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Municipal Groundwater Supply Expansion Investigation
River Lot 70 – Parish of St. Paul

Proposed Bray Road Municipal Supply Well

Rural Municipality of East St. Paul – Manitoba

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Report to:

Stantec

Stantec Consulting Limited

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Rural Municipality of East St. Paul – Manitoba

APEGM
Certificate of Authorization
Friesen Drillers Limited
No. 4016 Date: Dec 17/2012

PROVINCE OF MANITOBA
J. J. BELL
Member
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REGISTERED PROFESSIONAL ENGINEER
Dec 17/2012

December 17, 2012

Prepared by: J.J.(Jeff) Bell, B.Sc.(G.E.), P.Eng. Date: Dec. 17/2012

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Authorized by: John M. Friesen Date: Dec. 17/2012

Acknowledgements

Friesen Drillers acknowledges with appreciation the following individuals for their assistance and contributions during the completion of this study:

- Rural Municipality of East St. Paul
  - Mayor and Council
  - Mr. Jerome Mauws
  - Mr. Bruce Schmidt
  - Ms. Carol Oppermann
  - Mr. Don Winsor
  - Mr. Nikolaus Homuth
  - Mr. Justin Synchena
- Stantec Consulting
  - Mr. Brett Ransom, P. Eng.
  - Mr. Len Chambers, P. Eng.
  - Mr. Cameron Dyck, P. Eng.
  - Mr. Jamie Brewster, P. Eng.
- Manitoba Conservation and Water Stewardship.
  - Mr. Rob Matthews, P. Geo.
  - Ms. Kristina Anderson, P. Geo.
  - Mr. Chris Romano

Study Team

The study team consisted of the following individuals:

- Mr. Jeff Bell, B.Sc.(G.E.), P.Eng. – Hydrogeological Engineer
- Ms. Paulynn Estrella, B.Sc.(Mn.E.) – Engineering Assistant
- Mr. James Friesen – Driller
- Mr. Chris Wilson – Pumping test crew
- Mr. Jason Friesen – Operations Manager

Notes

This study will utilize imperial measures, with the exception of water quality data and some velocity information, which will use metric measures. The use of the study will follow the limitations and disclaimer in the report. Some of the data collected during this study was obtained from Manitoba Conservation and Water Stewardship. Friesen Drillers has made no attempts to verify the information. It is assumed to be correct. The reports collected for background research on this aquifer have been obtained from public sources.

Executive Summary

Friesen Drillers was retained by Stantec Consulting to undertake a hydrogeological assessment of a proposed groundwater supply for the Rural Municipality (RM) of East St. Paul. The proposed site was selected in 2004, as part of a testing program conducted by Stantec and Friesen Drillers. The proposed site is located north of the community of Birds Hill, along PR 212, at the junction of Bray Road. The well site is on lands owned by Manitoba Infrastructure and Transportation. An agreement has been made to access the well site in the future.

The existing well fields are licensed for approximately 994.24 acre feet/year. The requested allocation from the new well would add approximately 567.5 acre feet/year. This allocation is required for additional growth in the RM. The project was commenced in 2010. A groundwater exploration permit was applied for and granted by Manitoba Conservation and Water Stewardship, based on a scope of work prepared by Friesen Drillers.

The well site is located in a highly transmissive area of the carbonate bedrock aquifer. The groundwater quality is typical of the carbonate aquifer in the area. An inventory of water wells was conducted within a 1250 m radius of the proposed well sites. The inventory consisted of a mailed out form, and review of the local water well database.

A 10 inch diameter well was installed at the site and tested for 72 hours. Approximately 3.5 feet of drawdown resulted at the pumping well after the 72 hour period. The groundwater quality remained stable throughout the testing. Eleven wells were monitored at various distances for well responses during the pumping tests.

Although springs in the pilot channel of the floodway are evident south of the ski hill area and north of Dunning Road, no springs were noted near the proposed well site. With the very little predicted drawdown at the proposed site, seepage into the aquifer during flood operations is not expected.

The well is expected to provide a small amount of drawdown at distance during operation. This drawdown is well below the annual fluctuation in the aquifer.

Additional monitoring and annual reporting is required to monitor the carbonate aquifer in the RM area. Additional details of the recommendations are contained in the report.

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Introduction

Friesen Drillers Limited is pleased to present this report detailing the results of our investigation into a proposed municipal groundwater supply expansion for the Rural Municipality (RM) of East St. Paul. The investigation focused on a test well location (TW03-04), which is located at Provincial Road (PR) 202 and Bray Road West. This original test well was constructed by Friesen Drillers Limited in December 2004, under the supervision of Stantec Consulting (Stantec, 2004).

The RM of East St. Paul currently relies on three other well fields for water supply. This site has been proposed as a future water supply for the growing community.

The following report details the results of the investigation.

Scope of Work

The RM of East St. Paul developed a well field in the overburden gravels on the east side of the Red River Floodway in the early 1990's. A water supply pipeline was installed and several wells were developed in this area. The intent of this water supply was to collect seepage losses that were occurring in to the Red River Floodway from the Birds Hill Glacio-Fluvial deposit. A water rights license from Manitoba Conservation and Water Stewardship (MCWS) is in place for this well field. An additional supply well was installed into the carbonate aquifer at this location.

Subsequently, a new well field was also developed at Wenzel Road and Provincial Trunk Highway (PTH) 59, which is the location of the RM of East St. Paul water treatment plant. This supply well was installed in 2004, and was licensed shortly afterwards by MCWS, under a separate license. Shortly afterwards, an environment act license was applied for through Manitoba Environment for the entire RM of East St. Paul water supply.

The RM of East St. Paul is a growing community, and future water supplies will be needed in the next 20 years (Stantec Consulting, personal communication, 2010). The increase in water supplies is estimated to be an additional 567.49 acre feet/year (700 dam^3/year). In order to provide the additional water supplies, the RM of East St. Paul undertook test drilling in 2004 to locate a suitable well field.

One of the locations selected in 2004 was deemed to be the source for the future water supply. Stantec Consulting was retained to undertake the technical assessment of the well field, and undertake the civil engineering and planning for the installation. In order to provide the hydrogeological assessment, Friesen Drillers was retained to undertake the aquifer and well capacity assessment for the Bray road test well location.

The scope of services for this aquifer and well field capacity assessment include the following:

- Undertake a review of the background site history relating to the water supply.
- Review the background geology and hydrogeology.
- Review all of Manitoba Conservation and Water Stewardship's (MCWS) hydrograph monitoring stations for long term water levels and groundwater chemistry.
- Review the background stable environmental isotopic data for the RM.
- Undertake a well inventory within a 1,250 m radius of the production well site
- Design and install a large diameter production well, and complete the required developing.
- Undertake a 72 hour pumping test on the proposed supply well, with a pressure transducer monitoring network to monitor water level response over pumping period.
- Collection of groundwater quality samples for isotope and geochemical analysis.
- Review the capacity of the well field, and calculate the proposed impact from pumping.

Scope of Work (cont'd)

- Complete a detailed report of the investigations that is suitable for submission to MCWS.

Although Stantec Consulting gave the approval to complete the project in January 2012, preliminary work was conducted throughout 2010 and 2011.

The approximate boundaries and location of the RM of East St. Paul is shown below as Figure 1.

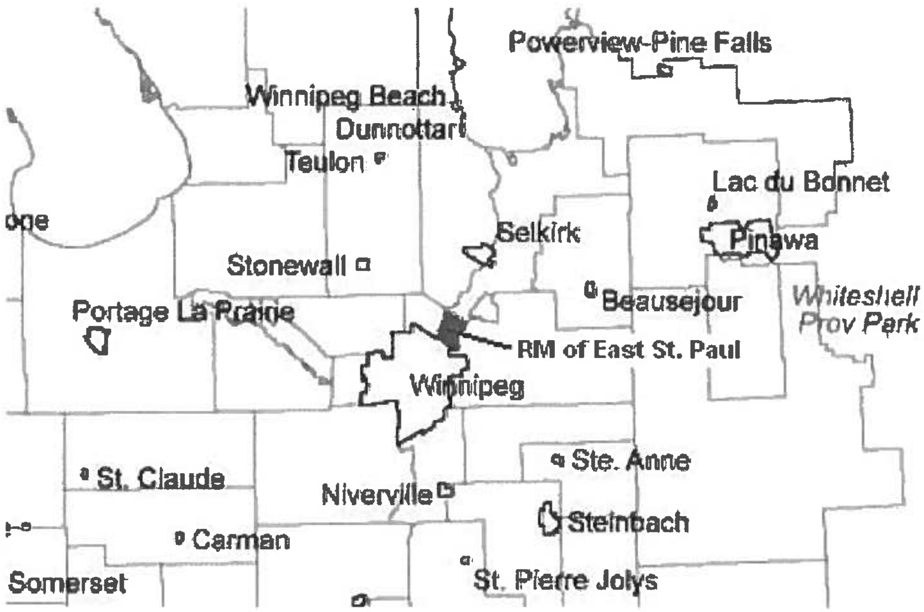

Figure 1 – Location of the RM of Rockwood, Manitoba (source – www.amm.ca)

Regulatory Requirements for Municipal Groundwater Supplies

Water Rights Act and Existing Licenses

The Province of Manitoba has the responsibility to distribute water under the Water Rights Act. This act requires that anyone using water exceeding 25,000 L/day for commercial, industrial, agricultural, and municipal use must obtain a license under the act. This is also required for industrial and geothermal heating/cooling applications. Water rights licensing is based on a first in time, first in right procedure. For groundwater projects, an exploration permit is required prior to starting the project. In order to provide approval for the exploration permit, MCWS reviews the available aquifer allocation (if available), to determine if the project is potentially suitable.

Upon completion of the testing of the project, MCWS reviews the proponent's proposal to determine if there are any third party impacts that may result. If these impacts are present, mitigation factors may be required. These include such things are groundwater interference plans, well repairs, replacements, and pump inspections. These programs are usually undertaken by the proponent of the project. Reports are usually prepared for the project by a consulting hydrogeological engineer or hydrogeologist.

If the application is deemed acceptable and third party impacts are managed or addressed, MCWS will issue a license for the diversion of groundwater. The proponent then has the right, under some conditions, to the water supply for a specific duration. The right is also protected from other use in the area.

For the RM of East St. Paul, there are currently three water rights licenses in place. The details are contained below:

- License No. 2005–060 – SE33-11-4EPM – 158.09 acre feet/year – Oasis Road Carbonate Aquifer supply well
- License No. 2007-074 – SE33-11-4EPM – 290.0 acre feet/year – Oasis Road sand and gravel supply wells (3)
- License No. 2009-030 – River Lot 101 – Parish of St. Paul – 496.15 acre feet/year - Wenzel Road Carbonate Aquifer supply well

Water Rights Act and Existing Licenses (cont'd)

There a number of conditions and clauses on each license. Copies of the current licenses are attached as Appendix A.

The land where the Bray Road (TW03-04) test well is located on lands that are controlled by Manitoba Infrastructure and Transportation, of the Province of Manitoba. Prior to undertaking any additional work on the well site, the RM of East St. Paul arranged for a land access agreement for the well site for the testing and the future well development. A copy of the permit agreement is attached as Appendix B.

It is not known if Stantec Consulting applied for a groundwater exploration permit in 2004 for the test drilling sites within the RM of East St. Paul. Since the exploration permits are only typically valid for one year, it was decided that a new exploration permit would be applied for prior to undertaking any testing or monitoring.

Friesen Drillers submitted a groundwater exploration permit on July 5, 2011. The application provided a requested new diversion allocation of 700 dam^3/year (567.49 acre feet/year). MCWS – Groundwater Licensing Section issued a groundwater exploration permit on August 9th, 2011. There were a number of conditions on the exploration permit, which corresponded well with the defined scope of work for the project. The authorization permit allowed for the testing of the wells under the supervision of a consulting hydrogeologist or hydrogeological engineer.

A copy of the groundwater license application and subsequent authorization is attached as Appendix C.

Environment Act License

In the event that a requested groundwater supply project exceeds 200 dam^3/year, an environment act license is also required. This is required under the Environment Act of the Province.

An Environment Act Proposal is prepared by the proponent for a water supply project. This proposal usually involves the identification of any potential environmental effects from the water supply diversion. The proposal usually identifies potential third party impacts and possible effects. Mitigation measures are usually proposed and evaluated. The proposal is usually advertised for public comment and review. Often times, environmental groups and organizations review these proposals to ensure that environmental effects are taken into consideration. In the event that there is a significant amount of public opposition to a potential project, the Minister of Conservation and Water Stewardship may order a Clean Environment Commission to hold public hearings to review the project and the proposed concerns. Although these public hearings are rare, they have been held for water supply projects in Manitoba in the past.

Copies of environment act proposals are also submitted to various organizations within governments for comments and review. Often, water supply proposals involving groundwater use are reviewed by the provincial groundwater management section. If the environmental impacts are deemed to be minor, or the mitigation proposals are acceptable, the director will issue an environment act license for the development or project.

The requirement for environment act assessments for water supplies was put into force in the in the mid 1990's. As a result of this requirement, several water supply systems that did not originally obtain an environment act license, would be requested to undertake this aspect upon a request for additional groundwater use allocation.

The RM of East St. Paul currently has an environment act license for their existing well fields at Oasis Road and Wenzel Road. The completion of an Environment Act Assessment application is deemed to be outside of the scope of services for the technical assessment of the aquifer and well yield at the Bray Road site. This will be completed at a later date, if required.

Water Supply Requirements

As part of the investigations, the RM of East St. Paul provided some parts of a water supply and sewerage feasibility study that was undertaken for the RM by Stantec Consulting. This study focused on the current and future water supply and sewerage requirements. The study also looked at the projected population and the existing infrastructure at the growth rates experienced by the RM. The East St. Paul area is popular for municipal development, and projections have shown that up to 100 new residential houses could be constructed annually.

Water Supply Requirements (cont'd)

Currently, the RM of East St. Paul is licensed to extract approximately 994.24 acre feet/year (1,226.39 dam^3/year). This volume apparently meets the current water supply requirements, but does not provide much additional capacity to service increased residential land development. According to information provided by Stantec, an additional 567.49 acre feet/year (700 dam^3/year) will provide the additional water supplies required for the proposed residential development in the RM. A summary of the projected 20-year water demand is provided in Appendix D.

Site Setting

RM of East St. Paul is immediately north of the City of Winnipeg. The RM encompasses about 16.25 sq. miles, and is bisected by the Red River Floodway, and PTH 59, which run north through the RM. The RM borders the Red River to the west, the RM of St. Clements to the North, and the RM of Springfield to the south. The main community in the RM is the Village of Birds Hill. The area is home to about 9,000 people, and has a population density of about 556 persons per square mile (Stats Canada, 2012).

The land drainage in the area is generally directed towards ditching, which ultimately ends up in the Red River. The largest drainage feature in the RM is the Red River Floodway, which passes north through the RM, to the discharge north of Lockport, Manitoba.

Development around the RM is typically residential, with detached private residences being the most common. There are large areas that are currently undeveloped, which are used for light agricultural and hay production.

Surrounding the well field at Bray Road and PR202, the following land use is present:

- North: Agricultural lands and rural residential properties, followed by the RM of East St. Paul municipal landfill facility (~ 2,700 feet north).
- East: Red River Floodway, followed by additional rural residential properties.
- South: Rural residential properties, with the Village of Birds Hill (approximately 1.7 miles south)
- West: Rural residential and agricultural properties, with the Red River lying approximately 2.3 miles west.

The approximate boundaries of the RM are shown below as Figure 2.

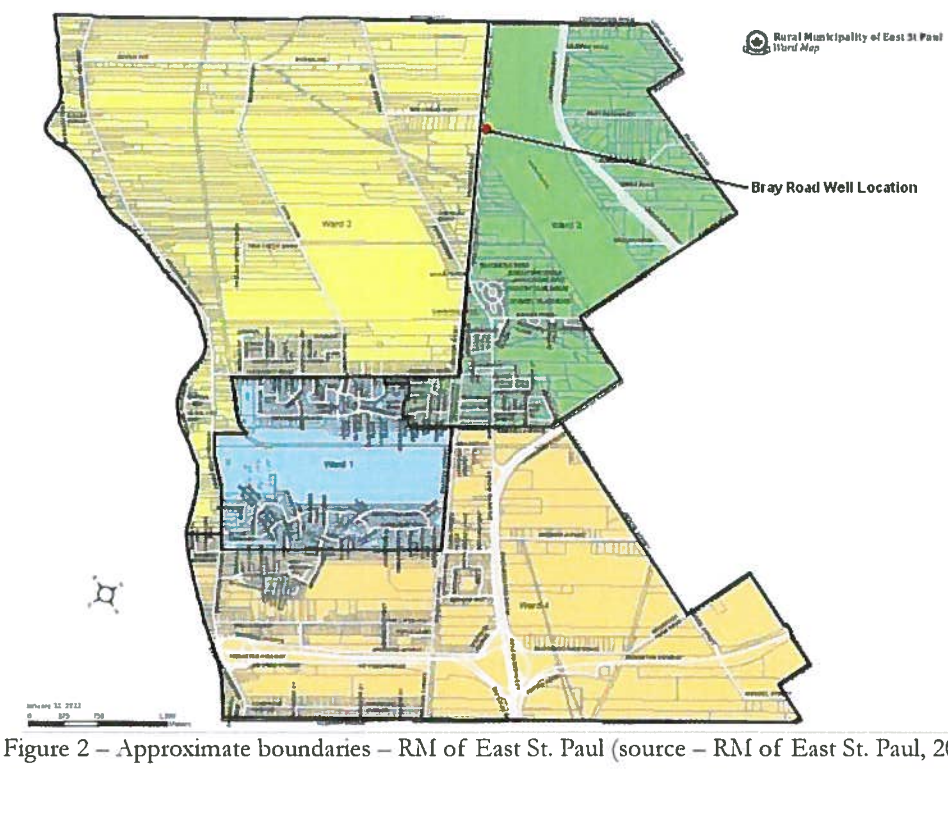

Figure 2 – Approximate boundaries – RM of East St. Paul (source – RM of East St. Paul, 2012)

Geology and Hydrogeology of the East St. Paul

Bedrock Geology

The East St. Paul area is located within the eastern fringes of the Western Canadian Sedimentary Basin (WCSB), or the Williston Basin. The WCSB is a wide spread wedge shaped sedimentary basin with Precambrian bedrock as the basement feature. Figure 3, shown below, details the extent of the WCSB, and shows the location of the study area.

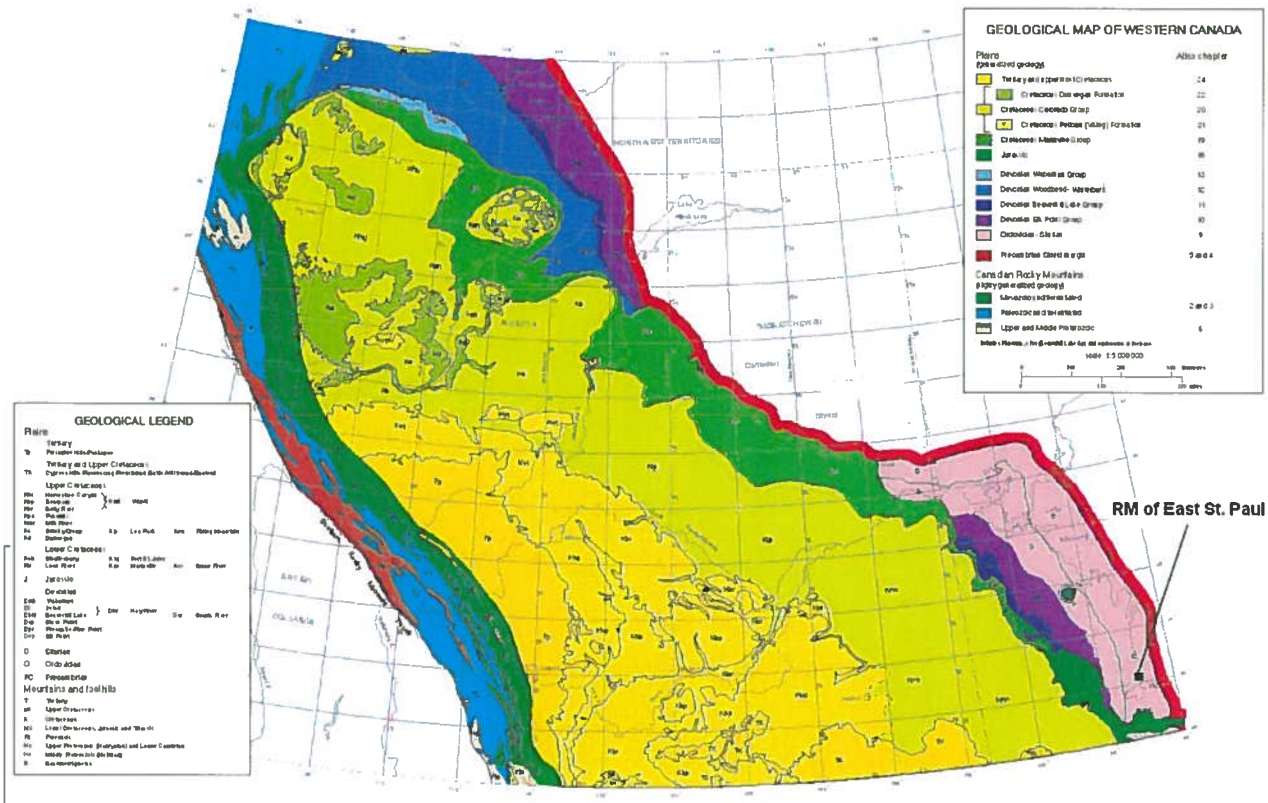

Figure 3 – WCSB showing location of the East St. Paul area. (source - Alberta Geological Survey, 2009)

The basin extends throughout the central Canadian plains, and underlies about 1.4 million km^2. The basin extends north into the Northwest Territories, to the eastern fringes of the Rocky Mountains, and westerly, into central Manitoba. A large portion of the basin extends into the northwest United States. Precambrian igneous and metamorphic rocks form the basal geologic unit across the WCSB.

The Precambrian basement bedrock is expected to lie at a depth of over 450 feet below grade within the RM of East St. Paul. This is expected to change within the RM, as the formation typically dips about 5 to 10 feet every mile westward. This follows the dip of the WCSB in the area. Overlying the peneplanned Precambrian Surface is the Winnipeg Formation sandstone. The sandstone sequence is thought to be about 50 to 80 feet thick in the area. The Winnipeg Formation consists mainly of layered silica sandstone and marine shales. The sandstone is in general very weakly cemented in many places, although it is speculated to be reasonably well cemented in the East St. Paul area. In general, very few, if any known test holes have been drilled into this unit within the RM. Overlying the sandstone is a thin (2 to 3 m in some places) sequence of marine shales. This shale sequence acts as an aquitard overlying the sandstone units.

Overlying the Winnipeg Formation is the carbonate bedrock of the Red River Formation, which typically consists of alternating layers of limestone and dolostone with very thin basal shale layers. There is a conformable transfer between the two geological units. It is reported that the carbonate sequence, through the Selkirk and Fort Garry Members, is approximately 300 feet in total thickness within the RM area (Betcher, 1985). The Red River Formation and the overlying carbonate units, are collectively called the carbonate evaporite unit in Manitoba. This unit extends south of the Steinbach area, through the Manitoba Interlake, to The Pas, and beyond. The upper surfaces of the carbonate bedrock have been eroded, worn, and highly damaged by erosional unconformities and Pleistocene glaciations. The surface has also been impacted by some karstic features in the geologic past.

A regional geological cross section approximately includes the RM of East St. Paul is shown on the following page as Figure 4.

Bedrock Geology (cont'd)

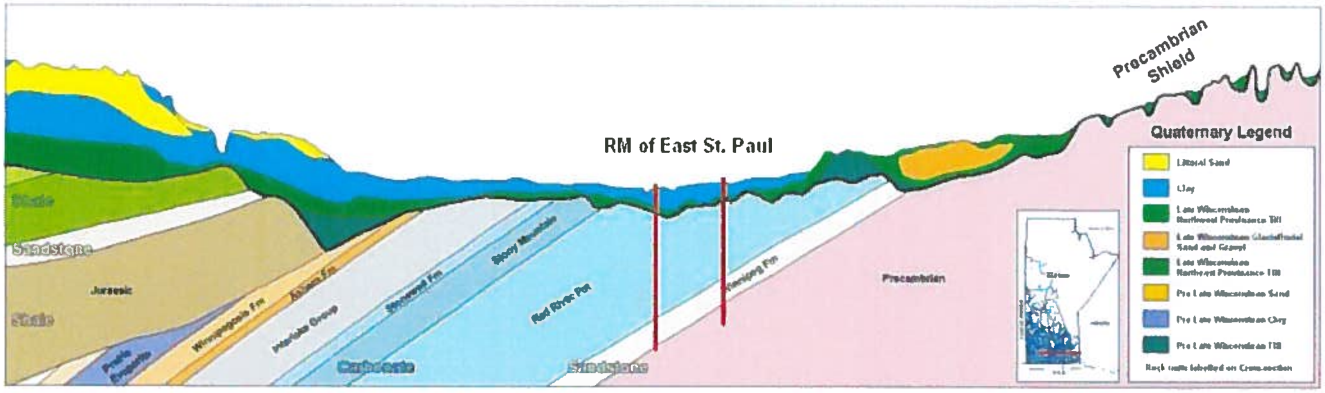

Figure 4 – Geological cross section approximately through the RM of East St. Paul (source – Matile and Keller, 2007)

Surficial Geology

The carbonate bedrock surface was extensively eroded during the pre-glacial period. This erosion resulted in significant damage to the upper surfaces. Joint sets, fractures, and voids were present, along with an extensive karstic development. Some of these features have been infilled with more recent sediments. A dense basal till unit, with some layers of sand and gravel, was deposited directly on the carbonate bedrock surface during the glaciations. Some of the previous permeable features were infilled during this period.

After the final glacial retreat, a pro-glacial lake developed, which resulted in the deposition of water laid tills, and glacio fluvial silty grey clays. During this period of post glacial retreat, the Birds Hill Glacio-Fluvial complex developed, which has a prominent effect on the local geology and hydrogeology of the East St. Paul area.

The Birds Hill Glacio-Fluvial Complex was formed during the final glacial retreat from the southern Manitoba area. Several large ice channels were created within two distinct lobes in the frontal section of the glacier (Matile and Barton, 1984). During melting, well sorted sand and gravel was deposited within the steep walls of the ice channels; which resulted in several large, esker type deposits. After the final melting of the main glacier, large ice bergs and sand and gravel deposits separated the complex from the remainder of glacial Lake Agassiz (Matile and Barton, 1984). After final melting of the residual ice, clays and low energy deposition of silts and clays occurred around and within the complex. These were also significantly altered by erosion and wave action from the lake. Recent deposits have occurred following the final retreat of Lake Agassiz (Matile and Barton, 1984). Render (1970) created a generalized east west cross section of the complex to show the groundwater dynamics of the area. This cross section is shown below as Figure 5.

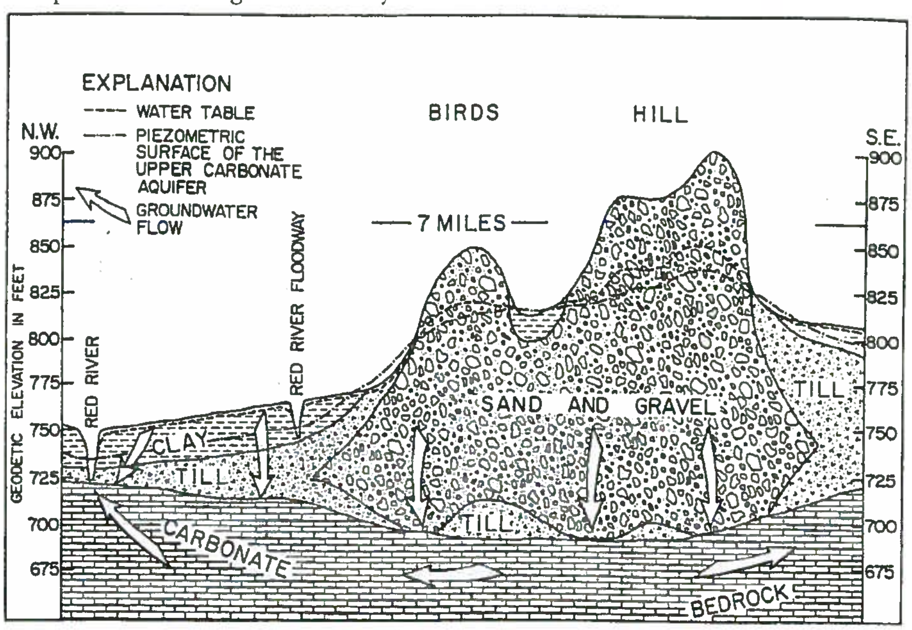

Figure 5 – Render's east – west cross section through Bird's Hill area showing generalized hydrogeology (source – Render, 1970)

Hydrogeology

The Birds Hill Glacio-Fluvial complex acts as a significant source of recharge for the carbonate aquifer in the region. Due to the highly permeable nature of the sands and gravels deposited in the area, and their close proximity to the carbonate aquifer, recharge has direct access to the aquifer. Static water levels in the carbonate aquifer and overlying sands and gravels have been measured throughout the Birds Hill area by staff from MCWS. This monitoring has concluded that groundwater mounding is occurring from the extensive recharge, which flows radially outwards in the carbonate aquifer.

Groundwater flow in the carbonate bedrock of the Red River Formation generally occurs in the fracture and joint sets in the rock. The size, extent, and interconnectivity of the fracture system govern horizontal and vertical groundwater movement through the bedrock. Due to this geologic condition, aquifer transmissivity and storativity can vary significantly over a relatively short distance, resulting in substantial variations in well yield (Render, 1970). The Red River Formation is considered to be a significant resource throughout the central portion of Manitoba, being developed for municipal, commercial, and private water supply systems (Betcher et. al, 1995).

Groundwater flow in the carbonate aquifer within the RM of East St. Paul is shown below as Figure 6.

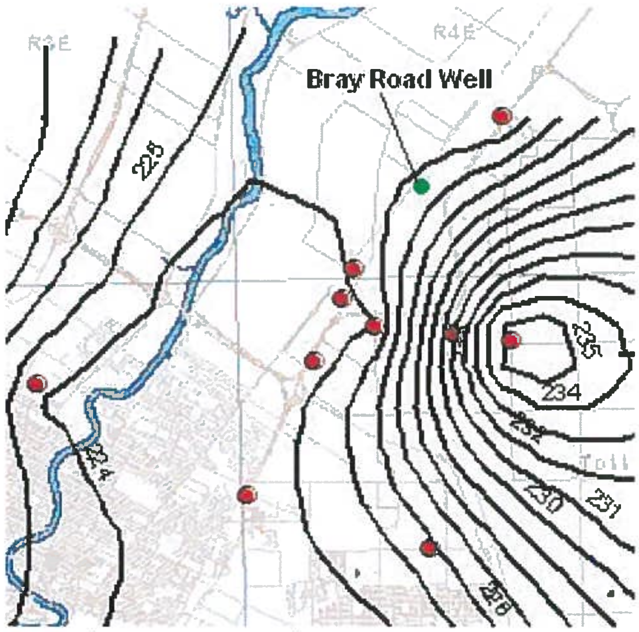

Figure 6 – Groundwater flow in the carbonate aquifer – RM of East St. Paul area (Source – MCWS, 2010)

In Render's 1970 paper, the Bray Road area between the Red River Floodway and the Red River was identified as a high permeability area. In Baracos et. al, 1983, additional pumping test evaluation for the transmissivity mapping of Winnipeg also showed the area as having high permeability, with transmissivity values ranging from 100,000 to 150,000 U.S.G.P.D./ft.

Groundwater flows radially outwards from the Birds Hill Glacio-Fluvial complex towards the Red River, where there is thought to be points of groundwater discharge into the Red River. East of the Red River Floodway, the potentiometric surface is very closely spaced, which indicates that the transmissive conditions are substantially different in the fringes of the Birds Hill complex. Woodbury (1992) noted that the floodway was deemed as a partial line sink for the area, as there is some evidence in the south part of the RM of groundwater seepage into the low flow channel. There are several springs in the area south of Birds Hill that exist in the low flow channel. West of the Red River Floodway, the potentiometric surface flattens out considerably, indicating that transmissive conditions change considerably.

Woodbury noted that there was some evidence of Red River water being present in the aquifer within the corridor between Henderson Highway and the Red River. Through a review of the geology, especially around the Lister Rapids area, where the carbonate bedrock is known to have very shallow burial under the glacial drift. The Red River is thought to be a major source of groundwater discharge for the carbonate aquifer in the immediate area.

Local Hydrograph Review

In order to review the regional groundwater flow directions and the long term response in the carbonate aquifer and Birds Hill Glacio-Fluvial complex over the last 30 years across the RM of East St. Paul well site, the following MCWS chart hydrograph stations were accessed for potentiometric elevations:

- GO5OJ002 – RL 271 – Parish of St. Andrews – Carbonate Aquifer
- G05OJ006 – SW34-11-4E – Sand and Gravel Aquifer
- G05OJ008 – NW17-12-5E – Carbonate Aquifer
- G05OJ010 – RL 101 - Parish of St. Paul – Carbonate Aquifer
- G05OJ013 – SW36-11-4E – Sand and Gravel Aquifer
- G05OJ077 – RL 71 – Parish of St. Paul – Carbonate Aquifer
- G05OJ079 – SW34-11-4E – Carbonate Aquifer
- G05OJ080 – SW35-11-4E – Carbonate Aquifer
- G05OJ082 – RL 94 – Parish of St. Paul – No Log
- G05OJ103 – RL 17 – Parish of St. Paul – No Log
- G05OJ128 – RL 21 – Parish of St. Paul – No Log
- G05OJ147 – NE30-11-5E – Sand and Gravel Aquifer
- G05OJ148 – SE33-11-4E – Sand and Gravel Aquifer
- G05OJ160 – NE30-11-5E – Sand and Gravel Aquifer & Carbonate Aquifer
- G05OJ171 – RL 113 – Parish of St. Paul – Sand and Gravel Aquifer
- G05OJ172 – RL 106 - Parish of St. Paul – Carbonate Aquifer
- G05OJ173 – RL 101 – Parish of St. Paul – Carbonate Aquifer

Hydrograph data source – MCWS, 2012

Through a review of the hydrographs, the following comments can be noted. The aquifer in the area appears to respond quickly to seasonal and climatic variations. During drier periods, such as what occurred in the summer of 1992, the aquifer seems to lower rapidly. Recharge also seems to occur fast. The down gradient observation wells seem to respond slightly slower, with a pressure effect that is similar to a pipeline and reservoir. If the potential in the reservoir falls, there would be a loss in potential in the down gradient water line. There is some slight evidence in OJ010 and OJ006 that floodway has had some influence on the area, as there is a marked drawdown in the first few years of the chart record after completion of the project. This may be a result of regional effects, as the floodway did provide some spring discharge of groundwater from the carbonate aquifer north and south of the RM of East St. Paul.

Two of the longest term hydrograph stations in the RM of East St. Paul area are shown below. Overall, the hydrographs since the mid 1970's have reflected climatic conditions. Drawdown from the existing RM water supply wells has not been detected in these key hydrograph records of G05OJ010 and G05OJ002, which are shown below as Figures 7 and 8. The total annual change seems to be about 3 to 4 feet on average. Total precipitation from 1990 to present is also shown as Figure 9. All of the hydrographs are attached in Appendix E.

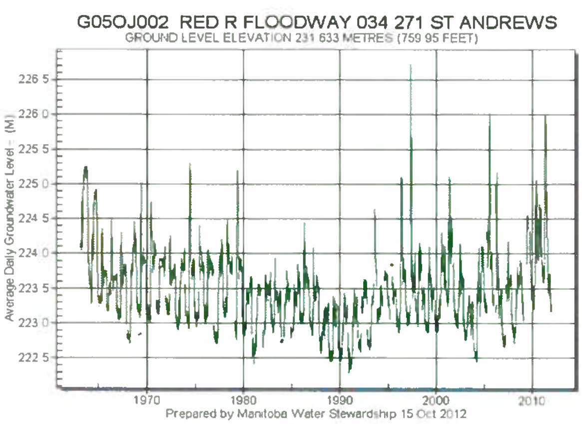

Figure 7 – G05OJ002 (source – MCWS, 2012)

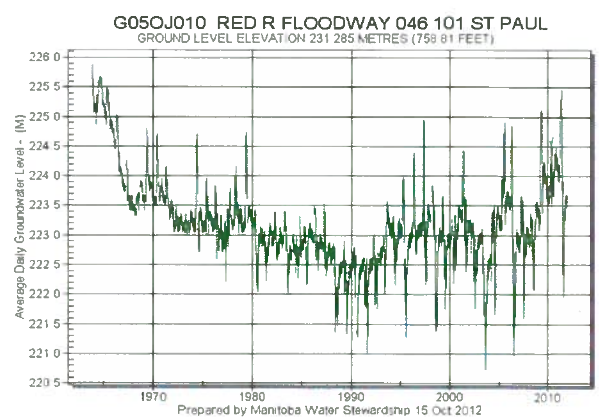

Figure 8 – G05OJ010 (source – MCWS, 2012)

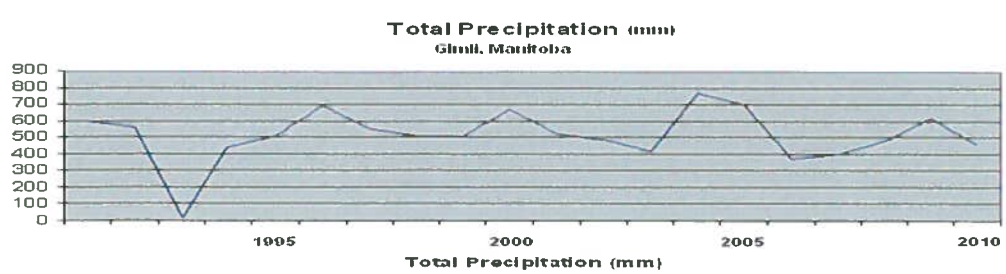

Figure 9 – Total precipitation – Gimli, Manitoba (source – Environment Canada, 2010)

Local Hydrograph Review (cont'd)

As part of the hydrograph review, the groundwater flow directions around the RM were mapped with the hydrograph stations that were available. The potentiometric surface mapping is shown below as Figure 10. The hydrograph station locations are also shown in the map. In general, the mapped flow directions compare well with the regional groundwater flow in the area.

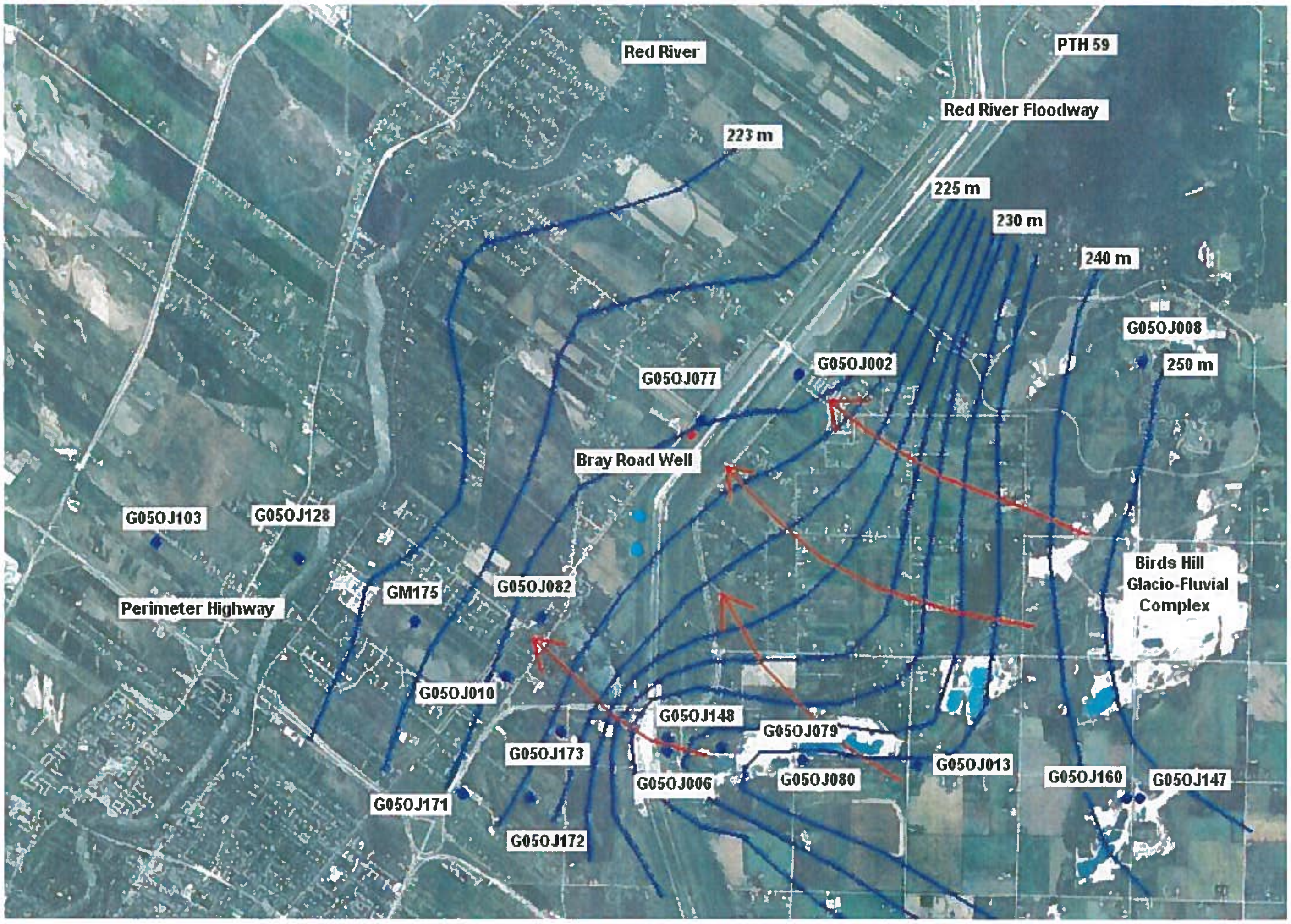

Figure 10 – Mapped groundwater flow directions – RM of East St. Paul area (data source – MCWS, 2012)

Regional Groundwater Geochemistry

In order to determine the background groundwater geochemistry across the RM of East St. Paul, the following MCWS hydrograph station sampling results were reviewed.

- G05OJ002 – RL 271 – Parish of St. Andrews – Carbonate Aquifer
- G05OJ006 – SW34-11-4E – Sand and Gravel Aquifer
- G05OJ008 – NW17-12-5E – Carbonate Aquifer
- G05OJ010 – RL 101 - Parish of St. Paul – Carbonate Aquifer
- G05OJ013 – SW36-11-4E – Sand and Gravel Aquifer
- G05OJ077 – RL 71 – Parish of St. Paul – Carbonate Aquifer
- G05OJ079 – SW34-11-4E – Carbonate Aquifer
- G05OJ080 – SW35-11-4E – Carbonate Aquifer
- G05OJ082 – RL 94 – Parish of St. Paul – No Log
- G05OJ171 – RL 113 – Parish of St. Paul – Sand and Gravel Aquifer
- G05OJ172 – RL 106 - Parish of St. Paul – Carbonate Aquifer
- GM175

Hydrograph data source – MCWS, 2012

The results were plotted on a piper diagram to allow for a comparison of the results. The plot is shown on the following page as Figure 11. Table 1, also shown on the following page, provides some key groundwater quality parameters.

Regional Groundwater Geochemistry (cont'd)

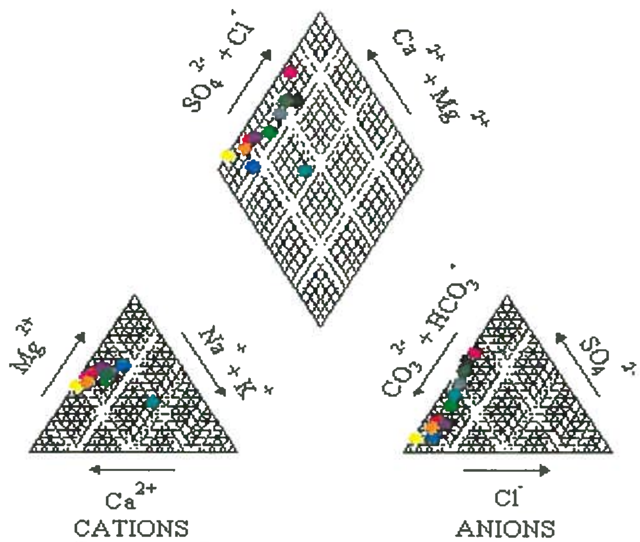

Figure 11 – Piper plot (data source – MCWS, 2012)

Table 1 RM of East St. Paul Regional Groundwater Geochemistry – Carbonate Aquifer – MCWS Hydrograph Stations			
Well Name	**Total Dissolved Solids**	**Electrical Conductivity**	**Chloride**
GO5OJ002 – RL 271 – Parish of St. Andrews	893 mg/L	1,220 umhos/cm	14.9 mg/L
G05OJ006 – SW34-11-4E	241 mg/L	454 umhos/cm	10.8 mg/L
G05OJ008 – NW17-12-5E	284 mg/L	452 umhos/cm	4 mg/L
G05OJ010 – RL 101 - Parish of St. Paul	482 mg/L	770 umhos/cm	25.5 mg/L
G05OJ013 – SW36-11-4E	463 mg/L	N.A.	16 mg/L
G05OJ077 – RL 71 – Parish of St. Paul	752 mg/L	1,130 umhos/cm	19.4 mg/L
G05OJ079 – SW34-11-4E	298 mg/L	500 umhos/cm	12.5 mg/L
G05OJ080 – SW35-11-4E	255 mg/L	488 umhos/cm	9.89 mg/L
G05OJ082 – RL 94 – Parish of St. Paul	487 mg/L	857 umhos/cm	39.7 mg/L
G05OJ171 – RL 113 – Parish of St. Paul	670 mg/L	852 umhos/cm	22.8 mg/L
G05OJ172 – RL 106 - Parish of St. Paul	718 mg/L	1,000 umhos/cm	19.8 mg/L
GM175	732 mg/L	1,040 umhos/cm	186 mg/L

Table 1 – Groundwater chemistry (data source – MWS, 2012)

The groundwater in the RM of East St. Paul is expected to be a Calcium/Magnesium/Bicarbonate/Sulphate type groundwater. Generally, the total dissolved solids are expected to be less than 500 to 800 mg/L, with relatively low concentrations of sodium and chloride. Groundwater quality is expected to be quite good for the carbonate aquifer, as the site is relatively close to a major source of recharge. It should be noted that these samples were all collected by MCWS at their provincial hydrograph station locations. Friesen Drillers has not verified the sample results, and has assumed them to be correct and representative of actual conditions. The groundwater quality was noted to change somewhat, with further radial movement from the Birds Hill Glacio-Fluvial complex. The Total Dissolved Solids (TDS) gradually increase as groundwater moves through the aquifer through an ion exchange process.

In 2006, saline groundwater was encountered in the carbonate aquifer located on the north end of Rebeck Road (see Appendix F). MCWS wasn't able to determine the origin of this water. It is thought that this was due to an unknown well completed in the sandstone aquifer. This is expected to be a localized issue and is not expected to cause an issue in the Bray Road Area.

It is interesting to note that in the in the G05OJ010 location, MCWS collected samples for the analysis of isotopes of oxygen. The ratios of the main isotopes that comprise the water molecule ($^{18}O/^{16}O$) and $^{2}H/^{1}H$ are important for hydrogeological investigations (Freeze and Cherry, 1979). The units are presented in delta (δ) units as parts per thousand or ‰ (Freeze and Cherry, 1979) relative to standard mean oceanic water (SMOW). The two isotopes of water have different freezing and vapour points, which leads to different concentrations as a result of freezing, condensation, melting, and evaporation (Freeze and Cherry, 1979). As water is evaporated from

Regional Groundwater Geochemistry (cont'd)

the ocean, there is a decline in the ^{18}O concentration by a specific amount. As the vapor condenses, the precipitation has a higher ^{18}O concentration. This process continues as the vapor moves inland, and undergoes many cycles of condensation and evaporation. This fact makes deuterium and oxygen 18 very useful for hydrogeological investigations, as the origin and mixing of different waters can be determined. In order to determine the changes from local precipitation, deuterium and oxygen 18 results are plotted to determine the local meteoric water line, which would be expected to be the typical concentrations in recent precipitation events in the Winnipeg area.

Within Manitoba, glacial water (~ 10,000 years ago), typically shows oxygen 18 concentrations of -19 to -23 δ (‰ V – SMOW). Waters that are mixing with older glacial waters typically indicate about -17 to -19 δ (‰ V – SMOW), while recent water is -14 to -16 (‰ V – SMOW) (Freeze and Cherry, 1979).

The water sample collected from OJ010 indicates Deuterium levels of about -105.19 ‰, with an ^{18}O level of about -13.55 ‰. This, as expected, indicates very recent groundwater. This is likely due to the fact that the OJ010 site is located very near to Birds Hill Glacio-Fluvial complex. When these values were plotted in comparison to the Meteoric Water line for Gimli (IAEA, 2012), the results were noted to plot on the meteoric water line (shown below as Figure 12). This suggests that the groundwater has not undergone significant alteration since it fell as precipitation.

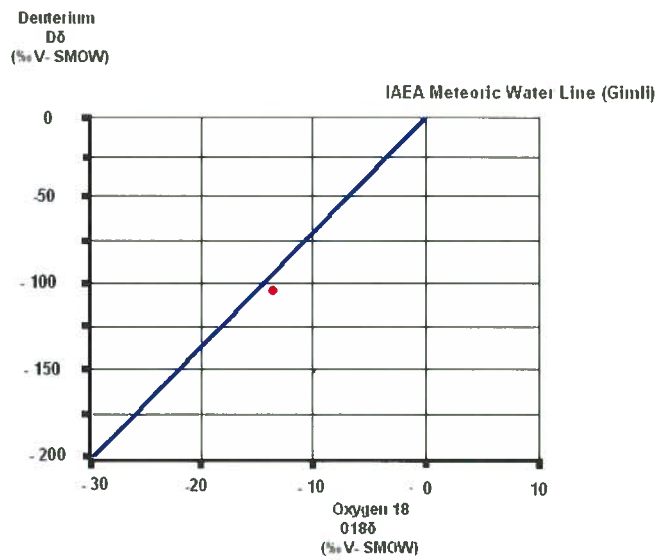

Figure 12 – OJ010 plot.

Another important occurrence in water in the hydrological cycle is the measurement of Tritium. Although tritium is known to occur naturally in groundwater, the quantities are thought to be less than 2 to 4 TU (Tritium Units). Increases in tritium were noted as a result of the extensive testing of nuclear weapons by the Union of Soviet Socialist Republics and the United States in the 1950's and into the early 1960's. Since the cessation of nuclear testing the levels of Tritium have been monitored extensively in Canada (Fritz and Clark, 1997). Since tritium has a half life of 12.3 years, groundwater that was recharged at surface before 1953 is expected to have a tritium level less than 2 to 4 TU (Freeze and Cherry, 1979). Therefore, if groundwater contains levels between 5-10 TU, the water present is thought to have originated after 1953. At G05OJ010, the Tritium level was noted to be 6 T.U., which also indicates that groundwater at the site is very modern groundwater, and has been in the aquifer system for 5 – 10 years (Fritz and Clark, 1997).

Well Inventory

As part of the requirements from MCWS – Water Rights Licensing Section, a well inventory of risk for private and commercial wells located within a 1,250 m radius of the Bray Road well location, was requested in the permit. The inventory would seek to determine the number of private wells in the area that may be located within the potential drawdown cone of the proposed supply well location. The RM of East St. Paul provided mapping of the 1,250 m radius, along with the names and addresses of the land owners.

A map showing the well inventory area is on the following page as Figure 13. The river lots included in the survey include the following:

- River Lots 60 to 118 – Parish of St. Paul

Well Inventory (cont'd)

- River Lots 282 to 287 – Parish of St. Clements

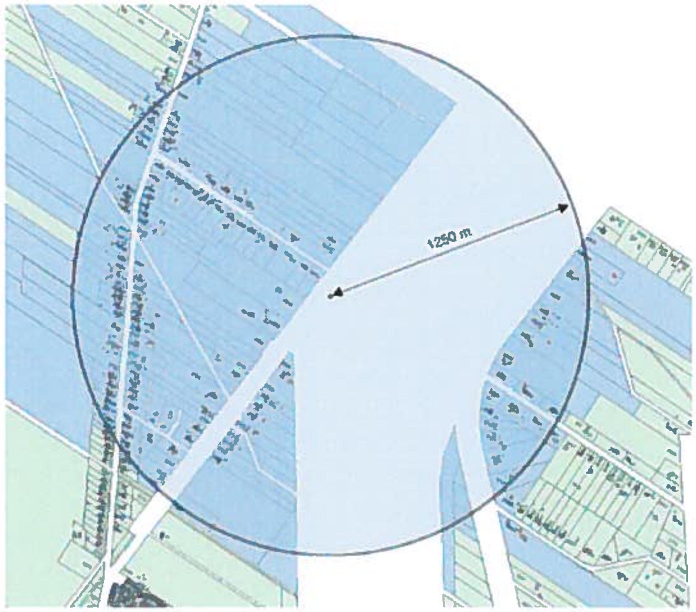

Figure 13 – Well inventory – Bray Road location (source – RM of East St. Paul, 2012)

In order to provide specific details of the well installations, land owners within the radius were sent an information request on specific well details. A copy of the cover letter and the form are attached. The completed forms are also attached. Overall, of the 176 properties lying within the specified area, 43 forms were returned (see Appendix G). Copies of the forms are attached. Figure 14, shown below, indicates the properties that provided specific well details.

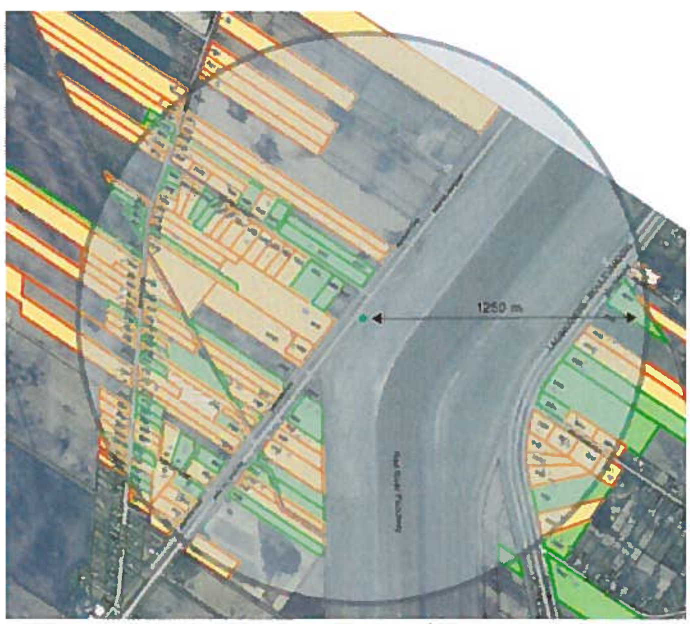

Figure 14 – Well inventory land owner responses (orange = no response/green = submitted form) (source – RM of East St. Paul)

In order to attempt to link specific well owners with the water well records contained in the GWDRILL database, The well inventory was undertaken inside the boundaries of the above noted sections using the May, 2010 version of MCWS's GWDRILL water well database. Aerial photographs were also used in the identification process. Overall a total of 59 water wells were located within the database that could be linked to addresses or land owners by name. The table in Appendix G provides the specific details.

Well Inventory (cont'd)

The GWDRILL database contains well logs that have been drilled by licensed water well drillers since 1964. It is highly possible that other wells would exist in the area.

Overall, the vast majority of wells reviewed during the well inventory were open hole carbonate wells, with 40 to 50 feet of casing. Many of the wells are of fairly recent construction (after 1970), with a few being reported to be older than 90 years. Most wells appear to have modern style pitless unit connections, with some wells being completed in the basement. Due to the static water levels that are present, most wells appear to be mechanized with submersible type pumps and two line jetmatic pumps.

Most wells in the area appear to be capable of dealing with several feet of static water fluctuation, judging from the long term hydrograph response at G05OJ002.

Field Investigations and Testing

Well Installation and Development

Friesen Drillers Limited mobilized to the East St. Paul area in December, 2011. A Foremost DR-24W dual rotary drill rig was used to over drill the existing test well at the Bray Road TW-03-04 site. The existing PVC casing was extracted, and the rig was set up over the existing borehole. Approximately 54 feet of 10 inch diameter welded steel casing was installed. The open hole section of the borehole was then reamed to 9.75 inch diameter. The borehole was advanced to the same depth as the original test well, which was 120 feet below grade. Upon completion of the drilling, the borehole was developed with compressed air for a 4 hour period. During the developing, it was noted that the fractures encountered were very large from 70 to 80 feet below grade. The borehole developed very quickly, and no detectable fines were noted. The driller noted that the well appeared to be of very high capacity.

Complete geologic and borehole construction logs are attached as Appendix H.

A temporary well cap was installed on the well.

It should be noted that the well site was accessed through the ditch lying on the east side of PR 202. Access to the well site was provided by the existing approach that is maintained by Manitoba Infrastructure and Transportation (MIT). The site access was provided under the legal agreement that exists between the RM of East St. Paul and MIT.

Aquifer Monitoring, Climatic Monitoring and Geodetic Surveying

As part of the well inventory requirements, a number of well sites were chosen for observation monitoring wells during the 72 hour pumping test detailed in the MCWS – Groundwater Exploration Permit. Observation wells were chosen for the distance and location from the Bray Road well. Two MCWS hydrograph stations, along with the RM of East St. Paul loading station at PTH 59 and Coronation Street were also used. The majority of the observation wells were selected from residents in the area who indicated that they would be willing to allow their private wells to be used for monitoring. The locations of the selected observation wells are detailed below and shown on the following page Figure 15.

Solinst M30/F100 automatic, data recording pressure transducers were installed in each of the selected observation wells. The transducers used were the non-vented type, which require barometric pressure correction. A barometric pressure logger was deployed to the site for use in data correction. In addition, a number of wells were also monitored manually using a Powers water level sounding M-Scope. The transducers were set to record data on ten minute intervals, and were installed about a week before the pumping test. The majority of the instruments were removed about one week after the test, with several longer term stations being left in place for an additional month.

- 1740 Bray Road - Transducer
- 4000 St. Andrews Road - Transducer
- 1960 Bray Road – Transducer
- 3486 Raleigh Street - Transducer
- 87 Chrisluk Drive - Transducer
- Loading Station – Coronation Street - Transducer
- G05OJ002 – Transducer
- G05OJ077 – Manual readings
- OBS – North – Manual readings
- OBS – South – Manual readings
- Supply well – Manual readings

Aquifer Monitoring, Climatic Monitoring, and Geodetic Surveying (cont'd)

Figure 15 – Observation well locations (source – www.googleearth.com, 2012)

Barometric pressure changes have been noted to cause water level fluctuations in confined aquifers (Walton, 1987). As such, barometric pressure monitoring is important so as to not interpret water level changes as possible boundary conditions. In order to provide accurate regional data during the completion of the testing, hourly barometric pressure readings were obtained from Environment Canada for the duration of the testing. The daily readings for the four days of aquifer testing are presented below as Figure 16.

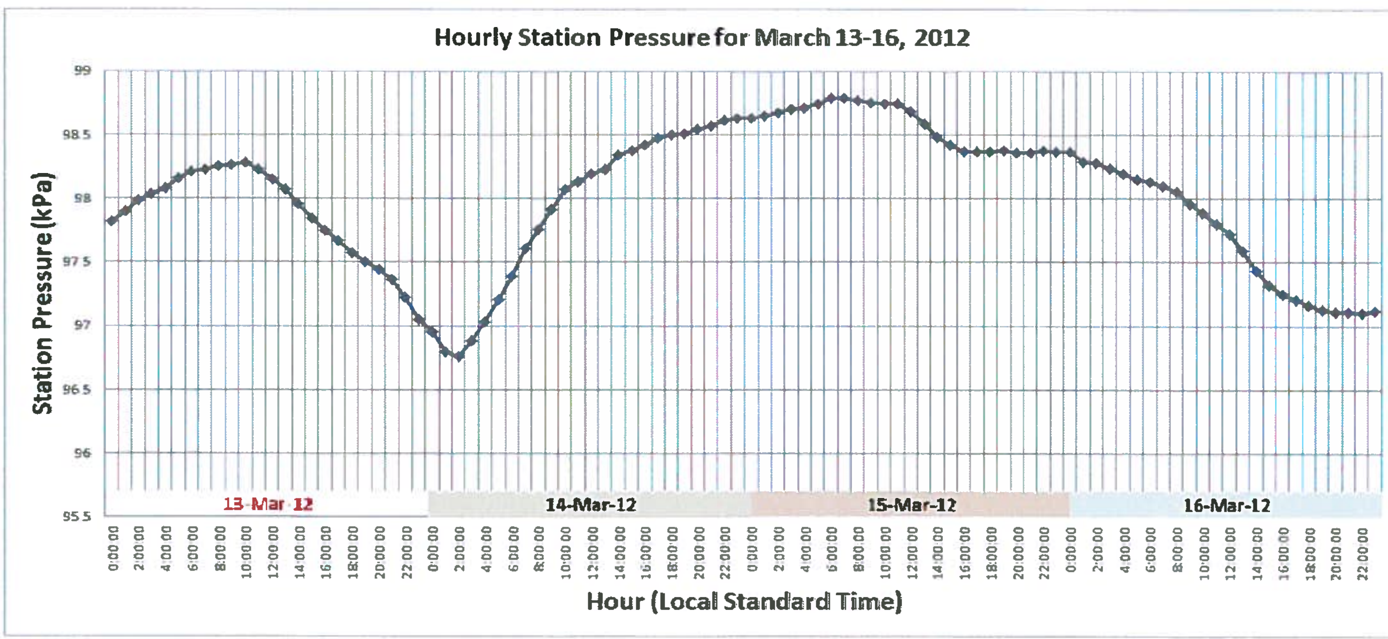

Figure 16 – March 13-16, 2012 (data source – Environment Canada, 2012).

The corrected transducer plots and water levels measured in each observation well are attached as Appendix I.

In order to determine the exact location and elevation of the observation well network, the RM of East St. Paul arranged for a geodetic surveying crew to attend the site. Each observation well location was surveyed with a geodetic GPS total station. In addition to the observation wells, the elevations of the Red River and the water in the low flow channel of the Red River Floodway were also surveyed during the pumping testing. The survey data is also contained in Appendix I.

Physical Investigations for Groundwater/ Surface Water Interactions

During the early years of the floodway operation, concerns were raised about the possibility of contaminated surface floodwaters entering the aquifer through the springs. In effect, it was thought that the hydraulic loading of the floodwaters in the channel would enter the aquifer and cause regional water quality and bacteriological issues with water supplies (Render, 1971). Render's study in 1971 concluded that no evidence of bacteriological contamination was found in the monitoring program. Groundwater monitoring also concluded that flow velocities were less than 0.40 m/day, and the duration of channel operation was relatively short. A more extensive study during the 1974 flood came to basically the same conclusions (Render and Fritz 1975). After the passing of the flood, contaminated surface water that entered the aquifer would then begin to discharge back through the springs which had allowed the initial entry. Woodbury also undertook extensive geochemical sampling in the RM to determine if river water had entered the aquifer and penetrated significant distances (Woodbury, 1992). Through extensive isotopic, geochemical, physical hydrogeology, and numerical modeling exercises, Woodbury indicated that groundwater had not penetrated significantly inwards due to the low seepage velocities (Woodbury, 1992). Another favorable factor is that there have been no known occurrences of groundwater contamination following any of the floods that have occurred over the past 43 years of floodway usage. In places, such as the Lister Rapids, the Red River acts as a groundwater discharge area for the carbonate aquifer. However due to the hydraulic gradient in the carbonate aquifer and the low drawdown of the Brady Road Well, it appears unlikely for the new well to draw river water back into the aquifer.

Friesen Drillers was retained by Stantec Consulting in early 2010 to undertake preliminary work on this project. On four separate occasions, the author walked the channel of the Red River Floodway from the PTH 59 Bridge to Dunning Road looking for evidence of groundwater discharge or seepage springs. During the construction of the floodway, groundwater discharge occurred through a few small springs (the largest being 50 gallons per minute) in the area between the PTH 1 Bridge, and areas north towards the outlet structure. These springs occurred due to the level of the potentiometric surface in the carbonate aquifer at the time being substantially above the level of the bottom of the Floodway excavation. Also some evidence of groundwater discharge was noted at the Birds Hill/Spring Hill area, where the glacio-fluvial complex was cut by the floodway channel. Throughout the channel area examined, there was no evidence of discharge occurring north towards Dunning Road on the four occasions that the channel was observed.

It should be noted that Render observed some minor spring discharge in the area, according to mapping from 1969. North of Dunning Road towards the outlet, some larger areas of spring discharge were noted. The area north of Birds Hill was not noted for spring type seepage during the 1971 investigations by Render. Investigations undertaken during the channel modifications to the recently expanded Red River Floodway also support this review.

Pumping Test, Geochemical, and Environmental Isotope Sampling

In order to obtain aquifer parameters and to determine how the Bray well responds to pumping, a 72 hour pumping test was conducted. The testing duration was stated in the scope of work and approved by MCWS – Groundwater Licensing Section. Recovery was to be monitored to at least 90% of the static water level.

A 15 hp Berkeley submersible pump and motor was installed in the Bray well at a depth of 50 feet below grade. Power was supplied by an on-site portable generator. During the installation and set up, the pump and motor were tested briefly for one hour to determine the well yield. This allowed the discharge valve to be set. This was undertaken approximately one week before the testing. The actual pumping test was scheduled for March 13, 2012. It should be noted that at the time of the pumping test, ground frost was still present.

The flow rate was maintained through each test using an orifice meter. The flow meter was checked every half hour. Water levels were monitored using a Powers M-scope well sounder in the pumping well. The flow from the meter was pumped and piped over the berm of the floodway, and was allowed to discharge to the low flow channel.

During the 72 hour pumping test on the Bray well, field measurements of basic water quality parameters were collected. The field instruments were calibrated prior to the test. Field measurements were taken to show the water quality results prior to the release of CO_2 from the sample, which can affect the results over short periods of time. The summary of water quality testing results is shown on the following as Table 1. In addition, groundwater samples were collected from the pumping discharge in laboratory supplied analytical sample bottles every 24 hours. The samples were submitted to ALS Laboratories for routine water quality parameters and metals scan analysis. The results will be discussed in the data analysis section. In addition to the routine analysis, two environmental isotope samples were collected for the analysis of $Oxygen^{18}$ and Deuterium isotopes.

Pumping Test, Geochemical, and Environmental Isotope Sampling (cont'd)

Table 1 Field Water Quality Measurements – Bray Road Well 72 Hour Pumping Test Bray Road Supply Well – Municipal Groundwater Supply Expansion			
Pumping Time	**Electrical Conductivity**	**Field Turbidity**	**pH**
12 hours	962 umhos/cm	5.52 NTU	7.7
24 hours	971 umhos/cm	2.35 NTU	8.0
36 hours	955 umhos/cm	1.25 NTU	8.0
48 hours	975 umhos/cm	0.57 NTU	7.9
60 hours	941 umhos/cm	0.84 NTU	7.8
72 hours	905 umhos/cm	0.82 NTU	7.7

Table 1 – Field parameters - Bray Road Supply Well – Municipal Groundwater Supply Expansion

The following water levels and pumping rates, shown in Table 2, below were recorded during the pumping tests from the Bray Road supply well.

Table 2 Pumping Test Specific Details Bray Road Supply Well – Municipal Groundwater Supply Expansion								
Well	**Pumping Time**	**Northing**	**Easting**	**Casing Depth**	**Total Depth**	**Static Water Level**	**Pumping Water Level**	**Pumping Rate**
Bray Road	72 hour	5540076.442 m	644349.767 m	54 ft.	120 ft.	35.33 ft.	38.83 ft.	491 U.S.G.P.M.

Table 2 – Pumping test details – Bray Road Supply Well – Municipal Groundwater Supply Expansion

Data Analysis

Aquifer Testing Analysis

The Theis method (1935) method is the most common approach for analyzing the results from aquifer pumping tests. Critical assumptions integral to the method are detailed as follows:

- Darcy's law is valid
- The aquifer is horizontal and constant thickness
- The aquifer is infinite in areal extent
- The aquifer is bounded by impermeable strata above and below
- Uniform hydraulic conductivity
- Isotropic hydraulic conductivity
- Head always remains above the top of the pumped aquifer
- There are no water level changes that are not due to the pumping.
- Infinitesimal diameter of well
- Fully penetrating the aquifer formation
- Perfectly efficient well
- Single pumping well
- Constant pumping rate
- Constant storage properties through time
- The head is known everywhere prior to pumping.

Through a review of the assumptions, it can be seen that some of the conditions for the analysis of the pumping tests conducted at the on the Bray Road well are invalid for the Theis (1935) approach. The Theis (1935) approach is highly idealized to the assessment of the aquifer, and represents the state of the art for the determination of aquifer parameters. The method has been found to be reasonably workable for aquifer engineering evaluation, all over the world, for nearly 80 years. The conditions are also not being violated overly severely, at the Bray Road site, so this approach was used for the test analysis. However the effects of partial aquifer penetration and barometric effects were taken into account though the analysis.

The data was entered into Waterloo Hydrogeologic's AquiferTest Professional v4.20, for analysis of aquifer parameters. The data was analyzed using the Cooper-Jacob (1946), and Theis (1935) methods, although the exact same result should be expected, as the Cooper - Jacob (1946) method is simply a straight line approximation of the Theis (1935) method. In order to determine the acceptability of the results, a derivative analysis was used, which is also shown on the attached plot (Bourdet, et. al., 1989). The hydraulic parameters that were determined are shown on the following page as Table 3. The pumping data are attached as Appendix J.

Aquifer Testing Analysis (cont'd)

Table 3 **Aquifer Parameters – Bray Road Well 72 Hour Pumping Test** **Bray Road Supply Well – Municipal Groundwater Supply Expansion**		
	Supply Well	
Drawdown	3.50 ft @ 491 U.S.GPM – 72 hours	
Static Water Level	35.33 ft from top of casing	
Available Drawdown	18.67 ft (at the time of testing)	
Specific Capacity	140.29 U.S.GPM/ft	
Method	**Transmissivity**	**Storativity**
Theis Method[1]	429,000 U.S.G./day/ft	1.00×10^{-4}
Cooper - Jacob Method[2]	429,000 U.S.G./day/ft	1.00×10^{-4}
Theis Recovery Method[3]	429,000 U.S.G./day/ft	1.00×10^{-4}
Notes [1] Theis (1935) method using Waterloo Hydrogeologic Limited – Aquifer Test Professional v4.20 [2] Cooper - Jacob (1946) method using Waterloo Hydrogeologic Limited – Aquifer Test Professional v4.20 [3] Theis Recovery (1935) method using Waterloo Hydrogeologic Limited – Aquifer Test Professional v4.20		

Table 3 – Aquifer Parameters – Bray Road Supply Well – Municipal Groundwater Supply Expansion

In general, the aquifer was determined to have an approximate transmissivity of about 430,000 U.S.G./ft., based on the results of the 72 hour single pumping well test, and the data from the nearest of the ten observation wells. The Storage Coefficient was determined to be 1.0×10^{-4}, which is the same value that has been calculated over many years in the floodway area by multiple researchers. The observation well distances from the pumping well were determined from the surveying data to be as follows:

- 1740 Bray Road – Transducer – 2,632 ft.
- 4000 St. Andrews Road – Transducer – 673 ft.
- 1960 Bray Road – Transducer – 620 ft.
- 3486 Raleigh Street – Transducer – 5,995 ft.
- 87 Chrisluk Drive – Transducer – 3,447 ft.
- Loading Station – Coronation Street – Transducer – 3,800 ft.
- G05OJ002 – Transducer – 8,732 ft.
- G05OJ077 – Manual readings – 200 ft.
- OBS – North – Manual readings – 2,960 ft.
- OBS – South – Manual readings – 3,445 ft.
- Supply well – Manual readings – 0 ft.

During the analysis, the $t_{critical}$ was assumed to be less than approximately 30 minutes for casing storage; therefore, the data previous to 30 minutes was not used in the analysis. The Cooper-Jacob (1946) method was used primarily, since emphasis is not placed on early time measurements. The pumping well configuration was not fully penetrating. Based on the test holes drilled in the area, the aquifer is not continuous, or isotropic, and displays a strong spatial variability. These conditions indicate a fundamental breech in the conditions of Theis (1935). Following standard practise, the aquifer was assumed to be Theissian. This may or may not be totally correct in this instance; however, as the Theis (1935) assumptions are almost never met in any real aquifer. This methodology is used following the standard practise. It was assumed that skin effects for the supply well would be minimal after the developing and jetting procedures.

The barometric pressure correction was calculated to be from 0.26 feet to about 0.53 feet, for the duration of the pumping test. Some of the groundwater level fluctuations in the distant hydrograph records maybe partially due to barometric effects. However, they are more likely due to some minor drawdown effects caused by the pumping test well and effects of combined local acerage pumpage. It is also possible when the water level changes are so small that wind and tidal effects maybe included. Comparison of the barometric changes with the water level changes in G05OJ002 suggest that the barometric efficiency of this well is very low and therefore the barometer played only a very small part in the small water level changes shown on the following page Figure 17. It is thought likely that the other observation wells drilled in similar geology would have similar barometric efficiencies.

Aquifer Testing Analysis (cont'd)

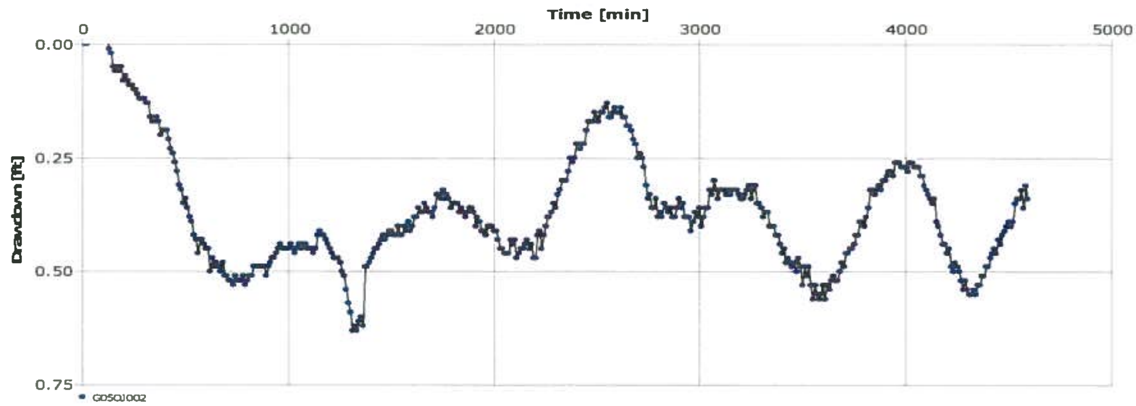

Figure 17 – G05OJ002 Record

The drawdown versus time, Theis (1935), Cooper – Jacob (1946), and Theis Recovery (1935) methods are shown below and on the following pages as Figure 18, 19, 20 and 21.

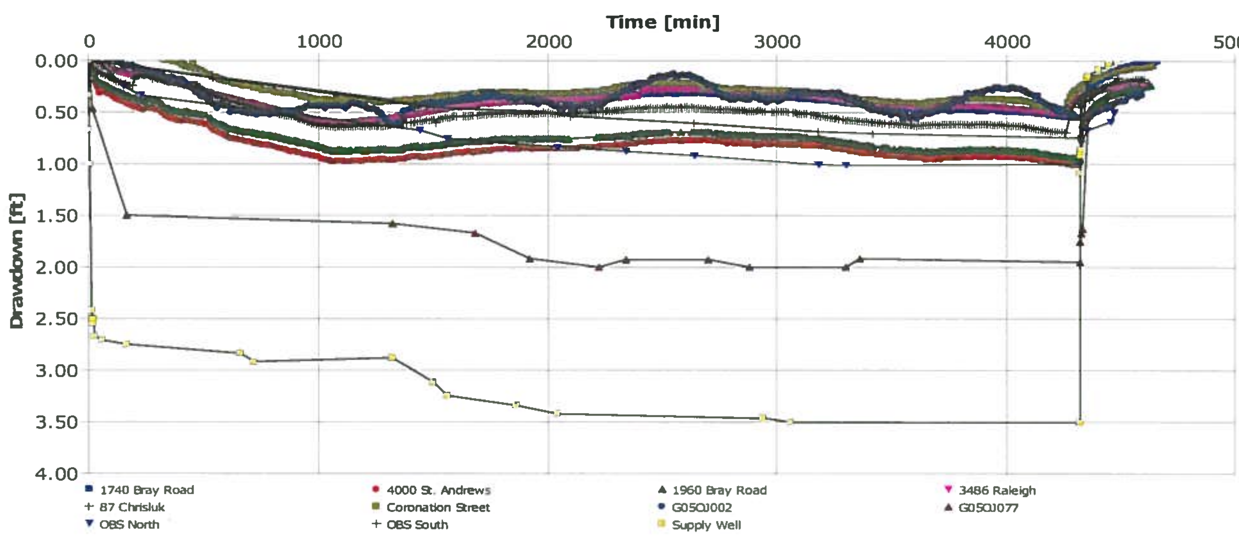

Figure 18 – Drawdown vs. Time for the Bray Road well. The constant pumping rate is 491 U.S.G.P.M.

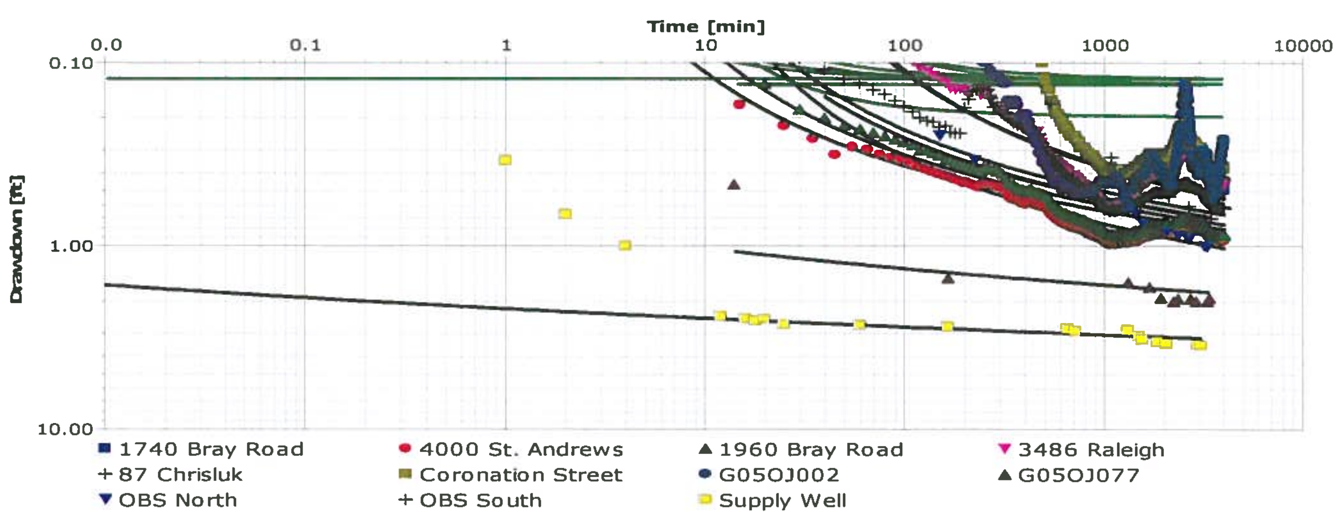

Figure 19 - The Theis (1935) plot with derivative analysis for the Bray Road well. The constant pumping rate is 491 U.S.G.P.M.

Aquifer Testing Analysis (cont'd)

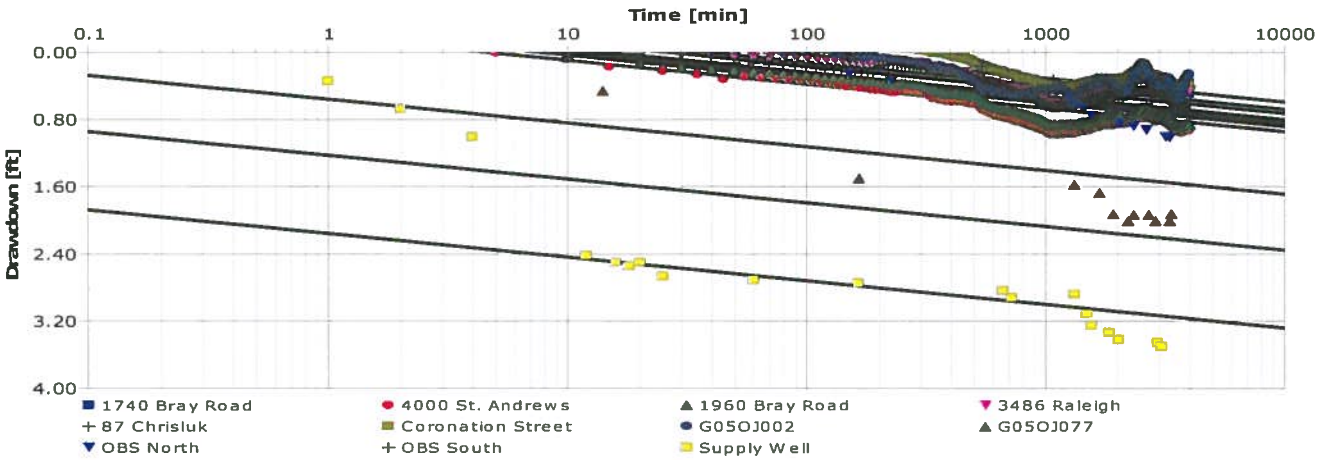

Figure 20 – The Cooper – Jacob (1946) plot for the Bray Road well. The constant pumping rate is 491 U.S.G.P.M.

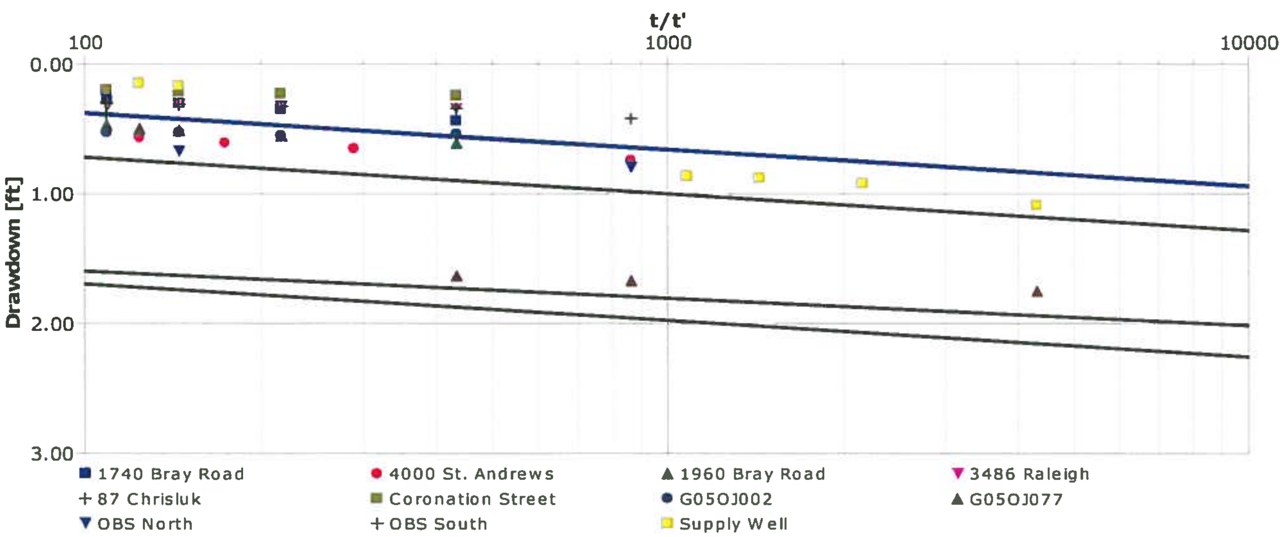

Figure 21 - The Theis Recovery (1935) plot for the Bray Road well. The constant pumping rate is 491 U.S.G.P.M.

The results from the analysis indicate that there are positive and negative boundaries in the Cooper-Jacob (1946) analysis. However these breaks in the slope of the drawdown curves are all in observation well data from distant wells were the total drawdown was less than 1 foot. Due to the fact that when the drawdown is so small the data could contain effects of other impacts on the aquifer such as municipal and acerage pumpage, these breaks in the drawdown curve were not felt to be reliable data for boundary analysis. There is an indication of negative boundary in the pumping well data (it is recognized that pumping well data is not usually used for boundary analysis at about one day into the test). While data is limited, this boundary also appears to have occurred in the nearby observation well G05OJ077. The occurrence of negative boundary is not surprizing as the Transmissivity at the pumping well site is high and there are bound to be areas with lower Transmissivity in the surrounding region.

As many as 5 different slopes were noted to occur at the following time steps:

- Slope #1 – Time 0 to ~ 400 minutes – Normal Cooper – Jacob (1946) decline
- Slope #2 – ~ 400 minutes to ~ 1,100 minutes – Negative boundary

Aquifer Testing Analysis (cont'd)

- Slope #3 - ~ 1,100 minutes to 2,800 minutes – Positive boundary
- Slope #4 - ~ 2,800 minutes to ~ 4,000 minutes – Negative boundary
- Slope #5 - ~ 4,000 minutes to end of test – Positive boundary

The distinct slopes are shown below as Figure 22.

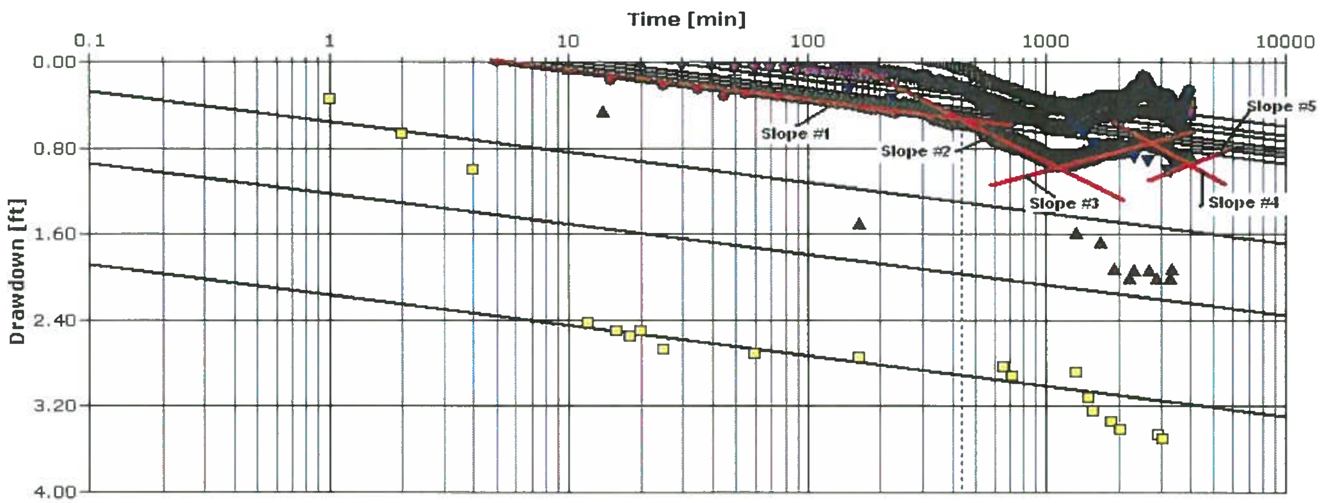

Figure 22 – Distinct Cooper-Jacob (1946) slopes

Typically, slope changes in an aquifer water level drawdown analysis reveal encountering a boundary condition in the aquifer. These usually take effect, and stay in effect for the duration of the testing unless additional boundary conditions are encountered. If, for example, the drawdown cone of the Bray Road supply well encountered a change in transmissivity which was negative, it is thought that the slope in the analysis would be also negative, or downward. If the test encountered a positive boundary, such as a constant head boundary, the boundary effect would be positive, or the rate of drawdown would decrease and would remain positive for the duration of the testing. It is also possible that some of the observation wells may be in areas of decreased transmissivity, although one would expect to see this occurring in specific directions away from the observation wells.

Overall, the drawdown at distance is very small, and indicates that the area is very transmissive, with a fairly flat gradient across the RM. Based on the analysis of the 72 hour pumping and recovery test, it is thought that a transmissivity of 430,000 U.S.G./day/foot and a storage coefficient of 1.0 x 10^{-4} is representative of actual site conditions, and reflects how the Bray Road well will respond to long term pumping at 491 U.S.G.P.M..

Geochemical Sampling and Results

During the pumping and recovery test on the Bray Road well, a total of 4 water samples were collected for analytical analysis. The groundwater samples were collected in laboratory supplied sample bottles. Upon collection, the sample was kept cool for delivery to the analytical laboratory. All samples were analyzed by ALS Laboratories in Winnipeg (L1124801 and L1124753). A formal copy of the laboratory analytical results is attached as Appendix K.

The major results are shown on the following page as Table 4. Figure 23, shown on the following page, depicts the Piper plot comparing the on-site results with the MWS observation wells. Figure 24, also shown on the following page shows the isotopic results presented against the standard mean oceanic water line for the area (IAEA, 2012).

Geochemical Sampling and Results (cont'd)

Table 4 Groundwater Sampling Results – Bray Road Well 72 Hour Pumping Test Bray Road Supply Well – Municipal Groundwater Supply Expansion							
Well Name	**Total Dissolved Solids**	**Chloride**	**Nitrate**	**Conductivity**	**Sodium**	**Deuterium Dδ (‰ V- SMOW)**	**Oxygen 18 018δ (‰ V- SMOW)**
12 hours	716 mg/L	16.8 mg/L	N.D.	970 umhos/cm	45.6 mg/L	N.A.	N.A.
48 hours	679 mg/L	16.9 mg/L	N.D.	937 umhos/cm	42.7 mg/L	N.A.	N.A.
72 hours	673 mg/L	16.9 mg/L	N.D.	936 umhos/cm	41.7 mg/L	N.A.	N.A.
Final results	645 mg/L	16.9 mg/L	N.D.	934 umhos/cm	36.6 mg/L	-105.50	-14.7

Table 4 – Groundwater analytical results (source - ALS L1124801 and L1124753)

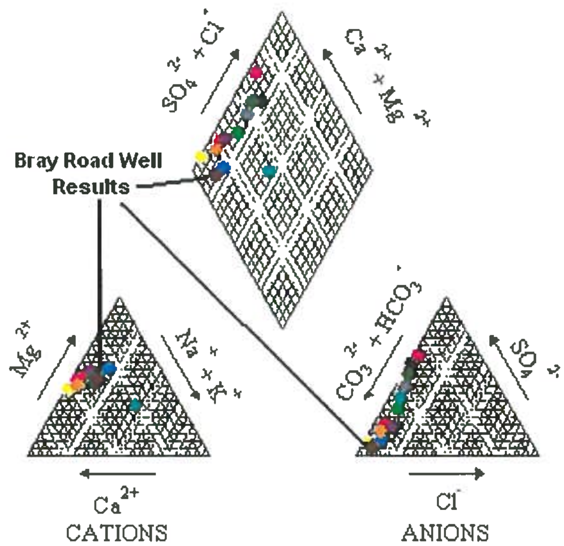

Figure 23 – Piper plot comparing MCWS hydrograph stations and the Bray Road well analytical results.

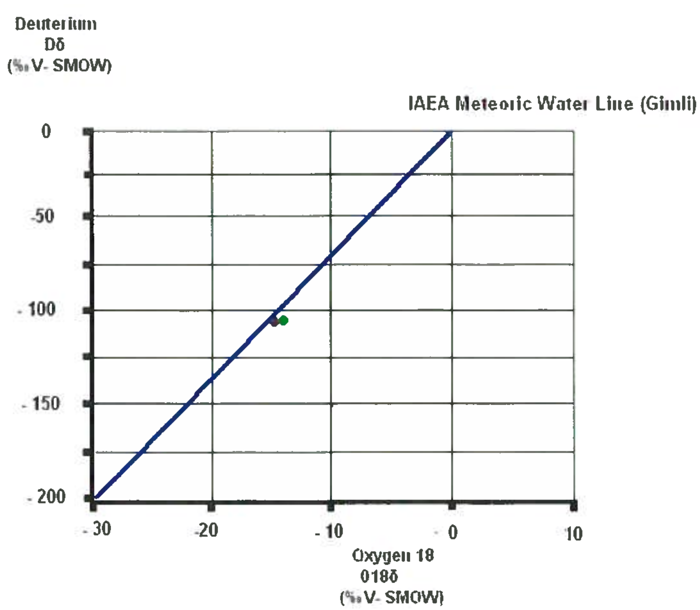

Figure 24 – Bray Road well plotted against the local Meteoric Water Line (IAEA, 2012)

Geochemical Sampling and Results (cont'd)

The results in general compare very well with the regional water quality in the area. The groundwater is a Calcium/Magnesium/Bicarbonate/Sulphate type, which is expected. Overall, the groundwater is very hard, with lower levels of sodium and chloride. The nitrates show non-detectable levels, which is expected. This is not the case in other areas where carbonate bedrock is shallower to surface and there is little confining material present.

The water sample collected from the Bray Road well matches well with the OJ010 sample. The Deuterium level is -105.50 ‰, with an ^{18}O level of about -14.70 ‰. This, as expected, indicates very recent groundwater. This is likely due to the fact that the OJ010 site is located very near to Birds Hill Glacio-Fluvial complex. When these values were plotted in comparison to the Meteoric Water line for Gimli (IAEA, 2012), the results were noted to plot on the meteoric water line (shown above as Figure 26). This suggests that the groundwater has not undergone significant alteration since it fell as precipitation.

Discussions

Long Term Hydrograph Response

The RM of East St. Paul is located very near to a major recharge area in the carbonate aquifer at the Birds Hill Glacio-Fluvial complex. Through reviewing all of the regional hydrograph data, the following comments can be made:

- The operation of the existing wells for the RM of East St. Paul has not produced a major drawdown cone that has been detected by the regional hydrograph network that is operated by MCWS. Drawdown cones would typically be expected around major pumping centers. The potentiometric surface mapping shows there is very little gradient across the central area of the RM, which indicates fairly transmissive conditions.

- The aquifer is susceptible to seasonal and climatic variations. Water levels in the carbonate aquifer appear to decline very rapidly during prolonged dry periods. The aquifer appears to be very similar to an open reservoir and pipe analogy. When the water level in the reservoir falls, the potential in the pipe declines very rapidly. This means that during prolonged dry periods, static water levels in the area will respond very rapidly, and decline accordingly.

- During periods of recharge, the aquifer also responds very quickly.

- The hydrograph record generally reflects very little overall fluctuation, over the past 50 years. There is some slight decline noted from 1965 to 1970, but recently, water levels appear to be as high as was recorded at that time. There is seasonal and climatic change, but there has been no detectable long term water level decline, as shown below as Figure 25 in G05OJ002. The hydrograph station is located near the Dunning Road Area.

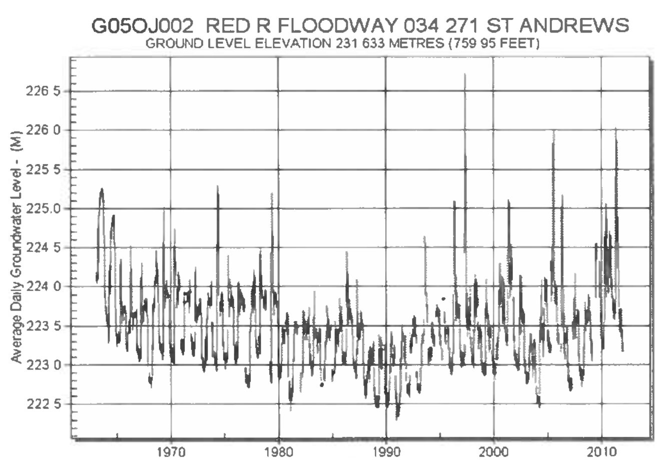

Figure 25 – G05OJ002 (1964 – present) – (source – MCWS, 2012)

Prediction of Long Term Regional Effects

In order to conservatively determine the long term effects of operating the RM of East St. Paul Bray Road well field at higher than the proposed pumping rate, the drawdown was calculated at a distance using the Theis equation at an average pumping rate of 491 U.S.G.P.M., after one year of operation for the site. The 491 U.S.G.P.M is greater than the requested allocation of 567.49 acre feet per year. These drawdowns follow all the assumptions of the Theis method. Drawdowns were calculated using Walton's B8.BAS Fortran code (Walton, 1983).

The drawdown at a radial distance of 5,280 feet from the supply well was determined to be approximately 1.27 feet after pumping one year continuously at a rate of 491 U.S.G.P.M.. In order to provide a conservative estimation, the local aquifer transmissivity was assumed to be uniform across the area at 429,000 U.S.GPD/ft, with an assumed storage coefficient of 1.0×10^{-4}.

The area is well populated, and to a large extent, the aquifer is well utilized by private residences. To the author's knowledge, a sustainable yield for the aquifer in this area has not been determined. In reviewing the local static water levels, it can be assumed that most private well systems in the area have taken current conditions as static for the area. The hydrograph record certainly indicates that there is more annual water level fluctuation in any given year than additional drawdown that would be created from the operation of the Bray Road well.

It should be noted that the estimated drawdown is without taking into account natural gradients and the effects of other unknown pumping wells that may be present.

Table 5 **Drawdown Estimation at Distance after One Year of Pumping at 491 U.S.G.P.M.** **Bray Road Supply Well – Municipal Groundwater Supply Expansion** All calculations following the Theis (1935) equation and assumptions								
Distance								
Well	**0.5 mile**	**1.0 mile**	**1.5 miles**	**2.0 miles**	**2.5 miles**	**3.0 miles**	**3.5 miles**	**4.0 miles**
3.52 feet	1.46 feet	1.27 feet	1.17 feet	1.09 feet	1.03 feet	0.99 feet	0.95 feet	0.91 feet

Table 5 – Expected drawdown resulting from 491 U.S.G.P.M. after one year at the Bray Road well.

Surface Water/Groundwater Interactions

Render (1971) could not find any evidence of the bacteriological contamination during the operation of the floodway. With the general lack of spring discharge in the channel in the area of the Bray Well, it is not expected that bacterial contamination is an issue. Groundwater velocities were calculated by Woodbury to be less than 0.56 meter/day, and with the short durations of floodway use, it is expected that groundwater would move very slowly through the system, and would be forced out after the passing of the flood. In addition, bacteria in general have limited life within the aquifer system, and are expected to die off in short order.

Assuming the following conditions for determining velocity in the Bray Road Area:

- Transmissivity of 100,0000 U.S.GPD/ft (average regional)
- Aquifer thickness of 40 feet
- Porosity of 0.1
- A head difference between the pilot channel and the Bray Road well of 11 feet
- A radial distance of 1300 feet

The calculated velocity is about 1.8 m./day, with a travel time of 46 days. It is recommended that frequent sampling be of municipal wells be conducted during the passing of a flood. Increasing the transmissivity to 400,000 U.S.GPD/ft, will also increase the velocity.

Through a review of the surveyed elevations, the static water levels in the carbonate aquifer are about 0.4 m lower than the elevations of the water in the low flow channel. This indicates a downward gradient, with a slight head difference. The passing of a flood in the floodway does cause a pressure effect rise in static water level in the carbonate aquifer. This is expected, due to the presence of connections to the aquifer along the channel that occur to the north and south.

Surface Water/Groundwater Interactions (cont'd)

With the very little drawdown that is expected from the Bray Road well in operation, it is not expected that a significant enough hydraulic gradient would be created to allow for Floodway pilot channel seepage into the aquifer. In addition, due to the strong transmissive conditions, the general east to west flow gradient is not expected to be altered significantly enough to affect inflow to the aquifer at the Red River; even during flooding conditions.

Integrated Water Supply and Watershed Planning Study

A water supply investigation and development of this size requires careful planning and assessment. Although it is assumed that groundwater supplies are the best option, an integrated water supply and watershed planning study is an important tool in the evaluation process.

An integrated planning study for water supply would identify future and prospective water supply sources, and the relative availability. This would document and address items such as river supplies, allocations, and other water supply alternatives. This is important for future water supply licensing and environment act licensing.

Integrated water supply and watershed planning studies are often required in obtaining environment act licensing for new proposed water supplies in the province.

Conclusions and Recommendations

Based on our study of the RM of East St. Paul proposed Bray Road municipal water supply, we offer the following conclusions and recommendations:

- Overall, the Bray Road well has very strong hydraulic performance with little drawdown at the supply well. The pumping test resulted in 3.5 feet of drawdown at the well after 72 hours, pumping 491 U.S.G.P.M. This result tends to fit with Render's transmissivity mapping for the area (Render, 1970) and previous short term test work by Stantec Consulting Limited (2004).

- The monitoring wells to the south are reasonably extensive. The monitoring network is not as extensive to the north. The RM should install three dedicated observation wells around the Bray Road well to further define the potentiometric surface to the north. These wells should also be used as part of a regional annual reporting of the static water levels in the area. The RM should retain a hydrogeological engineer/hydrogeologist annually to review the static water levels and geochemistry in the area, and provide a report. The observation well network should be sampled annually for groundwater quality and environmental isotopes. At least two of these observation wells should be located near the river, to the north and south, to monitor static water levels. Automatic data recording pressure transducers should be used.

- Additional monitoring is also needed between the Bray Road well and the low flow channel of the Red River Floodway. There is a well located nearby that is on the west bank of the floodway that is likely the property of the Floodway Authority, and could be used for this purpose. Sampling should be frequent during the operation of the Red River Floodway.

- The RM should develop an aquifer/well head protection program for all the municipal wells, and develop a contingency plan should the aquifer become impacted in some manner.

- According to our data collection and analysis, Bray Road well is capable of providing the requested additional allocation of 700 dam per annum, under normal seasonal and climatic conditions. The analysis indicates that the requested allocation will not result in a significant amount of additional drawdown one mile from the pumping wells.

- The groundwater quality in the well should be closely monitored. This should be done weekly during the operation of the floodway, and 4 times annually during the first few years of operation. This work should be conducted by a hydrogeologist/hydrogeological engineer.

- In the event of lower static water levels in the carbonate aquifer, water levels in the pumping wells should be closely monitored.

- Each well should be closely monitored for well performance. The RM should continue performing a regular servicing/maintenance program for each well.

- Review meeting with Groundwater Licensing
- Review meeting with Manitoba Conservation
- The RM of East St. Paul Emergency Protection Plan for groundwater supplies should be continued (see Appendix L). This requires review from a hydrogeological engineer/hydrogeologist.
- The RM of East St. Paul should undertake an annual review of the carbonate aquifer in the area. This work should be conducted by a hydrogeological engineer/hydrogeologist. The monitoring network should be reviewed, along with the water quality sampling program and municipal pumping records.

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