

APPENDIX 'I'

HYDROGEOLOGIC INVESTIGATION REPORT AND RECOMMENDATIONS



August 24, 2016

File: Waverley Underpass

Dillon Consulting Limited
1558 Wilson Place
Winnipeg, MB R3T 0V4

Attention: Mr. David Wiebe, P.Eng.

Dear Mr. Wiebe:

**RE: City of Winnipeg - Waverley Underpass
Potential Bedrock Groundwater Concerns
Hydrogeologic Investigation Report and Recommendations**

W.L. Gibbons & Associates Inc. (WLG) is pleased to provide the following report documenting the results of the hydrogeologic investigations undertaken at the proposed Waverley Underpass site. The purpose of this work program was to verify the hydrogeologic conditions beneath the Waverley Underpass site, particularly with regards to the groundwater contained within the upper portion of the limestone bedrock. Based on discussions with project personnel and other information provided by the project team, the following is the current understanding of the situation:

- Geotechnical investigations by AECOM have identified that the bedrock groundwater pressures beneath the proposed site are in the 225.0 to 225.8 (+/-) m range (approximately 7.7 to 8.5 m below grade). Review of the long term groundwater monitoring record for the area (Appendix A) indicates that bedrock groundwater pressures in this area can vary from 216 to 226 meters.
- The proposed underpass will require the installation of a lift station to provide drainage of water from the underpass. As currently designed, the lift station will require an excavation to a depth of 219 meters. Based on estimates by AECOM geotechnical personnel, a potential risk of bedrock groundwater problems during construction has been identified, and that in order to achieve a factor of safety against base heave of 1.5, the bedrock groundwater pressures would need to be approximately 0.5 meters lower than the base of the excavation for the lift station.

Activities completed as part of this work program include the following:

- Review of the available information on the hydrogeology of the area, including the geotechnical test hole logs completed by AECOM personnel. The relevant geotechnical test holes (TH 14-02, 04 and 29) are included in Appendix B with the locations shown on Figure 1.
- Application for and receipt of a Groundwater Exploration Permit from the MB Water Use Licensing Section authorizing the completion of a groundwater exploration program. (Copy in Appendix C)

- The installation of a 150 mm (6 inch) test well at a location proximate to the proposed lift station.
- The completion of a pumping test on the test well at a rate of 2.0 Lps (27 Igpm)
- Data assessment and reporting.

1.0 Site Setting

1.1 Physical Setting

The project site is located at the intersection of Waverley Street with the CN main rail line within the City of Winnipeg. Surrounding land uses include:

- Northwest – CN Mainline followed by commercial and then residential
- Northeast – CN Mainline followed by commercial and then residential
- Southwest – Residential, institutional (school, church)
- Southeast – Commercial

1.2 Geologic/Hydrogeologic Setting

The subsurface geology at the proposed lift station site consists of clay to a depth of approximately 10 to 11 meters followed by 4.8 to 5.2 meters of glacial till. Limestone bedrock is encountered at a depth of 18.0 meters. The available information indicates that the 1.5 meters above the bedrock consists of highly fractured limestone (“rubble”) with clay, sand and gravel infill.

Groundwater in significant quantities is found within the upper fractured carbonate aquifer zone, as well as from fractured carbonate rock below a depth of 91 meters (300 feet). This assessment is primarily concerned with the potential impacts associated with the groundwater in the upper aquifer zone, as this groundwater pressure is acting directly on the base of the overburden profile.

The provincial government maintains a network of groundwater level monitoring stations across the city. The compiled data from a monitoring station located 350 meters from the site at Taylor and Ebby Avenue (Station OC-008) is included in Appendix A. Also included in Appendix A for reference are the compiled groundwater records for stations located on McGillvray Boulevard (OC-053), in Southwest Winnipeg (OC-019), and in downtown Winnipeg (OJ-021). Based on this compiled information, the following is noted:

- Station OC-008 is located near to a geothermal cooling system at 1305/1325 Taylor (Taylor and Ebby Avenue). From the start of groundwater monitoring to approximately 2010, the monitoring record exhibited a sharp decline every summer when the geothermal system was operating. Since approximately 2010, the sharp declines in summer have ceased and it appears the system has either been decommissioned or has been converted to a non-consumptive groundwater cooling system (ie: groundwater is

returned to the aquifer). A similar pattern can be seen at Station OC-019 (Inland Cement area) and in the downtown Winnipeg area (Station OJ-012 – Law Courts Building). This pattern throughout Winnipeg of the conversion of geothermal systems to non-consumptive systems, and other declining groundwater use, has resulted in a rise in groundwater levels throughout Winnipeg since the mid 1960's (Station OJ-021 – Downtown Winnipeg). In the area of the Waverley Underpass, the rise in groundwater levels has been on the order of 2 meters. Elsewhere such as the downtown Winnipeg area, the rise has been on the order of 6 meters. With the decline in groundwater use, groundwater levels are rising to the predevelopment levels.

- The highest groundwater levels were recorded in the spring of 2011 in the Waverley Underpass area at 226.4 meters. This significant rise in groundwater levels coincides with the overall high precipitation and flooding that occurred in the early part of that year. Since the spring of 2011, groundwater levels have been declining and are currently in the 224 meter range (+/- 1 meter).
- The monitoring records clearly show that groundwater levels have varied from a low of approximately 216 meters to a high of 226 meters, depending on the precipitation patterns and changes in consumptive groundwater use. For the short term (ie: the next year), it is reasonable to expect that groundwater levels will be in the 224 (meter (+/- 1 meter)) range, with the highest levels most likely to occur in early spring.

Groundwater flow in the bedrock aquifer occurs within the fractures and joint sets in the rock. The size, extent and interconnectivity of these openings in the rock determine the degree of transmissivity (ie: the ability to transmit water) of the aquifer. As the transmissivity is a function of the degree of fracturing, the transmissivity and the well yield can vary substantially over short distances. Published maps of the transmissivity distribution in the area (Baracos, Shields and Kjartanson, 1983) indicate that the transmissivity is in the range of 1.4×10^{-3} to 7.0×10^{-3} m²/s in the Waverley Underpass site area. Site specific investigations since the 1983 report have provided estimates of transmissivity in the 1.9×10^{-3} to 2.2×10^{-3} m²/s range at the Shindico Realty Building, as well as an estimate of transmissivity of 2.0×10^{-3} m²/s at the Central Park Lodge. These more recent test results are consistent with the published 1983 information.

The groundwater flow direction in the upper bedrock aquifer during a typical summer is shown in Figure 2 and during a typical winter is shown in Figure 3. The information shown is from 2006. The groundwater flow direction beneath the site is to the east towards the Red River as well as the industrial areas to the east in St. Boniface. This flow direction is due partially to the natural discharge of groundwater to the Red and Assiniboine Rivers, but mostly due to consumptive groundwater pumping which occurs in the downtown and St. Boniface areas. As illustrated in Figures 2 and 3, the groundwater flow directions shift between summer and winter as consumptive groundwater systems used for cooling are turned on and off. Note: A groundwater level depression is evident to the immediate northeast of the site in the summer of 2006 at station OC-008 which is proximate to a consumptive geothermal cooling system (1305/1325 Taylor). As noted previously, the system is no longer consumptively using groundwater and therefore the depression in groundwater levels is no longer occurring.

2.0 Site Specific Hydrogeologic Investigations

A hydrogeologic investigation was undertaken at the Waverley Underpass site to obtain site specific information on the hydrogeologic conditions, and specifically to obtain estimates of transmissivity at this site.

Specific details of the design of the investigation are as follows:

- As the intention was to control groundwater levels in the immediate area of the proposed lift station, a test well was to be drilled as close as practical to the proposed lift station. It was intended that the test wells would remain for subsequent use as a monitoring location. A significant limiting factor in the selection of the test well location was the need to obtain permission from the current users of the land to access the site. Project personnel completed a negotiation with the land user and an acceptable location was determined. Dillon survey personnel marked the location of the test well, lift station and rail shoofly to be constructed. The test well was drilled at the marked location.
- Prior to the start of drilling, AECOM personnel obtained underground utility clearances for the area and copies were provided to WLG personnel.

2.1 Test Well TW 16-01 Installation

Test well TW 16-01 was drilled at the northeast corner of the school field (Figure 1) on August 4 and 5, 2016. A copy of the Driller's Report outlining the stratigraphy encountered and the final well construction details are included in Appendix D. The stratigraphy consists of 12.8 m of clay followed by 4.0 m of glacial till. From a depth of 16.8 to 18.3 m, a limestone rubble zone was encountered. This rubble zone consisted of highly fractured limestone bedrock pieces with clay, sand and gravel in the interstices. The rubble zone produced water while drilling. Dolomite bedrock was encountered below a depth of 18.3 m with a bentonitic shale layer at a depth of 21.9 to 22.6 m. Small fractures were encountered at depths of 21.3 and 21.9 m. The casing was advanced through the rubble zone into the competent bedrock at a depth of 18.6 m and the test hole was advanced to a depth of 23.8 m. per standard practice for wells of this nature. After the rubble zone was cased off, the well produced less water.

2.2 Aquifer Pumping Test

A 6 hour pumping test was completed on August 5, 2016 on test well TW 16-01. The test consisted of the pumping of the test well at an average rate of 2.0 Lps with the discharge directed to grade at the site. In preparation for the pumping test on Well TW 16-01, transducers were installed in monitoring wells TH 14-02 and TH 14-04, both installed in the bedrock, and TH 14-29 installed in the till to obtain information on the response of the groundwater levels to pumping at a distance from the pumping well. The transducers continuously recorded water levels from August 4, 2016 to August 6, 2016. Plots of the recorded changes in groundwater levels are included in Appendix E, with a plot of the recorded changes in pumping well TW 16-01 during the test.

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

- The pumping of test well TW 16-01 at 2.0 Lps induced a drawdown of approximately 8.1 meters in groundwater levels in that well. Minor fluctuations in the groundwater levels evident on the plot are due to changes in the pumping rate to maintain a near constant rate of pumping.
- Monitoring well TH 14-02 monitors the bedrock groundwater levels at a distance of 24 meters from the test well TW 16-01. The pumping of test well TW 16-01 induced a maximum drawdown in bedrock monitoring well TH 14-02 of approximately 0.25 meters. Only approximately 35% recovery of groundwater levels was achieved 17 hours after the cessation of pumping. The results are indicative of an aquifer with a low transmissivity where groundwater can only move slowly to replenish the groundwater removed by pumping.
- Monitoring well TH 14-04 monitors the bedrock groundwater levels at a distance of 109 meters from the test well TW 16-01. The pumping of test well TW 16-01 induced a maximum drawdown in monitoring well TH 14-04 of approximately 0.05 meters. Only approximately 50% recovery of groundwater levels was achieved 17 hours after the cessation of pumping. The recorded gradual fluctuations in groundwater levels when no pumping was occurring are most likely attributable to barometric pressure fluctuations. The source of the transient spikes in groundwater levels may be due to monitoring equipment issues or some other source.
- Monitoring well TH 14-29 monitors the till groundwater levels at a distance of 66 meters from the test well TW 16-01. The pumping of test well TW 16-01 induced a maximum drawdown in monitoring well TH 14-29 of approximately 0.02 meters at the end of the pumping test. It is also noted that the response to the pumping from test well TW 16-01 did not start until approximately one hour after the start of pumping. Following the cessation of pumping, groundwater levels continued to decline and no recovery in groundwater levels had occurred 17 hours after the cessation of pumping. The recorded response is typical of a leaky aquifer scenario where hydraulic restrictions between two aquifers result in a delayed response.

2.3 Transmissivity Estimates

The analyses of the data obtained from the pumping test are included in Appendix F. The transmissivity was found to vary from a low of 8.4×10^{-4} (TH 14-02 – Till) to 6.6×10^{-3} m²/s (TH 14-04). The results from monitoring well TH 14-04 are higher than the expected range for this area and are considered anomalous. Further testing is required to confirm this result and the appropriate value of transmissivity for estimating pumping rates that will be required to depressurize this site and the drawdown effects at a distance. The results of this analysis indicate a high degree of variability in the transmissivity and a potential complex hydraulic interaction between the upper bedrock, the overlying rubble zone, and the glacial tills. Further testing is required to obtain the information needed to better assess this complex hydraulic relationship.

2.4 Assessment

The results from the drilling of test well TW 16-01 indicate that the rubble zone located directly over the bedrock is capable of producing water and that the upper 5.5 meters of the bedrock does not contain significant fractures capable of transmitting large volumes of water. As the casing was installed into the top of the bedrock (per standard procedure for initial test wells of this nature), the flow of water from the rubble zone was cut off and the well was only capable of producing 2.0 Lps. It is reasonable to expect that if the well had been constructed in a manner that flow from the rubble zone was captured, the capacity of the well would have been higher and the drawdown effects greater.

The intention of this work program is to depressurize the groundwater directly below the proposed lift station. The rubble zone and the upper portion of the bedrock is where the high groundwater pressures exist and therefore future test wells should target pumping from both the rubble zone and the upper bedrock. It is recommended that future test wells at this site be constructed with a well screen placed in the rubble zone and the borehole extended downwards to a depth of 6.0 meters into the bedrock. It is also recommended that any future test wells be placed directly proximate to the proposed lift station so that they can be used as pumping wells for any future groundwater depressurization system. Given that the land directly below the proposed lift station is currently being used by others and access is limited, it is recommended that the installation of any future test wells be delayed until full access to this site is available or permission to access the proposed lift station area is obtained.

Preliminary estimates of the potential pumping rates required to depressurize the groundwater at this site are included in Appendix G. The estimates assume a drawdown of 7.5 meters at the proposed lift station site will be required. The assumed drawdown requirement is based on the high historic groundwater level of 226.0 meters and assumes groundwater will need to be drawn down to 218.5 meters (0.5 meters below the base of the lift station excavation). The estimates are also based on the transmissivity estimates obtained from the current pumping tests as well as other transmissivity estimates from the area. Based on this preliminary analysis, it is estimated that a pumping rate ranging from 11 Lps to 63 Lps will be required to achieve the required drawdown from this site. The higher estimate of 63 Lps is based on the anomalously high transmissivity estimate obtained from the monitoring well TH 14-04 data. Based on experience from pumping rates that have been achieved for this area, it is considered very unlikely that a pumping rate of 63 Lps will be required. It is considered more likely that the required pumping rate will be on the order of 18.9 Lps derived using the transmissivity estimate of $2.0 \times 10^{-3} \text{ m}^2/\text{s}$ from other pumping tests in this area. It is recommended that for future planning, a pumping rate of 18.9 Lps be used until better estimates are available following the recommended follow-up testing.

3.0 Existing Groundwater Users

As part of this hydrogeologic assessment, the existing groundwater users within 800 meters of the proposed lift station were identified by searching the provincial GWDRIIL database containing the Driller's Reports for wells drilled within the province, and by requesting

information on existing licensed groundwater users within the area from the Water Use Licensing Section of MB Sustainable Development. The following groundwater users in the area were identified:

- Shindico Realty – Taylor Ave and Waverley Street – A non-consumptive groundwater heating and cooling system is located at this site at a distance of approximately 275 meters from the proposed lift station.
- Mackinnon House – 969 Cambridge – A non-consumptive groundwater cooling system is located at this site at a distance of approximately 360 meters from the proposed lift station. It is understood that this system only operates in the summer.
- 1305/1325 Taylor Avenue (Taylor Towers) - A groundwater cooling system is located at this site at a distance of approximately 430 meters from the proposed lift station. The system historically has only operated in the summer, and based on the groundwater records appears to have been either decommissioned or converted to a non-consumptive groundwater cooling system. The current status of this system should be confirmed.
- Central Park Lodge – Poseidon Bay and Ebby Avenue - A non-consumptive groundwater cooling system is located at this site at a distance of approximately 525 meters from the proposed lift station. It is understood that this system only operates in the summer.
- Winnipeg Humane Society – Waverley Street and Hurst Way - A non-consumptive groundwater heating and cooling system is located at this site at a distance of approximately 260 meters from the proposed lift station.
- The Waverley – Waverley Street and Wilkes Avenue – A single well is present at this site that is understood to potentially be used for landscape watering purposes. The status of this water well should be confirmed. The distance from the proposed lift station is 110 meters.

Although there are a significant number of geothermal systems and water wells in the area, the largest influence on regional static water levels in the past (Figures 2 and 3) has been the consumptive cooling system well use at 1305/1325 Taylor Avenue. This system operated for many years after the failure of the return well by using groundwater for cooling water supply, with discharge into the city sewer. The latest information from the groundwater monitoring record suggests that this system may have been shut down or converted to a non-consumptive cooling system. This system appeared to be a major influence on groundwater levels in the area, creating as much as 6.0 m of drawdown in the area during operations.

All of the existing water supply systems were operational while the 1305/1325 Taylor Avenue system was still inducing a significant drawdown in the area and the systems were capable of managing that drawdown. In addition, it is expected that most of these existing systems will be at an operational equilibrium following years of use, with the injection upconing/pumping drawdown likely creating an aquifer hydraulic equilibrium within 300 meters of distance from either supply or return well. All of the systems in the area appear to have a suitable level (3 to 4 m) of available drawdown during normal operations based on the available information.

Estimates of the potential drawdown at a distance that may occur due to pumping at the proposed lift station are included in Appendix G. The estimates are based on the currently available estimates of transmissivity that vary from $1.1 \times 10^{-3} \text{ m}^2/\text{s}$ (TH 14-02) to $7.9 \times 10^{-3} \text{ m}^2/\text{s}$ (TH 14-04). As noted previously, further site testing is required to better assess the transmissivities that will actually be encountered at this site. The estimate also assumes a drawdown of 7.5 meters at the proposed lift station site will be required. This drawdown is based on the high historic groundwater level of 226.0 meters and assumes groundwater will need to be drawn down to 218.5 meters.

The estimated drawdown at a distance of 800 meters from the lift station site will be in the range of 0.8 to 1.0 meters. The estimated drawdown at a distance of 275 meters (Shindico and Humane Society) would be in the range of 1.7 to 2.0 meters. Therefore, it is reasonable to expect that drawdown induced by pumping at the lift station will be unlikely to have an adverse effect on these existing systems. The current status of these existing systems should be confirmed prior to the start of pumping at the lift station. This would include confirmation of the current operational status of the systems (especially the 1305/1325 Taylor Avenue system), confirmation that there have been no changes in the operational parameters for these systems (ie: increased pumping rates), and confirmation of the current available drawdown in these wells when they are operational.

Although adverse effects to the existing systems are not anticipated, standard practice for construction bedrock aquifer depressurization projects of this nature is to implement a groundwater level monitoring program to verify the absence of any adverse effects, and to implement a Groundwater Interference Complaint Response plan detailing the actions that will be taken if an unexpected adverse effect does not occur.

The existing bedrock and till monitoring wells (TW 16-01, TH 14-02, 04 and 29) are considered to be suitable for monitoring the groundwater response to pumping on the north side of the lift station site. It is recommended that an additional bedrock monitoring well be installed on the south side of the site towards the Humane Society system to allow the groundwater response in that direction to be monitored. In addition, the owners of the existing systems should be approached to determine if they are willing to have monitoring equipment installed to record the groundwater response within their wells. All monitoring wells should be equipped with water level transducers set to continuously record the changes in groundwater levels. The data from these transducers should be regularly retrieved and assessed with respect to any unexpected changes in groundwater levels and any potential adverse effects to the existing systems.

A Groundwater Interference Complaint Response Plan should be implemented for this project. The plan would outline the steps to be taken in the event that adverse effects to existing groundwater users have occurred or are perceived to have occurred. An example of a typical groundwater complaint response plan implemented for the Red River Floodway Expansion Project is included in Appendix H. A similar plan tailored for the Waverley Underpass Project should be prepared and implemented, and copies provided to the owners of the existing systems so that they are aware of the process to address any concerns they may have.

4.0 Assessment of Options to Depressurize the Aquifer During Construction

The hydrogeologic investigation at the Waverley Underpass site has provided information which indicates that a pumping rate on the order of 18.9 Lps will be required to achieve 7.5 meters of drawdown below the proposed lift station. Nominally, the required drawdown could be achieved by installing 200 mm diameter wells proximate to the proposed lift station. For preliminary design purposes, it should be assumed that 4 wells would be installed, one on each side of the lift station excavation. The wells should be placed as close as possible to the lift station excavation but not too close that they interfere with the necessary construction work. Four wells are recommended as they will provide primary and back-up pumping capacity (ie: only two or three wells will be operated at any given time). The required pumping configuration and pumping rates would be determined following the installation and testing of the wells. Per standard practice on construction projects of this nature, it is recommended that the wells be installed and tested prior to tendering so that the contractor is only required to equip and operate the wells based on actual test results. Transmissivities and well capacities can vary significantly over short distances and therefore adjustments are commonly necessary to ensure the constructed pumping system achieves the required objective. This is best done before tendering to avoid claims for extra costs and delays from the contractor.

Other alternative methods to achieve the required groundwater depressurization include:

Secant Pile Walls – This method reduces the flow of water to the excavation by installing a wall of overlapping piles that are extended into the bedrock and form a vertical barrier that prevents the lateral movement of groundwater. Some residual seepage will still occur, particularly from the unsealed base, and groundwater pumping is still required, albeit a lower rates.

Grout curtain – As has been done at other sites such as the Red River Floodway Inlet Structure and the City of Winnipeg South End Wastewater Treatment Plant, the transmissivity of the aquifer can be reduced by injecting grout into the fractures in a ring around the proposed excavation. The grout would consist of a mixture of cement, bentonite and sand which is injected into the fractures via a series of hole drilled in a ring around the excavation limits. Grout injection would occur in a series of stages, and would continue until pumping tests from wells within the grout curtain confirm that the groundwater pressures can be lowered and maintained at the desired level at lower pumping rates.

Freeze Curtain – Similar to the grout curtain option, the transmissivity of the aquifer is reduced by freezing the aquifer in a ring around the excavation limits. A series of geothermal holes equipped with supply and return tubing loops are drilled around the excavation. A refrigeration plant is connected to the tubing and coolants are circulated to remove heat from the subsurface until the groundwater freezes. The frozen ground conditions are maintained for the duration of construction. Any residual groundwater seepage is pumped to the drainage system, as with the secant pile wall and grout curtain options.

5.0 Conclusion and Recommendations

The hydrogeologic investigation at the Waverley Underpass site has demonstrated that it will be possible to depressurize the aquifer during construction at pumping rates at a preliminary estimate of 18.9 Lps. Further testing will be required to confirm the transmissivity directly beneath the proposed lift station and the associated pumping rate necessary to achieve the depressurization target. The recommended follow-up testing would consist of the installation of 200 mm diameter wells proximate to the lift station and the completion of pumping tests. The pumping wells should be constructed so that the wells withdraw water from both the rubble zone above the bedrock and the upper portion of the bedrock. Pumping tests should be completed on each well so that information can be obtained to complete updated assessments of the transmissivity for this area and the potential drawdown effects at a distance. For preliminary design purposes, four pumping wells are recommended, with the wells placed on each side of the lift station excavation as close as possible without limiting the construction activities. Implementation of this follow-up testing program should be deferred until full access to the lift station site is available.

A groundwater monitoring program should be implemented for this site to monitor groundwater level changes caused by any pumping at the lift station site. The groundwater level monitoring program should include the existing four monitoring wells (TW 16-01, TH 14-02, 04 and 29), a new monitoring well installed to the south of the site, and at any private wells where the owner agrees to the installation of monitoring equipment. All monitoring wells should be equipped with water level transducers set to continuously record the changes in groundwater levels. The data from these transducers should be regularly retrieved and assessed with respect to any unexpected changes in groundwater levels and any potential adverse effects to the existing systems.

A Groundwater Interference Complaint Response Plan should be implemented for this project. The plan would outline the steps to be taken in the event that adverse effects to existing groundwater users have occurred or are perceived to have occurred. Copies of the plan should be provided to the owners of the existing systems in the area so that they are aware of the process to address any concerns they may have.

Alternatively, the contractors for the construction of this lift station could be required to prepare and submit a plan to control the groundwater pressures during construction in consideration of the following information and design constraints:

- The stratigraphy at this site consists of approximately 12.8 meters of clay followed by approximately 4.0 meters of glacial till. A rubble zone (fractured limestone, clay, sand and gravel) is present from a depth of 16.8 to 18.3 meters. Dolomite bedrock occurs at a depth of approximately 18.3 meters. Any submitted groundwater control plan should be required to demonstrate how groundwater will be controlled in the rubble zone and upper bedrock, and how any residual groundwater flow would be managed.
- The site is located in relatively close proximity to operating groundwater geothermal system that could be impacted by pumping at the Waverley Underpass site. Provincial

Mr. D. Wiebe, P.Eng.

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approvals to pump groundwater will be obtained for this project and will include conditions that existing groundwater users in the area not be adversely affected by pumping at the Waverley Underpass site. The contractor should be required to comply with all terms and conditions associated with regulatory approvals for the site.

- The nearby operating groundwater geothermal systems could be adversely affected by changes in water quality, in particular any turbidity generated by the construction activities. The generation of turbid water should be minimized and controlled to the degree practical. The 200 mm (8 inch) wells to be installed at this site should be used to pump any turbid groundwater generated and discharge it to waste.

We trust that the preceding meets your requirements. If you have any questions or require further information, please contact the undersigned.

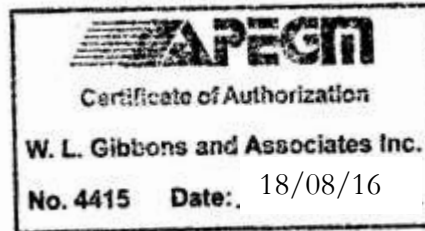
Sincerely,

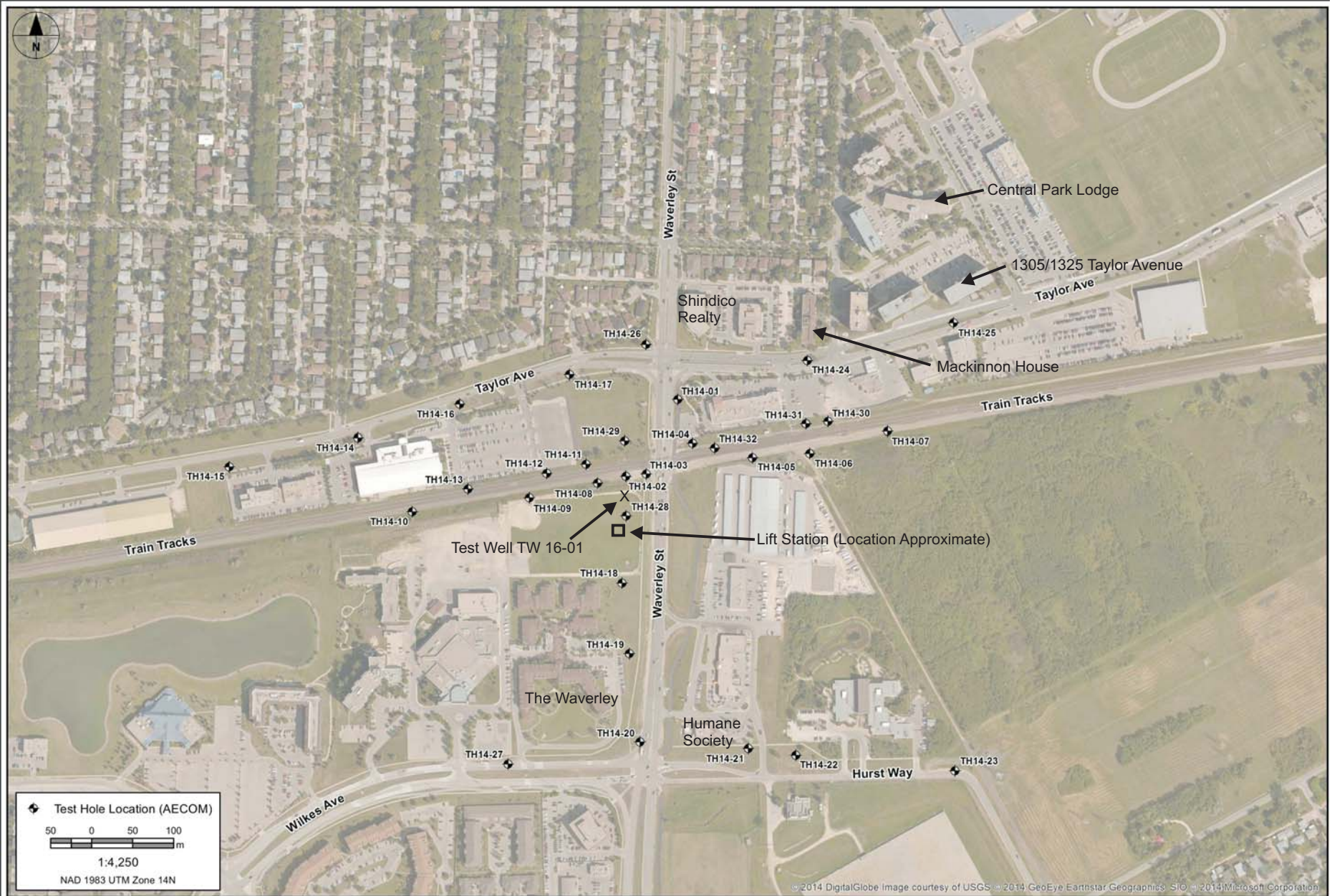


Steve Wiecek, P.Geo., P.Eng.

Senior Geologic Engineer

swiecek@mts.net





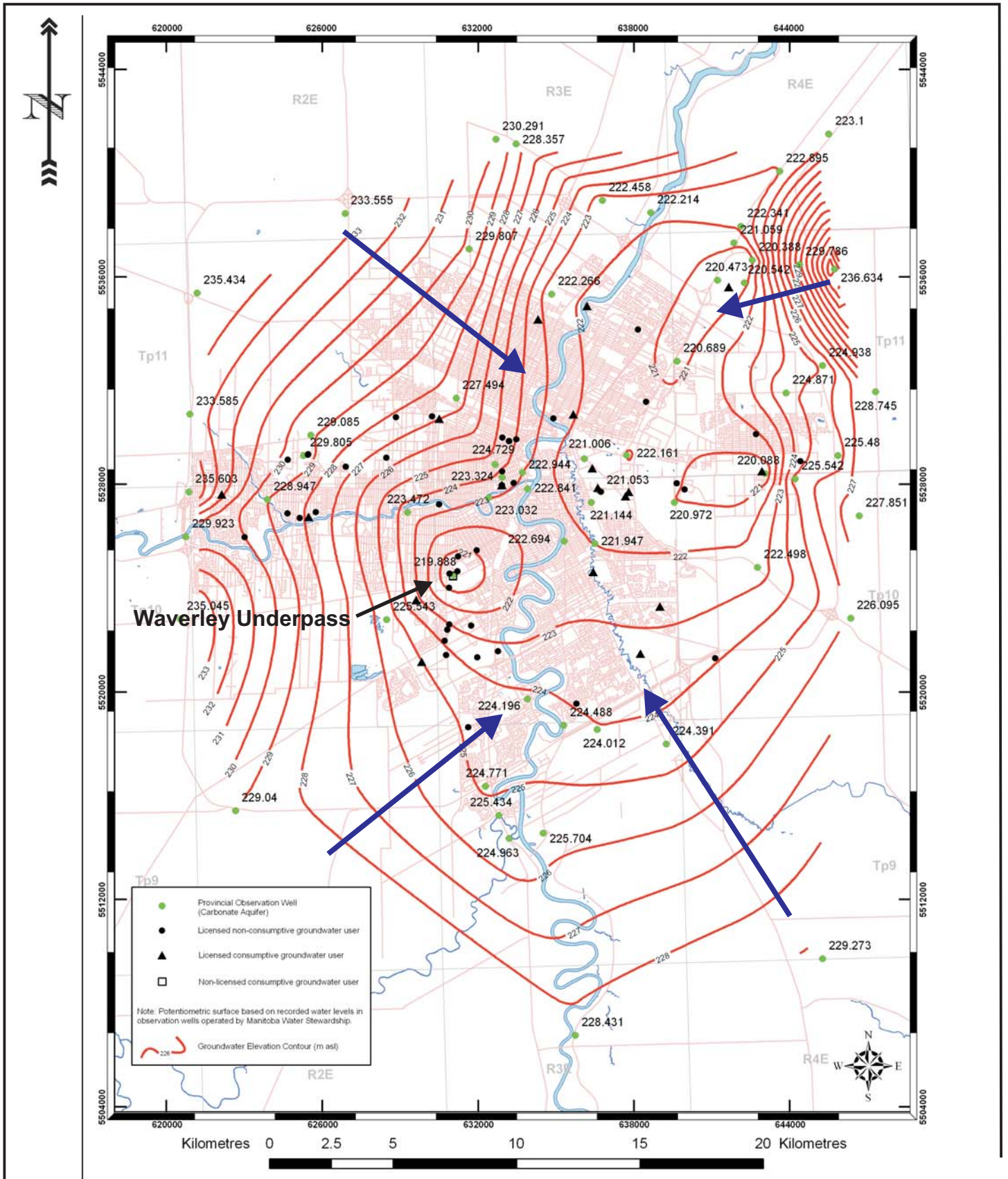
Base Plan Source - AECOM 2016

W. L. GIBBONS & ASSOC. INC.

HYDROGEOLOGY - GEOLOGICAL ENGINEERING

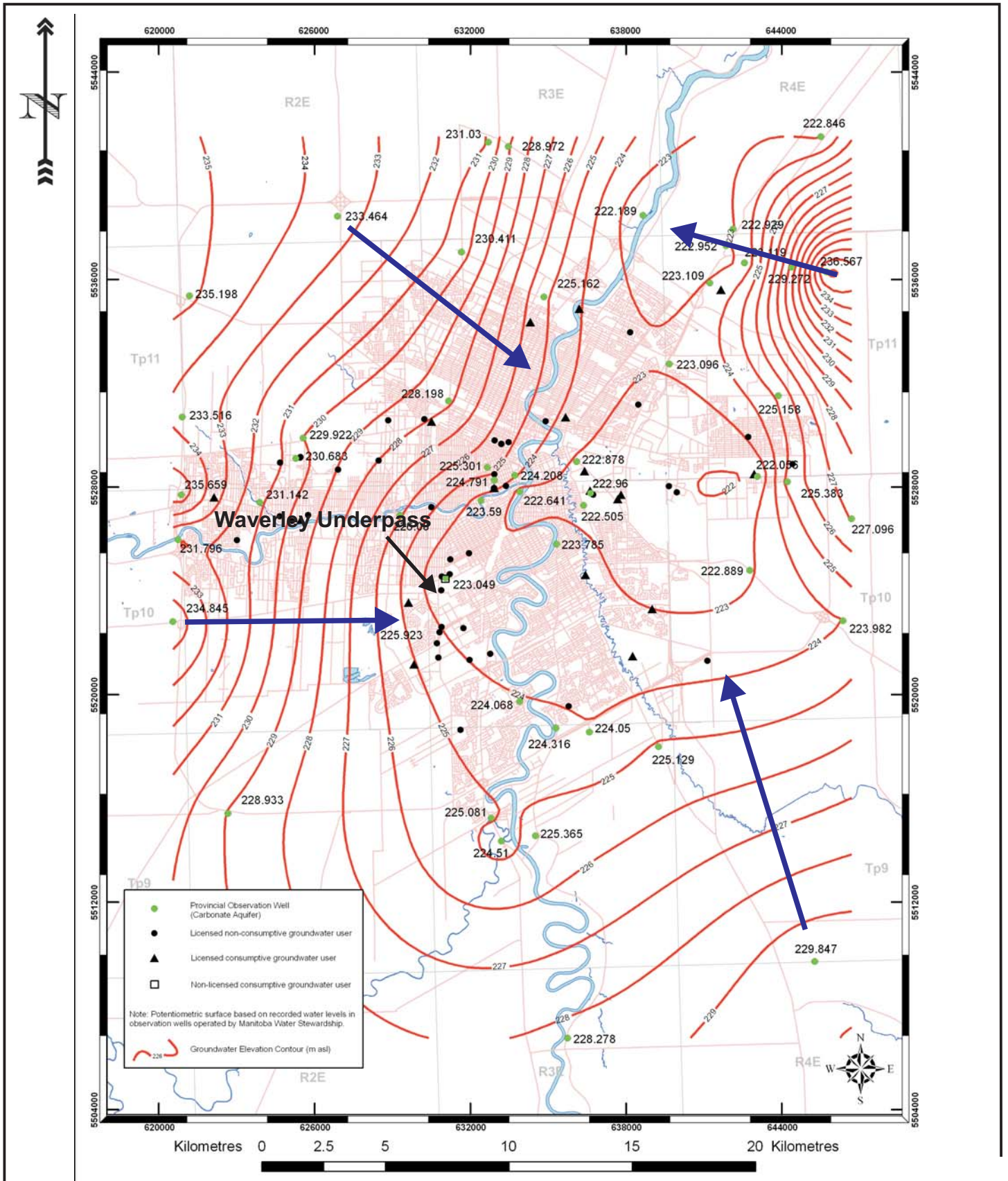
Designed By: BW
 Approved By: SW
 Date: 08/16

City of Winnipeg
 Waverley Underpass
Site Plan
Figure No. 1



 - Groundwater Flow Direction

City of Winnipeg
 Waverley Underpass
Summer Groundwater Levels
Figure No. 2

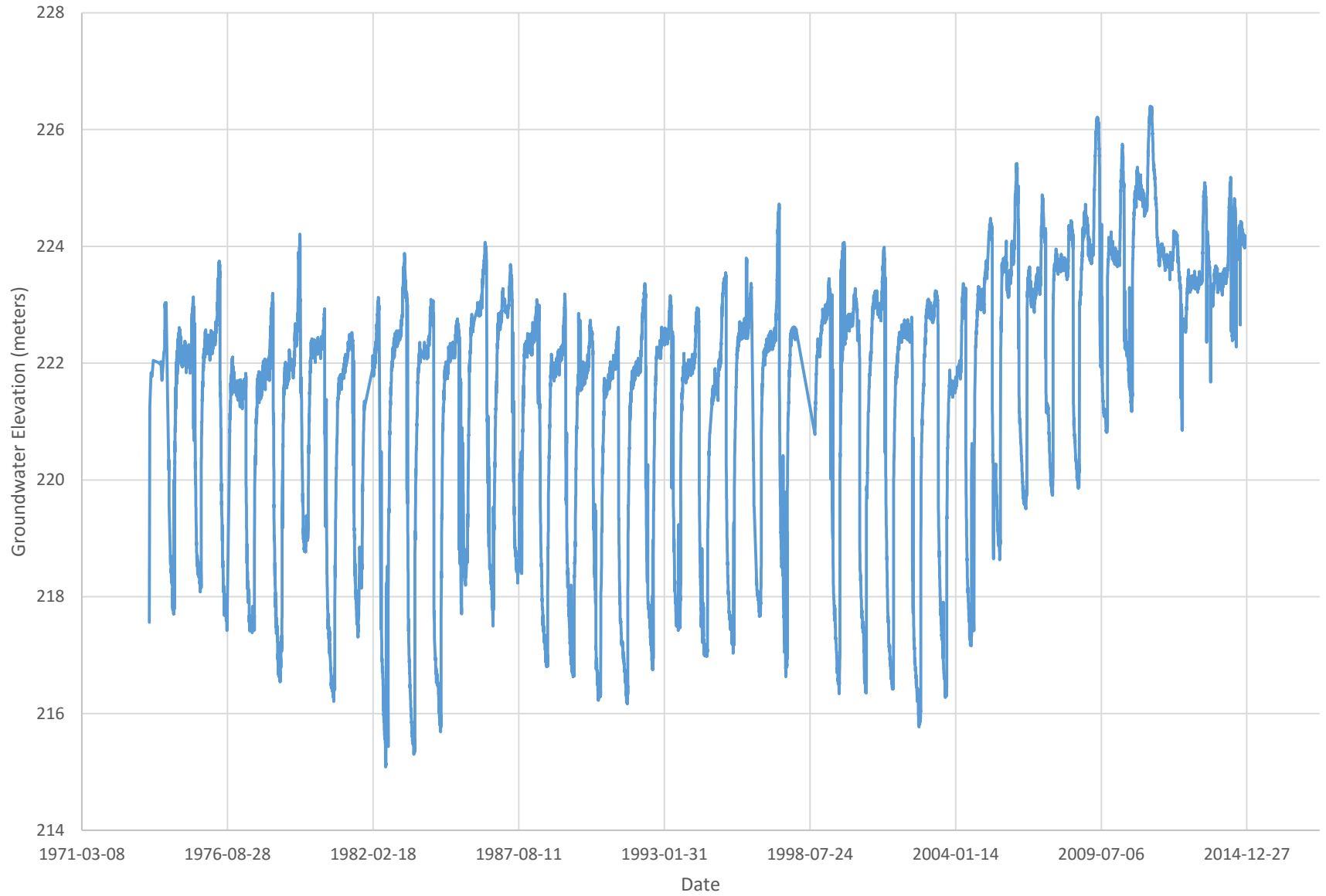


→ - Groundwater Flow Direction

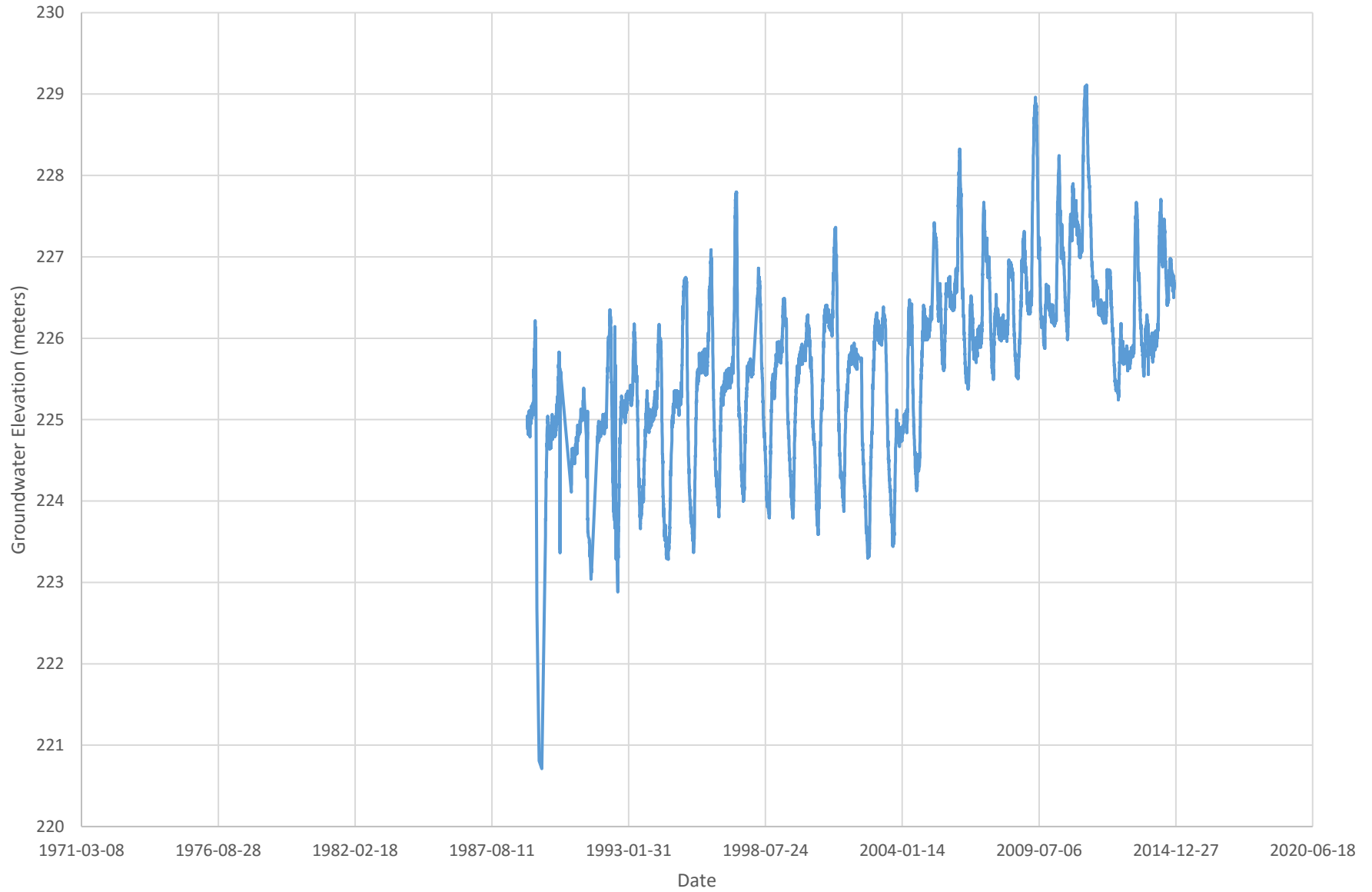
City of Winnipeg
 Waverley Underpass
Winter Groundwater Levels
Figure No. 3

**Appendix A
Long Term Groundwater
Monitoring Record**

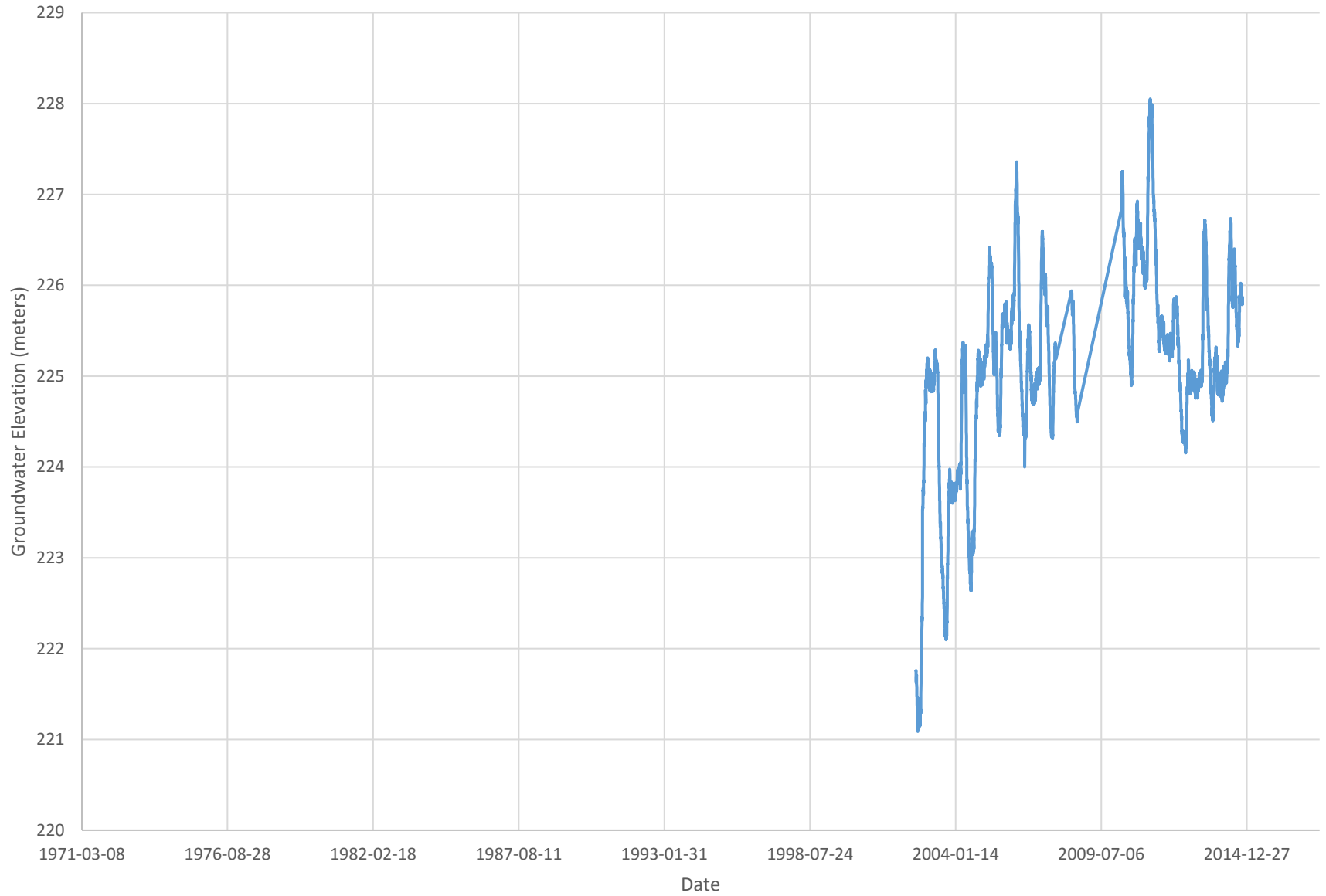
Waverley Underpass Groundwater Levels Station OC-008 - Taylor and Ebby Avenue



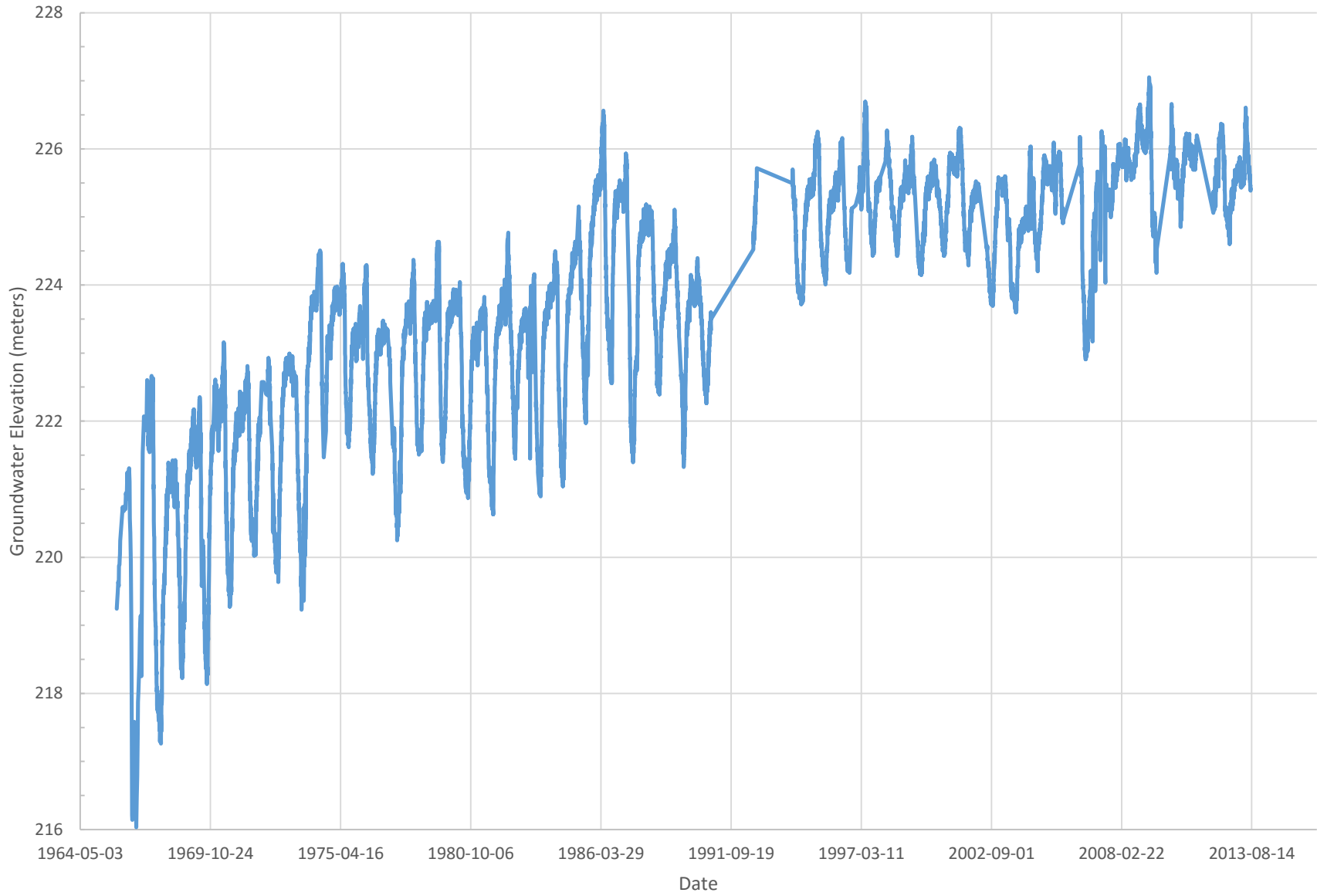
Southwest Winnipeg Bedrock Groundwater Levels Station OC-019 - Inland Cement



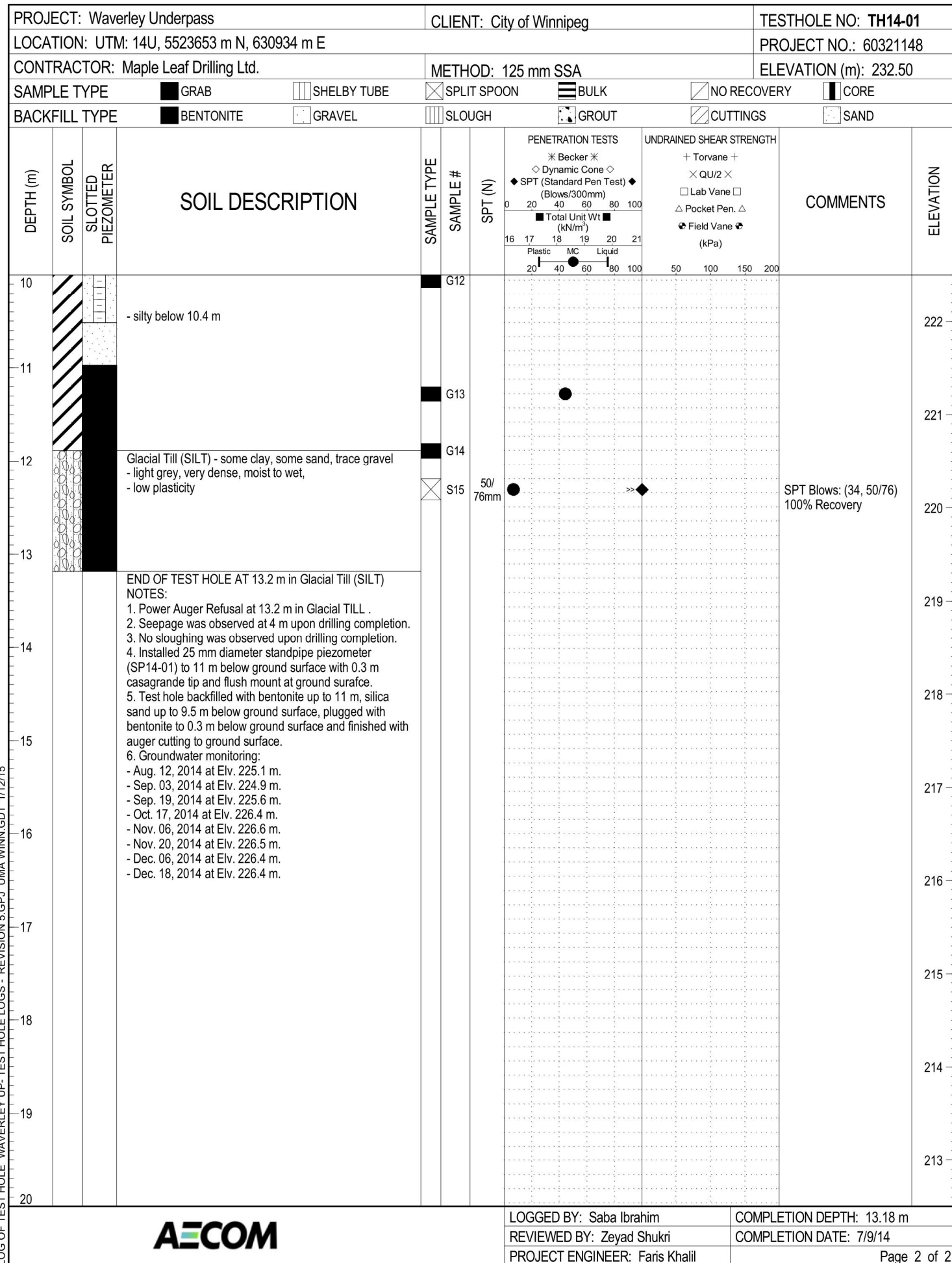
McGillvray Boulevard Bedrock Groundwater Levels Station OC-053 - 1.6 kms southeast of Waverley Underpass



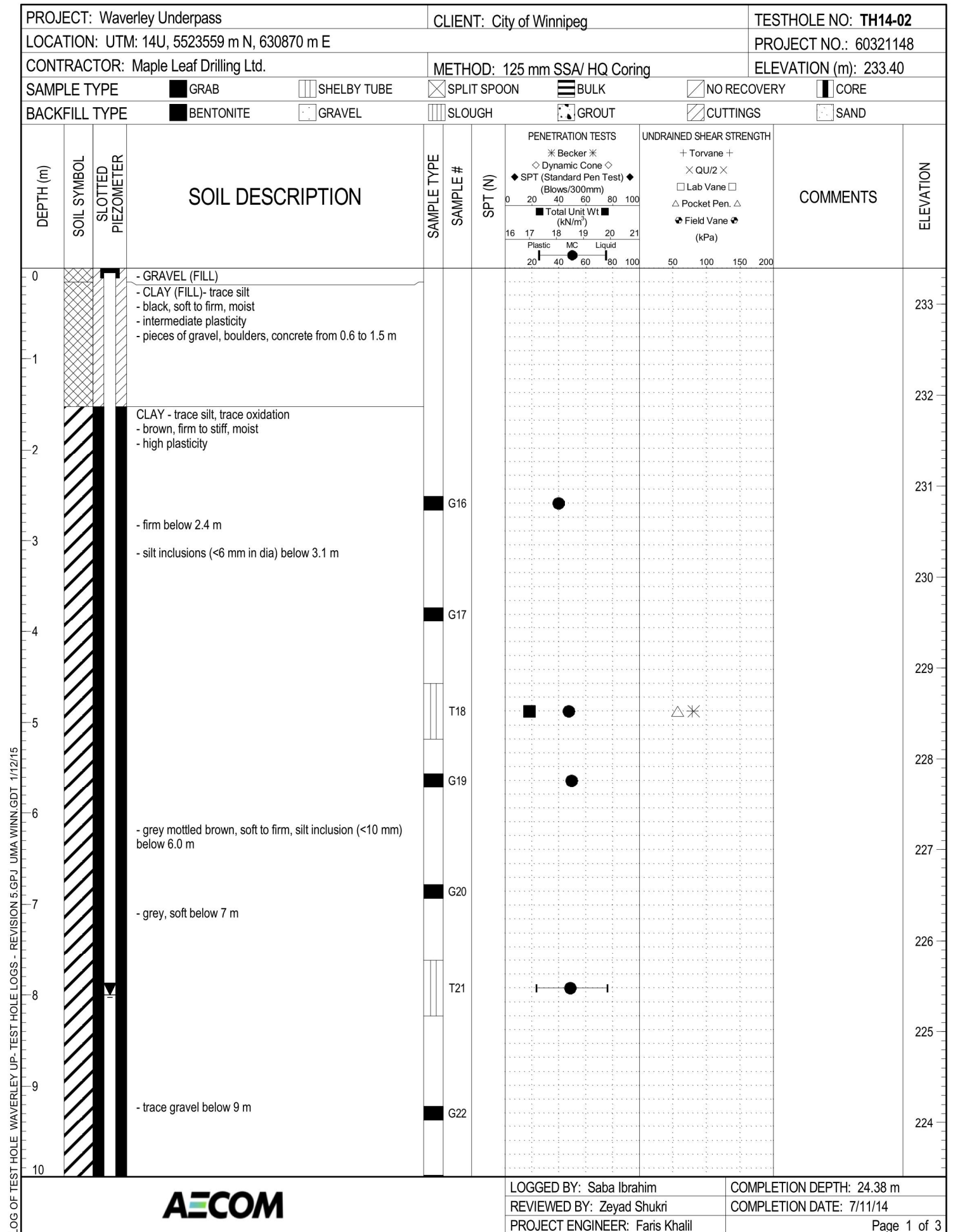
Downtown Bedrock Groundwater Levels Station OJ-021 - Law Courts Building



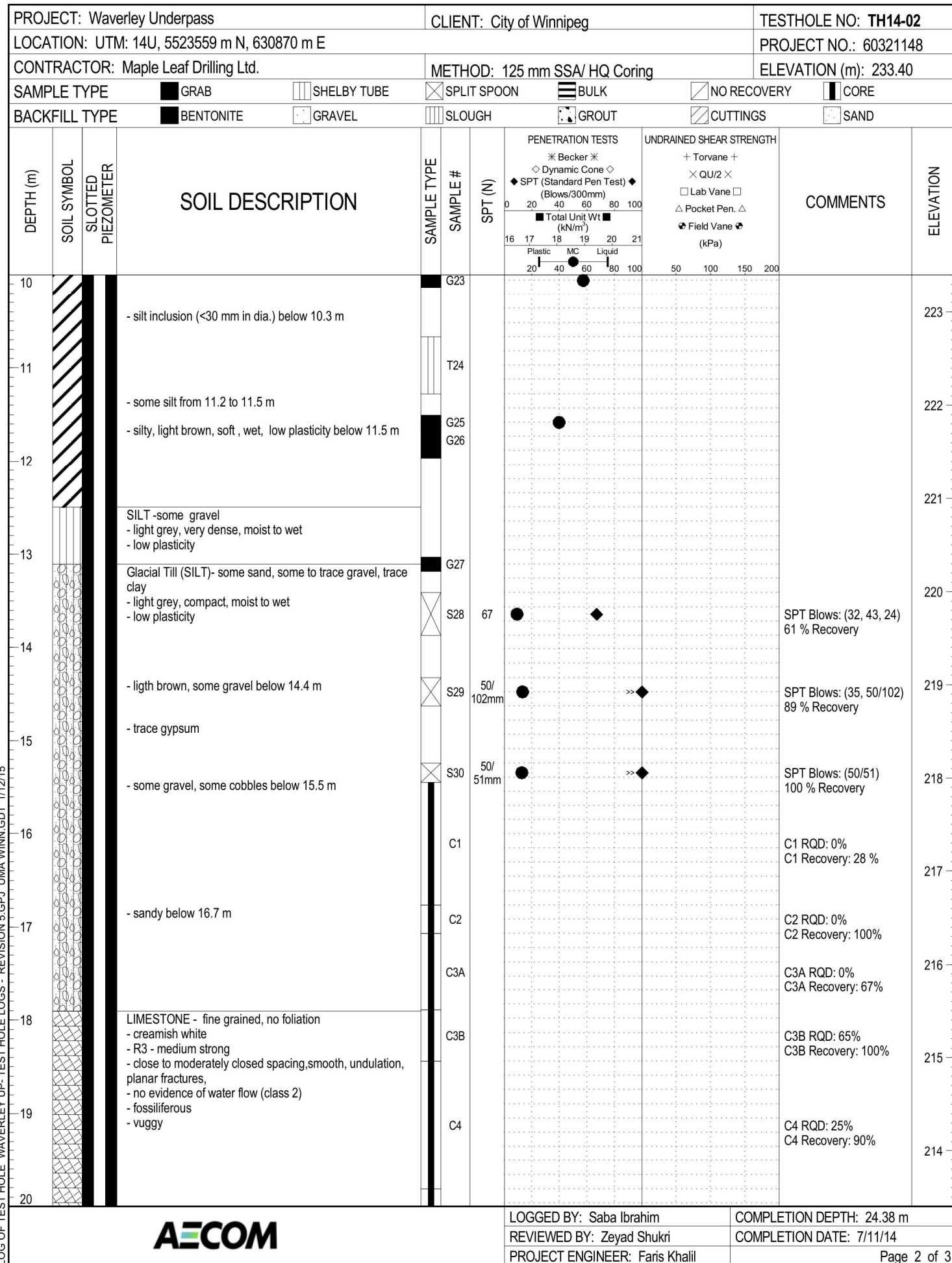
Appendix B
AECOM Geotechnical Logs



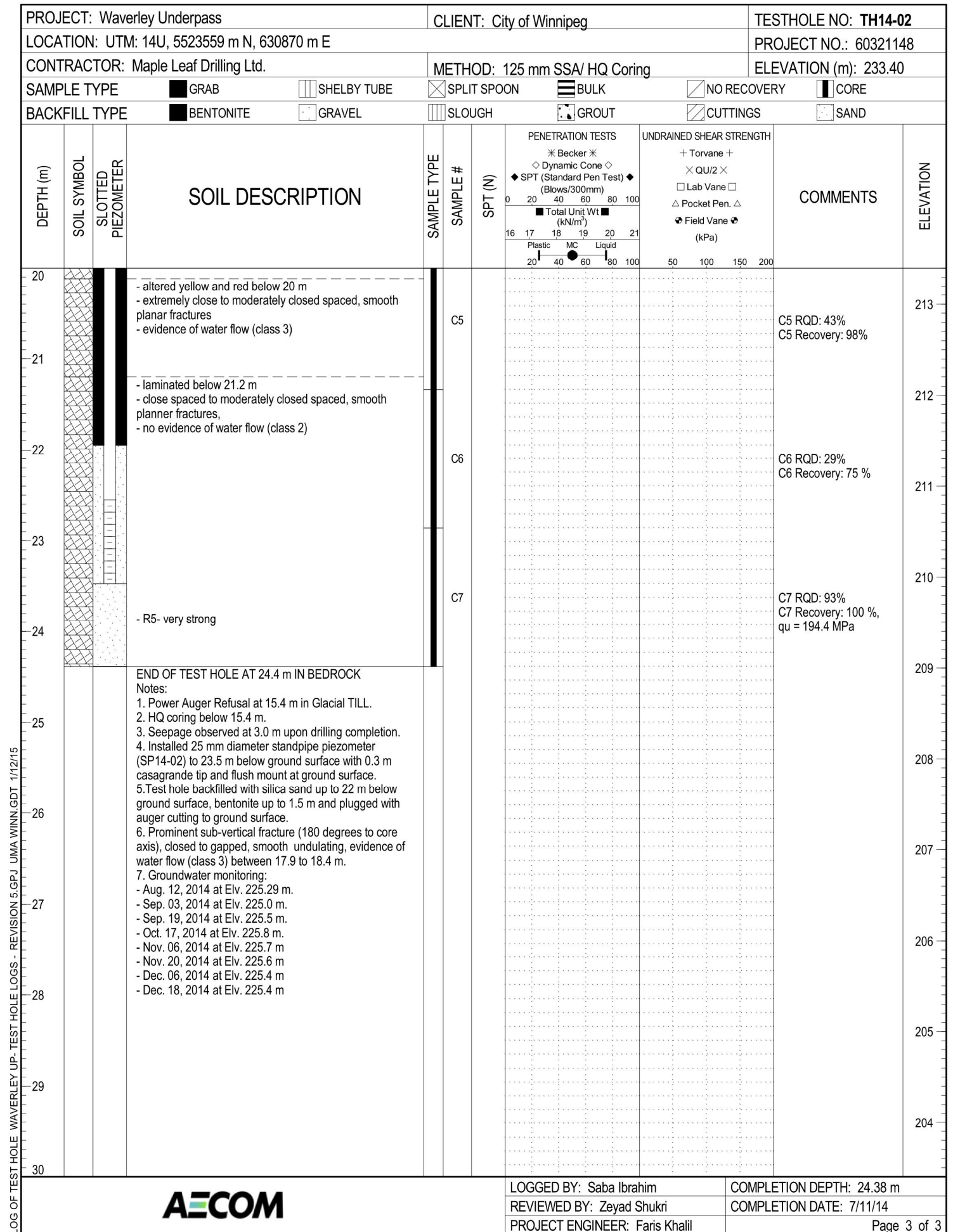
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LOG OF TEST HOLE - WAVERLEY UP- TEST HOLE LOGS - REVISION 5.GPJ - UMA WINN.GDT - 1/12/15



LOG OF TEST HOLE WAYERLEY UP- TEST HOLE LOGS - REVISION 5.GPJ UMA WINN.GDT 1/12/15



LOG OF TEST HOLE WAYERLEY UP- TEST HOLE LOGS - REVISION 5.GPJ UMA WINN.GDT 1/12/15

PROJECT: Waverley Underpass		CLIENT: City of Winnipeg		TESTHOLE NO: TH14-03					
LOCATION: UTM: 14U, 5523562 m N, 630895 m E		METHOD: 125 mm SSA/ HQ Coring		PROJECT NO.: 60321148					
CONTRACTOR: Maple Leaf Drilling Ltd.		ELEVATION (m): 233.66		ELEVATION (m): 233.20					
SAMPLE TYPE		METHOD		ELEVATION (m)					
<input checked="" type="checkbox"/> GRAB <input type="checkbox"/> SHELBY TUBE <input checked="" type="checkbox"/> SPLIT SPOON <input type="checkbox"/> BULK <input type="checkbox"/> NO RECOVERY <input type="checkbox"/> CORE		<input type="checkbox"/> SHELBY TUBE <input checked="" type="checkbox"/> SPLIT SPOON <input type="checkbox"/> BULK <input type="checkbox"/> NO RECOVERY <input type="checkbox"/> CORE		<input type="checkbox"/> SHELBY TUBE <input checked="" type="checkbox"/> SPLIT SPOON <input type="checkbox"/> BULK <input type="checkbox"/> NO RECOVERY <input type="checkbox"/> CORE					
DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	PENETRATION TESTS	UNDRAINED SHEAR STRENGTH	COMMENTS	ELEVATION
20		- recovered as coarse, sub angular to sub rounded light grey gravel between 20.3 to 21.9 m		C4				C4 RQD: 0% C4 Recovery: 100%	213
21				C5				C5 RQD: 19% C5 Recovery: 68 %	212
22		SHALE - very fine grained - blue, green - no foliation - R1- very weak - extremely close spaced, rough undulating fractures		C6				C6 RQD: 76% C6 Recovery: 100 %	211
23		LIMESTONE - white - fine grained - no foliation - R3- medium strong - close to moderately spaced, smooth fractures, closed, no evidence of water flow (class 2) - laminated below 22 m		C7				C7 RQD: 80% C7 Recovery: 100 % qu =120.9 MPa	210
24		- R5- very strong							209
25		END OF TEST HOLE AT 24.4 m IN BEDROCK Notes: 1. Power Auger Refusal at 14.3 m in Glacial TILL. 2. HQ coring below 14.3 m. 3. No sloughing was observed upon drilling completion. 4. No seepage was observed upon drilling completion. 5. Test hole backfilled with bentonite up to 3 m below ground level and with auger cutting to the ground surface.							208
26									207
27									206
28									205
29									204
30									204

LOG OF TEST HOLE WAYERLEY UP- TEST HOLE LOGS - REVISION 5.GPJ UMA WINN.GDT 1/12/15



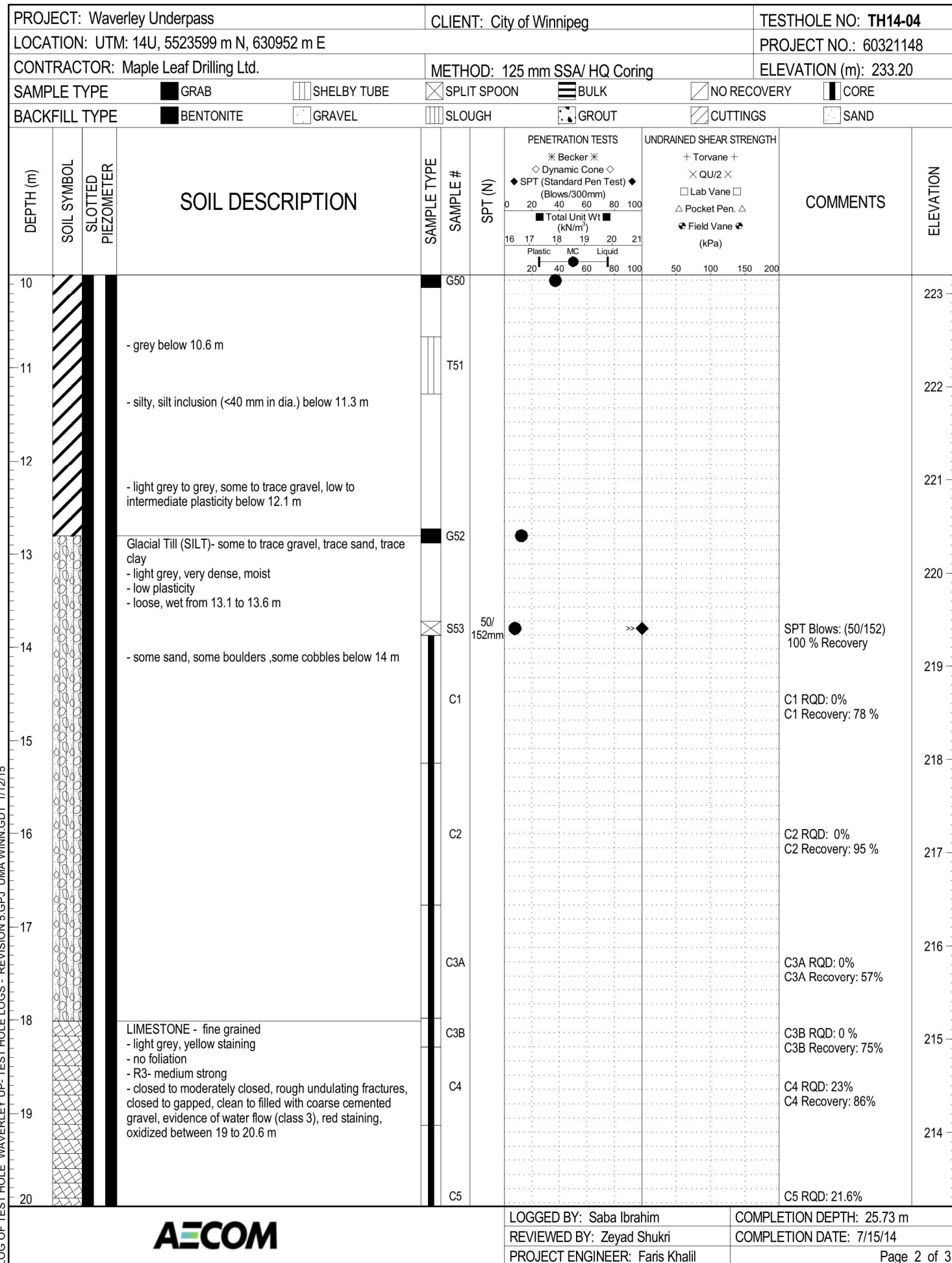
LOGGED BY: Saba Ibrahim COMPLETION DEPTH: 24.38 m
 REVIEWED BY: Zeyad Shukri COMPLETION DATE: 7/14/14
 PROJECT ENGINEER: Faris Khalil Page 3 of 3

PROJECT: Waverley Underpass		CLIENT: City of Winnipeg		TESTHOLE NO: TH14-04					
LOCATION: UTM: 14U, 5523599 m N, 630952 m E		METHOD: 125 mm SSA/ HQ Coring		PROJECT NO.: 60321148					
CONTRACTOR: Maple Leaf Drilling Ltd.		ELEVATION (m): 233.20		ELEVATION (m): 233.20					
SAMPLE TYPE		METHOD		ELEVATION (m)					
<input checked="" type="checkbox"/> GRAB <input type="checkbox"/> SHELBY TUBE <input checked="" type="checkbox"/> SPLIT SPOON <input type="checkbox"/> BULK <input type="checkbox"/> NO RECOVERY <input type="checkbox"/> CORE		<input type="checkbox"/> SHELBY TUBE <input checked="" type="checkbox"/> SPLIT SPOON <input type="checkbox"/> BULK <input type="checkbox"/> NO RECOVERY <input type="checkbox"/> CORE		<input type="checkbox"/> SHELBY TUBE <input checked="" type="checkbox"/> SPLIT SPOON <input type="checkbox"/> BULK <input type="checkbox"/> NO RECOVERY <input type="checkbox"/> CORE					
BACKFILL TYPE		METHOD		ELEVATION (m)					
<input checked="" type="checkbox"/> BENTONITE <input type="checkbox"/> GRAVEL <input type="checkbox"/> SLOUGH <input type="checkbox"/> GROUT <input type="checkbox"/> CUTTINGS <input type="checkbox"/> SAND		<input type="checkbox"/> SLOUGH <input type="checkbox"/> GROUT <input type="checkbox"/> CUTTINGS <input type="checkbox"/> SAND		<input type="checkbox"/> SLOUGH <input type="checkbox"/> GROUT <input type="checkbox"/> CUTTINGS <input type="checkbox"/> SAND					
DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	PENETRATION TESTS	UNDRAINED SHEAR STRENGTH	COMMENTS	ELEVATION
0		- GRAVEL (FILL) - CLAY (FILL)-trace silt - black, soft to firm, moist - intermediate plasticity - pieces of gravel, boulders, concrete from 0.6 to 1.5 m							233
1									232
2		CLAY - trace oxidation - brown, firm, moist - high plasticity							231
3		- soft to firm between 2.4 to 3 m		G43					230
4		- brown mottled light brown, silt inclusion (< 6 mm in dia.) below 3 m		G44					229
5		- dark brown, silt inclusion (<10 mm in dia.) below 4.5 m		T45					228
6		- grey mottled brown below 6 m		G46					227
7		- soft below 7.3 m		G47					226
8		- silt pocket at 8.3 m		T48					225
9		- trace gravel below 8.8 m - some silt to silty, light grey to grey below 9.1 m		G49					224
10									224

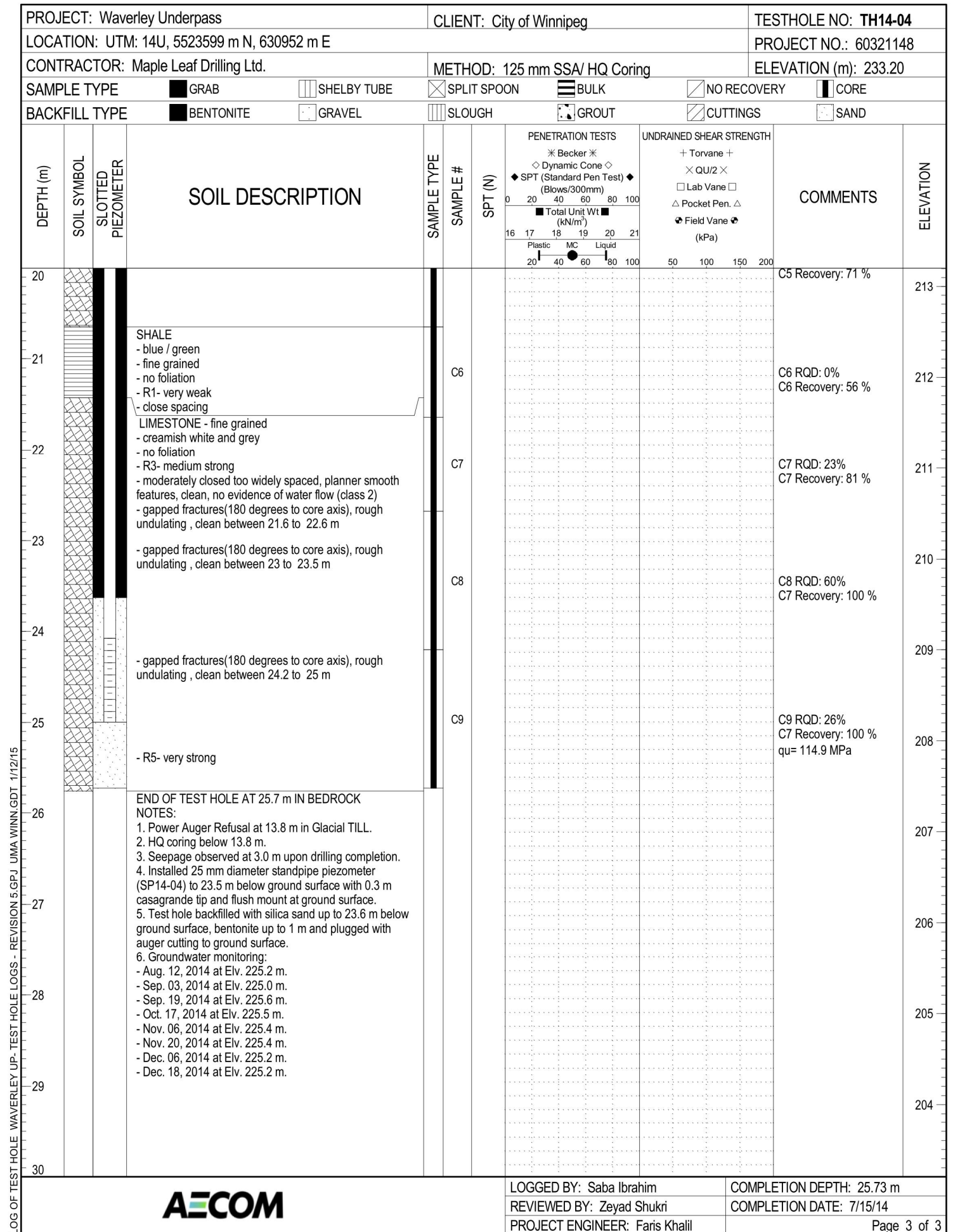
LOG OF TEST HOLE WAYERLEY UP- TEST HOLE LOGS - REVISION 5.GPJ UMA WINN.GDT 1/12/15



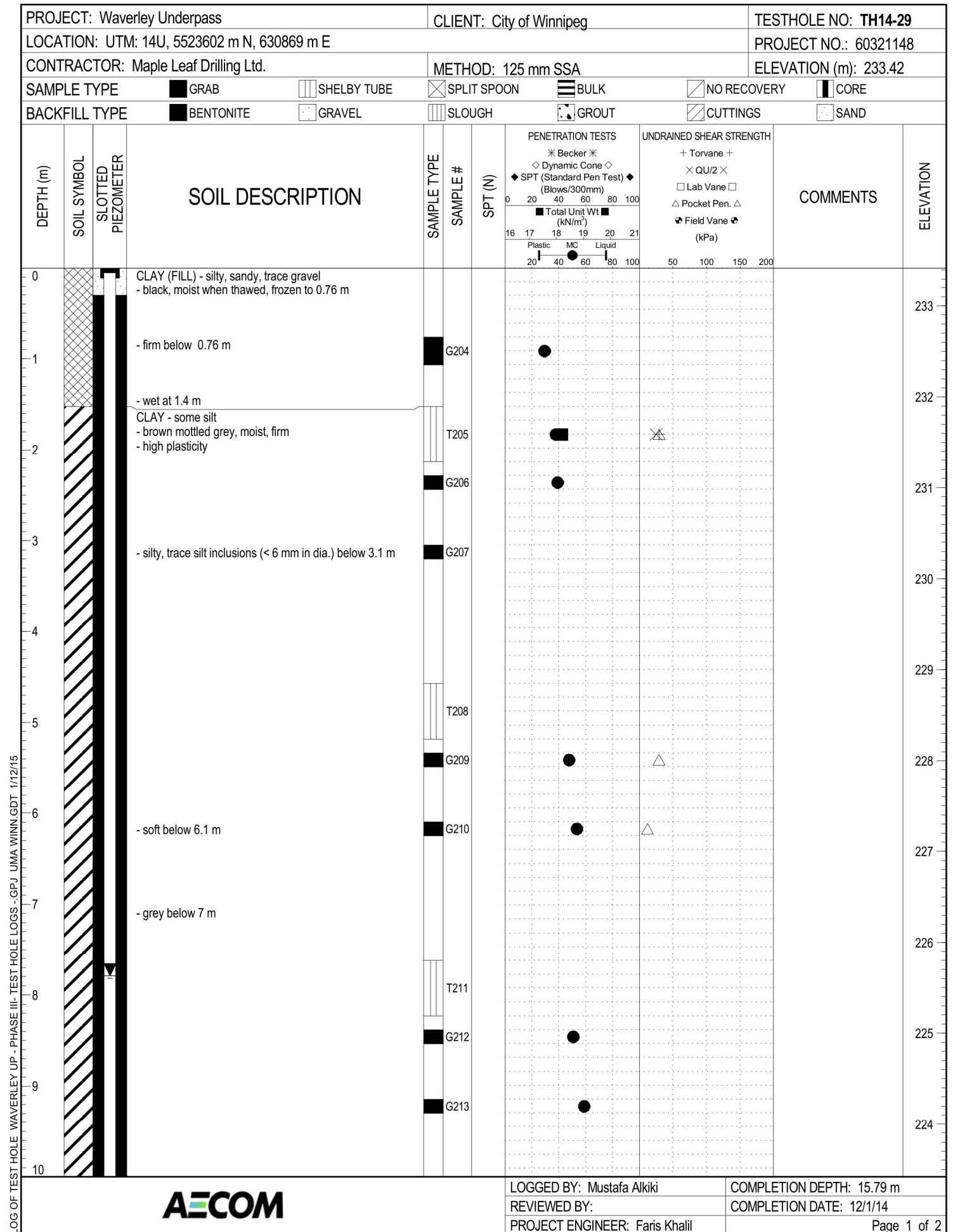
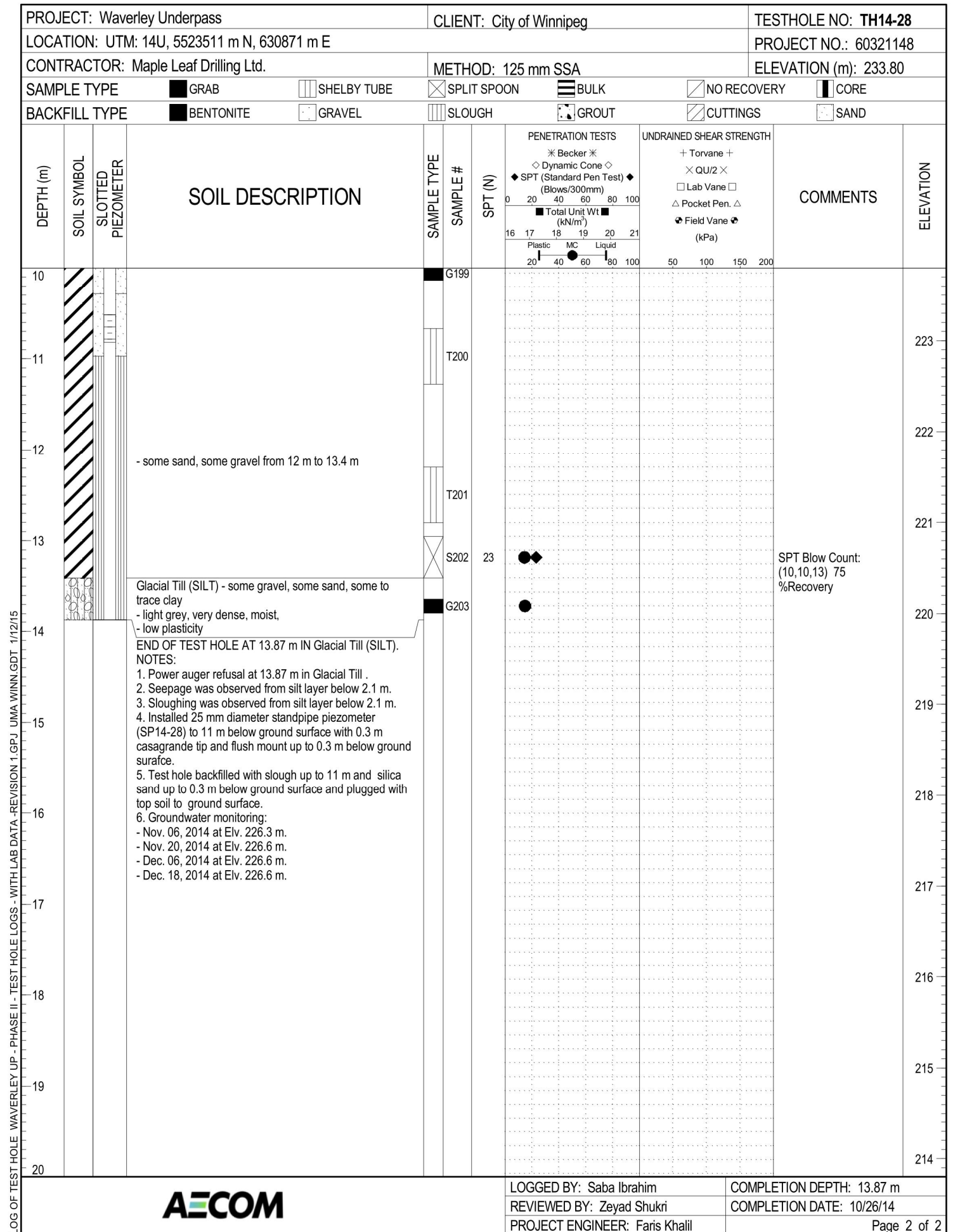
LOGGED BY: Saba Ibrahim COMPLETION DEPTH: 25.73 m
 REVIEWED BY: Zeyad Shukri COMPLETION DATE: 7/15/14
 PROJECT ENGINEER: Faris Khalil Page 1 of 3



LOG OF TEST HOLE WAYERLEY UP- TEST HOLE LOGS - REVISION 5.GPJ UMA WINN.GDT 1/12/15

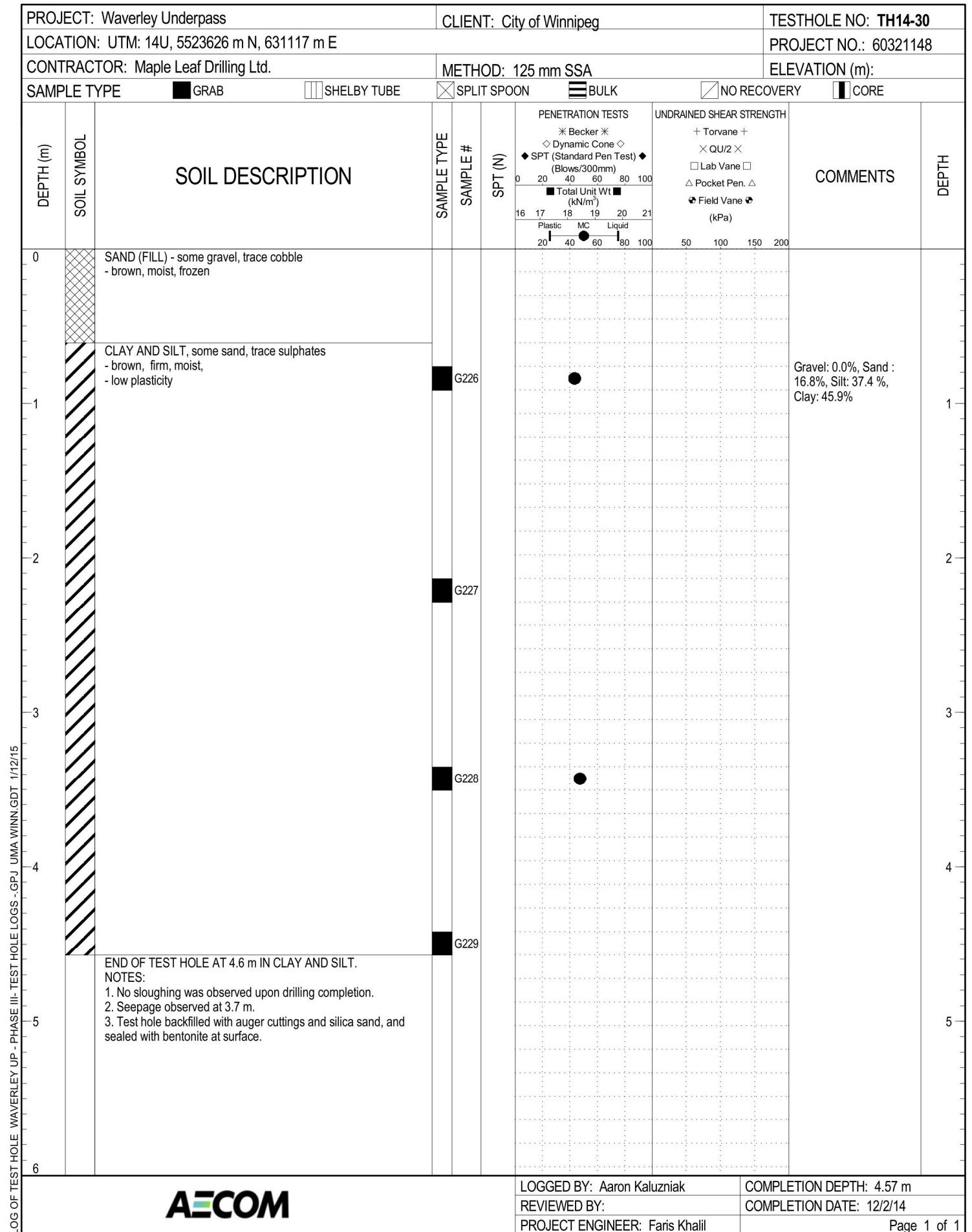
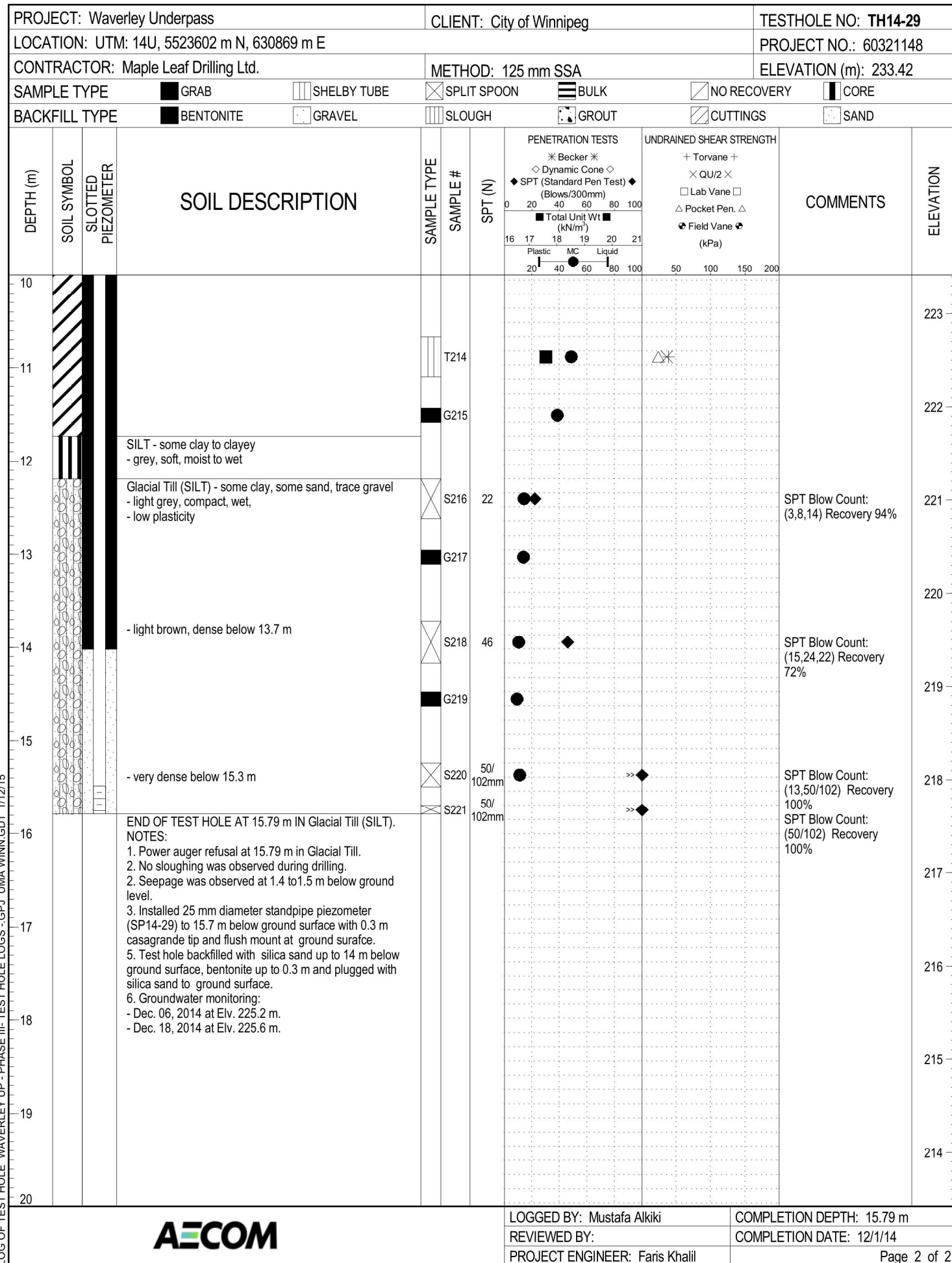


LOG OF TEST HOLE WAYERLEY UP- TEST HOLE LOGS - REVISION 5.GPJ UMA WINN.GDT 1/12/15



LOG OF TEST HOLE - WAVERLEY UP - PHASE II - TEST HOLE LOGS - WITH LAB DATA - REVISION 1.GPJ - UMA WINN.GDT - 1/12/15

LOG OF TEST HOLE - WAVERLEY UP - PHASE III - TEST HOLE LOGS - GPJ - UMA WINN.GDT - 1/12/15



LOG OF TEST HOLE - WAVERLEY UP - PHASE III - TEST HOLE LOGS - GPJ UMA WINN GDT 1/12/15

LOG OF TEST HOLE - WAVERLEY UP - PHASE III - TEST HOLE LOGS - GPJ UMA WINN GDT 1/12/15

Appendix C
Regulatory Approvals



June 27, 2016

File: Waverley Underpass

Manitoba Sustainable Development
Water Use Licensing Section
Box 16, 200 Saulteaux Crescent
Winnipeg, MB R3J 3W3

Attention: Mr. R. Matthews, P.Geo.
Manager

Dear Mr. Matthews:

**RE: City of Winnipeg
Waverley Underpass
Application For License To Construct A Well And Divert Groundwater**

On behalf of the City of Winnipeg, W.L. Gibbons & Associates Inc. (WLG) is writing you to obtain approvals to conduct a groundwater exploration program for the purposes of establishing the hydrogeologic conditions at the proposed Waverley Underpass site located on Waverley Street south of Taylor Avenue. The design of the lift station to be constructed as part of the underpass project will require excavation to depths at which base heave and/or groundwater seepage due to high groundwater pressures in the underlying bedrock aquifer become a concern. In order to mitigate this concern, it may be necessary to temporarily lower the groundwater pressures within the aquifer during construction. It is recognized that several geothermal systems are located in the area of this site which could be impacted by groundwater depressurization, and that mitigation of any potential impacts will be required. A completed Application For License To Construct A Well And Divert Groundwater is attached. The following letter provides further details on the proposed groundwater withdrawal.

The potential pumping rates required to achieve the necessary temporary depressurization is unknown at this stage and will be determined during the course of this study.

The proposed location for the lift station is on the west side of Waverley Street and south of Taylor Avenue and the CN rail tracks. The work will be conducted on municipal lands.

All information collected during this work program would be compiled into a report complete with copies of the Drillers Reports documenting the test hole results, well construction details, a site plan showing the locations of the wells, UTM coordinates for the wells, results of the pumping tests, and details of the pumping rates, discharge location and pumping duration. The report will also identify existing groundwater users in the area who might be impacted by the pumping and a plan to mitigate any potential impacts will be prepared. A copy of the report would be forwarded to MB Sustainable Development, Water Use Licensing Section in support of the application for a Water Rights License, if it is determined that a groundwater depressurization system will be required and therefore a Water Rights License will be required.

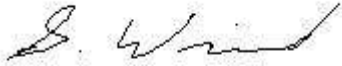
Mr. R. Matthews

June 27, 2016

Page 2

We trust that the preceding meets your requirements to issue the approvals. If you have any questions or require further information, please contact the undersigned at (204) 771-4389 or swiecek@mymts.net.

Sincerely,



Steve Wiecek, P.Geo., P.Eng.
Senior Geologic Engineer
swiecek@mts.net

SJW/sw

Cc: Mr. Cameron Ward – City of Winnipeg
Mr. Jordan Thompson - AECOM



Application for Licence to Construct a Well and Divert Groundwater

Demande de licence de construction d'un puits et de détournement d'eaux souterraines



Manitoba Water Stewardship
Water Licensing Branch
200 Saulteaux Crescent
Winnipeg MB R3J 3W3

Gestion des ressources hydriques Manitoba
Direction des licences d'utilisation de l'eau
200, croissant Saulteaux
Winnipeg (Manitoba) R3J 3W3

Pursuant to The Water Rights Act / En vertu de la Loi sur les droits d'utilisation de l'eau

APPLICANT'S NAME: City of Winnipeg NOM DU DEMANDEUR : Attn: Cameron Ward, P.Eng.	TELEPHONE: (204) 986-3508 TÉLÉPHONE :
POST OFFICE ADDRESS: 106 – 1155 Pacific Avenue ADRESSE POSTALE : Winnipeg, MB R3E 3P1	

hereby applies for authority to construct a water well(s) on the following described land(s): /
demande par la présente l'autorisation de construire un ou plusieurs puits sur le ou les biens-fonds suivants :

LSD / SUBDIVISION LÉGALE	OR QUARTER / OU QUART DE SECTION	SECTION	TOWNSHIP	RANGE / RANG	E OR W / EST OU OUEST
--------------------------------	--	---------	----------	-----------------	--------------------------

or otherwise described as / ou autrement décrit comme **_Waverley Underpass – Waverley Street South of Taylor and the CN Rail Lines**

and divert groundwater for / et de détourner des eaux souterraines pour des fins

Construction Dewatering
(domestic, municipal, agricultural, industrial, irrigation, other) / (domestiques, municipales, agricoles, industrielles, d'irrigation, autres)

purposes on the following described land: / sur le bien-fonds suivant :

LSD / SUBDIVISION LÉGALE	OR QUARTER / OU QUART DE SECTION	SECTION	TOWNSHIP	RANGE / RANG	E OR W / EST OU OUEST
--------------------------------	--	---------	----------	-----------------	--------------------------

or otherwise described as / ou autrement décrit comme _____

at the following rates: **_To Be Determined_** cubic metres per second / mètres cubes par seconde
aux taux suivants :
_____ cubic decametres per day / décamètres cubes par jour
_____ cubic decametres per year / décamètres cubes par année

Number of hectares to be irrigated / Nombre d'hectares à irriguer : _____ (if applicable / le cas échéant)

The above described lands are held as follows: (check applicable box) /
Type de possession des biens-fonds décrits ci-dessus (cocher la case appropriée) :

X as registered owner / propriétaire inscrit ρ purchased under agreement for sale / acheté selon une convention de vente
ρ lessee / preneur à bail ρ to be negotiated / à négocier

Copy(s) of the Certificate(s) of Title or Title Number(s) must be included /
Des copies des certificats de titre ou des numéros de titre doivent être inclus :

Date: June 27 _____ 2016 _____

(signature of applicant / signature du demandeur)

FOR OFFICE USE ONLY / RÉSERVÉ À L'ADMINISTRATION

Application filed with the Executive Director, Infrastructure and Operations, at Winnipeg, Manitoba on /
Demande déposée auprès du directeur général, Infrastructures et opérations, à Winnipeg (Manitoba), le

_____, 20 _____.

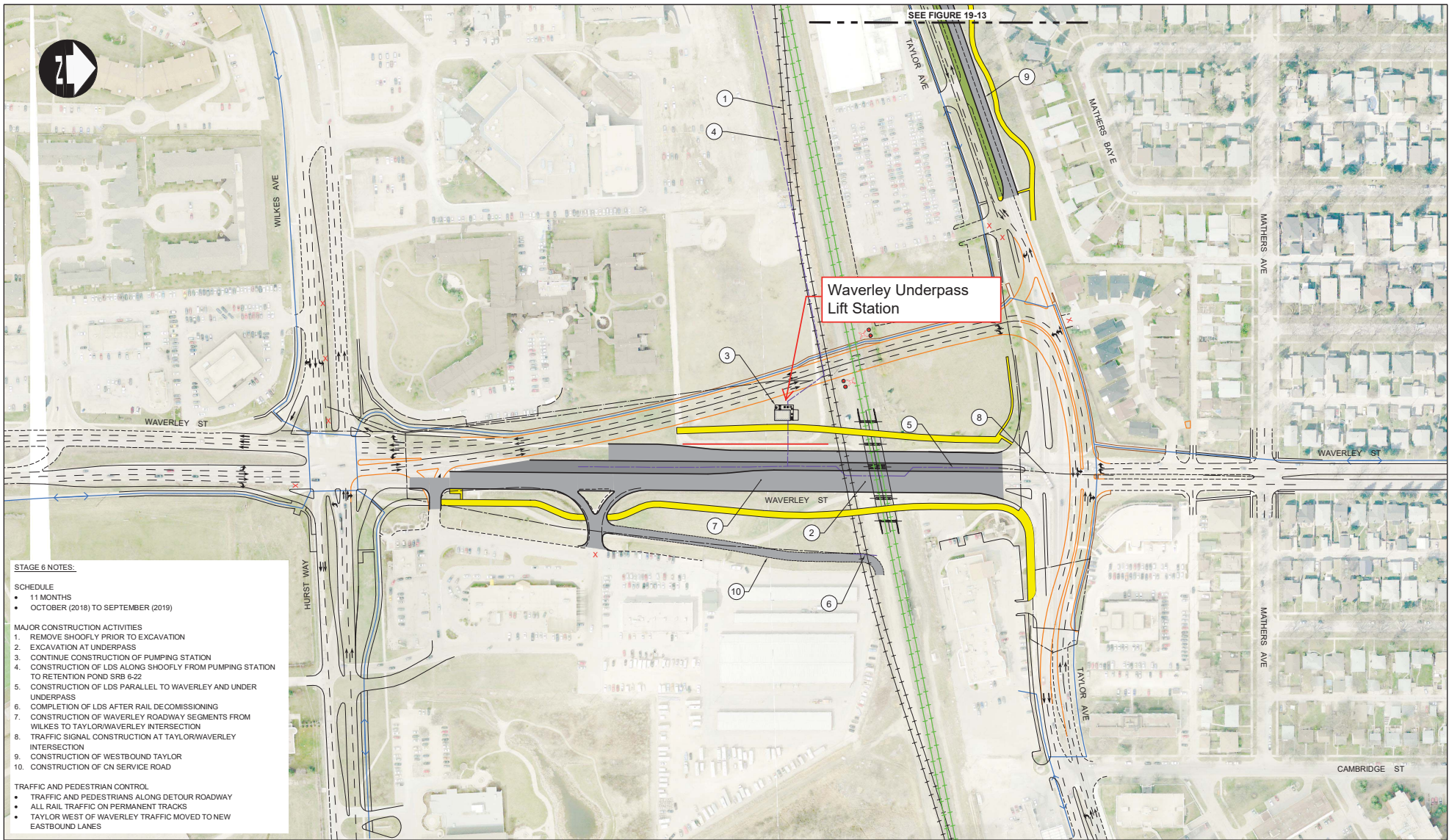
(Signature of Executive Director / Signature du directeur général)

** IMPORTANT **

FEE OF \$50.00 MUST ACCOMPANY THIS APPLICATION, CHEQUE AND APPLICATION TO BE MAILED TO:
LE PAIEMENT DES DROITS DE 50 \$ DOIT ACCOMPAGNER CETTE DEMANDE. FAIRE PARVENIR LE CHÈQUE ET LA DEMANDE
À L'ADRESSE SUIVANTE :

MANITOBA CONSERVATION
CASHIER'S OFFICE
BOX 42, 200 SAULTEAUX CRESCENT
WINNIPEG MB R3J 3W3

CONSERVATION MANITOBA
BUREAU DU CAISSIER
C. P. 42, 200, CROISSANT SAULTEAUX
WINNIPEG (MANITOBA) R3J 3W3



STAGE 6 NOTES:

SCHEDULE

- 11 MONTHS
- OCTOBER (2018) TO SEPTEMBER (2019)

MAJOR CONSTRUCTION ACTIVITIES

1. REMOVE SHOOFLY PRIOR TO EXCAVATION
2. EXCAVATION AT UNDERPASS
3. CONTINUE CONSTRUCTION OF PUMPING STATION
4. CONSTRUCTION OF LDS ALONG SHOOFLY FROM PUMPING STATION TO RETENTION POND SRB 6-22
5. CONSTRUCTION OF LDS PARALLEL TO WAVERLEY AND UNDER UNDERPASS
6. COMPLETION OF LDS AFTER RAIL DECOMMISSIONING
7. CONSTRUCTION OF WAVERLEY ROADWAY SEGMENTS FROM WILKES TO TAYLOR/WAVERLEY INTERSECTION
8. TRAFFIC SIGNAL CONSTRUCTION AT TAYLOR/WAVERLEY INTERSECTION
9. CONSTRUCTION OF WESTBOUND TAYLOR
10. CONSTRUCTION OF CN SERVICE ROAD

TRAFFIC AND PEDESTRIAN CONTROL

- TRAFFIC AND PEDESTRIANS ALONG DETOUR ROADWAY
- ALL RAIL TRAFFIC ON PERMANENT TRACKS
- TAYLOR WEST OF WAVERLEY TRAFFIC MOVED TO NEW EASTBOUND LANES



	ACTIVE TRACKS		VEHICULAR TRAFFIC ROADWAY CLOSED AT TRAFFIC
	INACTIVE TRACKS		TEMPORARY ROADWAY CONSTRUCTION
	SHOOFLY TRACKS CONSTRUCTION		PERMANENT ROADWAY CONSTRUCTION
	PERMANENT TRACKS/BRIDGE CONSTRUCTION		TEMPORARY AT CONSTRUCTION
	TEMPORARY CROSSING SIGNALS		PERMANENT AT CONSTRUCTION
	LDS/CS CONSTRUCTION		
	WATERMAIN CONSTRUCTION		

WAVERLEY UNDERPASS PRELIMINARY ENGINEERING STUDY

WAVERLEY UNDERPASS CONSTRUCTION STAGING STAGE 6 (1 OF 2)

SCALE: 1:2500

FIGURE 19-12

RECEIVED
JUL 27 2016
AECOM CANADA LTD.

60321148 (2050)
J. Thompson.

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

June 20, 2016

File: Winnipeg, City of -38

Cameron Ward, P. Eng.
106-1155 Pacific Avenue
Winnipeg, MB R3E 3P1

Dear Mr. Ward:

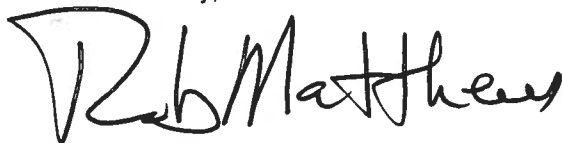
Attached herewith is a **Groundwater Exploration Permit** issued in response to an application submitted by Steve Wiecek, Senior Geologic Engineer, W.L. Gibbons & Associates Inc. on behalf of the City of Winnipeg registered on June 27, 2016, for a licence to construct well(s) and divert groundwater in connection with the construction of Waverley Underpass on **RL 46-48, Parish of St. Boniface**, Winnipeg.

The Groundwater Exploration Permit authorizes the City of Winnipeg to carry out a groundwater exploration program for purposes of establishing the hydrogeologic conditions at the Waverley Underpass construction site. 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: Steve Wiecek, W.L. Gibbons & Associates Inc.
Jordan Thompson, AECOM
Ronaldo Miranda, WULS

Groundwater Exploration Permit

Pursuant to The Water Rights Act

FILE – Winnipeg, The City of -38

is hereby permitted to explore for and construct a groundwater well or wells on the following described lands, **RL 46-48, Parish of St. Boniface**, for hydrogeologic site assessment 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 an 800 m 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 an 800 m 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 twenty-four (24) 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 20th day of July, A.D. 20 16


for The Honourable Minister of Sustainable Development

Appendix D
Drillers Report TW 16-01

Driller's Report

**MANITOBA
WATER STEWARDSHIP**



WELL LOCATION	QTR. ____ SEC. __ TWP. __ RGE. ____ E1. ____ R. LOT <u>46-48</u> PARISH <u>St. Boniface</u> REMARKS: <u>Waverley Underpass, 877 Wilkes Ave</u> <u>14U 0630863, 5523536</u>	Location Sketch of Well
WELL OWNER	NAME: <u>City of Winnipeg</u> ADDRESS: PHONE:	
WELL ID.	<u>TW 16-01</u>	
WELL USE	<u>Test Well</u>	
WATER USE	<u>Construction Dewatering</u>	
DATE	<u>August 4, 2016</u>	

WELL LOG	Depth Below Ground In Feet		DESCRIPTION	Water Record (Kind of Water)
	From	To		
	0	42	Clay	
	42	55	Till	
	55	60	Limestone Rubble with clay, sand and gravel, producing water	
	60	72	Dolomite (Red River Formation, Upper Fort Garry Member), hard Fractures at 70 and 72 feet	
	72	74	Bentonitic Shale, gray, soft, abundant pyrite	
	74	78	Dolomite (Red River Formation, Upper Fort Garry Member), hard	
		78	End of Hole	

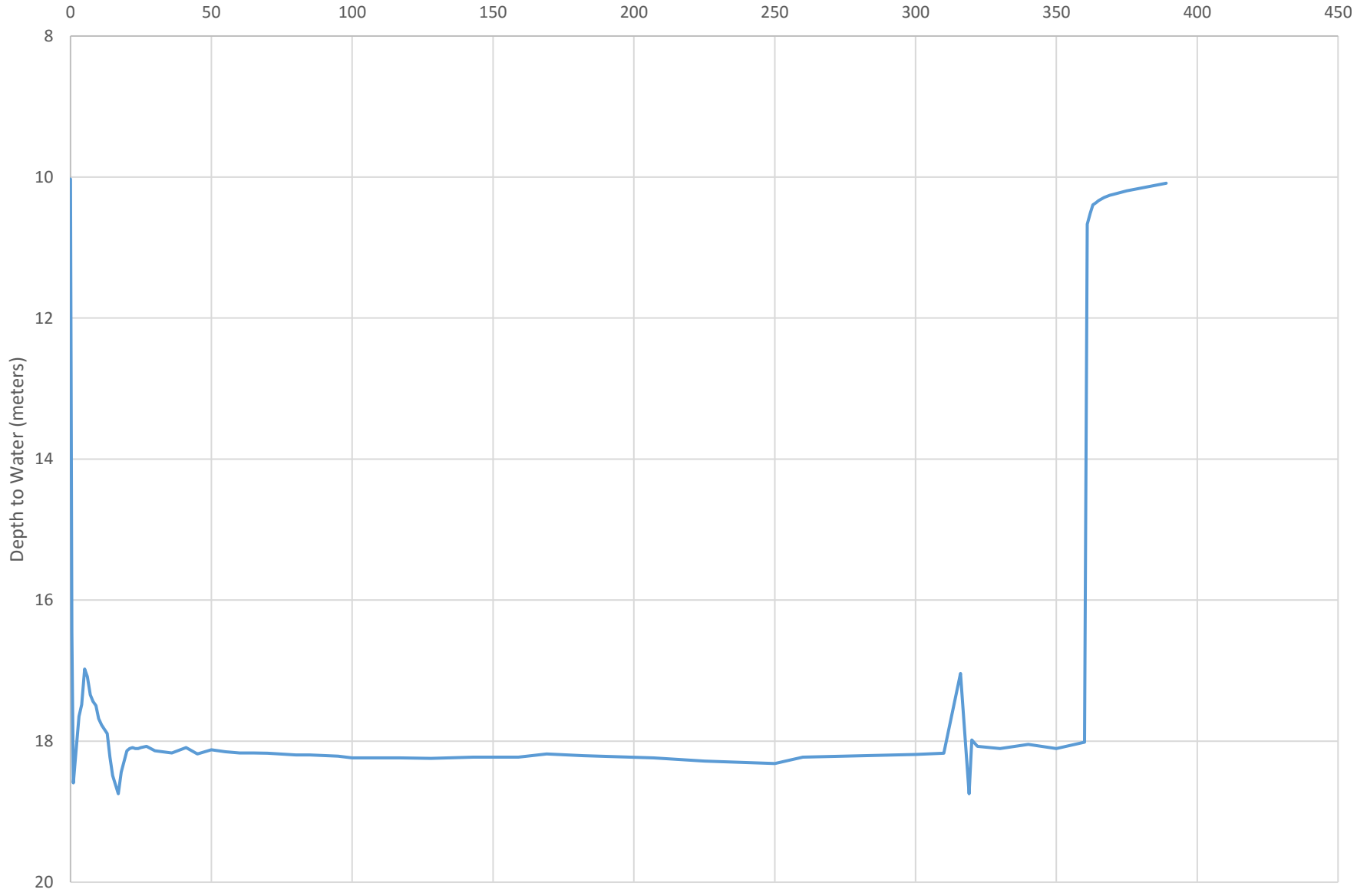
WELL CONSTRUCTION	Depth Below Ground Level In Feet		CASING	OPEN HOLE	PERFORATIONS	GRAVEL PACK	CASING GROUT	PITLESS UNIT	INSIDE DIAMETER INCHES	OUTSIDE DIAMETER INCHES	SCREEN SLOT SIZE NO. OR INCH	TYPE	MATERIAL	MAKE	
	From	To													
	0	61	X						6					Steel	
	61	78		X					5.75						
	Top Of Casing Or Pitless Adapter: <u>0</u> Feet Above <u> </u> Below <u>X</u> Ground Level Remarks: <u>Linden Christian School Field. 18 meters south of fence line/CN property limit and 50 meters west of west Edge of Waverley Street pavement. At request of school, well casing cut off at grade, sanitary seal installed at top Of casing, and a steel flushmount road box cover was installed over the well.</u>														

PUMPING TEST	Date Of Test: (y/mm/d) <u>16/08/05</u>	CONTRACTOR	Licence No.:
	Pumping / Flowing Rate: <u>27</u> I.G.P.M.		
	Water Level <u>32.9</u> ft. Above <u> </u> Ground Before Pumping: <u> </u> Below <u>X</u> Level		Name: <u>Friesen Drillers</u>
	Pumping Level <u>60.0</u> ft. Above <u> </u> Ground At End Of Test: <u> </u> Below <u>X</u> Level		Address: <u>Steinbach, MB</u> Phone:
	Duration Of Test: (Hrs:Min) <u>6:00</u>		Drill Operator: <u>Chris Loeppky</u>
	Water Temperature: <u> </u> Conductivity: <u> </u>		
	Recommended Pumping Rate: With Pump Intake At: <u> </u> ft. Below Ground Level		(Signature of Contractor)

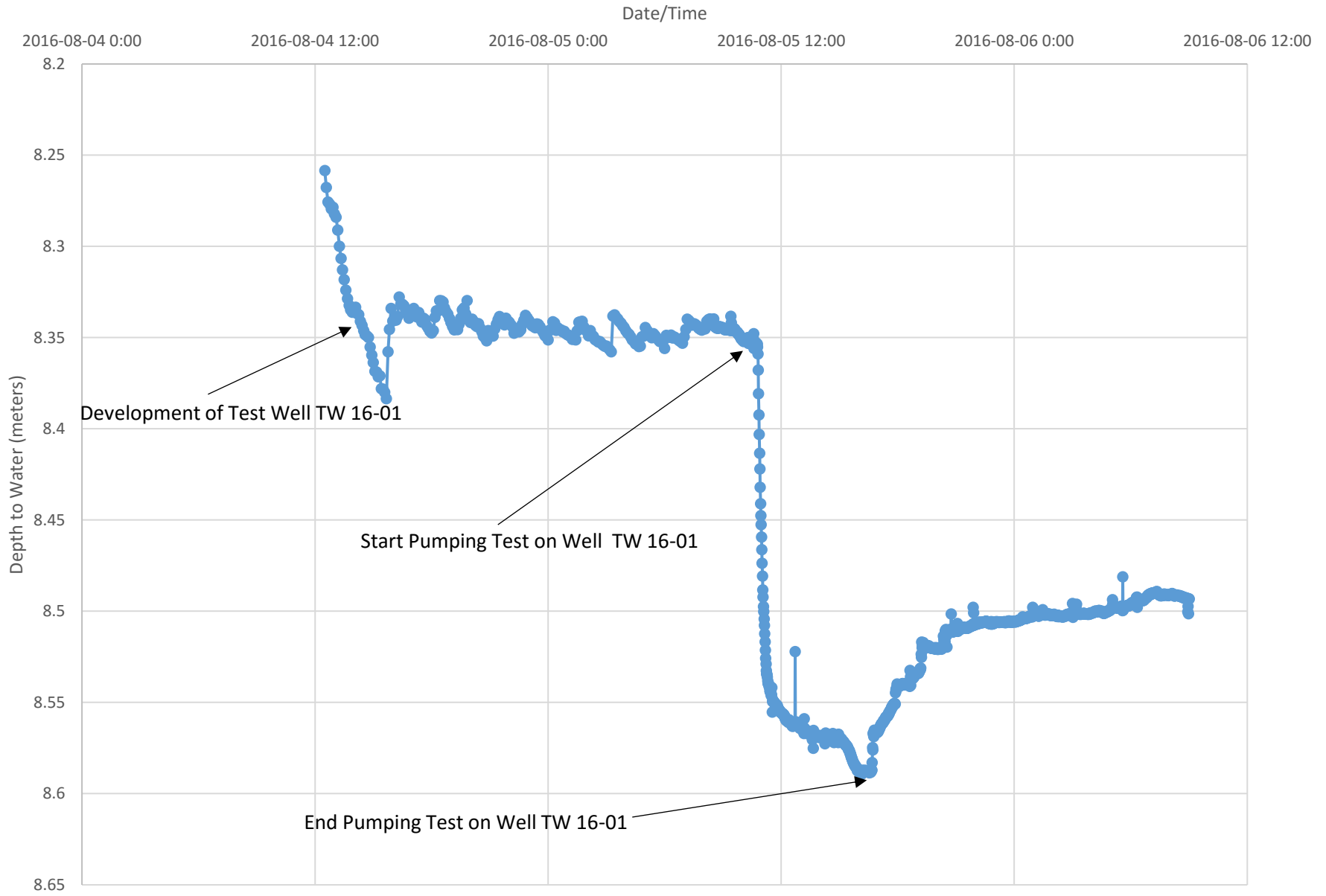
Appendix E
Pumping Test Results

Pumping Well TW 16=01

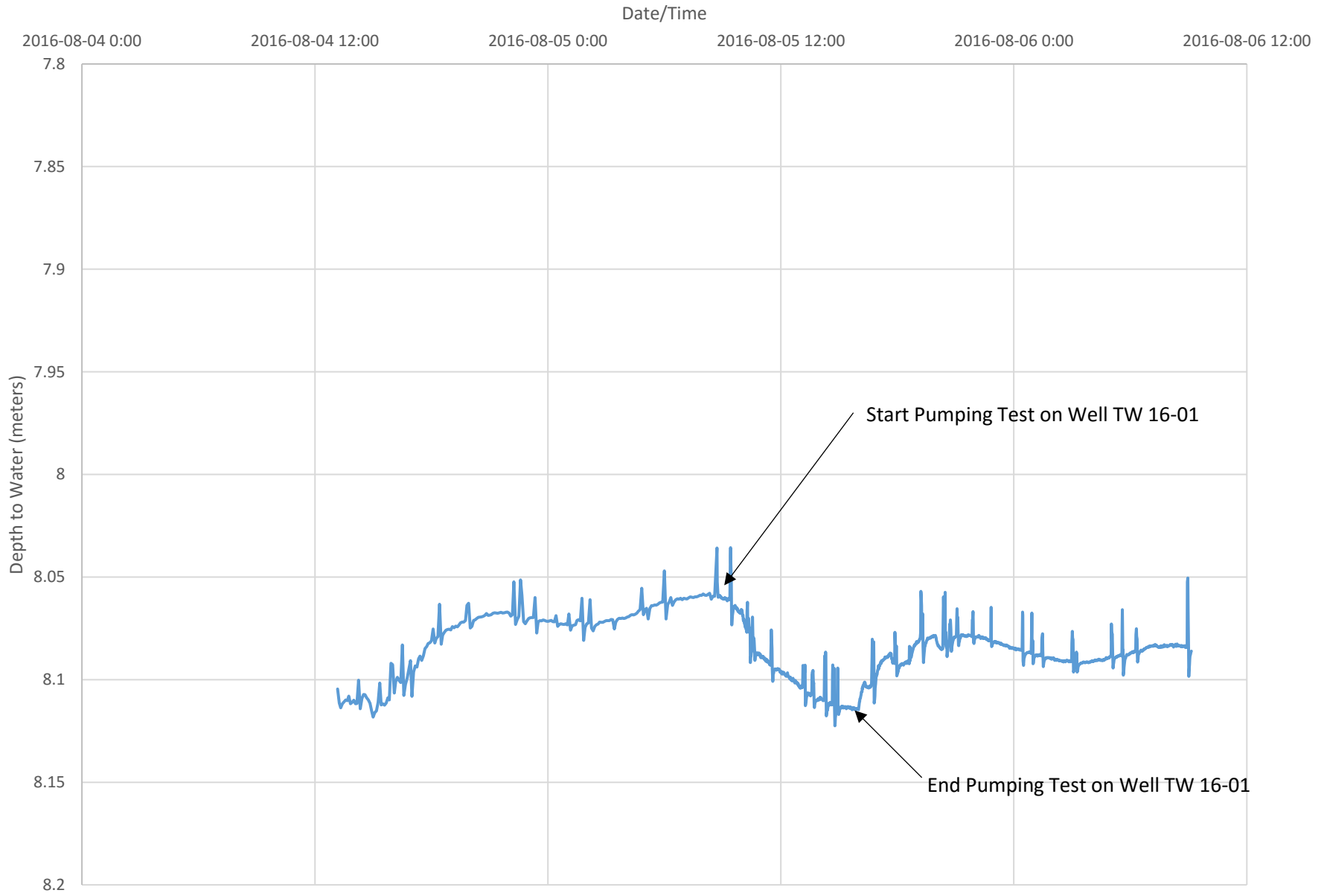
Elapsed Time Since Start of Pumping Test (minutes)



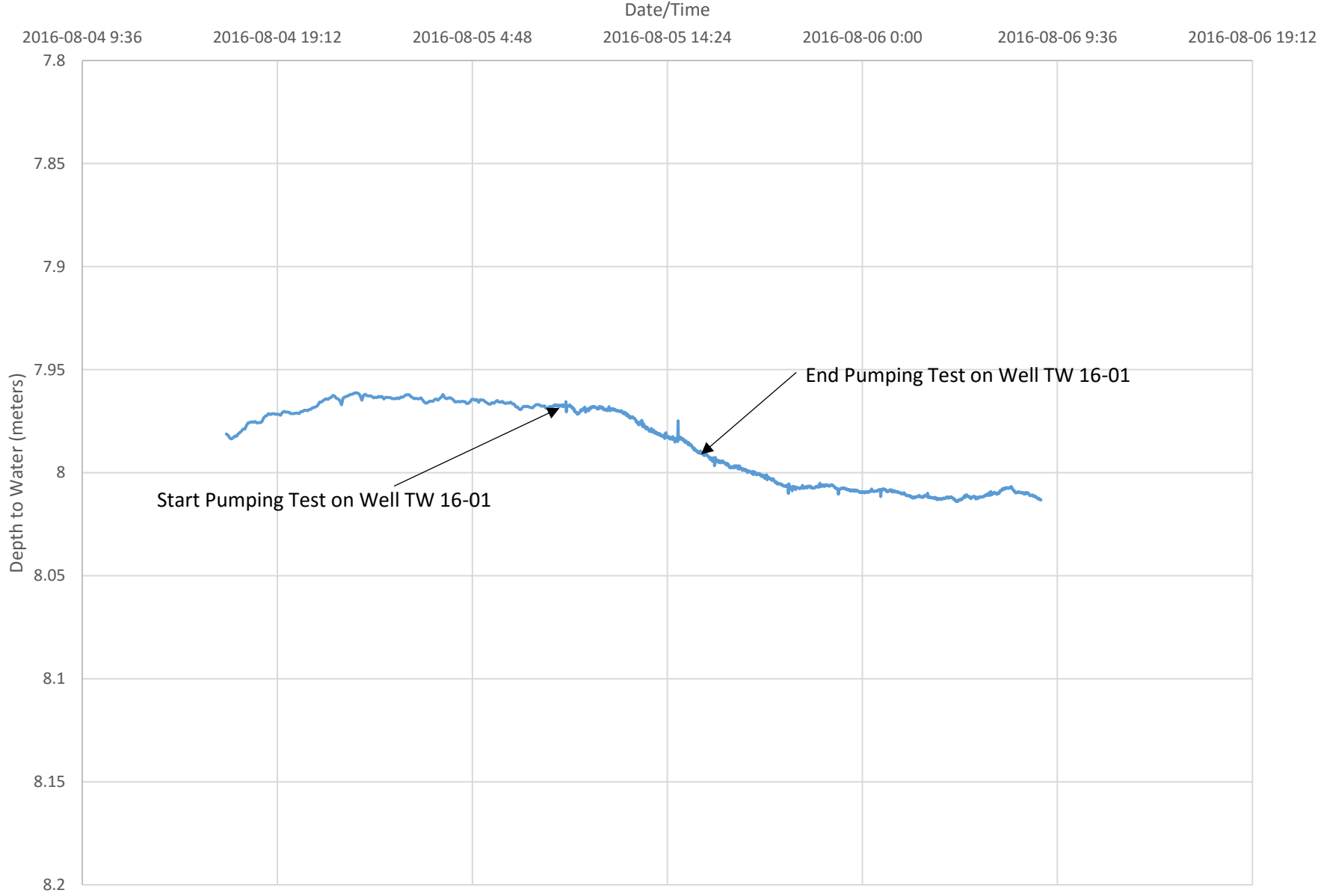
Monitoring Well TH 14-02 (Bedrock)



Monitoring Well TH 14-04 (Bedrock)



Monitoring Well TH 14-29 (Till)



Appendix F
Transmissivity Estimates

Transmissivity Calculation From Single Well Pump Test

Source Equation: Modified Nonequilibrium Jacob Equation

Reference: Driscoll, 1986, pg.1021

Assume: T value in log term = 30,000 USgpd/ft
S = 0.001 (Confined Aquifer)

Test Well TW 16-01 Results

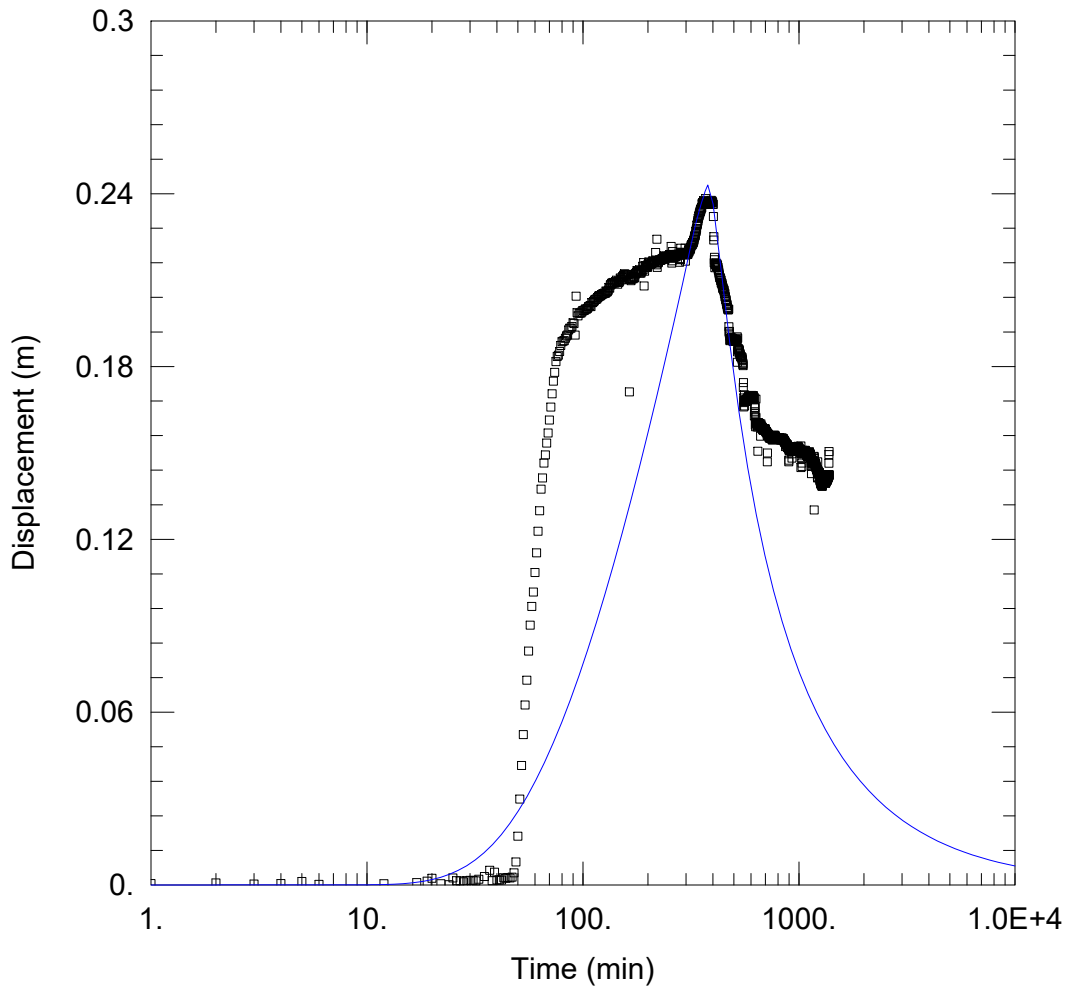
Enter the following values:

Pumping Rate (USgpm) =	32
Test Duration (days) =	0.25
Well Radius (feet) =	0.5
Drawdown (feet) =	27.1

Assume 6 inch well

Log Term = 6.954243

Transmissivity = 2167.876



WELL TEST ANALYSIS

Data Set: C:\...\TH 14-02.aqt
 Date: 08/16/16

Time: 10:46:46

PROJECT INFORMATION

Company: W.L. Gibbons & Associates Inc.
 Client: City of Winnipeg
 Project: 0201-002
 Location: Waverley Underpass
 Test Well: TW 16-01
 Test Date: August 5, 2016

WELL DATA

Pumping Wells

Observation Wells

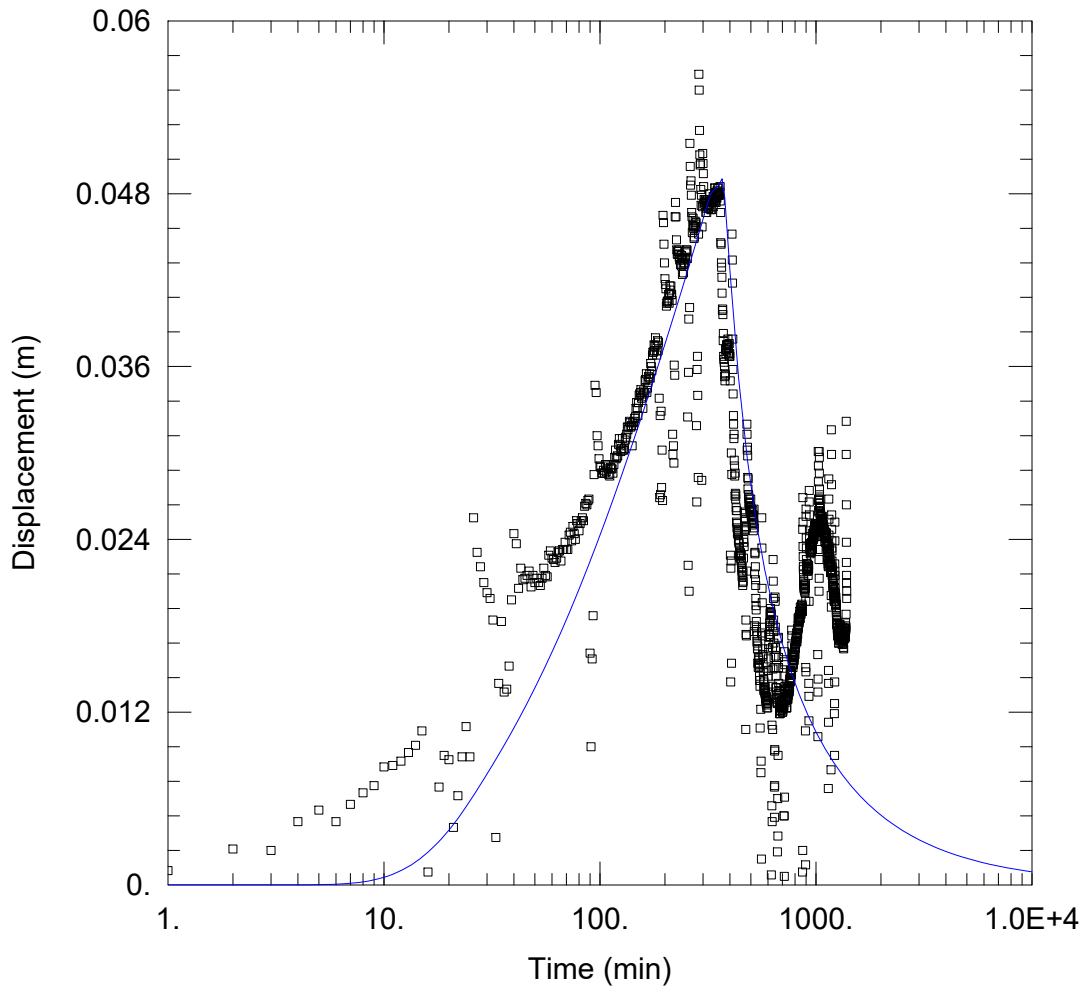
Well Name	X (m)	Y (m)
TW 16-01	0	0

Well Name	X (m)	Y (m)
□ TH 14-02	24	0

SOLUTION

Aquifer Model: Leaky
 T = 0.0008874 m²/sec
 r/B = 1.0E-5
 b = 4.3 m

Solution Method: Hantush-Jacob
 S = 0.02374
 Kz/Kr = 1.



WELL TEST ANALYSIS

Data Set: C:\...\TH 14-04.aqt
 Date: 08/16/16

Time: 10:47:02

PROJECT INFORMATION

Company: W.L. Gibbons & Associates Inc.
 Client: City of Winnipeg
 Project: 0201-002
 Location: Waverley Underpass
 Test Well: TW 16-01
 Test Date: August 5, 2016

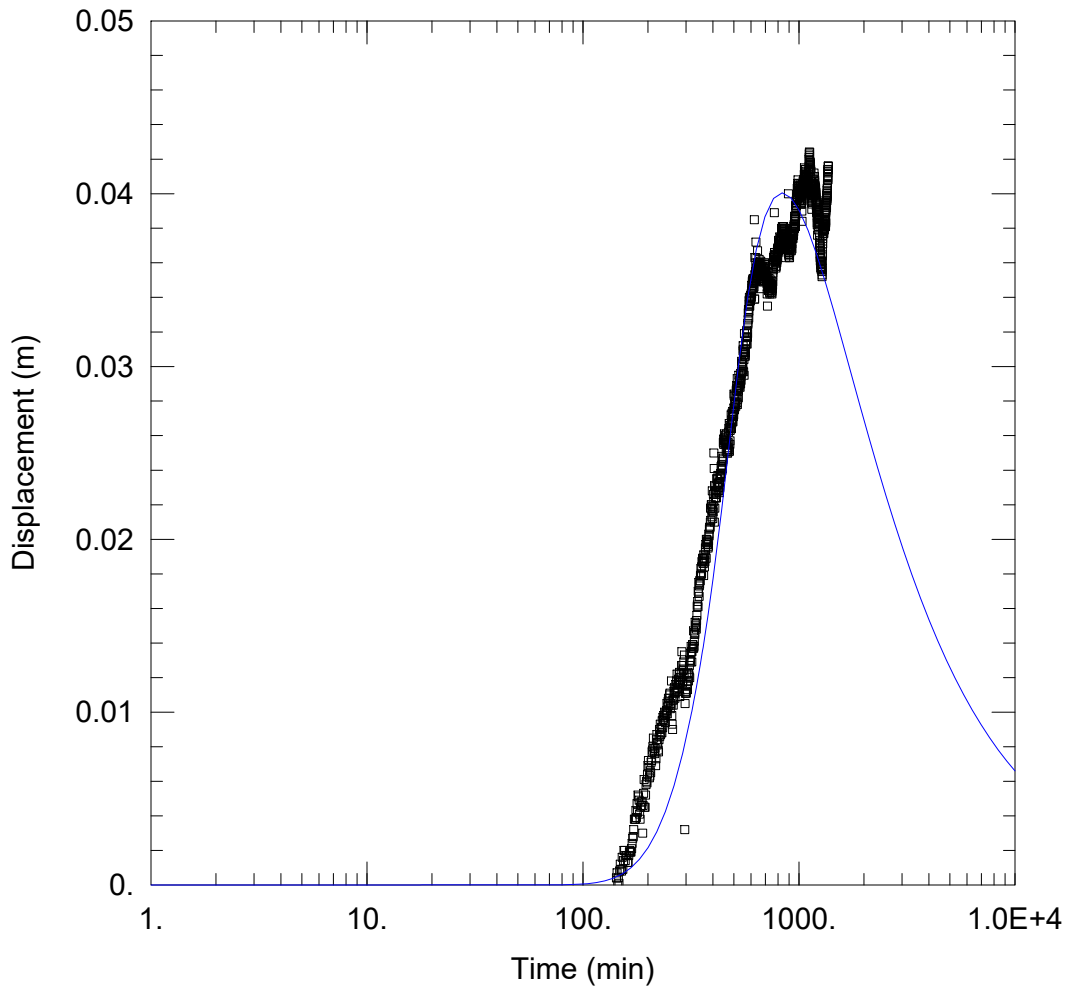
WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
TW 16-01	0	0	□ TH 14-04	109	0

SOLUTION

Aquifer Model: Leaky
 T = 0.006578 m²/sec
 r/B = 1.0E-5
 b = 4.3 m

Solution Method: Hantush-Jacob
 S = 0.003888
 Kz/Kr = 3.21E-7



WELL TEST ANALYSIS

Data Set: C:\...\TH 14-29.aqt
 Date: 08/16/16

Time: 10:47:59

PROJECT INFORMATION

Company: W.L. Gibbons & Associates Inc.
 Client: City of Winnipeg
 Project: 0201-002
 Location: Waverley Underpass
 Test Well: TW 16-01
 Test Date: August 5, 2016

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
TW 16-01	0	0	□ TH 14-29	66	0

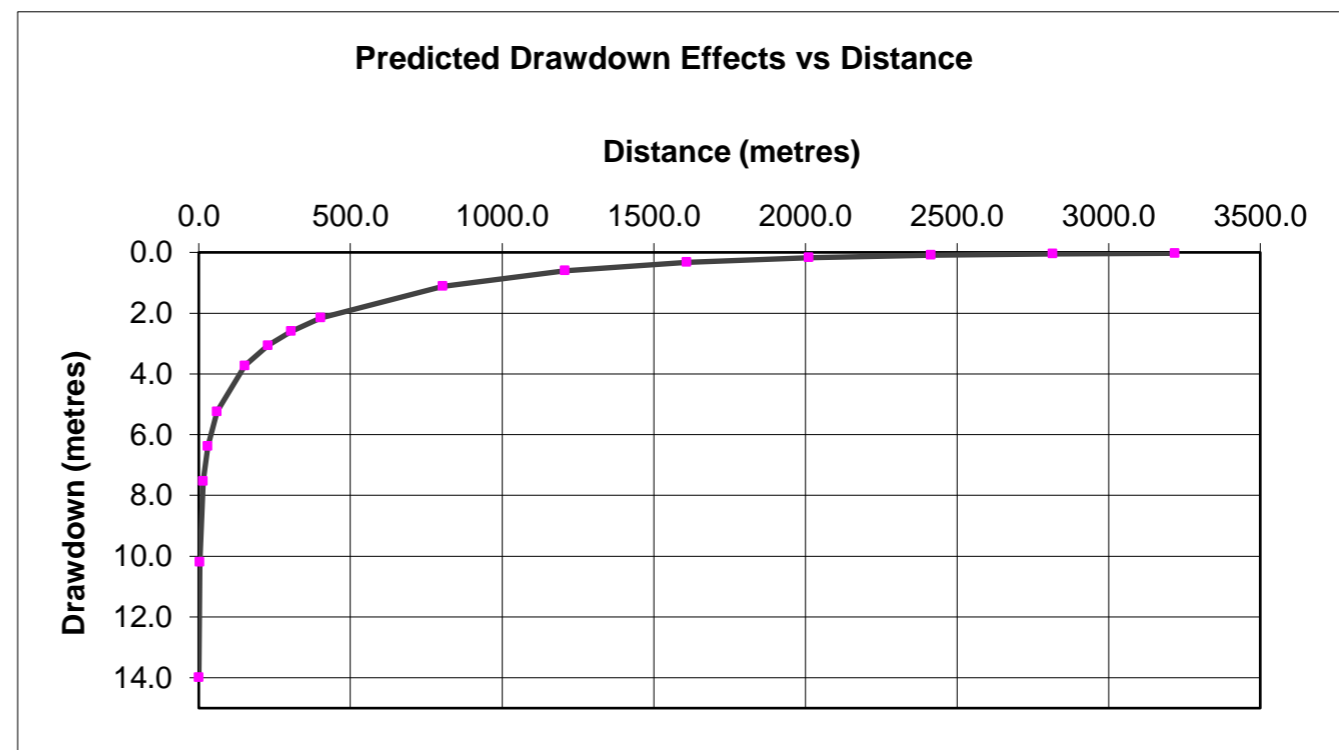
SOLUTION

Aquifer Model: Leaky
 $T = 0.0008359 \text{ m}^2/\text{sec}$
 $r/B = 1.0E-5$
 $b = 4.3 \text{ m}$

Solution Method: Hantush-Jacob
 $S = 0.02884$
 $Kz/Kr = 3.21E-7$

Appendix G
Distance-Drawdown Estimates

Distance-Drawdown Calculation				
Source Equation: Theis Nonequilibrium Well Equation				
Reference: Driscoll, 1986, pg. 218				
Assumptions as listed on pg. 218				
Enter the following values in red squares: NOTE UNITS				
Pumping Rate =			175	USgpm
Transmissivity =			7,400	USgpd/ft
Specific Yield/Storativity =			0.0001	dimensionless
time =			1	days
Distance (miles)	Distance (feet)	Distance (metres)	Drawdown (feet)	Drawdown (metres)
	1	0.3	45.90	14.0
	10	3.0	33.42	10.2
	50	15.2	24.70	7.5
	100	30.5	20.94	6.4
	200	61.0	17.18	5.2
	500	152.4	12.23	3.7
	750	228.6	10.06	3.1
	1000	304.8	8.53	2.6
0.25	1320	402.3	7.07	2.2
0.50	2640	804.7	3.65	1.1
0.75	3960	1207.0	1.97	0.6
1.00	5280	1609.3	1.06	0.3
1.25	6600	2011.7	0.56	0.2
1.50	7920	2414.0	0.29	0.1
1.75	9240	2816.4	0.16	0.0
2.00	10560	3218.7	0.10	0.0



Distance-Drawdown Calculation

Source Equation: Theis Nonequilibrium Well Equation

Reference: Driscoll, 1986, pg. 218

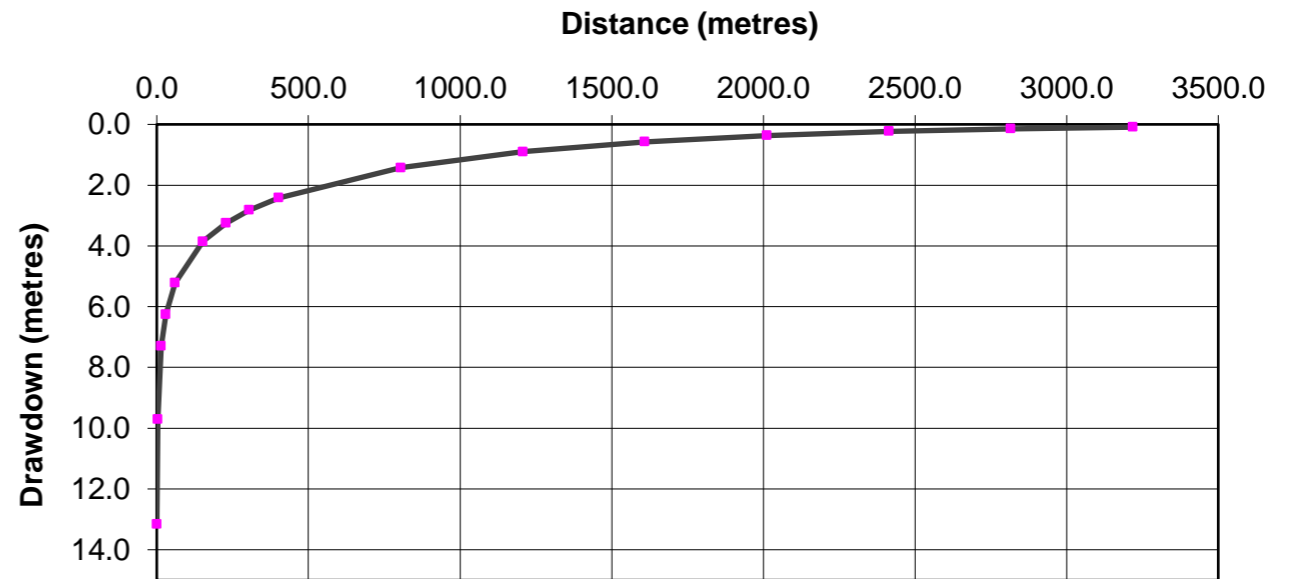
Assumptions as listed on pg. 218

Enter the following values in **red** squares: NOTE UNITS

Pumping Rate = **300** USgpm
 Transmissivity = **14,000** USgpd/ft
 Specific Yield/Storativity = **0.0001** dimensionless
 time = **1** days

Distance (miles)	Distance (feet)	Distance (metres)	Drawdown (feet)	Drawdown (metres)
	1	0.3	43.16	13.2
	10	3.0	31.85	9.7
	50	15.2	23.94	7.3
	100	30.5	20.54	6.3
	200	61.0	17.14	5.2
	500	152.4	12.64	3.9
	750	228.6	10.66	3.2
	1000	304.8	9.26	2.8
0.25	1320	402.3	7.92	2.4
0.50	2640	804.7	4.69	1.4
0.75	3960	1207.0	2.96	0.9
1.00	5280	1609.3	1.89	0.6
1.25	6600	2011.7	1.21	0.4
1.50	7920	2414.0	0.76	0.2
1.75	9240	2816.4	0.48	0.1
2.00	10560	3218.7	0.30	0.1

Predicted Drawdown Effects vs Distance



Distance-Drawdown Calculation

Source Equation: Theis Nonequilibrium Well Equation

Reference: Driscoll, 1986, pg. 218

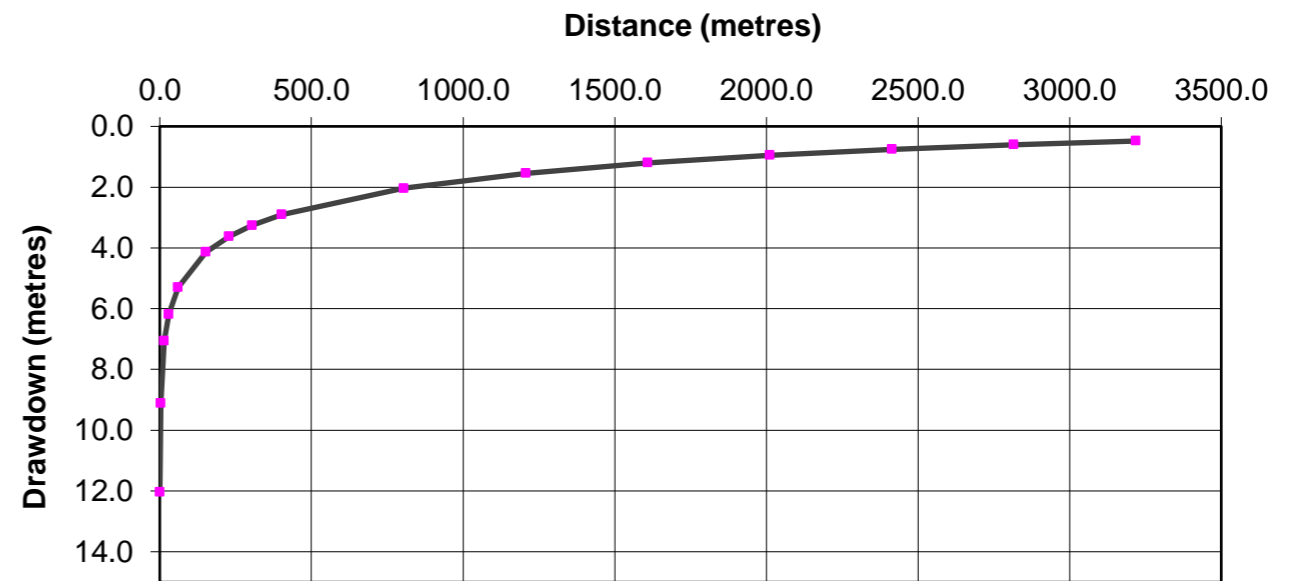
Assumptions as listed on pg. 218

Enter the following values in **red** squares: NOTE UNITS

Pumping Rate = 1000 USgpm
 Transmissivity = 55,000 USgpd/ft
 Specific Yield/Storativity = 0.0001 dimensionless
 time = 1 days

Distance (miles)	Distance (feet)	Distance (metres)	Drawdown (feet)	Drawdown (metres)
	1	0.3	39.47	12.0
	10	3.0	29.87	9.1
	50	15.2	23.17	7.1
	100	30.5	20.28	6.2
	200	61.0	17.39	5.3
	500	152.4	13.57	4.1
	750	228.6	11.89	3.6
	1000	304.8	10.69	3.3
0.25	1320	402.3	9.54	2.9
0.50	2640	804.7	6.69	2.0
0.75	3960	1207.0	5.06	1.5
1.00	5280	1609.3	3.94	1.2
1.25	6600	2011.7	3.12	0.9
1.50	7920	2414.0	2.48	0.8
1.75	9240	2816.4	1.98	0.6
2.00	10560	3218.7	1.58	0.5

Predicted Drawdown Effects vs Distance



Appendix H
Sample Groundwater Interference Complaint Response Plan

MANITOBA FLOODWAY AUTHORITY (MFA)
GROUNDWATER INTERFERENCE COMPLAINT RESPONSE PLAN

Two components of the Red River Floodway Expansion Project are the widening of the Main Floodway Channel and construction of new rail and roadway bridges. In areas where the channel is being widened, construction precautions will be implemented to mitigate adverse effects on groundwater supply wells. During construction of the bridges it will be necessary to temporarily depressurize the bedrock aquifer so that construction can proceed safely. This plan has been developed to provide a procedure to be followed in the event a complaint is received from a local resident or business that they believe their well supply system is being adversely affected by these construction activities.

1. Invoking the Groundwater Interference Complaint Response Plan

Groundwater interference is defined as a response in the groundwater aquifer to the floodway construction activities that causes a decrease in well performance such that the supply of water to the well is interrupted or that causes an unacceptable change in water quality. The Groundwater Interference Complaint Response Plan will be invoked when an owner located adjacent to an area of floodway expansion activities makes a groundwater interference complaint to MFA. Complaints can be made by telephone to a toll free 24-hour response line at 1-877-456-1201. Any resident contacting Manitoba Conservation, Manitoba Water Stewardship or a local Rural Municipality regarding a water complaint will immediately be referred to MFA. MFA will notify local residents and Rural Municipalities of the construction activities prior to starting the work. All calls will be received by a call referral agency, who will immediately refer the call to the MFA duty officer. Note: Personnel at the 24-hour contact number will only record the name, address, telephone number and time of the complaint prior to forwarding the call to the duty officer.

2. Groundwater Interference Complaint Response Procedures

MFA will assign a duty officer to respond to complaints 24 hours per day, 7 days per week. When a MFA duty officer receives a complaint, the following two stage procedure for responding to a groundwater interference complaint will be followed:

- Preliminary telephone complaint screening and response; and
- On-site well assessment and remediation.

The initial complaint screening and response will be completed by the MFA duty officer each time a groundwater interference complaint is received. Depending on the results of the complaint screening, it may be necessary to have an approved Investigator complete a more detailed well assessment. The procedures for both types of assessment are detailed below.

Preliminary Complaint Screening

The MFA duty officer will undertake a telephone complaint screening within 1 hour of the interference complaint. The screening is to identify the nature of the well problem, if the floodway expansion activities could be the cause of the problem, and to initiate emergency water supply.

- 1) The initial telephone assessment and discussion with the well owner may conclude that no further action is required on the part of MFA.
- 2) In the event that the MFA duty officer concludes that groundwater interference may have occurred as a result of the floodway expansion activities, the following actions will be taken:
 - a. Immediately offer or provide the resident with a reasonable amount of potable water depending on the extent of the water shortage and the residents' situation. This may involve making arrangements for water delivery by a Temporary Bulk Water Supply Contractor, and
 - b. Immediately contact MFA's technical experts to undertake a Well Assessment to determine the cause of the complaint and recommend follow-up action.

All costs associated with the investigation to determine the cause of the complaint and to supply a temporary water supply will be borne entirely by MFA.

Well Assessment

The complainant will be contacted by telephone to arrange an on-site assessment by an Investigating Technical Expert. The Technical Expert will initiate a timely on-site assessment as arranged with the resident.

- 1) In the event that the Technical Expert concludes that groundwater interference did not occur,
 - a. MFA will take no further action.
 - b. The resident will be responsible to arrange for all further corrective action and bear all associated costs.
- 2) In the event that the Technical Expert concludes that a bona fide groundwater interference may have occurred, MFA will take the following actions as appropriate:
 - a. With agreement of the affected resident, continue to deliver water to the resident at no cost to the resident;
 - b. Institute timely modifications to the well system to mitigate the problem in consultation with the owner. These modifications may include lowering or replacing the well pump; repairing/replacing the well or increasing the domestic well capacity;
 - c. Reduce the rate and amount of construction depressurization pumping or other engineering modifications so as to alleviate the observed interference. This action may not immediately restore water to the

private well and it may be necessary to continue action a. above in the interim.

d. other

3. Documentation

The interference complaint will be summarized on the attached Incident Report that, as a minimum, documents the following:

- 1) The location of the complaint (name, address, telephone number, map);
- 2) Investigation procedures and results; and
- 3) Any actions taken to restore water supply.

4. Notification

Manitoba Water Stewardship will be notified of all well interference complaints as follows:

- 1) MFA will notify Manitoba Water Stewardship, Water Licensing Branch and Manitoba Conservation, Regional Operations Division, by phone and e-mail immediately after the Technical Expert has confirmed that a well interference may have occurred.
- 2) The Incident Report documenting the well interference complaint will be submitted to Manitoba Water Stewardship, Water Licensing Branch; Manitoba Conservation, Regional Operation Division; Infrastructure Canada, local government, and the citizen affected within 5 working days of the complaint being resolved or water restored.

5. Continuous Groundwater Interference Complaint Response Plan

Improvements

MFA is undertaking the Floodway Expansion Project following an adaptive management strategy. Accordingly, the Groundwater Interference Complaint Response Plan may be amended to continuously improve the environmental mitigation provided. The Groundwater Interference Complaint Response Plan should be regarded as a living document that is updated whenever changes are warranted as the result of any of the contact information gathered; MFA response experience; or input from the public or the Groundwater Technical Experts Subcommittee. As a minimum, the Groundwater Interference Complaint Response Plan will be reviewed annually by the Project Management to ensure that the procedures are appropriate.

Note: All necessary contact information is provided on the attached Groundwater Interference Complaint Information Sheet.

Prepared: November 7, 2005
Approved: Date
Revised: Date

**MANITOBA FLOODWAY AUTHORITY (MFA)
GROUNDWATER INTERFERENCE COMPLAINT
INCIDENT REPORT**

<u>CONTACT INFORMATION</u>	
Name	
Address/location	
Phone Number	
Date and time complaint registered	
<u>NATURE OF COMPLAINT</u>	
Including: Description of problem and Dates when the problem occurred.	
<u>PRELIMINARY COMPLAINT SCREENING</u>	
Assessment completed by	
Date Completed	
INVESTIGATION Including investigation procedures, observations and results.	

<p>ACTIONS TAKEN By Owner or MFA</p>	
<p><u>SECONDARY WELL ASSESSMENT</u></p>	
<p>Name of Company</p>	
<p>Contact Person</p>	
<p>Date Completed</p>	
<p>INVESTIGATION Including investigation procedures, observations and results</p>	
<p>ACTIONS TAKEN By Owner, Investigator, or MFA</p>	
<p><u>COMPLAINT RESOLVED</u></p>	
<p>Date Water Supply Temporarily Restored</p>	
<p>Date Water Supply Restored</p>	
<p><u>NOTIFICATION MANITOBA WATER STEWARDSHIP</u></p>	
<p>Contact Person notified of bona fide interference</p>	
<p>Date Contacted</p>	