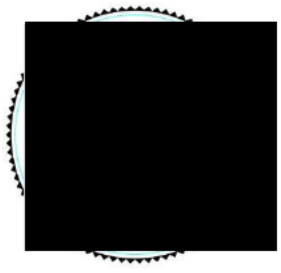
Environment Act Proposal
RM of Brokenhead Water Treatment Plant Upgrade

September 2022



The Manitoba Water Services Board

Table of Contents

Executive Summary

The Rural Municipality of Brokenhead (The RM) has requested The Manitoba Water Services Board (MWSB) to prepare an Environment Act Proposal for a Class 2 Development Licence under the Manitoba Environment Act for an upgrade of the Water Treatment Plant (WTP). The expansion and upgrade involves the following:

1. Installation of two new raw water supply wells and pipeline south of the existing water treatment plant;
2. Construction of a new Tyndall-Garson WTP reservoir;
3. Increase the draw of water from the new raw water supply wells, and;
4. Construction of two new reverse osmosis treatment trains.

The proposed upgrades will allow the RM to increase their water supply, as the existing WTP is nearing treatment capacity, and is unable to meet the projected future 20-year demand. This EAP is submitted for the proposed infrastructure, specifically for the new raw water supply wells.

The LUD of Tyndall-Garson encompasses the Villages of Tyndall and Garson, which have populations of 1001 and 748 respectively (2021 Census). They are supplied potable water from the WTP, which must be expanded to continue to supply them with a reliable and safe source of drinking water. The proposed expansion includes the installation of two new membrane trains on a single skid at the WTP, which is supplied groundwater from wells that draw water from the carbonate aquifer, and the construction of a new 442 m^3 reservoir to connect to the existing distribution system (JRCC, 2021).

The proposed treatment process consists of an integrated membrane system including a combination of reverse osmosis and nanofiltration elements. Concentrate water will continue to be discharged into the municipalities existing sewer system. With the proposed expansion the operating capacity of the Tyndall-Garson WTP will increase from 13 to 32.4 L/s and provide a reliable water source for the public water system for the foreseeable future.

List of Acronyms

AO	Aesthetic Objective
CIP	Clean-in-Place
DBP	Disinfection By-Product
DWSA	Drinking Water Safety Act
EAP	Environment Act Proposal
GCDWQ	Guidelines for Canadian Drinking Water Quality
GUDI	Groundwater Under Direct Influence of Surface Water
LUD	Local Urban District
MWSB	Manitoba Water Services Board
NF	Nanofiltration
ODW	Office of Drinking Water
OS	Operational Statements
PR	Public Road
RM	Rural Municipality
RO	Reverse Osmosis
TDS	Total Dissolved Solids
THM	Trihalomethane
TOC	Total Organic Carbon
UV	Ultraviolet
WTP	Water Treatment Plant

1.0 Introduction

The Rural Municipality of Brokenhead (RM) requested The Manitoba Water Services Board (MWSB) to prepare an Environment Act Proposal for a Class 2 Development Licence under the Manitoba Environment Act for an upgrade of the Water Treatment Plant (WTP) in the Rural Municipality of Brokenhead. This document provides the compiled information required on Manitoba Conservation's Environment Act Proposal Report Guidelines and Supplementary Guidelines for Municipal Water Supply Systems. This Environment Act Proposal includes components of the raw water wells and concentrate disposal and pipeline.

1.1 Background Information

The LUD of Tyndall-Garson which encompasses the Villages of Tyndall and Garson, shown in *Figure 1.1* below, is located approximately 40 km northeast of Winnipeg with populations of 1,001 and 748 respectively in the 2021 census. Tyndall and Garson are both in the RM of Brokenhead, and share the RM of Brokenhead WTP. The RM of Brokenhead receives raw water from a carbonate aquifer, which supplies water to the public water system from this shared WTP. Raw water is currently pumped from two groundwater wells in close proximity to the WTP. The wells alternate daily. Each well has an approximate capacity of 19.2L/s. (JRCC, 2021). The WTP was originally constructed in 2006, and currently has a rated treatment capacity of 13L/s (JRCC, 2021). The average day demand for the period from July 2019 to June 2020 was 297.7 m^3/day (JRCC, 2021). One jockey and four duty distribution pumps supply water to the distribution system depending on pressure and demand.

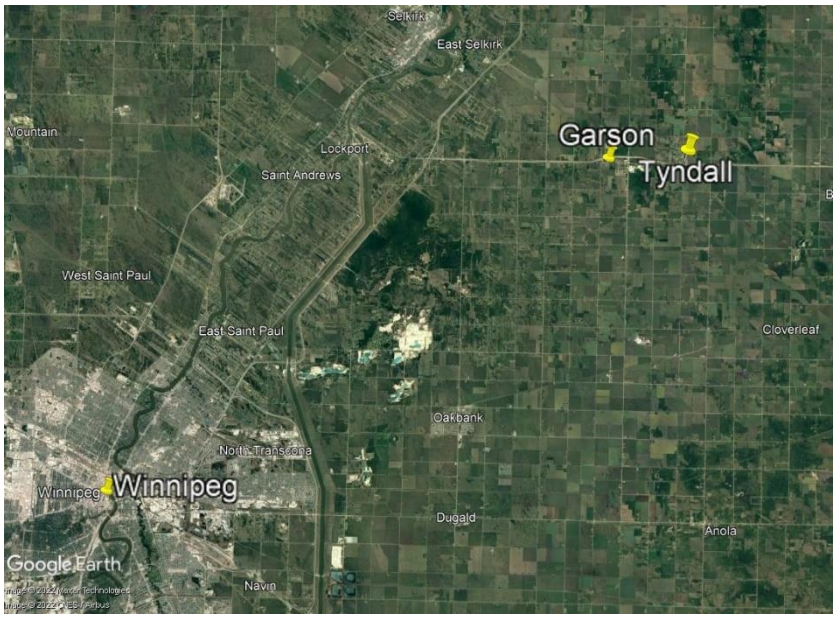


Figure 1.1 – Map of Tyndall - Garson

The water treatment process involves pre-filtration followed by a single train reverse osmosis membrane system. Raw water is pumped to the WTP building, where antiscalant is injected prior to the reverse osmosis, to prevent scaling on the membranes. After passing through the membranes, filtered water is injected with a corrosion inhibitor and sodium hydroxide to raise the pH. Water is chlorinated for disinfection before it is stored in a two-chamber 988 m3 reservoir. Water is pumped using one jockey and four duty pumps. The jockey pump was designed for 6L/s and the duty pumps were designed for 25L/s. The reservoir was designed to accommodate 60L/s fire flow for a 2 hour duration (JRCC, 2021).

The existing WTP was constructed in 2006, and is nearing treatment capacity to supply the needs of the RM into the future, as a steady growth rate is currently experienced and is projected to further increase.

1.1.1 Previous Studies

The following previous reports have been reviewed in preparation of this Environment Act Proposal.

***RM of Brokenhead – Water Treatment Plant Upgrade Feasibility Study Letter Report,* JR Cousin Consultants Ltd., 2021**

In 2021, JR Cousin Consultants Ltd. (JRCC) was retained by MWSB to prepare a feasibility study letter report to review solutions to provide treatment for the next 20 years.

***Garson/Tyndall Water Treatment Plant Upgrade Pre-Design Letter Report,* JR Cousin Consultants Ltd., 2021**

In 2021, JR Cousin Consultants Ltd. (JRCC) was retained by MWSB to examine the RM of Brokenhead Water System and presented options and alternatives for upgrading the existing infrastructure and treatment process.

***Preliminary Hydrogeological Testing Results Supplementary Groundwater Supply – Tyndall – Garson WTP Upgrade,* Friesen Drillers Ltd., 2022**

In 2022, Friesen Drillers Ltd. was retained by the RM of Brokenhead to study the geology and hydrogeology of the region including the RM of Brokenhead, specifically focusing on the area around Tyndall and Garson. Recent well assessments detailed an existing wellfield capacity of 27.6L/s, with a desire to increase raw water capacity by 25L/s. Friesens looked at 4 potential well locations and determined the well location with the best supply.

- The report recommended that continued monitoring of the aquifer should be undertaken by a network of monitoring wells to be established during testing. The monitoring wells could include provincial, municipal, and private wells.
- The report recommended that a single 10 inch well would provide sufficient capacity for the project.

***Rural Municipality of Brokenhead Water Treatment Plant Upgrade, Geotechnical Investigation Report,* TREK Geotechnical, 2022**

In 2021, TREK Geotechnical was retained by JRCC on behalf of the RM to review the geotechnical conditions surrounding the site of the proposed water treatment plant in the RM of Brokenhead.

- The new reservoir expansion area is located on the site of the existing WTP, immediately to the west of the existing building and reservoir. The soil generally consists of clay and silt.
- Groundwater depth on site at the time of drilling and a month afterwards was around 6.2m.

1.1.2 Population

Based on the 2016 Census, the Village of Tyndall had a population of 935, and increase of 2.41% over its 2011 population of 830. The Village of Garson had a population of 647, an increase of 6.02% over its 2011 population of 486. Based on discussion with the RM and MWSB, the projected population in the Villages will continue to increase over the next few years at an annual population growth rate factor of 6.02% per year for Garson and 2.41% for Tyndall. A 20-year population of approximately 4,487 is projected for the Villages (JRCC, 2021) as shown in *Figure 1.2* below.

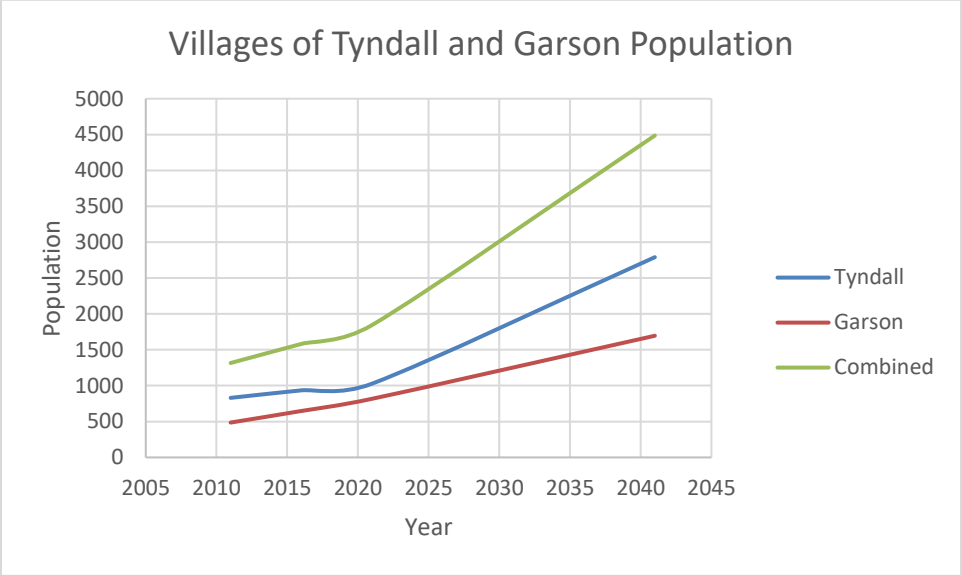


FIGURE 1.2 – VILLAGES OF TYNDALL AND GARSON POPULATION PROJECTION

1.1.3 Current and Projected Water Use

A WTP is designed based on peak-day demand. When calculating water consumption, typical average daily water usage ranges from 250 L/person/day to 300 L/person/day and peak day usage (peak day factor) is typically 1.5 to 2.0 times greater. Based on historical water consumption records, a 225 L/capita/day water usage and a peak day factor of 2.0 were utilized (JRCC, 2021).

The average day 20-year projected demand for the system is 1,070 m^3/day (JRCC, 2021). The projected 2041 max-day demand for the system is 2,795 m^3/day, with a peak hour flow of 58.9 L/s (JRCC, 2021). The new WTP will provide a reservoir which satisfies the required water storage, chlorine contact disinfection time, and emergency fire storage for a Class 5 WTP (240 L/s) with a total storage capacity of 1,415m^3. The projected treated water demands are summarized in *Table 1.1* below.

TABLE 1.1 – PROJECTED TREATED WATER DEMAND FOR THE RM OF BROKENHEAD

Projected Treated Water Demand for the RM of Brokenhead Water System		
	Quantity	**Units**
2016 Population	1,582	Capita
2041 Population (@1.6% Growth/yr)	4,758	Capita
Consumption/Capita/Day	225.0	L/c/day
2041 Average Day Consumption	1,692	m^3/day
2041 Average Day Demand	19.6	L/s
Peak Day factor	2.0	-
2041 Peak Day Consumption	2,795	m^3/day
2041 Peak Hour Demand (20-hour operating day)	58.9	L/s

1.1.4 Raw Water Source

Two wells provide the raw water supply for the RM of Brokenhead from a fractured limestone aquifer, the Lower Carbonate Aquifer. The water-bearing zone interface varies, but lies approximately 3-9m below the ground surface. The two existing wells were drilled in 2001 and 2011 and are at the site of the WTP, approximately 27.5m apart. The well screens are approximately 40m below the ground level in the fractured limestone. Based on the analysis, the wells are classified as non-GUDI wells (Friesen Drillers, 2021).

The new well site located on May Street consists of two wells located on the west side of the municipal road right-of-way, approximately 800m south of the existing water treatment plant.

The wells are recommended to be constructed into the carbonate aquifer utilizing a 250mm (10in) casing to a depth of 67m (220ft). Final installation during construction should include a pitless unit, bollards to protect the well-head, and mounding to ensure surface runoff from the surrounding area does not approach to the pitless unit and casing.

The well was noted to be producing clean water and located in the aquifer where clean factures existed, and produced significant yields sufficient to supply the proposed WTP project. Complete details are provided in the appended report.

1.1.5 Water Rights Act

The RM of Brokenhead utilizes Water Rights License No. 2005-083. The Licence allows the maximum instantaneous rate of withdrawal to be 0.02 m^3/s (20 L/s) and a maximum annual usage of 226 dam^3/yr from the aquifer.

In 2016, Friesen Drillers Ltd. completed a hydrogeological assessment of the carbonate aquifer as a municipal water supply for the RM of Brokenhead. From water use records,

the RM is currently using 116,435 m^3, approximately 50% of their annual allowance. An instantaneous pumping rate of 50 L/s is required for the proposed system to supply the projected maximum day demands. The estimated 20-year treated water demand is 19.6 L/s average day and 32.4 L/s peak day (JRCC, 2021). The WTP has been designed as a 50 L/s (raw water) WTP. *Table 1.2* summarizes the projected raw and treated water demand for the RM of Brokenhead.

TABLE 1.2 – PROJECTED TREATED WATER DEMAND FOR THE RM OF BROKENHEAD WTP

	Treated Demand	Raw Demand	Units
Instantaneous Withdrawal	32.4	50.0	L/s
Average Consumption	19.6	20.6	L/s
Annual Allocation	618,105,600	650,000,000	L/year
Annual Allocation	618,105.6	650,000	m^3/year
Annual Allocation	618.1	650	dam^3/year

According to the current Water Rights Act Licence, the maximum rate at which water may be diverted instantaneously shall not exceed 20 L/s and the total annual usage of water diverted in any one year shall not exceed 226 cubic decameters. As *Table 1.2* indicates, the demand will exceed the allowable withdrawal of the current Water Rights Licence, and a new licence will be required. In conjunction with the raw water exploration, Friesen's Drillers on behalf of the Town have applied for a Groundwater Exploration Permit (GEP) for the new sites. A new WRL will be applied for in conjunction with the installation of the new raw water supply system by Friesen Drillers to request an annual allocation of 528.5 acre-ft/year (650 dam^3/year).

The Office of Drinking Water (ODW) currently conducts annual audits of all public water systems which includes sampling and chemistry analysis every three years for secure groundwater sources and once per year for surface water and GUDI supply systems. In addition, the operator tests chlorine residuals daily on the treated water. The water quality analysis can be found summarized in *Table 1.3* on the following page. Water from the new wells is within the range of parameters experienced in the existing raw water quality data.

No raw water quality parameters currently exceed the GCDWQ maximum acceptable concentration health requirements. However, hardness, iron, and TDS all exceed the current or proposed GCDWQ aesthetic objectives. In treated water, all tested parameters met guidelines.

The proposed WTP upgrade will draw water from the same source as the existing plant.

TABLE 1.3 WATER QUALITY RESULTS (2022)

Parameter	Unit	GCDWQ	Existing Treated Water	Existing Wells Raw Water	New Well Raw Water
Alkalinity (Total)	mg/L		57.1	418-432	427
Ammonia	mg/L		<0.010	0.089-0.164	0.151
Arsenic	mg/L	≤ 0.01 ALARA**	0.00014	0.00021-0.00044	0.00063
Calcium	mg/L		0.538	58.5-63.9	71.7
Conductivity	umhos/cm		113	1000-1040	953
Fluoride	mg/L	≤ 1.5	<0.020	0.319-0.343	0.377
Hardness (Total) $CaCO_3$	mg/L	200/500a	2.74	**438-450**	**439**
Iron	mg/L	≤ 0.3	<0.010	**0.111 - 0.374**	**0.463**
Lead	mg/L	< 0.005 ALARA**	0.000159	0.000071-0.00461	0.000159
Manganese	mg/L	≤ 0.05/ 0.02	<0.00010	0.00567-0.00652	0.0188
Nitrate-N	mg/L	≤ 10	<0.0050	< 0.010	<0.0050
pH	pH units	6.5-8.5	7.81	8.23-8.26	8.16
Sodium	mg/L	200	27.0	55.5-62.5	53.4
Sulfate	mg/L	500	<0.30	53.5-65.2	45.4
Total Dissolved Solids	mg/L	500	69	**539-590**	479
Total Organic Carbon	mg/L	-	<0.50	1.12-1.28	2.53
True Color	CU	15	<5.0	< 5.0	<5.0
Turbidity	NTU	≤ 0.3 / 0.1[c]	<0.10	0.90-3.96	1.80
Uranium	mg/L	≤ 0.02	<0.000010	0.000308-0.000480	0.000180

[a] Hardness levels greater than 200 are considered poor but tolerable. Hardness levels greater than 500 are generally considered unacceptable
[b] THM based on average of quarterly samples
[c] Turbidity limits as follows: 1.0 NTU for slow sand or diatomaceous earth filtration, 0.3 NTU for chemically assisted filtration, and 0.1 NTU for membrane filtration; Turbidity results measured in the lab may reflect oxidation of the sample during transit and field testing would be required to verify results.
*Turbidity is a physical property that must be measured on site. It is anticipated that on site testing would demonstrate that the high turbidity recorded is a result of the high iron content oxidizing and precipitating in the raw water during transit.
[DLA] Detected Limit Adjusted for required dilution
*Manganese MAC and AO levels proposed to become 0.05 and 0.02 respectively in future.
** ALARA: As Low As Reasonably Achievable

1.1.6 Compliance Plan

A compliance plan to address all outstanding regulatory issues has not been completed for the existing WTP. The proposed WTP project will satisfy all outstanding compliance issues.

2.0 Description of Proposed Development

2.1 Project Description

The proposed development includes:

- The construction of a two new raw water production wells south of the existing water treatment plant including well mechanization and a 150mm raw water supply pipeline;
- construction of a new 442 m^3 reservoir, and;
- two new nanofiltration and reverse osmosis treatment trains installed on one skid.

The treated water from the expanded WTP and new reservoir will connect to the existing treated water distribution system to service residents throughout the Communities.

Figure 2.1 below shows the location of the new reservoir site with respect to the existing WTP.

FIGURE 2.1 – LOCATION OF WTP (GOOGLE EARTH, 2019)

2.1.1 Water Source

Water will be supplied from the carbonate groundwater aquifer which has supplied Brokenhead since 2006. With the past operating history of the system, the quantity, quality, reliability and sustainability has been demonstrated for 16 years. Additional testing has been completed to demonstrate the efficacy of the system for the foreseeable future.

2.1.1.1 Well Installations

Friesen Drillers Ltd. completed pumping tests of each municipal supply well to determine the capacity of the fractured limestone aquifer. The significant work surrounding these wells and the search for new wells at the existing site is covered more thoroughly in the appended report (See Section 3). Recent testing of well one at the WTP site provided a preliminary estimate of transmissivity for the aquifer of 149 m^2/day (12,000 USGPD/ft). (Friesen Drillers, 2021).

The overlying geology of the area consists of interlayered clay and till with variable amounts of sand and gravel. The upper surface of the carbonate aquifer bedrock ranges from depths of 5-11m (18-36ft) below grade.

As part of the upgrade there will be the installation of two new production wells with adequate pumping capacity to satisfy the 50 L/s projected future demand. The new production wells will be equipped with pitless units, mechanized, and protected from surrounding runoff and vehicular traffic, and will operate similarly to the existing wells. The proposed location of the new production wells and proximity to the proposed WTP location is shown in *Figure 2.2* below.

FIGURE 2.2 - NEW PRODUCTION WELLS LOCATION (GOOGLE EARTH, 2022)

2.1.1.2 Raw Water Quality

During the 72-hour pump test, water samples were collected and submitted for laboratory analysis to characterize the raw water quality of the aquifer. The results indicated that the aquifer is suitable water for nanofiltration and reverse osmosis treatment which will produce high quality treated water. The water quality summary is as shown above in *Table 1.3.* The results of the water analysis are consistent with previous tests performed over the past few decades, indicating that the aquifer yields consistent water quality. The well is also considered to be installed in a confined aquifer and is not in artesian condition. The complete raw water analysis can be found in *Appendix C*.

2.1.1.3 Water Treatment Plant

The RM of Brokenhead WTP is classified as a Class 2 Water Treatment Facility. The existing 13 L/s treatment system will be expanded with two additional treatment trains producing a total of 32.4 L/s nanofiltration and reverse osmosis treated water. The proposed filtration process with primary and secondary disinfection through chlorine injection is effective in protecting against viruses and cysts such as Cryptosporidium oocysts and Giardia lamblia cysts, and removing hardness, lead, arsenic, nitrates, total dissolved solids, iron, manganese and softening the water to acceptable concentrations. The process will effectively remove the aesthetic parameters of hardness, iron and manganese. The expanded treatment system will supply the projected 20-year population demand of the Communities while continuing to treat water that meets the GCDWQ and the Drinking Water Safety Act.

The detailed design of the proposed WTP will be finalized for tender once the Environment Act Licence has been received and funding has been secured.

2.1.1.4 Backwash and Concentrate Disposal

Membrane systems generate a mineralized concentrate stream. Concentrate streams vary between 10%-30% of the total flow from membrane systems depending on the arrangement and type of membranes selected. The proposed system has a combined instantaneous reject rate from the new skid of 4.66L/s. The average day reject in design year 20 would be 300 m^3 per day (Pers. Comm. – JRCC, Aug 12, 2022).

The current concentrate is disposed of to the municipal wastewater treatment system. The additional concentrate created by the increased treatment is anticipated to be treated in the same manner. It is contained in a chamber in the water treatment plant which is then pumped into the municipal sewer system to

the lagoon. The lagoon was designed for a population of 3,753, or around year 16 for the WTP design, and the design of the lagoon included the reject from the WTP.

2.1.1.5 Operation and Maintenance

The RM is responsible for operation and maintenance of the well site, WTP, and concentrate discharge. An operator is required to periodically inspect that system performance is maintained. In addition, the operators will be required to submit bi-weekly water samples for bacteriological testing in accordance with the Manitoba *Drinking Water Quality Standards Regulation*. Operators will read customer water meters on a quarterly basis and respond to maintenance issues related to the system.

Operators will be required to operate the facility in a safe and efficient manner in accordance with relevant operations manuals and Drinking Water Safety Act regulations. Operation requirements will include measurements, monitoring, sampling, testing, record-keeping and reporting. Operators will be required to do Clean-In-Place (CIP) maintenance initiated on trans-membrane pressure drop and change Membrane Treatment Unit (MTU) pre-filters. In addition, operators must ensure the equipment is inspected and properly maintained. Operators will receive training during the commissioning phase by the selected equipment supplier, Delco Water.

Other typical operating costs include; chemicals, maintenance personnel, electricity costs, general repairs, water and bacteriological testing, and a reserve fund for future membrane replacement or expansion and staff certification and training. Operating and maintenance costs are recovered through the sale of water in the distribution system.

2.2 Certificate of Title

The reservoir expansion and the treatment capacity upgrades at the Brokenhead WTP will be constructed on land owned by the RM of Brokenhead.

The raw water wells and mechanization infrastructure will be installed in the municipal right-of-way (ROW) within the Rural Municipality of Brokenhead. Raw water supply pipeline will be installed along municipal ROW along May Street and on land owned by the RM. Easements will be requested if necessary to facilitate the installation of the pipeline.

2.3 Mineral rights

All mineral rights associated with lands for the existing and proposed new facilities belong to the Crown.

2.4 Existing and Adjacent Land Use

The proposed land for the development will be on municipal and provincially owned land in road right-of-ways. Existing and adjacent land use will not change as a result of this development.

2.5 Land Use Designation and Zoning

The proposed land for development will be government road allowances and land adjacent to the development that is predominately agricultural. Zoning designation for this development is not applicable.

2.6 Project Schedule

The development of the water treatment plant project is anticipated to occur as a single phase project. The project is scheduled to commence in 2023 depending on the availability of funding and the receipt of all approvals.

2.7 Project Funding

Provincial and municipal funding has been secured for this project.

2.8 Regulatory Approvals

The following branches/departments will be provided with copies of plans and specifications for information purposes and for the purposes of approvals and agreements:

Manitoba Environment, Climate and Parks
- Office of Drinking Water
- Water Stewardship

Manitoba Transportation and Infrastructure

The contractor will be required to contact telephone, Hydro, gas, and communication utilities for utility locations and approvals.

A letter was sent by the RM to local residences advising them of the well investigation.

2.9 Storage of Petroleum Products and Other Chemicals

Fuel will not be stored on-site at any time or location along the proposed construction route or near any well. Fuel will be supplied by fuelling trucks which are regulated under The Storage and

Handling of Petroleum Products and Allied Products Regulation. Records of fuel volumes and an emergency response plan which includes spill prevention, notification and response will be implemented. No fuelling activities will be permitted within 100m of watercourses during construction. During construction, the contractors will be required to ensure that all equipment is properly maintained to prevent leaks of fuel and motor fluids.

There will be no storage of petroleum products or other chemicals at any of the well sites during operation of the proposed development. Maintenance activities for the wells do not require refuelling on-site. Chemicals associated with the operation of the existing plant and for the new treatment trains include antiscalant (Vitec 3000), corrosion inhibitor (Clearhib 5), sodium hydroxide and sodium hypochlorite. Chemicals will be stored in designated areas within the plant complete with spill containment. General household cleaning products will also be stored at this site.

2.10 Duty to Consult

The proposed project does not involve any federally owned or Reserve lands. The Brokenhead Ojibway Nation (Brokenhead 4 Indian Reserve) is approximately 30 km north of Tyndall and Garson and is the nearest First Nation to the site.

3.0 Physical Environment

3.1 Physiographic Setting and Climate

The RM of Brokenhead is located in southeastern Manitoba, about 40 km northeast of Winnipeg. The topography of the area has some slight elevation changes varying between 218 and 311 m geodetic elevation.

Based on Environment Canada climate data, the mean annual temperature in the area is approximately 3 degrees Celsius with below zero average daily temperatures from November through March. Although the station closest to Tyndall/Garson (Beausejour) has no recorded data since 2005, precipitation records over the past decade for Oakbank and Pinawa (approximately 22 km southwest and 44km east of Tyndall/Garson respectively) is presented in *Figure 3.1* below. Mean annual precipitation was found to be 590 mm/year during this period (Environment Canada, 2018).

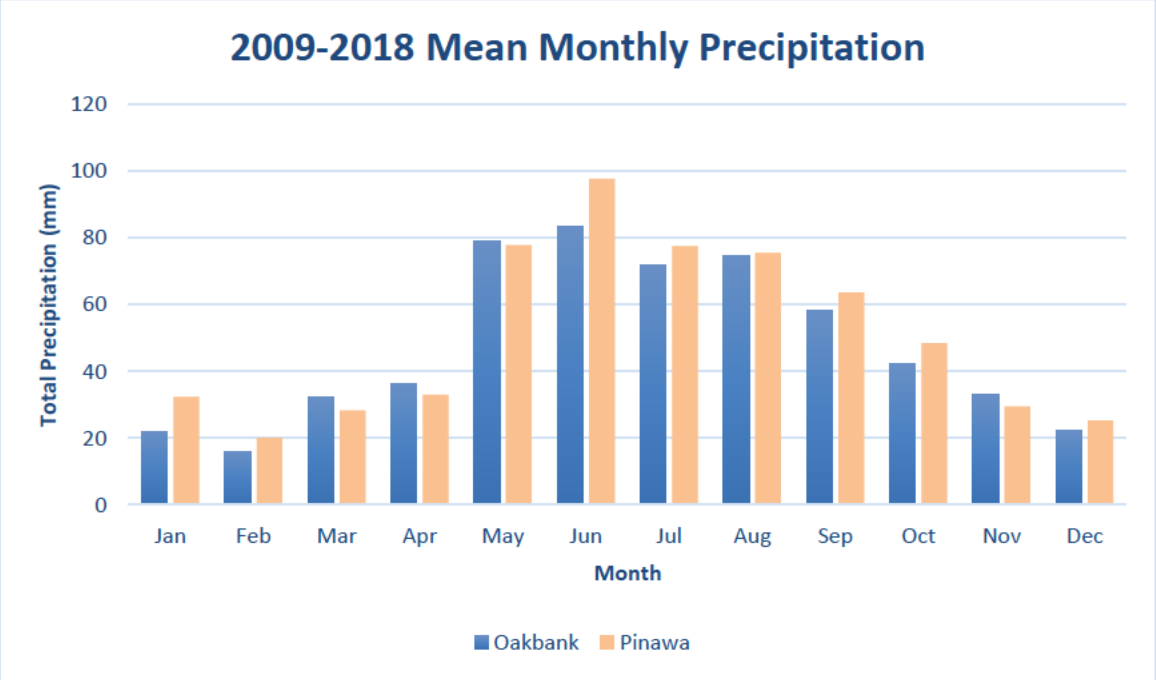


FIGURE 3.1 - 2009-2018 MEAN MONTHLY PRECIPITATION

3.2 Hydrogeology

Early investigations of the hydrogeology of the area have identified the area to be under the Western Canadian Sedimentary Basin hydrogeological region of Canada, in southeastern Manitoba. The bedrock beneath the RM of Brokenhead consists of basal Winnipeg Formation shale and sandstone, with overlying Red River Formation dolomitic limestone, deposited upon

Precambrian granites. The key aquifer in this area is the Red River Formation Aquifer (Friesen Drillers, 2021).

The Red River Formation Aquifer is the current water source for the existing two groundwater wells and the two new wells will also withdraw water from the same zone. An investigation by Friesen Drillers Ltd. was completed to determine the effects of further development within this aquifer. A diagram of the regional hydrogeology and can be found in *Appendix A*.

Investigations of this aquifer through pumping the existing wells have provided an estimate of the transmissivity of the aquifer as 149 m3/d/m (12,000 USGPD/ft). The complete report is included in *Appendix E*. The report recommended that the wellfield is able to supply the requested 650 dam^3/year of annual allocation at a pumping rate of 52.6 L/s. It also noted that the drawdown of the proposed wells will be within the historical natural groundwater fluctuation and no impacts on surrounding users is anticipated.

The report demonstrated that the groundwater levels typically fluctuate seasonally by 2-4m. The ground water level typically rises during spring discharge and gradually lowers during summer and winter months. Groundwater levels are influenced by the precipitation received. The report concluded that due to the precipitation, annual usage, and high transmissivity, the aquifer is able to sustainably supply the proposed development for Brokenhead.

3.3 Hydrology

Devils Creek is the tributary that runs between the Communities of Tyndall and Garson, discharging into Lake Winnipeg. The development of the RM of Brokenhead Water Treatment Plant should not have an impact on this creek, as appropriate measures will be taken to ensure sediment control. The discharge from the water treatment plant will be discharged into the municipalities sewer system, being treated by the lagoon and thus will not have impact on Devils Creek.

Flows on Devils Creek are monitored seasonally by the Water Survey of Canada at Station 05OJ016, with data up to 2020. Mean monthly flows between March and October, when data is collected, varied from 0m^3/s to 11.5m^3/s over the 1971 to 2020 period. Mean discharge data for Devils Creek can be found summarized below in *Table 3.1* (Environment Canada, 2022).

Table 3.1 – DEVILS CREEK – 2009-2020 MEAN MONTHLY DISCHARGE

	March	April	May	June	July	August	September	October
2009	1.15	7.45	1.68	3.37	1.62	0.761	0.427	0.242
2010	1.55	0.718	3.35	4.67	1.56	0.357	1.65	1.63
2011	0.381	7.65	1.63	0.577	0.122	0.061	0.071	0.098
2012	0.656	0.205	0.255	0.23	0.106	0.08	0.068	0.07

2013	0	2.59	1.25	0.458	0.41	0.112	0.079	0.082
2014	0.005	3.7	1.15	3.05	1.05	0.085	0.11	0.108
2015	0.536	0.351	1.31	0.244	0.255	1.45	0.355	0.252
2016	2.58	3.24	0.342	3.46	1.6	0.644	0.269	0.319
2017	-	-	0.543	0.21	0.302	0.106	0.107	0.098
2018	-	0.738	0.1	0.112	0.052	0.037	0.054	0.061
2019	0.247	2.37	0.162	0.066	0.062	0.043	0.255	2.03
2020	0.453	2.36	0.487	0.21	0.07	0.047	0.058	0.062
Average (m^3/s)	0.7558	2.852	1.022	1.388	0.601	0.315	0.292	0.421
Minimum (m^3/s)	0	0.205	0.1	0.066	0.052	0.037	0.054	0.061
Maximum (m^3/s)	2.58	7.65	3.35	4.67	1.62	1.45	1.65	2.03

Figure 3.2 below shows daily discharge characteristics for Devils Creek (Station 05OJ016).

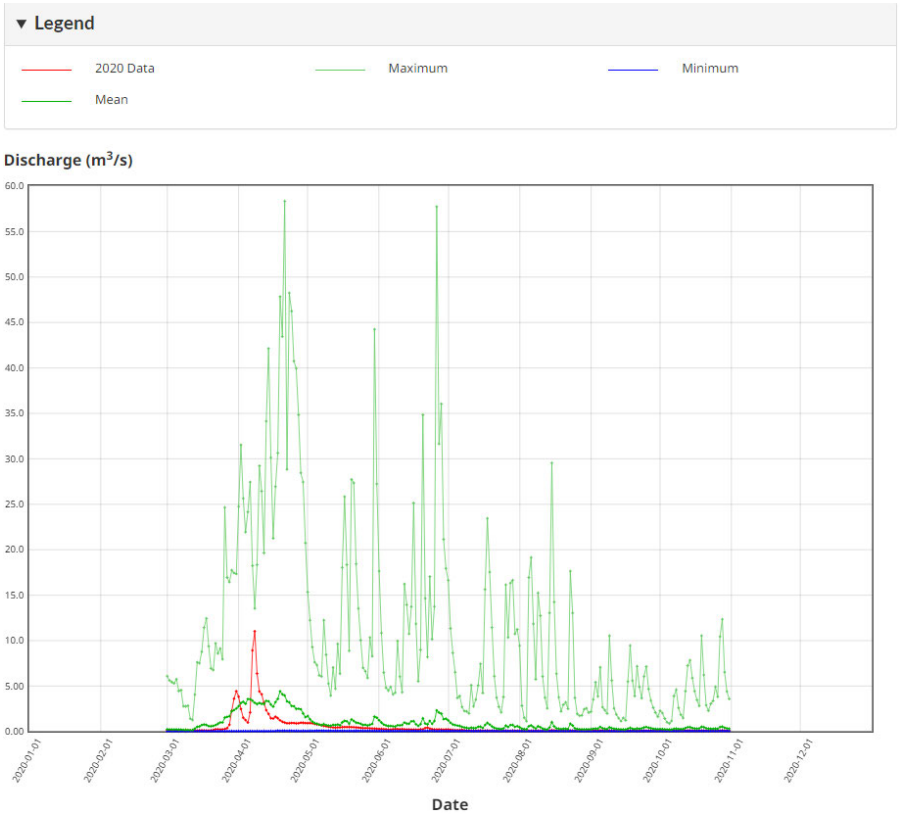


FIGURE 3.2 WATER SURVEY OF CANADA STATISTICS CORRESPONDING TO 52 YEARS OF DATA RECORDED FROM 1971 - 2022

3.4 Fish and Fish Habitat

The RM of Brokenhead is located in the Lake of the Woods Ecoregion, within the Boreal Shields Ecozone.

The Department of Fisheries and Oceans (DFO) has an aquatic species at risk map, which identifies species at risk. Devils Creek is not home to any species at risk.

Fish species found in Devils Creek have been provided from the Fish and Wildlife Branch of the Department of Natural Resources and Northern Development. The list of species provided include everything found in the creek and is not specific to the species present in the vicinity of Tyndall – Garson. Devils Creek is home to the following species:

- Central Mudminnow (*Umbra limi*)
- Johnny Darter (*Etheostoma nigrum*)
- Blacksided Darter (*Percina maculata*)
- Brook Stickleback (*Culaea inconstans*)
- Fathead Minnow (*Pimephales promelas*)
- Blacknose Dace (*Rhinichthys obtusus*)
- Black Crappie (*Pomoxis nigromaculatus*)
- Brown Bullhead (*Ameiurus nebulosus*)
- Burbot (*Lota lota*)
- Common Carp (*Cyprinus carpio*)
- Channel Catfish (*Ictalurus punctatus*)
- Emerald Shiner (*Notropis atherinoides*)
- Freshwater Drum (*Aplodinotus grunniens*)
- Goldeye (*Hiodon alosoides*)
- Northern Pike (*Esox Lucius*)
- Rock Bass (*Ambloplites rupestris*)
- Sauger (*Sander canadensis*)
- Tadpole Madtom (*Notorus gyrinus*)
- Trout Perch (*Percopsis omiscomaycus*)
- Walleye (*Sander vitreus*)
- White Bass (*Morone chrysops*)
- White Sucker (*Catostomus commersonii*)
- Yellow Perch (*Perca flavescens*)

Devils Creek is classified as a Class 2 waterbody, a waterbody which has slight limitations to the production of fish. Recreational fishing has been identified as a general use.

Brokenhead River is located near Devils Creek, and is in the same ecoregion, and as such is anticipated to have similar fish species to Devils Creek.

Fish species found in the Brokenhead River have been provided from the Department of Sustainable Development – Wildlife and Fisheries Branch. It was noted that the list of species provided include all that have been found in the waterbody and does not pertain to a site specific area. Brokenhead River provides year round habitat for many species varying in size, including:

- Stone Cat (*Noturus flavus*)
- Northern Redbelly Dace (*Chrosomus eos*)
- Black Bullhead (*Ameiurus melas*)
- Blacknose Shiner (*Notropis heterolepis*)
- Blacksided Darter (*Percina maculata*)
- Brook Stickleback (*Culaea inconstans*)
- Brown Bullhead (*Ameiurus nebulosus*)
- Burbot (*Lota lota*)
- Carp (*Cyprinus carpio*)
- Central Midminnow (*Umbra limi*)
- Chestnut Lamprey (*Ichthyomyzon castaneus*)
- Common Shiner (*Luxilus cornutus*)
- Fathead Minnow (*Pimephales promelas*)
- Finescale Dace (*Phoxinus neogaeus*)
- Freshwater Drum (*Aplodinotus grunniens*)
- Hornyhead Chub (*Nocomis biguttatus*)
- Johnny Darter (*Etheostoma nigrum*)
- Longnose Dace (*Rhinichthys cataractae*)
- Mimic Shiner (*Notropis volucellus*)
- Northern Pike (*Esox Lucius*)
- Pearl Dace (*Margariscus nachtriebi*)
- Rock Bass (*Ambloplites rupestris*)
- Shorthead Redhorse (*Moxostoma macrolepidotum*)
- Smallmouth Bass (*Micropterus dolomieu*)
- Tadpole Madtom (*Notorus gyrinus*)
- Walleye (*Sander vitreus*)
- White Sucker (*Catostomus commersonii*)
- Yellow Perch (*Perca flavescens*)

Recreational angling and commercial net have been identified as general uses.

3.5 Wildlife Habitat and Vegetation

The RM of Brokenhead is located in the Lake of the Woods Ecoregion within the Boreal Shield Ecozone. The Ecological Framework of Canada website contains information on the wildlife and vegetation within this region (Ecological Framework of Canada, 1995).

Characteristic Wildlife:

- Moose (*Alces alces*)
- Black Bear (*Ursus americanus*)
- Wolf (*Canis lupus*)
- Lynx (*Lynx canadensis*)
- Snowshoe Hare (*Lepus americanus*)
- Woodchuck (*Marmota monax*)
- Ruffed Grouse (*Bonasa umbellus*)
- Hooded Merganser (*Lophodytes cucullatus*)
- Pileated Woodpecker (*Dryocopus pileatus*)
- Bald Eagle (*Haliaeetus leucocephalus*)
- Turkey Vulture (*Cathartes aura*)
- Herring Gull (*Larus argentatus*)
- Waterfowl (*Anseriformes*)

Characteristic Vegetation:

- Trembling Aspen (*Populus tremuloides*)
- Paper Birch (*Betula papyrifera*)
- Jack Pine (*Pinus banksiana*)
- White Spruce (*Picea glauca*)
- Black Spruce (*Picea mariana*)
- Balsam Fir (*Abies balsamea*)
- White Pine (*Pinus strobus*)
- Tamarack (*Larix laricina*)

3.6 Socioeconomic

The project area is located within the Rural Municipality of Brokenhead. The RM of Brokenhead had a population of 5,122 in the 2016 Census and is one of the quickest growing municipalities in Manitoba with a 10.5% growth rate from 2011 to 2016. The main economic base of the area is agriculture and various local quarries.

3.7 Heritage Resources

Most project activities will occur in previously disturbed municipal and provincial right-of-ways. The proponent will work with Heritage Resources Branch to mitigate any concerns as required.

4.0 Potential Environmental Effects

An environmental effect includes any change that the project may cause to the environment. Environmental effects were identified from interactions between proposed project activities and environmental components. Mitigation measures and follow-up activities were identified for environmental effects determined to be adverse.

4.1 Air Quality

During construction, dust will be raised by construction equipment and there will be gaseous and particulate emissions from the construction equipment. Water spraying is an important, common and practical procedure that would be applied as required to alleviate potential dust problems. Emissions of gases and particulates would be minimized by keeping machinery in good working order. Any effects would be localized, temporary and insignificant. During operation of the development there will be no releases of pollutants to the air.

4.2 Soils

During construction, there is a risk of fuel or lubricant spills from heavy equipment and vehicle operation. The storage of fuel or lubricants within the area of the well construction site will not be allowed. Therefore, the potential spills will be very small in size and standard construction spill clean-up procedures, including the removal of any impacted soil, will be used to prevent impact.

During operation, project activities are limited to regular monitoring and maintenance activities that have a negligible effect on soil disturbance and compaction because of low vehicle traffic and the use of established routes to access the wells and WTP. Regular monitoring and maintenance activities will have a negligible effect on soil contamination since fuel trucks and other hazardous substances will not be brought on-site on a regular basis. The potential adverse effect on soil quality is assessed to be minor.

4.3 Surface Water, Fish and Fish Habitat

Minor and short term impacts on surface water may occur as a result of construction activity in road allowance ditches during runoff events. The impact on surface water would include sediment that may be eroded from excavation activities, minor engine leaks and potential fuel spills should runoff events occur during construction. Horizontal directional drilling will be conducted to install the concentrate water pipeline to the river outlet. This will eliminate excavation within the riparian zone and minimize impacts. There is potential for some loss of drilling mud to surface water. Impacts to fisheries and fish habitat are considered minor.

4.4 Groundwater Quality

Groundwater quality can be impacted by surface activities and surface water quality. Mitigation measures are necessary to protect groundwater quality during construction activities. The proposed activities are unlikely to result in adverse changes to water quality.

Nevertheless, the potential still exists and monitoring of the raw water quality will be required to identify any such adverse effects and allow the appropriate adjustments in the system operation to be made.

4.5 Groundwater Levels

A new WRL will be applied for related to the installation of the new production wells. The available information indicates that the proposed withdrawal of groundwater is unlikely to result in adverse changes to groundwater levels outside of normal seasonal variation. Nevertheless, the potential still exists and monitoring of the groundwater levels will be required to identify any such adverse effects and allow the appropriate adjustments in the system operation to be made.

4.6 Vegetation

Construction will occur primarily within municipal right of ways or easements that are previously disturbed, regularly managed, and comprised primarily of grasses. As the areas are already disturbed, they are unlikely to contain rare plant species, and the amount of vegetation disturbance is expected to be minimal.

During operation, monitoring and maintenance activities including access to the well sites will be restricted to designated and previously disturbed areas. Potential effects to vegetation are considered to be negligible.

4.7 Wildlife Habitat and Vegetation

The construction and operation activities associated with this project will be limited to areas already developed for hydro lines or urban or agricultural uses. The potential adverse effects of wildlife habitat loss were assessed to be negligible to minor.

4.8 Noise and Vibration

During the construction phase of the project, there will be several sources of sound emissions including equipment used for construction. The types of noises heard due to construction are dominated by equipment engines. However, miscellaneous short term impact noises (ie: dump truck gates, excavator buckets) are often heard. The noise will be in addition to regular community and highway activities, and the effects are considered minor.

Scheduling of various site activities can minimize the impact of noise. This would include scheduling construction for day-time hours to avoid sleep disturbance and the disruption of evening domestic activities. All equipment used on site will be fitted with appropriate mufflers and will be maintained in good working order to minimize noise levels.

4.9 Employment/Economy

Socio-economic implications are not expected as a result of environmental impacts as they are considered minor and short-term. Some economic implications may exist for the RM due to the costs of developing the water system; however, the RM will have a sustainable potable water supply to meet future demands. There will be some local economic benefit during construction. The proposed project will address the issue of limited treatment capacity of treated water for the RM. The potential effects of the project on employment and the economy are assessed to be positive.

4.10 Human Health and Well Being

The potential adverse effects of the project on human health are assessed to be negligible to minor. Short term temporary increases in noise and dust emissions will occur during construction that is considered to be minor effects. During operation, there will be a minor increase in vehicular traffic associated with monitoring and maintenance activities. The potential effects are considered minor.

The project will result in the construction of a reservoir expansion at the current water treatment plant, the addition of equipment to increase treatment capacity and the mechanization of groundwater wells designed and operated to produce a treated water supply to meet current water quality standards. This will produce a higher standard of living in Tyndall and Garson. The effects of this on human health and wellbeing are considered positive.

4.11 Climate Change

There are no predicted impacts to climate as a result of the project activities.

5.0 Environmental Management Measures

Environmental management practices proposed to prevent or mitigate environmental effects that were determined to be adverse are identified and described below.

5.1 Air Quality

Emissions resulting from construction and transportation equipment may be mitigated by the utilization of well maintained vehicles and operating to reduce unnecessary idling.

The impact of dust may be mitigated by the use of an approved dust suppressant, limiting construction during high wind periods, and re-establishment of vegetation as soon as possible.

Burning of shrubs etc. will only occur on days and times where wind conditions are favorable. Burning could be limited to days permitted for burning according to the Manitoba Crop Residual Burning Program.

5.2 Soils

Mitigation to potential soil impacts through contamination from petroleum products include preparation of an emergency response plan for potential spills, use of spill clean-up equipment and materials, using properly maintained equipment, and using appropriate fuelling equipment.

Re-establishment of vegetation as soon as possible after disturbance will limit loss of soil due to wind or water erosion. Backfilling with soil stockpiles as soon as possible and minimizing the amount of soil disturbance can be implemented.

5.3 Surface Water

Mitigation of surface water issues may be achieved by limiting open cut trenching to within 30m ahead or behind the pipe laying, redirecting surface water runoff, pumping accumulated water to adjacent ditches and providing erosion control practices as required.

Petroleum leaks or spills will be mitigated by use of properly maintained equipment, use of spill clean-up equipment and materials, and use of appropriate fuelling equipment. A prepared emergency response plan can be implemented in the event of a significant spill. In the event of a reportable spill, Manitoba Conservation and Water Stewardship will be notified through the emergency response line and appropriate measures will be taken according to Manitoba Environment, Climate and Parks requirements.

A 100m setback to watercourses will be maintained for fuelling activities. Vehicles will avoid entering the riparian zones. Re-establishment of vegetation will occur as soon as possible on areas of disturbed soil.

5.4 Groundwater

Groundwater is primarily protected by the natural hydrogeology in the area. Mitigation of potential groundwater impacts from petroleum products can be mitigated as described in Section 5.3. The availability of groundwater usage for this proposal and potential future users will be assessed through the Water Rights Act Licensing process. Groundwater monitoring will be performed as required to address potential issues associated with water quality and water level changes.

The recommended water quality sampling program consists of quarterly sampling of groundwater for the first year of operation. Following this initial year of sampling, the recommended frequency is a minimum of annually. The laboratory analyses should include conductivity, hardness, alkalinity, total dissolved solids, major cations and anions (calcium, sodium, magnesium, hydrogen carbonate, sulfate, chloride), dissolved metals (including arsenic), and total iron and manganese. The samples should be collected at a designated location on the raw water side of the water treatment system using sample bottles and methods in accordance with the laboratory instructions. [Note: This sampling is separate from any routine sampling program required as part of the operation from the water treatment plant].

The recommended groundwater level monitoring program would include the use of existing wells on the current WTP property. The monitoring well will be equipped with continuous groundwater level monitoring devices such as digital pressure transducers capable of recording groundwater levels on at least a daily basis. The information would be downloaded on a regular basis (typically quarterly) and be input into a suitable database capable of generating charts of water level trends over time. It is assumed at this stage that the Province will continue to maintain the groundwater monitoring stations, and will make the information available on an annual basis.

The availability of groundwater usage for potential future users will be assessed through the Water Rights Act Licensing process.

5.5 Vegetation and Wildlife

Displacing whole portions of topsoil with any known rare or endangered plant species can be implemented if necessary such that this material and plants can be placed back in its original location with minimal disturbance. Re-establishment of vegetation will occur as soon as possible on disturbed areas. Impacts to wildlife habitat can be limited by minimizing the area of construction, soil disturbance and vegetation disturbance. Other impacts resulting from dust or smoke will be minimized as previously indicated. Noise disturbance will be limited by use of muffling vehicles and equipment, limiting idling and limiting the construction area.

Any potential loss and disturbance to vegetation and wildlife during operation may be mitigated by restricting vehicular traffic to designated and previously disturbed areas, and by limiting monitoring and maintenance activities to previously disturbed areas.

5.6 Fisheries

Fisheries impacts will be minimized by implementing practices to reduce soil and contaminate runoff as previously mentioned in Sections 5.3 and 5.5. The project area is not located near any river or other fish habitat. The proponent will work with the provincial officials should any concerns arise.

5.7 Noise and Vibration

Limiting any noise-creating activities, including regular maintenance and monitoring activities to normal working hours, and limiting unnecessary long-term idling can mitigate any potential increased noise and vibration effects.

5.8 Water Conservation

Water conservation measures include metering and pricing of water. Water conservation information in water bill mailings can be implemented. Leak detection will consist of reconciling on a quarterly basis the volume of water pumped and charged to ratepayers. Since these services are metered, abnormalities can be identified and rectified.

5.9 Socio-Economic Implications

There are no known negative environmental socio-economic impacts that require mitigation. Since the proposed development would provide a reliable healthy drinking water supply, it would be expected to enhance quality of life and economic viability for the Town. The proposed project may provide some economic benefits to the area for local businesses and employment opportunities during construction phase.

6.0 References

Ecological Framework of Canada. (n.d.). Lake of the Woods*. Ecoregions of Canada.* Retrieved from http://www.ecozones.ca/english/region/91.html

Friesen Drillers Ltd. *Preliminary Hydrogeological Testing Results Supplementary Groundwater Supply – Tyndall-Garson WTP Upgrade Rural Municipality of Brokenhead.* Steinbach, MB. May, 2022.

Government of Canada. (2018). Historical Climate Data. *Station Results.* Retrieved from http://climate.weather.gc.ca/historical_data/search_historic_data_stations_e.html?searchType=stnProv&timeframe=1&lstProvince=MB&optLimit=yearRange&StartYear=1840&EndYear=2019&Year=2019&Month=1&Day=13&selRowPerPage=25

JR Cousin Consultants Ltd. *RM of Brokenhead – Water Treatment Plant Upgrade – Pre-Design Letter Report*. Winnipeg, MB. December, 2021.

JR Cousin Consultants Ltd. *RM of Brokenhead – Water Treatment Plant Upgrade Feasibility Study*. Winnipeg, MB. February, 2021.

JR Cousin Consultants Ltd. *RM of Brokenhead – Water Treatment Plant Upgrade – Population and Water Demand*. Winnipeg, MB. October, 2021.

Appendix A

Hydrogeology of Southern Manitoba

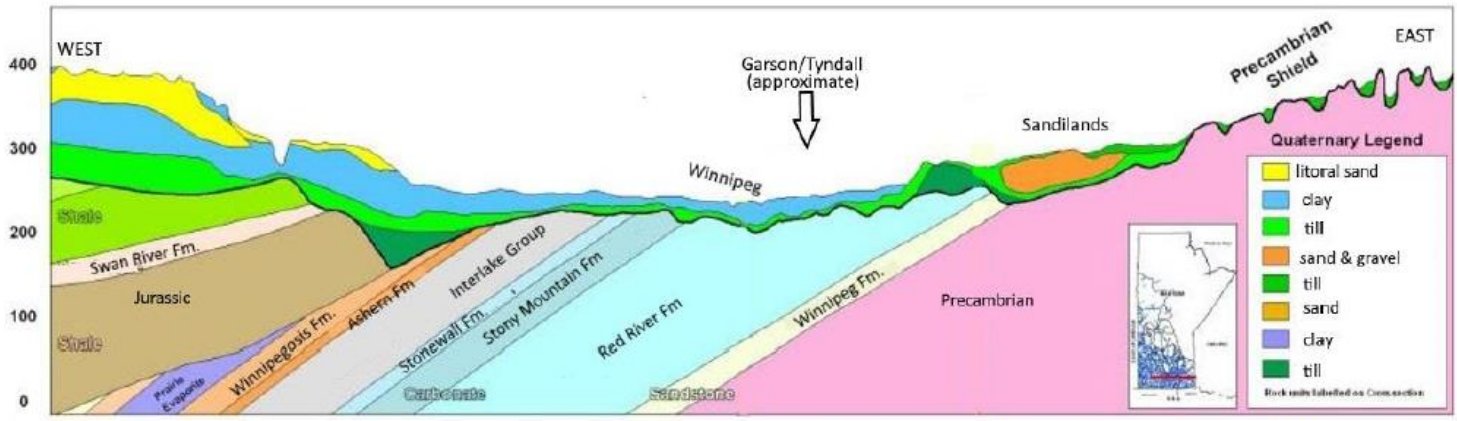


Figure 4 - Geology of southern Manitoba; elevation given in meters. (Source – Alberta Geological Survey, 2007)

HYDROGEOLGOY OF TYNDALL GARSON (FRIESEN DRILLERS LTD 2022)

Appendix B

Water Rights Licence

MG-14854 (English)

Licence to Use Water for Municipal-Distribution System Purposes

Manitoba Water Stewardship
Infrastructure and Operations Division
200 Saulteaux Cresc.
Winnipeg, Manitoba
R3J 3W3

Project: Garson/Henryville/Tyndall Municipal Well

Issued in accordance with the provisions of
The Water Rights Act and regulations made thereunder.

Licence No.: **2005-083**

U.T.M.: Zone 14 666300 E
5549387 N

Know all men by these presents that in consideration of and subject to the provisos, conditions and restrictions hereinafter contained, the Minister of Water Stewardship for the Province of Manitoba does by these presents give full right and liberty, leave and licence to **The Rural Municipality of Brokenhead** in the Province of Manitoba (hereinafter called "the LICENSEE") to divert water from a **fractured limestone** aquifer by means of a water well, pump, pipeline(s) and other appurtenances (hereinafter called "the WORKS"), located on the following described lands:

the Northwest Quarter of Section 2, in Township 13 and Range 6, East of the Principal Meridian in Manitoba, more particularly described on Certificate of Title No. 1981315 and Plan 2248 WLTO,

and more particularly shown on a plan filed in the office of the Executive Director, Infrastructure and Operations Division, a copy of which plan is hereto attached and marked Exhibit "A" for **municipal-distribution system** purposes on the following described lands:

parts of Sections 2, 3, 4, and 11, in Township 13 and Range 6 East of the Principal Meridian in Manitoba.

This licence is issued upon the express condition that it shall be subject to the provisions of The Water Rights Act and Regulations and all amendments thereto and, without limiting the generality of the aforesaid, to the following terms and conditions, namely:

1. The water shall be used solely for **municipal-distribution system** purposes.
2. The WORKS shall be operated in accordance with the terms herein contained.
3. a) The maximum rate at which water may be diverted pursuant hereto shall not exceed **0.020 cubic metres per second (0.7 cubic feet per second)** .

   b) The total quantity of water diverted in any one year shall not exceed **226 cubic decametres (183.22 acre feet)** .
4. Water shall not be diverted during any period when the water level in the aquifer as measured at the well is more than **48.77 metres (160.0 feet)** beneath the surface of the ground.
5. The LICENSEE does hereby remise, release and forever discharge Her Majesty the Queen in Right of the Province of Manitoba, of and from all manner of action, causes of action, claims and demands whatsoever which against Her Majesty the LICENSEE ever had, now has or may hereafter have, resulting from the use of water for **municipal-distribution system** purposes.
6. In the event that the rights of others are infringed upon and/or damage to the property of others is sustained as a result of the operation or maintenance of the WORKS and the rights herein granted, the LICENSEE shall be solely responsible and shall save harmless and fully indemnify Her Majesty the Queen in Right of the Province of Manitoba, from and against any liability to which Her Majesty may become liable by virtue of the issue of this Licence and anything done pursuant hereto.
7. This Licence is not assignable or transferable by the LICENSEE and when no longer required by the LICENSEE this Licence shall be returned to the Executive Director, Infrastructure and Operations Division, for cancellation on behalf of the Minister.
8. Upon the execution of this Licence the LICENSEE hereby grants the Minister or the Minister's agents the right of ingress and egress to and from the lands on which the WORKS are located for the purpose of inspection of the WORKS and the LICENSEE shall at all times comply with such directions and/or orders that may be given by the Minister or the Minister's agents in writing from time to time with regard to the operation and maintenance of the WORKS.
9. If for any reason whatsoever the Minister deems it advisable to cancel this Licence, he may do so by letter addressed to the LICENSEE at **Box 490, Beausejour, MB, R0E 0C0, Canada** and thereafter this Licence shall be determined to be at an end.
10. Notwithstanding anything preceding in this Licence, the LICENSEE must have legal control, by ownership or by rental, lease, or other agreement, of the lands on which the WORKS shall be placed.
11. The term of this Licence shall be **twenty (20) years** and this Licence shall become effective only on the date of execution hereof by a person so authorized in the Department of Water Stewardship. The LICENSEE may apply for renewal of this Licence not more than 365 days and not less than 90 days prior to the expiry date.
12. This Licence expires automatically upon the loss of the legal control of any of the lands on which the WORKS are located unless the Licence is transferred or amended by the Minister upon application for Licence transfer or amendment.

Page 1 of 2

13. The LICENSEE shall keep records of daily and annual water use and shall provide a copy of such records to the Executive Director, Infrastructure and Operations Division, not later than February 1st of the following year.

14. A flow meter must be installed, positioned to accurately measure instantaneous pumping rate and accumulative withdrawals from the water source.

15. The LICENSEE does hereby agree to correct, to the satisfaction of the Minister, any water supply problems to other currently existing wells, dugouts, or other forms of supply, which are partly or wholly attributable, in the opinion of the Minister, to the diversion of water as authorized by this Licence.

16. The LICENSEE shall hold and maintain all other regulatory approvals that may be required and shall comply with all other regulatory requirements for the construction, operation, or maintenance of the WORKS or to divert or use water as provided by this Licence.

17. The LICENSEE shall install an observation well equipped with a water level recorder at a location to be agreed upon in consultation with Manitoba Water Stewardship within one year of this Licence coming into effect and thereafter the LICENSEE shall maintain said observation well, change water level charts as required, and submit water level charts to Manitoba Water Stewardship.

18. The LICENSEE shall agree that this water level information shall be available for public scrutiny and may be made accessible on a web site.

In witness whereof I the undersigned hereby agree to accept the aforesaid Licence on the terms and conditions set forth therein and hereby set my hand and seal this 6th day of June A.D. 20 06

SIGNED, SEALED AND DELIVERED
in the presence of

[redacted] } [redacted] (Seal)

Witness Licensee Manager.

Canada, PROVINCE OF MANITOBA To Wit:

I, _____ of the _____

of _____ in the Province of Manitoba, MAKE OATH AND SAY:

1. That I was personally present and did see _____, the within named party, execute the within instrument.
2. That I know the said _____ and am satisfied that he/she is of the full age of eighteen years.
3. That the said instrument was executed at _____ aforesaid and that I am subscribing witness thereto.

SWORN BEFORE me at the _____

in the Province of Manitoba this _____ day of _____ A.D. 20 ____.

[redacted] }

A COMMISSIONER FOR OATHS
in and for the Province of Manitoba

[redacted]
Witness

My Commission expires _____

Issued at the City of Winnipeg, in the Province of Manitoba, this 30 day of June A.D. 20 06.

[redacted]
The Honourable the Minister of Water Stewardship

Licence No.2005-083 Page 2 of 2

Appendix C

Raw & Treated Water Quality Analysis

Friesen Drillers Ltd
ATTN: JUSTIN NEUFELD
307 PTH 12 N
Steinbach MB R5G 1L9

Date Received: 23-JUN-22
Report Date: 08-JUL-22 14:09 (MT)
Version: FINAL

Client Phone: 204-326-2485

Certificate of Analysis

Lab Work Order #: L2717354
Project P.O. #: SUPPLEMENTARY TESTING
Job Reference: GARSON-TYNDALL
C of C Numbers:
Legal Site Desc:

[redacted]
Hua Wo
Chemistry Laboratory Manager

ADDRESS: 1329 Niakwa Road East, Unit 12, Winnipeg, MB R2J 3T4 Canada | Phone: +1 204 255 9720 | Fax: +1 204 255 9721
ALS CANADA LTD Part of the ALS Group An ALS Limited Company

GARSON-TYNDALL

L2717354 CONTD....
PAGE 2 of 7
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2717354-1 TH1-LOWER							
Sampled By: CLIENT on 22-JUN-22 @ 14:00							
Matrix: WATER							
MB Chemistry for PWS							
Alkalinity, Bicarbonate							
Bicarbonate (HCO3)	521		1.2	mg/L		28-JUN-22	
Alkalinity, Carbonate							
Carbonate (CO3)	<0.60		0.60	mg/L		28-JUN-22	
Alkalinity, Hydroxide							
Hydroxide (OH)	<0.34		0.34	mg/L		28-JUN-22	
Alkalinity, Total (as CaCO3)							
Alkalinity, Total (as CaCO3)	427		1.0	mg/L		27-JUN-22	R5807776
Ammonia by colour							
Ammonia, Total (as N)	0.151		0.010	mg/L		29-JUN-22	R5809257
Bromide in Water by IC (Low Level)							
Bromide (Br)	0.074		0.010	mg/L		23-JUN-22	R5806712
Chloride in Water by IC (Low Level)							
Chloride (Cl)	54.2		0.10	mg/L		23-JUN-22	R5806712
Colour, True							
Colour, True	<5.0		5.0	CU		23-JUN-22	R5806414
Conductivity							
Conductivity	953		1.0	umhos/cm		27-JUN-22	R5807776
Dissolved Organic Carbon by Combustion							
Dissolved Organic Carbon	2.62		0.50	mg/L		08-JUL-22	R5818439
Fluoride in Water by IC							
Fluoride (F)	0.377		0.020	mg/L		23-JUN-22	R5806712
Hardness Calculated							
Hardness (as CaCO3)	439		0.20	mg/L		29-JUN-22	
Langelier Index 4C							
Langelier Index (4 C)	0.86					30-JUN-22	
Langelier Index 60C							
Langelier Index (60 C)	1.6					30-JUN-22	
Nitrate in Water by IC (Low Level)							
Nitrate (as N)	<0.0050		0.0050	mg/L		23-JUN-22	R5806712
Nitrite in Water by IC (Low Level)							
Nitrite (as N)	<0.0010		0.0010	mg/L		23-JUN-22	R5806712
Sulfate in Water by IC							
Sulfate (SO4)	45.4		0.30	mg/L		23-JUN-22	R5806712
Total Dissolved Solids (TDS)							
Total Dissolved Solids	479		20	mg/L		27-JUN-22	R5809260
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.0171		0.0030	mg/L	28-JUN-22	28-JUN-22	R5809652
Antimony (Sb)-Total	<0.00010		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Arsenic (As)-Total	0.00063		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Barium (Ba)-Total	0.0473		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Beryllium (Be)-Total	<0.00010		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Bismuth (Bi)-Total	<0.000050		0.000050	mg/L	28-JUN-22	28-JUN-22	R5809652
Boron (B)-Total	0.284		0.010	mg/L	28-JUN-22	28-JUN-22	R5809652
Cadmium (Cd)-Total	<0.0000050		0.0000050	mg/L	28-JUN-22	28-JUN-22	R5809652
Calcium (Ca)-Total	71.7		0.050	mg/L	28-JUN-22	28-JUN-22	R5809652
Cesium (Cs)-Total	0.000019		0.000010	mg/L	28-JUN-22	28-JUN-22	R5809652
Chromium (Cr)-Total	0.00066		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Cobalt (Co)-Total	0.00020		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Copper (Cu)-Total	<0.00050		0.00050	mg/L	28-JUN-22	28-JUN-22	R5809652
Iron (Fe)-Total	0.463		0.010	mg/L	28-JUN-22	28-JUN-22	R5809652
Lead (Pb)-Total	0.000159		0.000050	mg/L	28-JUN-22	28-JUN-22	R5809652

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

GARSON-TYNDALL

L2717354 CONTD....
PAGE 3 of 7
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2717354-1 TH1-LOWER							
Sampled By: CLIENT on 22-JUN-22 @ 14:00							
Matrix: WATER							
Total Metals in Water by CRC ICPMS							
Lithium (Li)-Total	0.0375		0.0010	mg/L	28-JUN-22	28-JUN-22	R5809652
Magnesium (Mg)-Total	70.3		0.0050	mg/L	28-JUN-22	28-JUN-22	R5809652
Manganese (Mn)-Total	0.0188		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Molybdenum (Mo)-Total	0.000683		0.000050	mg/L	28-JUN-22	28-JUN-22	R5809652
Nickel (Ni)-Total	0.00120		0.00050	mg/L	28-JUN-22	28-JUN-22	R5809652
Potassium (K)-Total	6.84		0.050	mg/L	28-JUN-22	28-JUN-22	R5809652
Phosphorus (P)-Total	<0.050		0.050	mg/L	28-JUN-22	28-JUN-22	R5809652
Rubidium (Rb)-Total	0.00387		0.00020	mg/L	28-JUN-22	28-JUN-22	R5809652
Selenium (Se)-Total	<0.000050		0.000050	mg/L	28-JUN-22	28-JUN-22	R5809652
Silicon (Si)-Total	5.22		0.10	mg/L	28-JUN-22	28-JUN-22	R5809652
Silver (Ag)-Total	<0.000010		0.000010	mg/L	28-JUN-22	28-JUN-22	R5809652
Sodium (Na)-Total	53.4		0.050	mg/L	28-JUN-22	28-JUN-22	R5809652
Strontium (Sr)-Total	0.486		0.00020	mg/L	28-JUN-22	28-JUN-22	R5809652
Tellurium (Te)-Total	<0.00020		0.00020	mg/L	28-JUN-22	28-JUN-22	R5809652
Thallium (Tl)-Total	<0.000010		0.000010	mg/L	28-JUN-22	28-JUN-22	R5809652
Thorium (Th)-Total	<0.00010		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Tin (Sn)-Total	<0.00010		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Titanium (Ti)-Total	0.00054		0.00030	mg/L	28-JUN-22	28-JUN-22	R5809652
Tungsten (W)-Total	<0.00010		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Uranium (U)-Total	0.000180		0.000010	mg/L	28-JUN-22	28-JUN-22	R5809652
Vanadium (V)-Total	<0.00050		0.00050	mg/L	28-JUN-22	28-JUN-22	R5809652
Zinc (Zn)-Total	0.0050		0.0030	mg/L	28-JUN-22	28-JUN-22	R5809652
Zirconium (Zr)-Total	<0.00020		0.00020	mg/L	28-JUN-22	28-JUN-22	R5809652
Total Organic Carbon by Combustion							
Total Organic Carbon	2.53		0.50	mg/L		06-JUL-22	R5817379
Turbidity							
Turbidity	1.80		0.10	NTU		24-JUN-22	R5806979
UV Transmittance (Calculated)							
Transmittance, UV (254 nm)	93.5		1.0	%T/cm		24-JUN-22	R5807135
pH							
pH	8.16		0.10	pH units		27-JUN-22	R5807776
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	FIELD					28-JUN-22	R5808617
Aluminum (Al)-Dissolved	0.0021		0.0010	mg/L	28-JUN-22	28-JUN-22	R5809652
Antimony (Sb)-Dissolved	<0.00010		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Arsenic (As)-Dissolved	0.00060		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Barium (Ba)-Dissolved	0.0461		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Beryllium (Be)-Dissolved	<0.00010		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Bismuth (Bi)-Dissolved	<0.000050		0.000050	mg/L	28-JUN-22	28-JUN-22	R5809652
Boron (B)-Dissolved	0.290		0.010	mg/L	28-JUN-22	28-JUN-22	R5809652
Cadmium (Cd)-Dissolved	<0.0000050		0.0000050	mg/L	28-JUN-22	28-JUN-22	R5809652
Calcium (Ca)-Dissolved	64.7		0.050	mg/L	28-JUN-22	28-JUN-22	R5809652
Cesium (Cs)-Dissolved	0.000017		0.000010	mg/L	28-JUN-22	28-JUN-22	R5809652
Chromium (Cr)-Dissolved	0.00025		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Cobalt (Co)-Dissolved	0.00019		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Copper (Cu)-Dissolved	0.00062		0.00020	mg/L	28-JUN-22	28-JUN-22	R5809652
Iron (Fe)-Dissolved	0.441		0.010	mg/L	28-JUN-22	28-JUN-22	R5809652
Lead (Pb)-Dissolved	0.000142		0.000050	mg/L	28-JUN-22	28-JUN-22	R5809652
Lithium (Li)-Dissolved	0.0358		0.0010	mg/L	28-JUN-22	28-JUN-22	R5809652
Magnesium (Mg)-Dissolved	67.4		0.0050	mg/L	28-JUN-22	28-JUN-22	R5809652
Manganese (Mn)-Dissolved	0.0180		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652

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

GARSON-TYNDALL

L2717354 CONTD....
PAGE 4 of 7
Version: FINAL

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2717354-1 TH1-LOWER							
Sampled By: CLIENT on 22-JUN-22 @ 14:00							
Matrix: WATER							
Dissolved Metals in Water by CRC ICPMS							
Molybdenum (Mo)-Dissolved	0.000665		0.000050	mg/L	28-JUN-22	28-JUN-22	R5809652
Nickel (Ni)-Dissolved	0.00097		0.00050	mg/L	28-JUN-22	28-JUN-22	R5809652
Phosphorus (P)-Dissolved	<0.050		0.050	mg/L	28-JUN-22	28-JUN-22	R5809652
Potassium (K)-Dissolved	6.72		0.050	mg/L	28-JUN-22	28-JUN-22	R5809652
Rubidium (Rb)-Dissolved	0.00394		0.00020	mg/L	28-JUN-22	28-JUN-22	R5809652
Selenium (Se)-Dissolved	<0.000050		0.000050	mg/L	28-JUN-22	28-JUN-22	R5809652
Silicon (Si)-Dissolved	4.95		0.050	mg/L	28-JUN-22	28-JUN-22	R5809652
Silver (Ag)-Dissolved	0.000017		0.000010	mg/L	28-JUN-22	28-JUN-22	R5809652
Sodium (Na)-Dissolved	49.8		0.050	mg/L	28-JUN-22	28-JUN-22	R5809652
Strontium (Sr)-Dissolved	0.483		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Tellurium (Te)-Dissolved	<0.00020		0.00020	mg/L	28-JUN-22	28-JUN-22	R5809652
Thallium (Tl)-Dissolved	<0.000010		0.000010	mg/L	28-JUN-22	28-JUN-22	R5809652
Thorium (Th)-Dissolved	<0.00010		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Tin (Sn)-Dissolved	<0.00010		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Titanium (Ti)-Dissolved	<0.00030		0.00030	mg/L	28-JUN-22	28-JUN-22	R5809652
Tungsten (W)-Dissolved	<0.00010		0.00010	mg/L	28-JUN-22	28-JUN-22	R5809652
Uranium (U)-Dissolved	0.000185		0.000010	mg/L	28-JUN-22	28-JUN-22	R5809652
Vanadium (V)-Dissolved	<0.00050		0.00050	mg/L	28-JUN-22	28-JUN-22	R5809652
Zinc (Zn)-Dissolved	0.0089		0.0010	mg/L	28-JUN-22	28-JUN-22	R5809652
Zirconium (Zr)-Dissolved	<0.00020		0.00020	mg/L	28-JUN-22	28-JUN-22	R5809652

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

ALS Environmental

L2717354-COFC

COC #: OL-2858

Page 1 of 1

Report To			Distribution: ☐Fax ☐Mail ☑Email	Service Requested
Company:	Friesen Drillers Limited		☐Criteria on Report (select from Guidelines below)	◉Regular (Standard Turnaround Times - Business Days) - R
Contact:	Justin Neufeld, P.Geo.		Report Type: ☐Excel ☑Digital	○Priority (3 Days) - surcharge will apply - P
Address:	307 PTH 12 N Steinbach, MB Canada, R5G 1T8		Report Format:	○Priority (2 Days) - surcharge will apply - P2
			Report Email(s): Justin@friesendrillers.com Jeff@friesendrillers.com	○Emergency (1-2 day) – surcharge will apply - E
				○Same Day or Weekend Emergency - surcharge will apply - E2
				○Specify date required - X
Phone:	204-326-2485 Fax: 204-326-2483			Analysis Requests
Invoice To	☑Email ☐Mail		EDD Format:	
Company:	Friesen Drillers Limited		EDD Email(s):	
Contact:	Kim Friesen			
Address:	307 PTH 12 N Steinbach, MB Canada, R5G 1T8		Project Info	
			Job #: Garson-Tyndall	
			PO/AFE: Supplementary Testing	
Email:	Accts@friesendrillers.com		LSD:	
Phone:	204-326-2485		Quote #:	
Lab Work Order # (lab use only)			ALS Contact: Judy	Sampler: AF

Sample #	Sample Identification (This will appear on the report)	Coordinates Longitude	Coordinates Latitude	Date	Time	Sample Type	Number of Containers	MB-PWS-CH	Dissolved Metals
								Please indicate below Filtered, Preserved or both(F, P, F/P)	
	TH1-Lower			Jun-22-2022	02:00 PM	Water	2	R	R

Special Instructions/Comments	The questions below must be answered for water samples (check Yes or No)	Guidelines
	Are any sample taken from a regulated DW system? ☐Yes ☐No If yes, please use an authorized drinking water COC Is the water sampled intended to be potable for human consumption? ☐Yes ☐No	SAMPLE CONDITION (lab use only) ☐Frozen ☐Cold ☐Ambient ☐Cooling Initiated

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by:	Date:	Time:	Received by: [redacted]	Date: JUN 23 2022	Time: [redacted]	Temperature: 6.2°C	Verified by:	Date:	Time:	Observations: ☐Yes If Yes add SIF

RM of Brokenhead - Water Treatment Plant
ATTN: GRANT PLISCHKE
Brokenhead, RM of
Box 490
Beauseiour MB R0E 0C0

Date Received: 10-SEP-19
Report Date: 24-SEP-19 11:22 (MT)
Version: FINAL

Client Phone: 204-266-2021

Certificate of Analysis

Lab Work Order #: L2344116
Project P.O. #: NOT SUBMITTED
Job Reference: RM OF BROKENHEAD - PWS 29.31
C of C Numbers:
Legal Site Desc: 36330

[redacted]
Hua Wo
Chemistry Laboratory Manager

ADDRESS: 1329 Niakwa Road East, Unit 12, Winnipeg, MB R2J 3T4 Canada | Phone: +1 204 255 9720 | Fax: +1 204 255 9721
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ANALYTICAL REPORT

L2344116 CONTD....
PAGE 2 of 7
24-SEP-19 11:22 (MT)

Physical Tests (WATER)

Analyte	Unit	Guide Limit #1	Guide Limit #2	ALS ID	L2344116-1	L2344116-2	L2344116-3
				Sampled Date	10-SEP-19	10-SEP-19	10-SEP-19
				Sampled Time	09:00	09:00	09:00
				Sample ID	RM OF BROKENHEAD 1 - RAW WELL 1	RM OF BROKENHEAD 1 - RAW WELL 2	RM OF BROKENHEAD 2 - TREATED
Colour, True	CU	15	-		<5.0	<5.0	<5.0
Conductivity	umhos/cm	-	-		1040	1000	113
Hardness (as CaCO3)	mg/L	-	-		430 ***	450 ***	2.74 ***
Langelier Index (4 C)	No Unit	-	-		0.69	0.90	-2.3
Langelier Index (60 C)	No Unit	-	-		1.7	1.7	-1.5
pH	pH units	7.00-10.5	-		8.24	8.23	7.81
Total Dissolved Solids	mg/L	500	-		661	639	69
Transmittance, UV (254 nm)	%T/cm	-	-		95.5	95.7	99.3
Turbidity	NTU	-	-		3.96	0.90	<0.10

Federal Guidelines for Canadian Drinking Water Quality (MAR, 2019)
#1: GCDWQ - Aesthetic Objective/Other Value
#2: GCDWQ - Maximum Acceptable Concentrations (MACs)

Anions and Nutrients (WATER)

Analyte	Unit	Guide Limit #1	Guide Limit #2	ALS ID	L2344116-1	L2344116-2	L2344116-3
				Sampled Date	10-SEP-19	10-SEP-19	10-SEP-19
				Sampled Time	09:00	09:00	09:00
				Sample ID	RM OF BROKENHEAD 1 - RAW WELL 1	RM OF BROKENHEAD 1 - RAW WELL 2	RM OF BROKENHEAD 2 - TREATED
Alkalinity, Total (as CaCO3)	mg/L	-	-		432	418	57.1
Ammonia, Total (as N)	mg/L	-	-		0.164	0.089	<0.010
Bicarbonate (HCO3)	mg/L	-	-		526	510	69.7
Bromide (Br)	mg/L	-	-		0.106	0.099	<0.010
Carbonate (CO3)	mg/L	-	-		<0.60	<0.60	<0.60
Chloride (Cl)	mg/L	250	-		72.7	73.9	3.35
Fluoride (F)	mg/L	-	1.5		0.343	0.319	<0.020
Hydroxide (OH)	mg/L	-	-		<0.34	<0.34	<0.34
Nitrate (as N)	mg/L	-	10		<0.010 ***	<0.010 ***	<0.0050
Nitrite (as N)	mg/L	-	1		<0.0020 ***	<0.0020 ***	<0.0010
Sulfate (SO4)	mg/L	500	-		65.2	53.5	<0.30

Federal Guidelines for Canadian Drinking Water Quality (MAR, 2019)
#1: GCDWQ - Aesthetic Objective/Other Value
#2: GCDWQ - Maximum Acceptable Concentrations (MACs)

Organic / Inorganic Carbon (WATER)

Analyte	Unit	Guide Limit #1	Guide Limit #2	ALS ID	L2344116-1	L2344116-2	L2344116-3
				Sampled Date	10-SEP-19	10-SEP-19	10-SEP-19
				Sampled Time	09:00	09:00	09:00
				Sample ID	RM OF BROKENHEAD 1 - RAW WELL 1	RM OF BROKENHEAD 1 - RAW WELL 2	RM OF BROKENHEAD 2 - TREATED
Dissolved Organic Carbon	mg/L	-	-		1.43	0.93	<0.50
Total Organic Carbon	mg/L	-	-		1.28	1.12	<0.50

Federal Guidelines for Canadian Drinking Water Quality (MAR, 2019)
#1: GCDWQ - Aesthetic Objective/Other Value
#2: GCDWQ - Maximum Acceptable Concentrations (MACs)

Detection Limit for result exceeds Guide Limit. Assessment against Guide Limit cannot be made.
Analytical result for this parameter exceeds Guide Limit listed on this report.
* Please refer to the Reference Information section for an explanation of any qualifiers noted.

ALS Environmental

ANALYTICAL REPORT

L2344116 CONTD....
PAGE 3 of 7
24-SEP-19 11:22 (MT)

Total Metals (WATER)

				ALS ID	L2344116-1	L2344116-2	L2344116-3
				Sampled Date	10-SEP-19	10-SEP-19	10-SEP-19
				Sampled Time	09:00	09:00	09:00
				Sample ID	RM OF BROKENHEAD 1 - RAW WELL 1	RM OF BROKENHEAD 1 - RAW WELL 2	RM OF BROKENHEAD 2 - TREATED
Analyte	Unit	Guide Limit #1	Guide Limit #2				
Aluminum (Al)-Total	mg/L	0.1	-		<0.0030	<0.0030	0.0048
Antimony (Sb)-Total	mg/L	-	0.006		<0.00010	<0.00010	<0.00010
Arsenic (As)-Total	mg/L	-	0.01		0.00021	0.00044	0.00014
Barium (Ba)-Total	mg/L	-	1		0.0429	0.0430	0.00059
Beryllium (Be)-Total	mg/L	-	-		<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Total	mg/L	-	-		<0.000050	<0.000050	<0.000050
Boron (B)-Total	mg/L	-	5		0.238	0.291	0.205
Cadmium (Cd)-Total	mg/L	-	0.005		<0.0000050	<0.0000050	<0.0000050
Calcium (Ca)-Total	mg/L	-	-		58.5	63.6	0.536
Cesium (Cs)-Total	mg/L	-	-		0.000022	0.000024	<0.000010
Chromium (Cr)-Total	mg/L	-	0.05		0.00016	<0.00010	0.00012
Cobalt (Co)-Total	mg/L	-	-		<0.00010	<0.00010	<0.00010
Copper (Cu)-Total	mg/L	1	2		0.00255	0.00077	0.0133
Iron (Fe)-Total	mg/L	0.3	-		0.111	0.374	<0.010
Lead (Pb)-Total	mg/L	-	0.005		0.000461	0.000071	0.000159
Lithium (Li)-Total	mg/L	-	-		0.0309	0.0376	0.0020
Magnesium (Mg)-Total	mg/L	-	-		71.0	70.6	0.338
Manganese (Mn)-Total	mg/L	0.02	0.12		0.00567	0.00652	<0.00010
Molybdenum (Mo)-Total	mg/L	-	-		0.000675	0.000547	<0.000050
Nickel (Ni)-Total	mg/L	-	-		0.00054	<0.00050	<0.00050
Phosphorus (P)-Total	mg/L	-	-		<0.030	<0.030	0.390
Potassium (K)-Total	mg/L	-	-		6.54	7.37	0.375
Rubidium (Rb)-Total	mg/L	-	-		0.00365	0.00425	0.00023
Selenium (Se)-Total	mg/L	-	0.05		0.000108	<0.000050	<0.000050
Silicon (Si)-Total	mg/L	-	-		4.56	4.99	0.22
Silver (Ag)-Total	mg/L	-	-		<0.000010	<0.000010	<0.000010
Sodium (Na)-Total	mg/L	200	-		55.5	62.5	27.0
Strontium (Sr)-Total	mg/L	-	7		0.447	0.510	0.00251
Sulfur (S)-Total	mg/L	-	-		18.9	22.7	<0.50
Tellurium (Te)-Total	mg/L	-	-		<0.00020	<0.00020	<0.00020
Thallium (Tl)-Total	mg/L	-	-		<0.000010	<0.000010	<0.000010
Thorium (Th)-Total	mg/L	-	-		<0.00010	<0.00010	<0.00010
Tin (Sn)-Total	mg/L	-	-		<0.00010	<0.00010	<0.00010

Federal Guidelines for Canadian Drinking Water Quality (MAR, 2019)
#1: GCDWQ - Aesthetic Objective/Other Value
#2: GCDWQ - Maximum Acceptable Concentrations (MACs)

Detection Limit for result exceeds Guide Limit. Assessment against Guide Limit cannot be made.
Analytical result for this parameter exceeds Guide Limit listed on this report.
* Please refer to the Reference Information section for an explanation of any qualifiers noted.

ALS Environmental

ANALYTICAL REPORT

L2344116 CONTD....
PAGE 4 of 7
24-SEP-19 11:22 (MT)

Total Metals (WATER)

				ALS ID	L2344116-1	L2344116-2	L2344116-3
				Sampled Date	10-SEP-19	10-SEP-19	10-SEP-19
				Sampled Time	09:00	09:00	09:00
				Sample ID	RM OF BROKENHEAD 1 - RAW WELL 1	RM OF BROKENHEAD 1 - RAW WELL 2	RM OF BROKENHEAD 2 - TREATED
Analyte	Unit	Guide Limit #1	Guide Limit #2				
Titanium (Ti)-Total	mg/L	-	-		<0.00030	<0.00030	<0.00030
Tungsten (W)-Total	mg/L	-	-		<0.00010	<0.00010	<0.00010
Uranium (U)-Total	mg/L	-	0.02		0.000480	0.000308	<0.000010
Vanadium (V)-Total	mg/L	-	-		<0.00050	0.00050	<0.00050
Zinc (Zn)-Total	mg/L	5	-		0.0071	0.0031	<0.0030
Zirconium (Zr)-Total	mg/L	-	-		<0.00020	<0.00020	<0.00020

Federal Guidelines for Canadian Drinking Water Quality (MAR, 2019)
#1: GCDWQ - Aesthetic Objective/Other Value
#2: GCDWQ - Maximum Acceptable Concentrations (MACs)

Volatile Organic Compounds (WATER)

				ALS ID	L2344116-1	L2344116-2
				Sampled Date	10-SEP-19	10-SEP-19
				Sampled Time	09:00	09:00
				Sample ID	RM OF BROKENHEAD 1 - RAW WELL 1	RM OF BROKENHEAD 1 - RAW WELL 2
Analyte	Unit	Guide Limit #1	Guide Limit #2			
Benzene	mg/L	-	0.005		<0.00050	<0.00050
1,1-dichloroethene	mg/L	-	0.014		<0.00050	<0.00050
Dichloromethane	mg/L	-	0.05		<0.0050	<0.0050
Ethylbenzene	mg/L	0.0016	0.14		<0.00050	<0.00050
MTBE	mg/L	0.015	-		<0.00050	<0.00050
Tetrachloroethene	mg/L	-	0.01		<0.00050	<0.00050
Toluene	mg/L	0.024	0.06		<0.00050	<0.00050
Trichloroethene	mg/L	-	0.005		<0.00050	<0.00050
o-Xylene	mg/L	-	-		<0.00050	<0.00050
M+P-Xylenes	mg/L	-	-		<0.00040	<0.00040
Xylenes (Total)	mg/L	0.02	0.09		<0.00064	<0.00064
Surrogate: 4-Bromofluorobenzene (SS)	%	-	-		87.6	87.6
Surrogate: 1,4-Difluorobenzene (SS)	%	-	-		100.0	102.2

Federal Guidelines for Canadian Drinking Water Quality (MAR, 2019)
#1: GCDWQ - Aesthetic Objective/Other Value
#2: GCDWQ - Maximum Acceptable Concentrations (MACs)

Detection Limit for result exceeds Guide Limit. Assessment against Guide Limit cannot be made.
Analytical result for this parameter exceeds Guide Limit listed on this report.
* Please refer to the Reference Information section for an explanation of any qualifiers noted.

Appendix D

Membrane Treatment System Projection

Integrated Membranes Solutions Design Software, 2018

Created on: 2022-05-10 01:43:00

Permeate Throttling (Variable)

Project name	Brokenhead		Permeate flow/train	209.50	gpm
Calculated by	ABoth		Total product flow	419.00	gpm
HP Pump flow	246.47	gpm	Number of trains	2	
Feed pressure	142.9	psi	Raw water flow/train	246.47	gpm
Feed temperature	0.5	°C(32.9°F)	Permeate recovery	85.00	%
Feed water pH	8.24		Element age	0.0	years
Chem dose, mg/l, -	None		Flux decline %, per year	5.0	
Specific energy	1.52	kwh/kgal	Fouling factor	1.00	
Pass NDP	106.5	psi	SP increase, per year	7.0	%
Average flux rate	12.5	gfd	Inter-stage pipe loss	0.207	bar
			Feed type	Brackish Well Non-Fouling	

Pass - Stage	Perm. Flow gpm	Flow / Vessel Feed gpm	Flow / Vessel Conc gpm	Flux gfd	DP psi	Flux Max gfd	Beta	Stagewise Pressure Perm. psi	Stagewise Pressure Boost psi	Stagewise Pressure Conc psi	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1	119.6	41.1	21.2	14.3	9.3	15.2	1.16	11	0	133.6	7	ESPA4-LD	30	6 x 5M
1-2	65.8	31.7	15.3	11.8	6.2	12.8	1.18	11	0	124.4	22.4	ESPA4-LD	20	4 x 5M
1-3	24.2	30.5	18.4	8.7	6.3	9.8	1.11	11	0	115.1	80.4	ESPA4-LD	10	2 x 5M

Ion (mg/l)	Raw Water	Feed Water	Permeate Water	Concentrate 1	Concentrate 2	Concentrate 3
Hardness, as CaCO3	437.23	437.23	1.499	848.7	1761.6	2914.9
Ca	58.50	58.50	0.201	113.6	235.7	390.0
Mg	71.00	71.00	0.243	137.8	286.1	473.3
Na	55.50	55.50	4.761	106.2	215.0	344.0
K	6.54	6.54	0.561	12.5	25.3	40.5
NH4	0.21	0.21	0.035	0.4	0.8	1.1
Ba	0.043	0.043	0.000	0.1	0.2	0.3
Sr	0.477	0.477	0.002	0.9	1.9	3.2
Mn+2	0.007	0.007	0.000	0.0	0.0	0.0
Fe+2	0.111	0.111	0.000	0.2	0.4	0.7
H	0.00	0.00	0.000	0.0	0.0	0.0
CO3	3.59	3.59	0.001	15.2	73.3	214.6
HCO3	528.00	528.00	12.267	1023.0	2074.3	3330.6
SO4	65.20	65.20	0.153	126.6	262.8	435.1
Cl	72.70	72.70	1.689	140.7	290.2	476.5
F	0.34	0.34	0.022	0.7	1.3	2.1
NO3	0.00	0.00	0.000	0.0	0.0	0.0
PO4	0.00	0.00	0.000	0.0	0.0	0.0
OH	0.00	0.00	0.000	0.0	0.0	0.0
SiO2	9.75	9.75	0.204	18.9	39.0	64.0
B	0.29	0.29	0.173	0.5	0.7	1.0
CO2	7.21	7.21	7.21	7.21	7.21	7.21
NH3	0.00	0.00	0.00	0.00	0.00	0.00
TDS	**872.28**	**872.28**	**20.31**	**1697.18**	**3607.18**	**6777.19**
pH	**8.24**	**8.24**	**8.86**	**8.61**	**8.78**	**8.88**

Saturations	Raw Water	Feed Water	Concentrate	Limits
CaSO4 / ksp * 100, %	2	2	22	400
SrSO4 / ksp * 100, %	1	1	11	1200
BaSO4 / ksp * 100, %	101	101	855	10000
SiO2 saturation, %	11	11	50	140
CaF2 / ksp * 100, %	1	1	114	50000
Ca3(PO4)2 saturation index	0.0	0.0	0.0	2.4
CCPP, mg/l	59.98	59.98	935.80	850
Langelier saturation index	0.57	0.57	2.85	2.8
Ionic strength	0.02	0.02	0.12	
Osmotic pressure, psi	6.7	6.7	43.3	

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Permeate Throttling (Variable)

Project name	Brokenhead		Permeate flow/train	209.50	gpm
Calculated by	ABoth		Total product flow	419.00	gpm
HP Pump flow	246.47	gpm	Number of trains	2	
Feed pressure	142.9	psi	Raw water flow/train	246.47	gpm
Feed temperature	0.5	°C(32.9°F)	Permeate recovery	85.00	%
Feed water pH	8.24		Element age	0.0	years
Chem dose, mg/l, -	None		Flux decline %, per year	5.0	
Specific energy	1.52	kwh/kgal	Fouling factor	1.00	
Pass NDP	106.5	psi	SP increase, per year	7.0	%
Average flux rate	12.5	gfd	Inter-stage pipe loss	0.207	bar
			Feed type	Brackish Well Non-Fouling	

Pass - Stage	Perm. Flow	Flow / Vessel Feed	Flow / Vessel Conc	Flux	DP	Flux Max	Beta	Stagewise Pressure Perm.	Stagewise Pressure Boost	Stagewise Pressure Conc	Perm. TDS	Element Type	Element Quantity	PV# x Elem #
	gpm	gpm	gpm	gfd	psi	gfd		psi	psi	psi	mg/l			
1-1	119.6	41.1	21.2	14.3	9.3	15.2	1.16	11	0	133.6	7	ESPA4-LD	30	6 x 5M
1-2	65.8	31.7	15.3	11.8	6.2	12.8	1.18	11	0	124.4	22.4	ESPA4-LD	20	4 x 5M
1-3	24.2	30.5	18.4	8.7	6.3	9.8	1.11	11	0	115.1	80.4	ESPA4-LD	10	2 x 5M

Pass - Stage	Element no.	Feed Pressure	Pressure Drop	Conc Osmo.	NDP	Permeate Water Flow	Permeate Water Flux	Beta	Permeate (Stagewise cumulative) TDS	Ca	Mg	Na	Cl
		psi	psi	psi	psi	gpm	gfd						
1-1	1	142.9	2.56	7.4	123.9	4.2	15.2	1.1	4.7	0.045	0.055	1.112	0.384
1-1	2	140.3	2.19	8.3	120.4	4.1	14.7	1.11	5.1	0.049	0.06	1.212	0.419
1-1	3	138.1	1.84	9.5	117.4	4	14.3	1.12	5.6	0.054	0.066	1.331	0.46
1-1	4	136.3	1.52	10.9	114.4	3.9	14	1.14	6.2	0.06	0.073	1.476	0.511
1-1	5	134.8	1.22	12.9	111.4	3.8	13.6	1.16	7	0.068	0.082	1.657	0.575
1-2	1	130.6	1.75	14.5	105.1	3.6	12.8	1.11	13.4	0.131	0.159	3.172	1.108
1-2	2	128.8	1.47	16.5	101.8	3.4	12.4	1.12	14.9	0.146	0.177	3.526	1.233
1-2	3	127.3	1.21	19	98.2	3.3	11.9	1.14	16.8	0.164	0.2	3.966	1.39
1-2	4	126.1	0.97	22.2	94.2	3.2	11.4	1.16	19.2	0.188	0.228	4.525	1.59
1-2	5	125.2	0.76	26.5	89.6	3	10.8	1.18	22.4	0.22	0.267	5.261	1.854
1-3	1	121.4	1.66	29.1	82	2.7	9.8	1.09	50.8	0.504	0.611	11.897	4.237
1-3	2	119.7	1.44	32	77.7	2.6	9.3	1.09	56.4	0.56	0.68	13.189	4.707
1-3	3	118.3	1.24	35.3	73.2	2.4	8.7	1.1	63	0.627	0.761	14.716	5.265
1-3	4	117.1	1.07	39.1	68.5	2.3	8.2	1.1	70.9	0.707	0.858	16.532	5.931
1-3	5	116	0.91	43.4	63.5	2.1	7.5	1.11	80.4	0.803	0.975	18.705	6.734

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Permeate Throttling (Variable)

Project name	Brokenhead				
Calculated by	ABoth		Permeate flow/train	209.50	gpm
HP Pump flow	246.47	gpm	Total product flow	419.00	gpm
Feed pressure	142.9	psi	Number of trains	2	
Feed temperature	0.5	°C(32.9°F)	Raw water flow/train	246.47	gpm
Feed water pH	8.24		Permeate recovery	85.00	%
Chem dose, mg/l, -	None		Element age	0.0	years
Specific energy	1.52	kwh/kgal	Flux decline %, per year	5.0	
Pass NDP	106.5	psi	Fouling factor	1.00	
Average flux rate	12.5	gfd	SP increase, per year	7.0	%
			Inter-stage pipe loss	0.207	bar
			Feed type	Brackish Well Non-Fouling	

THE FOLLOWING PARAMETERS EXCEED RECOMMENDED DESIGN LIMITS

Concentrate Langelier saturation index (2.9) is higher than limit (2.8).
Concentrate CCPP (935.8) is higher than limit (850).

The above saturations limits only apply when using effective scale inhibitor or dispersant. Without scale inhibitor or dispersant, the saturation and precipitation limit of the contaminant should not exceed its solubility in solution.

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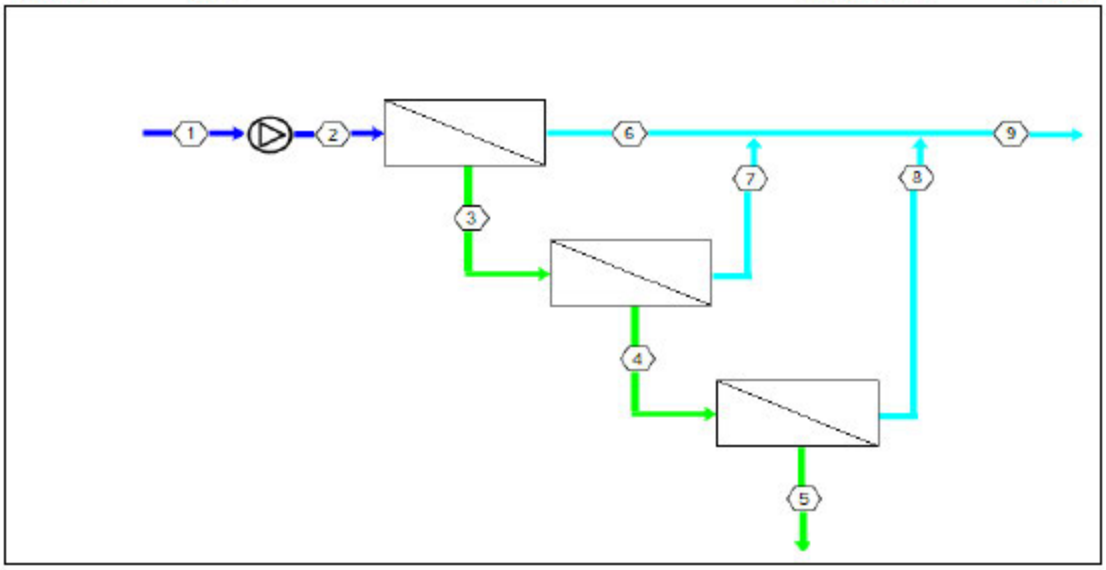
Permeate Throttling (Variable)

Project name Brokenhead Page : 4/4

Temperature : 0.5 °C Element age, P1 : 0.0 years



Stream No.	Flow (gpm)	Pressure (psi)	TDS (mg/l)	pH	Econd (µs/cm)	Langelier
1	246	0	872	8.24	1303	0.570
2	246	143	872	8.24	1303	0.570
3	127	134	1697	8.51	2332	1.39
4	61.1	124	3507	8.79	4511	2.26
5	36.9	115	5777	8.98	7204	2.85
6	120	11.0	7.00	6.19	9.20	-6.310
7	65.8	11.0	22.4	6.69	28.9	-4.836
8	24.2	11.0	80.4	7.25	104	-3.216
9	210	11.0	20.3	6.65	26.3	-4.952

Appendix E

RM of Brokenhead Preliminary Hydrogeological Testing Results – Friesen Drillers

Friesen DRILLERS

May 27, 2022

Ms. Dee Genaille, M.Sc., P.Eng.
Senior Design Engineer
Manitoba Water Services Board
2010 Currie Blvd, Brandon, MB R7A 6Y9

Dear Ms. Genaille,

Subject **Preliminary Hydrogeological Testing Results**
Supplementary Groundwater Supply - Tyndall-Garson WTP Upgrade
Rural Municipality of Brokenhead

Friesen Drillers is pleased to provide this letter to detail the preliminary results of hydrogeological investigations undertaken for the planned expansion of the groundwater supply for Tyndall-Garson, in the Rural Municipality of Brokenhead (RM).

Project Background

The RM maintains a municipal water supply system currently developed from two supply wells located on the WTP property. The groundwater treatment includes a reverse osmosis process as part of a Class 2 Water Treatment Facility & Class 2 Distribution Facility (RM of Brokenhead, 2020). The treated water is stored in reservoirs that have a capacity of 228,000 gallons (1,035,120 liters). As of 2020, the municipal system had 654 services connected, including 640 domestic and 14 commercial connections (RM of Brokenhead, 2020).

Recent well assessments indicated that the existing wellfield has a combined maximum capacity of 27.6 L/s, or about 440 U.S.G.P.M. (FDL, 2021). It is understood that the WTP upgrades will have a design flow rate of 50 L/s, or about 792.5 U.S.G.P.M. An additional raw water capacity of 25 L/s (396.3 U.S.G.P.M.) has been requested to supply the upgraded WTP. The total annual withdrawal is also projected to increase from an allocation of 226 dam^3/year to 650 dam^3/year (Pers. Comm. – MWSB, Nov. 5, 2021).

Public Consultations – Well Inventory

A review of the provincial water well database indicated over 200 private domestic wells could be present around the WTP site (GWDRILL, 2018). It was further noted that many of these wells may no longer be in use, as a larger number of residences have switched to the municipal system. Friesen Drillers was retained in the current project to conduct a hybrid style well inventory campaign. The main objectives of the well inventory were to identify existing groundwater users that may be impacted by increased pumping, and to establish the number of abandoned wells that remain to be sealed. Further, the inventory identified potential monitoring sites from residents willing to participate in the testing process.

The well inventory was conducted in March-April, 2022. Residences located within a 1-mile radius of the existing WTP site received a letter by mail inviting them to participate in the inventory. All residents who agree to participate in the well inventory were asked background questions about their wells, such as the age of the well, the well driller, the type of well connection/well pump, and if any issues have been experienced and whether unsealed wells are present on their property. The inventory was done either over the telephone or through email. No mechanic assessments have been completed to date.

A total of 17 residents responded to the inventory request. Detailed results of the well inventory will be compiled as part of a separate letter and will be included in the final report to be submitted to Manitoba Environment, Climate, and Parks.

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Preliminary Testing Results

Prior to any field work, a Groundwater Exploration Permit (GEP) was obtained from Manitoba Environment Climate and Parks (MECP). A copy of the GEP is attached.

The test well locations were selected with input from the RM and the project team. It was understood that the preferred locations for additional supply wells would be as close to the existing WTP site as feasible to minimize additional infrastructure costs. It was noted that the proximity to existing wells should be balanced with the impacts of well interference. If new well(s) are placed adjacent to existing wells, then pumping impacts between new and existing supply wells could reduce overall yields. As a result, a series of test sites was selected, including locations at the WTP and progressively farther south. In total, four test wells were drilled, all located along May Street, as shown in Figure 1. Buried utilities were marked at each site prior to drilling.

Figure 1 – Test hole locations (TH1-4); Tyndall-Garson, RM of Brokenhead. (Source – Google Earth, 2022)

The test well construction details are shown in Table 1. Each test well included multi-level completion into the upper and the lower zones of the carbonate aquifer. This allowed for an assessment of the hydraulic interconnection between the various zones of the bedrock. From the testing, the upper surface of the bedrock was encountered at depths of 18-36 ft. below grade. The upper fractured zone extended from the top of the bedrock to about 140 ft. below grade. The deeper fractured zone extended to a depth of about 220 ft. below grade.

Table 1
Test Well Construction Details
Tyndall-Garson – RM of Brokenhead

Well ID	Well Tag	UTMX	UTMY	Upper Zone	Lower Zone
Well 1	No. 7599	666316	5549359	18-130 ft.	130-220 ft.
Well 2	No. 7623	666317	5549502	24-140 ft	140-219 ft.
Well 3	No. 7624	666308	5549729	30-140 ft.	140-218 ft.
Well 4	No. 7626	666316	5549426	36-145 ft.	145-220 ft.

Table 1 - Test well construction details, RM of Brokenhead.

Short-term capacity tests were conducted on both the upper and lower zones of the aquifer at each test site. The hydraulic testing results are shown in Table 2. The results indicated a fairly high level of variability between sites, which is typical for the fractured bedrock aquifer. The highest specific capacity results were reported from the lower zone of TH1, followed by TH3. In general, the upper zone of the aquifer was found to have a significantly lower yield than the lower zone.

Preliminary Testing Results (Cont'd)

Table 2
Hydraulic Testing Results
Tyndall-Garson – RM of Brokenhead

Well ID	Aquifer Zone	Static Level (ft. below grade)	Pumping Level (ft. below grade)	Test Rate (U.S.G.P.M.)	Specific Capacity (U.S.G.P.M./ft.)
Well 1 (Tag 7599)	Upper	9.8	19.9	69	6.8
Well 1 (Tag 7599)	Lower	15.6	28.7	89	6.8
Well 2 (Tag 7623)	Upper	17.2	27.1	4.5	<0.5
Well 2 (Tag 7623)	Lower	22.9	32.1	28	3.0
Well 3 (Tag 7624)	Upper	24.1	38.1	3.4	<0.5
Well 3 (Tag 7624)	Lower	28.3	40.5	78	6.5
Well 4 (Tag 7626)	Upper	25.6	35.6	2.5	<0.5
Well 4 (Tag 7626)	Lower	19.8	32.1	27	2.2

Table 2 - Hydraulic testing results, RM of Brokenhead.

Groundwater samples were collected from the upper and lower aquifer zones. Selected samples were submitted to an accredited laboratory for analysis of routine geochemistry and stable environmental isotopes (^{18}oxygen and deuterium). The results of the laboratory analysis are attached (L2707736). In addition to the laboratory analysis, basic field parameters were measured in the field. The results of the preliminary geochemical analysis are shown in Table 3.

The total dissolved solids (TDS) content ranged from about 400 mg/L at Well 1-Lower, to about 850 mg/L at Well 4-Upper. The average TDS value was about 600 mg/L, with lower aquifer zones reporting slightly higher concentrations than the upper aquifer zone within the same test well. These results were consistent with TDS values of 550-640 mg/L, previously reported for the existing supply wells (FDL, 2021). The salinity values ranged from about 400 to 700 mg/L, with an average of about 500 mg/L. In general, the geochemistry appeared to be consistent with regional conditions and suitable for the intended use for a treated municipal water supply. It should also be noted that the geochemistry could change slightly with pumping over time. It would be recommended that the WTP design team review the chemistry and provide comment on the options moving forward.

It was also noted that some fracture sediment was observed in the water samples, which produced some elevated turbidity results. The turbidity was generally higher from samples in the upper zone (ALS-L2707736). It is anticipated that with more rigorous well development efforts, the turbidity values could be improved from the reported testing values. It is common for new wells in the carbonate aquifer to initially produce elevated turbidity and to gradually clean up with development or pumping over time.

Table 3
Preliminary Geochemistry
Tyndall-Garson – RM of Brokenhead

Well ID	Aquifer Zone	Electrical Conductivity (uS/cm)	Total Dissolved Solids (mg/L)	Turbidity (NTU)
Well 1[1]	Upper	689	461	111
Well 1[1]	Lower	677	397	49.8
Well 2[2]	Upper	797	573	n.a.
Well 2[2]	Lower	847	606	n.a.
Well 3[1]	Upper	837	600	218
Well 3[2]	Lower	1,129	805	n.a.
Well 4[1]	Upper	855	847	398
Well 4[1]	Lower	870	516	19.1
Notes	[1] Data from ALS-L2707736 [2] Field measurements - FDL, 2022 n.a. – data not available			

Table 3 - Preliminary geochemistry, RM of Brokenhead. (Data source – ALS- L2707736; FDL, 2022)

Data Analysis

Estimated Well Yields

The estimated yield at each test well location, based on the hydraulic assessments, is shown in Table 4. Due to the higher capacity, increased available drawdown, and better confined aquifer conditions observed for the lower aquifer zone, only the lower zone at each tested location was considered for a larger well completion.

The results in Table 4 suggest that Well 1 would have the highest estimated flow rate potential. It should be noted that specific capacity values tend to increase slightly when the borehole diameter is increased, as would be the case for a production well. Further, specific capacity can also vary for different pumping rates. The installation and testing of a larger diameter production well would be necessary to confirm actual well yields at each site. However, depending on specific project requirements, each of the tested sites could warrant the installation of a larger diameter test well. Even the lowest estimated yields were greater than the maximum range for a 5-inch well.

Table 4 Estimated Well Yield Tyndall-Garson – RM of Brokenhead			
Well ID	**Specific Capacity (U.S.G.P.M./ft.)**	**Production Casing Depth (ft.)**	**Estimated Rate (U.S.G.P.M.)**
Well 1 (Tag 7599)	6.8	130 ft.	350-400
Well 2 (Tag 7623)	3.0	140 ft.	200-250
Well 3 (Tag 7624)	6.5	140 ft.	150-200
Well 4 (Tag 7626)	2.2	145 ft.	150-200
Notes	*Capacity of Well 3 was reduced due to well interference impacts from existing supply wells.		

Table 4 – Estimated well yield; RM of Brokenhead.

Discussion and Recommendations

An increased raw water capacity of 25 L/s (396.3 U.S.G.P.M.) was requested to supply the upgraded WTP. This assumed the existing supply wells have a combined maximum capacity of 27.6 L/s, or about 440 U.S.G.P.M. As there is potential for well interference between new and existing supply wells, the new wells will likely need to produce slightly more than 400 U.S.G.P.M. to make up for any reductions in the existing well capacities. Testing and monitoring will be necessary to confirm the details of the potential well interference impacts.

As Well 1 had the highest tested capacity and is located farthest from the WTP (i.e., lowest inference potential), the Well 1 site would be recommended for further testing. Recommendations for further testing are provided in the following sections.

As the estimated capacity of the Well 1 test site is approaching the target of 400 U.S.G.P.M., it is anticipated that only one new production well in addition to TH1 may be necessary to make up the required flow. Selection of a secondary site for conversion and testing was not immediately obvious from the data. However, the limitations of TH3, due to interference at the WTP, make it less suitable for further testing.

In comparing results from the TH2 and TH4 sites, the preliminary hydraulic capacity at TH2 (3.0 U.S.G.P.M./ft.) was similar, though slightly higher than at TH4 (2.2 U.S.G.P.M./ft.). The TDS content was also similar, with TH4 (516 mg/L) reporting a slightly lower value than TH2 (606 mg/L). It appears that both sites would likely be sufficient to provide the required pumping volumes in conjunction with TH1. As the TH2 site provides a bit more spacing between the well sites, it might have a slight advantage over TH4. It is recommended that the WTP design team review and comment on the geochemistry and flow requirements of the options moving forward.

Production Well Design and Construction

Larger diameter production wells will be needed to achieve the flow rates requested in this project. The construction of larger diameter wells should include steel casing that is extended through the overburden and upper fractured zone of the bedrock. The well casing should be installed to the depths noted in Table 4 and be grouted in place. Next, the borehole should be advanced, open-hole, to the final completion depth in the deeper fractured zone of the Carbonate Aquifer. The final depths should be approximately 220 ft. below grade.

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Production Well Design and Construction (Cont'd)

Based on the testing results, it is recommended that a test well with 10-inch diameter completion be constructed at the Well 1 test site. This design would allow for up to an 8-inch submersible pump, which could produce 400 U.S.G.P.M. or more. The conditions noted for the remaining test sites were more suitable for 8-inch diameter completions. This design would allow for up to a 6-inch submersible pump capable of about 150-300 U.S.G.P.M. An 8-inch diameter completion well could be constructed at either the TH2 or TH4 sites.

As turbidity was noted during testing, contingencies for additional well development during construction would be recommended. Generally, this can be accomplished by surging action using compressed air, although surge blocks and cable-tool may also be required. The well development efforts should be supervised by a qualified hydrogeologist/hydrogeological engineer.

72 Hour Pumping Test

After the production wells have been constructed, a 72-hour pumping test should be completed on the new production wells. A minimum of 24-hour testing duration is required by MECP for a water supply greater than 200 dam^3/year produced from a confined aquifer source. However, given the considerations for potential interactions between upper and lower zones of the aquifer, and the presence of aggregate extraction operations within a mile of the site, a longer testing duration is recommended. A 72-hour testing duration would also allow the drawdown cone to develop around the wells and allow for an assessment of the aquifer response to pumping from both the new and existing supply well sites.

The target pumping rate from the new production wells should be at least 396 U.S.G.P.M. (25 L/s). The existing supply wells should also be pumped for a period of time during the test to confirm the capacity of the full system. At the cessation of pumping, the water level recovery should be monitored until at least 90% recovery is reached, as is required by regulations. Details of the pumping test should be designed and supervised by a qualified hydrogeologist/hydrogeological engineer.

Aquifer Monitoring Plan

Monitoring the aquifer response to pumping will be a critical component of the hydrogeological analysis. A network of monitoring transducers would be necessary to delineate the drawdown cone during pumping and to assess the potential interaction between the upper and lower zones of the carbonate aquifer in the area. Understanding these dynamics will be important to assess a number of key technical considerations, including the potential for third party well interreference, potential changes to groundwater quality with pumping, and source water protection. All of these considerations are crucial to assess the long term viability of the expanded groundwater supply.

To obtain the necessary monitoring data, a network of monitoring wells should be established during testing. The network could include a combination of provincial, municipal and private wells. The recently completed well inventory identified numerous residents who are willing to have a transducer installed in their private wells. This information should be compiled and strategic observation well locations selected. In addition, the existing municipal production and test wells should be instrumented to monitor for groundwater level fluctuations at distance from the test site. The observation wells will allow for simultaneous monitoring of the upper and lower zones of the carbonate aquifer.

Details of the groundwater monitoring plan should be designed and supervised by a qualified hydrogeologist/hydrogeological engineer.

Groundwater Sampling and Analysis

The groundwater quality and the potential changes to quality during pumping is an important aspect of the pumping test. To adequately assess the potential changes, groundwater samples should be collected throughout the pumping test. In addition, field measurements of parameters such as pH, turbidity, electrical conductivity, and turbidity should be measured at regular intervals during the pumping test.

The groundwater samples should be sent to an accredited laboratory for analysis of routine geochemistry, stable environmental isotopes of oxygen and hydrogen. A Test 72D sample set, along with any other requested analyses, should also be collected from the new production wells at the end of the 72-hour pumping interval.

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Licence Applications - Hydrogeological Analysis and Reporting

Upon completion of the pumping tests, the drawdown/recovery data should be analyzed by a licensed professional hydrogeologist/ hydrogeological engineer. The conclusions and recommendations from the testing should be presented in a sealed report. The report should aim to satisfy the requirements to obtain a Water Use License and an Environment Act License as related to the develop a groundwater supply for municipal purposes.

The contents of the hydrogeological report should include but not be limited to the following:

- Description of local and regional geological/hydrogeological conditions.
- Review of historical hydrograph and meteorological data.
- Assessment of existing groundwater users and groundwater development.
- Assessment of the recharge dynamics for the regional groundwater systems.
- Pumping test analysis, including and assessment of the interactions between the upper and lower zones of the carbonate aquifer.
- Projected aquifer drawdown calculations and estimated long term impacts to aquifer and nearby groundwater users.
- Review and assessment of the well inventory results in the context of the water supply expansion.

We thank you for the opportunity to be of service on this project. Please contact the undersigned with any questions or comments about this report.

Sincerely,

Friesen Drillers Limited

Justin Neufeld, B.Sc.,(G.Sc.), P.Geo.
Groundwater Geologist

Reviewed by,

Friesen Drillers Limited

Jeff Bell, B.Sc.(G.E.), P.Eng.
Hydrogeological Engineer

Attachments Groundwater Exploration Permit – RM of Brokenhead
Drillers Logs – TH1-TH4 – Friesen Drillers
Geochemistry Analysis – ALS-L2707736

References

GWDRILL, 2018. Provincial Water Well Database; Groundwater Management Section – Province of Manitoba.

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