry Design Rehabilitated Conditions

Boundary Type	Inflows		Outflows		Outflow – Inflow	
	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)	(m^3/day)	(mm/year)
Recharge (RCH)	1,672	39.4	0	0	-1,672	-39.4
Constant Head (CHD)	7	0.2	1,303	30.7	1,296	30.5
River (RIV)	6	0.1	7	0.2	1	0.02
Drain (DRN)	0	0	20	0.5	20	0.5
Well (WEL)	0	0	6	0.1	6	0.1
Lateral GW Flow	721	17.0	1,070	25.2	349	8.2
TOTAL	**2,406**	**56.7**	**2,406**	**56.7**	**-0.01**	
Discrepancy (%)					**-0.0004**	

These results indicate that there is not a substantial difference in water budget components at either the Site level or the subwatershed level if the internal road allowances are excavated as part of the alternate quarry design.

H.9 LIMITATIONS

MODFLOW-USG was used to simulate steady-state groundwater movement for baseline October conditions at the Site and to simulate steady-state groundwater flow conditions under full quarry development and rehabilitated conditions. Transient effects, such as daily or seasonal fluctuations in aquifer potentials, storage, and changes in precipitation and evapotranspiration were outside of the scope of this study. The steady-state model provides a reasonable representation of groundwater conditions during the driest part of the year and allows for the simulation of changes to these groundwater conditions as a result of the proposed quarry development. This model and its predictions can be updated if desired as more information becomes available, to incorporate additional subsurface observations, and to test and re-evaluate the model predictions.

Services performed by WSP Canada Inc. were conducted in a manner consistent with a level of care and skill ordinarily exercised by members of the environmental engineering and consulting profession. This report presents the results of data compilation and computer simulations of a complex geologic setting. Due to the nature of subsurface investigations which explore a relatively large volume of material with a small number of boreholes, data gaps are likely to be present in the information obtained by and supplied to WSP Canada Inc. Models constructed from these data are limited by the quality and completeness of the information available at the time the work was performed. Computer models represent a deliberate simplification of the actual geologic conditions. This report does not exhaustively cover an investigation of all possible environmental conditions or circumstances that may exist in the study area. It should be recognized that the passage of time affects the information provided in this report.

Environmental conditions and the amount of data available can change. Discussions relating to the baseline conditions are based upon information that existed at the time the conclusions were formulated.

REFERENCES

Anderson, M.P. and Woessner, W.W. 1992. *Applied Groundwater Modeling: Simulation of Flow and Advective Transport.* San Diego: Academic Press, 1992.

Bear, J. 1979. *Hydraulics of Groundwater*. Toronto: McGraw-Hill Book Company, 1979.

Doherty, J. 2015a. *Calibration and Uncertainty Analysis for Complex Environmental Models*. Watermark Numerical Computing, Brisbane, Australia, 2015.

Doherty, J. 2015b. *Groundwater Data Utilities.* Watermark Numerical Computing, Queensland, Australia, November 2015.

Doherty, J. and National Centre for Groundwater Research and Training, Australia. 2015. *PLPROC – A Parameter List Processor*. Watermark Numerical Computing, Queensland, Australia, November 2015.

Doherty, J. 2016. *PEST – Model-Independent Parameter Estimation and Uncertainty Analysis, User Manual: 6th Edition*. Watermark Numerical Computing, Queensland, Australia, April 2016.

Domenico, P. and Schwartz, F. 1990. *Physical and Chemical Hydrogeology*. New York: John Wiley & Sons, Inc., 1990.

Environmental Systems Research Institute (ESRI). 2017. ArcGIS Desktop version 10.5.1.

Environmental Simulations Inc., 2017. *Guide to Using Groundwater Vistas Version 7*. Environmental Simulations Inc., Reinholds, PA.

Farvolden, R.N., and Nunan, J.P. 1970. *Hydrogeologic Aspects of Dewatering at Welland*. Canadian Geotechnical Journal, Vol. 7, No. 2, pp. 194-204.

Frind, E.O. 1970. *Theoretical Analysis of Aquifer Response Due to Dewatering at Welland*. Canadian Geotechnical Journal, Vol. 7, No. 2, pp. 205-216.

Harbaugh, A.W. 1990. *A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular three-dimensional ground-water flow model*. U.S. Geological Survey Open-File Report 90-392, 46pp.

Jagger Hims Limited (JHL), 2004. *Resource Assessment, Rolling Meadows Site, Townships of Thorold and Niagara Falls, Regional Municipality of Niagara*. Prepared for Walker Brother Quarries Limited, July 2004. JHL Project No. 0981023.02.

Muffels, C., et al. 2018. *User's Guide for mod-PATH3DU. A groundwater path and travel-time simulator*. S.S.Papadopulos & Associates, Inc., Bethesda, MD and University of Waterloo, Waterloo, ON. Updated November 2018. Available at http://mp3du.sspa.com/man/.

Neville, C.J. and Keizer, P. 2005. *Estimation of transmissivity from specific capacity data, Technical memorandum*. S.S. Papadopulos & Associates, Inc., June 2005. SSPA Project No. 958.

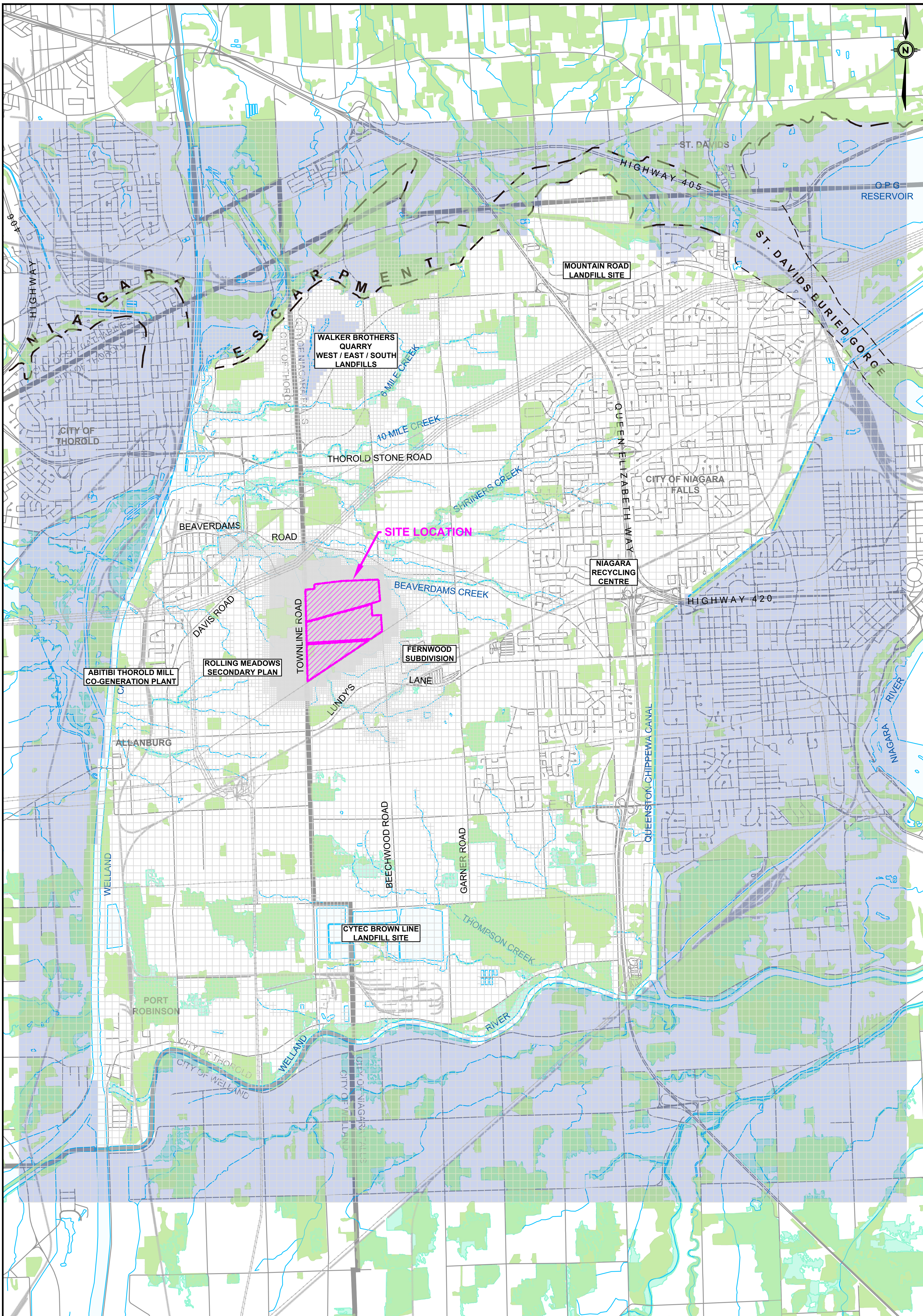
Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., and Hughes, J.D. 2017. *MODFLOW-USG Version 1.4.00: An Unstructured Grid Version of MODFLOW for Simulating Groundwater Flow* *and Tightly Coupled Processes Using a Control Volume Finite-Difference Formulation*. U.S. Geological Survey Techniques and Methods, book 6, chapter A45, 66pp.

Spitz, K. and Moreno, J. 1996. *A Practical Guide to Groundwater and Solute Transport Modeling*. New York: John Wiley & Sons, Inc., 1996.

S.S. Papadopulos & Associates, Inc. 2006. *Analysis of Groundwater Flow for the Walker Environmental Assessment*. Prepared for Walker Industries Holdings Limited, February 2006.

Yager, R.M. 1996. *Simulated Three-Dimensional Ground-Water Flow in the Lockport Group, A Fractured Dolomite Aquifer Near Niagara Falls, New York*. United States Geological Survey Water-Supply Paper 2487. Prepared in cooperation with the U.S. Environmental Protection Agency.

FIGURES



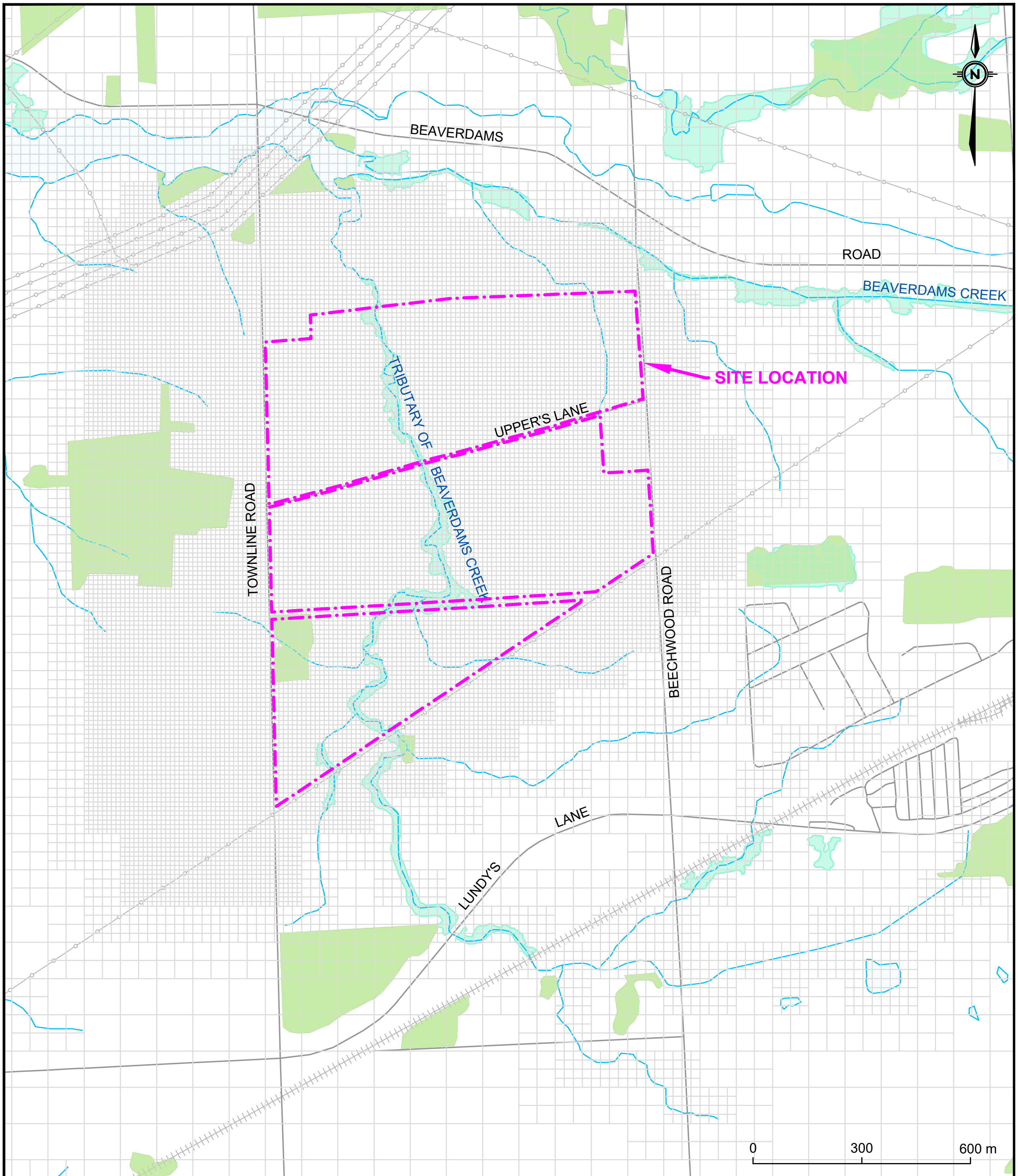
MODEL DOMAIN GRID

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 50,000
DRAWN BY:	JLD
FIGURE No:	H-1

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH1-SP.DWG



LEGEND

MODEL GRID

LOCAL MODEL GRID

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

SCALE: 1 : 15,000

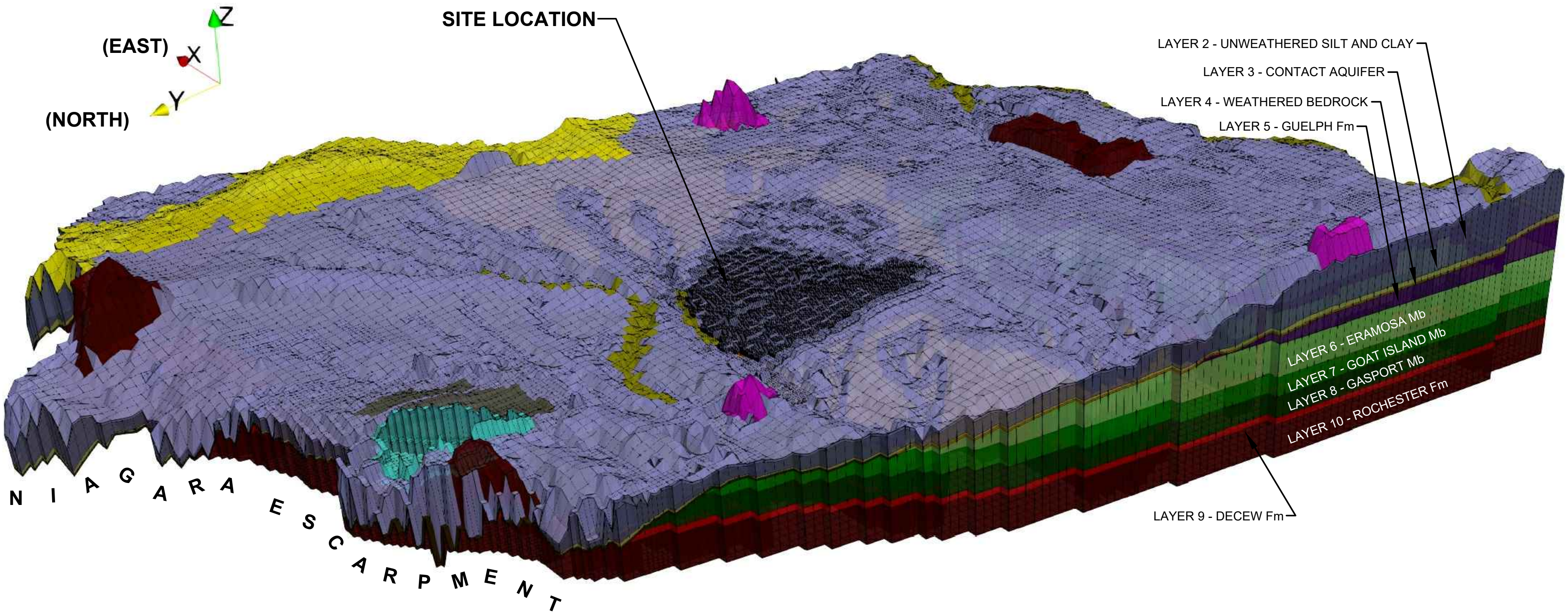
DRAWN BY: JLD

DATE: OCTOBER 2021

PROJECT: 161-11633-00

FIGURE No: H-1A

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH1-SP.DWG



HYDRAULIC CONDUCTIVITY ZONES

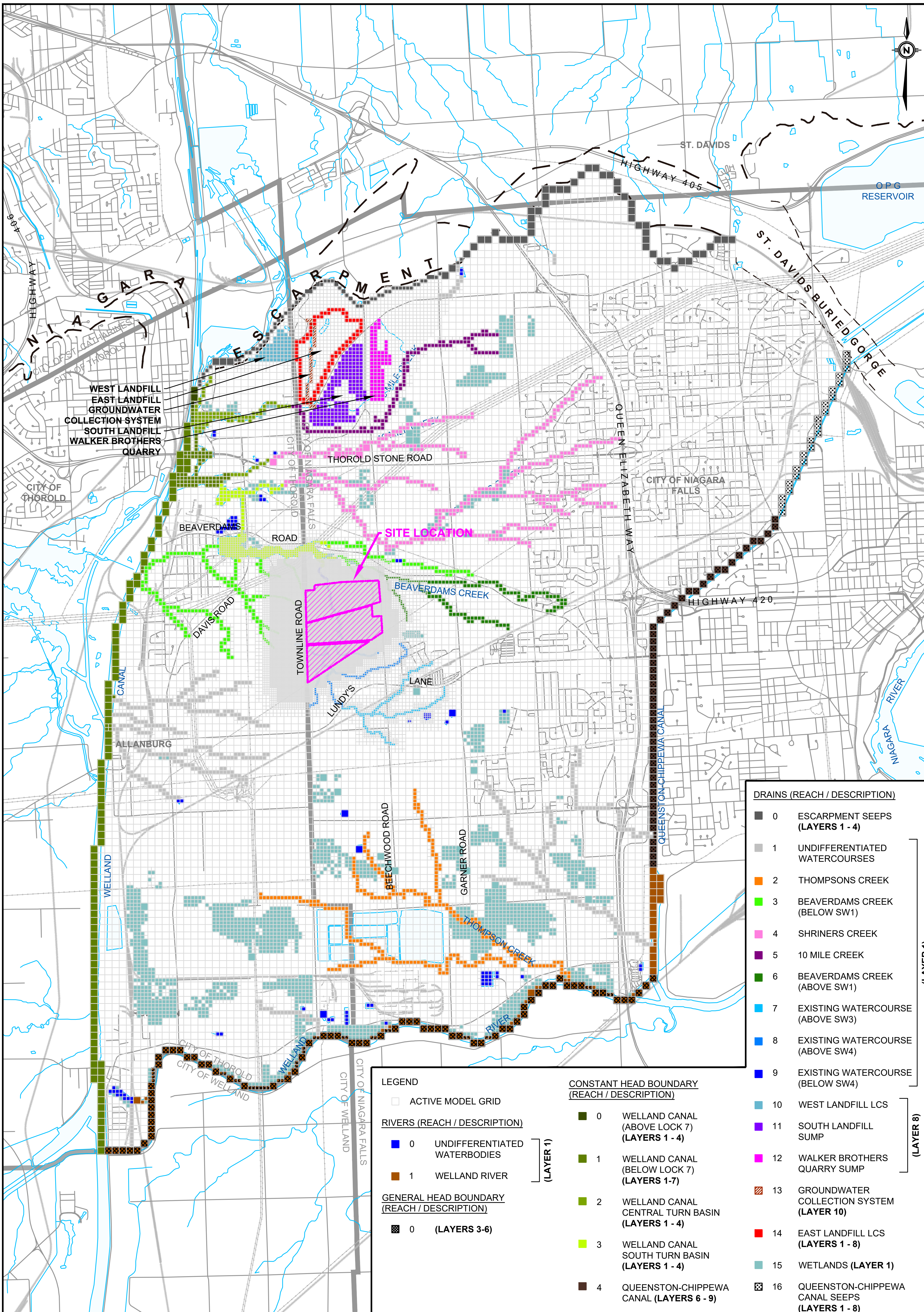
- ROCHESTER FORMATION
- DECEW FORMATION
- GASPORT MEMBER
- GOAT ISLAND MEMBER
- ERAMOSA MEMBER
- GUELPH FORMATION
- WEATHERED ERAMOSA MEMBER
- WEATHERED GOAT ISLAND MEMBER
- CONTACT AQUIFER
- UNWEATHERED SILT AND CLAY
- WEATHERED SILT AND CLAY
- SAND AND GRAVEL
- MAN-MADE DEPOSITS
- ALLUVIAL DEPOSITS
- ACTIVE QUARRY
- UNLINED LANDFILL
- LINED LANDFILL
- CONFINING BED "WINDOW"
- HIGH-PERMEABILITY ZONE AROUND PW1

3-DIMENSIONAL VIEW OF MODEL LAYERS

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
DRAWN BY:	JLD
SCALE:	NOT TO SCALE
FIGURE No:	H-2

wsp



LEGEND

ACTIVE MODEL GRID

RIVERS (REACH / DESCRIPTION)

- 0 UNDIFFERENTIATED WATERBODIES (LAYER 1)
- 1 WELLAND RIVER (LAYER 1)

GENERAL HEAD BOUNDARY (REACH / DESCRIPTION)

- 0 **(LAYERS 3-6)**

CONSTANT HEAD BOUNDARY (REACH / DESCRIPTION)

- 0 WELLAND CANAL (ABOVE LOCK 7) **(LAYERS 1 - 4)**
- 1 WELLAND CANAL (BELOW LOCK 7) **(LAYERS 1-7)**
- 2 WELLAND CANAL CENTRAL TURN BASIN **(LAYERS 1 - 4)**
- 3 WELLAND CANAL SOUTH TURN BASIN **(LAYERS 1 - 4)**
- 4 QUEENSTON-CHIPPEWA CANAL **(LAYERS 6 - 9)**

DRAINS (REACH / DESCRIPTION)

- 0 ESCARPMENT SEEPS **(LAYERS 1 - 4)**
- 1 UNDIFFERENTIATED WATERCOURSES (LAYER 1)
- 2 THOMPSONS CREEK (LAYER 1)
- 3 BEAVERDAMS CREEK (BELOW SW1) (LAYER 1)
- 4 SHRINERS CREEK (LAYER 1)
- 5 10 MILE CREEK (LAYER 1)
- 6 BEAVERDAMS CREEK (ABOVE SW1) (LAYER 1)
- 7 EXISTING WATERCOURSE (ABOVE SW3) (LAYER 1)
- 8 EXISTING WATERCOURSE (ABOVE SW4) (LAYER 1)
- 9 EXISTING WATERCOURSE (BELOW SW4) (LAYER 1)
- 10 WEST LANDFILL LCS (LAYER 8)
- 11 SOUTH LANDFILL SUMP (LAYER 8)
- 12 WALKER BROTHERS QUARRY SUMP (LAYER 8)
- 13 GROUNDWATER COLLECTION SYSTEM **(LAYER 10)**
- 14 EAST LANDFILL LCS **(LAYERS 1 - 8)**
- 15 WETLANDS **(LAYER 1)**
- 16 QUEENSTON-CHIPPEWA CANAL SEEPS **(LAYERS 1 - 8)**

0 1,000 2,000 m

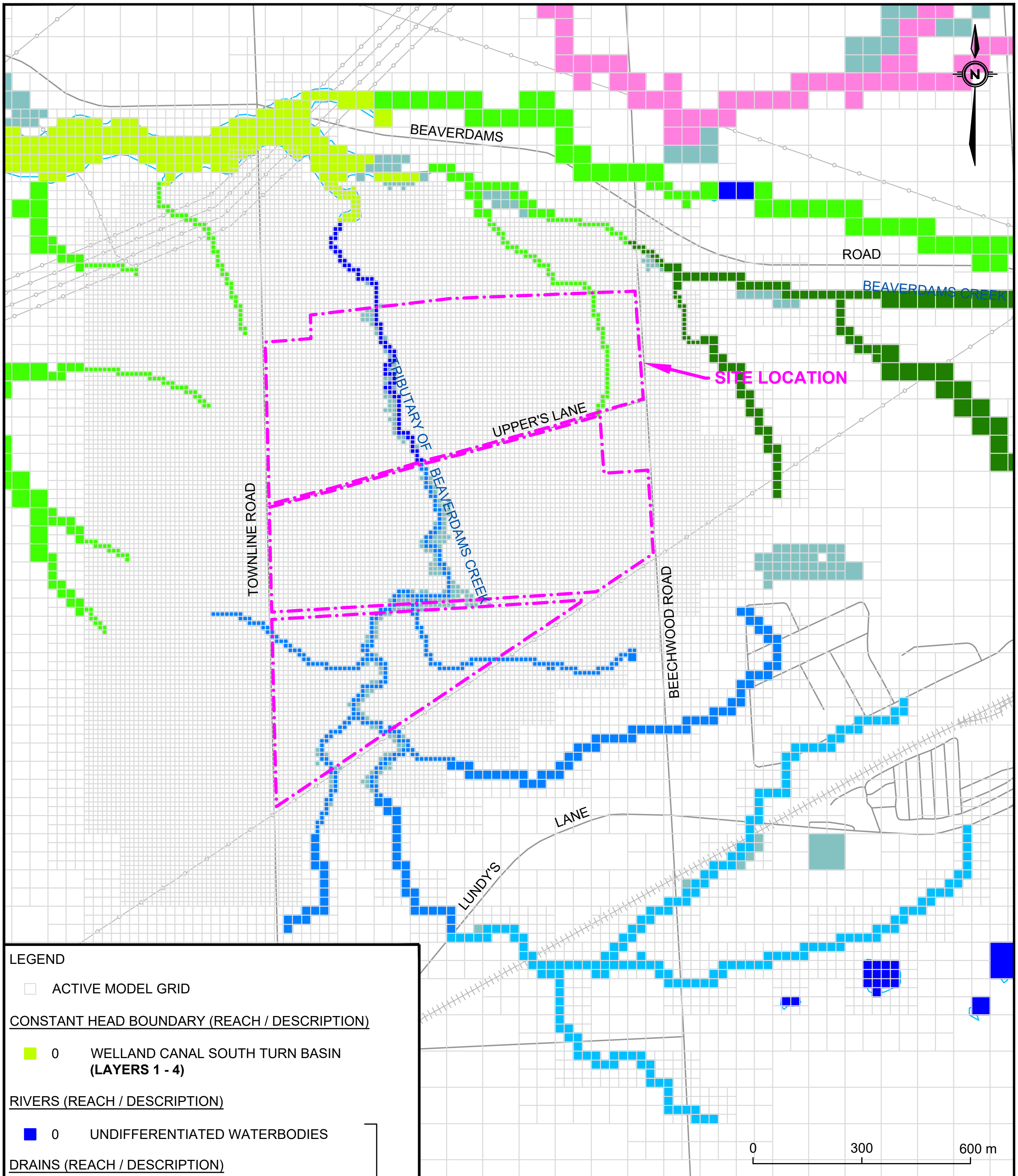
BOUNDARY CONDITIONS

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 50,000
DRAWN BY:	JLD
FIGURE No:	H-3

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH3-SP.DWG



LEGEND

ACTIVE MODEL GRID

CONSTANT HEAD BOUNDARY (REACH / DESCRIPTION)

0 WELLAND CANAL SOUTH TURN BASIN **(LAYERS 1 - 4)**

RIVERS (REACH / DESCRIPTION)

0 UNDIFFERENTIATED WATERBODIES

DRAINS (REACH / DESCRIPTION)

3 BEAVERDAMS CREEK (BELOW SW1)

4 SHRINERS CREEK

6 BEAVERDAMS CREEK (ABOVE SW1)

7 EXISTING WATERCOURSE (ABOVE SW3)

8 EXISTING WATERCOURSE (ABOVE SW4)

9 EXISTING WATERCOURSE (BELOW SW4)

15 WETLANDS

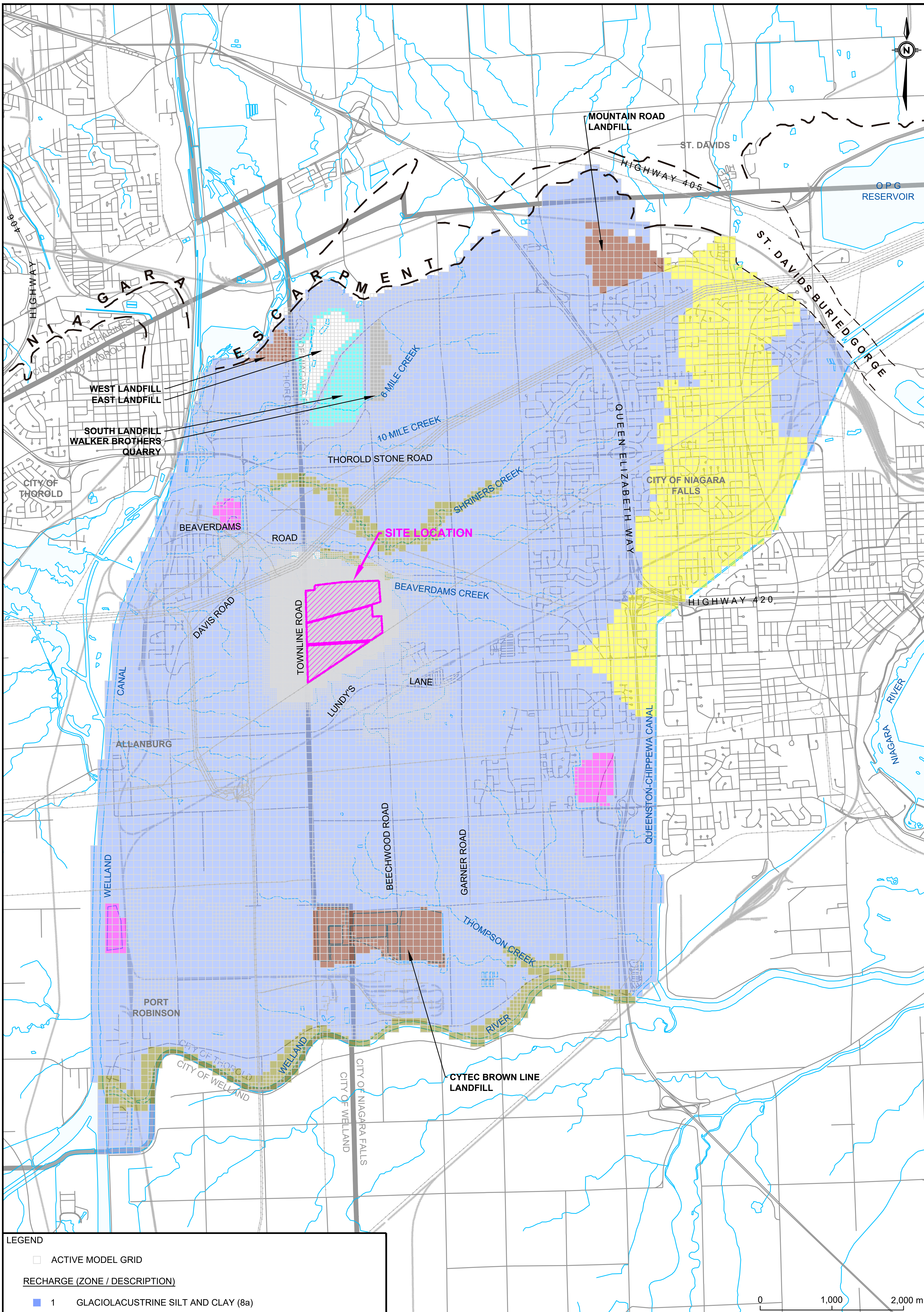
(LAYER 1)

LOCAL BOUNDARY CONDITIONS

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

SCALE:	1 : 15,000
DRAWN BY:	JLD
DATE:	OCTOBER 2021
PROJECT:	161-11633-00
FIGURE No:	**H-3A**

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH3-SP.DWG



LEGEND

ACTIVE MODEL GRID

RECHARGE (ZONE / DESCRIPTION)

- 1 GLACIOLACUSTRINE SILT AND CLAY (8a)
- 2 GLACIOLACUSTRINE SAND AND GRAVEL (9)
- 3 ANTHROPOGENIC DEPOSITS (21)
- 4 MODERN ALLUVIAL DEPOSITS (19)
- 5 ACTIVE QUARRY EXCAVATION
- 6 UNLINED LANDFILL
- 7 LANDFILL WITH LCS

RECHARGE ZONES

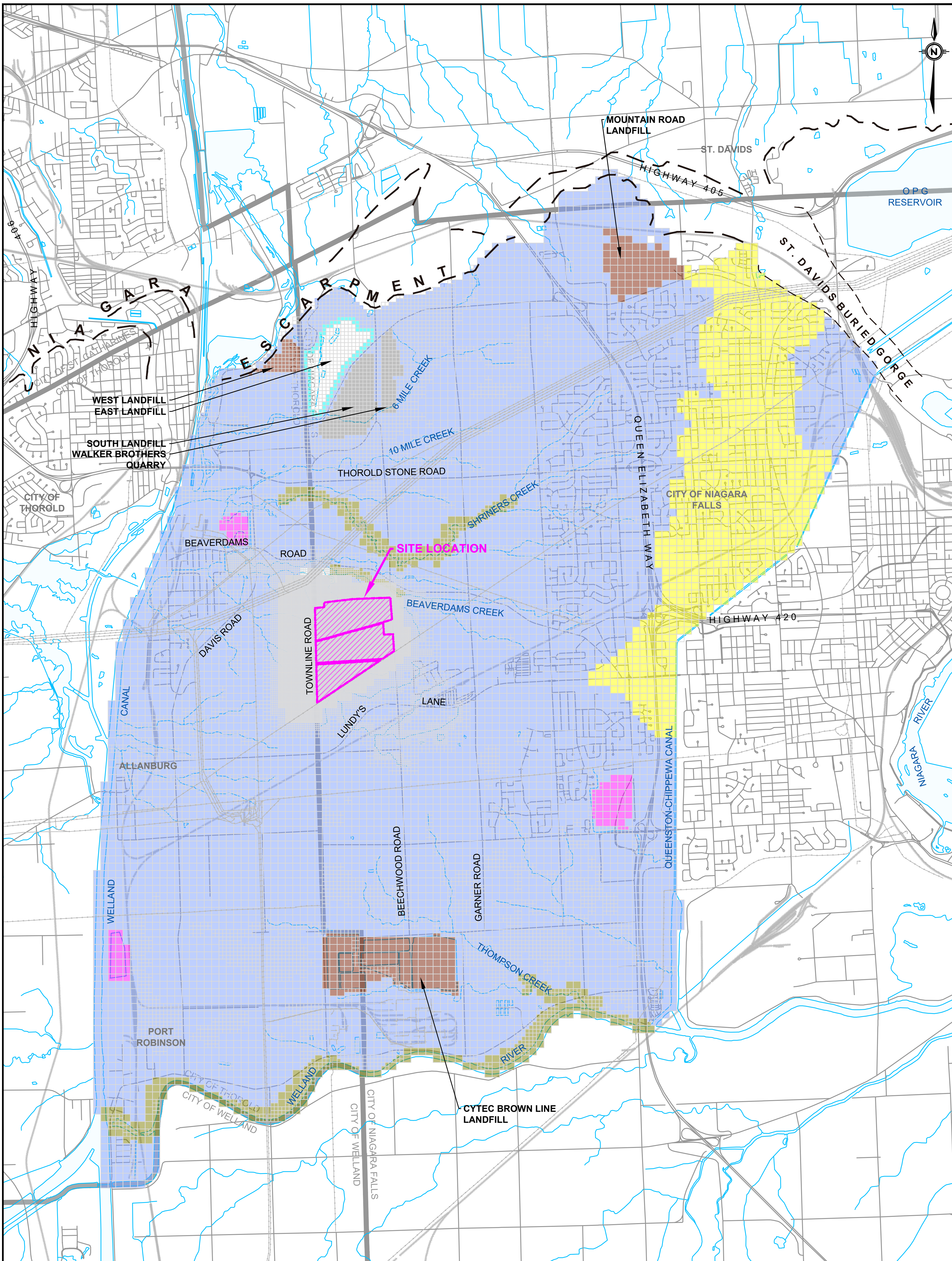
NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 50,000
DRAWN BY:	JLD

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

FIGURE No: H-4

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH4-SP.DWG



LEGEND

ACTIVE MODEL GRID

HYDRAULIC CONDUCTIVITY (ZONE / DESCRIPTION)

- 11 WEATHERED GLACIOLACUSTRINE SILT AND CLAY (8a)
- 12 GLACIOLACUSTRINE SAND AND GRAVEL (9)
- 13 ANTHROPOGENIC DEPOSITS (21)
- 14 MODERN ALLUVIAL DEPOSITS (19)
- 15 ACTIVE QUARRY EXCAVATION
- 16 UNLINED LANDFILL
- 17 LANDFILL WITH LCS

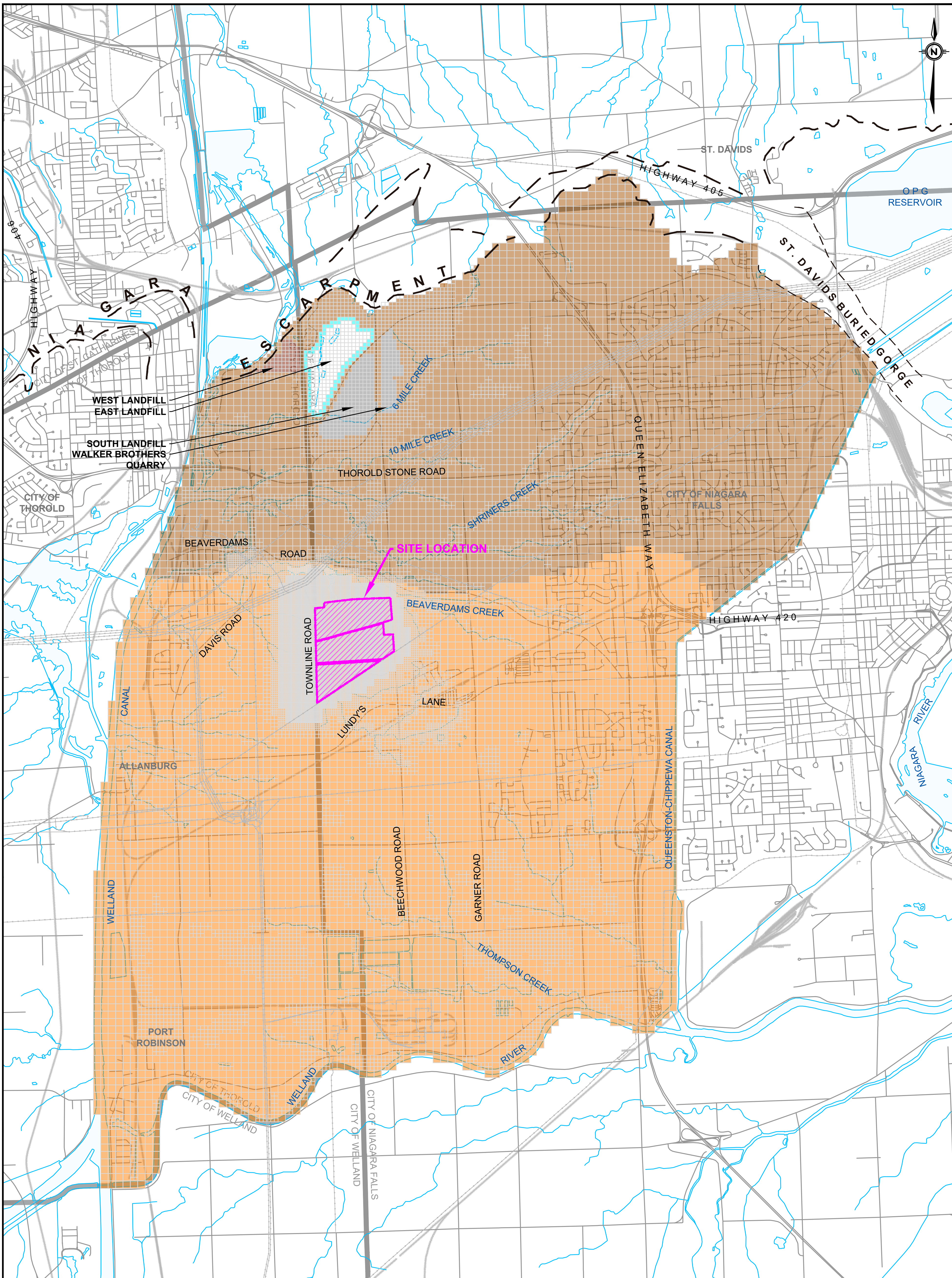
LAYER 1 HYDRAULIC CONDUCTIVITY ZONES

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 50,000
DRAWN BY:	JLD
FIGURE No:	H-5

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH5-SP.DWG



LEGEND

ACTIVE MODEL GRID

HYDRAULIC CONDUCTIVITY (ZONE / DESCRIPTION)

- 7 WEATHERED ERAMOSA MEMBER / GUELPH FORMATION BEDROCK
- 8 WEATHERED GOAT ISLAND MEMBER / GASPORT MEMBER BEDROCK
- 15 ACTIVE QUARRY EXCAVATION
- 16 UNLINED LANDFILL
- 17 LANDFILL WITH LCS
- 18 CONFINING BED "WINDOW"

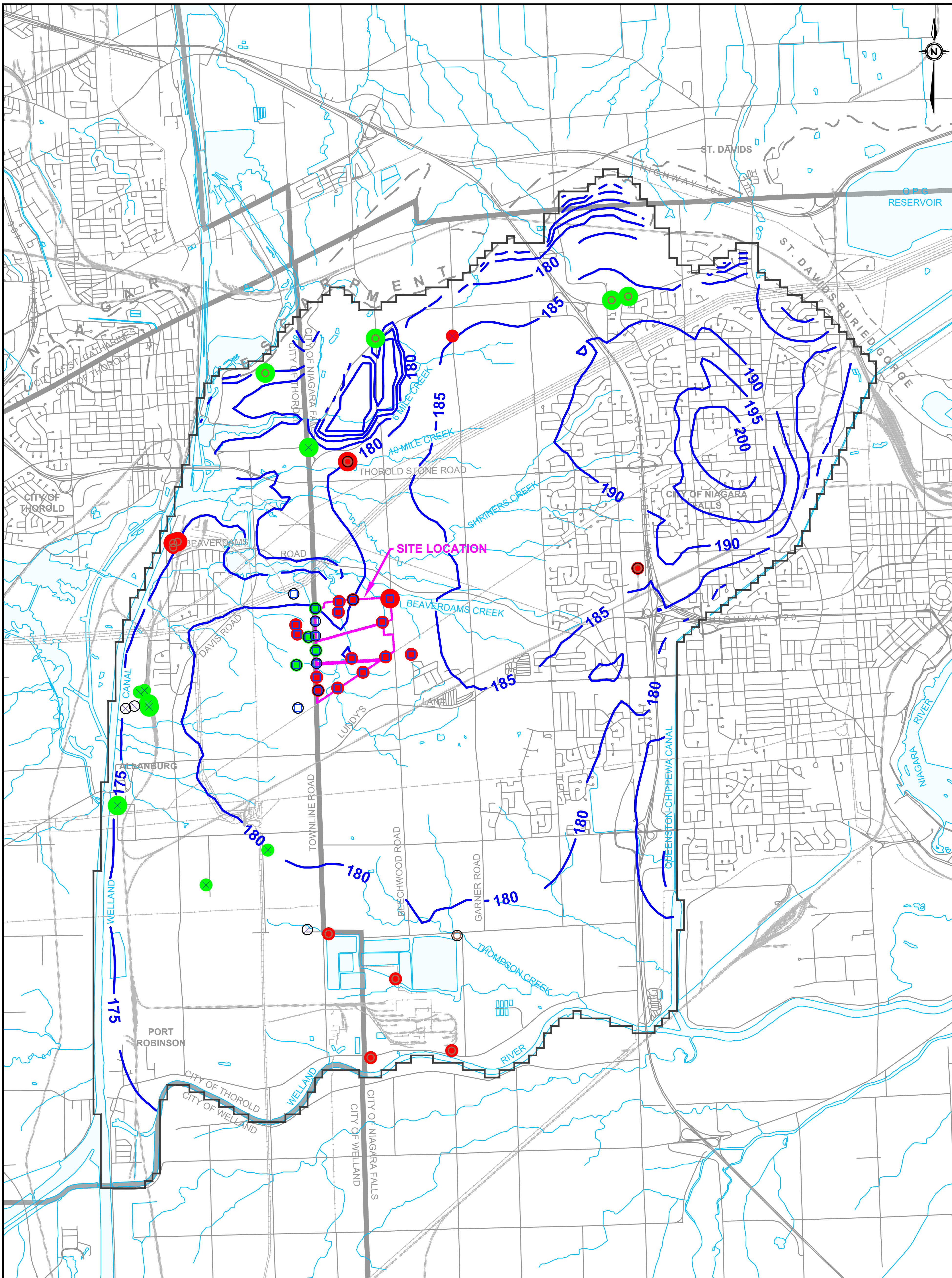
LAYER 4 HYDRAULIC CONDUCTIVITY ZONES

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 50,000
DRAWN BY:	JLD
FIGURE No:	H-6

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH6-SP.DWG



LEGEND

ACTIVE MODEL DOMAIN

185 SIMULATED GROUNDWATER CONTOURS, 5 m INTERVALS (mASL)

TARGET TYPE (GROUP / DESCRIPTION)		RESIDUALS
1	SITE WELL DATA	OVER-PREDICTION > 5 m
2	OTHER HIGH-QUALITY WELLS	OVER-PREDICTION 1 m - 5 m
3	MECP WATER WELL RECORDS	± 1 m
		UNDER-PREDICTION 1 m - 5 m
		UNDER-PREDICTION > 5 m

SPATIAL DISTRIBUTION OF CALIBRATED RESIDUALS - CONTACT AQUIFER

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021

PROJECT: 161-11633-00

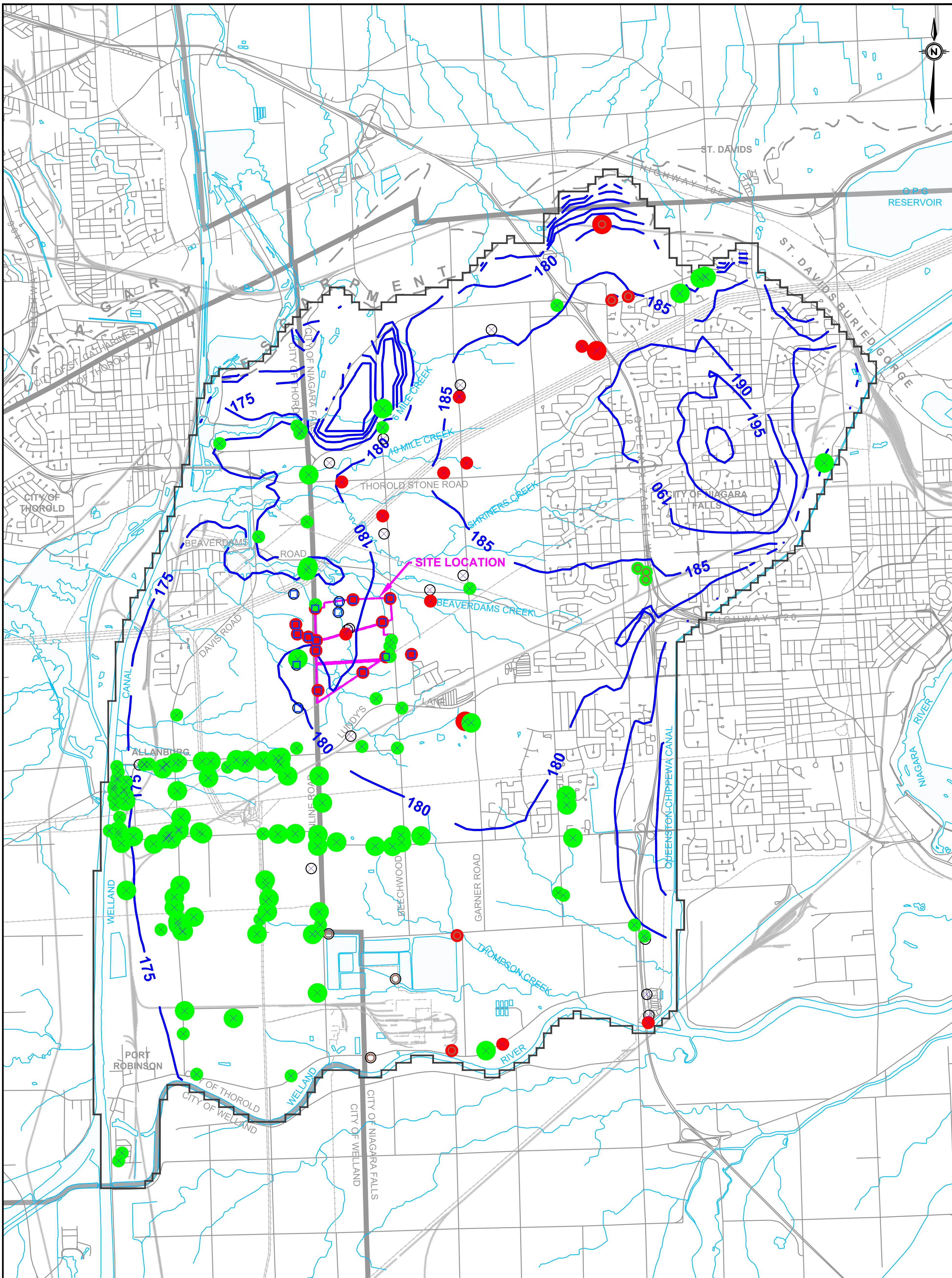
SCALE: 1 : 50,000

DRAWN BY: JLD

FIGURE No: H-7

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH7-SP.DWG



LEGEND

ACTIVE MODEL DOMAIN

185 SIMULATED GROUNDWATER CONTOURS, 5 m INTERVALS (mASL)

TARGET TYPE (GROUP / DESCRIPTION)		RESIDUALS
1	SITE WELL DATA	OVER-PREDICTION > 5 m
2	OTHER HIGH-QUALITY WELLS	OVER-PREDICTION 1 m - 5 m
3	MECP WATER WELL RECORDS	± 1 m
		UNDER-PREDICTION 1 m - 5 m
		UNDER-PREDICTION > 5 m

SPATIAL DISTRIBUTION OF CALIBRATED RESIDUALS - SHALLOW BEDROCK AQUIFER

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE: OCTOBER 2021

PROJECT: 161-11633-00

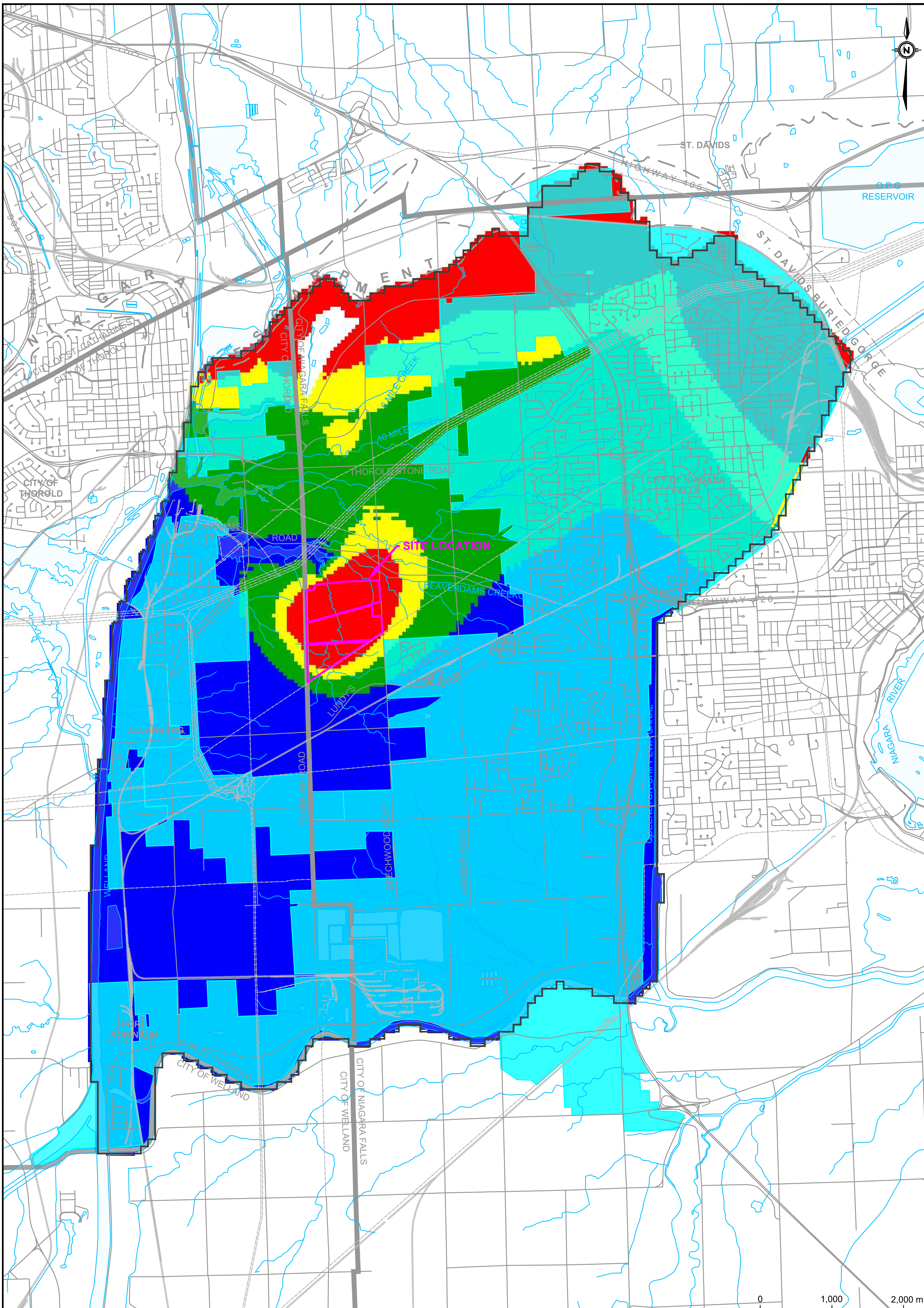
SCALE: 1 : 50,000

DRAWN BY: JLD

FIGURE No: H-8

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH8-SP.DWG



LEGEND

ACTIVE MODEL DOMAIN

APPROXIMATE EXISTING WATER SYSTEM (MASTER SERVICING PLAN, NIAGARA REGION, 2016)

SHALLOW AND DEEP BEDROCK AQUIFER AVAILABLE DRAWDOWN (m)

- < 3
- 3 - 10
- 10 - 20
- > 20

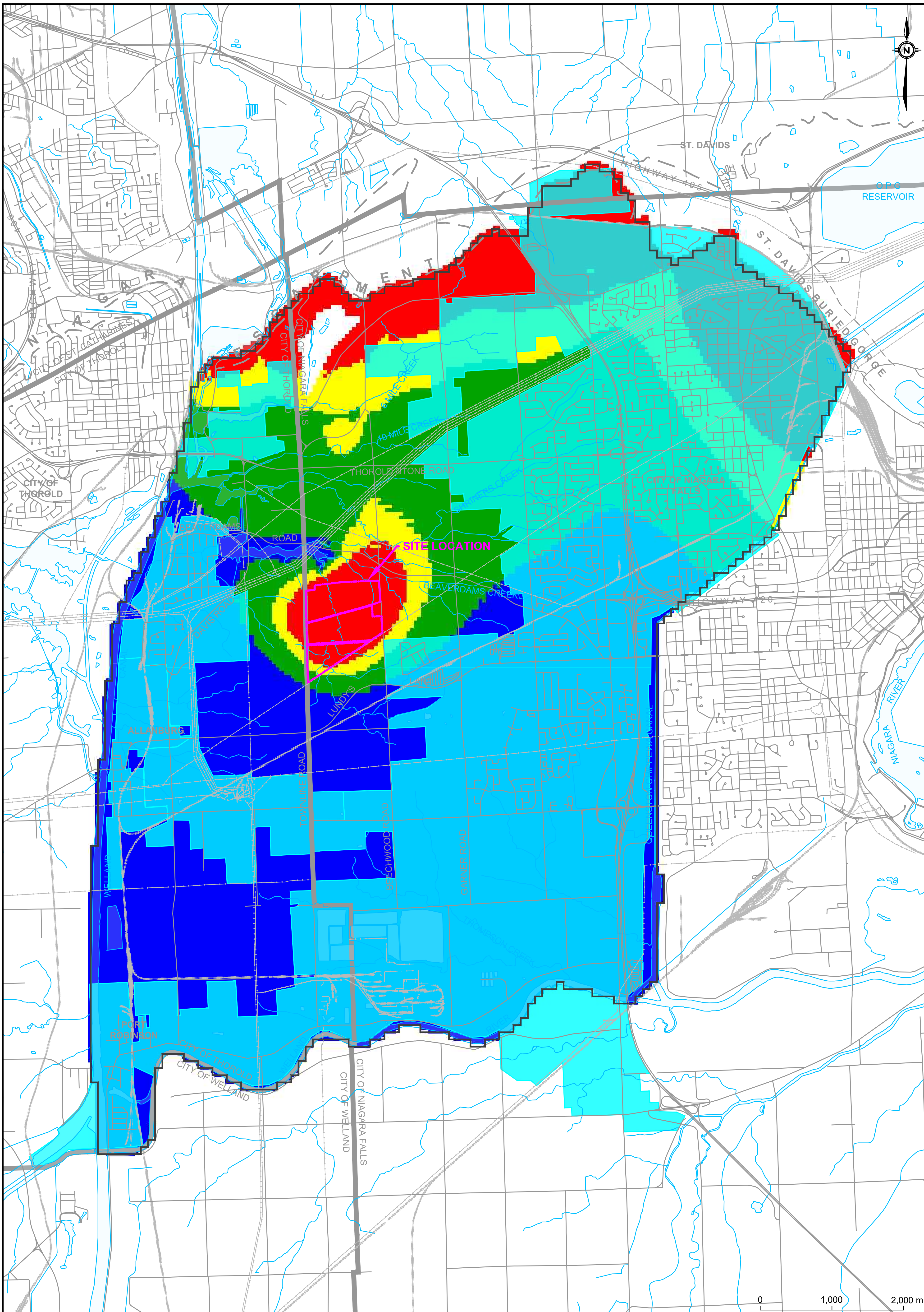
SHALLOW AND DEEP BEDROCK AQUIFER PREDICTED AVAILABLE DRAWDOWN - FULL QUARRY DEVELOPMENT

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 50,000
DRAWN BY:	JLD
FIGURE No:	H-9

55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH9-SP.DWG



LEGEND

ACTIVE MODEL DOMAIN

APPROXIMATE EXISTING WATER SYSTEM (MASTER SERVICING PLAN, NIAGARA REGION, 2016)

SHALLOW AND DEEP BEDROCK AQUIFER AVAILABLE DRAWDOWN (m)

- < 3
- 3 - 10
- 10 - 20
- > 20

SHALLOW AND DEEP BEDROCK AQUIFER PREDICTED AVAILABLE DRAWDOWN - FULL DEVELOPMENT OF ALTERNATE QUARRY DESIGN

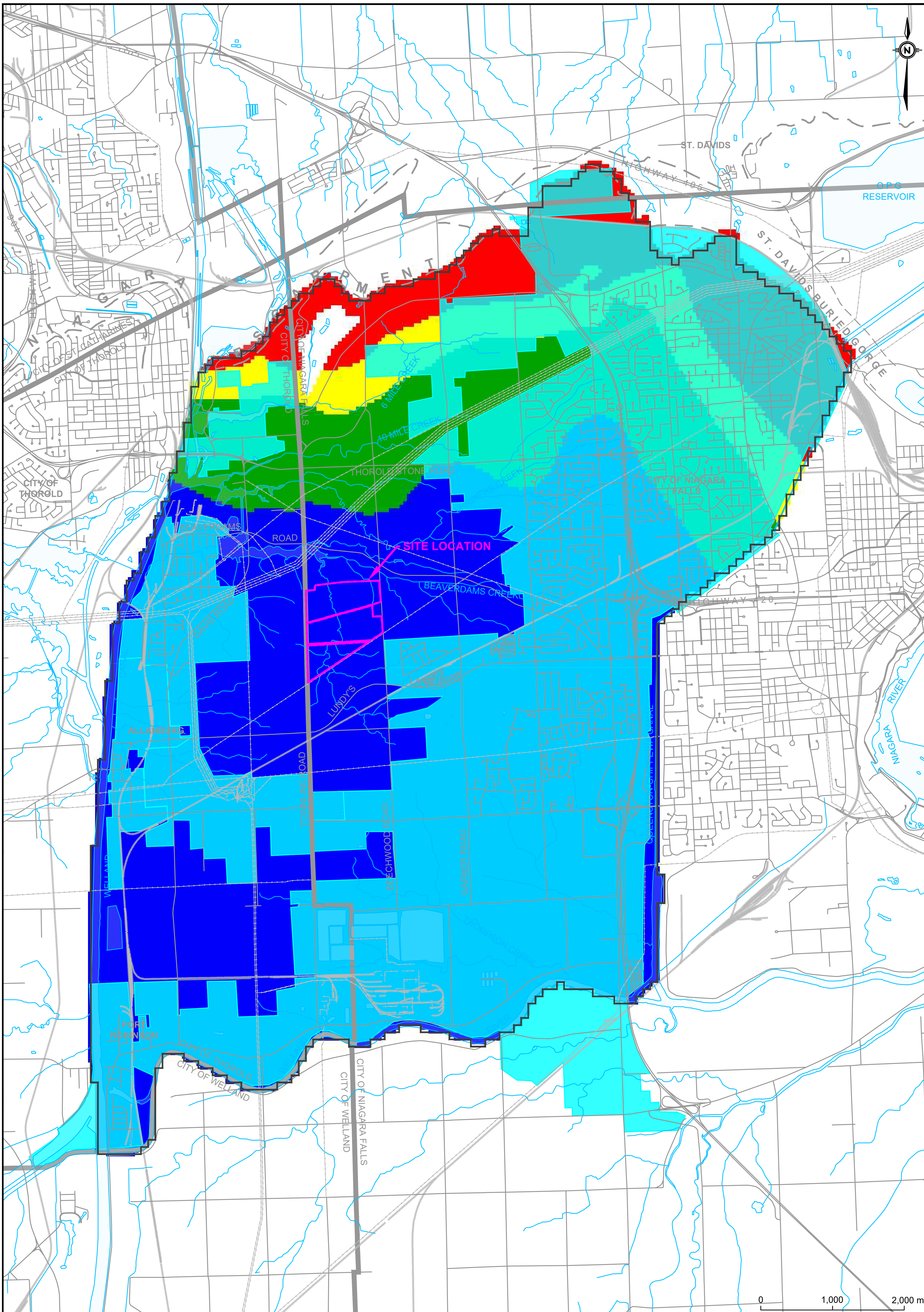
NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 50,000
DRAWN BY:	JLD

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

FIGURE No: **H-9A**

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH9A-SP.DWG



LEGEND

ACTIVE MODEL DOMAIN

APPROXIMATE EXISTING WATER SYSTEM (MASTER SERVICING PLAN, NIAGARA REGION, 2016)

SHALLOW AND DEEP BEDROCK AQUIFER AVAILABLE DRAWDOWN (m)

- < 3
- 3 - 10
- 10 - 20
- > 20

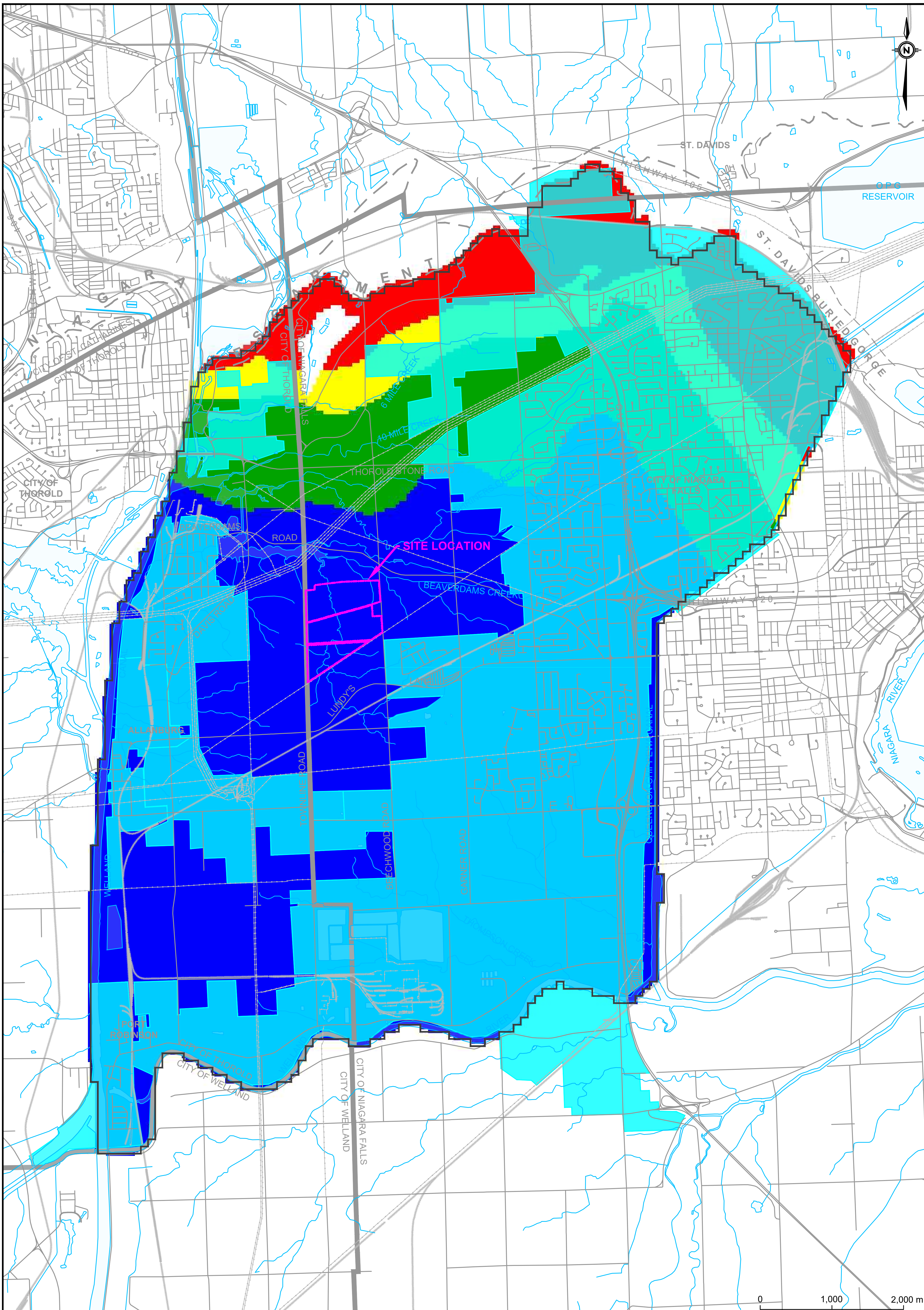
SHALLOW AND DEEP BEDROCK AQUIFER PREDICTED AVAILABLE DRAWDOWN - FINAL REHABILITATION

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 50,000
DRAWN BY:	JLD
FIGURE No:	H-10

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH10-SP.DWG



LEGEND

ACTIVE MODEL DOMAIN

APPROXIMATE EXISTING WATER SYSTEM (MASTER SERVICING PLAN, NIAGARA REGION, 2016)

SHALLOW AND DEEP BEDROCK AQUIFER AVAILABLE DRAWDOWN (m)

- < 3
- 3 - 10
- 10 - 20
- > 20

SHALLOW AND DEEP BEDROCK AQUIFER PREDICTED AVAILABLE DRAWDOWN - FINAL REHABILITATION OF ALTERNATE QUARRY DESIGN

NUMERICAL GROUNDWATER MODEL REPORT
PROPOSED UPPER'S QUARRY
THOROLD / NIAGARA FALLS, ON
For Walker Aggregates Inc.

DATE:	OCTOBER 2021
PROJECT:	161-11633-00
SCALE:	1 : 50,000
DRAWN BY:	JLD

wsp
55 KING STREET, SUITE 700
ST. CATHARINES, ON L2R 3H5
T 905-687-1771 | F 905-687-1773 | www.wsp.com

FIGURE No: **H-10A**

\\CASCR1DAT01\VOL1\PROJECTS\2016\161-11633 UPPERS LANE\00\02 GW MODELLING\GRAPHICS\161-11633-2-FH10A-SP.DWG

APPENDIX

I CLIMATE DATA

Table I-1: 30 Year Climate Normal (1961 - 1990)

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-4.7	0.0	0.0	0.8	0.0	67.0	200.0	67.0	0.0
February	-4.1	0.0	0.0	0.8	0.0	68.3	200.0	68.3	0.0
March	1.0	0.1	3.0	1.0	3.1	71.0	200.0	67.9	0.0
April	7.3	1.8	30.3	1.1	33.9	76.3	200.0	42.4	0.0
May	13.6	4.5	62.3	1.3	79.1	73.7	194.6	0.0	0.0
June	19.0	7.5	91.8	1.3	117.5	90.9	168.0	0.0	0.0
July	22.0	9.4	108.8	1.3	141.4	67.5	94.0	0.0	0.0
August	21.2	8.9	104.2	1.2	125.1	83.2	52.1	0.0	0.0
September	17.1	6.4	81.2	1.0	84.5	97.7	65.3	0.0	0.0
October	10.6	3.1	46.7	1.0	44.3	75.5	96.5	0.0	0.0
November	4.7	0.9	18.2	0.8	14.7	87.3	169.1	0.0	0.0
December	-1.4	0.0	0.0	0.8	0.0	94.7	200.0	63.8	0.0
Total	**8.9**	**42.5**			**643.7**	**953.1**		**309.4**	**0.0**
					Net Water Surplus	**309.4**	**mm**		

Table I-2: 2007 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-2.2	0.0	0.0	0.8	0.0	97.8	200.0	97.8	0.0
February	-8.4	0.0	0.0	0.8	0.0	39.8	200.0	39.8	0.0
March	0.6	0.0	1.3	1.0	1.3	61.4	200.0	60.1	0.0
April	5.5	1.2	19.6	1.1	22.0	82.9	200.0	60.9	0.0
May *	15.0	5.3	67.2	1.3	85.3	39.0	153.7	0.0	0.0
June *	21.3	8.9	103.3	1.3	132.2	19.0	40.5	0.0	0.0
July *	21.4	9.0	103.9	1.3	135.0	47.2	0.0	0.0	47.3
August *	22.3	9.6	109.2	1.2	131.1	21.8	0.0	0.0	109.3
September *	18.8	7.4	88.6	1.0	92.1	54.0	0.0	0.0	38.1
October *	14.9	5.2	66.6	1.0	63.3	57.6	0.0	0.0	5.7
November	3.4	0.6	10.9	0.8	8.8	90.3	81.5	0.0	0.0
December	-1.8	0.0	0.0	0.8	0.0	112.6	194.1	0.0	0.0
Total	**9.2**	**47.1**			**671.1**	**723.4**		**258.6**	**200.4**
					Net Water Surplus	**58.2**	**mm**		

Notes:
- calculations based on Thornthwaite Mather Method
- °C calculated mean of daily temperatures for the month, in degrees Celcius
- I denotes Heat Index
- E denotes Evapotranspiration
- WHC denotes Water Holding Capacity
- A value of 200 mm was used for the water holding capacity of the soils (clay loam soil moderately deep-rooted crops).
- climate normal data from the Niagara Falls climatological station located at latitude 43°8'00"N, longitude 79°05'00"W
- Temperature and precipitation data from the Welland-Pelham climatological station located at latitude 42°58'00"N, longitude 79°20'00"W
- * Data from the Niagara College weather station located at latitude 43°15'00"N, longitude 79°16'00"W

Table I-3: 2008 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-1.5	0.0	0.0	0.8	0.0	43.4	200.0	43.4	0.0
February	-4.5	0.0	0.0	0.8	0.0	103.1	200.0	103.1	0.0
March	-1.4	0.0	0.0	1.0	0.0	100.3	200.0	100.3	0.0
April	8.9	2.4	38.4	1.1	43.0	48.7	200.0	5.7	0.0
May *	12.6	4.0	57.3	1.3	72.8	57.6	184.8	0.0	0.0
June *	20.3	8.3	99.3	1.3	127.1	90.6	148.4	0.0	0.0
July *	22.0	9.4	108.9	1.3	141.6	94.8	101.6	0.0	0.0
August *	20.0	8.1	97.6	1.2	117.1	65.4	49.9	0.0	0.0
September *	17.6	6.7	84.2	1.0	87.6	103.8	66.1	0.0	0.0
October *	9.8	2.8	42.9	1.0	40.7	59.6	84.9	0.0	0.0
November	3.1	0.5	11.4	0.8	9.2	80.6	156.3	0.0	0.0
December	-1.8	0.0	0.0	0.8	0.0	131.5	200.0	87.8	0.0
Total	**8.8**	**42.1**			**639.0**	**979.4**		**340.4**	**0.0**
					Net Water Surplus	**340.4**	**mm**		

Table I-4: 2009 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-8.8	0.0	0.0	0.8	0.0	74.3	200.0	74.3	0.0
February	-3.6	0.0	0.0	0.8	0.0	72.3	200.0	72.3	0.0
March	1.0	0.1	3.4	1.0	3.5	100.7	200.0	97.2	0.0
April	7.5	1.8	32.6	1.1	36.5	124.3	200.0	87.8	0.0
May *	14.0	4.7	65.8	1.3	83.6	64.2	180.6	0.0	0.0
June *	17.8	6.8	86.2	1.3	110.4	108.2	178.4	0.0	0.0
July *	19.5	7.8	95.6	1.3	124.2	102.0	156.2	0.0	0.0
August *	21.1	8.8	104.4	1.2	125.3	131.4	162.3	0.0	0.0
September *	17.0	6.3	81.9	1.0	85.2	34.8	111.9	0.0	0.0
October *	9.4	2.6	42.0	1.0	39.9	68.4	140.4	0.0	0.0
November	6.0	1.3	25.3	0.8	20.5	37.3	157.2	0.0	0.0
December	-1.8	0.0	0.0	0.8	0.0	108.2	200.0	65.4	0.0
Total	**8.3**	**40.3**			**629.1**	**1026.1**		**397.0**	**0.0**
					Net Water Surplus	**397.0**	**mm**		

Notes:
- calculations based on Thornthwaite Mather Method
- °C calculated mean of daily temperatures for the month, in degrees Celcius
- I denotes Heat Index
- E denotes Evapotranspiration
- WHC denotes Water Holding Capacity
- A value of 200 mm was used for the water holding capacity of the soils (clay loam soil moderately deep-rooted crops).
- Temperature and precipitation data from the Welland-Pelham climatological station located at latitude 42°58'00"N, longitude 79°20'00"W
- * Data from the Niagara College weather station located at latitude 43°15'00"N, longitude 79°16'00"W

Table I-5: 2010 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-4.9	0.0	0.0	0.8	0.0	53.8	200.0	53.8	0.0
February	-4.6	0.0	0.0	0.8	0.0	35.5	200.0	35.5	0.0
March	2.9	0.4	10.4	1.0	10.6	49.8	200.0	39.2	0.0
April	9.6	2.7	41.6	1.1	46.6	58.7	200.0	12.1	0.0
May	14.8	5.1	68.7	1.3	87.3	102.5	200.0	15.2	0.0
June	19.0	7.5	91.8	1.3	117.5	143.9	200.0	26.4	0.0
July	21.9	9.3	108.2	1.3	140.7	32.0	91.3	0.0	0.0
August	21.1	8.8	103.7	1.2	124.4	19.7	0.0	0.0	13.4
September	15.4	5.5	72.0	1.0	74.8		0.0	0.0	74.8
October	9.8	2.8	42.6	1.0	40.5	31.0	0.0	0.0	9.5
November	3.0	0.5	10.8	0.8	8.7	52.5	43.8	0.0	0.0
December	-3.7	0.0	0.0	0.8	0.0	46.0	89.8	0.0	0.0
Total	**8.7**	**42.6**			**651.1**	**625.4**		**182.2**	**97.7**
					Net Water Surplus	**84.5**	**mm**		

Table I-6: 2011 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-7.6	0.0	0.0	0.8	0.0	49.6	200.0	49.6	0.0
February	-5.1	0.0	0.0	0.8	0.0	65.0	200.0	65.0	0.0
March	-0.4	0.0	0.0	1.0	0.0	115.3	200.0	115.3	0.0
April	7.2	1.7	27.2	1.1	30.5	123.0	200.0	92.5	0.0
May *	14.1	4.8	62.2	1.3	79.0	132.8	200.0	53.8	0.0
June *	19.6	7.9	93.2	1.3	119.3	70.0	150.7	0.0	0.0
July *	24.8	11.2	124.4	1.3	161.8	43.6	32.5	0.0	0.0
August *	22.0	9.4	107.4	1.2	128.9	64.4	0.0	0.0	32.0
September *	18.1	7.0	84.5	1.0	87.9	110.0	22.1	0.0	0.0
October *	11.0	3.3	45.8	1.0	43.5	104.0	82.6	0.0	0.0
November	7.3	1.8	27.7	0.8	22.4	76.4	136.5	0.0	0.0
December	1.5	0.2	4.0	0.8	3.1	88.7	200.0	22.1	0.0
Total	**9.4**	**47.2**			**676.4**	**1042.8**		**398.4**	**32.0**
					Net Water Surplus	**366.4**	**mm**		

Notes:
- calculations based on Thornthwaite Mather Method
- °C calculated mean of daily temperatures for the month, in degrees Celcius
- I denotes Heat Index
- E denotes Evapotranspiration
- WHC denotes Water Holding Capacity
- A value of 200 mm was used for the water holding capacity of the soils (clay loam soil moderately deep-rooted crops).
- Temperature and precipitation data from the Welland-Pelham climatological station located at latitude 42°58'00"N, longitude 79°20'00"W
- * Data from the Niagara College weather station located at latitude 43°15'00"N, longitude 79°16'00"W

Table I-7: 2012 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-1.4	0.0	0.0	0.8	0.0	96.6	200.0	96.6	0.0
February	-0.4	0.0	0.0	0.8	0.0	37.6	200.0	37.6	0.0
March	7.2	1.7	26.1	1.0	26.8	55.9	200.0	29.1	0.0
April	6.6	1.5	23.4	1.1	26.2	63.6	200.0	37.4	0.0
May *	17.1	6.4	77.7	1.3	98.7	47.0	148.3	0.0	0.0
June *	20.8	8.6	99.5	1.3	127.3	67.0	87.9	0.0	0.0
July *	24.3	10.9	121.0	1.3	157.3	30.6	0.0	0.0	38.8
August *	22.3	9.6	108.6	1.2	130.3	66.0	0.0	0.0	64.3
September *	17.0	6.3	77.2	1.0	80.2	140.6	60.4	0.0	0.0
October *	11.2	3.4	45.6	1.0	43.3	183.4	200.0	0.4	0.0
November	3.7	0.6	11.3	0.8	9.1	14.4	200.0	5.3	0.0
December	1.7	0.2	4.2	0.8	3.3	81.5	200.0	78.2	0.0
Total	**10.8**	**49.3**			**702.8**	**884.2**		**284.6**	**103.1**
					Net Water Surplus	**181.4**	**mm**		

Table I-8: 2013 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-1.9	0.0	0.0	0.8	0.0	67.8	200.0	67.8	0.0
February	-4.9	0.0	0.0	0.8	0.0	80.5	200.0	80.5	0.0
March	0.1	0.0	0.3	1.0	0.3	14.8	200.0	14.5	0.0
April	6.7	1.6	29.0	1.1	32.4	102.9	200.0	70.5	0.0
May	15.0	5.3	71.4	1.3	90.7	79.6	188.9	0.0	0.0
June	18.2	7.0	88.7	1.3	113.5	147.0	200.0	22.5	0.0
July	21.6	9.1	107.4	1.3	139.6	65.7	126.1	0.0	0.0
August	19.3	7.7	94.7	1.2	113.6	83.9	96.4	0.0	0.0
September	15.1	5.3	71.9	1.0	74.8	75.4	97.0	0.0	0.0
October	11.6	3.6	53.5	1.0	50.9	133.0	179.1	0.0	0.0
November	2.5	0.4	9.6	0.8	7.8	51.3	200.0	22.6	0.0
December	-3.4	0.0	0.0	0.8	0.0	100.9	200.0	100.9	0.0
Total	**8.3**	**39.9**			**623.5**	**1002.8**		**379.3**	**0.0**
					Net Water Surplus	**379.3**	**mm**		

Notes:
- calculations based on Thornthwaite Mather Method
- °C calculated mean of daily temperatures for the month, in degrees Celcius
- I denotes Heat Index
- E denotes Evapotranspiration
- WHC denotes Water Holding Capacity
- A value of 200 mm was used for the water holding capacity of the soils (clay loam soil moderately deep-rooted crops).
- Temperature and precipitation data from the Welland-Pelham climatological station located at latitude 42°58'00"N, longitude 79°20'00"W
- * Data from the Niagara College weather station located at latitude 43°15'00"N, longitude 79°16'00"W

Table I-9: 2014 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-7.3	0.0	0.0	0.8	0.0	45.8	200.0	45.8	0.0
February	-8.6	0.0	0.0	0.8	0.0	63.0	200.0	63.0	0.0
March	-4.3	0.0	0.0	1.0	0.0	35.4	200.0	35.4	0.0
April	6.7	1.6	27.9	1.1	31.2	114.6	200.0	83.4	0.0
May *	14.2	4.8	66.0	1.3	83.8	114.6	200.0	30.8	0.0
June *	20.3	8.3	99.4	1.3	127.3	106.0	178.7	0.0	0.0
July *	20.4	8.4	100.0	1.3	130.0	103.4	152.1	0.0	0.0
August *	20.4	8.4	100.0	1.2	120.0	21.2	53.3	0.0	0.0
September *	17.1	6.4	81.7	1.0	85.0	76.2	44.5	0.0	0.0
October *	11.5	3.5	51.8	1.0	49.2	52.0	47.3	0.0	0.0
November	2.5	0.4	9.0	0.8	7.3	50.8	90.8	0.0	0.0
December	0.6	0.0	1.8	0.8	1.4	37.6	127.0	0.0	0.0
Total	**7.8**	**41.7**			**635.2**	**820.6**		**258.3**	**0.0**
					Net Water Surplus	**258.3**	**mm**		

Table I-10: 2015 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-7.1	0.0	0.0	0.8	0.0	55.9	200.0	55.9	0.0
February	-13.1	0.0	0.0	0.8	0.0	34.1	200.0	34.1	0.0
March	-2.6	0.0	0.0	1.0	0.0	32.9	200.0	32.9	0.0
April	7.0	1.7	27.0	1.1	30.2	66.9	200.0	36.7	0.0
May *	16.9	6.3	78.4	1.3	99.5	59.0	159.5	0.0	0.0
June *	18.1	7.0	85.1	1.3	109.0	173.2	200.0	23.7	0.0
July *	21.8	9.2	106.6	1.3	138.6	34.6	96.0	0.0	0.0
August *	20.5	8.4	99.0	1.2	118.8	92.4	69.6	0.0	0.0
September *	19.6	7.9	93.7	1.0	97.5	123.0	95.1	0.0	0.0
October *	10.7	3.2	45.1	1.0	42.8	86.2	138.5	0.0	0.0
November	6.4	1.5	24.2	0.8	19.6	36.4	155.3	0.0	0.0
December	4.4	0.8	15.4	0.8	12.0	47.2	190.5	0.0	0.0
Total	**8.6**	**45.9**			**668.1**	**841.8**		**183.3**	**0.0**
					Net Water Surplus	**183.3**	**mm**		

Notes:
- calculations based on Thornthwaite Mather Method
- °C calculated mean of daily temperatures for the month, in degrees Celcius
- I denotes Heat Index
- E denotes Evapotranspiration
- WHC denotes Water Holding Capacity
- A value of 200 mm was used for the water holding capacity of the soils (clay loam soil moderately deep-rooted crops).
- Temperature and precipitation data from the Welland-Pelham climatological station located at latitude 42°58'00"N, longitude 79°20'00"W
- * Data from the Niagara College weather station located at latitude 43°15'00"N, longitude 79°16'00"W

Table I-11: 2016 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-3.2	0.0	0.0	0.8	0.0	41.9	200.0	41.9	0.0
February	-2.2	0.0	0.0	0.8	0.0	82.6	200.0	82.6	0.0
March	3.5	0.6	10.3	1.0	10.6	77.1	200.0	66.5	0.0
April	5.4	1.1	17.9	1.1	20.1	37.8	200.0	17.7	0.0
May *	14.9	5.2	65.0	1.3	82.6	24.2	141.6	0.0	0.0
June *	20.2	8.2	95.7	1.3	122.5	21.6	40.8	0.0	0.0
July *	23.8	10.5	117.8	1.3	153.1	37.6	0.0	0.0	74.8
August *	24.3	10.9	120.9	1.2	145.1	70.2	0.0	0.0	74.9
September *	19.6	7.9	92.1	1.0	95.8	46.6	0.0	0.0	49.2
October *	12.6	4.0	52.6	1.0	49.9	100.4	50.5	0.0	0.0
November	6.1	1.4	20.9	0.8	17.0	56.7	90.2	0.0	0.0
December	-0.9	0.0	0.0	0.8	0.0	62.2	152.4	0.0	0.0
Total	**10.3**	**49.8**			**696.6**	**658.9**		**208.7**	**198.8**
					Net Water Surplus	**9.9**	**mm**		

Table I-12: 2017 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-1.2	0.0	0.0	0.8	0.0	65.3	200.0	65.3	0.0
February	0.6	0.0	1.5	0.8	1.2	54.0	200.0	52.8	0.0
March	0.1	0.0	0.2	1.0	0.2	109.4	200.0	109.2	0.0
April	9.3	2.6	38.9	1.1	43.5	132.9	200.0	89.4	0.0
May *	13.2	4.3	58.9	1.3	74.9	164.2	200.0	89.3	0.0
June *	19.5	7.8	93.7	1.3	120.0	96.2	176.2	0.0	0.0
July *	21.3	8.9	104.1	1.3	135.4	125.0	165.8	0.0	0.0
August *	20.3	8.3	98.3	1.2	118.0	88.4	136.2	0.0	0.0
September *	18.3	7.1	86.9	1.0	90.4	30.2	76.0	0.0	0.0
October *	14.2	4.8	64.3	1.0	61.1	114.0	129.0	0.0	0.0
November	3.8	0.7	13.4	0.8	10.9	98.1	200.0	16.2	0.0
December	-5.1	0.0	0.0	0.8	0.0	52.0	200.0	52.0	0.0
Total	**9.5**	**44.5**			**655.5**	**1129.7**		**474.2**	**0.0**
					Net Water Surplus	**474.2**	**mm**		

Notes:
- calculations based on Thornthwaite Mather Method
- °C calculated mean of daily temperatures for the month, in degrees Celcius
- I denotes Heat Index
- E denotes Evapotranspiration
- WHC denotes Water Holding Capacity
- A value of 200 mm was used for the water holding capacity of the soils (clay loam soil moderately deep-rooted crops).
- Temperature and precipitation data from the Welland-Pelham climatological station located at latitude 42°58'00"N, longitude 79°20'00"W
- * Data from the Niagara College weather station located at latitude 43°15'00"N, longitude 79°16'00"W

Table I-13: 2018 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-5.6	0.0	0.0	0.8	0.0	49.9	200.0	49.9	0.0
February	-1.3	0.0	0.0	0.8	0.0	74.7	200.0	74.7	0.0
March	-0.8	0.0	0.0	1.0	0.0	46.2	200.0	46.2	0.0
April	3.4	0.6	11.1	1.1	12.5	107.2	200.0	94.7	0.0
May *	17.2	6.5	79.8	1.3	101.4	61.6	160.2	0.0	0.0
June *	19.7	7.9	94.2	1.3	120.5	42.0	81.7	0.0	0.0
July *	23.8	10.5	118.5	1.3	154.0	56.6	0.0	0.0	15.7
August *	23.0	10.0	113.7	1.2	136.4	98.4	0.0	0.0	38.0
September *	19.1	7.6	90.7	1.0	94.3	0.0	0.0	0.0	94.3
October *	10.2	2.9	42.3	1.0	40.2	60.2	20.0	0.0	0.0
November	2.1	0.3	6.2	0.8	5.0	112.3	127.3	0.0	0.0
December	0.3	0.0	0.6	0.8	0.5	69.7	196.5	0.0	0.0
Total	**9.3**	**46.3**			**664.7**	**778.8**		**265.5**	**148.0**
					Net Water Surplus	**117.5**	**mm**		

Table I-14: 2019 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-5.4	0.0	0.0	0.8	0.0	53.3	200.0	53.3	0.0
February	-3.0	0.0	0.0	0.8	0.0	59.2	200.0	59.2	0.0
March	-1.3	0.0	0.0	1.0	0.0	61.6	200.0	61.6	0.0
April	6.7	1.6	27.6	1.1	30.9	94.5	200.0	63.6	0.0
May	12.5	4.0	56.7	1.3	72.0	97.2	200.0	25.2	0.0
June *	18.6	7.3	89.7	1.3	114.8	102.0	187.2	0.0	0.0
July *	23.3	10.2	116.4	1.3	151.3	39.2	75.1	0.0	0.0
August *	21.1	8.8	103.8	1.2	124.5	124.6	75.2	0.0	0.0
September *	18.2	7.0	87.5	1.0	91.0	89.6	73.8	0.0	0.0
October	11.0	3.3	48.9	1.0	46.5	118.6	146.0	0.0	0.0
November	1.2	0.1	3.8	0.8	3.1	32.0	174.9	0.0	0.0
December	-0.2	0.0	0.0	0.8	0.0	99.7	200.0	74.6	0.0
Total	**8.6**	**42.3**			**634.0**	**971.5**		**337.5**	**0.0**
					Net Water Surplus	**337.5**	**mm**		

Notes:
- calculations based on Thornthwaite Mather Method
- °C calculated mean of daily temperatures for the month, in degrees Celcius
- I denotes Heat Index
- E denotes Evapotranspiration
- WHC denotes Water Holding Capacity
- A value of 200 mm was used for the water holding capacity of the soils (clay loam soil moderately deep-rooted crops).
- Temperature and precipitation data from the Welland-Pelham climatological station located at latitude 42°58'00"N, longitude 79°20'00"W
- * Data from the Niagara College weather station located at latitude 43°15'00"N, longitude 79°16'00"W

Table I-15: 2020 Water Budget

Month	Mean Temperature °C	I	E mm	Daylight Factor	E Adj. mm	Total Precipitation mm	WHC mm	Surplus mm	Deficit mm
January	-0.4	0.0	0.0	0.8	0.0	75.6	200.0	75.6	0.0
February	-2.2	0.0	0.0	0.8	0.0	48.5	200.0	48.5	0.0
March	4.0	0.7	15.1	1.0	15.5	71.0	200.0	55.5	0.0
April	5.6	1.2	22.3	1.1	25.0	73.0	200.0	48.0	0.0
May	12.0	3.8	53.9	1.3	68.5	57.8	189.3	0.0	0.0
June	19.5	7.8	94.6	1.3	121.1	52.8	121.0	0.0	0.0
July	23.4	10.3	116.9	1.3	151.9	70.8	39.9	0.0	0.0
August	21.0	8.7	103.1	1.2	123.7	17.4	0.0	0.0	66.5
September	15.5	5.5	72.5	1.0	75.4	41.4	0.0	0.0	34.0
October	9.9	2.8	43.1	1.0	41.0	75.2	34.2	0.0	0.0
November	7.0	1.7	28.9	0.8	23.4	72.8	83.6	0.0	0.0
December	0.6	0.0	1.7	0.8	1.3	66.5	148.8	0.0	0.0
Total	**9.7**	**42.5**			**646.8**	**722.8**		**227.6**	**100.5**
					Net Water Surplus	**127.1**	**mm**		

Notes:
- calculations based on Thornthwaite Mather Method
- °C calculated mean of daily temperatures for the month, in degrees Celcius
- I denotes Heat Index
- E denotes Evapotranspiration
- WHC denotes Water Holding Capacity
- A value of 200 mm was used for the water holding capacity of the soils (clay loam soil moderately deep-rooted crops).
- Temperature and precipitation data from the Welland-Pelham climatological station located at latitude 42°58'00"N, longitude 79°20'00"W