APPENDIX A

GEOTECHNICAL INVESTIGATION MEMORANDUM

UPDATED GEOTECHNICAL ASSESSMENT
RUBY AND AUBREY STREET OUTFALL CHAMBERS UPGRADE
WINNIPEG, MANITOBA

CITY OF WINNIPEG, WATER & WASTE DEPARTMENT
MATERIALS MANAGEMENT REFERENCE NO.318-2017 (FILE NO D-316)

Submitted to:

City of Winnipeg
Engineering Services Division
Design and Construction Branch
110-1199 Pacific Avenue
Winnipeg, Manitoba
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Attention: Mr. Doug Berg, CET.

Submitted by:

Amec Foster Wheeler Environment & Infrastructure

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28 September 2017

Amec Foster Wheeler File No. WX1793201

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1.0 INTRODUCTION

As authorized by Mr. Doug Berg, CET, of the City of Winnipeg, Engineering Services Division, Design and Construction Branch, Amec Foster Wheeler Environment and Infrastructure, a Division of Amec Foster Wheeler Americas Limited (Amec Foster Wheeler), is pleased to provide an update of the geotechnical assessments for the proposed Ruby and Aubrey Streets Outfall Gate Chambers based on recent geotechnical and hydrogeologic assessments (i.e. pump test) performed on site. The update of geotechnical assessment was performed in accordance with to the project scope presented in Amec Foster Wheeler's proposal WPG2016.593R3, dated 21 February 2017.

2.0 BACKGROUND

In 2016, Amec Foster Wheeler was engaged by MMM/WSP to perform a geotechnical investigation to evaluate the subsurface soil and groundwater conditions and then to provide recommendations for the foundation and excavation of the proposed two outfall gate chambers at the Ruby and Aubrey Sites. At the time of the investigation, a total of two (2) test holes were drilled with one hole at each site. Geotechnical recommendations were provided in the geotechnical report[1] to support the design and tender for construction at both the Ruby and Aubrey Sites.

The outfall chamber at the Ruby Site was later awarded to Rocky Road Recycling (RRR) for the construction in the winter (around Oct) of 2016. It is understood that RRR acquired Friesen Driller Ltd (Friesen), a hydrogeological sub-consultant to drill a pumping well for the purpose of developing a dewatering plan to dewater the basal aquifer at the site to create a safe excavation for construction at the Ruby Site. It was reported by Friesen Drillers that the bedrock conditions at the proposed Ruby Outfall location may vary substantially from what could reasonably be assumed from the available published information on the hydrogeology of the area. This initial work by the contractor identified issues that they indicated would need to be addressed before the project could proceed to construction including:

- Apparent High Aquifer Transmissivity;
- Impacts on Brackish/Saline Groundwater Interface;
- Disposal of the Pumped Water;
- Third Party Impacts;
- River Water Intrusion;
- Base Heave/Piping During Construction; and
- Cracks and Shifting Foundations / Settlement

Based on Friesen's findings, and further meetings between the City of Winnipeg, MMM/WSP & Amec Foster Wheeler, it was concluded that further detailed hydrogeologic and geotechnical

[1] Geotechnical investigation, Ruby and Aubrey Street Outfall Chambers Upgrade, Winnipeg, Manitoba, Amec File No. WX17932, dated 16 June 2016

assessments would be required to address the concerns that are listed above. The following section presents the agreed upon preliminary scope of work designed to address these potential issues. It should be noted that the authorized scope of work for the hydrogeologic and geotechnical assessment was specifically tailored to the Aubrey Site, as it was understood that the City of Winnipeg's preference was to work on that site first. Following completion of the study, however, it was determined that the findings may apply to both sites

3.0 SCOPE OF WORK

The approved scope included both hydrogeologic and geotechnical components. The hydrogeologic scope was completed by W.L. Gibbons & Associates Ltd. (WLG) and included the following:

- Data compilation and review;
- Field investigations;
- Bedrock monitoring well installations;
- Bedrock pump testing;
- Well monitoring; and
- Preliminary hydrogeologic assessments of the results including:
    - Transmissivity of the bedrock aquifer at both Ruby and Aubrey locations;
    - Potential pumping rates needed to depressurize the two sites using standard pump and discharge techniques;
    - Potential third party impacts;
    - Brackish/saline groundwater interface impacts.

The results of the hydrogeologic study are contained in a separate report provided in its entirety in Appendix B. The geotechnical scope was completed by Amec Foster Wheeler in conjunction with the hydrogeologic scope outlined above and included the following:

- Field investigations;
- Vibrating wire piezometer installation;
- Piezometer monitoring; and
- Preliminary geotechnical engineering assessments of the results at both Ruby and Aubrey locations including:
    - Updated dewatering requirements for construction;
    - Updated shoring design recommendations; and
    - Comments and recommendations relating to settlement potential arising from construction dewatering.

The following sections describe the results of the geotechnical study, summarize key findings of the hydrogeologic study and provide recommendations for dewatering and shoring to satisfy the geotechnical and hydrogeological conditions.

4.0 FIELD INVESTIGATION

Amec Foster Wheeler performed test hole drilling and monitoring well installation between 09 May and 12 May of 2017. Prior to completing the field investigation, all underground utilities were cleared from the proposed well installation locations. All field activities were completed without incident.

Test hole drilling and monitoring well installation were performed by Maple Leaf Drilling using a track mounted drill rig (Acker Renegade) equipped with solid stem augers and coring capabilities. During the field investigation, a total of four (4) test holes were drilled at both the Ruby and Aubrey Sites combined. In general, all test holes were cored into the bedrock for well installation, except test hole 2017-TH02 (Aubrey) where the test hole was terminated to 8.8 m below the existing grade in the clay with a vibrating wire piezometer installed at the exploration depth. Test holes/monitoring wells locations are presented in Figure 1 and the test hole soil logs are presented in Appendix A. The details of these holes are also summarized and presented in the following table:

Table 1: Details of Test hole and Well Installations

No	Site	Test Hole ID	Ground Surface Elevation (m)	Top of Till B.G. (m)	Top of Bedrock B.G. (m)	Depth of Hole B.G. (m)	Screen Section B.G (m)
1	Aubrey	2017-TH01	231.53	10.52 (221.01)	21.03 (210.50)	25.91 (205.62)	21.3 to 22.9 (210.2 to 208.7)
2		2017-TH02	231.57	NA	NA	8.8 (222.7)	8.8* (222.7)
3	Ruby	2017-TH01	232.00	14.02 (217.98)	16.92 (215.08)	22.86 (209.14)	19.2 to 22.3 (212.8 to 209.7)
4		2017-TH02	231.48	13.26 (218.22)	16.82 (214.66)	22.86 (208.62)	16.6 to 19.7 (214.9 to 211.8)

Notes:
1) Number in the brackets are geodetic elevations;
2) B.G – Depth below grade.
3) * - Tip level of the vibrating wire piezometer

Some disturbed soil samples were collected from the augers during test hole drilling. Once auger refusal was met, drilling of the hole proceeded with coring through cobbles, boulders, dense till and bedrock to achieve a target depth for well installation. At the end of drilling, all collected disturbed and core samples were properly sealed and delivered to Amec Foster Wheeler's Winnipeg laboratory for further soil testing and sample review.

Subsurface soils on site were generally consistent with those observed in the geotechnical investigation performed in 2016 (i.e. 2016-TH01 (Ruby) & 2016-TH02 (Aubrey)). Soil conditions specifically consisted of silty, sandy medium to high plastic alluvial clay to depths of 7 to 8 m

below grade followed by either soft to firm high plastic lacustrine clay or the continued alluvial clay to depths of 11.5 to 14 m below grade. A 1.5 to 2 m thick sand layer was encountered at the bottom of the alluvial clay that extended from about 8 to 10.3 m below grade at the Ruby site. Only thin sand lenses were encountered within the clay at the Aubrey Site. Glacial till was present below the clay and extended to depths of 17 to 20 m below the existing grade. Highly fractured bedrock was encountered immediately below the till and generally continued to the depths explored at each monitoring well installation.

A 150 mm diameter pumping test well (TW17-01) was later installed by Friesen Drillers Ltd under the supervision of WLG on 06 June 2017. The pumping test well was cored to 25 m below grade with steel casing installed to 19.5 m below grade. Soil conditions at the pumping test well consisted of about 10.7 m of clay followed by glacial till to about 18.9 m below grade, below which limestone bedrock was encountered. A pump test was later performed between the hours of 10:30 and 17:21 on 07 June 2017. The locations of the monitoring wells and the pumping test well are presented in Figures 1 to 3. Details of the test well log, pump test and the hydrogeologic study can be found in WLG's report[2] as presented in Appendix B

5.0 SUMMARY OF FINDINGS OF HYDROGEOLOGIC STUDY

Based on the results of the hydrogeologic assessment provided by WLG, together with groundwater monitoring results obtained during the pumping test conducted at the Aubrey Site, and historic river level data, four (4) major conclusions can be drawn that are related to geotechnical assessments presented in Sections 6.0 and 7.0. These conclusions are:

1. A high horizontal hydraulic connection exists between the river and alluvial clay.
    a. Clay deposits at both the Ruby and Aubrey Sites consist largely of alluvial clay with intermittent layers of silt and sand. This is particularly prevalent at the Ruby Site, where a layer of sand approximately 1.5 m thick was encountered at both monitoring wells 2016-TH01 (Ruby) and 2017-TH02 (Ruby). The presence of the sand layer will increase the horizontal conductivity between the river and the clays.
    b. Prior to performing the pump test and between 12 May 2017 and 07 June 2017, the groundwater levels observed in the basal (glacial till and bedrock) aquifer and the porewater pressure (PWP) head in the clay each decreased by about 1.5 m. This magnitude of change is similar to the changes observed in river levels during the same period. This suggests that the hydraulic conditions in the bedrock aquifer and overburden soils (clays & glacial till) are highly influenced by the river level in the Assiniboine River. Historical movement of the river levels relative to the PWPs in the clay and the groundwater conditions in bedrock aquifer are presented in Figures 4 & 5.

[2] City of Winnipeg, Ruby and Aubrey Street Outfall Upgrade, Hydrogeologic Assessment Report, Prepared by W.L. Gibbons & Associates Inc., Aug 2017

2. A high hydraulic connection exists between the bedrock and the glacial till within each site, as well as between the Ruby and Aubrey Sites.

    a. During coring of the test holes for well installations at both the Aubrey and Ruby Sites, it was observed that the glacial till was generally sandy and gravelly, and the upper part of the bedrock was highly fractured. Therefore, the bedrock aquifer is likely highly connected to the glacial till at both the Aubrey and Ruby Sites.

    b. Water in the pumping well (TW17-01) was drawn down about 2.1 m during the pump test. Monitoring data obtained at the monitoring wells indicated corresponding drawdowns of 0.6 to 1.4 m within the bedrock at the Ruby and Aubrey Sites, respectively. This observation suggests a strong lateral hydraulic connection within the bedrock over both short and long distances, and as such, the drawdown cone resulting from pumping at either of the sites is likely to be wide. Refer to hydrogeologic report for all pumping test results presented in Appendix B.

3. A low vertical hydraulic connection exists between the basal aquifer (glacial till & bedrock) and the overlying clay during dewatering.

    a. Review of PWPs recorded in the clay at the Aubrey Site (i.e. at 2017-TH02 (Aubrey) indicates a drop in porewater pressure of less than 0.05 m of water pressure (i.e. 0.5 kPa) during the aquifer pump testing in the bedrock as shown in Figure 6. This change is likely associated with the recorded changes in river levels over the same period, which are of similar magnitude to those observed in the clay, rather than the large changes in groundwater level in the basal aquifer. As such, changes in groundwater conditions induced within the bedrock aquifer as a result of the short duration pump test appear to have little effect on groundwater conditions in the clay and therefore the vertical connection between the clay and the basal aquifer is low during dewatering.

4. A high rate of drawdown and recovery exists within the basal aquifer resulting from dewatering.

    a. Drawdown of the basal aquifer was recorded to occur over a very short time with approximately 80% of the drawdown occurring within 2 hours following initiation of the pumping test (Refer to Figure 6). On completion of the pumping test, groundwater levels within the bedrock aquifer at both the Ruby and Aubrey Sites were observed to recover in about 10 hours following cessation of pumping.

6.0 POTENTIAL GROUND SETTLEMENT DURING DEWATERING

Based on the above noted findings, it is suggested that the potential for ground settlement induced by construction dewatering of the basal (glacial till & bedrock) aquifer is low, which is consistent with the early preliminary assessment described in Amec Foster Wheeler's proposal [3]. The reasons for this low potential for ground settlement during the construction dewatering are as follows:

1. In general, overburden soils settle if the effective stress level in the soil increases. Increases in effective stress result from two general conditions which may be either permanent or temporary and include: 1) direct loading to the ground surface through the placement of heavy objects or raising of soil grades above the current grade; or 2) reducing the groundwater level within the soil. In the case of this project, consideration is only being given to second mechanism.

2. Groundwater levels in the riverbank soils fluctuate seasonally due to many natural influences including changes in precipitation and runoff patterns, changes in river levels and changes in underlying bedrock aquifer conditions. Seasonal changes are natural and occur year after year in varying degrees.

3. As indicated in Section 5.0, groundwater conditions in the riverbank appear to be highly influenced by changes in river level (Refer to Figures 4 & 5). That is, the water level in the clay was observed to decrease by approximately 1.8 m between early May and late June 2017 as the river level decreased likely due to the presence of horizontal layers of more permeable silt and sand in the clay that provide a strong lateral connection to the river.

4. Also, as indicated in Section 5.0, the effects of the 7 hr. pump test on groundwater conditions in the clay at the Aubrey Site appear to be negligible in comparison to the natural changes in groundwater conditions that occur resulting from changes in river levels. That is, the water level in the clay did not appear to respond to pumping in the underlying bedrock aquifer. This suggests that the vertical connection between the bedrock and the clay is weak in comparison to the lateral connection to the river.

5. Therefore, settlement associated with changes in effective stress due to changes in groundwater conditions is likely to be more highly influenced by naturally occurring changes in the river level than those induced by pumping from the bedrock aquifer.

6. Furthermore, any settlement that results specifically from dewatering of the basal aquifer is expected to be small in comparison to that resulting from annual and seasonal changes in river levels and difficult to both quantify and separate.

7. Another consideration is the rate of settlement that may occur within the clay as a result of changes in effective stress. The rate of settlement is directly related to the rate of

[3] WPG2016.593R3 – Scoping Level Hydrogeological & Geotechnical Assessments for the proposed Ruby and Aubrey Streets Outfall Chamber Upgrades, dated 21 February 2017

change of the effective stress. Since the vertical permeability of the clay is low, decreases in effective stress in the clay would also be expected to occur slowly as dewatering of the bedrock occurs, and any resulting settlement will also occur over a long period (i.e. much longer than the duration of construction). Furthermore, once pumping has stopped any settlement that has occurred will be reversed since the groundwater in the bedrock will recover very quickly and therefore, the overall effect on settlement is expected to be minimal.

It should be noted that although, the magnitude of consolidation settlement caused by the construction dewatering process is expected to be small, the actual settlement magnitude remains unknown.

7.0 GEOTECHINCAL ASSESSMENT

Based on the result of hydrogeologic assessment, Amec Foster Wheeler re-evaluated the excavation dewatering requirement to address basal heave/piping potential of the chambers at both the proposed Ruby and Aubrey Sites. Recommendations for excavation and shoring for the project development were previously provided in the geotechnical investigation report[1]. The following shows the assessment for each site as it relates to three potential modes of excavation failure as well as general seepage considerations. Each failure mode will be described for the Ruby Site only, but will not be repeated for the Aubrey Site.

7.1 Ruby Site

7.1.1 Base Stability Against Shear Failure

Base shear failure occurs in deep excavations in soft to firm clays which are overstressed in shear. This mechanism is a function of the shape and size of the excavation, the shear strength of the clay present at the base of the excavation and the weight of the soils above and outside of the excavation base. According to the Canadian Foundation Engineer Manual (CFEM), 4th Edition, if the factor of safety (FS) against base shear failure is less than 1.5, the depth of penetration of the support system **MUST** extend below the base of the excavation. Furthermore, in designing a shoring system for stability against base shear failure, a FS greater than 2.0 should generally be targeted. If the FS is less than 2.0, substantial deformation may occur.

Amec Foster Wheeler's previous geotechnical report determined that after excavation to the proposed chamber elevation of about 220 m, about 1.5 m of clay will remain between the base of the gate chamber and the top of the glacial till. The clay is soft and weak and subject to potential base shear failure. Since the factor of safety (FS) for base stability against base shear failure is less than 1.5 for these conditions, Amec Foster Wheeler recommends that a shoring system consisting of continuous piles penetrating below the base of the excavation and into the glacial till be used to prevent such a failure (i.e. consistent with CFEM). Such a system may consist of either driven sheet piles or a drilled tangent / secant pile wall based in the till. It is understood that the contractor would like to use a soldier pile and timber lagging system for the shoring at the Ruby site. While this shoring system may also be considered, the contractor should be aware

that spacing of the soldier piles and the depth of embedment of these piles into the underlying till must be suitably designed to prevent deformation of the clay between the piles and therefore failure of the base in shear. As a result, a soldier piles with timber lagging shoring system is not preferred.

7.1.2 Base Stability Against Piping Failure

A second mechanism that must be considered for the excavation and shoring design is protection of the excavation base against piping failure. Piping failure is also a function of the shape, size and depth of the excavation, but is further related to the seepage exit gradient and the soil type present at the base of the excavation.

It is understood that the proposed chamber will have a rectangular shape about 4.3 m wide x 7 m long and about 11.9 m deep below the existing grade. The excavation will be based in soft alluvial clay and the underlying glacial till is highly connected to the bedrock aquifer such that water pressure in the bedrock is readily conveyed to the clay / till interface. These conditions result in a significant potential for piping to occur without implementing dewatering of the bedrock aquifer, irrespective of the type of shoring system selected. Therefore, to prevent base piping (seepage) failure, the water level in the bedrock aquifer must be lowered to a minimum of 222 m (i.e. a maximum of 2 m above the base of the excavation).

7.1.3 Base Stability Against Heave

A third mechanism that must be considered for the excavation and shoring design is protection of the excavation base against heave. Similar to the previous two failure mechanisms, base heave is also a function of the shape and size of the excavation, as well as the characteristics of the material present at the base of the excavation, but is also a function of the water pressure present below the base of the excavation.

As previously discussed, the base of the excavation will be founded in soft alluvial clay underlain by glacial till which is strongly hydraulically connected to the bedrock below. Therefore, to prevent base heave from occurring, the groundwater in the basal aquifer (glacial till & bedrock) needs to be lowered to at least 1 m below the base of the excavation.

7.1.4 General Seepage Considerations

Soil conditions encountered at test holes 2016-TH01 (Ruby) and 2017-TH02 (Ruby) indicate the presence of a sand layer about 1.5 m thick within in the clay deposit and about 1.5 to 2 m above the base of the proposed excavation. It is suspected that this sand layer may be connected to the river and therefore lateral seepage from this layer should be expected during the excavation. Depending on the type of shoring system selected by the contractor (i.e. continuous or timber lagging), loss of ground from behind the shoring wall should also be expected. Where the loss of ground is significant, this can affect construction and safety conditions adjacent to the excavation as well as the performance of existing near surface structures. On this basis, the contractor

should select a shoring option that seeks to minimize the amount of seepage and the potential for loss of ground. As a result, a continuous shoring system (i.e. sheet pile) would be an advantage. An internal dewatering system inside the excavation may also be required to address water seeping into the excavation.

7.1.5 Conclusions and Recommendations for the Ruby Site

On the basis of the above findings for the three (3) potential modes of excavation failure including general seepage considerations, Amec Foster Wheeler recommends that the groundwater in the basal aquifer be lower to about 1 m minimum below the base of the excavation. Furthermore, while various shoring alternatives may be considered, a continuous sheet pile shoring system is preferred at the Ruby Site due to potential challenges associated with achieving base shear stability and heaving associated with the presence of soft clay, as well as controlling potential lateral seepage and loss of ground from behind the shoring walls relating to interbedded sand lenses/layers in the clay even if construction dewatering is executed on site.

If a soldier pile with timber lagging shoring system is selected, the contractor would need to design the spacing of the solider piles to prevent soft clay from failing or squeezing into the open excavation below the timber lagging and between the soldier piles since the FS for base stability against shear failure is less than the minimum design criterion stated. These findings and recommendations are consistent with Amec Foster Wheeler's previous 2016 geotechnical report[1].

7.2 Aubrey Site

7.2.1 Base Stability Against Shear Failure

The subsurface soils at the Aubrey site are a little different than those at the Ruby site. Specifically, the depth to the glacial till is shallower and no thick sand layer was observed within the alluvial clay at the test holes advanced at the Aubrey Site. On this basis, excavation of the proposed gate chamber to about Elevation (El). 220 m at the Aubrey Site would extend approximately 1 m below the top of the glacial till layer. Given that the base of the excavation is founded within the glacial till, base stability against shear failure is not a concern at the Aubrey Site. As a result, the shoring system required at the Aubrey Site do not need to penetrate below the base of the excavation to prevent shear failure.

7.2.2 Base Stability Against Piping Failure

It is understood that the proposed chamber at the Aubrey Site is about 5.4 m wide x 7 m long and about 11.6 m deep to about El. 220 m below the existing grade and that the base of the chamber will be founded in the pervious glacial till. Given the high water levels in the basal aquifer, construction dewatering to lower the basal aquifer to below the base of the excavation will be required to prevent piping failure through the base of the excavation.

7.2.3 Base Stability Against Heave

Similar to what had been presented in the previous geotechnical report[1] and the findings at the Ruby Site, the groundwater in the basal aquifer (glacial till & bedrock) needs to be lowered to a minimum of 1 m below the base of the excavation to protect the bearing surface from heaving.

7.2.4 General Seepage Considerations

Similar to conditions at the Ruby Site, soil conditions encountered at test holes 2016-TH01 (Aubrey) and 2017-TH02 (Aubrey) indicate the presence of variable sand and silt lenses within the alluvial clay deposit above the base of the proposed excavation. On this basis, the contractor should select a shoring option that seeks to minimize the amount of seepage and the potential for loss of ground behind / through the shoring wall. As a result, a continuous shoring system (i.e. sheet pile) would be an advantage. An internal dewatering system inside the excavation may also be required to address water seeping into the excavation.

7.2.5 Conclusions and Recommendations for the Aubrey Site

Based on the above findings, for the three (3) potential modes of excavation failure including general seepage considerations, Amec Foster Wheeler recommends that the groundwater in the basal aquifer be lower to about 1 m minimum below the base of the excavation. While a soldier pile and timber lagging shoring system is possible for the Aubrey Site, a continuous sheet pile shoring system is recommended to help control potential lateral seepage and loss of ground from behind the shoring walls relating to interbedded sand lenses/layers in the clay even if construction dewatering is executed on site. These findings and recommendations are consistent with Amec Foster Wheeler's previous geotechnical report.

8.0 CLOSURE

The findings and recommendations presented herein for design of the proposed Ruby and Aubrey outfall gate chambers are based on a geotechnical evaluation of the findings in the geotechnical test hole drilled at the sites and should be should be read in conjunction with the Amec Foster Wheeler's geotechnical investigation report. If conditions are encountered that appear to be different from those shown in the test hole logs and described in this report, or if the assumptions stated herein are not in keeping with the design, Amec Foster Wheeler should be notified and given the opportunity to review the current recommendations in light of any new findings. Recommendations presented herein may not be valid if an adequate level of inspection is not provided during construction, or if relevant building code requirements are not met.

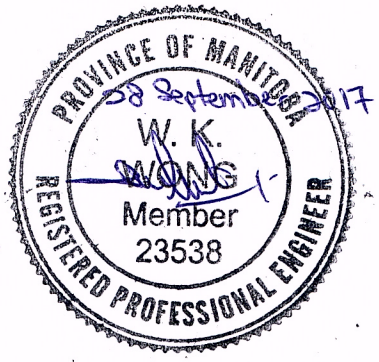
Soil conditions, by their nature, can be highly variable across a construction site. The placement of fill during and prior to construction activities on a site can contribute to variable soil conditions. A contingency amount should be included in the construction budget to allow for the possibility of variations in soil conditions, which may result in modification of the design, and/or changes in construction procedures.

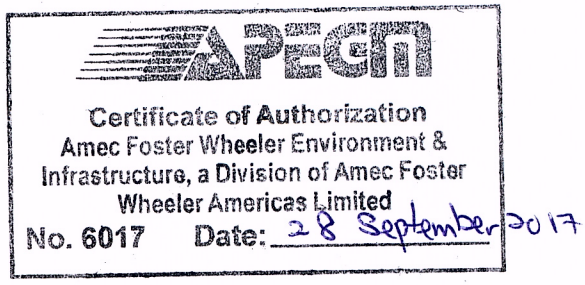
This report has been prepared for the exclusive use of City of Winnipeg, and their design agents, for specific application to the development described within this report. The data and recommendations provided herein should not be used for any other purpose, or by any other parties, without review and written advice from Amec Foster Wheeler.

The findings and recommendations of this report have been prepared in accordance with generally accepted soil and foundation engineering practices. No other warranty is made, either expressed or implied.

Respectfully submitted,

Amec Foster Wheeler Environment & Infrastructure,
A Division of Amec Foster Wheeler Americas Limited





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Senior Associate Geotechnical Engineer
Manager of Geotechnical Services

FIGURES

Figure 1: Site and Test Hole Location Plan
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Figure 3: Riverbank Profile for the Proposed Aubrey Site Outfall Chamber
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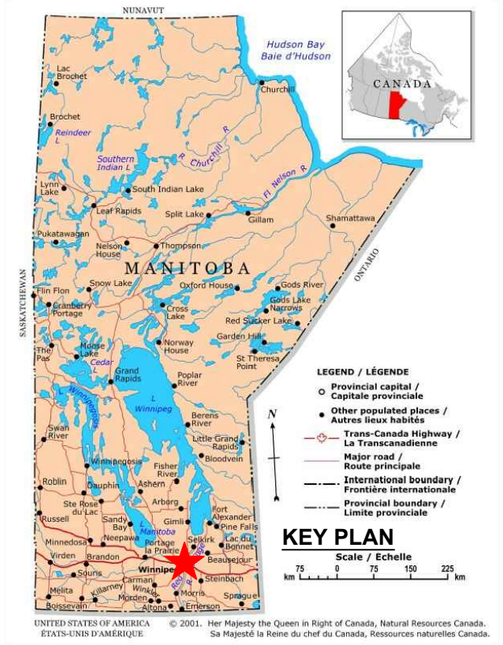
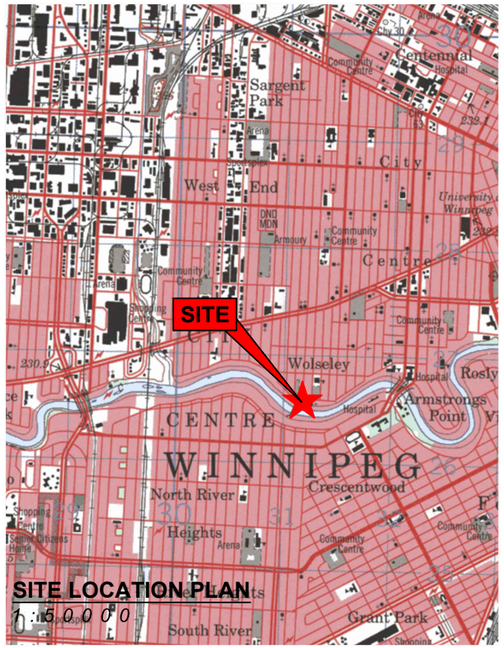
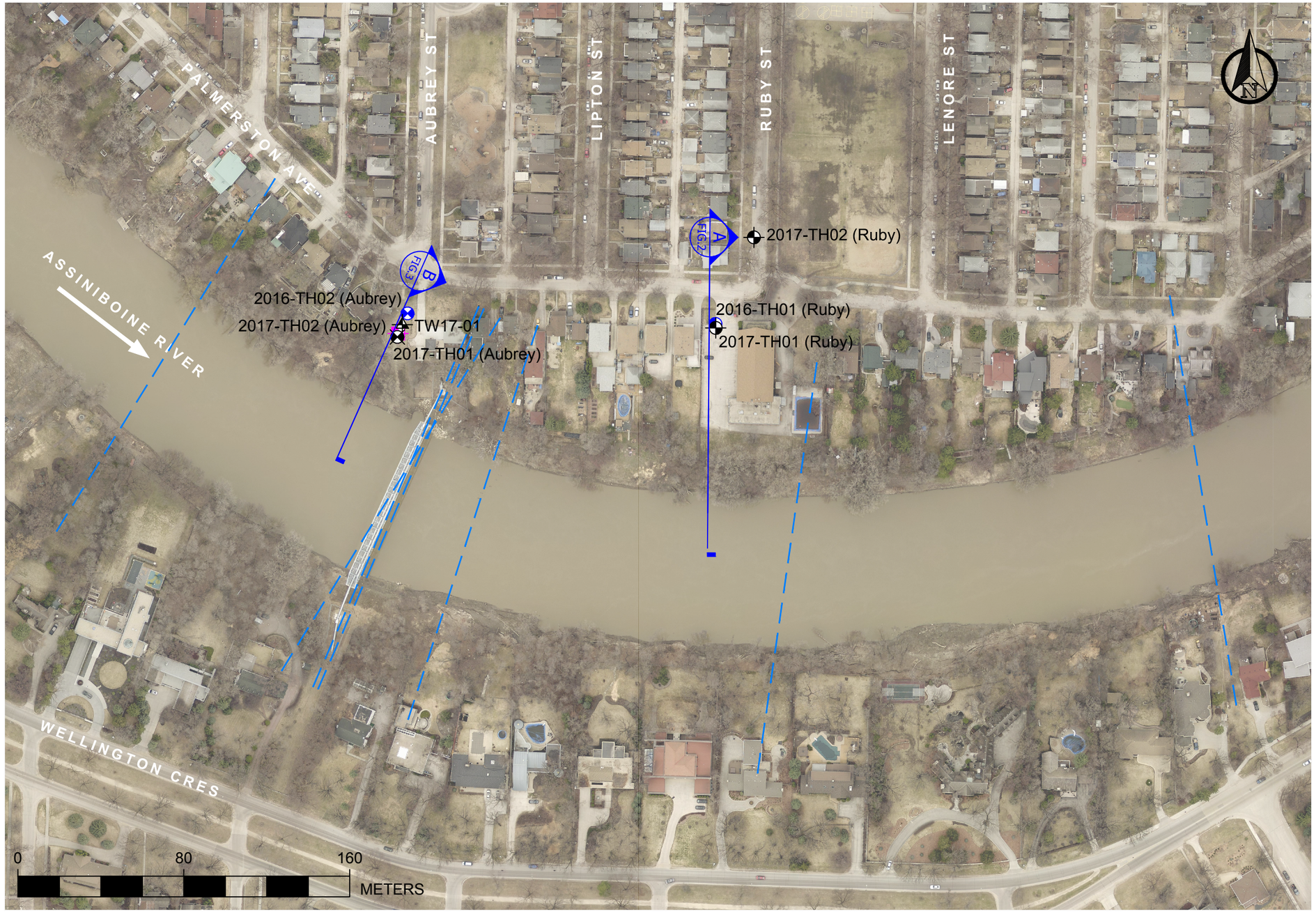






- IMAGE FROM MLI WEBSITE

LEGEND:

CITY OF WINNIPEG HEC-RAS CROSS SECTION (2011 BATHYMETRIC & LIDAR SURVEY DATA)

	RUBY SITE	AUBREY SITE
25mm DIAMETER WELL (CLAY & TILL)	⊕	⊕
50mm DIAMETER WELL (BEDROCK)	⊕	⊠
VIBRATING WIRE PIEZOMETER		⊞
150mm DIAMETER PUMPING WELL (APPROXIMATE)		⊕

REVISION	BY	DATE
----	----	----

CLIENT: CITY OF WINNIPEG

Amec Foster Wheeler
Environment & Infrastructure
440 DOVERCOURT DRIVE
WINNIPEG, MANITOBA R3Y 1N4
PHONE: 204.488.2997 FAX:204.489.8261

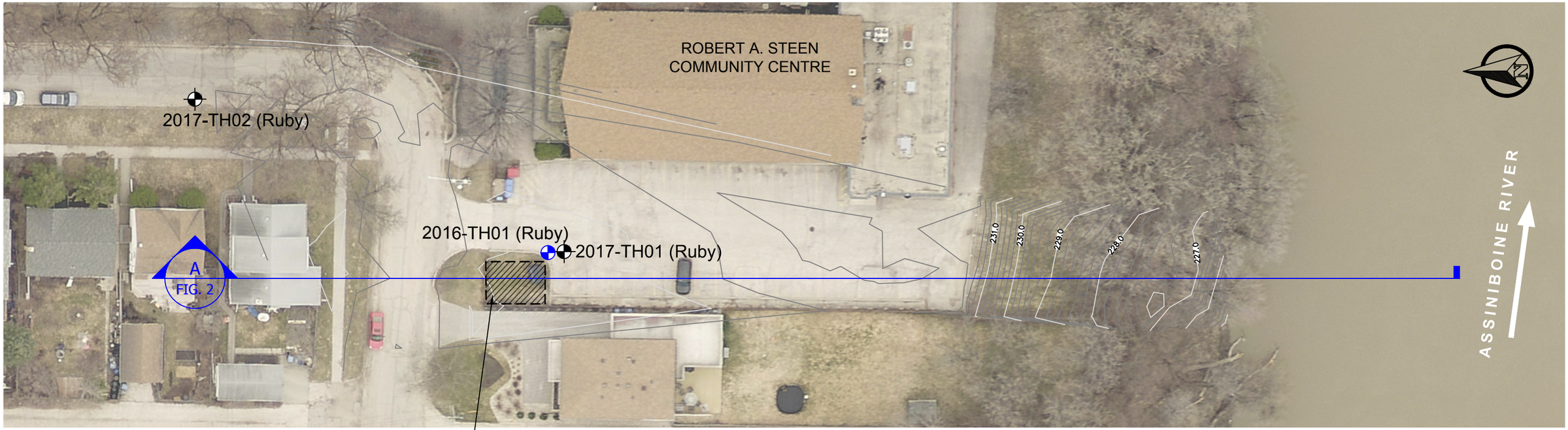
DWN BY: MD
CHK'D BY: WKW
DATUM: NAD83
PROJECTION: UTM Zone 14 U
SCALE: AS SHOWN

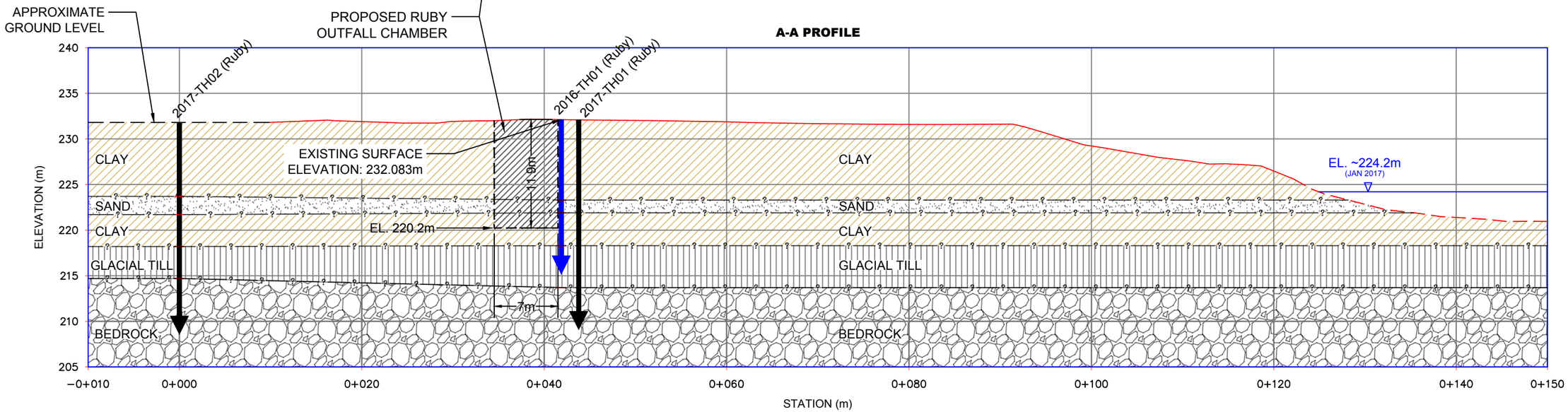
GEOTECHNICAL AND HYDROGEOLOGIC ASSESSMENTS RUBY AND AUBREY OUTFALL CHAMBERS UPGRADE WINNIPEG, MANITOBA

SITE AND TEST HOLE LOCATION PLAN

DATE: SEPTEMBER 2017
PROJECT NO: WX1793201
REV. NO.: A
FIGURE NO: FIGURE 1

P:\JOBS\17900'S\17930'S\WX1793201 – RUBY & AUBREY OUTFALL CHAMBER –\DRAWINGS\WX1793201.DWG





- IMAGE FROM http://winnipeg.ca/ppd/maps_aerial.stm

LEGEND:

- MMM PROFILE (05 MAY 2016 SURVEY)
- ESTIMATED CHANNEL PROFILE FROM HEC-RAS (2011 BATHYMETRIC & LIDAR SURVEY DATA)
- 25mm DIAMETER WELL (CLAY & TILL)
- 50mm DIAMETER WELL (BEDROCK)
- ESTIMATED SOIL LAYER —?—

REVISION	BY	DATE
----	----	----

CLIENT: CITY OF WINNIPEG

Amec Foster Wheeler
Environment & Infrastructure
440 DOVERCOURT DRIVE
WINNIPEG, MANITOBA R3Y 1N4
PHONE: 204.488.2997 FAX:204.489.8261

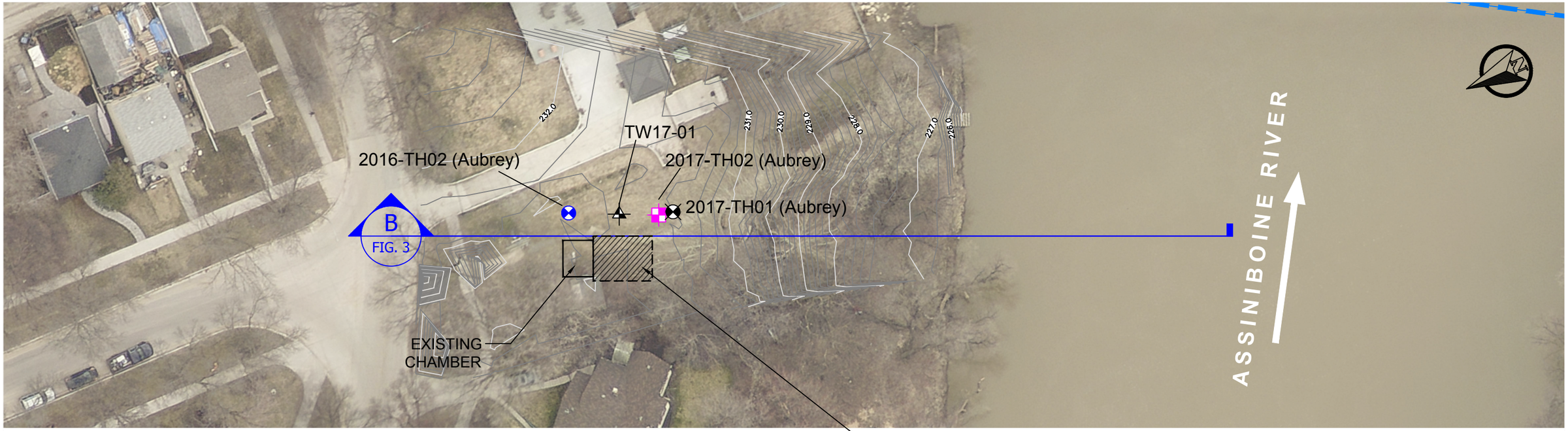
DWN BY:	MD
CHK'D BY:	WKW
DATUM:	NAD83
PROJECTION:	UTM Zone 14 U
SCALE:	AS SHOWN

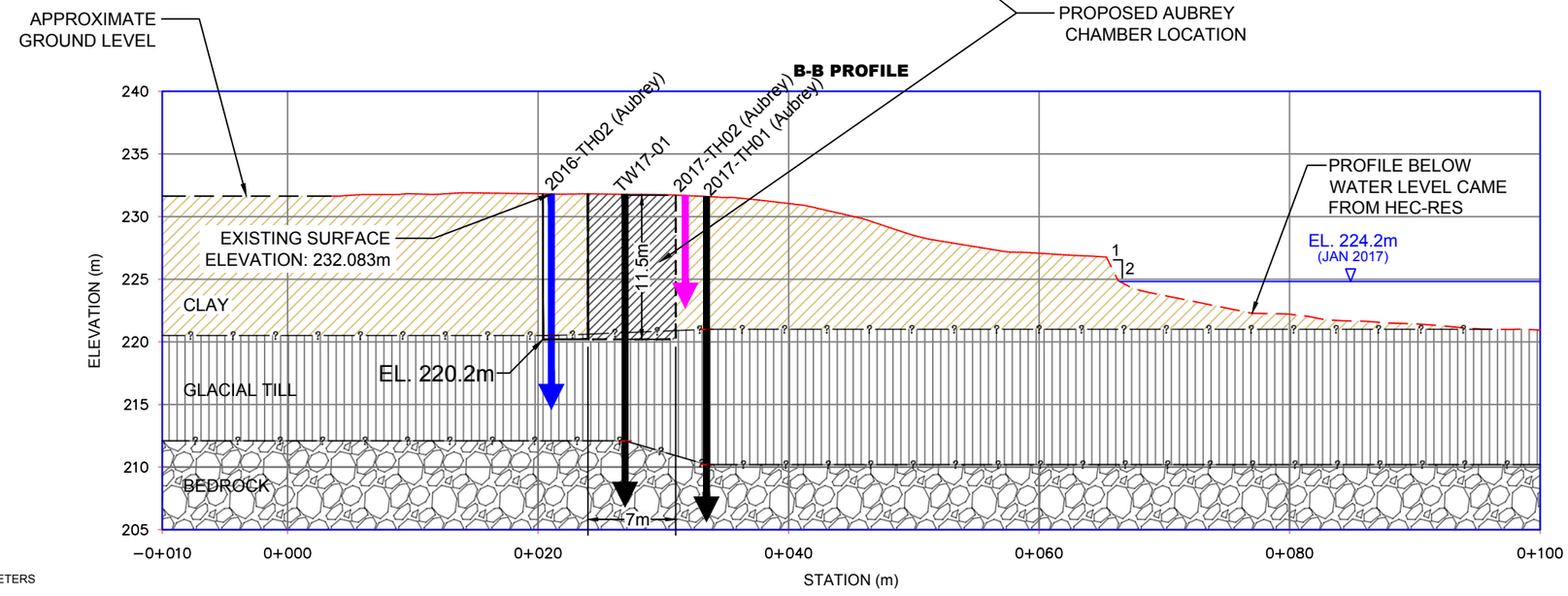
GEOTECHNICAL AND HYDROGEOLOGIC ASSESSMENTS RUBY AND AUBREY OUTFALL CHAMBERS UPGRADE WINNIPEG, MANITOBA

RIVERBANK PROFILE FOR THE PROPOSED RUBY SITE CHAMBER OUTFALL

DATE:	SEPTEMBER 2017
PROJECT NO:	WX1793201
REV. NO.:	A
FIGURE NO:	FIGURE 2

P:\JOBS\17900'S\17930'S\WX1793201 – RUBY & AUBREY OUTFALL CHAMBER –\DRAWINGS\WX1793201.DWG





- IMAGE FROM http://winnipeg.ca/ppd/maps_aerial.stm

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- MMM PROFILE (05 MAY 2016 SURVEY)
- ESTIMATED CHANNEL PROFILE FROM HEC-RAS (2011 BATHYMETRIC & LIDAR SURVEY DATA)
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- 50mm DIAMETER WELL (BEDROCK)
- VIBRATING WIRE PIEZOMETER
- 150mm DIAMETER PUMPING WELL (APPROXIMATE)
- ESTIMATED SOIL LAYER

REVISION	BY	DATE
----	----	----

CLIENT: CITY OF WINNIPEG

Amec Foster Wheeler
Environment & Infrastructure
440 DOVERCOURT DRIVE
WINNIPEG, MANITOBA R3Y 1N4
PHONE: 204.488.2997 FAX:204.489.8261

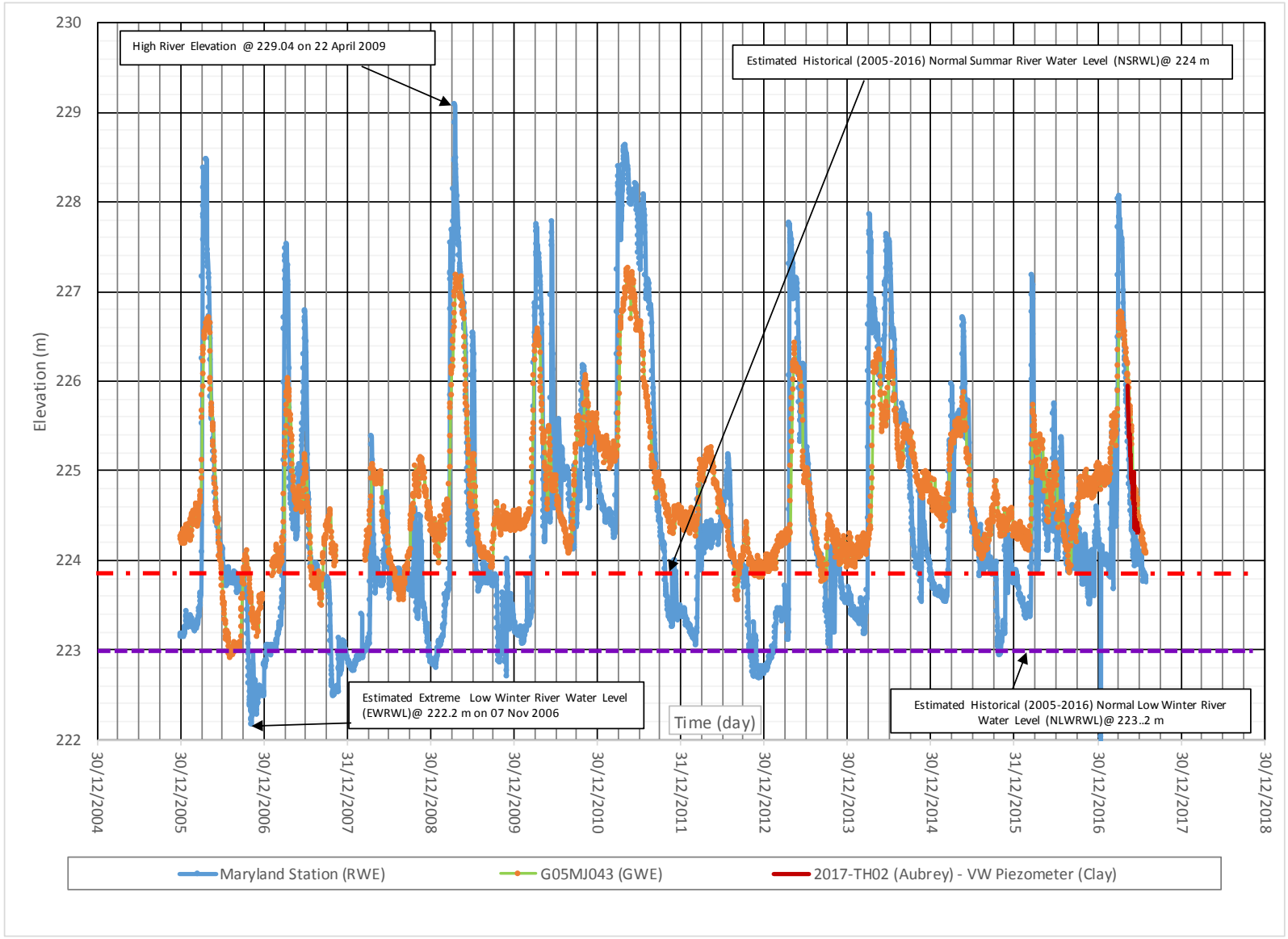
DWN BY:	MD
CHK'D BY:	WKW
DATUM:	NAD83
PROJECTION:	UTM Zone 14 U
SCALE:	AS SHOWN

GEOTECHNICAL AND HYDROGEOLOGIC ASSESSMENTS RUBY AND AUBREY OUTFALL CHAMBERS UPGRADE WINNIPEG, MANITOBA

RIVERBANK PROFILE FOR THE PROPOSED AUBREY SITE OUTFALL CHAMBER

DATE:	SEPTEMBER 2017
PROJECT NO:	WX1793201
REV. NO.:	A
FIGURE NO:	FIGURE 3

P:\JOBS\17900'S\17930'S\WX1793201 – RUBY & AUBREY OUTFALL CHAMBER –\DRAWINGS\WX1793201.DWG



amec foster wheeler

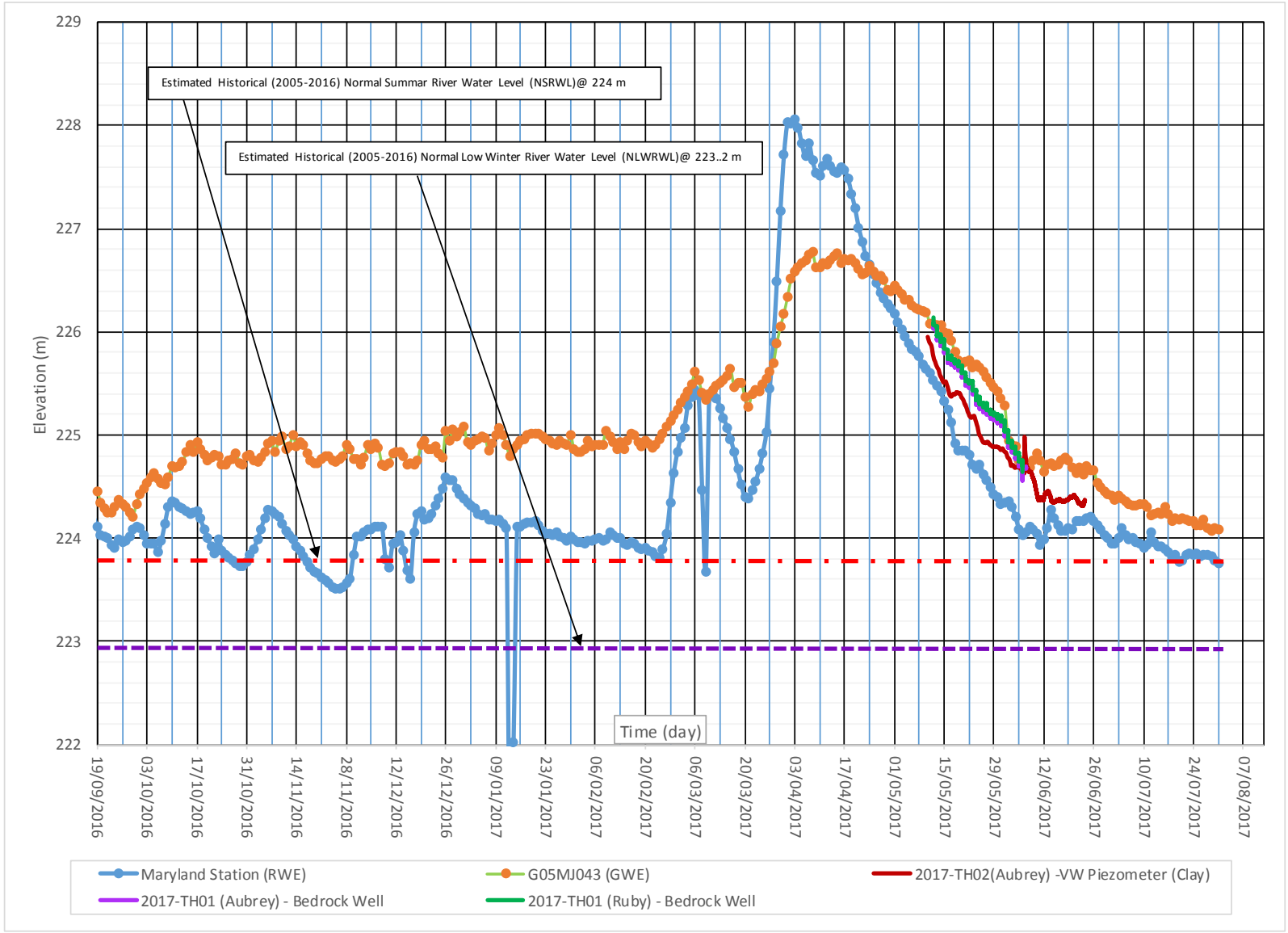
Client:

Winnipeg
City of Winnipeg

Proposed Ruby and Aubrey Outfall Gate Chamber Upgrades
980 & 1016 Palmerton Avenue,
Winnipeg, Manitoba

General Historical Assiniboine River Elevations, Groundwater Elevations and Porewater Pressures in Clay

Project No.:	WX1793201
Date:	Sept 2017
Scale:	As Shown
Drawn By:	WKW
Figure:	4



amec foster wheeler

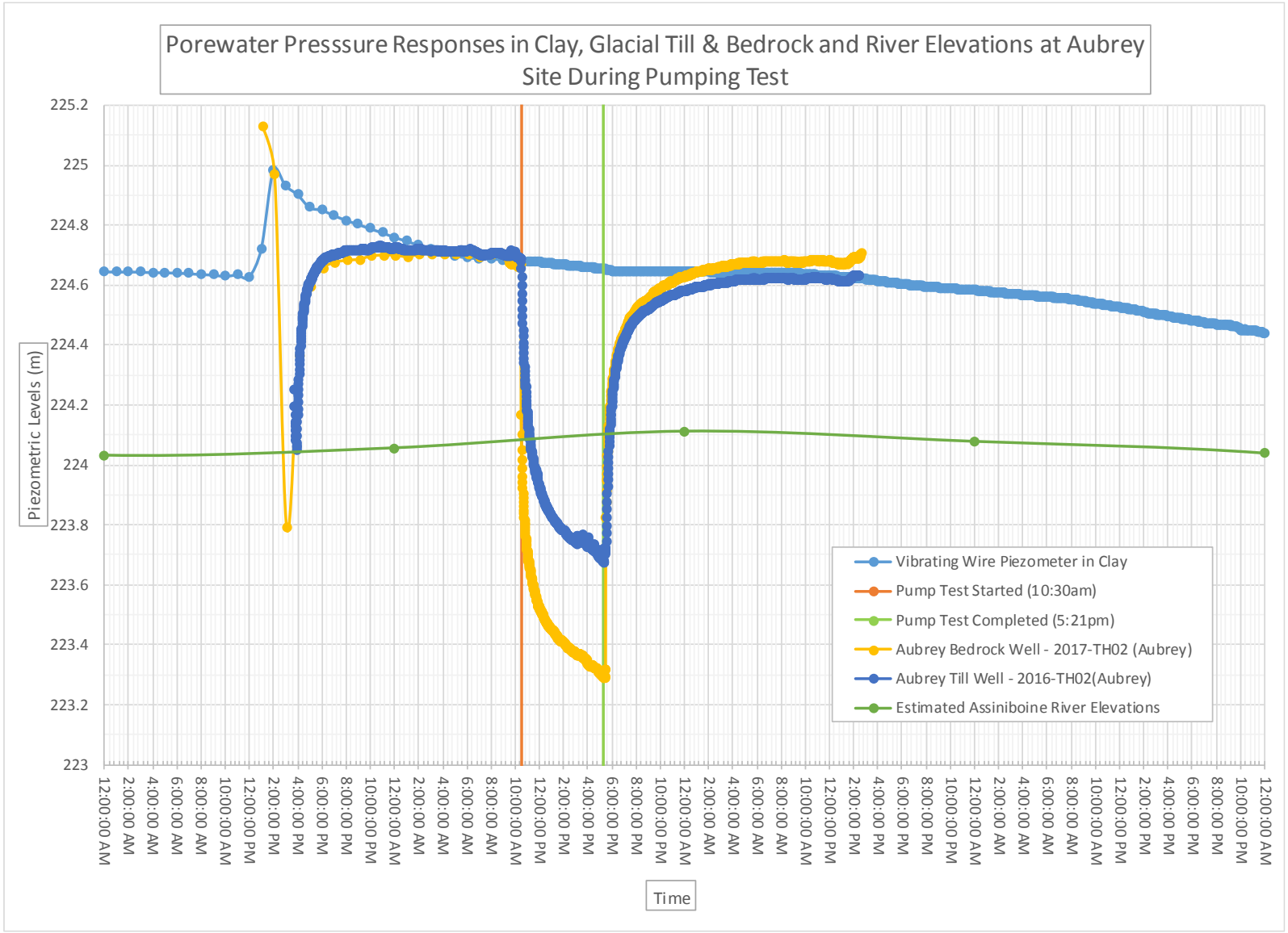
Client:

Winnipeg
City of Winnipeg

Proposed Ruby and Aubrey Outfall Gate Chamber Upgrades
980 & 1016 Palmerton Avenue,
Winnipeg, Manitoba

2016-2017 Assiniboine River Elevations, Groundwater Elevations and Porewater Pressures in Clay

Project No.:	WX1793201
Date:	Sept 2017
Scale:	As Shown
Drawn By:	WKW
Figure:	5



amec foster wheeler	**Client:** Winnipeg **City of Winnipeg**	**Proposed Ruby and Aubrey Outfall Gate Chamber Upgrades** **980 & 1016 Palmerton Avenue,** **Winnipeg, Manitoba** **Porewater Pressure Responses at Aubrey Site During Pumping Test**	Project No.:	WX1793201
			Date:	Sept 2017
			Scale:	As Shown
			Drawn By:	WKW
			Figure:	6

APPENDIX A

Ruby Site Soil Logs

- Explanation of Terms and Symbols
- Test Hole Log: 2016-TH01(Ruby)
- Test Hole Log: 2017-TH01(Ruby)
- Test Hole Log: 2017-TH02(Ruby)

EXPLANATION OF TERMS AND SYMBOLS

The terms and symbols used on the borehole logs to summarize the results of field investigation and subsequent laboratory testing are described in these pages.

It should be noted that materials, boundaries and conditions have been established only at the borehole locations at the time of investigation and are not necessarily representative of subsurface conditions elsewhere across the site.

TEST DATA

Data obtained during the field investigation and from laboratory testing are shown at the appropriate depth interval.

Abbreviations, graphic symbols, and relevant test method designations are as follows:

*C	Consolidation test	*ST	Swelling test
D_R	Relative density	TV	Torvane shear strength
*k	Permeability coefficient	VS	Vane shear strength
*MA	Mechanical grain size analysis	w	Natural Moisture Content (ASTM D2216)
	and hydrometer test	w_l	Liquid limit (ASTM D 423)
N	Standard Penetration Test (CSA A119.1-60)	w_p	Plastic Limit (ASTM D 424)
N_d	Dynamic cone penetration test	E_f	Unit strain at failure
NP	Non plastic soil	γ	Unit weight of soil or rock
pp	Pocket penetrometer strength	γ_d	Dry unit weight of soil or rock
*q	Triaxial compression test	ρ	Density of soil or rock
q_u	Unconfined compressive strength	ρ_d	Dry Density of soil or rock
*SB	Shearbox test	C_u	Undrained shear strength
SO_4	Concentration of water-soluble sulphate	→	Seepage
		▼	Observed water level

* The results of these tests are usually reported separately

Soils are classified and described according to their engineering properties and behaviour.

The soil of each stratum is described using the Unified Soil Classification System[1] modified slightly so that an inorganic clay of "medium plasticity" is recognized.

The modifying adjectives used to define the actual or estimated percentage range by weight of minor components are consistent with the Canadian Foundation Engineering Manual[2].

Relative Density and Consistency:

Cohesionless Soils

Relative Density	SPT (N) Value
Very Loose	0-4
Loose	4-10
Compact	10-30
Dense	30-50
Very Dense	>50

Cohesive Soils

Consistency	Undrained Shear Strength c_u (kPa)	Approximate SPT (N) Value
Very Soft	0-12	0-2
Soft	12-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

Standard Penetration Resistance ("N" value)
The number of blows by a 63.6kg hammer dropped 760 mm to drive a 50 mm diameter open sampler attached to "A" drill rods for a distance of 300 mm after an initial penetration of 150 mm.

[1] "Unified Soil Classification System", Technical Memorandum 36-357 prepared by Waterways Experiment Station, Vicksburg, Mississippi, Corps of Engineers, U.S. Army. Vol. 1 March 1953.

[2] "Canadian Foundation Engineering Manual", 3rd Edition, Canadian Geotechnical Society, 1992.

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISIONS			SYMBOLS: USCS	SYMBOLS: GRAPH	SYMBOLS: COLOUR	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75um)	GRAVELS MORE THAN HALF THE COARSE FRACTION LARGER THAN 4.75mm	CLEAN GRAVELS (TRACE OR NO FINES)	GW		RED	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	$C_u=D_{60}/D_{10}$ >4; $C_c=(D_{30})^2/(D_{10}xD_{60})$ = 1 to 3
			GP		RED	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS
		DIRTY GRAVELS (WITH SOME OR MORE FINES)	GM		YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR PI LESS THAN 4
			GC		YELLOW	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ATTERBERG LIMITS ABOVE "A" LINE AND PI MORE THAN 7
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SANDS (TRACE OR NO FINES)	SW		RED	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_u=D_{60}/D_{10}$ >6; $C_c=(D_{30})^2/(D_{10}xD_{60})$ = 1 to 3
			SP		RED	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS
		DIRTY SANDS (WITH SOME OR MORE FINES)	SM		YELLOW	SILTY SANDS, SAND-SILT MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR PI LESS THAN 4
			SC		YELLOW	CLAYEY SANDS, SAND-CLAY MIXTURES	ATTERBERG LIMITS ABOVE "A" LINE AND PI MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75um)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	W_L < 50%	ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (SEE BELOW)
		W_L > 50%	MH		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SAND OR SILTY SOILS	
	CLAYS ABOVE "A" LINE NEGLIGIBLE ORGANIC CONTENT	W_L < 30%	CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY OR SILTY CLAYS, LEAN CLAYS	
		30% < W_L < 50%	CI		GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS	
		W_L > 50%	CH		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	
	ORGANIC SILTS & CLAYS BELOW "A" LINE	W_L < 50%	OL		GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINES CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G. SF IS A MIXTURE OF SAND WITH SILT OR CLAY
		W_L > 50%	OH		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY	
HIGHLY ORGANIC SOILS			PT		ORANGE	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOUR OR ODOUR, AND OFTEN FIBROUS TEXTURE

SPECIAL SYMBOLS

LIMESTONE		OILSAND	
SANDSTONE		SHALE	
SILTSTONE		FILL (UNDIFFERENTIATED)	

SOIL COMPONENTS

FRACTION	U.S. STANDARD METRIC SIEVE SIZE		DEFINING RANGES OF PERCENT BY WEIGHT OF MINOR COMPONENTS	
GRAVEL	PASSING	RETAINED	PERCENT	DESCRIPTOR
COARSE	76mm	19mm		
FINE	19mm	4.75mm	35 - 50	AND
SAND				
COARSE	4.75mm	2.00mm	30 - 35	Y / EY
MEDIUM	2.00mm	425µm	10 - 20	SOME
FINE	425µm	75µm		
FINES (SILT OR CLAY BASED ON PLASTICITY)	75µm		1 - 10	TRACE

OVERSIZED MATERIAL

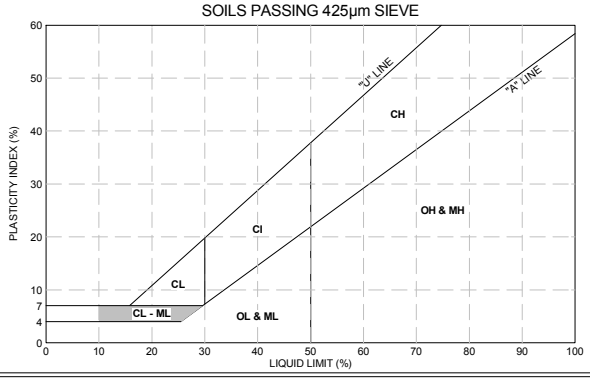
ROUNDED OR SUBROUNDED:

COBBLES 76mm to 200mm
BOULDERS > 200mm

NOT ROUNDED:

ROCK FRAGMENTS ? 76mm
ROCKS > 0.76 CUBIC METRE IN VOLUME

PLASTICITY CHART FOR SOILS PASSING 425µm SIEVE



NOTES:

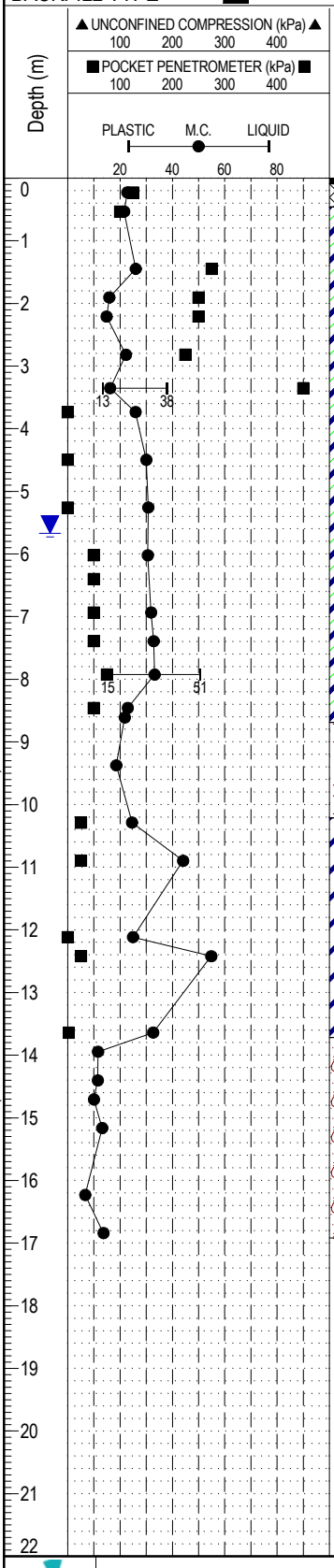
1. ALL SIEVE SIZES MENTIONED ARE U.S. STANDARD ASTM E.11.
2. COARSE GRAINED SOILS WITH TRACE TO SOME FINES GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS A WELL GRADED GRAVEL SAND MIXTURE WITH TRACE TO SOME CLAY.
3. DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

amec foster wheeler

PROJECT: Ruby & Aubrey Outfall Chambers	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2016-TH01 (Ruby)**
CLIENT: MMM Group Limited	DRILL TYPE: Renegade Track Rig	PROJECT NO: WX17932
UTM: N5526579.1 E631231.3	DRILL METHOD: 125mm SSA	ELEVATION: 232.08 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand



Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	WELL INSTALLATION	COMMENTS	ELEVATION (m)
0		ASPH	ASPHALT - Approximate 90mm thick		1				232
1		CI-CH	CLAY (FILL) - silty, some sand, trace gravel, medium to high plastic, moist, stiff, dark greyish brown		2				231
2			CLAY (ALLUVIAL) - silty, trace to some sand, medium to high plastic, moist, stiff, dark greyish brown mottled dark grey, occasional sand lenses - and sand, greyish brown below 1.8m - brown, occasional oxidized inclusions below 2.7m		3 4 5 6 7			Ground water level: - 6.4m below ground surface on 12/05/2016 - 5.7m below ground surface on 31/05/2016 Hydrometer Analysis Results @ "3.0m": Gravel= 0.0% Sand= 23.4% Silt= 46.8% Clay= 29.8%	230 229
3									
4		CI-CH	- trace to some sand, silty to and silt, very soft, very moist to wet, occasional to frequent silt pockets (~5mm thick) from 3.7 to 6.1m		8 9 10				228
5								Unconfined Compression Test: Sample 7 (3.0m - 3.6m) Max Stress: 270.6 kPa @ 8.7% strain M.C: 16.2% ..SPT: 1,1,2; Rec: full	227
6			- trace gravel, firm to stiff, dark greyish brown, frequent oxidized inclusions below 6.1m		11 12				226
7					13	3			225
8			- silty, some sand, moist, dark grey, occasional fine sand seams (<3mm thick), frequent oxide pockets (<2cm thick) below 7.3m - sandy, grey below 8.2m		14 15 16 17			Unconfined Compression Test: Sample 15 (7.6m - 8.2m) Max Stress: 97.7 kPa @ 5.8% strain M.C: 33.2%	224
9		SM	SAND - silty, poorly graded, fine grained, wet, compact, brown		18	14		..SPT: 4,7,7; Rec: full	223
10					19				222
11		CH	CLAY (ALLUVIAL) - silty, high plastic, very moist, soft to firm, dark grey, occasional sand inclusions, occasional silt and sulphate inclusions - trace to some gravel, occasional sand pockets (~5cm to 10cm dia.) below 11.1m		20	4		..SPT: 2,2,2; Rec: 230mm	221
12					21				220
13			- wet, very soft below 12.5m		22	5		..SPT: 3,2,3; Rec: 150mm	219
14		ML	SILT (TILL) - sandy, some gravel, trace clay, low plastic, wet, compact, light greyish brown - gravelly below 14.2m		23 24 25 26	27 12		..SPT: 2,15,12; Rec: 150mm ..SPT: 8,4,8; Rec: 230mm	218 217
15					27				
16					28	24		..SPT: 8,18,6; Rec: 50mm	216
17			AUGER REFUSAL AT 16.9m BELOW GRADE. Notes: - Seepage & sloughing observed at zones from 4.3m to 6.1m, from 8.5m to 10.2m and below 13.7m during and on completion of drilling. - Test hole remained open to 14.6m and water level at 6.4m below grade was observed prior to backfilling.\ - One 25mm diameter standpipe installed on completion of drilling.		29				215
18									214
19									213
20									212
21									211
22									

WX17932 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:52 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: KE	COMPLETION DEPTH: 16.9 m
REVIEWED BY: WKW	COMPLETION DATE: 12 May 2016
Figure No. A01	Page 1 of 1

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH01(RUBY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526577.2 E631231.4	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 232 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand

▲ UNCONFINED COMPRESSION (kPa) ▲ 100 200 300 400

■ POCKET PENETROMETER (kPa) ■ 100 200 300 400

PLASTIC M.C. LIQUID 20 40 60 80

Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
0		ASPH	ASPHALT - 50mm thick					- Overburden was drilled out and auger cuttings spun up, no samples were taken until Bedrock was encountered.	232
			CLAY - silty, high plastic, moist, firm to stiff (inferred), brown						
1									231
2									230
3									229
4									228
5									227
6									226
7		CH							225
8								- slight to moderate seepage was observed at 7.6m	224
9									223
10									222
11									221
12									220
13									219
14			SILT (TILL) - trace to some sand and gravel, low plastic, moist, compact to dense (inferred), tan-brown						218
15									217
16		ML	- suspected gravelly below 16.2m						216
17		LI	AUGER REFUSAL WAS ENCOUNTERED AT 16.9m BELOW GRADE ON SUSPECTED COBBLES OR BEDROCK. SWITCH TO CORING METHOD.		1			- significant seepage was observed at 16.5m	215
18		LI	LIMESTONE AND COBBLES - occasional limestone pieces ~50mm diameter, sub-angular		2				214
		CL			3				
					4				
19		LI	LIMESTONE (BEDROCK) - occasional to frequent fractures - orange to red below 18.3m		5				213
					6				
20			CLAY - silty, low plastic, moist, soft (inferred), red to orange					- RQD = 81%, from 19.4 to 19.8m	

WX1793201 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:56 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: AL	COMPLETION DEPTH: 22.9 m
REVIEWED BY: WKW	COMPLETION DATE: 10 May 2017
Figure No.	Page 1 of 2

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH01(RUBY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526577.2 E631231.4	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 232 m

SAMPLE TYPE: Shelby Tube | No Recovery | SPT (N) | Grab Sample | Split-Pen | Core

BACKFILL TYPE: Bentonite | Pea Gravel | Drill Cuttings | Grout | Slough | Sand

Depth (m)	▲ UNCONFINED COMPRESSION (kPa) ▲ 100 200 300 400 ■ POCKET PENETROMETER (kPa) ■ 100 200 300 400 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
20				- 100mm thick soft silty clay layer at 18.4m - occasional to frequent silty clay lenses to 18.6m		7			- RQD = 43%, weathered rock from 19.8 to 21.3m	212
21				LIMESTONE - frequent fractures from 18.9m to 19.3m						211
22			LI			8			- RQD = 48%, weathered rock from 21.3 to 22.9m	210
23				- 75mm thick red silty clay layer at 22.4m						209
24				TEST HOLE TERMINATED AT 22.9m BELOW GRADE. NOTES: - Moderate sloughing was encountered below 7.6m below grade. - Slight to moderate seepage observed below 7.6m and significant seepage was observed below 16.5m during drilling. - Test hole remained open to 22.9m below grade after completion of coring. - A 50mm diameter standpipe was installed in the bedrock. - Protected with a flush mount casing and well capped with a J-Plug.						208
25										207
26										206
27										205
28										204
29										203
30										202
31										201
32										200
33										199
34										198
35										197
36										196
37										195
38										194
39										193
40										

WX1793201 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:56 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: AL	COMPLETION DEPTH: 22.9 m
REVIEWED BY: WKW	COMPLETION DATE: 10 May 2017
Figure No.	

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH02(RUBY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526620.8 E631249.8	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 231.48 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand

Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
0		ASPH	ASPHALT - 25mm thick		1				231
		CONC	CONCRETE - 100mm thick		2				
1		GR CH	GRAVEL (FILL) - sandy, poorly graded, medium to coarse grained, damp, compact (inferred), light greyish brown		3				
			CLAY (FILL) - silty, trace sand, high plastic, moist, firm, grey to dark grey, occasional organic, silt and rootlets inclusions		4				230
2			- stiff below 0.8m		5				
			- very stiff, brown, occasional to frequent silt inclusions below 1.5m		6				229
3					7				
			CLAY (ALLUVIAL) - silty, medium to high plastic, moist, stiff, greyish brown, occasional light grey silt lenses ~2mm thick		8			- Sample 8 @ 3.0m: Unconfined Compressive Strength = 131.8 kPa Bulk Density = 2007 kg/m^3	228
4			- occasional silt inclusions below 2.6m						
		CI-CH	- firm to stiff, brown, frequent sand inclusions, occasional rootlets at 3.7m		9				227
5			- firm below 4.6m						
									226
6					10				
					11			- Sample 11 @ 6.1m: Unconfined Compressive Strength = 108.1 kPa Bulk Density = 1980 kg/m^3	225
					12				
7			- occasional to frequent very moist to wet silt and sand pockets ~5mm diameter at 6.9m						224
			- occasional sand inclusions below 7.6m		13	15		- shelby tube wet, suspected slight seepage at 6.7m	
8			SAND - poorly graded, fine to medium grained, compact, wet, greyish brown						223
		SP	- trace to some silt and clay below 8.2m		14				
9			- no silt or clay at 8.8m		15	13			222
			- medium grained below 9.1m						
10			- some gravel ~20mm diameter, angular, medium to coarse grained below 9.5m		16				
			CLAY (LACUSTRINE) - silty, high plastic, very moist, soft to firm, dark grey, occasional sand and sulphate inclusions		17				221
11			- soft, no sand inclusions below 10.5m		18	9			
		CH							220
12					19				
					20			Hydrometer Analysis Results @ "12.0m": Gravel= 1.5% Sand= 14.4% Silt= 24.0% Clay= 60.0%	219
13					21				
		ML	SILT (TILL) - sandy, some clay, trace gravel, low plastic, very moist, light greyish brown						218
14			SAND (TILL) - some silt to silty, some gravel to gravelly, mosit, dense, light greyish brown, sub-angular gravel (<25mm dia.)		22	50			
			- gravelly, very dense, occasional limestone inclusions below 14.5m		23				217
15		SP-SM	- dense, occasional to frequent very moist sand inclusions below 15.7m		24	64			
			- cobbles and boulders below 15.9m		25				
					26	49		Hydrometer Analysis Results @ "15.1m": Gravel= 26.2% Sand= 44.1% Silt= 23.2% Clay= 6.6%	216
16					27				
					28	87/350			215
17			BEDROCK (LIMESTONE)		29				
		LI	- highly fractured below 17.1m		30				
18					31			- samples washed off augers, no sample recovery at 16.0m - Auger refusal @ 16.8m - samples washed off augers, no sample recovery at 16.8m	214
		CL-ML	CLAY - and silt, trace gravel, low to non-plastic, moist, grey,						
19			- damp, reddish orange below 18.3m		32			- RQD = 70.0%, moderately weathered rock at 16.8m - RQD = 7.7%, completely weathered rock at 17.1m	213
		LI	LIMESTONE- highly fractured, 40mm thick silt seam at 18.9m						
20			- occasional to frequent fractures, occasional oxidized					- RQD = 52.6%, moderately	212

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH02(RUBY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526620.8 E631249.8	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 231.48 m

SAMPLE TYPE: Shelby Tube | No Recovery | SPT (N) | Grab Sample | Split-Pen | Core

BACKFILL TYPE: Bentonite | Pea Gravel | Drill Cuttings | Grout | Slough | Sand

Depth (m)	▲ UNCONFINED COMPRESSION (kPa) ▲ 100 200 300 400 ■ POCKET PENETROMETER (kPa) ■ 100 200 300 400 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
20				inclusions within fractures below 19.7m		33			weathered rock at 19.7m	211
21				- 25mm thick light greyish silt lens at 21.0m - occasional fractures below 21.0m		34			- RQD = 78%, moderately weathered rock from 21.0 to 21.9m	210
22			LI	- 25mm thick reddish brown silt seam at 22.2m		35			- RQD = 79% from 21.9 to 22.9m	209
23				TEST HOLE TERMINATED AT 22.9m BELOW GRADE. NOTES: - Significant sloughing and seepage was encountered below 7.9m below grade. - Test hole remained open to 19.8m below grade after completion of coring. - A 50mm diameter standpipe was installed in the bedrock. - Protected with a flush mount casing and well capped with a J-Plug.						208
24										207
25										206
26										205
27										204
28										203
29										202
30										201
31										200
32										199
33										198
34										197
35										196
36										195
37										194
38										193
39										192
40										

WX1793201 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:56 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: AL	COMPLETION DEPTH: 22.9 m
REVIEWED BY: WKW	COMPLETION DATE: 12 May 2017
Figure No.	Page 2 of 2

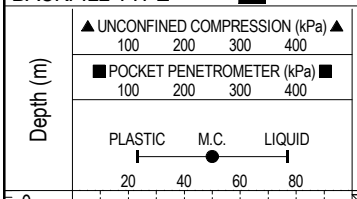
Aubrey Site Soil Logs

- Test Hole Log: 2016-TH02(Aubrey)
- Test Hole Log: 2017-TH01(Aubrey)
- Test Hole Log: 2017-TH02(Aubrey)

PROJECT: Ruby & Aubrey Outfall Chambers	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2016-TH02 (Aubrey)**
CLIENT: MMM Group Limited	DRILL TYPE: Renegade Track Rig	PROJECT NO: WX17932
UTM: N5526584.2 E631082.8	DRILL METHOD: 125mm SSA	ELEVATION: 231.81 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand



Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	WELL INSTALLATION	COMMENTS	ELEVATION (m)
0		OH CH	ORGANIC CLAY (TOPSOIL) - silty, trace sand, high plastic, moist		1				231
1			CLAY (FILL) - silty, trace sand, trace gravel, high plastic, moist, stiff, dark greyish brown mottled light brown, occasional oxidized inclusions		2				230
2			CLAY (ALLUVIAL) - silty, trace sand, high plastic, moist, stiff, dark greyish brown, occasional silt inclusions, trace organics, occasional black stains (5mm to 10mm thick) - brown, silty to and silt, firm to soft below 2.0m - silty, sandy and sand, medium plastic, moist, very stiff below 3.0m - high plastic, dark greyish brown, occasional silt lenses (1mm to 2mm thick), occasional oxidized inclusions below 3.7m		3			Ground water level: - 8.8m below ground surface on 12/05/2016 - 7.2m below ground surface on 31/05/2016	229
3					4				228
4					5				227
5					6				226
6		CI-CH	- medium to high plastic, moist, stiff, dark greyish brown, some oxidation below 5.0m - wet sand lenses (~1mm to 5mm thick) at 6.7m		7				225
7					8				224
8					9				223
9					10				222
10					11				221
11					12	10		..SPT: 4,4,6; Rec: 410mm	220
12					13				219
13					14				218
14					15				217
15					16				216
16					17				215
17					18	5		Unconfined Compression Test: Sample 14 (7.6m - 8.2m) Max Stress: 101.0 kPa @ 9.8% strain M.C: 33.2% Hydrometer Analysis Results @ "9.1m": Gravel= 0.0% Sand= 5.8% Silt= 59.7% Clay= 34.5%	214
18					19				213
19					20				212
20					21				211
21			- some sand, high plastic, moist to very moist, firm, dark grey, frequent light grey till inclusions (1 to 5 cm dia) below 10.7m						210
22			SILT (TILL) - clayey, some sand, trace gravel, low plastic, compact, very moist to wet, light brown - some clay, some gravel to gravelly, wet below 12.2m		22	20		..SPT: 2,2,3; Rec: full Unconfined Compression Test: Sample 20 (10.6m - 11.2m) Max Stress: 57.2 kPa @ 6.3% strain M.C: 33.3%	
					23				
					24	18		..SPT: 2,9,11; Rec: 300mm	
					25				
					26	16		..SPT: 9,9,9; Rec: 50mm ..SPT: 5,9,7; Rec: 100mm	
		ML	- gravelly, wet, light greyish brown, occasional sand lenses below 14.5m		27	23		..SPT: 10,12,11; Rec: 50mm	
					28	8		..SPT: 5,5,3; Rec: 50mm	
					29			..SPT: 10/50mm	
			AUGER REFUSAL AT 17.2m BELOW GRADE. Notes: - Seepage & sloughing observed below 11.3 m on completion of drilling. - Seepage observed at the sand lenses at 6.7 m during drilling. - Test hole remained open to 17.2m and water level at 8.8m below grade was observed prior to backfilling. - One 25mm diameter standpipe installed on completion of drilling.						

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: KE	COMPLETION DEPTH: 17.2 m
REVIEWED BY: WKW	COMPLETION DATE: 12 May 2016
Figure No. A02	Page 1 of 1

WX17932 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:52 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH01(AUBREY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526572.8 E631077.9	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 231.53 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand

▲ UNCONFINED COMPRESSION (kPa) ▲ 100 200 300 400

■ POCKET PENETROMETER (kPa) ■ 100 200 300 400

PLASTIC M.C. LIQUID 20 40 60 80

Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
0			OVERBURDEN DRILLED OUT TO 6.1m, SOIL SAMPLING TO BEGIN FROM THIS POINT.						231
1									230
2									229
3									228
4									227
5									226
6			CLAY - silty, high plastic, moist, stiff, greyish brown, occasional silt inclusions		1				225
7									224
8		CH	- and silt, some fine grained sand, very moist, very soft, mottled grey and brown below 7.6m - grey, occasional black organic staining below 8.5m		2				223
9			- firm, grey to dark grey, occasional silt lenses ~2mm thick below 9.1m		3				222
10									221
11			SILT (TILL) - gravelly, some sand, trace clay, low plastic, moist to very moist, compact (inferred), dark grey - sandy, compact to dense (inferred), grey below 11.3m		4				220
12					5				219
13									218
14			- wet below 13.7m		6				217
15		ML			7				216
16			- occasional gravel limestone pieces ~50mm diameter, angular below 15.2m - gravelly and sandy below 16.2m						215
17					8				214
18									213
19					9			- suspected samples may have washed off during drilling.	212
20					10				

WX1793201 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:55 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: AL	COMPLETION DEPTH: 25.9 m
REVIEWED BY: WKW	COMPLETION DATE: 9 May 2017
Figure No.	Page 1 of 2

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH01(AUBREY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526572.8 E631077.9	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 231.53 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand

▲ UNCONFINED COMPRESSION (kPa) ▲ 100 200 300 400

■ POCKET PENETROMETER (kPa) ■ 100 200 300 400

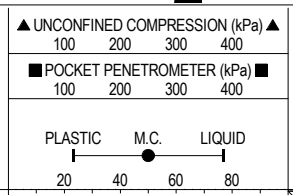
PLASTIC M.C. LIQUID 20 40 60 80

Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
20		ML							211
21		BR	- harder drilling, frequent limestone pieces below 20.7m AUGER REFUSAL ON SUSPECTED BEDROCK OR COBBLES AT 21.0m		11 12			- switch to coring from solid stem augers at 21.0m	210
22		LI	BEDROCK AND COBBLES LIMESTONE - tan to light grey, occasional to frequent oxidation		13			- suspected silty and fine grained sand, possibly washed away, no sample from 22.0m to 22.9m	209
23		CL	CLAY - silty, trace sand and gravel, low plastic, moist, stiff, greysih brown		14				208
24		LI	LIMESTONE		15				207
25		CL	- occasional clay seam ~10mm thick at 24.5m CLAY - silty, some sand to sandy, low plastic, moist to very moist, firm, grey		16				206
26			- sandy, increased silt content, wet, greyish brown TEST HOLE TERMINATED AT 25.9m BELOW GRADE.						205
27			NOTES: - Moderate to significant sloughing was encountered below 10.5m below grade.						204
28			- Significant seepage was observed from 13.7m during drilling.						203
29			- Test hole remained open to 21.6m below grade after completion of coring.						202
30			- A 50mm diameter standpipe was installed in the bedrock.						201
31			- Protected with a flush mount casing and well capped with a J-Plug.						200
32									199
33									198
34									197
35									196
36									195
37									194
38									193
39									192
40									

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH02(AUBREY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526574.5 E631078.3	DRILL METHOD: 125mm Solid Stem Augers	ELEVATION: 231.57 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand



Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	COMMENTS	ELEVATION (m)
0		OL	TOPSOIL (GRASS) - 25mm thick		1			231
1		CH	CLAY (FILL) - silty, trace sand, high plastic, moist, stiff, greyish brown, occasional organic clay inclusions and rootlets		2			
2			CLAY (ALLUVIAL) - silty, trace sand, high plastic, moist, stiff, brown - brown to dark brown occasional fine silt lenses ~1mm thick below 1.5m - very stiff below 2.1m - brown, occasional oxidation and sulphate inclusions below 3.1m - increased silt content from 3.7m to 5.2m		3			230
3					4			229
4					5			228
5		CH	- firm, no oxidation and sulphate inclusions below 4.6m		6			227
6			- stiff below 6.1m		7			226
7			- soft to firm below 6.7m		8			225
8					9 10 11			224 223
9			- very moist to moist, very soft, occasional oxidation inclusions below 8.4m - firm, grey to dark grey below 8.5m		12			222
10			TEST HOLE TERMINATED AT 9.1m BELOW GRADE. NOTES: - Slight sloughing was encountered below 8.2m below grade. - Moderate seepage was observed from 8.4m during drilling. - Test hole remained open to 9.0m below grade after completion of drilling. - Water level was measured to 8.2m below grade after completion of drilling. - A single Vibrating Wire (S/N: VW43218) was installed to a depth of 8.8m below grade and fully grouted. - Protected with an above ground steel casing.					221
11								220
12								219
13								218
14								217
15								216
16								215
17								214
18								213
19								212
20								

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: AL	COMPLETION DEPTH: 9.1 m
REVIEWED BY: WKW	COMPLETION DATE: 9 May 2017
Figure No.	Page 1 of 1

APPENDIX B

Hydrogeologic Assessment Report

City of Winnipeg
Ruby and Aubrey Street Outfall Upgrade
Hydrogeologic Assessment Report

Prepared by: W.L. Gibbons & Associates Inc.
64 St. Andrew Road
Winnipeg, MB R2M 3H6

August, 2017

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1.0 Introduction

W.L. Gibbons & Associates Inc. (WLG) was retained by AMEC Foster Wheeler (AFW) to provide hydrogeologic services in association with the City of Winnipeg Aubrey Street Outfall Gate Chamber Project (Figures 1 and 2). The purpose of this work program was to undertake investigations of the hydrogeologic conditions beneath the Aubrey site so that decisions could be made concerning the groundwater control and depressurization requirements needed during the proposed construction of the upgrades to the outfall facilities. The work program undertaken was considered the minimum needed to obtain scoping level hydrogeologic information on the Aubrey site. At a meeting on August 2, 2017 with City of Winnipeg and AFW representatives, the decision was made to proceed with the Ruby Street upgrades in the winter of 2017/18 and the Aubrey Street upgrades in the winter of 2018/19. The scope of work for the hydrogeologic assessment was expanded to include the Ruby Street upgrades as well.

Based on information provided by AFW (AFW report, 2016), it is understood that the upgrades at both sites will require the depressurization of the bedrock groundwater to an elevation of 219.2 meters.

1.0 Background

It is understood, based on information provided by AMEC Foster Wheeler (AFW) that initial work by the contractor for the Ruby Street upgrades discovered that the bedrock conditions varied substantially from what could be reasonably assumed from the available published information on the hydrogeology of the area. This initial work by the contractor identified issues that will need to be addressed before the upgrades can proceed including:

- Aquifer Transmissivity
- Fresh/Brackish Groundwater Interface
- Disposal of the Pumped Water
- Third Party Impacts
- River Water Intrusion
- Base Heave/Piping During Construction

The scope of work developed for this initial phase of the hydrogeologic investigation was designed to obtain additional information primarily relative to the aquifer transmissivity, in addition to some desk top level information on the brackish/saline groundwater interface, and potential third party impacts of pumping. Additional more comprehensive investigations would be required in future to more fully address these issues, as well as the other issues identified at these sites.

2.0 Regional Setting

In general, the stratigraphy in the area of the Ruby and Aubrey site consists of alluvial clays to a depth of 11.3 to 13.7 m (37.1 to 44.9 ft, per AFW, 2016) followed by glacial silt till to the top of the bedrock sequence at a depth of approximately 18.6 m (61.0 ft, per current test hole TW 17-01). Thin sand layers and lenses are present within the alluvial clays that are water bearing and may result in some seepage into the excavation. Based on past experience, this seepage can typically be managed with standard construction dewatering techniques. As such, this investigation was primarily focussed on the potential effects of groundwater within the underlying carbonate bedrock aquifer.

The overburden stratigraphy is underlain by an extensive regional fractured bedrock aquifer consisting of limestones and dolomites of the Fort Garry Member of the Red River Formation. The upper portion of this bedrock is highly fractured and forms an extensive aquifer referred to as the Carbonate Aquifer which underlies the City of Winnipeg. Published information (Render, 1970 and Baracos et al, 1983) indicate that the regional transmissivity of this aquifer typically ranges from 1.4×10^{-3} to 7.1×10^{-3} m^2/s (8,100 to 41,000 Igpd/ft). However, it is known that transmissivities can vary substantially over very short distances depending on the degree and interconnectivity of the fracturing.

Groundwater levels beneath the City of Winnipeg have been rising since the late 1960's and early 1970's due to a decline in the consumptive use of groundwater from the aquifer. In the late 1800's, prior to the significant use of groundwater, the potentiometric surface (ie: groundwater pressure) was estimated to be from 0.3 to 1.0 m (1 to 3 ft) above grade in the northwest part of the city and 3.0 to 6.0 m (9.8 to 19.7 ft) below grade in the downtown area. Over time, the consumptive use of groundwater for industrial, commercial and geothermal purposes developed which resulted in the formation of a drawdown cone which extended to a depth of 21 to 24 m (68.9 to 78.7 ft) below grade at its deepest point. Since the late 1960's to 1970's, the consumptive use of groundwater has decreased substantially due to the loss of several major industrial users and the conversion of most geothermal systems to non-consumptive use due primarily to the costs associated with the city sewer discharge levies. It is important to note that significant portions of the city were built when groundwater levels were depressed. With the rise of groundwater levels, seepage to deep foundations has been occurring, and groundwater has now become a significant issue for any deep excavation within the city. Figure 3 provides a plot of the rise in groundwater levels across the city for the period 1970 to 2009.

Figure 3 provides a chart of groundwater levels over time as recorded in provincial monitoring station MJ-043, located approximately 1 mile east of the Aubrey site. The overall trend has been for rising groundwater levels since the early 1970's. Of significance is the significant change in the annual variation in water levels that occurred in approximately 2005. Prior to 2005, there was an annual decline in water levels every summer associated with the operation of a geothermal cooling system near to this monitoring station. Subsequent to 2005, it is very clear that this geothermal system is no longer consumptively pumping groundwater and as a result there has been an approximately 2.0 m (6.6 ft) rise in groundwater levels in the area of that monitoring station. The status of that geothermal system is unknown but the trend in the city is for

the conversion of these former consumptive geothermal systems to either non-consumptive systems, or replacement with mechanical systems. The primary impetus for the conversion of these geothermal systems has been the increasing cost of the city sewer discharge levy. It is also important to note that the use of groundwater for heating and cooling in the city has been increasing substantially. However, few if any of these systems are designed to consumptively use groundwater. If some of these systems were converted to consumptive use, it would be possible to lower groundwater levels and alleviate the groundwater issues associated with deep excavations and existing deep foundations.

Figure 4 provides a plot of the rise in bedrock groundwater levels that has occurred in the period from 1970 to 2009. The rise in groundwater levels has been up to 6 meters with the greatest rise occurring in the downtown area and to the east (the former center of the pre-1970's drawdown cone).

Water quality within the Carbonate Aquifer beneath the City of Winnipeg varies from fresh (Total Dissolved Solids (TDS) <1,000 mg/l) to brackish (TDS – 1,000 to 10,000 mg/l, Figure 5). In general, the water is fresh east of the Red River, and brackish west of the river. In the Aubrey site area, the published regional information indicates that the water is slightly brackish (TDS = 1,000 to 1,500 mg/l) with the TDS concentrations increasing towards the south, and declining to the north.

3.0 Aubrey Site Investigation

An initial hydrogeologic investigation was undertaken by WLG at the Aubrey site to obtain site specific information on the hydrogeologic conditions, and specifically to obtain estimates of the transmissivity of the aquifer at this site.

Specific details of the investigations completed are as follows:

- Prior to the start of drilling, AFW obtained underground utility clearances for the area and copies were provided to WLG.
- WLG verified with the provincial Water Use Licensing Section that the Groundwater Exploration Permit (GEP) originally issued to the city as part of the Ruby site work was still valid for the proposed investigation at the Aubrey site. A copy of the GEP is included in Appendix A.
- AFW personnel were responsible for the installation of three 50 mm (2 in) diameter monitoring wells as follows: a bedrock monitoring well at the Aubrey site, a bedrock monitoring well at the Ruby site (proposed new gate chamber), and a bedrock monitoring well on Ruby Street adjacent to the existing gate chamber. Copies of the test hole logs associated with the new and existing monitoring wells at the two sites are included in Appendix B.
- WLG was responsible for the installation of a 150 mm (6 in) diameter test well, and the completion of the associated pumping test.

3.1 Test Well TW 17-01 Installation

Test well TW 17-01 was drilled at the Aubrey site (Figure 2) on June 6, 2017. A copy of the Driller's Report outlining the stratigraphy encountered and the final well construction details are included in Appendix B. The stratigraphy consists of 10.7 m (35.1 ft) of clay followed by 1.5 m (4.9 ft) of glacial till. From a depth of 12.2 m 18.9 m (40.0 to 62.0 ft), a transition zone from the overlying till to the underlying limestone bedrock was encountered. This transition zone consisted of a complex mixture of till, sand and gravel with limestone bedrock pieces. The percentage of broken limestone increased with depth. The transition zone did not produce a significant volume of water during the drilling process which suggested that the permeability of these materials was low. Limestone bedrock was encountered below a depth of 18.9 m (62.0 ft). Red shale interbeds were encountered within the limestone at various depths to the maximum depth of drilling of 25.0 m (82.0 ft). Fractures were noted at various depths in the limestone and the test hole began producing water as soon as the limestone was encountered. The casing was advanced through the transition zone into the competent bedrock at a depth of 19.5 m (64.0 ft).

3.2 Aquifer Pumping Test

Prior to the start of the aquifer pumping test, approvals were received from the city to discharge the water to the WWS manhole located on the grassed area east of the

driveway. As part of the test set-up, the manhole in the driveway was sealed using polyethylene sheeting and sand bags. A copy of the approvals documentation is included in Appendix A.

The pumping test was completed on June 7, 2017 on test well TW 17-01. The test consisted of the pumping of the test well at an average rate of 7.2 lps (95 Igpm) with the discharge directed to designated WWS manhole. In preparation for the pumping test, digital water level transducers were installed in the on-site monitoring wells Till MW (AFW – TH01 Aubrey) and Bedrock MW (AFW-TH01 Aubrey). Digital transducers were also installed in monitoring wells at the proposed Ruby site (Till MW (AFW – TH01 (Ruby) and TH01 (Ruby)) and the existing Ruby site (Bedrock MW (AFW – TH02 (Ruby)). The transducers in the bedrock monitoring wells at the Aubrey and proposed Ruby site were installed on May 12, 2017 to obtain information on the longer term water level trend. The remaining transducers were installed just prior to the pumping test. Plots of the recorded changes in groundwater levels are included in Appendix C, with a plot of the recorded changes in test well TW 17-01 made during the test.

Based on the plots of the recorded changes in groundwater level in Appendix C, the following is noted:

- During the period from May 12 to June 6, 2017, groundwater levels at both bedrock monitoring wells declined by approximately 1.5 m (4.9 ft). This coincided with an observed decline in Assiniboine River water levels over the same period which suggests some degree of hydraulic connectivity between the aquifer and the river. On June 8, 2017, the river level was surveyed relative to the groundwater level in the Aubrey bedrock monitoring well. On that date, the river level was 7.5 m (24.6 ft) below the grade at the monitoring well and the coinciding groundwater level was 6.8 m (22.3 ft) below grade. The results indicate that groundwater levels were approximately 0.7 m (2.3 ft) above the river levels and that the tendency would be for groundwater to flow to the river under natural conditions if a hydraulic connection exists.
- The pumping of test well TW 17-01 at 7.2 lps (95 Igpm) induced a drawdown of approximately 2.1 m (6.9 ft) in groundwater levels in that well.
- The 150 mm (6 in) diameter test well TW 17-01 has a specific capacity of 0.95 lps/m of drawdown (14.3 Igpm/ft). Assuming a pump installed at the base of the casing (19.5 m/64.0 ft) and a maximum drawdown of 3 m (9.8 ft) above the pump, the indicated well capacity is on the order of 33.6 lps (450 Igpm). Note: The maximum sized pump that can be installed in a 150 mm (6 in) diameter well is typically limited to a pumping rate of approximately 11.4 Lps (150 Igpm). A larger diameter well would be required to accommodate a larger pump needed to pump at this maximum well capacity.
- The pumping of the test well induced a drawdown of approximately 1.4 m (4.6 ft) in the Aubrey bedrock monitoring well at a distance of 6 m (19.7 ft) from the test well. Within the Aubrey till monitoring well at a distance of 6.5 m (21.3 ft), the drawdown was 0.96 m (3.1 ft) indicating a strong hydraulic connectivity in this

location between the bedrock aquifer and the tills. Full recovery of groundwater levels was achieved 10 hours after the cessation of pumping.

- At the proposed Ruby site, a distance of approximately 150 m (492 ft) from the test well, a drawdown in bedrock groundwater levels of 0.94 m (3.1 ft) was recorded, suggesting that the pumping of groundwater induces a relatively flat drawdown cone, typical of higher transmissivity aquifers and indicative of a strong hydraulic connection between the two sites. Within the till monitoring well at the Ruby site, no response to pumping was detected, suggesting that the hydraulic connection between the bedrock aquifer and the till is weak to non-existent at the Ruby Site.
- At the existing Ruby site, a distance of approximately 170 m (558 ft) from the test well, drawdown in bedrock groundwater levels of 0.66 m (2.2 ft) was recorded. These results also suggest that the pumping of groundwater induces a relatively flat drawdown cone, typical of higher transmissivity aquifers and indicative of a strong hydraulic connection between the two sites.

3.3 Transmissivity Estimates

The analyses of the data obtained from the pumping test are included in Appendix D. The results are summarized as follows:

	Transmissivity		
Observation Well	**m^2/s**	**Igpd/ft**	**Storativity**
TW 17-01	4.3×10^{-3}	24,630	4.6×10^{-4}
Aubrey Bedrock MW	4.5×10^{-3}	26,040	9.2×10^{-4}
Aubrey Till MW	3.7×10^{-3}	21,610	1.5×10^{-2}(?)
Proposed Ruby Bedrock MW	4.2×10^{-3}	24,440	2.7×10^{-5}
Existing Ruby Bedrock MW	5.0×10^{-3}	28,780	7.3×10^{-5}
Average Bedrock Transmissivity	**4.5×10^{-3}**	**25,973**	

The transmissivity was found to vary from a low of 3.7×10^{-3} (21,610 Igpd/ft, Aubrey Till MW) to 5.0×10^{-3} m^2/s (28,780 Igpd/ft, Ruby On-site Bedrock Well (AFW – TH-1)). The average bedrock transmissivity of 4.5×10^{-3} m^2/s (25,973 Igpd/ft) is considered appropriate for estimating the drawdowns over time and distance.

3.4 Water Quality

As part of the pumping test, water quality samples were collected and submitted for laboratory analysis after 0.5 hours of pumping, 4 hours of pumping and at the end of the test. The samples were tested for routine water quality parameters (Table 1) and total/e. coliform (Table 2). The laboratory certificates of analysis are included in Appendix E.

The water quality was found to be slightly brackish (TDS = 1440 mg/l), consistent with expectations based on the published regional water quality data (Figure 5). There was no discernable change in water quality over the duration of the test which would suggest the influx of river water or poorer quality water. However, the test may not have been run long enough to induce any such changes. Days of pumping may be required to observe any significant changes in water quality. Based on the site location proximate to the river, long term pumping may result in the influx of river water which would have an effect of lowering the total dissolved solids. Conversely, long term pumping could induce either the influx of better quality of groundwater from the north (Figure 5), or poorer quality groundwater from the south (TDS = 2,000 mg/l).

The water quality results from this test are considered suitable for the initial assessment of the potential discharge location for the pumped water during construction. While water quality may vary during long term pumping, it is expected that water quality will improve over time (if river water or fresher groundwater from the north intrudes) or it will degrade slightly (the TDS concentration may trend towards 2,000 mg/l) if poorer quality water intrudes from the south.

The concentrations of Total Coliform varied from 5 MPN/100ml at the start of the test to 18 MPN/100 ml at the end of the test. Escherichia Coliform were not detected. The slight increase in Total Coliform suggests that a rising trend may have been occurring. However, the magnitude of the increase is small and could be within the range of normal fluctuations. The absence of Escherichia Coliform suggests that surface water intrusion was not occurring but cannot be taken as definitive evidence of a lack of connection to the river.

3.5 Assessment

3.5.1 Bedrock/Till Hydraulic Interaction

The results from the drilling of test well TW 17-01 at the Aubrey site indicate that the transition zone above the bedrock (consisting of a complex mixture of till, sand and gravel with limestone bedrock pieces) is not capable of producing a significant volume of water. However, the results of the subsequent pumping test have shown that a reasonably strong hydraulic connection exists between the bedrock aquifer and the overlying transition zone, and that groundwater pressures in the transition zone respond rapidly to pumping within the bedrock aquifer. Therefore, it is recommended that the top of the transition zone be considered the top of the aquifer for the purposes of the geotechnical assessment of the potential for base heave to occur in this case.

3.5.2 Bedrock Groundwater Depressurization

The results of the pumping test indicate that the aquifer at the Aubrey site has a transmissivity of approximately 4.5 x 10^{-3} m^2/s (26,000 Igpd/ft). Information provided by AFW indicates that groundwater levels would need to be drawn down to 219.2 meters to facilitate construction (approximately 12.6 m/41.3 ft below grade). Assuming a static

water level of 7.1 m (23.3 ft) below grade (as measured on June 7, 2017), the amount of drawdown needed would be approximately 5.5 m (18.0 ft). To achieve this level of drawdown, the pumping rate would need to be on the order of 31.5 lps (400 lgpm). It will be necessary to install larger diameter well(s) capable of accepting the larger pumps needed to achieve the required pumping capacity. See Section 5 for recommendations for the required wells.

4.0 Ruby Site Investigation

Current investigations completed as part of the WLG assessment at the Ruby site were limited to the installation of a bedrock monitoring well to complement the till monitoring well at that site, and the measurement of the groundwater level response to pumping at the Aubrey site. Previous investigations at the Ruby site were completed by Friesen Drillers Ltd. and are documented in their report dated November 16, 2016.

4.1 Pumping Well Installation

The initial plan to depressurize the Ruby site in 2016 was to install four 125 mm (5 in) diameter wells proximate to the excavation. However, a major zone of broken rock and fractured bedrock was encountered and open hole conditions could not be maintained using standard mud rotary drilling and well construction methods. In response to this, a dual rotary drilling rig was mobilized to the site and an attempt was made to install a 200 mm (8 in) diameter well. The first step in this process was to install a 300 mm (12 in) diameter steel surface casing to maintain open hole conditions for the installation of the 200 mm (8 inch) diameter well. The steel casing was installed to a depth of 15.7 m (51.5 ft) and a smaller diameter open hole then drilled to a depth of 29.9 m (98 ft). A brief well capacity test was then done where it was estimated that the aquifer transmissivity conditions were very high and that a well in excess of the planned 200 mm (8 in) diameter well would be needed to achieve the required pumping capacity. The work program was then cancelled and no further work was done to complete the installation of the 200 mm (8 in) diameter well.

The current “pumping” well at the Ruby site consists of 300 mm (12 in) diameter steel surface casing to a depth of 15.7 m (51.5 ft) followed by 300 mm (12 in) diameter open hole to a depth of 20.7 m (68 ft), and then 270 mm (10 5/8 in) diameter open hole to a depth of 29.9 m (98 ft). It is understood that the open hole portion of the well collapsed during and after the pumping test. The well as currently constructed is not in a suitable condition to serve as a pumping well for the depressurization of the Ruby site. Upgrades to this well will be required to achieve suitable conditions for this to be used as a pumping well. See Section 5 for recommendations for the required wells.

4.2 Pumping Test

A 3 hour pumping test was completed on this well at a rate of 23.4 Lps (309 Igpm) with the drawdown in water levels only recorded in the pumping well. The results of this preliminary pumping test indicated that the well had a specific capacity of 13.0 Lps/m (51.5 Igpm/ft).

4.3 Transmissivity Estimate

The results of this single well pumping test were analyzed using the Theis (1935) and the Cooper-Jacob (1946) methods to derive an estimate of transmissivity of 1.9×10^{-2} m^2/s (112,800 Igpd/ft). It is noted that the estimated transmissivity from this test is

substantially higher than the expected transmissivity for this area of the city based on published data, and is substantially higher than the 4.2 x 10^{-3} m^2/s (24,440 Igpd/ft) determined from the Ruby bedrock monitoring well during the Aubrey site pumping test completed by WLG. Several factors may be resulting in this discrepancy including:

- The Ruby site pumping test was completed with observations made only in the pumping well. These types of single well tests are inherently less accurate than tests completed using monitoring wells to record groundwater level changes.
- The Ruby site pumping test was relatively short (3 hours) and the potential exists that negative boundary conditions that would reduce the overall transmissivity had not yet been intersected by the drawdown cone.
- The analysis of the Ruby bedrock monitoring well data from the Aubrey site pumping test was assessing the bulk transmissivity between the two sites, and does not necessarily provide an accurate estimate of transmissivity specifically at the Ruby site. The Aubrey pumping test results do indicate that the transmissivity in the area of the Ruby site is more likely to be closer to the 4.2 x 10^{-3} m^2/s (24,440 Igpd/ft) transmissivity estimate from the Aubrey test than the 1.9 x 10^{-2} m^2/s (112,800 Igpd/ft) transmissivity estimate obtained from the Ruby test.

Further pumping testing at the Ruby site would be required to confirm the actual transmissivity of the aquifer in that area.

4.4 Water Quality

As part of the pumping test on the Ruby site well, a water sample was collected for laboratory analysis. The results of this analysis have been compiled on Table 1. The results are consistent with the results of the Aubrey site samples.

4.5 Assessment

4.5.1 Bedrock/Till Hydraulic Interaction

The results from the Aubrey pumping test found no evidence of a hydraulic response to pumping in the till monitoring well data at the Ruby site. The information suggects that a hydraulic connection between the bedrock and the till does not exist at the Ruby site and that, therefore, it may be suitable to consider the base of the till to be considered the top of the aquifer for the purposes of the geotechnical assessment of the potential for base heave to occur in this case. The more conservative approach would be to consider the top of the till as the top of the aquifer, as per the situation at the Aubrey site.

4.5.2 Bedrock Groundwater Depressurization

The results of the pumping test completed by WLG indicates that the aquifer at the Ruby site has a transmissivity of approximately 4.5 x 10^{-3} m^2/s (26,000 Igpd/ft). However, the Friesen Drilling testing indicates that a much higher transmissivity may exist at the Ruby site. While it is considered most likely that the lower transmissivity is closer to the actual transmissivity at Ruby, in the absence of formal pumping tests at the Ruby site it is prudent to consider both the lower and upper ends of the potential range

of transmissivity for the purposes of assessing the potential pumping rates needed to achieve the required level of depressurization.

Information provided by AFW indicates that groundwater levels would need to be drawn down to 219.2 meters to facilitate construction (approximately 12.9 m/42.3 ft below grade). Assuming a static water level of 7.3 m (23.9 ft) below grade (as measured on June 7, 2017), the amount of drawdown needed would be approximately 5.6 m (18.4 ft). To achieve this level of drawdown, the pumping rate would need to be on the order of 31.5 lps (400 Igpm) if the transmissivity is 4.5×10^{-3} m^2/s (26,000 Igpd/ft). If the transmissivity is 1.9×10^{-2} m^2/s (112,800 Igpd/ft), the required pumping rate would increase to 113.5 Lps (1,500 Igpm). Pumping tests upon the completion of the upgrades to the Ruby pumping well would be required to confirm the actual transmissivity at that site and therefore the pumping rate required to achieve the appropriate level of drawdown. To accommodate a pump capable of pumping at 113.5 Lps (1,500 Igpm), a 300 mm (12 in) diameter well would be required at the Ruby site. See Section 5 for recommendations for this pumping well.

5.0 Groundwater Control Assessment

The City has indicated that it is their intention to proceed with the upgrades to the Ruby site in the winter of 2017/18 and then complete the Aubrey site upgrades in the winter of 2018/19. Due to the proximity of the two sites, and the demonstrated strong hydraulic connection between the two, there is the potential to develop a groundwater depressurization system that would control groundwater pressures at both sites. In preparing this assessment of the potential options to control groundwater, the following has been assumed:

- Per the AFW 2016 report, it is understood that the groundwater pressure at both sites needs to be lowered to an elevation of 219.2 meters.
- The measured depths to groundwater made in June of 2017 at both sites have been used as the base case in the calculation of the potential pumping rates needed to achieve the required depressurization. It must be recognized that groundwater pressures vary over the course of the year with the lowest groundwater pressures typically occurring in the fall and winter and the highest pressures occurring in the spring and summer (Figure 3). As construction will proceed in the winter, it is reasonable to expect that groundwater pressures will be lower than recorded in June 2017. Prior to construction, the actual groundwater pressures at that time will need to be measured and the system design parameters adjusted accordingly.
- Although some testing has been done at both sites, it is common in the Carbonate Aquifer for transmissivities and the associated pumping rates to vary significantly over short distances and even when wells are enlarged and fully developed. It is reasonable to expect that the actual conditions encountered may vary from that assumed based on the current information, and that adjustments to the system design will be required to accommodate any variations. The key uncertainty is the actual transmissivity of the aquifer at the Ruby site. The well reconstruction and testing will need to be completed well before the start of construction to allow time for system design modifications to be made.
- The recommendations outlined below are considered to be one method of controlling groundwater pressures at the two sites. The contractor should be accorded the opportunity to submit a groundwater plan recommending an alternate strategy for review by the Project Team.

5.1 Groundwater Pumping Wells

Existing pumping wells at the two sites include the partially completed 300 mm (12 in) diameter well at the Ruby Site and the 150 mm (6 in) diameter test well at the Aubrey site. Neither well is considered suitable for use as a pumping well for the purposes of groundwater depressurization at these sites. The recommended upgrades to the existing wells are as follows:

- **Ruby Well** – The existing “pumping” well at the Ruby site should be reconstructed to consist of a 300 mm (12 in) steel casing to a depth of approximately 16.9 meters (55.5 ft) below grade (AFW test hole log TH01 (Ruby) indicates bedrock was encountered at that depth). To maintain an open hole in the known rubbled bedrock conditions, a screen should be installed below the casing to the maximum depth of drilling of 30.5 m (100 ft). The recommended slot size for the screen is 100 slot with a pea gravel filter pack placed around the screen. As the well is only intended for use until the Ruby and Aubrey upgrades are complete, the use of mild steel instead of stainless steel for the well screen is acceptable. The well should be developed with air lift pumping, surge blocks and jetting (as appropriate) to remove fines and maximize the well capacity. Upon completion of the well development, an 8 hour pumping test should be completed to determine the specific capacity of the well, the total well capacity, and the aquifer transmissivity. During the pumping test, groundwater level changes should be recorded at regular intervals in the pumping well, and all monitoring wells (Proposed Ruby Site, Existing Ruby Site, and Aubrey Site).
- **Aubrey Well** – The existing 150 mm (6 in) steel casing on test well TW 17-01 should be removed and a new 300 mm (12 in) well constructed. Well construction should consist of 300 mm (12 in) steel casing to a depth of approximately 19.5 m (64 ft) followed by a 100 slot screen complete with pea gravel filter pack to the maximum depth of drilling of 30.5 m (100 ft). As the well is only intended for use until the Ruby and Aubrey upgrades are complete, the use of mild steel instead of stainless steel for the well screen is acceptable. The well should be developed with air lift pumping, surge blocks and jetting (as appropriate) to remove fines and maximize the well capacity. Upon completion of the well development, an 8 hour pumping test should be completed to determine the specific capacity of the well, the total well capacity, and the aquifer transmissivity. During the pumping test, groundwater level changes should be recorded at regular intervals in the pumping well, and all monitoring wells (Proposed Ruby Site, Existing Ruby Site, and Aubrey Site).

Upon completion of the well upgrades, pumping tests will need to be completed to confirm the final capacities of the wells, the transmissivities of the aquifer, and the required pumping rates needed to achieve the appropriate level of aquifer depressurization.

5.2 Groundwater Pumps

In designing the groundwater depressurization system, the effect of varying groundwater levels during the course of the year need to be taken into consideration. As is illustrated on Figure 3, groundwater levels can be expected to fluctuate over a range of up to 3 meters, with the highest levels typically occurring in spring/summer and the lowest levels occurring in winter. If at the time of construction, groundwater levels are 3 meters higher than at present (June 7, 2017), the pumping rate would need to be increased to achieve the necessary drawdown. It is understood that construction would occur in the winter when groundwater levels can be expected to be low. Nevertheless,

the contractor should be required to provide a pumping system capable of operating over a suitable range to accommodate the potential fluctuations in groundwater levels.

There is a reasonably high level of certainty associated with the transmissivity of the aquifer at the Aubrey site based on the formal pumping test completed by WLG. Utilizing a transmissivity of 4.5×10^{-3} m^2/s (26,000 Igpd/ft), and an assumed drawdown requirement of 5.5 m (18 ft) at Aubrey, the estimated pumping rate would on the order of 31.5 lps (400 Igpm). If the Aubrey well is to be used as a backup well for the Ruby well (a distance of approximately 150 meters), the required pumping rate would be on the order of 64.4 Lps (850 Igpm), utilizing the same transmissivity and drawdown requirement. The capacity of the upgraded Aubrey well to be pumped at the higher rate needed for the Ruby site will need to be confirmed after the well upgrades to 300 mm (12 in) diameter have been completed.

There is a level of uncertainty with the transmissivity of the aquifer at the Ruby site due to the lack of a formal pumping test at that site. Utilizing a transmissivity of 4.5×10^{-3} m^2/s (26,000 Igpd/ft), and an assumed drawdown requirement of 5.5 m (18 ft) at Ruby, the estimated pumping rate would on the order of 31.5 lps (400 Igpm). If the Ruby well is to be used as a backup well for the Aubrey well (a distance of approximately 150 meters), the required pumping rate would be on the order of 64.4 Lps (850 Igpm), utilizing the same transmissivity and drawdown requirement. If the transmissivity of the aquifer at the Ruby site is found to be 1.9×10^{-2} m^2/s (112,800 Igpd/ft), the pumping requirement would increase to 113.7 Lps (1,500 Igpm) to achieve 5.5 m (18 ft) of drawdown at the Ruby site. If the Ruby well is to be used as a backup well for the Aubrey well (a distance of approximately 150 meters), the required pumping rate would be on the order of 219.7 Lps (2,900 Igpm), utilizing the same higher transmissivity and drawdown requirement. It is considered unlikely that such a high pumping rate could be achieved with an upgraded well at the Ruby site. If the higher transmissivity is confirmed to be valid in subsequent testing, consideration will need to be given to installing back-up wells at both the Ruby and Aubrey sites.

5.3 Groundwater Discharge

An appropriate discharge location for the groundwater will need to be determined. This could include discharge to the city sanitary or stormwater system or direct discharge to the adjoining Assiniboine River. For initial planning purposes, the water quality results provided in Table 1 are considered suitable for assessing the preferred discharge location and the discharge criteria that would be applied. Over long term pumping, it should be expected that the water quality would change partially as groundwater from the surrounding area is drawn towards the pumping well. Per Figure 5, the Total Dissolved Solids (TDS) concentration decreases to the north of the Aubrey site and increases to the south. Predicting how the water quality would change over time would require detailed knowledge of the distribution of transmissivity in the area of influence of pumping. This level of detailed information is not available and is beyond the scope of this study. However, as a worst case, it should be assumed that the pumping would

preferentially draw water from the south and therefore the water quality would trend from the current measured TDS of 1400 mg/l (+/-) towards 2,000 mg/l (+/-).

For planning purposes, a pumping rate of up to 64.4 Lps (850 Igpm) should be assumed for the Aubrey site and a pumping rate of up to 113.7 Lps (1,500 Igpm) should be assumed for the Ruby site. It is considered likely that discharge of these volumes of water directly to the river in the winter will result in open water conditions being maintained, and the appropriate safety plan should be implemented.

5.4 Regulatory Approvals

The project will be required to obtain approvals to pump the groundwater from the provincial Water Use Licensing Section, and approvals to discharge the water from the appropriate municipal/provincial/federal regulators (depending on the discharge option selected). A copy of this report should be forwarded to the regulators in support of any application for approvals.

5.4.1 Potential Third Party and Environmental Impacts

The pumping of groundwater for this project can be expected to have a radius of influence (drawdown >0.3 meters) of up to 2.4 to 3.2 kms (Figures 5 and 6). This analysis assumes that the transmissivity measured at this site of 4.5×10^{-3} m^2/s (26,000 Igpd/ft) is uniform over the area of influence, and that the pumping rate would be on the order of 31.5 lps (400 Igpm). The actual drawdowns that will occur are dependent on the transmissivity distribution with lower drawdown occurring in areas of higher transmissivity and higher drawdown occurring in areas of low transmissivity.

5.4.1.1 Existing Groundwater Users

A preliminary review of the provincial GWDrill water well database has found that there are a number of geothermal heating and cooling systems within the potential radius of influence of the Ruby and Aubrey sites. Of particular concern are the systems located on or near Wellington Crescent to the south of the site, and one potential geothermal system at a residence on Palmerston Avenue, east of the Ruby site. Standard Water Rights Licensing practice includes a requirement that the proponent complete: a well inventory to identify existing third party groundwater users that may be affected by the pumping; an assessment the potential for third parties to be affected; and, the development of a mitigation plan outlining the steps that would be taken in the event that an impact to existing users would occur. For groundwater users identified in the well inventory who will or might be affected, a typical mitigation plan would include the lowering of their pumps to compensate for the transient drawdown in groundwater levels, and other actions, as appropriate, to mitigate the impacts. It is recommended that a detailed well inventory be completed and that a mitigation plan be prepared.

5.4.1.2 Potential River Water Intrusion

The Ruby and Aubrey sites are located proximate to the Assiniboine River and the pumping of groundwater would have the effect of temporarily reversing the normal flow gradient of groundwater towards the river. The available monitoring information indicates that groundwater levels respond to changes in river levels which suggests some degree of hydraulic connectivity between the two. The pumping test results from the Ruby and Aubrey sites were inconclusive as to whether this hydraulic connection was strong or whether it is in the immediate area of either site.

It is reasonable to assume with the currently available information that some river water may intrude into the aquifer during the pumping at both sites. Based on experience elsewhere in or near the city, any river water that does intrude into the aquifer can be expected to be localized to the immediate area of the pumping sites, and will flow back to the river once pumping ceases and the normal flow gradient from the aquifer to the river is restored. Given that: there are no known users of groundwater for drinking water purposes in the area; that the geothermal systems are unlikely to be affected by any change in water quality; and, that the effects will very likely be transitory, the potential influx of river water to the aquifer is not a significant concern. A water quality monitoring plan should be implemented during and after construction to confirm this assessment.

5.4.1.3 Fresh/Brackish Groundwater Interface

As is shown on Figure 5, the Aubrey site is located in an area of brackish groundwater (TDS > 1,000 mg/l and <10,000 mg/l) and the expected radius of influence of pumping is expected to be within this zone of brackish groundwater. As such, the pumping of groundwater at these sites is unlikely to result in the influx of saline groundwater (> 10,000 mg/l) to the area. Depending on the distribution of transmissivity, the pumping of groundwater may result in the movement of groundwater with a higher TDS concentration (>/= 2,000 mg/l) towards the north towards the pumping sites, which would represent a change of approximately 25% in the TDS concentration currently measured at the Aubrey site (1440 mg/l). The effects of any movement of poorer quality water can also be expected to be transient, and would dissipate over time as the normal groundwater flow gradients are restored after pumping ceases. Given that there are no known users of groundwater for drinking water purposes in the area; that the geothermal systems in the area are unlikely to be affected by any change in water quality; and, that the effects will very likely be transitory, the potential movement of poorer quality groundwater from the south is not a significant concern. A water quality monitoring plan should be implemented during and after construction to confirm this assessment.

5.5 Groundwater Monitoring Plan

A groundwater level and groundwater quality monitoring plan will need to be implemented to provide information for the monitoring and control of the groundwater depressurization system and to verify that adverse third party or environmental impacts are not occurring.

5.5.1 Groundwater Level Monitoring

The recommended groundwater level monitoring would consist of the regular measurement of groundwater levels within the two pumping wells, the existing 5 monitoring wells at these two sites, and at any private wells in the area of influence where the owner agrees to the installation of monitoring equipment. Note: Pending the results of the well inventory and subsequent reassessment of the potential for third party impacts, it may be necessary to install additional monitoring wells in areas where enhanced monitoring may be warranted.

All monitoring wells should be equipped with digital water level transducers set to record groundwater levels on a regular basis. The frequency of measurements would vary from every minute at the start of pumping to hourly after the drawdown cone has been established and steady state conditions achieved. Manual readings of the groundwater levels in the pumping wells should be made hourly. The information from the monitoring program should be downloaded regularly and assessed by qualified personnel to confirm the contractor is operating the system in a manner that achieves the required level of depressurization, and not in a manner that results in avoidable adverse effects to existing groundwater users in the area.

5.5.2 Groundwater Quality Monitoring

Investigations to date have shown that there is the potential for the project pumping to induce changes in the groundwater quality. It is anticipated that the groundwater quality changes will not be significant and that the changes will be transient. To verify that adverse groundwater quality changes are not occurring, a groundwater quality monitoring program should be initiated and maintained through to the end of construction.

During pumping periods, a Troll 9500 multi-parameter transducer or similar instrument should be installed in the bedrock monitoring well at the site being pumped, and operated to record changes in electrical conductivity, turbidity and pH. The insitu water quality monitoring should be supplemented with the collection of water samples from the discharge of the groundwater system and submission to a laboratory for routine water quality analysis (MUN-WTP72D analytical package). Samples should be collected at the initiation of pumping and after every month during pumping.

The insitu water quality transducer should be downloaded at the same time as the water level monitoring transducers and the information assessed by qualified personnel and reported on in conjunction with the water level monitoring results, and any available laboratory results.

6.0 Conclusions

A hydrogeologic assessment was undertaken by WLG to obtain information on the hydrogeologic conditions beneath the Ruby and Aubrey sites so that decisions could be made concerning the groundwater control requirements needed during the proposed construction of the upgrades to the outfall facilities. The work program at the Aubrey site consisted of the installation of a test well and monitoring wells, and the completion of a pumping test complete with water quality sampling. The work program at the Ruby site was limited to the installation of a bedrock monitoring well (by AFW) and the monitoring of the groundwater response to the Aubrey site pumping. Based on the results of this investigation and the preliminary review of other sources of information the following conclusions are made:

6.1 Aubrey Site

- The stratigraphy beneath the Aubrey site consists of 10.7 m (35 ft) of clay followed by 1.5 m (5 ft) of till. Below the till is a transition zone which consists of a complex mixture of till, sand and gravel, and broken limestone. The limestone bedrock was intersected at a depth of 18.9 m (62 ft) below grade.
- Observations made during the drilling indicate that the transition zone did not produce a significant volume of groundwater. However, subsequent results from the pumping test did indicate a reasonably strong hydraulic connection between the bedrock aquifer and the overlying overburden materials, with groundwater pressures within the transition zone responding rapidly to the pumping within the bedrock. Fractures, and significant volumes of water were encountered from the top of the bedrock to the depth of drilling of 25 meters below grade. The upper bedrock was competent and remained open after drilling.
- Monitoring of the groundwater levels from May 12 to June 6, 2017 found that the groundwater levels do respond to changes to river levels. On June 7, 2017, the groundwater level was approximately 0.7 meters above the river level, indicating the normal flow gradient is from the bedrock aquifer towards the river. The results indicate some degree of hydraulic connection between the river and the bedrock aquifer. However, no evidence of river water intrusion during the pumping test was noted in the water quality results.
- The pumping test found that the transmissivity of the bedrock aquifer in the Aubrey area is 4.5×10^{-3} m^2/s (26,000 Igpd/ft). A strong groundwater level response was noted in the overburden materials above the bedrock aquifer at the Aubrey site.
- The drawdown cone that developed during the pumping test was relatively flat with similar drawdown in bedrock groundwater levels recorded at the Ruby site as at the Aubrey site. The potential therefore exists to complete the construction at both sites using a single groundwater depressurization system.
- The water quality at the Aubrey site was found to be brackish (TDS = 1440 mg/l). Although no significant change in water quality was noted during the test, it is reasonable to assume that longer term pumping may have the potential to induce the intrusion of river water to the aquifer (resulting in a reduction in TDS) and/or the movement of poorer quality groundwater from the south (resulting in an increase in TDS). There is insufficient information at this stage to do a detailed prediction of the changes in water quality that may occur. However, as a worst

case, it is reasonable to expect that the TDS concentration may increase to the 2,000 mg/l range.

- The effects of any river water intrusion or movement of poorer quality water during the construction pumping can be expected to be transitory with the water quality returning to normal over time after pumping ceases and the normal groundwater flow gradients are restored. Given that there are no known users of groundwater for drinking water purposes in the expected radius of influence, the effects of any short term changes in water quality are not expected to be significant.
- Based on the current measured groundwater level of 7.1 meters below grade (June 7, 2017) and the design groundwater depressurization target of 12.6 meters below grade (per AFW 2016), a groundwater depressurization system capable of pumping 31.5 lps (400 Igpm) would be required. Groundwater levels vary by up to 3 m (9.8 ft) during the year with higher levels in the summer and lower levels in the winter. The groundwater system would need to be sized to accommodate these changes in groundwater levels. The system design would need to be adjusted based on the actual groundwater levels that occur at the time of construction.

6.2 Ruby Site

- The stratigraphy beneath the Ruby site consists of 14.0 m (46 ft) of clay followed by 2.9 m (9.5 ft) of till (Per AFW log TH01 (Ruby)), and then limestone bedrock to the maximum depth of drilling of 22.9 m (75 ft). The upper 0.6 m (2 ft) of the limestone was rubbled. Per the Friesen log for the nearby 12 inch well, the stratigraphy consists of 15.2 m (50 ft) of clay followed by limestone rubble and broken limestone rock to the maximum depth of drilling of 29.9 m (98 ft). The results indicate that the bedrock conditions vary significantly over short distances at the Ruby site.
- No evidence of river water intrusion during the pumping test was noted in the water quality results.
- The pumping test by Friesen indicated that the transmissivity of the bedrock aquifer in the Ruby area is 1.9×10^{-2} m^2/s (112,800 Igpd/ft). Based on the Aubrey site pumping test by WLG, the estimated transmissivity is on the order of 4.5×10^{-3} m^2/s (24,440 Igpd/ft). The variation in apparent transmissivity results may be related to the varying testing methods and other factors. Further testing at the Ruby site is required to confirm the transmissivity prior to finalizing pumping system designs.
- No groundwater level response was noted in the overburden materials above the bedrock aquifer at the Ruby site.
- Based on the current measured groundwater level of 7.3 m (23.9 ft) below grade (June 7, 2017) and the design groundwater depressurization target of 12.9 m (42.3 ft) below grade (per AFW 2016), a groundwater depressurization system capable of pumping 31.5 lps (400 Igpm) would be required if the transmissivity is 4.5×10^{-3} m^2/s (24,440 Igpd/ft). If the transmissivity is 1.9×10^{-2} m^2/s (112,800 Igpd/ft), the required pumping rate increases to 113.5 Lps (1,500 Igpm). Groundwater levels vary by up to 3 meters during the year with higher levels in the summer and lower levels in the winter. The groundwater system would need to be sized to accommodate these changes in groundwater levels. The system design would need to be adjusted based on the actual groundwater levels that occur at the time of construction.

6.3 General

- A suitable discharge location for the groundwater will need to be determined prior to construction. Potential options include the city sanitary or storm water system or directly to the river. For planning purposes, the water quality results obtained from these tests are considered suitable for assessing the preferred option for discharge.
- The preliminary review of the provincial water well database has identified a number of geothermal heating and cooling systems in the area, including several on or near Wellington Crescent to the south, and one potential system at a residence on Palmerston Avenue to the east of the site. Further investigations will be required to assess the potential for these systems to be affected by the project pumping, and develop an appropriate mitigation plan.

7.0 Recommendations

7.1 General

The following general recommendations apply to both the Ruby and Aubrey Sites:

- A detailed inventory of existing groundwater users in the area who may be affected by the project pumping should be completed. The well inventory would include: a detailed review of the provincial water well database to identify existing users and complete an initial desk-top assessment of the potential for the systems to be impacted; a follow-up inspection of any systems identified as potentially being affected to obtain additional information on the capacity of the systems to tolerate drawdown.
- A Groundwater Interference Complaint Response Plan should be prepared and implemented. The plan would outline the procedures to be followed if a complaint is received from an existing groundwater user.
- A water level and water quality monitoring program should be implemented to establish the baseline pre-construction water levels and water quality, monitor changes during construction, assess the information for evidence of a potential adverse effect, and post-construction monitoring to confirm that no long term lasting effects remain. The recommended monitoring program includes the following:
    - All existing 5 monitoring wells at the two sites should be equipped with digital water level transducers set to record groundwater levels on a regular basis.
    - During pumping periods, a Troll 9500 or equivalent multi-parameter transducer should be installed in the bedrock monitoring well proximate to the pumping well to monitor for changes in electrical conductivity, turbidity and pH.
    - Water quality samples should be collected at the start of pumping, and monthly for the period of pumping and submitted to a laboratory for routine water quality analysis (the MUN-WTP72D analytical package is recommended).
    - The information from the monitoring program should be downloaded regularly and assessed by qualified personnel to confirm that the required level of groundwater depressurization is being maintained, and that potential adverse effects to existing users are not occurring. The recommended frequency of data collection is daily for the first week of pumping, and then weekly for the duration of pumping.
- Regulatory approvals will be required from the provincial Water Use Licensing Section to authorize the withdrawal of groundwater, and from the responsible authority for the selected discharge location for the water. A copy of this report should be forwarded to the regulators in partial support of an application for approvals.
- The contractor should be required to submit a groundwater management plan detailing the design of the groundwater control system to be used to depressurize the bedrock aquifer to the required 12.6 meters below grade.

7.2 Ruby Site

The following recommendations are made relative to the proposed construction at the Ruby site:

- A critical uncertainty to finalizing the groundwater control plan is the transmissivity applicable to the aquifer at the Ruby site. It is recommended that the Ruby well be upgraded to a full pumping well, as described below, and that an 8 hour pumping test be completed on the well at its maximum capacity. During the test, groundwater level changes should be digitally recorded at regular intervals in the pumping and all monitoring wells. The results of this test should be assessed by qualified personnel to determine the transmissivity applicable to the Ruby site, and the groundwater control plans for both the Ruby and Aubrey sites should be finalized, including the required pumping rates. The analysis should include a determination as to whether a second back-up pumping well will be required at the Ruby site to provide back-up pumping capacity in the event of the failure of the primary well or its installed components, or if the Aubrey well will be suitable for use as a back-up well.
- The existing “pumping” well at the Ruby site should be reconstructed to be a fully functioning 300 mm (12 in) diameter well complete with casing to the top of the bedrock, and a screen in the open hole portion of the well. The recommended depth of the well is 30.5 m (100 ft).

7.3 Aubrey Site

The following recommendations are made relative to the proposed construction at the Aubrey site:

- The existing 150 mm (6 in) diameter test well should be upgraded to a fully functioning 300 mm (12 in) diameter well complete with casing to the top of the bedrock and a screen in the open hole portion of the well. The recommended depth of the well is 30.5 m (100 ft). It is recommended that an 8 hour pumping test be completed on the upgraded well at its maximum capacity. During the test, groundwater level changes should be digitally recorded at regular intervals in the pumping and all monitoring wells. The results of this test should be assessed by qualified personnel to confirm the suitability of the use of this well to be the primary pumping well for the depressurization of this site, or whether additional wells will be required. The groundwater control plan for the Aubrey site should then be finalized, including the required pumping rates.
- The results of the pumping test on the upgraded Ruby well should be assessed to determine whether that well is suitable to provide back-up pumping capacity for the Aubrey well, or whether a second well at Aubrey is required.

8.0 References

AFW, 2016, “Geotechnical Investigation, Ruby and Aubrey Street Outfall Chambers Upgrade, Winnipeg, Manitoba” Amec Foster Wheeler Environment and Infrastructure, June 16, 2016.

Baracos et al, 1983, “Geological Engineering Maps and Report For Urban Development of Winnipeg” Department of Geological Engineering, University of Manitoba, Edited by A. Baracos, D. Shields and B. Kjartanson.

Friesen Drillers Ltd., January 6, 2017. Proposed Dewatering of the Proposed Ruby Gat Chamber, Palmerston Avenue and Ruby Street – City of Winnipeg – River Lots 61/62/63 – Parish of St. James.

Render, 1970, “Geohydrology of the Metropolitan Winnipeg Area as Relates to Groundwater Supply and Construction”, Canadian Geotechnical Journal, 7, pp. 243-274.

9.0 Closure

The information and data contained in this report, including without limitation the results of any sampling and analyses conducted by W.L. Gibbons & Associates Inc. (WLG) pursuant to its agreement with the Client, has been developed or obtained through the exercise of WLG's professional judgement and are set forth to the best of WLG's knowledge, information and belief. Although every effort has been made to confirm that this information is factual, complete, and accurate, WLG makes no guarantees or warranties whatsoever, whether expressed or implied, with respect to such information or data.

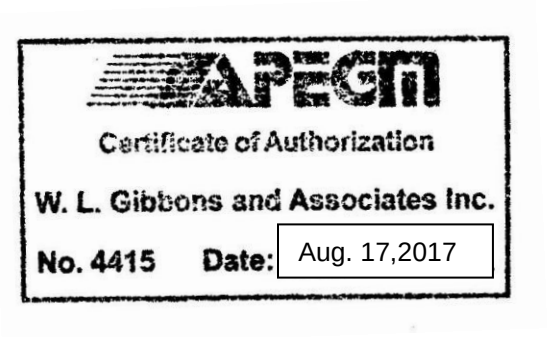
WLG shall not by act of issuing this report be deemed to have represented thereby that any assessment conducted by it have been exhaustive or will identify all risks associated with the development of water supplies within the study area. Persons relying on the results thereof do so at their own risk.

Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by the Client, their officers and employees, and others having legitimate business relations with the Client. Any such use and reliance shall be subject to the limitations set forth in the preceding paragraphs.

Respectfully Submitted.

W.L. Gibbons & Associates Inc.

Steve Wiecek, P.Geo., P.Eng.
Senior Geologic Engineer



Tables

Table 1
City of Winnipeg
Ruby & Aubrey Street Outfall Upgrades
Water Quality Data
Sheet 1 of 2

	Aubrey TW 17-01 Pumping Test		Ruby 12 inch	Canadian Drinking
	Sample TW 17-01-30	Sample TW 17-01-F	Well Pumping Test	Water Quality
Parameters	t = 30 minutes	t = 7 hours	9/11/2016	Guidelines
Total Alkalinity (as CaCO3)	366	363	393	
Bicarbonate (as HCO3)	447	443	480	
Carbonate (as CO3)	<0.6	<0.6	<0.6	
Hydroxide (OH)	<0.34	<0.34	<0.34	
Ammonia, Total (as N)	0.213	0.206		
Total Carbon	76.7	73.6		
Total Inorganic Carbon	75.5	72.5		
Total Organic Carbon	1.24	1.15		
Chloride (Cl)	326	335	330	250
True Colour (CU)	<5	<5		15
Conductivity (umhos/cm)	2050	2060	1880	
Fluoride (F)	0.34	0.34	0.35	1.5
Hardness (as CaCO3)	684	709	758	
Cation - Anion Balance	5.8	6.2		
Anion Sum	23.6	23.9		
Cation Sum	26.5	27.1		
Langelier Index (4°C)	0.14	0.22		
Langelier Index (60°C)	0.89	0.97		
Nitrate-N	<0.2	<0.2	<0.2	10
Nitrate and Nitrite as N	<0.22	<0.22	<0.22	10
Nitrite-N	<0.1	<0.1	<0.1	1
Sulphate (SO4)	338	344	342	500
Total Dissolved Solids	1440	1450	1400	500
Total Kjedahl Nitrogen	0.24	0.22		
UV Transmittance (245nm)	95.5	95.3		
Turbidity (NTU)	9.6	10.2	81.6	
pH	7.33	7.4	7.51	

Note: All units in mg/l except as noted.

Table 1
City of Winnipeg
Ruby & Aubrey Street Outfall Upgrades
Water Quality Data
Sheet 2 of 2

	Aubrey TW 17-01 Pumping Test		Ruby 12 inch	Canadian Drinking
	Sample TW 17-01-30	Sample TW 17-01-F	Well Pumping Test	Water Quality
Parameters	t = 30 minutes	t = 7 hours	9/11/2016	Guidelines
Aluminum (Al)	0.065	0.0364		0.1
Antimony (Sb)	<0.0002	<0.0002		0.006
Arsenic (As)	0.00775	0.00776		0.0100
Barium (Ba)	0.018	0.0181		1
Beryllium (Be)	<0.0002	<0.0002		
Bismuth (Bi)	<0.0002	<0.0002		
Boron (B)	0.496	0.518		5
Cadmium (Cd)	<0.00001	<0.00001		0.005
Calcium (Ca)	122	129	150	
Cesium (Cs)	<0.0001	<0.0001		
Chromium (Cr)	<0.001	<0.001		0.05
Cobalt (Co)	0.00032	0.00029		
Copper (Cu)	<0.0002	<0.0002		1
Iron (Fe)	0.808	0.88	2.08	0.3
Lead (Pb)	0.000125	<0.00009		0.01
Lithium (Li)	0.113	0.12		
Magnesium (Mg)	92.3	94.2	92.8	
Manganese (Mn)	0.0122	0.0119	0.0929	0.050
Molybdenum (Mo)	0.00103	0.00101		
Nickel (Ni)	<0.002	<0.002		
Phosphorous (P)	<0.1	<0.1		
Potassium (K)	20.6	21	17.6	
Rubidium (Rb)	0.00833	0.00849		
Selenium (Se)	<0.001	<0.001		0.01
Silicon (Si)	7.47	7.65		
Silver (Ag)	<0.0001	<0.0001		
Sodium (Na)	282	283	233	200
Strontium (Sr)	1.07	1.12		
Tellurium (Te)	<0.0002	<0.0002		
Thallium (Tl)	<0.0001	<0.0001		
Thorium (Th)	<0.0001	<0.0001		
Tin (Sn)	<0.0002	<0.0002		
Titanium (Ti)	0.00275	0.00161		
Tungsten (W)	<0.0001	<0.0001		
Uranium (U)	0.00115	0.00116		
Vanadium (V)	<0.0002	<0.0002		
Zinc (Zn)	0.0032	<0.002		
Zirconium (Zr)	<0.0004	<0.0004		

Note: All units in mg/l except as noted.

Table 2
City of Winnipeg
Aubrey Street Outfall Upgrade
Coliform Data
Sheet 1 of 2

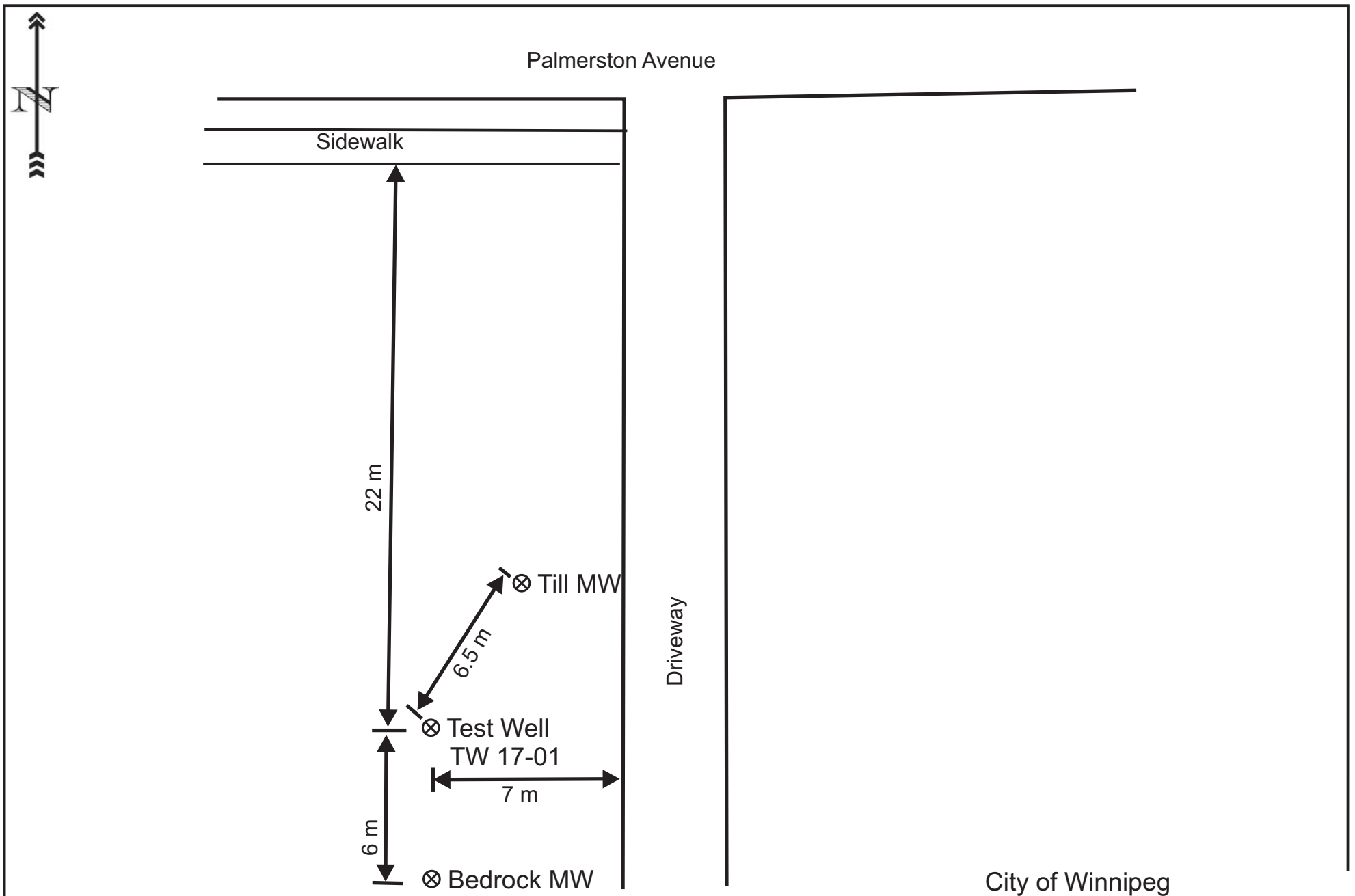
Parameters	Test Well TW 17-01 Pumping Test			Canadian Drinking Water Quality Guidelines
	Sample TW 17-01-30 t = 30 minutes	Sample TW 17-01-4 t = 4 hours	Sample TW 17-01-F t = 7 hours	
Total Coliforms	5	8	18	100
Escheria Coli	0	0	0	0

Figures

City of Winnipeg
Aubrey St. Outfall Upgrade
Overall Site Plan
Figure No. 1

W. L. GIBBONS & ASSOC. INC.
HYDROGEOLOGY - GEOLOGICAL ENGINEERING

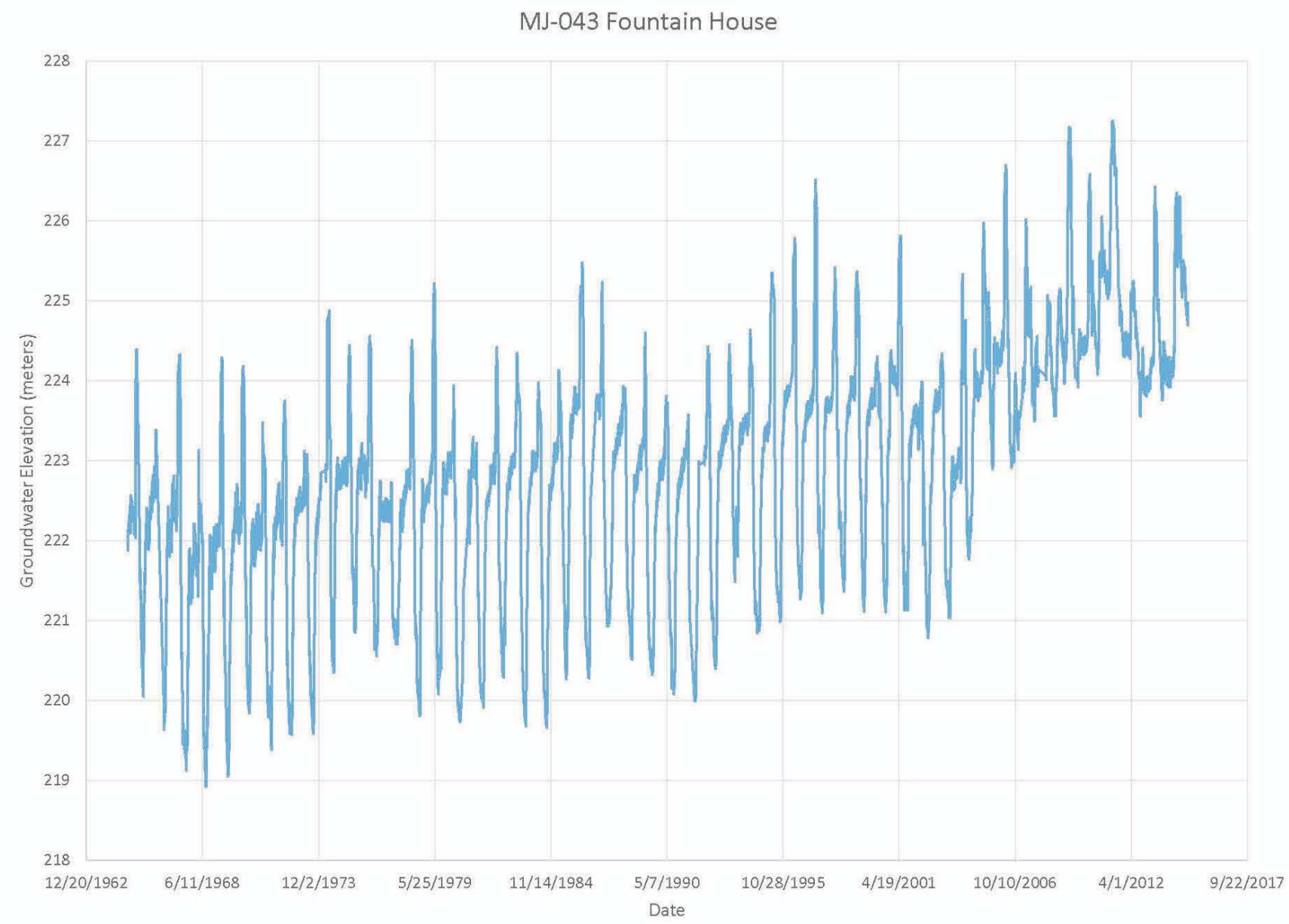
Designed By: BW
Approved By: SW
Date: 06/17



W. L. GIBBONS & ASSOC. INC.
HYDROGEOLOGY - GEOLOGICAL ENGINEERING

Designed By: BW
Approved By: SW
Date: 06/17

City of Winnipeg
Aubrey St. Outfall Upgrade
Detailed Site Plan
Figure No. 2



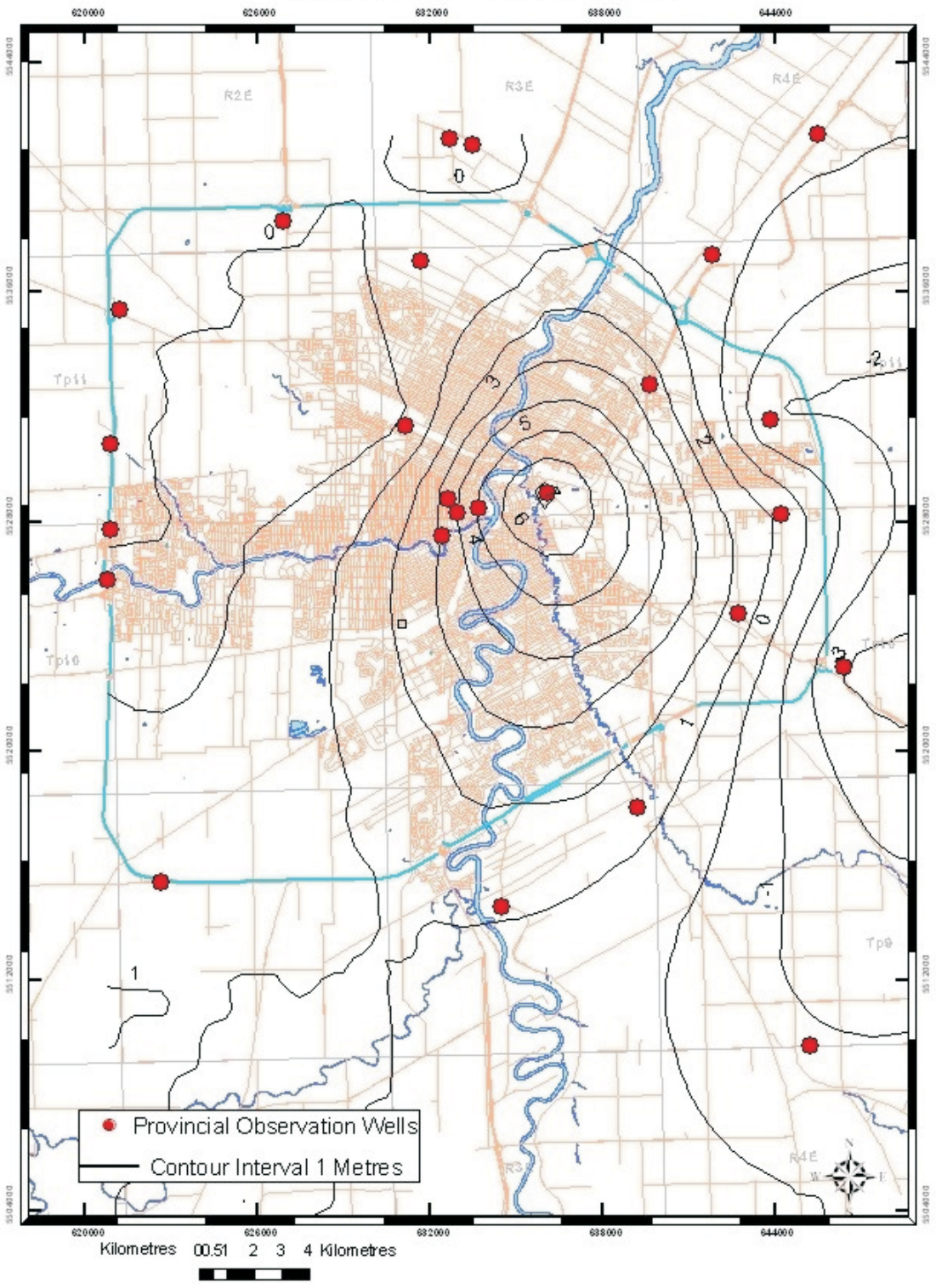
Provincial Groundwater Monitoring Station MJ-043 is located approximately 1 mile east of Aubrey Street

W. L. GIBBONS & ASSOC. INC.
HYDROGEOLOGY - GEOLOGICAL ENGINEERING

Designed By: BW
Approved By: SW
Date: 06/17

City of Winnipeg
Aubrey St. Outfall Upgrade
Groundwater Elevations
Figure No. 3

Carbonate Aquifer Potentiometric Surface
Winnipeg Area
Water Level Difference Spring 2009 & 1970



UTM NAD83, Zone 14

Groundwater Management Section
November, 2010

Manitoba
Water Stewardship

City of Winnipeg
Aubrey St. Outfall Upgrade
Groundwater Level Changes
Figure No. 04

W. L. GIBBONS & ASSOC. INC.
HYDROGEOLOGY - GEOLOGICAL ENGINEERING

Designed By: BW
Approved By: SW
Date: 06/17

Source: Baracos et al, 1983
Total Dissolved Solids Concentration in mg/l

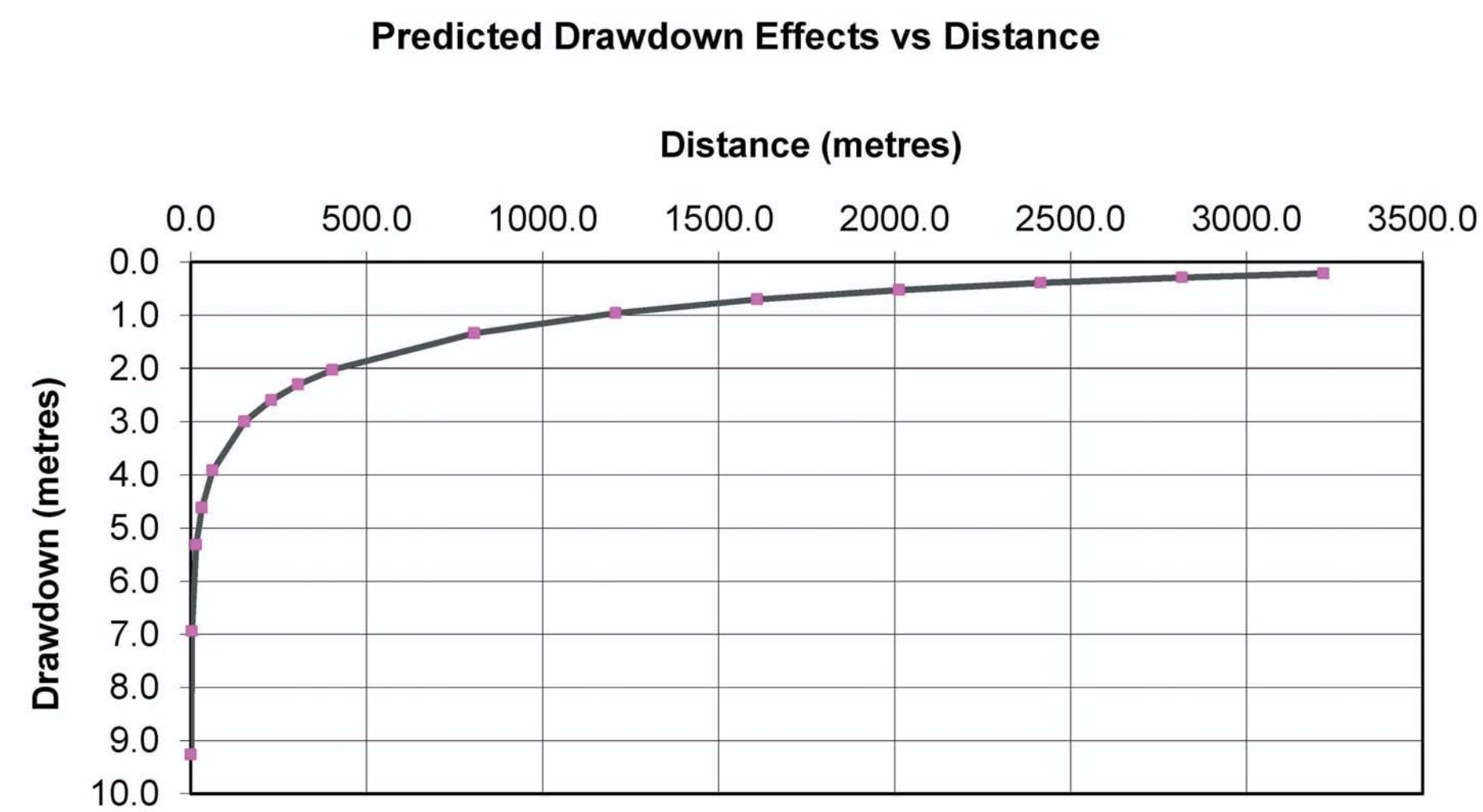
City of Winnipeg
Aubrey St. Outfall Upgrade

Total Dissolved Solids

W. L. GIBBONS & ASSOC. INC.
HYDROGEOLOGY - GEOLOGICAL ENGINEERING

Designed By: BW
Approved By: SW
Date: 06/17

Figure No. 5



Assumed Pumping Rate: 31.5 lps (400 lgpm)
Assumed Transmissivity: 4.5 x 10^{-3} m^2/s (26,000 lgpd/ft)
Assumed Duration: 3 months

City of Winnipeg
Aubrey St. Outfall Upgrade

Predicted Drawdown Effects

Figure No. 6

W. L. GIBBONS & ASSOC. INC.
HYDROGEOLOGY - GEOLOGICAL ENGINEERING

Designed By: BW
Approved By: SW
Date: 06/17

Appendix A
Approvals Documentation

Manitoba
Sustainable Development

Water Use Licensing Section
Box 16, 200 Saulteaux Crescent
Winnipeg, Manitoba, Canada R3J 3W3
T 204-945-6118 F 204-948-2357
Rob.Matthews@gov.mb.ca

November 3, 2016

File: Winnipeg, City of -39 (Ruby/Aubrey Outfall Chamber Upgrades)

Newton Conti, P.Eng.
Design and Specifications Engineer
City of Winnipeg
110-1199 Pacific Avenue
Winnipeg, MB R3E 3S8

Dear Mr. Conti:

Attached herewith is a **Groundwater Exploration Permit** issued in response to an application submitted by Friesen Drillers Ltd. on behalf of the City of Winnipeg and Rocky Road Recycling Ltd. registered on October 13, 2016, for a licence to construct well(s) and divert groundwater in connection with the proposed Ruby and Aubrey outfall chambers upgrade at 980 & 1016 Palmerston Avenue, respectively, on **River Lots 61 & 63, Parish of St. James**, Winnipeg, Manitoba.

The Groundwater Exploration Permit authorizes the City of Winnipeg to carry out exploration test drilling for purposes of constructing four 5-inch diameter wells into a carbonate aquifer up to a depth of 120 ft bgl and conduct aquifer pump testing. The purpose of the pump testing is to determine the aquifer conditions at the proposed construction site and to determine water level impacts on existing local wells and/or registered projects with earlier precedence dates than the proposed project. Please note that during testing, pumping must cease if any local water supplies are negatively impacted as a result of testing. The City of Winnipeg would further be responsible to correct any water supply problems or provide temporary water supply to anyone whose water supplies are negatively impacted as a result of testing. Please familiarize yourself with the terms and conditions of the Groundwater Exploration Permit.

A licensing decision on this project will be held pending submission of the required information. Please note that diversion of water without a Water Rights Licence or written authorization would constitute a violation of *The Water Rights Act* and may be subject to enforcement.

Please contact Ronaldo Miranda, directly at 204-945-6475 should you have any questions regarding the requirements outlined in this letter and the attached permit or the water rights licensing aspects of this project.

Yours truly,

Rob Matthews
Manager
Water Use Licensing Section

cc: J. Paulynn Estrella – Legal, E.I.T., Friesen Drillers Ltd.
Gilles (Gil) Legal, C.E.T., G.S.C., Rocky Road Recycling Ltd.
Graham Phipps, SD
Ronaldo Miranda, SD

Manitoba
Sustainable Development
Water Use Licensing Section

FORM F

200 Saulteaux Crescent
Winnipeg, Manitoba
R3J 3W3

Groundwater Exploration Permit

Pursuant to The Water Rights Act

FILE – Winnipeg, The City of -39

is hereby permitted to explore for and construct a groundwater well or wells on the following described lands, **980 & 1016 Palmerston Avenue, River Lots 61 & 63, Parish of St. James, Winnipeg,** for **dewatering and depressurizing** purposes, subject, however, to the following conditions:

1. The permittee must have legal access to the site where the exploration work and project wells are to be located.

2. This Authorization is not transferable or assignable to any other party.

3. Prior to undertaking any work or construction of any works authorized by this permit the permittee is required to retain the services of a hydrogeologist registered with Association of Professional Engineers and Geoscientists of Manitoba (APEGM), who would be required to:
   - Plan and supervise the drilling of boreholes, test wells, production wells, observation wells and well pump testing as authorized by this permit.
   - Conduct a constant rate pumping test on proposed dewatering well(s) in accordance with Form H (http://www.gov.mb.ca/conservation/waterstewardship/licensing/wlb/pdf/form_h_july_2013.pdf).
   - Carry out an inventory of private and commercial wells within a 1 mile radius of the project well site. The inventory may need to be expanded based on the assessment of the expected area of water level drawdown impact resulting from future pumping.
   - Prepare and submit to the Water Use Licensing Section a technical report on drilling of boreholes and wells, pump testing of well, well inventory and water quality sampling. The report would contain, but not limited to, such things as: well driller's reports for test wells, dewatering wells and observation wells; a plan showing the location of these wells on the property and/or GPS locations of the wells; an analysis of aquifer pumping tests; calculations of transmissivity; and a description of the amount of water level interference that would be expected to occur at existing local wells that are located within a 1 mile radius of the project well site. The report would also indicate if any local wells are expected to be adversely affected by the proposed use of water and where these wells are located. Two copies of the report shall be submitted, one hardcopy and one digital copy.

4. During any pumping tests that may be conducted, pumping must cease immediately if any local water supplies are negatively impacted as a result of the tests. The permittee is also responsible to correct any water supply problems or provide temporary water supply to anyone whose water supplies are negatively impacted as a result of the tests.

5. This permit expires within twelve (12) months of the date of issuance.

6. Please note that diversion of water without a Water Rights Licence or written authorization would constitute a violation of The Water Rights Act and may be subject to enforcement.

Issued at the City of Winnipeg in the Province of Manitoba, this 3rd day of November, A.D. 2016

Rob Matthews
for The Honourable Minister of Sustainable Development

Winnipeg

Water and Waste Department • Service des eaux et des déchets

2017 Temporary Disposal Permit
Sewer By-law No. 92/2010

Company and Contact Information

Company Name: **W.L. Gibbons & Associates Inc.**
Discharge Location: **1016 Palmerston Avenue** Discharge Type: **Well Water**
Permit Holder 24 Hr Contact: **Steve Wiecek** **204-771-4389**

Permit Information

Permit Number: **010 – 2017** Effective date: **June 7, 2017**
Date Issued: **June 6, 2017** Valid Until: **June 8, 2017**

Conditions and Responsibilities

- The permit holder must contact the Water and Waste Department staff noted at the bottom:
  - a minimum of 24 hours prior to the intended discharge start time.
- The permit holder must:
  - ensure that a contact person overseeing the discharge is available on site at all times during the discharge.
- The permit holder must ensure that the total discharge does not exceed:
  - a maximum flow rate of 9.5 L/s (150 USGM),
  - the proposed maximum volume of 72,000 Imp gallons.
- The permit holder must ensure that the discharge at 1016 Palmerston Avenue:
  - only goes into the WWS manhole on 1016 Palmerston Avenue. Located in the grassed area, just north of the paved area,
  - the manhole located in the centre of the driveway must be sealed, not allowing any water to drain into,
  - the odour control filter must be removed from the discharge manhole before pumping commences and replaced when the pumping has finished,
  - is monitored at all times by the contact person, or an on site designate,
  - occurs only at the WWS connection indicated on the attached map,
  - occurs between June 7, 2017 and June 8, 2017,
  - does not contain prohibited substances listed in Schedules A of the Sewer By-law,
  - does not contain substances that exceed the limits listed in Schedule B of the Sewer By-law,
  - does not create a nuisance or hazardous conditions.
- The permit holder must stop discharging:
  - in the event of wet weather, or forecasted wet weather, and only resume after receiving approval from the Water and Waste Department contact,
  - if the flow is abnormal (i.e. backing up, or not flowing well) the applicant must stop, and consult with the Water and Waste Department contact before continuing,
  - immediately upon request from the Water and Waste Department.
- The City of Winnipeg:
  - will issue an invoice for the appropriate charges.
- This permit authorizes the permit holder to discharge to the City's WWS subject to the terms and conditions set out above. This permit does not authorize usage of the City's street or any property for this purpose (separate permits or approvals may be required for these uses). By applying for this permit, the applicant accepts full responsibility and liability for any harm or damages that may be caused by the temporary discharge other than to the City's drainage systems.

Water and Waste Department contact: **McPhillips Control Centre (204-986-7948)**

Signature: _____
Permit Holder

Date: 05/06/17

Recommended By: _____
Glen Hagen
Industrial Waste Services Branch
Head

Approved By: _____
Renee Groselle
Manager,
Environmental Standards Division

THE CITY OF WINNIPEG BY– LAW NO. 92/2010

Conditions pertaining to the issuance and validity of this permit are as in Part 3, 6, 7 and 8 of City of Winnipeg Sewer By-Law No. 92/2010

PART 3 GENERAL

Permits, licences and authorizations

9(1) When a permit, licence or authorization is required by or under the By-law, a designated employee may issue or renew the permit, licence or authorization if:

(a) the applicant provides the information required to assess the application;

(b) the applicant pays the applicable fee for the permit, licence or authorization; and

(c) the application meets the requirements set out in this By-law.

9(3) A designated employee may issue or renew a permit, licence or authorization, with or without conditions, for either an indefinite or limited period of time.

9(6) The holder of a permit or authorization must comply with any conditions imposed on the permit, licence or authorization.

9(7) It is a condition of any permit, licence or authorization issued under this By-law that the applicant consent to the entry of a designated employee to the property at any reasonable time, without notice, in order to conduct an inspection or otherwise administer or enforce this By-law.

9(8) Subject to different requirements imposed as a condition of the permit, licence or authorization, the holder of the permit, licence or authorization must, within ten business days, inform a designated employee of any changes to the information submitted in the application, and a failure to do so voids the permit, licence or authorization.

11(1) A designated employee may, without notice and without a hearing, suspend a permit, licence or authorization for up to 30 days if an activity authorized by the permit, licence or authorization poses an immediate and substantial risk to human health or safety, property, or the environment. After imposing an emergency suspension, the designated employee must:

(a) immediately notify the holder of the permit, licence or authorization:

  (i) of the suspension,

  (ii) of the date the suspension will expire;

  (iii) of the reasons why the designated employee has concluded that the activity authorized by the permit, licence or authorization poses an immediate and substantial risk to human health or safety, property, or the environment; and

  (iv) of the actions that must be taken or circumstances that must exist, if any, that will result in the suspension being lifted before the expiration date;

(b) lift the suspension as soon as the immediate and substantial risk to human health or safety, property, or the environment no longer exists.

11(2) A designated employee may, without notice and without a hearing, suspend a permit, licence or authorization for up to 30 days if the information submitted in the application was incorrect and, had the correct information been known, the permit, licence or authorization would not have been issued. After imposing an emergency suspension, the designated employee must:

(a) immediately notify the holder of the permit, licence or authorization:

  (i) of the suspension;

  (ii) of the date the suspension will expire; and

  (iii) of the incorrect information submitted in the application;

(b) lift the suspension if it was an imposed error.

Suspending and cancelling a permit, licence or authorization

10(3) A designated employee may suspend or cancel a permit, licence or authorization if:

(a) the holder of the permit, licence or authorization has failed to comply with this By-law, the Water Works By-law, the Lot Grading By-law, other relevant legislation, or conditions imposed on the licence, permit or authorization;

(b) the applicant provided false or misleading information in the application that had an effect on the decision to grant the permit, licence or authorization;

(c) the past conduct of the holder of the permit, licence or authorization creates a reasonable concern that the authorized activity will not comply with this By-law, another by-law, other relevant legislation, or conditions imposed on the licence, permit or authorization; or

(d) an activity authorized by the permit, licence or authorization poses a risk to human health or safety, property, or the environment.

Fees, rates, charges, and deposits

17(2) The Director may determine when invoices and bills are issued.

17(3) Invoices and bills must be paid within 30 days of being issued.

17(4) A late payment charge in the form of interest payable at a rate determined by City Council is imposed on the outstanding balance of a fee, rate or charge that is not paid as required in subsection (1) and (3). The fee is imposed on the outstanding balance, including the amount of the late payment charge, for every 30-day period that a fee, rate or charge is overdue.

PART 6 CONNECTION REQUIREMENTS

Temporary above-ground wastewater disposal permit required

30(1) The owner or occupant of property must not allow to be disposed of overland to the land drainage or wastewater systems unless a designated employee has, in accordance with Section 9, issued a permit for the disposal.

30(2) A designated employee may issue a permit authorizing wastewater to be disposed of overland where the wastewater system is able to accommodate the disposal and where it will not pose a risk to human health or safety, property, or the environment.

Temporary above-ground land drainage connections permitted

32 A designated employee may, in writing, authorize land drainage from other than a single-family or two-family property to be discharged above ground through pipes, hoses, trenches or pumps on a temporary basis where:

(a) the land drainage system or wastewater system is able to accommodate the discharge; and

(b) the discharge will not pose a risk to human health or safety, property, or the environment.

PART 7 DISCHARGES OF WASTEWATER

Wastewater must be discharged to wastewater system

40 Unless otherwise authorized in this Part, wastewater must be discharged only to the wastewater system.

Discharge rate limits

43(1) In order to prevent the wastewater system from being overloaded, a designated employee may require the generator of wastewater to limit the rate of discharge of wastewater to the wastewater sewer. The generator of wastewater must comply with such a requirement.

43(3) If a designated employee imposes a limit under subsection (1), the generator must construct and maintain a discharge control device acceptable to the designated employee.

PART 8 DISCHARGES OF LAND DRAINAGE

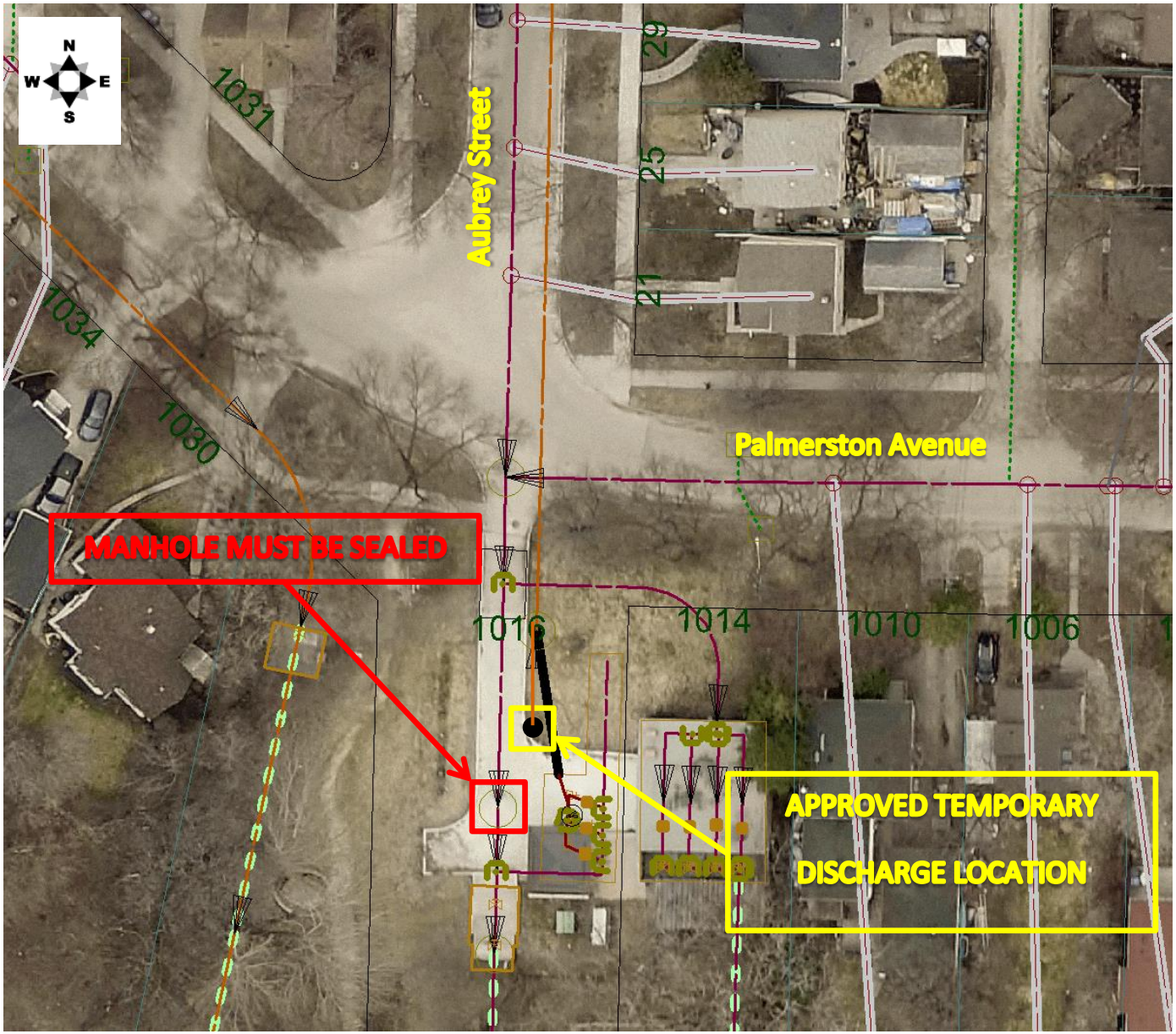
Land drainage must be discharged to land drainage system

55 Unless otherwise authorized in this Part, land drainage must be discharged only to the land drainage system or a combined sewer.

Discharge rate limits

60(1) In order to prevent the land drainage system or wastewater system from being overloaded, a designated employee may require the generator of land drainage to limit the discharge rate of land drainage to the land drainage or wastewater system.

60(3) If a designated employee imposes a limit under subsection (1), the owner must construct, use and maintain a discharge control device acceptable to the designated employee.



*Aubrey Street Outfall: Temporary Discharge Location

- Temporary Discharge Approved to open grate wastewater sewer manhole located in grassed area, just North of paved area.

- Prior to discharge, the combined sewer manhole located in the centre of the driveway/paved area, upstream of the outfall, must be sealed.

- Prior to discharge, the odour control filter must be removed from the discharge manhole.

- After discharge ceases, odour control filter must be replaced in the discharge manhole.

Appendix B
Test and Monitoring Well Logs

Driller's Report

MANITOBA
WATER STEWARDSHIP

WELL LOCATION	QTR. ____ SEC. __ TWP. __ RGE. ___ E1.___ R. LOT _____ PARISH _____ REMARKS: UTM: 14U 0631083 5526587 Address: 1020 Palmerston Avenue	Location Sketch of Well
WELL OWNER	NAME: City of Winnipeg ADDRESS: PHONE:	
WELL ID.	TW 17-01	
WELL USE	Test Well	
WATER USE	Construction Dewatering	
DATE	06/06/2017	

WELL LOG

Depth Below Ground In Feet From	Depth Below Ground In Feet To	DESCRIPTION	Water Record (Kind of Water)
0	1	Top Soil	
1	35	Clay	
35	40	Till	
40	50	Transition Zone- Till with sand gravel. Did not produce significant volumes of water.	
50	62	Transition Zone – Till with broken limestone. Did not produce significant volumes of water.	
62	73	Limestone with red shale layers – Some clay in fractures at 66 to 67 feet.	
		Fractures at 68, 70 and 78 to 79 feet. Began producing water at top of	
		Limestone.	
73	74	Red shale	
74	82	Limestone	

WELL CONSTRUCTION

Depth Below Ground Level In Feet From	Depth Below Ground Level In Feet To	CASING	OPEN HOLE	PERFORATIONS	GRAVEL PACK	CASING GROUT	PITLESS UNIT	INSIDE DIAMETER INCHES	OUTSIDE DIAMETER INCHES	SCREEN SLOT SIZE NO. OR INCH	TYPE		MATERIAL		MAKE
0	64	X						6					Steel		
64	82		X					5.75							

Top Of Casing Or Pitless Adapter: 2 Feet Above X Below _____ Ground Level

Remarks: Aubrey Street Outfall Gate Chamber. Approximately 22 meters south of city sidewalk, 6 meters north Of bedrock monitoring well and 6.5 meters southwest of till monitoring well.

PUMPING TEST

Date Of Test: (y/mm/d) 2017/06/07	
Pumping / Flowing Rate: 95 I.G.P.M.	
Water Level 23.2 ft. Above _____ Ground Before Pumping: Below X Level	
Pumping Level 30.1 ft. Above _____ Ground At End Of Test: Below X Level	
Duration Of Test: (Hrs:Min) 7:00	
Water Temperature: _____. Conductivity: _____.	
Recommended Pumping Rate: With Pump Intake At: ft. Below Ground Level	

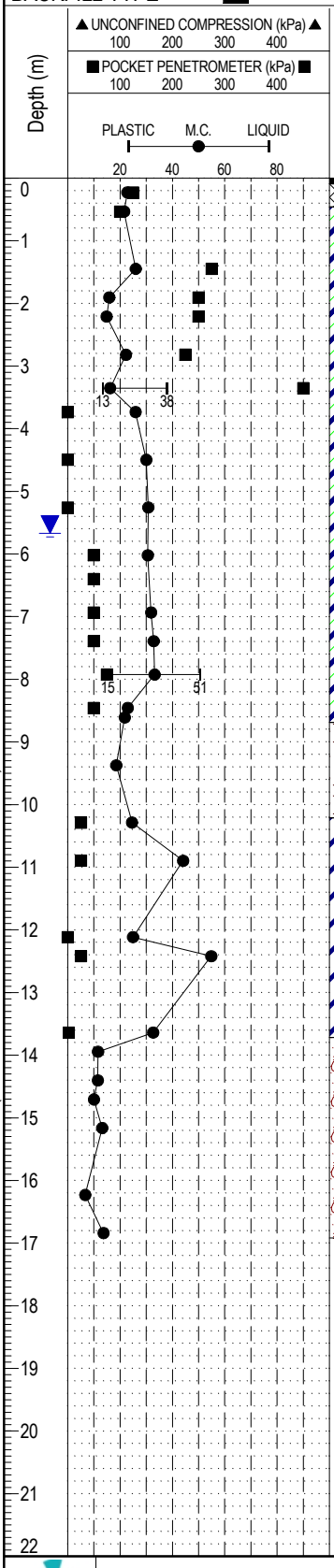
CONTRACTOR

Licence No.:
Name: Friesen Drillers Ltd.
Address: Steinbach, MB Phone
Drill Operator: Peter Friesen
(Signature of Contractor)

PROJECT: Ruby & Aubrey Outfall Chambers	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2016-TH01 (Ruby)**
CLIENT: MMM Group Limited	DRILL TYPE: Renegade Track Rig	PROJECT NO: WX17932
UTM: N5526579.1 E631231.3	DRILL METHOD: 125mm SSA	ELEVATION: 232.08 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand



Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	WELL INSTALLATION	COMMENTS	ELEVATION (m)
0		ASPH	ASPHALT - Approximate 90mm thick		1				232
1		CI-CH	CLAY (FILL) - silty, some sand, trace gravel, medium to high plastic, moist, stiff, dark greyish brown		2				231
2			CLAY (ALLUVIAL) - silty, trace to some sand, medium to high plastic, moist, stiff, dark greyish brown mottled dark grey, occasional sand lenses - and sand, greyish brown below 1.8m - brown, occasional oxidized inclusions below 2.7m		3 4 5 6 7			Ground water level: - 6.4m below ground surface on 12/05/2016 - 5.7m below ground surface on 31/05/2016 Hydrometer Analysis Results @ "3.0m": Gravel= 0.0% Sand= 23.4% Silt= 46.8% Clay= 29.8%	230 229
3									
4		CI-CH	- trace to some sand, silty to and silt, very soft, very moist to wet, occasional to frequent silt pockets (~5mm thick) from 3.7 to 6.1m		8 9 10				228
5								Unconfined Compression Test: Sample 7 (3.0m - 3.6m) Max Stress: 270.6 kPa @ 8.7% strain M.C: 16.2% ..SPT: 1,1,2; Rec: full	227
6			- trace gravel, firm to stiff, dark greyish brown, frequent oxidized inclusions below 6.1m		11 12				226
7					13	3			225
8			- silty, some sand, moist, dark grey, occasional fine sand seams (<3mm thick), frequent oxide pockets (<2cm thick) below 7.3m - sandy, grey below 8.2m		14 15 16 17			Unconfined Compression Test: Sample 15 (7.6m - 8.2m) Max Stress: 97.7 kPa @ 5.8% strain M.C: 33.2%	224
9		SM	SAND - silty, poorly graded, fine grained, wet, compact, brown		18	14		..SPT: 4,7,7; Rec: full	223
10					19				222
11		CH	CLAY (ALLUVIAL) - silty, high plastic, very moist, soft to firm, dark grey, occasional sand inclusions, occasional silt and sulphate inclusions - trace to some gravel, occasional sand pockets (~5cm to 10cm dia.) below 11.1m		20	4		..SPT: 2,2,2; Rec: 230mm	221
12					21				220
13			- wet, very soft below 12.5m		22	5		..SPT: 3,2,3; Rec: 150mm	219
14		ML	SILT (TILL) - sandy, some gravel, trace clay, low plastic, wet, compact, light greyish brown - gravelly below 14.2m		23 24 25 26	27 12		..SPT: 2,15,12; Rec: 150mm ..SPT: 8,4,8; Rec: 230mm	218 217
15					27				
16					28	24		..SPT: 8,18,6; Rec: 50mm	216
17			AUGER REFUSAL AT 16.9m BELOW GRADE. Notes: - Seepage & sloughing observed at zones from 4.3m to 6.1m, from 8.5m to 10.2m and below 13.7m during and on completion of drilling. - Test hole remained open to 14.6m and water level at 6.4m below grade was observed prior to backfilling.\ - One 25mm diameter standpipe installed on completion of drilling.		29				215
18									214
19									213
20									212
21									211
22									

WX17932 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:52 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: KE	COMPLETION DEPTH: 16.9 m
REVIEWED BY: WKW	COMPLETION DATE: 12 May 2016
Figure No. A01	Page 1 of 1

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH01(RUBY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526577.2 E631231.4	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 232 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand

▲ UNCONFINED COMPRESSION (kPa) ▲ 100 200 300 400

■ POCKET PENETROMETER (kPa) ■ 100 200 300 400

PLASTIC M.C. LIQUID 20 40 60 80

Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
0		ASPH	ASPHALT - 50mm thick					- Overburden was drilled out and auger cuttings spun up, no samples were taken until Bedrock was encountered.	232
			CLAY - silty, high plastic, moist, firm to stiff (inferred), brown						
1									231
2									230
3									229
4									228
5									227
6									226
7		CH							225
8								- slight to moderate seepage was observed at 7.6m	224
9									223
10									222
11									221
12									220
13									219
14			SILT (TILL) - trace to some sand and gravel, low plastic, moist, compact to dense (inferred), tan-brown						218
15									217
16		ML	- suspected gravelly below 16.2m						216
17		LI	AUGER REFUSAL WAS ENCOUNTERED AT 16.9m BELOW GRADE ON SUSPECTED COBBLES OR BEDROCK. SWITCH TO CORING METHOD.		1			- significant seepage was observed at 16.5m	215
18		LI	LIMESTONE AND COBBLES - occasional limestone pieces ~50mm diameter, sub-angular		2				214
		CL			3				
					4				
19		LI	LIMESTONE (BEDROCK) - occasional to frequent fractures - orange to red below 18.3m		5				213
					6				
20			CLAY - silty, low plastic, moist, soft (inferred), red to orange					- RQD = 81%, from 19.4 to 19.8m	

WX1793201 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:56 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: AL	COMPLETION DEPTH: 22.9 m
REVIEWED BY: WKW	COMPLETION DATE: 10 May 2017
Figure No.	Page 1 of 2

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH01(RUBY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526577.2 E631231.4	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 232 m

SAMPLE TYPE: Shelby Tube | No Recovery | SPT (N) | Grab Sample | Split-Pen | Core

BACKFILL TYPE: Bentonite | Pea Gravel | Drill Cuttings | Grout | Slough | Sand

Depth (m)	▲ UNCONFINED COMPRESSION (kPa) ▲ 100 200 300 400 ■ POCKET PENETROMETER (kPa) ■ 100 200 300 400 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
20				- 100mm thick soft silty clay layer at 18.4m - occasional to frequent silty clay lenses to 18.6m		7			- RQD = 43%, weathered rock from 19.8 to 21.3m	212
21				LIMESTONE - frequent fractures from 18.9m to 19.3m						211
22			LI			8			- RQD = 48%, weathered rock from 21.3 to 22.9m	210
23				- 75mm thick red silty clay layer at 22.4m						209
24				TEST HOLE TERMINATED AT 22.9m BELOW GRADE. NOTES: - Moderate sloughing was encountered below 7.6m below grade. - Slight to moderate seepage observed below 7.6m and significant seepage was observed below 16.5m during drilling. - Test hole remained open to 22.9m below grade after completion of coring. - A 50mm diameter standpipe was installed in the bedrock. - Protected with a flush mount casing and well capped with a J-Plug.						208
25										207
26										206
27										205
28										204
29										203
30										202
31										201
32										200
33										199
34										198
35										197
36										196
37										195
38										194
39										193
40										

WX1793201 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:56 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: AL	COMPLETION DEPTH: 22.9 m
REVIEWED BY: WKW	COMPLETION DATE: 10 May 2017
Figure No.	

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH02(RUBY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526620.8 E631249.8	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 231.48 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand

Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
0		ASPH	ASPHALT - 25mm thick		1				231
		CONC	CONCRETE - 100mm thick		2				
1		GR CH	GRAVEL (FILL) - sandy, poorly graded, medium to coarse grained, damp, compact (inferred), light greyish brown		3				
			CLAY (FILL) - silty, trace sand, high plastic, moist, firm, grey to dark grey, occasional organic, silt and rootlets inclusions		4				230
2			- stiff below 0.8m		5				
			- very stiff, brown, occasional to frequent silt inclusions below 1.5m		6				229
3					7				
			CLAY (ALLUVIAL) - silty, medium to high plastic, moist, stiff, greyish brown, occasional light grey silt lenses ~2mm thick		8			- Sample 8 @ 3.0m: Unconfined Compressive Strength = 131.8 kPa Bulk Density = 2007 kg/m^3	228
4			- occasional silt inclusions below 2.6m						
		CI-CH	- firm to stiff, brown, frequent sand inclusions, occasional rootlets at 3.7m		9				227
5			- firm below 4.6m						
									226
6					10				
					11			- Sample 11 @ 6.1m: Unconfined Compressive Strength = 108.1 kPa Bulk Density = 1980 kg/m^3	225
					12				
7			- occasional to frequent very moist to wet silt and sand pockets ~5mm diameter at 6.9m						224
			- occasional sand inclusions below 7.6m		13	15		- shelby tube wet, suspected slight seepage at 6.7m	
8			SAND - poorly graded, fine to medium grained, compact, wet, greyish brown						223
		SP	- trace to some silt and clay below 8.2m		14				
9			- no silt or clay at 8.8m		15	13			222
			- medium grained below 9.1m						
10			- some gravel ~20mm diameter, angular, medium to coarse grained below 9.5m		16				
			CLAY (LACUSTRINE) - silty, high plastic, very moist, soft to firm, dark grey, occasional sand and sulphate inclusions		17				221
11			- soft, no sand inclusions below 10.5m		18	9			
		CH							220
12					19				
					20			Hydrometer Analysis Results @ "12.0m": Gravel= 1.5% Sand= 14.4% Silt= 24.0% Clay= 60.0%	219
13					21				
		ML	SILT (TILL) - sandy, some clay, trace gravel, low plastic, very moist, light greyish brown						218
14			SAND (TILL) - some silt to silty, some gravel to gravelly, mosit, dense, light greyish brown, sub-angular gravel (<25mm dia.)		22	50			
			- gravelly, very dense, occasional limestone inclusions below 14.5m		23				217
15		SP-SM	- dense, occasional to frequent very moist sand inclusions below 15.7m		24	64			
			- cobbles and boulders below 15.9m		25				
					26	49		Hydrometer Analysis Results @ "15.1m": Gravel= 26.2% Sand= 44.1% Silt= 23.2% Clay= 6.6%	216
16					27				
					28	87/350			215
17			BEDROCK (LIMESTONE)		29				
		LI	- highly fractured below 17.1m		30				
18					31			- samples washed off augers, no sample recovery at 16.0m - Auger refusal @ 16.8m - samples washed off augers, no sample recovery at 16.8m	214
		CL-ML	CLAY - and silt, trace gravel, low to non-plastic, moist, grey,						
19			- damp, reddish orange below 18.3m		32			- RQD = 70.0%, moderately weathered rock at 16.8m - RQD = 7.7%, completely weathered rock at 17.1m	213
		LI	LIMESTONE- highly fractured, 40mm thick silt seam at 18.9m						
20			- occasional to frequent fractures, occasional oxidized					- RQD = 52.6%, moderately	212

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH02(RUBY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526620.8 E631249.8	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 231.48 m

SAMPLE TYPE: Shelby Tube | No Recovery | SPT (N) | Grab Sample | Split-Pen | Core

BACKFILL TYPE: Bentonite | Pea Gravel | Drill Cuttings | Grout | Slough | Sand

Depth (m)	▲ UNCONFINED COMPRESSION (kPa) ▲ 100 200 300 400 ■ POCKET PENETROMETER (kPa) ■ 100 200 300 400 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
20				inclusions within fractures below 19.7m		33			weathered rock at 19.7m	211
21				- 25mm thick light greyish silt lens at 21.0m - occasional fractures below 21.0m		34			- RQD = 78%, moderately weathered rock from 21.0 to 21.9m	210
22			LI	- 25mm thick reddish brown silt seam at 22.2m		35			- RQD = 79% from 21.9 to 22.9m	209
23				TEST HOLE TERMINATED AT 22.9m BELOW GRADE. NOTES: - Significant sloughing and seepage was encountered below 7.9m below grade. - Test hole remained open to 19.8m below grade after completion of coring. - A 50mm diameter standpipe was installed in the bedrock. - Protected with a flush mount casing and well capped with a J-Plug.						208
24										207
25										206
26										205
27										204
28										203
29										202
30										201
31										200
32										199
33										198
34										197
35										196
36										195
37										194
38										193
39										192
40										

WX1793201 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:56 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

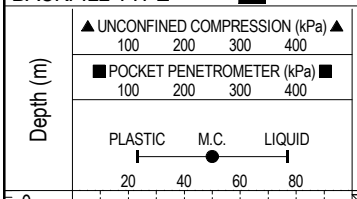
Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: AL	COMPLETION DEPTH: 22.9 m
REVIEWED BY: WKW	COMPLETION DATE: 12 May 2017
Figure No.	Page 2 of 2

PROJECT: Ruby & Aubrey Outfall Chambers	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2016-TH02 (Aubrey)**
CLIENT: MMM Group Limited	DRILL TYPE: Renegade Track Rig	PROJECT NO: WX17932
UTM: N5526584.2 E631082.8	DRILL METHOD: 125mm SSA	ELEVATION: 231.81 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand



Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	WELL INSTALLATION	COMMENTS	ELEVATION (m)
0		OH CH	ORGANIC CLAY (TOPSOIL) - silty, trace sand, high plastic, moist		1				231
1			CLAY (FILL) - silty, trace sand, trace gravel, high plastic, moist, stiff, dark greyish brown mottled light brown, occasional oxidized inclusions		2				230
2			CLAY (ALLUVIAL) - silty, trace sand, high plastic, moist, stiff, dark greyish brown, occasional silt inclusions, trace organics, occasional black stains (5mm to 10mm thick) - brown, silty to and silt, firm to soft below 2.0m - silty, sandy and sand, medium plastic, moist, very stiff below 3.0m - high plastic, dark greyish brown, occasional silt lenses (1mm to 2mm thick), occasional oxidized inclusions below 3.7m		3			Ground water level: - 8.8m below ground surface on 12/05/2016 - 7.2m below ground surface on 31/05/2016	229
3					4				228
4					5				227
5					6				226
6		CI-CH	- medium to high plastic, moist, stiff, dark greyish brown, some oxidation below 5.0m - wet sand lenses (~1mm to 5mm thick) at 6.7m		7				225
7					8				224
8					9				223
9					10				222
10					11				221
11					12	10		..SPT: 4,4,6; Rec: 410mm	220
12					13				219
13					14				218
14					15				217
15					16				216
16					17				215
17					18	5		Unconfined Compression Test: Sample 14 (7.6m - 8.2m) Max Stress: 101.0 kPa @ 9.8% strain M.C: 33.2% Hydrometer Analysis Results @ "9.1m": Gravel= 0.0% Sand= 5.8% Silt= 59.7% Clay= 34.5%	214
18					19				213
19					20				212
20					21				211
21			- some sand, high plastic, moist to very moist, firm, dark grey, frequent light grey till inclusions (1 to 5 cm dia) below 10.7m						210
22			SILT (TILL) - clayey, some sand, trace gravel, low plastic, compact, very moist to wet, light brown - some clay, some gravel to gravelly, wet below 12.2m		22	20		..SPT: 2,2,3; Rec: full Unconfined Compression Test: Sample 20 (10.6m - 11.2m) Max Stress: 57.2 kPa @ 6.3% strain M.C: 33.3%	
					23				
					24	18		..SPT: 2,9,11; Rec: 300mm	
					25				
					26	16		..SPT: 9,9,9; Rec: 50mm ..SPT: 5,9,7; Rec: 100mm	
		ML	- gravelly, wet, light greyish brown, occasional sand lenses below 14.5m		27	23		..SPT: 10,12,11; Rec: 50mm	
					28	8		..SPT: 5,5,3; Rec: 50mm	
					29			..SPT: 10/50mm	
			AUGER REFUSAL AT 17.2m BELOW GRADE. Notes: - Seepage & sloughing observed below 11.3 m on completion of drilling. - Seepage observed at the sand lenses at 6.7 m during drilling. - Test hole remained open to 17.2m and water level at 8.8m below grade was observed prior to backfilling. - One 25mm diameter standpipe installed on completion of drilling.						

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: KE	COMPLETION DEPTH: 17.2 m
REVIEWED BY: WKW	COMPLETION DATE: 12 May 2016
Figure No. A02	Page 1 of 1

WX17932 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:52 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH01(AUBREY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526572.8 E631077.9	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 231.53 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand

▲ UNCONFINED COMPRESSION (kPa) ▲ 100 200 300 400

■ POCKET PENETROMETER (kPa) ■ 100 200 300 400

PLASTIC M.C. LIQUID 20 40 60 80

Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
0			OVERBURDEN DRILLED OUT TO 6.1m, SOIL SAMPLING TO BEGIN FROM THIS POINT.						231
1									230
2									229
3									228
4									227
5									226
6			CLAY - silty, high plastic, moist, stiff, greyish brown, occasional silt inclusions		1				225
7									224
8		CH	- and silt, some fine grained sand, very moist, very soft, mottled grey and brown below 7.6m - grey, occasional black organic staining below 8.5m		2				223
9			- firm, grey to dark grey, occasional silt lenses ~2mm thick below 9.1m		3				222
10									221
11			SILT (TILL) - gravelly, some sand, trace clay, low plastic, moist to very moist, compact (inferred), dark grey - sandy, compact to dense (inferred), grey below 11.3m		4				220
12					5				219
13									218
14			- wet below 13.7m		6				217
15		ML			7				216
16			- occasional gravel limestone pieces ~50mm diameter, angular below 15.2m - gravelly and sandy below 16.2m						215
17					8				214
18									213
19					9			- suspected samples may have washed off during drilling.	212
20					10				

WX1793201 - RUBY & AUBREY OUTFALL CHAMBERS.GPJ 17/09/05 01:55 PM (GEOTECHNICAL REVISED WITH UTM INPUTS)

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: AL	COMPLETION DEPTH: 25.9 m
REVIEWED BY: WKW	COMPLETION DATE: 9 May 2017
Figure No.	Page 1 of 2

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH01(AUBREY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526572.8 E631077.9	DRILL METHOD: 125mm SSA & HQ Coring	ELEVATION: 231.53 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand

▲ UNCONFINED COMPRESSION (kPa) ▲ 100 200 300 400

■ POCKET PENETROMETER (kPa) ■ 100 200 300 400

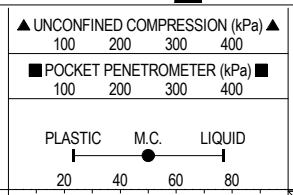
PLASTIC M.C. LIQUID 20 40 60 80

Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	SLOTTED PIEZOMETER	COMMENTS	ELEVATION (m)
20		ML							211
21		BR	- harder drilling, frequent limestone pieces below 20.7m AUGER REFUSAL ON SUSPECTED BEDROCK OR COBBLES AT 21.0m		11 12			- switch to coring from solid stem augers at 21.0m	210
22		LI	BEDROCK AND COBBLES LIMESTONE - tan to light grey, occasional to frequent oxidation		13			- suspected silty and fine grained sand, possibly washed away, no sample from 22.0m to 22.9m	209
23		CL	CLAY - silty, trace sand and gravel, low plastic, moist, stiff, greysih brown		14				208
24		LI	LIMESTONE		15				207
25		CL	- occasional clay seam ~10mm thick at 24.5m CLAY - silty, some sand to sandy, low plastic, moist to very moist, firm, grey		16				206
26			- sandy, increased silt content, wet, greyish brown TEST HOLE TERMINATED AT 25.9m BELOW GRADE.						205
27			NOTES: - Moderate to significant sloughing was encountered below 10.5m below grade.						204
28			- Significant seepage was observed from 13.7m during drilling.						203
29			- Test hole remained open to 21.6m below grade after completion of coring.						202
30			- A 50mm diameter standpipe was installed in the bedrock.						201
31			- Protected with a flush mount casing and well capped with a J-Plug.						200
32									199
33									198
34									197
35									196
36									195
37									194
38									193
39									192
40									

PROJECT: Ruby & Aubrey St. Outfall Chamber Upgrades	DRILLED BY: Maple Leaf Drilling Ltd.	BORE HOLE NO: **2017-TH02(AUBREY)**
CLIENT: City of Winnipeg	DRILL TYPE: Track Mounted Acker Renegade	PROJECT NO: WX1793201
UTM: N5526574.5 E631078.3	DRILL METHOD: 125mm Solid Stem Augers	ELEVATION: 231.57 m

SAMPLE TYPE: Shelby Tube; No Recovery; SPT (N); Grab Sample; Split-Pen; Core

BACKFILL TYPE: Bentonite; Pea Gravel; Drill Cuttings; Grout; Slough; Sand

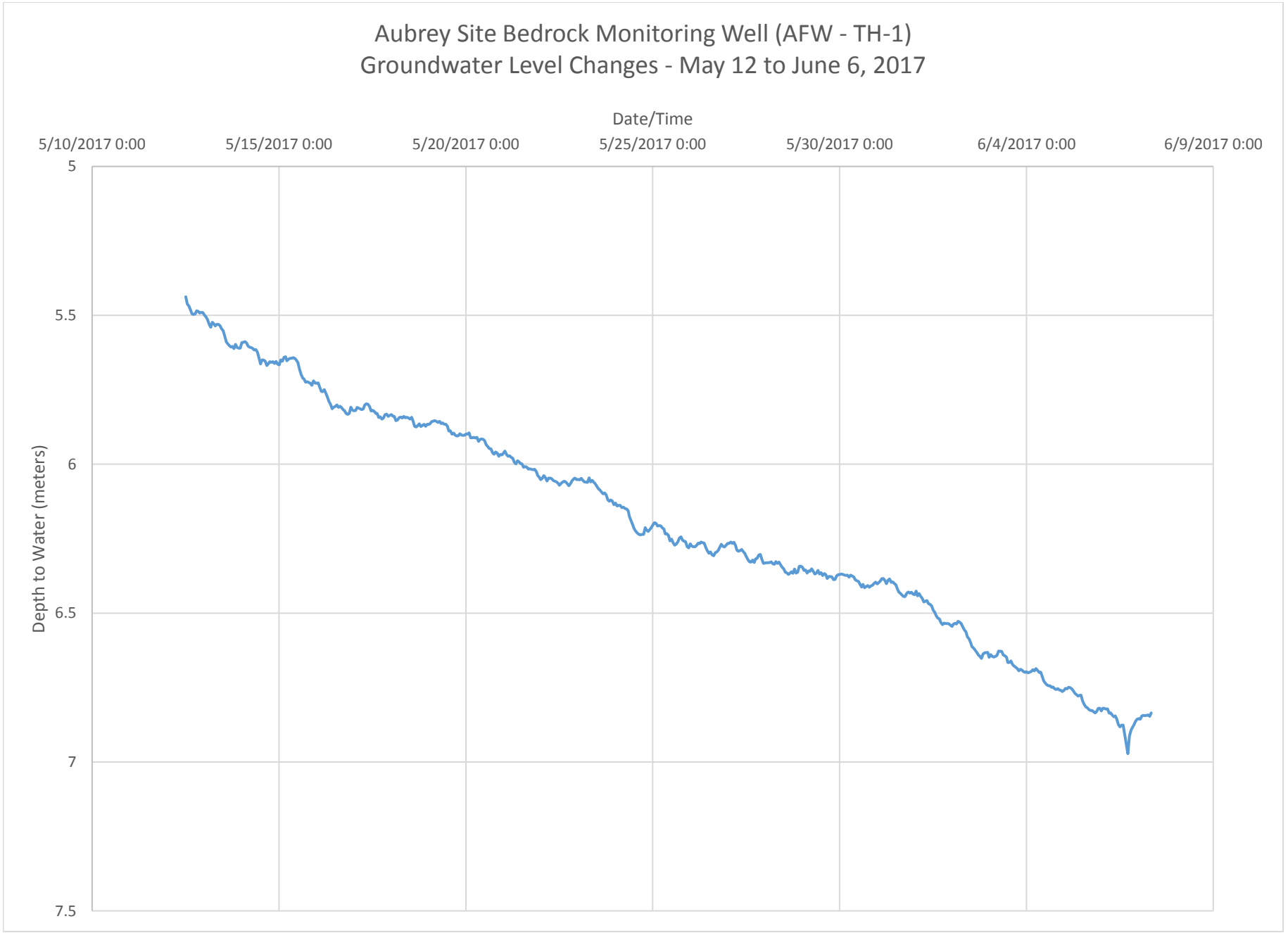


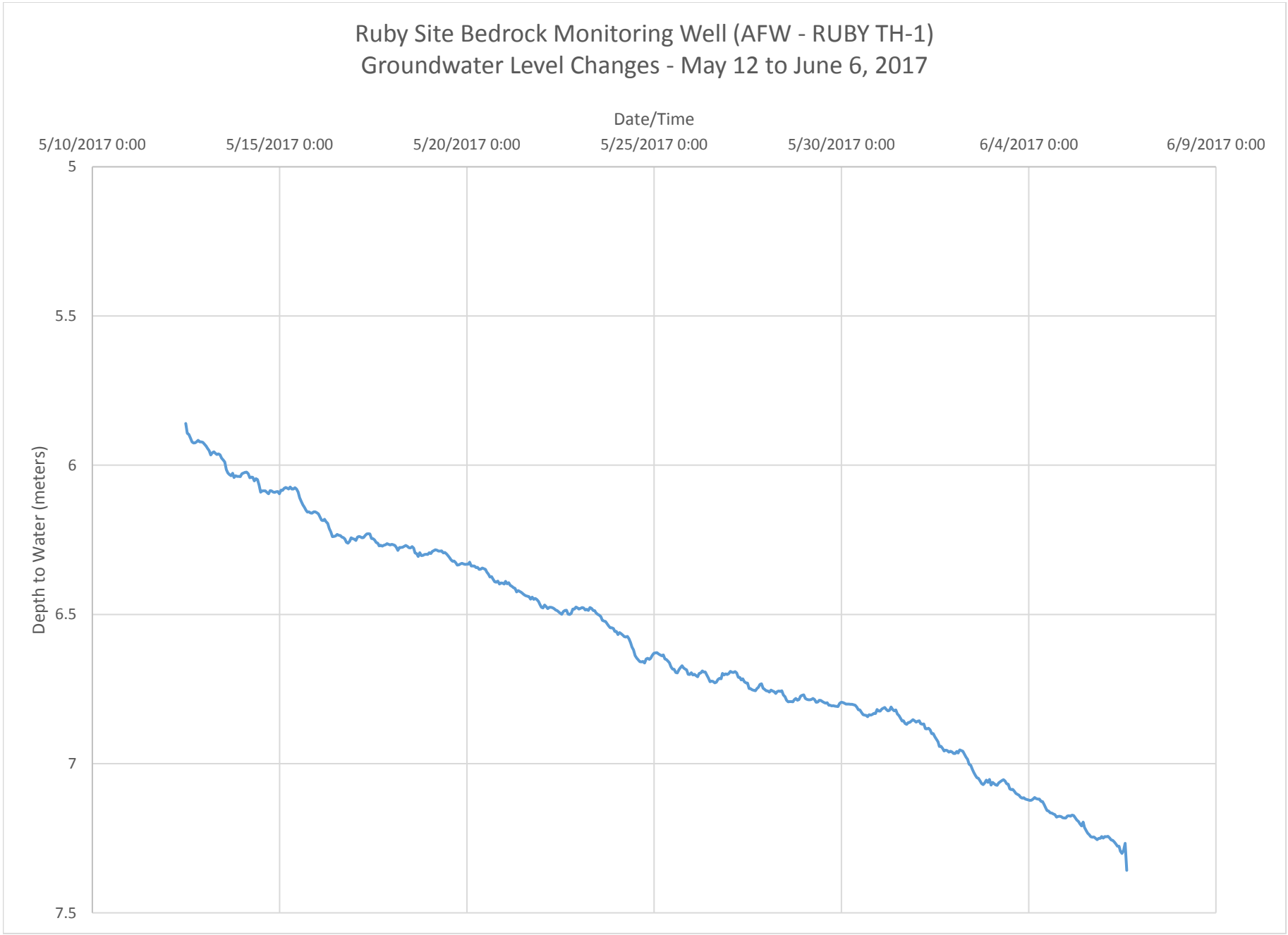
Depth (m)	SOIL SYMBOL	MUSCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	COMMENTS	ELEVATION (m)
0		OL	TOPSOIL (GRASS) - 25mm thick		1			231
1		CH	CLAY (FILL) - silty, trace sand, high plastic, moist, stiff, greyish brown, occasional organic clay inclusions and rootlets		2			
2			CLAY (ALLUVIAL) - silty, trace sand, high plastic, moist, stiff, brown - brown to dark brown occasional fine silt lenses ~1mm thick below 1.5m - very stiff below 2.1m - brown, occasional oxidation and sulphate inclusions below 3.1m - increased silt content from 3.7m to 5.2m		3			230
3					4			229
4					5			228
5		CH	- firm, no oxidation and sulphate inclusions below 4.6m		6			227
6			- stiff below 6.1m		7			226
7			- soft to firm below 6.7m		8			225
8					9 10 11			224 223
9			- very moist to moist, very soft, occasional oxidation inclusions below 8.4m - firm, grey to dark grey below 8.5m		12			222
10			TEST HOLE TERMINATED AT 9.1m BELOW GRADE. NOTES: - Slight sloughing was encountered below 8.2m below grade. - Moderate seepage was observed from 8.4m during drilling. - Test hole remained open to 9.0m below grade after completion of drilling. - Water level was measured to 8.2m below grade after completion of drilling. - A single Vibrating Wire (S/N: VW43218) was installed to a depth of 8.8m below grade and fully grouted. - Protected with an above ground steel casing.					221
11								220
12								219
13								218
14								217
15								216
16								215
17								214
18								213
19								212
20								

Amec Foster Wheeler
Winnipeg, Manitoba

LOGGED BY: AL	COMPLETION DEPTH: 9.1 m
REVIEWED BY: WKW	COMPLETION DATE: 9 May 2017
Figure No.	Page 1 of 1

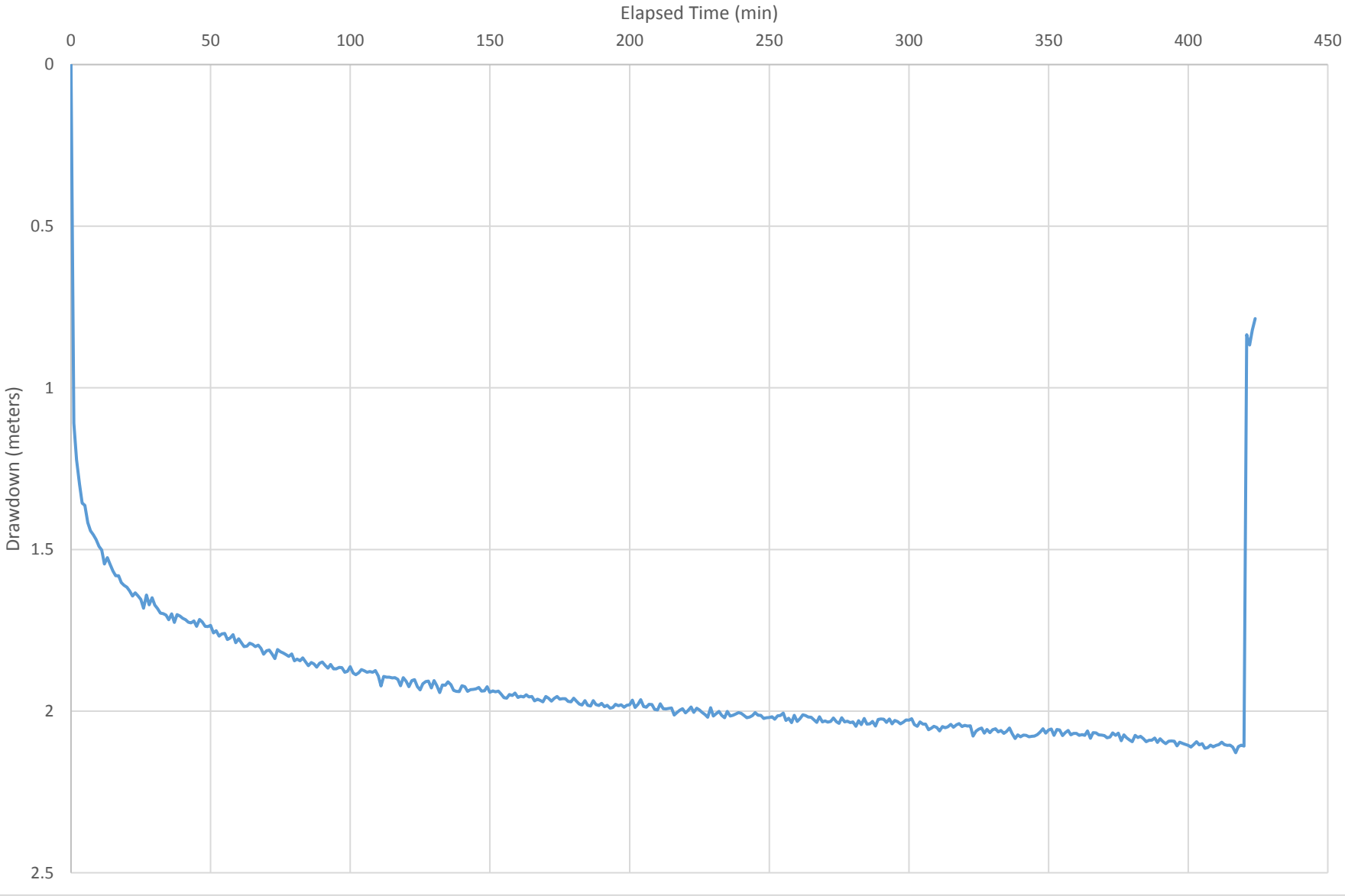
Appendix C
Groundwater Monitoring Results


Aubrey Site Bedrock Monitoring Well (AFW - TH-1)
Groundwater Level Changes - May 12 to June 6, 2017
Date/Time
5/10/2017 0:00
5/15/2017 0:00
5/20/2017 0:00
5/25/2017 0:00
5/30/2017 0:00
6/4/2017 0:00
6/9/2017 0:00
Depth to Water (meters)
5
5.5
6
6.5
7
7.5

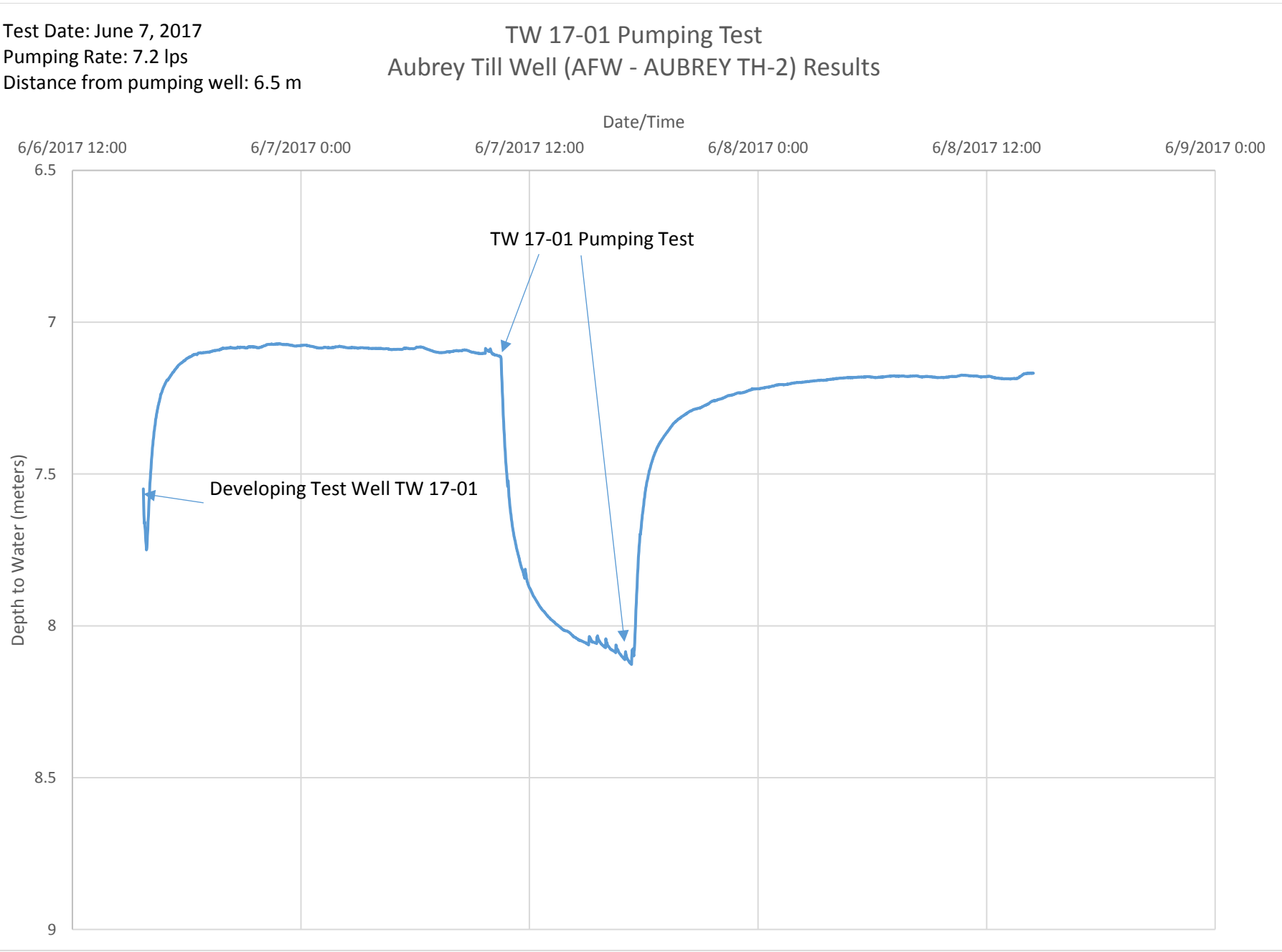

Ruby Site Bedrock Monitoring Well (AFW - RUBY TH-1)
Groundwater Level Changes - May 12 to June 6, 2017
Date/Time
5/10/2017 0:00
5/15/2017 0:00
5/20/2017 0:00
5/25/2017 0:00
5/30/2017 0:00
6/4/2017 0:00
6/9/2017 0:00
Depth to Water (meters)
5
5.5
6
6.5
7
7.5

Test Date: June 7, 2017
Pumping Rate: 7.2 lps
Measurements in pumping well

TW 17-01 Pumping Test
Test Well TW 17-01 Results

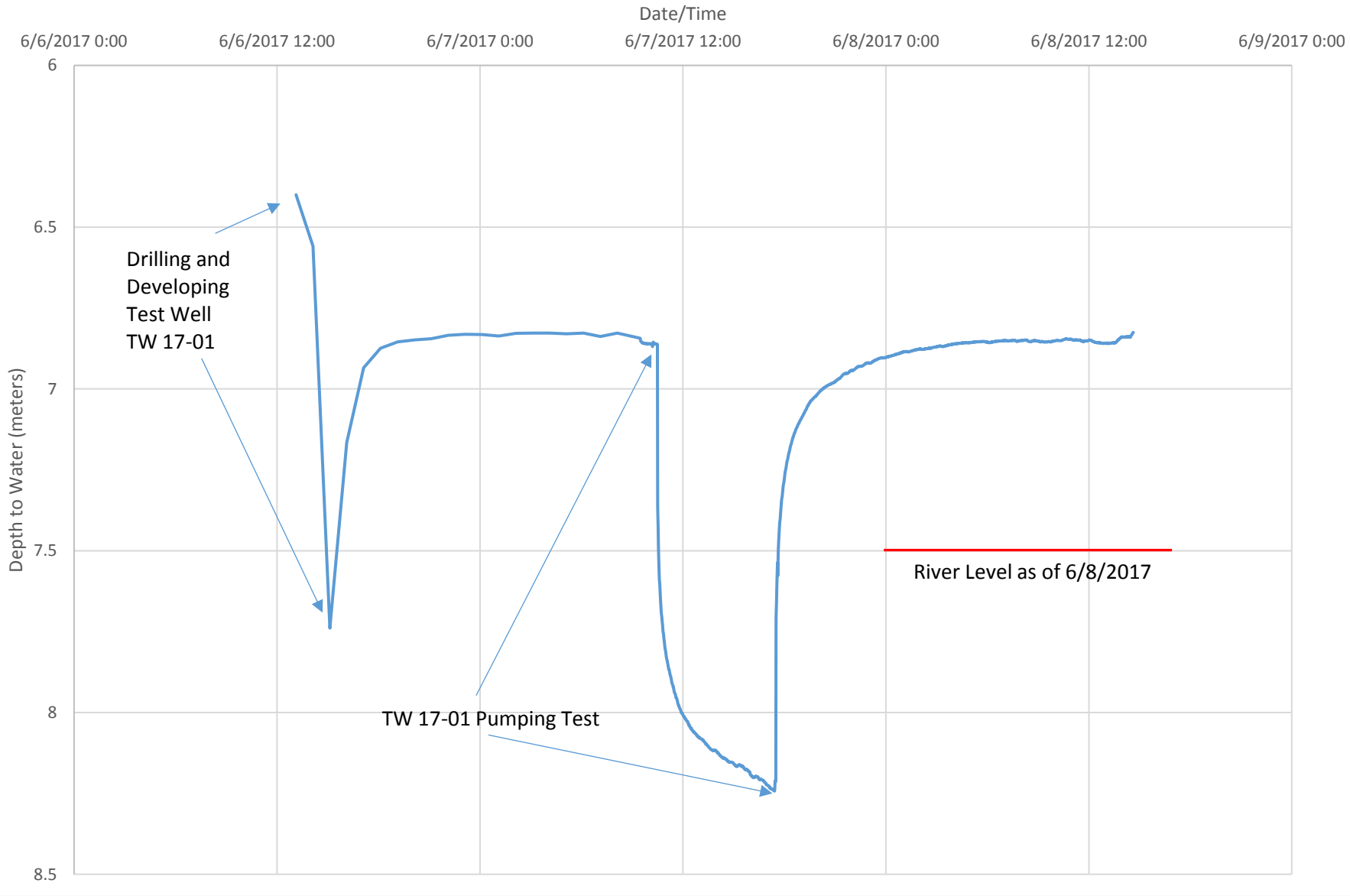


Test Date: June 7, 2017
Pumping Rate: 7.2 lps
Distance from pumping well: 6.5 m



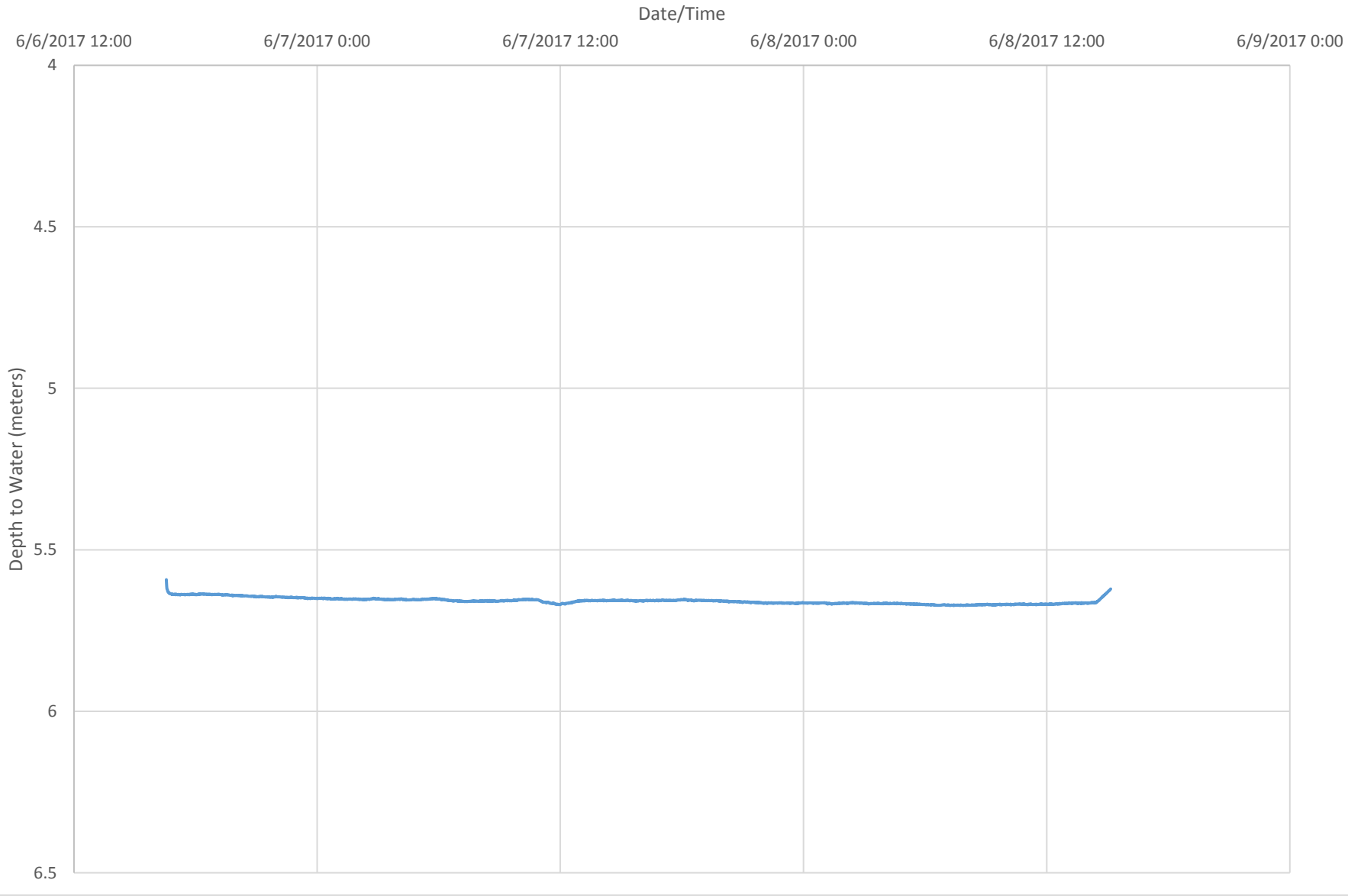
Test Date: June 7, 2017
Pumping Rate: 7.2 lps
Distance from pumping well: 6.0 m

TW 17-01 Pumping Test
Aubrey Site Bedrock Monitoring Well (AFW - Aubrey TH-1) Results



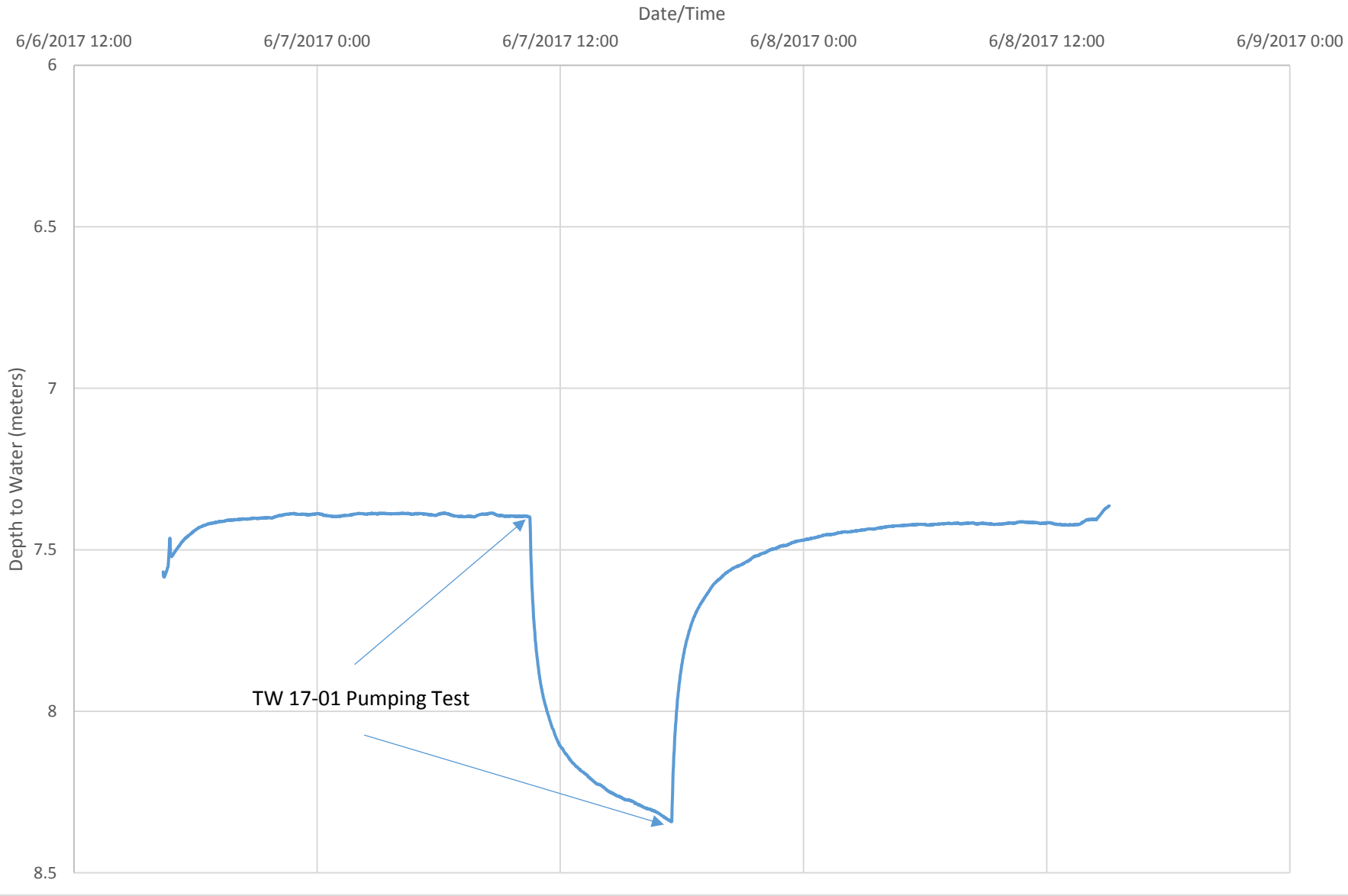
Test Date: June 7, 2017
Pumping Rate: 7.2 lps
Distance from pumping well: 150.0 m

TW 17-01 Pumping Test
Ruby Till Well (AFW - TH-1) Results



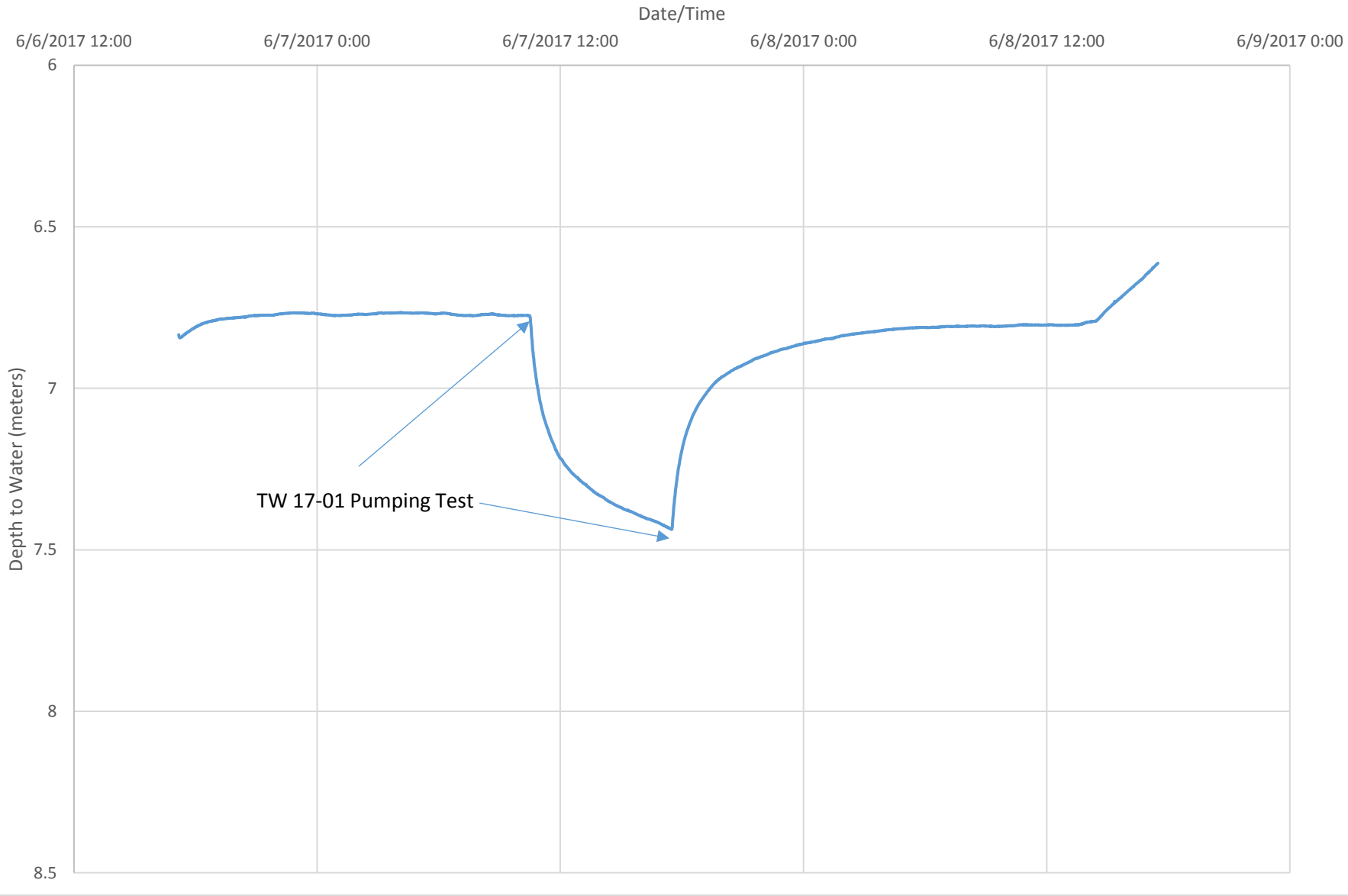
Test Date: June 7, 2017
Pumping Rate: 7.2 lps
Distance from pumping well: 150.0 m

TW 17-01 Pumping Test
Ruby On-site Bedrock Well (AFW - Ruby TH-1) Results

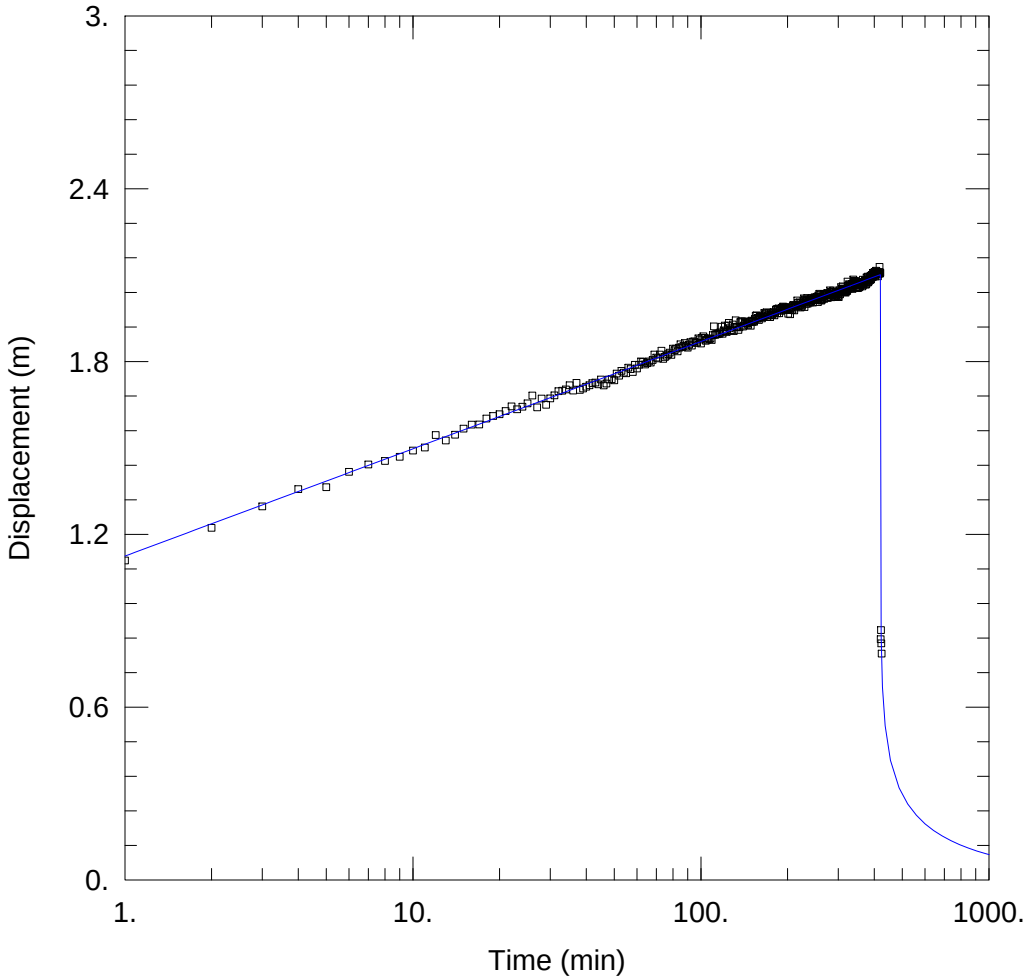


Test Date: June 7, 2017
Pumping Rate: 7.2 lps
Distance from pumping well: 170.0 m

TW 17-01 Pumping Test
Ruby Street Bedrock Well (AFW - Ruby TH-2) Results



Appendix D
Pumping Test Analysis



WELL TEST ANALYSIS

Data Set: C:\...\TW 17-01.aqt
Date: 06/29/17 Time: 15:50:25

PROJECT INFORMATION

Company: W.L. Gibbons & Associates
Client: City of Winnipeg
Project: Aubrey
Test Well: TW 17-01
Test Date: 2017/06/07

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TW 17-01	0	0

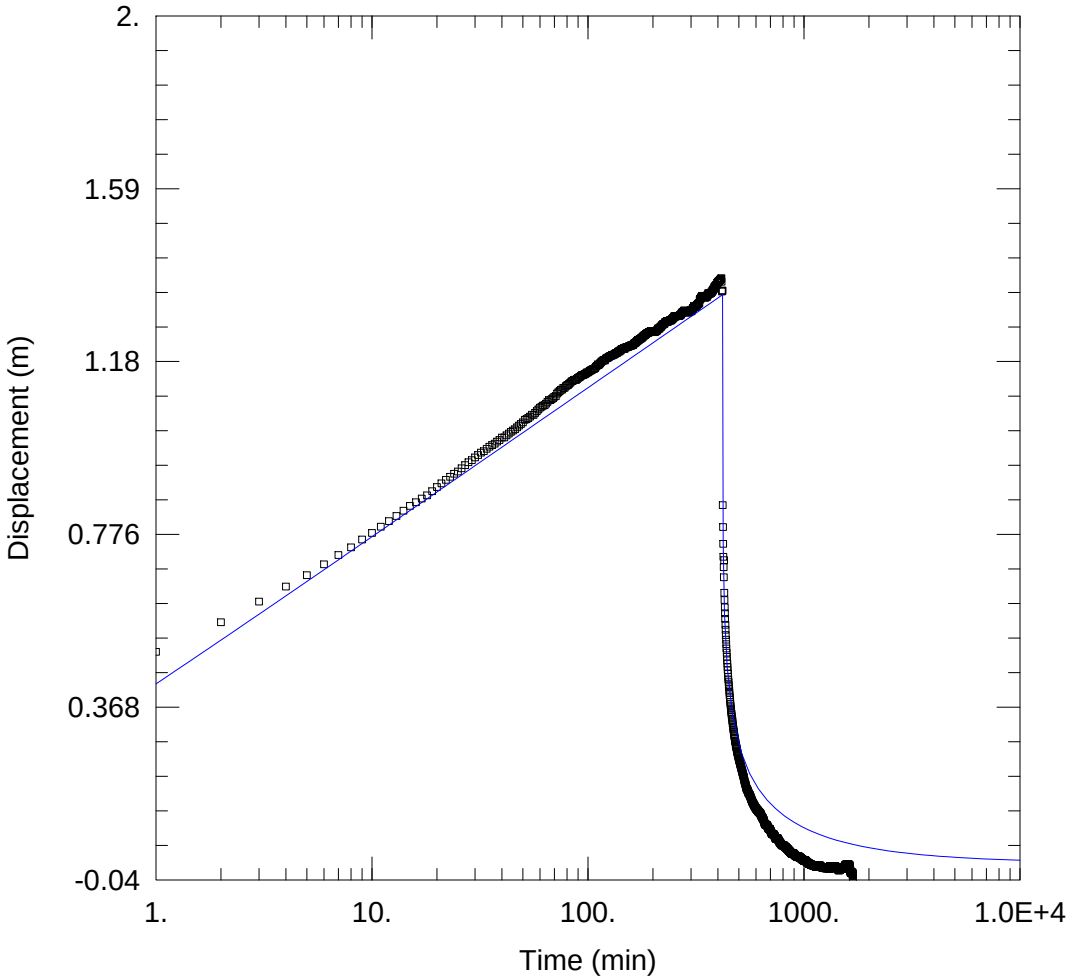
Observation Wells

Well Name	X (m)	Y (m)
TW 17-01	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2.463E+4 gal/day/ft
S = 0.0004576
Kz/Kr = 1.
b = 25. m



WELL TEST ANALYSIS

Data Set: C:\...\Aubrey Bedrock.aqt
Date: 06/29/17 Time: 15:51:30

PROJECT INFORMATION

Company: W.L. Gibbons & Associates
Client: City of Winnipeg
Project: Aubrey
Test Well: TW 17-01
Test Date: 2017/06/07

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TW 17-01	0	0

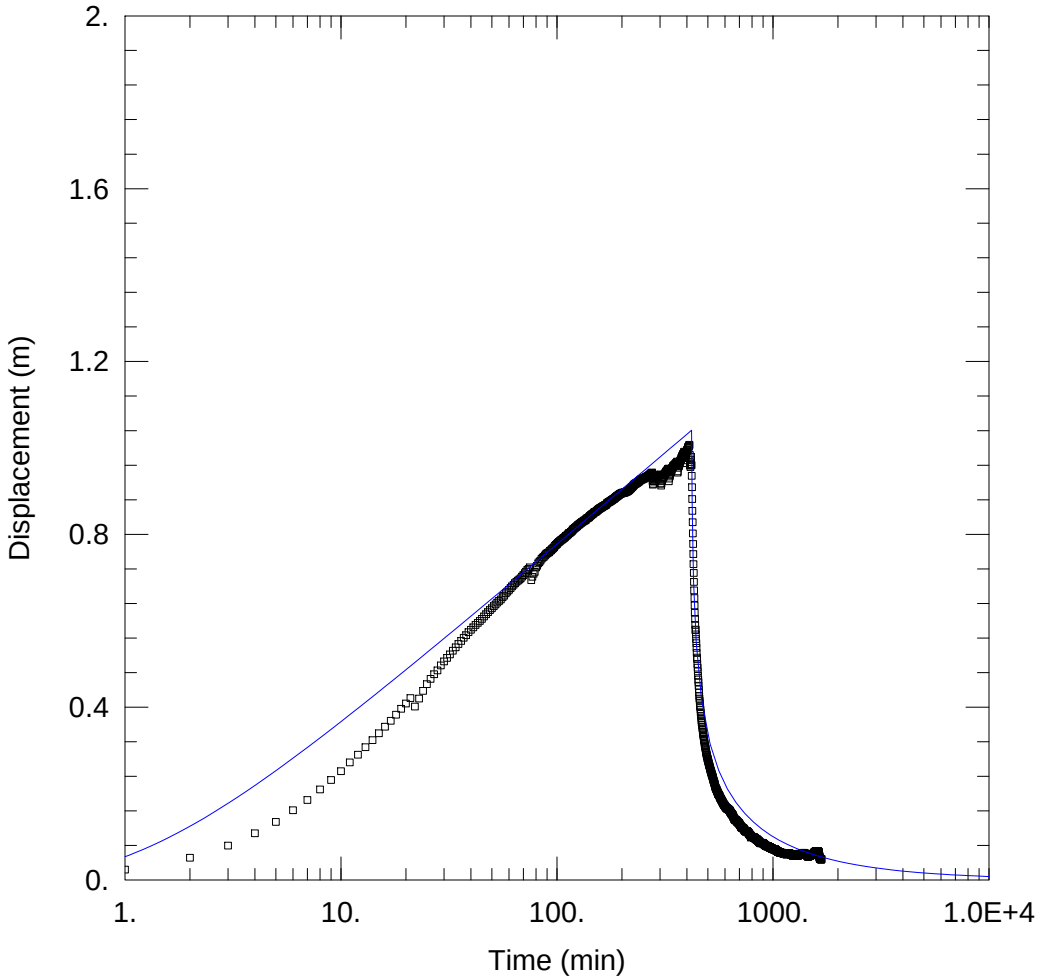
Observation Wells

Well Name	X (m)	Y (m)
▫ Aubrey Bedrock	6	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2.604E+4 gal/day/ft
S = 0.0009165
Kz/Kr = 1.
b = 25. m



WELL TEST ANALYSIS

Data Set: C:\...\Aubrey Till.aqt
Date: 06/29/17 Time: 15:52:13

PROJECT INFORMATION

Company: W.L. Gibbons & Associates
Client: City of Winnipeg
Project: Aubrey
Test Well: TW 17-01
Test Date: 2017/06/07

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TW 17-01	0	0

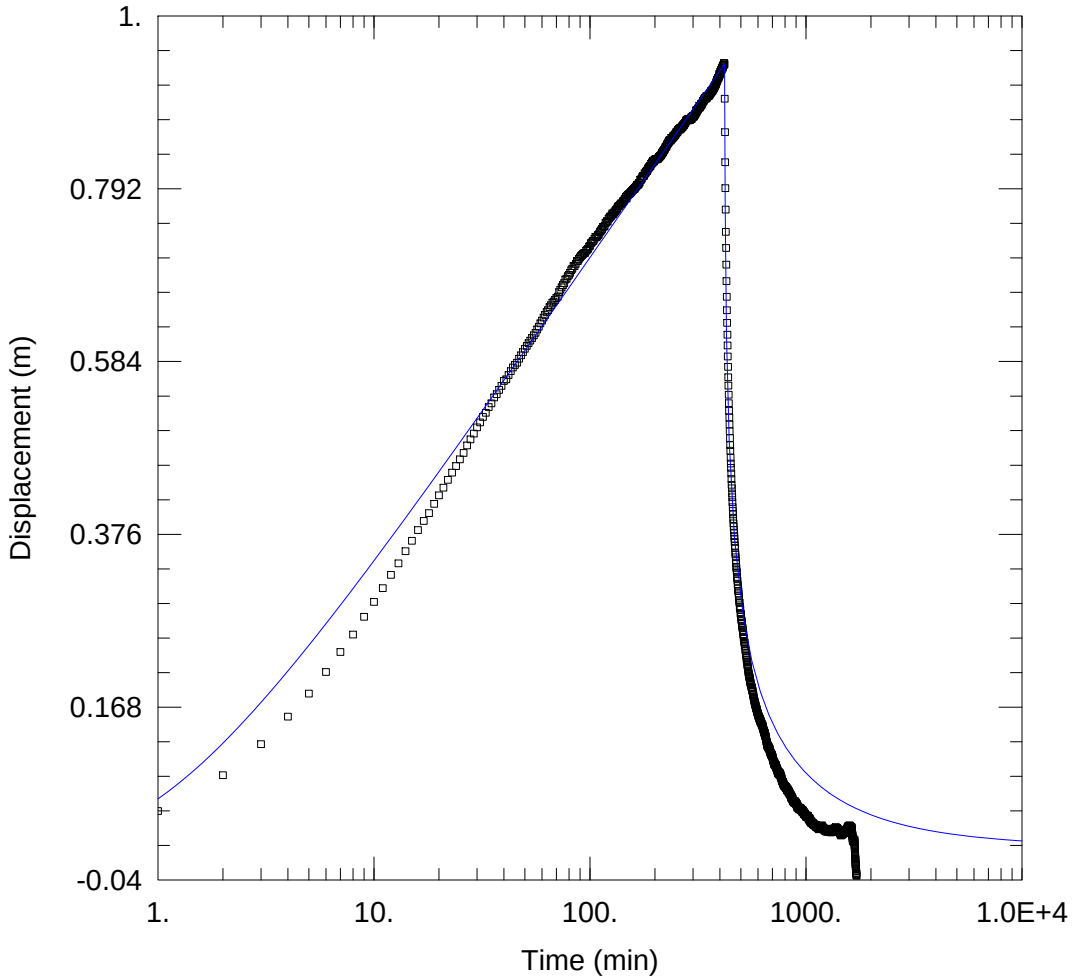
Observation Wells

Well Name	X (m)	Y (m)
▫ Aubrey Till	6.5	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2.161E+4 gal/day/ft
Kz/Kr = 1.
S = 0.01475
b = 25. m



WELL TEST ANALYSIS

Data Set: C:\...\Ruby On-Site Bedrock.aqt
Date: 06/29/17 Time: 15:52:44

PROJECT INFORMATION

Company: W.L. Gibbons & Associates
Client: City of Winnipeg
Project: Aubrey
Test Well: TW 17-01
Test Date: 2017/06/07

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TW 17-01	0	0

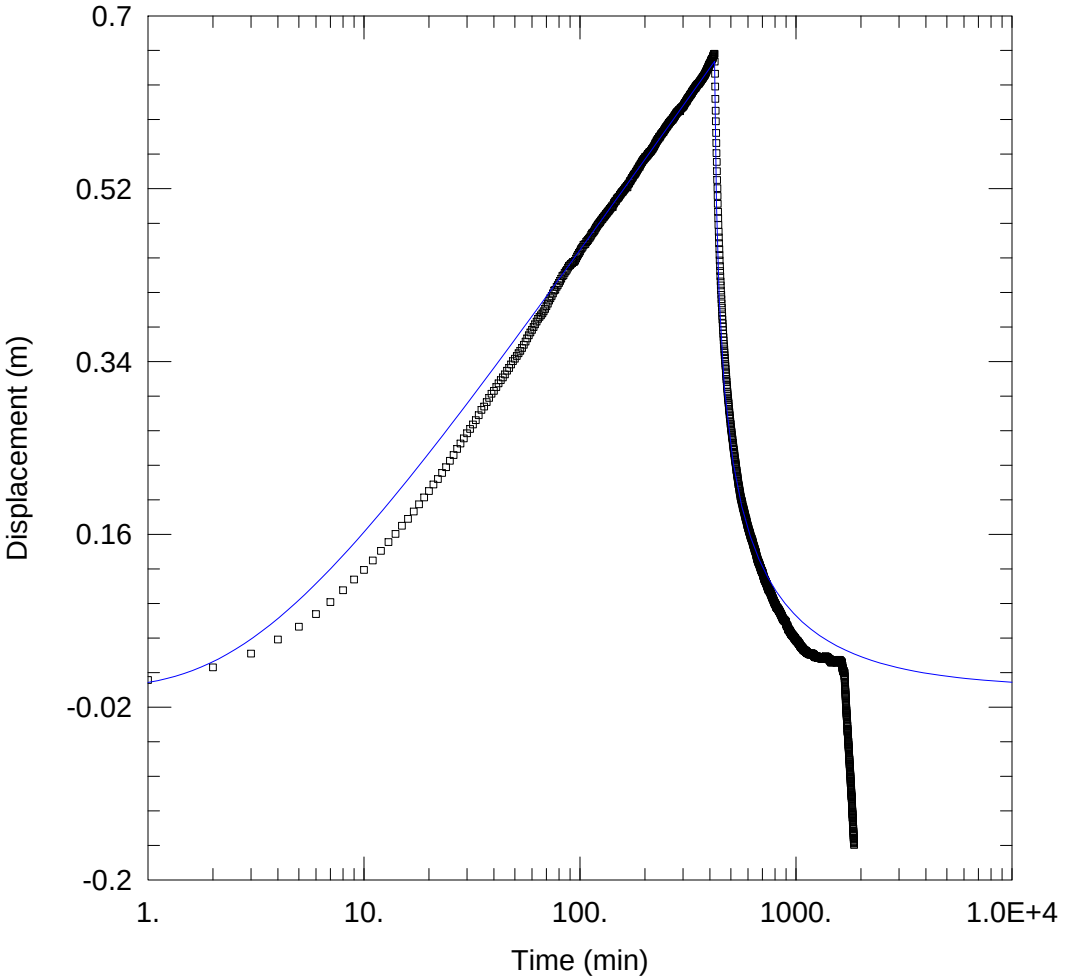
Observation Wells

Well Name	X (m)	Y (m)
▫ Ruby On-site Bdrk	150	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2.444E+4 gal/day/ft
S = 2.738E-5
Kz/Kr = 1.
b = 25. m



WELL TEST ANALYSIS

Data Set: C:\...\Ruby Street Bedrock.aqt
Date: 06/29/17 Time: 15:53:11

PROJECT INFORMATION

Company: W.L. Gibbons & Associates
Client: City of Winnipeg
Project: Aubrey
Test Well: TW 17-01
Test Date: 2017/06/07

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
TW 17-01	0	0

Observation Wells

Well Name	X (m)	Y (m)
▫ Ruby Street Bdrk	170	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 2.878E+4 gal/day/ft
S = 7.313E-5
Kz/Kr = 1.
b = 25. m

Appendix E
Laboratory Certificate of Analysis

WL Gibbons & Associates Inc.
ATTN: STEVE WIECEK
64 St. Andrew Road
Winnipeg MB R2M 3H6

Date Received: 08-JUN-17
Report Date: 14-JUN-17 14:59 (MT)
Version: FINAL

Client Phone: 204-771-4389

Certificate of Analysis

Lab Work Order #: L1938516

Project P.O. #: NOT SUBMITTED
Job Reference: AUBERG
C of C Numbers:
Legal Site Desc:

Hua Wo
Chemistry Laboratory Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1938516-1 TW 17-01-30							
Sampled By: SJW on 07-JUN-17							
Matrix:							
Total Coliform and E.coli							
Total Coliforms	5		0	MPN/100mL		08-JUN-17	R3743489
Escherichia Coli	0		0	MPN/100mL		08-JUN-17	R3743489
MB Conservation test 72D							
Alkalinity, Bicarbonate							
Bicarbonate (HCO3)	447		1.2	mg/L		09-JUN-17	
Alkalinity, Carbonate							
Carbonate (CO3)	<0.60		0.60	mg/L		09-JUN-17	
Alkalinity, Hydroxide							
Hydroxide (OH)	<0.34		0.34	mg/L		09-JUN-17	
Alkalinity, Total (as CaCO3)							
Alkalinity, Total (as CaCO3)	366		1.0	mg/L		08-JUN-17	R3743451
Ammonia by colour							
Ammonia, Total (as N)	0.213		0.010	mg/L		08-JUN-17	R3743360
Chloride in Water by IC							
Chloride (Cl)	326		5.0	mg/L		09-JUN-17	R3746506
Colour, True							
Colour, True	<5.0		5.0	CU		09-JUN-17	R3746697
Conductivity							
Conductivity	2050		1.0	umhos/cm		08-JUN-17	R3743451
Fluoride in Water by IC							
Fluoride (F)	0.34		0.20	mg/L		09-JUN-17	R3746506
Hardness Calculated							
Hardness (as CaCO3)	684	HTC	0.25	mg/L		12-JUN-17	
Ion Balance Calculation							
Cation - Anion Balance	5.8			%		13-JUN-17	
Anion Sum	23.6			me/L		13-JUN-17	
Cation Sum	26.5			me/L		13-JUN-17	
Langelier Index 4C							
Langelier Index (4 C)	0.14					13-JUN-17	
Langelier Index 60C							
Langelier Index (60 C)	0.89					13-JUN-17	
Nitrate in Water by IC							
Nitrate (as N)	<0.20	DLM	0.20	mg/L		09-JUN-17	R3746506
Nitrate+Nitrite							
Nitrate and Nitrite as N	<0.22		0.22	mg/L		13-JUN-17	
Nitrite in Water by IC							
Nitrite (as N)	<0.10	DLM	0.10	mg/L		09-JUN-17	R3746506
Sulfate in Water by IC							
Sulfate (SO4)	338		3.0	mg/L		09-JUN-17	R3746506
Total Carbon by Calculation							
Total Carbon	76.7		1.0	mg/L		12-JUN-17	
Total Dissolved Solids (TDS)							
Total Dissolved Solids	1440		20	mg/L		12-JUN-17	R3746423
Total Inorganic Carbon by Combustion							
Total Inorganic Carbon	75.5		0.50	mg/L		08-JUN-17	R3743698
Total Kjeldahl Nitrogen							
Total Kjeldahl Nitrogen	0.24		0.20	mg/L	12-JUN-17	14-JUN-17	R3747317
Total Metals by ICP-MS							
Aluminum (Al)-Total	0.0650		0.0050	mg/L	09-JUN-17	09-JUN-17	R3744486
Antimony (Sb)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Arsenic (As)-Total	0.00775		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1938516-1 TW 17-01-30							
Sampled By: SJW on 07-JUN-17							
Matrix:							
Total Metals by ICP-MS							
Barium (Ba)-Total	0.0180		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Beryllium (Be)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Bismuth (Bi)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Boron (B)-Total	0.496		0.010	mg/L	09-JUN-17	09-JUN-17	R3744486
Cadmium (Cd)-Total	<0.000010		0.000010	mg/L	09-JUN-17	09-JUN-17	R3744486
Calcium (Ca)-Total	122		0.10	mg/L	09-JUN-17	09-JUN-17	R3744486
Cesium (Cs)-Total	<0.00010		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Chromium (Cr)-Total	<0.0010		0.0010	mg/L	09-JUN-17	09-JUN-17	R3744486
Cobalt (Co)-Total	0.00032		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Copper (Cu)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Iron (Fe)-Total	0.808		0.010	mg/L	09-JUN-17	09-JUN-17	R3744486
Lead (Pb)-Total	0.000125		0.000090	mg/L	09-JUN-17	09-JUN-17	R3744486
Lithium (Li)-Total	0.113		0.0020	mg/L	09-JUN-17	09-JUN-17	R3744486
Magnesium (Mg)-Total	92.3		0.010	mg/L	09-JUN-17	09-JUN-17	R3744486
Manganese (Mn)-Total	0.0122		0.00030	mg/L	09-JUN-17	09-JUN-17	R3744486
Molybdenum (Mo)-Total	0.00103		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Nickel (Ni)-Total	<0.0020		0.0020	mg/L	09-JUN-17	09-JUN-17	R3744486
Phosphorus (P)-Total	<0.10		0.10	mg/L	09-JUN-17	09-JUN-17	R3744486
Potassium (K)-Total	20.6		0.020	mg/L	09-JUN-17	09-JUN-17	R3744486
Rubidium (Rb)-Total	0.00833		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Selenium (Se)-Total	<0.0010		0.0010	mg/L	09-JUN-17	09-JUN-17	R3744486
Silicon (Si)-Total	7.47		0.10	mg/L	09-JUN-17	09-JUN-17	R3744486
Silver (Ag)-Total	<0.00010		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Sodium (Na)-Total	282		0.030	mg/L	09-JUN-17	09-JUN-17	R3744486
Strontium (Sr)-Total	1.07		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Tellurium (Te)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Thallium (Tl)-Total	<0.00010		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Thorium (Th)-Total	<0.00010		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Tin (Sn)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Titanium (Ti)-Total	0.00275		0.00050	mg/L	09-JUN-17	09-JUN-17	R3744486
Tungsten (W)-Total	<0.00010		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Uranium (U)-Total	0.00115		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Vanadium (V)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Zinc (Zn)-Total	0.0032		0.0020	mg/L	09-JUN-17	09-JUN-17	R3744486
Zirconium (Zr)-Total	<0.00040		0.00040	mg/L	09-JUN-17	09-JUN-17	R3744486
Total Organic Carbon by Combustion							
Total Organic Carbon	1.24		0.50	mg/L		09-JUN-17	R3744763
Turbidity							
Turbidity	9.60		0.10	NTU		09-JUN-17	R3746427
UV Transmittance (Calculated)							
Transmittance, UV (254 nm)	95.5		1.0	%T/cm		09-JUN-17	R3745808
pH							
pH	7.33		0.10	pH units		08-JUN-17	R3743451
L1938516-2 TW 17-01-4							
Sampled By: SJW on 07-JUN-17							
Matrix:							
Total Coliform and E.coli							
Total Coliforms	8		0	MPN/100mL		08-JUN-17	R3743489
Escherichia Coli	0		0	MPN/100mL		08-JUN-17	R3743489

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1938516-3 TW 17-01-F							
Sampled By: SJW on 07-JUN-17							
Matrix:							
Total Coliform and E.coli							
Total Coliforms	18		0	MPN/100mL		08-JUN-17	R3743489
Escherichia Coli	0		0	MPN/100mL		08-JUN-17	R3743489
MB Conservation test 72D							
Alkalinity, Bicarbonate							
Bicarbonate (HCO3)	443		1.2	mg/L		09-JUN-17	
Alkalinity, Carbonate							
Carbonate (CO3)	<0.60		0.60	mg/L		09-JUN-17	
Alkalinity, Hydroxide							
Hydroxide (OH)	<0.34		0.34	mg/L		09-JUN-17	
Alkalinity, Total (as CaCO3)							
Alkalinity, Total (as CaCO3)	363		1.0	mg/L		08-JUN-17	R3743451
Ammonia by colour							
Ammonia, Total (as N)	0.206		0.010	mg/L		08-JUN-17	R3743360
Chloride in Water by IC							
Chloride (Cl)	335		5.0	mg/L		09-JUN-17	R3746506
Colour, True							
Colour, True	<5.0		5.0	CU		09-JUN-17	R3746697
Conductivity							
Conductivity	2060		1.0	umhos/cm		08-JUN-17	R3743451
Fluoride in Water by IC							
Fluoride (F)	0.34		0.20	mg/L		09-JUN-17	R3746506
Hardness Calculated							
Hardness (as CaCO3)	709	HTC	0.25	mg/L		12-JUN-17	
Ion Balance Calculation							
Cation - Anion Balance	6.2			%		13-JUN-17	
Anion Sum	23.9			me/L		13-JUN-17	
Cation Sum	27.1			me/L		13-JUN-17	
Langelier Index 4C							
Langelier Index (4 C)	0.22					13-JUN-17	
Langelier Index 60C							
Langelier Index (60 C)	0.97					13-JUN-17	
Nitrate in Water by IC							
Nitrate (as N)	<0.20	DLM	0.20	mg/L		09-JUN-17	R3746506
Nitrate+Nitrite							
Nitrate and Nitrite as N	<0.22		0.22	mg/L		13-JUN-17	
Nitrite in Water by IC							
Nitrite (as N)	<0.10	DLM	0.10	mg/L		09-JUN-17	R3746506
Sulfate in Water by IC							
Sulfate (SO4)	344		3.0	mg/L		09-JUN-17	R3746506
Total Carbon by Calculation							
Total Carbon	73.6		1.0	mg/L		12-JUN-17	
Total Dissolved Solids (TDS)							
Total Dissolved Solids	1450		20	mg/L		12-JUN-17	R3746423
Total Inorganic Carbon by Combustion							
Total Inorganic Carbon	72.5		0.50	mg/L		08-JUN-17	R3743698
Total Kjeldahl Nitrogen							
Total Kjeldahl Nitrogen	0.22		0.20	mg/L	12-JUN-17	14-JUN-17	R3747317
Total Metals by ICP-MS							
Aluminum (Al)-Total	0.0364		0.0050	mg/L	09-JUN-17	09-JUN-17	R3744486
Antimony (Sb)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Arsenic (As)-Total	0.00776		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1938516-3 TW 17-01-F							
Sampled By: SJW on 07-JUN-17							
Matrix:							
Total Metals by ICP-MS							
Barium (Ba)-Total	0.0181		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Beryllium (Be)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Bismuth (Bi)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Boron (B)-Total	0.518		0.010	mg/L	09-JUN-17	09-JUN-17	R3744486
Cadmium (Cd)-Total	<0.000010		0.000010	mg/L	09-JUN-17	09-JUN-17	R3744486
Calcium (Ca)-Total	129		0.10	mg/L	09-JUN-17	09-JUN-17	R3744486
Cesium (Cs)-Total	<0.00010		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Chromium (Cr)-Total	<0.0010		0.0010	mg/L	09-JUN-17	09-JUN-17	R3744486
Cobalt (Co)-Total	0.00029		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Copper (Cu)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Iron (Fe)-Total	0.880		0.010	mg/L	09-JUN-17	09-JUN-17	R3744486
Lead (Pb)-Total	<0.000090		0.000090	mg/L	09-JUN-17	09-JUN-17	R3744486
Lithium (Li)-Total	0.120		0.0020	mg/L	09-JUN-17	09-JUN-17	R3744486
Magnesium (Mg)-Total	94.2		0.010	mg/L	09-JUN-17	09-JUN-17	R3744486
Manganese (Mn)-Total	0.0119		0.00030	mg/L	09-JUN-17	09-JUN-17	R3744486
Molybdenum (Mo)-Total	0.00101		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Nickel (Ni)-Total	<0.0020		0.0020	mg/L	09-JUN-17	09-JUN-17	R3744486
Phosphorus (P)-Total	<0.10		0.10	mg/L	09-JUN-17	09-JUN-17	R3744486
Potassium (K)-Total	21.0		0.020	mg/L	09-JUN-17	09-JUN-17	R3744486
Rubidium (Rb)-Total	0.00849		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Selenium (Se)-Total	<0.0010		0.0010	mg/L	09-JUN-17	09-JUN-17	R3744486
Silicon (Si)-Total	7.65		0.10	mg/L	09-JUN-17	09-JUN-17	R3744486
Silver (Ag)-Total	<0.00010		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Sodium (Na)-Total	283		0.030	mg/L	09-JUN-17	09-JUN-17	R3744486
Strontium (Sr)-Total	1.12		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Tellurium (Te)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Thallium (Tl)-Total	<0.00010		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Thorium (Th)-Total	<0.00010		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Tin (Sn)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Titanium (Ti)-Total	0.00161		0.00050	mg/L	09-JUN-17	09-JUN-17	R3744486
Tungsten (W)-Total	<0.00010		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Uranium (U)-Total	0.00116		0.00010	mg/L	09-JUN-17	09-JUN-17	R3744486
Vanadium (V)-Total	<0.00020		0.00020	mg/L	09-JUN-17	09-JUN-17	R3744486
Zinc (Zn)-Total	<0.0020		0.0020	mg/L	09-JUN-17	09-JUN-17	R3744486
Zirconium (Zr)-Total	<0.00040		0.00040	mg/L	09-JUN-17	09-JUN-17	R3744486
Total Organic Carbon by Combustion							
Total Organic Carbon	1.15		0.50	mg/L		09-JUN-17	R3744763
Turbidity							
Turbidity	10.2		0.10	NTU		09-JUN-17	R3746427
UV Transmittance (Calculated)							
Transmittance, UV (254 nm)	95.3		1.0	%T/cm		09-JUN-17	R3745808
pH							
pH	7.40		0.10	pH units		08-JUN-17	R3743451

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects (e.g. chemical interference, colour, turbidity).
HTC	Hardness was calculated from Total Ca and/or Mg concentrations and may be biased high (dissolved Ca/Mg results unavailable).
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-CO3CO3-CALC-WP	Water	Alkalinity, Carbonate	CALCULATION
The Alkalinity of water is a measure of its acid neutralizing capacity.Alkalinity is imparted by bicarbonate, carbonate and hydroxide components of water. The fraction of alkalinity contributed by carbonate is calculated and reported as mg CO3 2-/L.			
ALK-HCO3HCO3-CALC-WP	Water	Alkalinity, Bicarbonate	CALCULATION
The Alkalinity of water is a measure of its acid neutralizing capacity.Alkalinity is imparted by bicarbonate, carbonate and hydroxide components of water. The fraction of alkalinity contributed by bicarbonate is calculated and reported as mg HCO3-/L			
ALK-OHOH-CALC-WP	Water	Alkalinity, Hydroxide	CALCULATION
The Alkalinity of water is a measure of its acid neutralizing capacity.Alkalinity is imparted by bicarbonate, carbonate and hydroxide components of water. The fraction of alkalinity contributed by hydroxide is calculated and reported as mg OH-/L.			
ALK-TITR-WP	Water	Alkalinity, Total (as CaCO3)	APHA 2320B
The Alkalinity of water is a measure of its acid neutralizing capacity. Alkalinity is imparted by bicarbonate, carbonate and hydroxide components of water. Total alkalinity is determined by titration with a strong standard mineral acid to the successive HCO3- and H2CO3 endpoints indicated electrometrically.			
C-TC-CALC-WP	Water	Total Carbon by Calculation	CALCULATED
Total carbon represents the sum of total inorganic carbon and total organic carbon. For the purpose of calculation, results less than the detection limit (DL) are treated as zero.			
C-TIC-HTC-WP	Water	Total Inorganic Carbon by Combustion	APHA 5310 B-WP
Sample is injected into a heated reaction chamber where it is acidified converting all inorganic carbon to CO2, which is then transported in the carrier gas stream and measured via a non-dispersive infrared analyzer.			
C-TOC-HTC-WP	Water	Total Organic Carbon by Combustion	APHA 5310 B-WP
Sample is acidified and purged to remove inorganic carbon, then injected into a heated reaction chamber where organic carbon is oxidized to CO2 which is then transported in the carrier gas stream and measured via a non-dispersive infrared analyzer.			
CL-IC-N-WP	Water	Chloride in Water by IC	EPA 300.1 (mod)
Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.			
COLOUR-TRUE-WP	Water	Colour, True	APHA 2120C
True Colour is measured spectrophotometrically by comparison to platinum-cobalt standards using the single wavelength method (450 - 465 nm) after filtration of sample through a 0.45 um filter. Colour measurements can be highly pH dependent, and apply to the pH of the sample as received (at time of testing), without pH adjustment. Concurrent measurement of sample pH is recommended.			
EC-WP	Water	Conductivity	APHA 2510B
Conductivity of an aqueous solution refers to its ability to carry an electric current. Conductance of a solution is measured between two spatially fixed and chemically inert electrodes.			
ETL-LANGELIER-4-WP	Water	Langelier Index 4C	Calculated
ETL-LANGELIER-60-WP	Water	Langelier Index 60C	Calculated
F-IC-N-WP	Water	Fluoride in Water by IC	EPA 300.1 (mod)
Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.			
HARDNESS-CALC-WP	Water	Hardness Calculated	APHA 2340B
Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.			
IONBALANCE-CALC-WP	Water	Ion Balance Calculation	APHA 1030E
Cation Sum, Anion Sum, and Ion Balance (as % difference) are calculated based on guidance from APHA Standard Methods (1030E Checking			

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**

Correctness of Analysis). Because all aqueous solutions are electrically neutral, the calculated ion balance (% difference of cations minus anions) should be near-zero.

Cation and Anion Sums are the total meq/L concentration of major cations and anions. Dissolved species are used where available. Minor ions are included where data is present. Ion Balance (as % difference) cannot be calculated accurately for waters with very low electrical conductivity (EC), and is reported as "Low EC" where EC < 100 uS/cm (umhos/cm). Ion Balance is calculated as:

Ion Balance (%) = [Cation Sum-Anion Sum] / [Cation Sum+Anion Sum]

MET-T-L-MS-WP	Water	Total Metals by ICP-MS	APHA 3030E/EPA 6020A-TL

This analysis involves preliminary sample treatment by hotblock acid digestion (APHA 3030E). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

N-TOTKJ-WP	Water	Total Kjeldahl Nitrogen	APHA 4500 NorgD (modified)

Aqueous samples are digested in a block digester with sulfuric acid and copper sulfate as a catalyst. Total Kjeldahl Nitrogen is then analyzed using a discrete analyzer with colorimetric detection.

NH3-COL-WP	Water	Ammonia by colour	APHA 4500 NH3 F

Ammonia in water samples forms indophenol when reacted with hypochlorite and phenol. The intensity is amplified by the addition of sodium nitroprusside and measured colourmetrically.

NO2+NO3-CALC-WP	Water	Nitrate+Nitrite	CALCULATION
NO2-IC-N-WP	Water	Nitrite in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-IC-N-WP	Water	Nitrate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

PH-WP	Water	pH	APHA 4500H

The pH of a sample is the determination of the activity of the hydrogen ions by potentiometric measurement using a standard hydrogen electrode and a reference electrode.

SO4-IC-N-WP	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

TC,EC-QT51-WP	Water	Total Coliform and E.coli	APHA 9223B QT51

This analysis is carried out using procedures adapted from APHA Method 9223B "Enzyme Substrate Coliform Test". E. coli and Total Coliform are determined simultaneously. The sample is mixed with a mixture of hydrolyzable substrates and then sealed in a 51-well packet. The packet is incubated at 35.0 – 0.5°C for 18 or 24 hours and then the number of wells exhibiting positive responses are counted. The final results are obtained by comparing the number of positive responses to a probability table.

TDS-WP	Water	Total Dissolved Solids (TDS)	APHA 2540 SOLIDS C,E

A well-mixed sample is filtered through a glass fiber filter paper. The filtrate is then evaportaed to dryness in a pre-weighed vial and dried at 180 – 2C. The increase in vial weight represents the total dissolved solids.

TURBIDITY-WP	Water	Turbidity	APHA 2130B (modified)

Turbidity in aqueous matrices is determined by the nephelometric method.

UV-%TRANS-WP	Water	UV Transmittance (Calculated)	APHA 5910B

Test method is adapted from APHA Method 5910B. A sample is filtered through a 0.45 um polyethersulfone (PES) filter and its UV Absorbance is measured in a quartz cell at 254 nm. UV Transmittance is calculated from the UV Absorbance result and reported as UV Transmittance per cm. The analysis is carried out without pH adjustment.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
WP	ALS ENVIRONMENTAL - WINNIPEG, MANITOBA, CANADA

Chain of Custody Numbers:

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

ALS Environmental
www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

L1938516-COFC

COC Number: 14 - 503946

Page 1 of 1

L1938516

Report To
Company: W.L. Gibbons + Associates Inc
Contact: Steve Wiecek
Address: 64 St. Andrew Road, Winnipeg, MB R2M3H6
Phone: 204-771-4389

Report Format / Distribution
Select Report Format: [X] PDF [ ] EXCEL [ ] EDD (DIGITAL)
Quality Control (QC) Report with Report [ ] Yes [X] No
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Email 2:

Select Service Level Below (Rush Turnaround Time (TAT) is not available for all tests)
R [X] Regular (Standard TAT if received by 3pm)
P [ ] Priority (2-4 business days if received by 3pm)
E [ ] Emergency (1-2 business days if received by 3pm)
E2 [ ] Same day or weekend emergency if received by 10am – contact ALS for surcharge.
Specify Date Required for E2,E or P:

Invoice To Same as Report To [X] Yes [ ] No
Copy of Invoice with Report [ ] Yes [X] No
Company:
Contact:

Invoice Distribution
Select Invoice Distribution: [X] EMAIL [ ] MAIL [ ] FAX
Email 1 or Fax: Swiecek@mymts.net
Email 2:

Project Information
ALS Quote #:
Job #: Aubrey
PO / AFE:
LSD:

Oil and Gas Required Fields (client use)
Approver ID: Cost Center:
GL Account: Routing Code:
Activity Code:
Location:

ALS Lab Work Order # (lab use only):
ALS Contact: C. Riddell Sampler: SJW

Analysis Request
Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

ALS Sample # (lab use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	MUN-WTP-72D (P)	Total and E. coli (P)	Number of Containers
	TW 17-01-30	Jun 27 17			✓	✓	6
	TW 17-01-4					✓	1
	TW 17-01-F				✓	✓	6
		As per Bottles					

Drinking Water (DW) Samples[1] (client use)
Are samples taken from a Regulated DW System? [ ] Yes [X] No
Are samples for human drinking water use? [ ] Yes [X] No

Special Instructions / Specify Criteria to add on report (client Use)

SAMPLE CONDITION AS RECEIVED (lab use only)
Frozen [ ] SIF Observations Yes [ ] No [ ]
Ice packs Yes [ ] No [ ] Custody seal intact Yes [ ] No [ ]
Cooling Initiated [ ]
INITIAL COOLER TEMPERATURES °C: 10.9°C
FINAL COOLER TEMPERATURES °C:

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Released by:	Date:	Time:	Received by:	Date:	Time:	Received by:	Date:	Time:
	08/08/17	9:00	David J.	8-6-17	8:55 am			

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY YELLOW - CLIENT COPY

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

1. If any water samples are taken from a **Regulated Drinking Water (DW) System**, please submit using an **Authorized DW COC form.**