COMMENTS RE: Proposed Beausejour Water Supply System – Environment Act Proposal FILE 6059.00

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OBJECTIVE

The present document puts forward comments with regard to the Proposed Beausejour Water Supply System as described in the Manitoba Environment Act Proposal FILE 6059.00. It focuses primarily on two aspects of the project: A) suitability of reverse osmosis as the treatment of choice, and B) concerns regarding the water source wells.

ACRONYMS used in this document

AO = Aesthetic objective

CDWQG = Canadian Drinking Water Guidelines https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/water-quality/guidelines-canadian-drinking-water-quality-summary-table.html#t2

EAP = Environment Act Proposal FILE 6059.00

EAPHR = Environment Act Proposal Hydrogeological Report (Appendix G of EAP)

RO = Reverse osmosis

WHO = World Health Organization

1.0 Reverse Osmosis (RO)

RO is a water treatment process which utilizes pressure to force water through a microporous membrane. Water molecules pass freely through the membrane and form the usable water (i.e. permeate). Solutes and particles which exceed the micropore size cannot cross the membrane and are retained in the wastewater (i.e. concentrate, aka retentate, aka brine) which is discharged and the rejected water is wasted. The efficiency of RO systems is highly variable and is dependent on numerous factors such as the concentration of materials in the raw water, pore size, water pressure. Removal of different substances is not related to their toxicity, but to molecular, colloidal or particle size and configuration. Because undesirable or toxic small molecules can cross the membrane, some reverse osmosis systems utilize an added activated carbon filter to remove these molecules from the permeate.

Quoting from Kozisek (2020) in a WHO report: “These technologies became more extensively applied in drinking water treatment in the 1960’s as limited drinking water sources in some coastal and inland arid areas could not meet the increasing water demands resulting from increasing populations, higher living standards, development of industry, and mass tourism. Demineralisation of water was needed where the primary or the only abundant water source available was highly mineralized brackish water or sea water. Drinking water supply was also of concern to ocean-going ships, and spaceships as well….. However, some countries focused on public health research in this field, mainly the former USSR where desalination was introduced to produce drinking water in some Central Asian cities."

RO water treatment plants are still largely used where raw water contains **very high total dissolved solids**, such as desalination plants for seawater, treatment of briny groundwaters, mitigation of mining waste and other industrial wastewater, and tertiary sewage treatment (Perez-Gonzalez et al., 2012), or where contaminated water must be reused. According to Joo and Tansel (2015), this technology is associated with "relatively high operational cost and energy consumption", as well as high environmental costs. The central question therefore arises why RO has been chosen as the process method for the Beausejour water treatment plant.

1.1 Water source quality and suitability of RO

Current water quality as reported in Appendix D (EAP) demonstrates the following items of note as summarized in Table 1 below. CDWQG exceedances are in **bold**.

Table 1. Notable water quality parameters in the two source wells located on Road 71N.
AO = aesthetic objective

Parameter	**East well**	**72 Hour pump test (range) West well**	**CDWQG maximum**
Total dissolved solids mg/L	475	372 - 431	500 (AO)
Total alkalinity mg/L (equivalent $CaCO_3$)	357	318 - 357	
pH	7.5	7.61 - 7.67	7.0 – 10.5
Hardness ($CaCO_3$)	497	353 - 376	80-100 suggested
Ammonia (N) mg/L	0.23	0.15 (72 hr only)	**<0.05 (N) preferred**
Calcium mg/L	94.9	63.2 - 64.4	
Magnesium mg/L	63.3	47.4 – 52.5	
Potassium mg/L	4.56	3.56 – 4.02	
Sulphate mg/L	61.3	29.7 - 39.0	500 (AO)
Iron mg/L	2.38	0.94 - 1.19	**0.3 (AO)**
Manganese mg/L	0.058	0.016	**0.02 (AO**)
Silica mg/L	15.9	16.4 (72 hr only)	
Organic carbon mg/L	2.84	1.96 (72 hr only)	

- **Total dissolved solids** are **within** the CDWQG.
- **Total alkalinity and pH** indicate moderately alkaline water of low aggressive index and minimal leaching capacity
- **Sulphate** is well within the CDWQG AO. Hydrogen sulphide gas is present in this aquifer (Pip, unpublished data) but was not included in the analytics of the EAP.
- **Hardness** is above the suggested CDWQG. The majority of hardness is contributed by calcium.
- **Iron** exceeds the CDWQG AO in all samples.
- **Manganese** shows a significantly greater East well value than the CDWQG AO, while the West well values are relatively constant and within the AO.
- **Ammonia** is a concern and indicates contamination.
- **Organic carbon** is a concern and indicates contamination. The organic concentration approaches/falls within the concentration found in many surface waters (2-5 mg/L) (Malaeb and Ayoub, 2011).
- Heavy metals (EAP, Appendix D and Addendum) are not a concern in the raw water.
- A problematic and substantial disparity exists between the East and West well values for total dissolved solids, hardness, calcium, magnesium, potassium, sulphate, iron, manganese, ammonia and organic carbon, where the East well concentrations are strikingly higher. The two wells are only 792 meters apart (EAP, p. 47), yet why is their water quality so different? The EAPHR seems to provide little comment on this matter.

The primary issues with this water are: A) hardness, B) iron, and C) evidence of contamination, viz. ammonia and organic carbon. Hardness and iron, the two principal reasons for treatment of this water, are aesthetic concerns: hardness promotes formation of scale on pipes and interferes with detergents, while iron causes staining of fixtures and laundry.

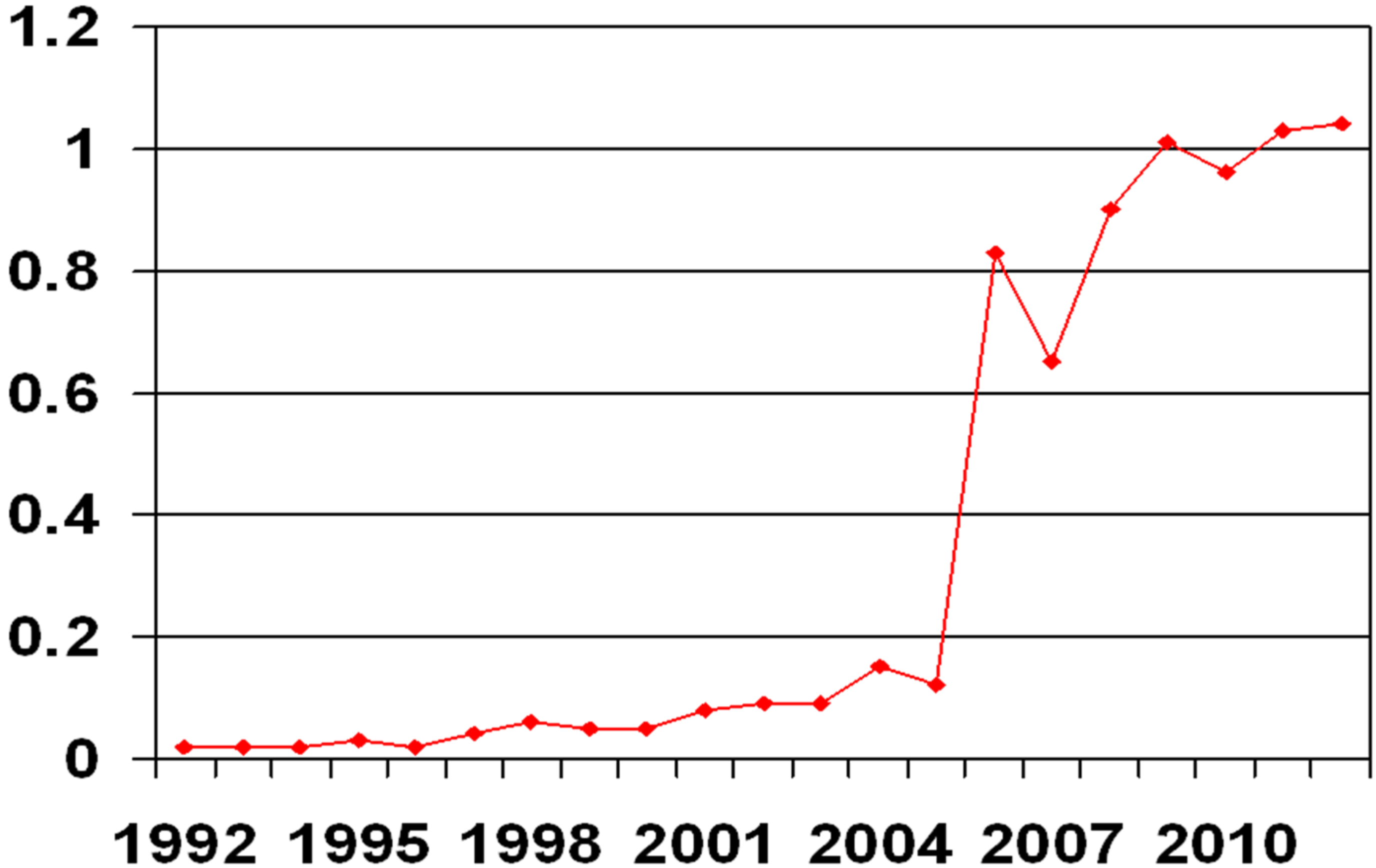
The presence of ammonia and organic carbon in this **confined** aquifer (EAP, p. 14), shows that the upper confining layer(aquitard) is not intact and pollutants have been allowed to intrude into the aquifer. According to the EAPHR (p. 71), "It is noted, however, that the confining layers include sandy materials, especially at the east well site. The permeable sand and gravel intervals will limit the overall effectivness [sic] of the overburden as a protective boundary. It should also be noted that quarry operations west of the sites, further reduce the local overburden cover and increase the potential for surface water impacts to reach the local groundwater aquifer." Here may be a clue to the East-West well conundrum: the East well is right on the edge of Town, where the sandy materials are unfortunately the enablers for percolation of pollutants. Indeed, both wells suffer from the occurrence of permeable deposits that: A) make these sites not the best choice for a permanent water supply, and B) require all the more that these sites be protected and restricted from any influences that might result in contamination.

Ammonia and organic carbon are most commonly associated with agricultural pollution (ammonia fertilizers, manure, pesticides) and with septic tank effluent or ejection systems (human and household waste) that are located near well casings of either abandoned wells or poorly constructed/maintained newer wells. As the number of wells drilled into the confined aquifer increases, the contamination potential escalates. Other drilling activities, for example unrestrained test core drilling in gravel pits (e.g. Road 70N) provide vastly more potential for intrusion of pollutants such as oil, mechanical fluids and human and animal waste, and these sites also become repositories for garbage dumping.

With regard to ammonia, the statement in the EAPHR (p. 63): "While Health Canada does set a limit on this parameter, it is an important consideration for the water treatment process." This should read "Health Canada does NOT set a limit…" Ammonia is also a consideration in the concentrate, because discharge to the Brokenhead River will affect fish and other biota, and be accompanied by nitrification to nitrite and nitrate.

During the three decades that I have lived just over 2 miles southwest of the West well location, I have monitored my well water weekly in my lab, until I retired. Figure 1 is comprised of data points which, for the sake of simplicity, represent the first week of April every three years.

Figure 1. Nitrate-N (mg/L)(vertical axis) in the first week of April every three years in my well water >2 miles southwest of the West well on Road 71N.



From Figure 1 it can be seen that nitrate-N in my well water abruptly increased around 2005, and the upward trend continued beyond to approximately 1 mg/L nitrate-N. During this time there was increased residential development in the Cloverleaf area 2 miles to the south, increased cattle production to the east, northeast and northwest of my property, and intensive drilling and excavation in the gravel pit diagonally across the road from my property. A new well was drilled ca. 2001 inside a cattle enclosure northwest of my property. However the specific cause(s) cannot be definitively attributed.

According to the EAPHR (p. 37), "From the available data, nitrate concentrations around Beausejour are below the MAC and were below detection limits in provincial stations G05OJ155 and G05SA011. Nitrate was detected at concentration of 2.6 mg/L in station G05OJ164, located west of Beausejour. The cause of the elevated nitrate in this area was not defined, although it is suspected that the bedrock in this area is relatively shallow with a thinner protective layer." Since station GO50J155 (Figure 13, EAPHR) was below detection limits and is located less than a mile from my property, this, as well as the differences in water quality between the East and

West production wells, illustrates how heterogeneous and unpredictable hydrological conditions are in the region, as well as the importance of direction of flow and contaminant plumes. The time of year may also be a factor: I selected the first week of April, as this falls within the snowmelt period and time of major recharge. Indeed nitrate-N in my well water varies throughout the year. It is suggested that many more sampling locations are needed in order to gain a better insight into nitrate conditions in the area.

The composition of the organic carbon found in the raw water samples (Table 1) has not been characterized, and it is not known whether these are natural compounds (e.g. humic acids, polysaccharides, lipids), or whether agricultural pesticides or petroleum compounds can also be detected. The performance of RO in removing these compounds will depend on their size. Small volatile organics will pass through the membrane, larger molecules will be removed more efficiently. Organic substances on the RO membrane have the potential for promoting growth of microorganisms and biofouling (Jiang et al., 2017).

Although not considered in the EAP, this aquifer contains the toxic dissolved gas hydrogen sulphide and small amounts of sporadic radon (Pip, unpublished data). For worker safety, the treatment plant must be well ventilated.

1.2 RO and Taste

According to Bruvold and Ongerth (1969) total dissolved solids affect the organoleptic properties of water, with values between 300-600 mg/L (i.e. the current well water) rated as **good**, and unacceptable above 1200 mg/L. Water containing less than 50 mg/L total dissolved solids has “negative taste characteristics” (Kozisek, 2020), and is aesthetically undesirable because of the “flat, insipid taste” (WHO, 2003). It is also perceived to be “less thirst quenching” (WHO, 1980).

Perceived **freshness** of water is correlated with calcium concentration (Vingerhoeds et al., 2016). Decreased alkalinity is associated with a “drying, bitter taste”(Burlingame et al., 2007).

For these reasons, bottled RO water may be remineralized, i.e. calcium carbonate, magnesium chloride as well as other salts are added to the permeate to improve taste (Vingerhoeds et al., 2016) (e.g. Dasani brand bottled water).

As a point of interest, my own raw well water, drawn from the same aquifer, is consistently commented on by visitors as having excellent taste, and some request taking a container of it back with them to Winnipeg. The calcium is the primary reason. Thus from the standpoint of taste, unamended RO water decreases consumer experience and satisfaction. While the distributed water from the treatment plant will consist of a blend of ca. 20% of raw water (EAP, pp. 15-16), it will not have the taste that it does now. Furthermore, the mandatory chlorine residual will be more noticeable for many consumers, who may defect in favor of bottled water, which is ozonated, carbonated, or has no disinfection at all (Pip, 2000a).

1.3 RO and health impacts

RO water contains low concentrations of dissolved minerals, and beneficial elements such as calcium, magnesium and potassium are particularly deficient in the permeate (Burlingame et al., 2007). According to Islam et al. (2016), RO drinking water does not support human health, and may be particularly harmful for children and low income consumers who are already prone to malnutrition. The latter authors define low total dissolved solids as <100 mg/L: thus all unamended RO permeate falls into this category. Water used in drinking and cooking can constitute a source of numerous micronutrients. These are especially valuable in that they are usually present in water in easily absorbed ionic forms, whereas in food they are often bound to organic molecules which may be less assimilable (Kozisek, 2020). RO can severely reduce these nutrients.

In a current WHO report, Kozisek (2020) commented that "It was clear from the very beginning that desalinated or demineralised water without further enrichment with some minerals might not be fully appropriate for consumption." Demineralized water adversely affects the ionic and water homeostatic mechanisms of the body. A WHO (1980) study summarized by Kozisek (2020) found that "Low-mineral water markedly: 1.) increased diuresis (nearly 20%, on average), body water volume, and serum sodium concentrations, 2.) decreased serum potassium concentration, and 3.) increased the elimination of sodium, potassium, chloride, calcium and magnesium ions from the body."

Many studies have reported an **inverse** relationship between **reduced hardness** in public water supplies and **increased incidence** of:

- **cardiovascular and heart disease** (e.g. Schroeder, 1960; Bernardi et al., 1995; Sauvant and Pepin, 2002; Kozisek, 2020)
- **hypertension** (Lutai, 1992 and Mudriy, 1999: both in Kozisek, 2020)
- **colon cancer** (Yang et al., 1997)
- **stomach cancer** (Yang et al., 1998)
- **esophageal, pancreatic, breast cancer** (see review by Kozisek, 2020)
- **higher mortality rates** (e.g. Crawford et al., 1968)
- **chronic degenerative diseases** (e.g. Donato et al., 2003; Nardi et al., 2003)
- **cognitive impairment in the elderly** (Jacqmin et al., 1994)
- **bone fractures in children** (Verd et al., 1992 in Kozisek, 2020)
- **low birth weight** (Yang et al., 2002)

The beneficial effects of calcium and magnesium in drinking water are particularly striking in cardiovascular disease, and **exposure to a deficient water supply need not be lengthy**.

According to Kozisek (2020), citing a heart attack study by Rubenowitz et al. (2000), "While the effects of most chemicals commonly found in drinking water manifest themselves after long exposure, the effects of calcium and, in particular, those of magnesium on the cardiovascular system are believed to reflect recent exposures. Only a few months exposure may be sufficient consumption time effects from water that is low in magnesium and/or calcium." Other symptoms linked to consumption of RO water include fatigue, and weakness and muscle cramps, suggestive of magnesium/calcium deficit (Kozisek, 2020).

The significant relationship between water of low hardness/calcium and higher incidence of many cancers is believed to result from the ability of calcium to form insoluble, unassimilable complexes with toxic heavy metals, and thus mitigate their carcinogenic effects (Pip, 2000). As hardness, pH and alkalinity decline, the solubility of metals increases. Intracellular absorption of metals is directly related to their solubility in water. While RO reduces metal concentrations in the permeate, and while metal concentrations in the raw well water in question are low, the concern here stems from the acquisition of metals within the distribution and plumbing systems after the finished water has exited the plant (see further discussion in section 1.6 below).

Water that is used in cooking and subsequently discarded presents another concern regarding the nutritional quality of the food that has been cooked. Water of low hardness may leach essential nutrients from vegetables, meats and cereals during the cooking process: for example up to 60% for calcium and magnesium, 66% for copper, 86% for cobalt. Hard water, on the other hand, is associated with smaller losses, and calcium content of the food may even increase (Haring and Van Delft, 1981).

Many rural residences in the Municipality of Brokenhead that draw their water from a private well contain a separate tap in the kitchen that supplies raw water for drinking and cooking, bypassing the softener, and thus providing all of the health benefits of the minerals in the water. My own residence was built in 1980 and was provided by the builder with such an arrangement: therefore the health benefits of hard water have been known for a long time.

After lengthy study, WHO issued the following conclusion, as summarized by Kozisek (2020):
"After evaluating the available health, organoleptic, and other information, the team recommended that demineralised water contain 1.) a minimum level for dissolved salts (100 mg/L), bicarbonate ion (30 mg/L), and calcium (30 mg/L); 2.) an optimum level for total dissolved salts (250-500 mg/L for chloride-sulfate water and 250-500 mg/L for bicarbonate water); 3.) a maximum level for alkalinity (6.5 meq/l), sodium (200 mg/L), boron (0.5 mg/L), and bromine (0.01 mg/L)."

Plainly, unamended RO drinking water does not approach most of these metrics. Note that **total dissolved salts in the raw water are already within the WHO optimum range of 250-500 mg/L.**

The EAP (p. 15-16) states that “The membrane system will be designed to reduce hardness ions to range between 80 – 120 mg/L CaC03). Membrane systems remove a significant portion of the dissolved minerals. In order to achieve an aesthetically–acceptable level of hardness, approximately 20% of the raw water flow will by-pass the membrane unit and receive treatment in a greensand pressure filter to be blended with treated membrane permeate following removal of iron and manganese. Alone, membrane permeate is generally chemically unstable and benefits from the addition of filtered greensand bypass water and/or caustic soda to adjust the pH to a suitable level within the distribution system. The blend flow will be set to increase the longevity of the membranes and decrease operational costs.”

Thus, energy will be used to remove minerals from the water, and energy will be used to blend raw water back in. We are not told what exactly is meant by “significant portion of the dissolved minerals” as it relates to the proposed system, nor what “suitable level” of pH will be sought, using sodium hydroxide (EAP, Figure 2.2), which will enrich the finished water with unhealthy sodium. Figure 2.2 also indicates that a “sequesting agent” [sic] will be added (surely “sequestering agent” is meant?), but is not specified. After all of this bypassing and blending, the EAP remains vague on details of the finished product. The composition of the blended water does not seem to be included in the model in Appendix E (EAP, p. 52) i.e. Table 3 below.

How will the “longevity of the membranes” and “operational costs” (EAP, p. 16) be assessed with respect to how the final blend flow will be determined? How long a period will be required for sufficient data? With respect to membrane longevity, what are the projected lifespans, how often will the membranes need replacement, and what are the projected costs?

1.4 RO and membrane fouling

RO membranes are subject over time to accumulation of deposits on the membrane surface or inside the micropores, and growth of organisms which cause decline in permeation and solute rejection (Malaeb and Ayoub, 2011). Fouling may require pretreatment of the raw water and more frequent membrane cleaning, involving the use of chemicals, and may affect membrane longevity (Jiang et al., 2017). Fouling may be associated with a variety of substances in the raw water, for example calcium carbonate and calcium sulphate which cause scaling, silica (e.g. see Table 1), and organic compounds. However in practice, fouling is usually attributable to several foulants operating together, and these foulants in turn may become colonized by bacteria (i.e. biofouling)(Jiang et al., 2017).

In the present case, hard water (Table 1) will present the potential for calcium carbonate scaling, which is one of the most common types of RO membrane fouling (Jiang et al., 2017). Silica (Appendix D, EAP), iron (Table 1) and large organic macromolecules can also present risk of colloidal fouling (Jiang et al., 2017). RO membrane fouling with organic matter (e.g. polysaccharides) is in turn aggravated by calcium (Lee et al., 2006). Organic matter in the raw water (Table 1) can further present the potential for biofouling. Iron and manganese fouling may occur with water that has not been pretreated to reduce these metals.

1.5 Manganese greensand filtration

According to the EAP (pp. 14-16) the portion of the raw water destined for blending with the permeate will pass through manganese greensand filters. In Figure 2.2 of the EAP, it appears that water destined for membrane treatment will bypass the greensand. Therefore iron and manganese in the RO stream will be removed by the membranes, but membrane fouling by iron and manganese seems to be not considered as a concern in the present design.

According to Joo and Tansel (2015), "The most significant drawbacks of using pressurized membrane systems for water treatment are membrane fouling and concentrate management." Iron and manganese fouling can be addressed by manganese greensand filters, which also reduce hydrogen sulphide (Ning, 2009). The composition and mechanics of manganese greensand filters have been reviewed by WCWC (2018). This type of filter is suitable where combined concentration of iron and manganese in the untreated water are less than 15 mg/L: the current raw water is well below this level (Table 1); other options to reduce these metals are water softening, or aeration and filtration (McFarland and Dozier, 1996).

At small concentrations, iron and manganese are essential elements in human nutrition (Pip, 199a). In order to be toxic, large quantities of iron must be ingested, and iron poisoning is rare and limited to certain idiopathic conditions (e.g. haematochromatosis)(Health Canada, 1978). Concerns with iron in water supplies are unrelated to health.

Groundwater is devoid of oxygen, and thus iron is present in soluble Fe(II) form. On exposure to oxidants, Fe(II) oxidizes to Fe(III) which is insoluble and precipitates. Above concentrations of 0.3 mg/L (the Canadian aesthetic objective), iron may color the water a reddish hue (due to oxidation of Fe(II)) when exposed to air, and can stain plumbing and laundry.

Iron may also affect taste, but sensitivity varies greatly in the population. Cohen et al. (1960) reported that 5% of a taste test panel were able to detect ferrous sulphate in distilled water at a concentration of 0.04 mg/L, ca. 20% detected a concentration of 0.3 mg/L, while about half of the panelists detected a concentration of 3.4 mg/L. Based on these data, the concentrations in the present raw water (Table 1) of ca. 1 mg/L in the West well and double that in the East well would not be detected by some of the population.

Iron may provide an opportunity for iron bacteria of various taxa to grow and colonize plumbing systems, creating aesthetic and mechanical issues with nuisance slimes and acidic exudates. According to Cullimore and McCann (1978), these bacteria cause "corrosion of water pumps, pressure tanks, galvanized pipes and fittings; the clogging of metal and plastic pipes; the reduction of water flow and water pressure and the coating of the resin beds of water softeners with slime, reducing efficiency and imparting unpleasant tastes and odours to the water". According to the latter authors, infestations are common in the southern Prairies, as is iron as a substrate in groundwater, and they are frequently the result of infected drill bits, tools and repair equipment. Cullimore and McCann (1978) found that suitable conditions for growth occur at iron concentrations above 0.2-0.5 mg/L., thus the present aquifer is easily at risk (Table 1). Problems ensue rapidly after a well has been drilled or repaired. Control of an infestation is difficult, and the problem often recurs because the bacteria easily spread outside the treatment zone (Cullimore and McCann, 1978). In southern Manitoba a number of cases have been associated with drill bits that have not been properly disinfected (Pip, unpublished data).

Excessive manganese may also cause colouring of the water and staining issues, and impart a metallic taste, as well as interfering with the disinfection treatment process (Ellis et al., 2000). High concentrations of manganese in drinking water have been linked to neurological diseases in the elderly (WHO, 2011), as well as in children (Health Canada, 2016). The raw source water contains relatively low manganese levels from the standpoint of human health risk, but whether it does or does not fall within the aesthetic objective is ambiguous as the results for the two wells vastly disagree (Table 1).

According to Figure 2.2 and p. 23 of the EAP, the greensand backwash will be discharged to the sewage lagoons; the volume that will be generated and the additional burden on the lagoons is not quantified. Section "2.1.1.4 Backwash and concentrate disposal" (EAP, p. 16) makes no mention of backwash in the text, and deals only with concentrate disposal to the Brokenhead River. However lagoon effluent is eventually routed to the river.

Incidentally, the manganese brown water problem in the City of Winnipeg water supply has been unrelated to greensand, but was due to manganese present in the ferric chloride coagulant used in the treatment process (City of Winnipeg, 2014).

1.4 Water wastage

As water resources of good quality continually dwindle on our planet, conserving those resources becomes imperative in securing our future existence. Approximately 3% of the earth's water is freshwater, the great majority of which is contained in polar ice caps, glaciers, and deep groundwater. Roughly 1.2% of the earth's freshwater can be used for consumption. (https://www.nationalgeographic.org/media/earths-fresh-water/)

1.4.1 Water (non)conservation

RO is contrary to all principles of water conservation. Recovery of usable water in RO treatment plants varies from 35 – 85% (Perez-Gonzalez et al., 2012). According to the EAP (p. 22), the proposed treatment plant is projected to produce 5.3 L of concentrate per **per second**; the public Notice of Environment Act Proposal reads: “Up to 6 litres per second of concentrate water would be produced in the treatment process.”. According to the EAP estimate (p. 15), 16% of the drawn water will be wasted. This amounts to **approximately 167,000,000 + L** of squandered water per year. This is equivalent to more than **67 Olympic swimming pools** per year (an Olympic pool contains 2,500,000 liters (source: Wikipedia)). Since a major reason for putting the new wells into production is the imminent insufficiency of the present water supply, it seems paradoxical and counterproductive to be profligate with what we do have, when demand for it is only going to increase.

The reported wastage of the RO treatment plant for nearby Tyndall-Garson is given in Table 2 (Brokenhead, 2013, p. 2-10): the percentage of reject water per raw intake water ranged from 25.1% to 29.9% between 2008 and 2011. The average daily water consumption increased as well, as did the number of users. The Beausejour EAP does not identify design details that will achieve nearly half of the expected wastage compared to that of the Tyndall-Garson plant.

Table 2. Water consumption and reject water percentage for the Tyndall-Garson RO water treatment plant (Brokenhead, 2013).

Year	2008	2009	2010	2011
Average Daily Raw Water Usage (m^3/day)	155	245	286	335
Average Daily Water Consumption (m^3/day)	115	171	205	237
Percentage Reject (Reject Water/Raw Water Intake)	25.1%	29.9%	28.3%	29.3%
Estimated Population (Calculated based on building permits issued since 2004)	1,254	1,286	1,342	1,405
Actual Average Per Capita Water Consumption (L/person/day)	91	133	153	169

RO with its extravagant waste is a poor option in light of burgeoning climate change, where water shortages and drought on the Prairies are expected to intensify, and therefore aquifer recharge will decline, while water usage will skyrocket. Coupled with increased demands of future development, increasing population in the Town and the surrounding area, and proliferating subdivisions with increased numbers of wells on the aquifer, it is irresponsible to fritter away so much water. The EAP estimates of projected water use (section1.1.3, p. 7) are based on per capita population but seem to omit industrial users, which may require vastly greater amounts of water (at bulk rates), and which users Beausejour may wish to attract. No data are provided for current industrial park consumption, or businesses such as car washes. As future demand increases, will the plant be enlarged to waste even more? Water is precious, and will become increasingly so.

In section 5.8, headed "Water Conservation" (EAP, p. 35), we find the paragraph: "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." We are talking about educating hapless consumers about water conservation and pernickety leak detection at the same time that we are discarding many Olympic-size pools of water. We should be ashamed.

While the amount of wasted water is in itself heartbreaking, it is doubly shocking that this untreated water contains the concentrated reject minerals, metals and organics, which will be piped untreated to the Brokenhead River. Joo and Tansel (2015) have reviewed the numerous available technologies for reducing volume of concentrate, and therefore wastage, citing the benefits and drawbacks of each. However in the end, reduced volume equals increased environmental toxicity, and the problem of disposal remains. Short of prohibitively expensive dewatering, environmentally benign solutions have yet to be found.

1.4.2 Water uses

According to U.S. statistics, only **1%** of distributed tapwater is consumed in drinking and cooking (Cotruvo et al., 2016). The remainder is used for washing, watering lawns and gardens, flushing toilets, filling pools and hot tubs, air conditioning, heating and cooling, or simply wasted. The same tapwater is also supplied to industrial users, who usually get it at a preferential bulk rate which discourages conservation.

In Beausejour, what is the rationale for using RO water to wash cars, water lawns, and flush toilets?

For those residents who want RO water to drink, they can buy it at a variety of outlets, or install their own home RO systems complete with activated carbon filters. They do not require RO water for all of their other needs.

1.5 Concentrate disposal

RO treatment plants generate large volumes of waste concentrates which pose “a potentially serious threat” to aquatic ecosystems (Perez-Gonzalez et al., 2012). The disposal of RO concentrates requires due consideration of their environmental impact (Mauguin and Corsin, 2005).

The calculated concentrate solute loads have been copied from the EAP (p. 52) in Table 3 below. It is proposed that this concentrate will be dumped untreated into the Brokenhead River. Water quality values for the Brokenhead River (ranges for the 2008 ice-free season) (Pip and Reinisch, 2012) are given in Table 4, where the third column references the final concentrate values from Table 3.

It is immediately apparent from Table 4 that the total dissolved solids and chloride values will require substantial dilution in the river before they approach ambient values, and therefore the zone immediately downstream of the effluent outfall may adversely affect the soft-water species in the river, especially during low volume and velocity conditions. Given the huge volume of concentrate (section 1.4.1 above), the annual load of total dissolved solids discharged to the river will amount to >670,000 kg, that will subsequently be carried to Lake Winnipeg.

Table 3. Concentrate projection from Appendix E, page 52 of EAP.

Ion (mg/l)	Raw Water	Feed Water	Permeate Water	Concentrate 1	Concentrate 2
Hardness, as CaCO3	375.41	484.52	28.506	1161.4	2348.9
Ca	64.10	82.73	4.867	198.3	401.1
Mg	52.50	67.76	3.986	162.4	328.5
Na	30.30	36.70	9.995	80.3	145.9
K	4.02	4.69	1.897	9.6	16.1
NH4	0.19	0.21	0.102	0.4	0.6
Ba	0.107	0.137	0.011	0.3	0.7
Sr	0.287	0.368	0.030	0.9	1.7
H	0.00	0.00	0.000	0.0	0.0
CO3	0.86	3.19	0.009	9.4	43.1
HCO3	432.00	551.17	50.312	1291.9	2558.4
SO4	39.00	50.80	1.436	123.2	252.6
Cl	32.20	40.10	7.005	91.7	175.4
F	0.28	0.32	0.137	0.7	1.1
NO3	0.00	0.00	0.000	0.0	0.0
PO4	0.00	0.00	0.000	0.0	0.0
OH	0.00	0.00	0.000	0.0	0.0
SiO2	16.40	20.32	3.931	48.1	87.3
B	0.00	0.00	0.000	0.0	0.0
CO2	20.40	20.40	20.40	20.40	20.40
NH3	0.00	0.00	0.00	0.00	0.00
TDS	**672.24**	**858.50**	**83.72**	**2015.02**	**4012.48**
pH	**7.61**	**7.71**	**6.71**	**8.06**	**8.33**

Table 4. Water quality in the Brokenhead River upstream from Highway 44 and downstream from agricultural manure spread fields, weekly samples spanning May 1 – November 5, 2008 (Pip and Reinisch, 2012). The river values are compared with the final concentrate values from Table 3.

Parameter	**Brokenhead River**	**Final concentrate**
Total dissolved solids mg/L	90 - 330	4012
Chloride mg/L	1.0 – 5.0	175
pH	6.9 – 8.1	8.3
Total alkalinity mg/L	90 - 190	NA
Nitrate (N) mg/L	0.12 – 0.67	NA
Orthophosphate mg/L	0.09 – 0.77	zero

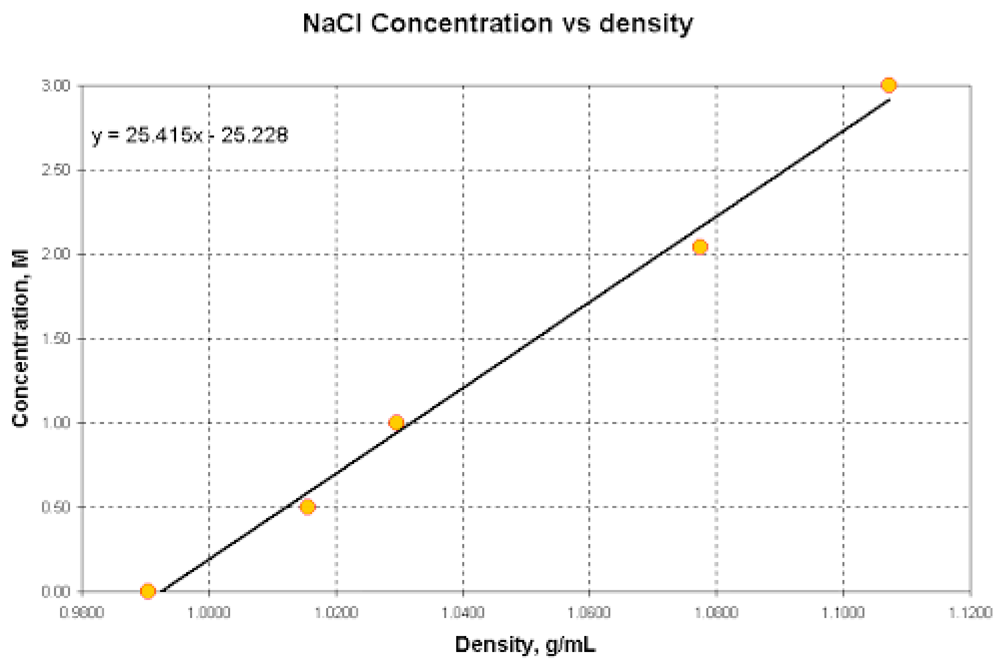
According to the EAP (pp. 26-27), "Two parameters above are conditionally exceed [sic] the limits of the Tier 2 guidelines: conductivity and total dissolved solids (TDS). The Water Quality Guidelines stipulate that discharge must be below a conductivity of 1000 µS/cm for periods where greenhouse irrigation is likely to occur and below 1500 µS/cm for periods when field, park, or garden irrigation is likely to occur. These guidelines also correlate to require a TDS of below 700 mg/L for greenhouse irrigation, or 500 –3500 mg/L crop dependant for field, park, or garden irrigation. Since irrigation is only likely to occur in the months of June, July or August, additional calculations are required to determine the minimum concentration which apply at the minimum flows observed in these conditions." Greenhouse irrigation occurs mostly in the winter and spring months, not June, July or August. How will the exceedances of total dissolved solids and conductivity be addressed? Will even more water be used to dilute the effluent to meet the Tier 2 guidelines?

According to the EAP (p. 22), "The discharge of the concentrate is through a discharge pipe with orifice holes installed on the bottom of the river to allow for an even discharge into the receiving waters", and "The concentrate flow from the WTP will undergo significant mixing upon entering the Brokenhead River." What is meant by "even discharge"? Will this be a diffuser laid across the bed of the river? If so, motile biota such as fish will be unable to avoid the discharge on travelling upstream. If not, the effluent will plume and travel some distance downstream until turbulence and eddy currents mix it. The least mixing will occur under conditions of low water levels and low current.

A complicating factor that has not been considered in the EAP is the high density of the concentrate compared to the river water. As solute concentration increases, so does the density of the solution (Figure 2). The dense concentrate, discharged at the bottom of the river, will tend to pool along the bottom unless flow at the bottom is turbulent. During low flow conditions, for example during drought years or in the latter part of summer, this trend analogous to meromixis could impair oxygenation of the bottom sediment and affect benthic communities in the vicinity and downstream of the outfall.

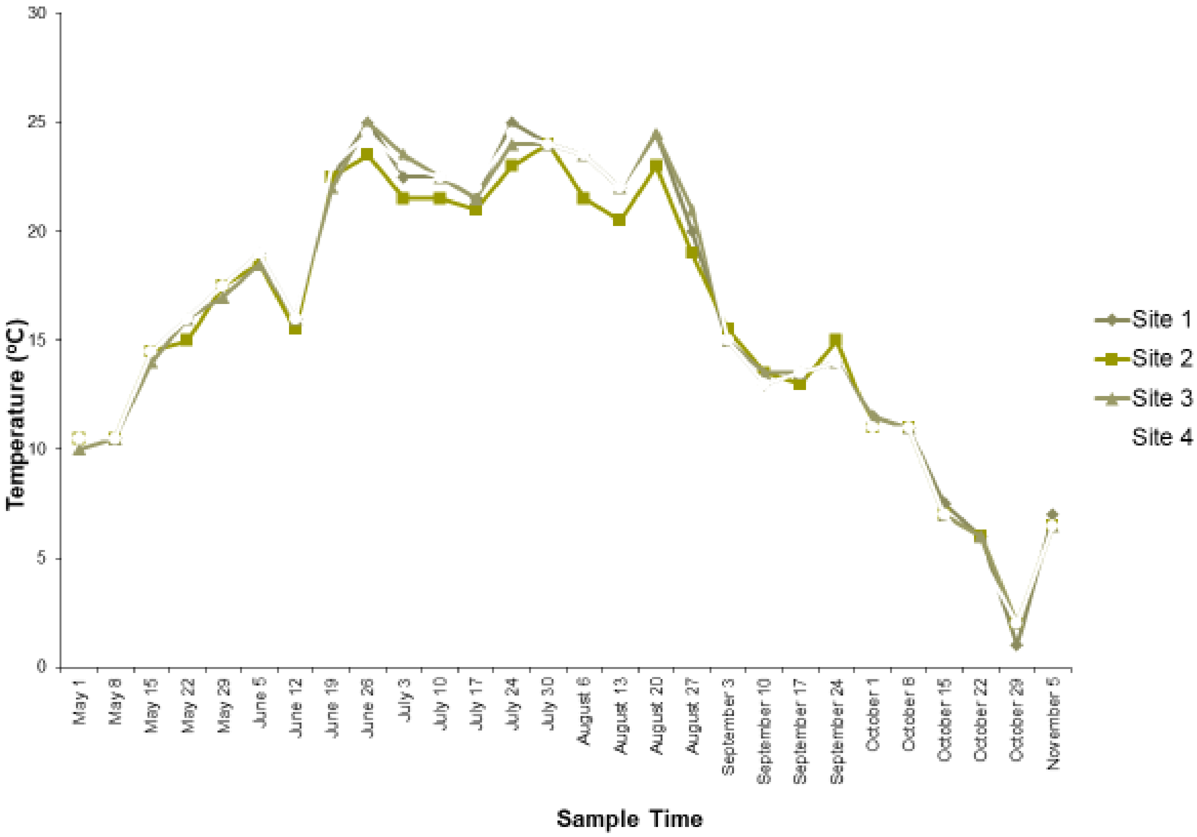
The effects of pooling will be aggravated by the dam structure that is located roughly 300 m downstream of the proposed outfall. This structure reduces turbulence and retains the water and its dissolved burden.

Figure 2. Relationship between aqueous solution density and salt concentration (http://chem.gmu.edu/results/samples/Density_sample_charts/density.htm)



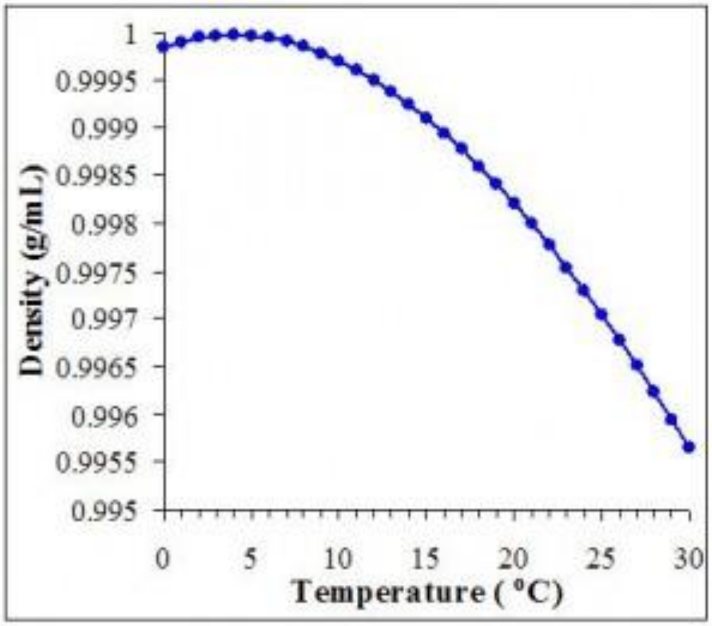
Stress on aquatic organisms will be compounded by the stress of low oxygen levels at high temperatures in summer, and under ice cover in winter. The weekly temperature profile of the Brokenhead River for the ice-free season of 2008 is shown in Figure 3 (Pip and Reinisch, 2012). From the second half of June through August, water temperatures reached 25^{o}C., which is in itself stressful for many of aquatic organisms in the river (Pip, 1993b). At these temperatures, oxygen saturation levels are low (see below), and additional stresses will have synergistic effects. Similarly, oxygen levels are very low under ice cover in winter as aeration from turbulence is absent.

Figure 3. Weekly temperature of Brokenhead River from May 1 – November 5, 2008 (Pip and Reinisch, 2012).



Density is also dependent on temperature, with decreasing density as temperature rises (Figure 4). When the temperature of the effluent is colder than the river water, for example in the summer when temperatures can be high (Figure 3), it will tend to sink and retard mixing, and may travel in a plume along the bottom until it is eventually incorporated fully downstream. This may expose benthic organisms to excessive concentrations of solutes along its path. When the temperature of the effluent is warmer than the river water, during the cold season, it will tend to rise to the top of the water column and travel in plumes for some distance downstream (Kalinowska and Rowinski, 2015). During winter this will create a zone of open water at and immediately downstream of the discharge point.

Figure 4. Relationship between water density and temperature.
https://www.lakescientist.com/temperature-and-ice/

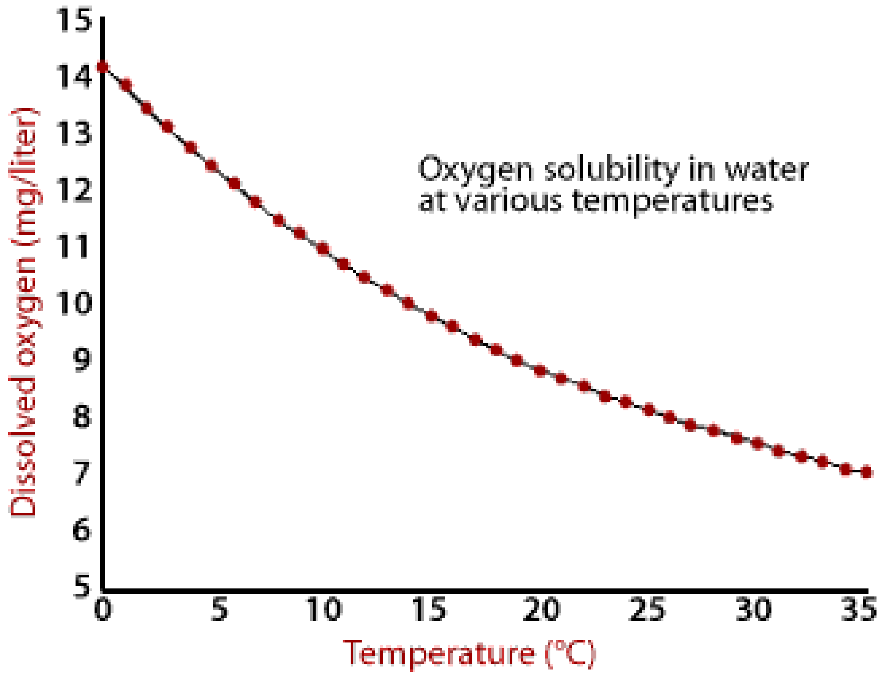


The EAP (p. 22) indicates that "While some ice cover will surround the discharge point, open water may persist into the winter depending on flow, however, no detrimental effects are anticipated from the discharge of membrane concentrate." Thermal pollution is a concern when effluents discharged into a natural water body are warmer than those of the receiving waters. This is particularly problematic in winter. The area of open water encourages waterfowl to remain instead of migrating (Svazas et al., 2001), resulting in starvation in the Manitoba climate.

Water temperature is one of the most important environmental factors that govern all aspects of fish ecology: life cycle, growth, behavior, feeding and spawning (Golovanov, 2013). According to Nakatani (1968), "The general effects of increased water temperatures on fish are well known. Increases in metabolic rates and oxygen requirements, in reduction in stamina, in sensitivity to toxic materials and fish diseases, are but some of the effects… associated with increased temperatures".

Higher temperatures govern the amount of dissolved oxygen in water: saturation values are **inversely** related to temperature (Figure 5). Thus warmer water may result in reduced oxygen availability for aquatic animals.

Figure 5. Relationship between water temperature and oxygen solubility.
http://www.cotf.edu/ete/modules/waterq3/WQassess3f.html



Other biota in the river are sensitive to temperature as well: the importance of this parameter has been documented in the distribution of freshwater macrophytes (Pip, 1989) and gastropods (Pip, 1993b). Aquatic microbial communities are altered, with impacts on nutrient cycling and budgets, and with consequences for all organisms in the system (Horvath and Brent, 1972). Benthic macroinvertebrate communities may show sensitivity even to relatively small river temperature changes (≤ 3^{o} C.) (Quevedo et al., 2018).

With respect to solute concentration, the large difference between the effluent and the river water in the vicinity of the discharge and beyond, will impact many aquatic organisms in the river, which contains vulnerable and endangered soft-water species such as the nationally recognized endangered Chestnut Lamprey (*Ichthyomyzon castaneus*).

The Brokenhead River is an aquatic ecosystem of notable interest in that it forms an abrupt western boundary for the dystrophic and nitrogen-poor waters to the east and northeast, where relatively insoluble Precambrian igneous and metamorphic rock ascends to the surface (e.g. Fig. 9, EAPHR). I have monitored the river as one of my long-range study sites since 1975. The aquatic communities in the river are those of bogs and granitic geological parent materials; the water quality is characterized by low total dissolved solids and alkalinity, calcium deficiency, low nitrogen and phosphorus, high dissolved organic matter with a predominance of humic and humolimnic acids (Pip, unpublished data).

A list of aquatic molluscs documented in the Brokenhead River is given in Table 4 (Pip, unpublished data). Species such as *Helisoma campanulatum* and *Gyraulus deflectus* are typical of the Precambrian Shield (Pip, 1988). *Amnicola walkeri, Armiger crista and Ferrissia paralella* are all very rare in Manitoba, and The Brokenhead River is one of the few places in the province where they have been found. The most spectacular example is the gastropod (snail) *Bulimnea megasoma* (Mammoth Lymnaea), which is the world's largest lymnaeid snail. The Brokenhead River constitutes this soft-water mollusc's westernmost occurrence in Canada. Abundant in the Brokenhead River in the 1960s and early 1970s, it is now almost extirpated there, and has been in catastrophic decline in Manitoba (Pip, 2000b).

Table 4. Aquatic molluscs documented in the Brokenhead River (Pip, unpublished data).

Lymnaea stagnalis
Stagnicola elodes
Bulimnea megasoma
Physa gyrina
Aplexa hypnorum
Heisoma trivolvis
H. campanulatum
Planorbula armigera
Promenetus exacuous
Armiger crista
Gyraulus deflectus
G. parvus
G. circumstriatus
Ferrissia paralella
Valvata tricarinata
Amnicola limosa
A.walkeri
Pyganodon grandis (unionid mussel)

Significant changes have occurred in the mollusc communities of the river since I began monitoring in 1975. Perhaps the most telling has been the disappearance of all but one of the freshwater mussel (unionid) species. Unionids are extremely sensitive to habitat degradation. Their long lifespans (100+ years for some species) and their lifestyle as filter feeders make them vulnerable to severe bioaccumulation and biomagnification of contaminants (Pip, 1995). The sole remaining species in the Brokenhead River is one of the two most tolerant Manitoba species that typically are the last to disappear in the face of advancing pollution.

The Brokenhead River also hosts stands of wild rice (*Zizania aquatica*), which has been shown to be sensitive to elevated total dissolved solids, total alkalinity and nitrate (Pip, 1984), and is usually found on the Precambrian Shield. The river is the westernmost natural occurrence of this plant in southeastern Manitoba. Harvesting of wild rice in Manitoba is the prerogative of indigenous peoples. The soft water habitat of wild rice renders it susceptible to heavy metal accumulation due to solubility of metals in such waters, and therefore preservation of water quality where rice will be used for human consumption is important (Pip, 1993c).

A list of aquatic macrophytes documented in the Brokenhead River is given in Table 5 (Pip, unpublished data). The high species diversity is typical of soft-water habitats.

Table 5. Aquatic macrophytes documented in the Brokenhead River (Pip, unpublished data).

Myriophyllum exalbescens
Ceratophyllum demersum
Utricularia vulgaris
Najas flexilis
Ranunculus aquatilis
R. flabellaris
Megalodonta beckii
Potamogeton pusillus
P. natans
P. richardsonii
P. foliosus
Nuphar variegatum
Lemna minor
L. trisulca
Zizania aquatica
Sagittaria cuneata
Alisma triviale
Sium suave
Sparganium sp.
Eleocharis sp.
Equisetum sp.

The macrophyte community composition mirrors that of the molluscs, with a number of species that are characteristic of dystrophic and Shield waters (Pip, 1984). *Utricularia vulgaris* is a submerged floating plant that is carnivorous in order to obtain the nitrogen that its environment normally lacks. It has specially modified leaves that trap zooplankton and insects, which are subsequently digested.

The concentrate will contain significant total dissolved solids, hardness, alkalinity, carbonates and calcium (Table 3), which are not favorable for some of the calciphobic species in the river. Potentially it may change the community composition and contribute to disappearance of some species downstream, with concomitant reduction in species diversity and ecosystem stability (Pip, 1987a and b).

The concentrate will also contribute nitrogen and phosphorus to the nutrient load of Lake Winnipeg. The table provided in the EAP (i.e. Table 2 above) is misleading because it purports that the orthophosphate will be zero, which is not true, and not possible. The phosphorus in the analytical report in Appendix D of the EAP was below detection limits for the analytical procedure used, **which is not synonymous with zero**. Levels below detection limits in the source water will be magnified in the concentrate to measurable values. Furthermore, at times there is indeed measurable orthophosphate in the aquifer (Pip, unpublished data). Similarly the nitrate concentration in Table 2 is reported as zero, implying no nitrite and nitrate contribution to the river. When the concentrate containing ammonia is discharged to the river, nitrification will convert ammonia to toxic nitrite and then nitrate.

According to Joo and Tansel (2015), "Untreated or improperly managed concentrate can result in adverse environmental effects", as "contaminants in concentrate can impact ecosystems and water quality in areas where the concentrate is discharged." Various approaches have been proposed to deal with the problem of untreated concentrate, for example demineralization using isothermal evaporation (Mohammadesmaeili, 2010). Biological treatment of RO concentrate from potable water systems of lower salinity has been described, but the drawback is that non-biodegradable substances in the concentrate still require that "some physical or chemical process (e.g. flocculation, precipitation, or adsorption) may be needed in addition to the biological treatment process." (Kim et al., 2016). Thus, concentrate disposal is a big problem with few mitigating solutions, and must be taken into account in considering whether RO is an appropriate choice for Beausejour.

Our environmental review and approval process suffers from the impediments of massive tunnel vision. Each new project is treated as though it were hanging by itself in space, rather than considered **in the context of all of the other pressures and stressors that are also acting on the same system.** The poor Brokenhead River is not a large river. Its flows can be small enough that it accommodates a number of low level crossings. Yet it already suffers the indignities of the Town of Beausejour sewage lagoon discharge effluents, livestock manure runoff (Pip and Reinisch, 2012), residential and recreational runoff, and a host of other impacts. Thus, while the impact of one single project can be shoe-horned into seeming that it is not that momentous by itself, it becomes objectionable indeed when added to the myriad other impacts, that may not just be additive, but in many cases, synergistic. We cannot continue to use the Brokenhead River as the sewer that will carry away our inconvenient problems while we avert our eyes.

1.6 RO and distribution system leaching

The Beausejour distribution system reportedly includes approximately 28,000 meters of pipe: "about 68% is cast or ductile iron installed between 1957 and 1985. The remaining 32% of piping material is PVC plastic pipe installed after 1985." (Beausejour, 2019). Plumbing systems within residences and businesses are various. In Manitoba, some plumbing systems installed prior to 1946 which have not been updated may consist of lead pipes. Copper plumbing systems installed between 1946 and 1989 are joined with 50:50 lead/tin solder, which can provide a significant source of lead leaching into the water. This is aggravated in hot water pipes. In 1989 the Manitoba Plumbing Code was revised so that all solders and fluxes used in new plumbing installations must contain no more than 0.2% lead. However even in newer systems, lead may still enter tapwater from sources such as brass plumbing fixtures, while certain types of PVC pipes may contain lead-based stabilizers that are added to extend the life of the plastic.

Hard water mitigates leaching of metals by forming scale on exposed surfaces, creating a barrier between the metal source and the water. However excessive scale can also be undesirable where it diminishes water flow, accumulates in boilers, and coats taps and filters.

According to Kozisek (2020), "Demineralised water is highly aggressive and if untreated, its distribution through pipes and storage tanks would not be possible. The aggressive water attacks the water distribution piping and leaches metals and other materials from the pipes and associated plumbing materials". Decreased alkalinity, hardness, pH and total dissolved solids are associated with a higher aggressive index and increased leaching and corrosion within the distribution and plumbing systems (Burlingame et al., 2007). Thus water mains, pipes, join solder, hoses, fittings, storage containers, hot water tanks, etc. may present a variety of metals and organic coatings that can be leached by RO water.

The EAP (Figure 2.2) indicates that sodium hydroxide will be added to raise the pH (to what level?) as well as a "sequesting agent" [sic]. The reduced hardness and total dissolved solids will still remain as factors influencing corrosivity (Volk et al., 2000).

2.0 Water Source Wells

Concerns regarding the wells can be categorized into two primary areas of concern: security and contamination potential. In large part both are due to the unhappy circumstances of the well locations, where a number of factors present potential risk.

2.1 Security

The two wells are located in a ditch beside a municipal roadway, Road 71N, and the East well is right on the edge of Town at the intersection of two busy roads. Road 71N sustains both thru traffic and daily visits from dog drivers who bring their animals to the ditch in their vehicles. The wells are prominently visible to all who pass by, and are conveniently directly accessible via the two field approaches across the ditch. People can drive right up to the wellheads if they want. Curiosity is a normal human trait.

The exposed and vulnerable condition of the wellheads is a major security concern. In addition to pranksters and idle youth, the world in which we live today is rife with vandals, terrorists and mentally unbalanced individuals and groups. Not in Beausejour? In 2019 RCMP raided the Beausejour home of a (later) nationally and internationally publicized neo-Nazi white supremacist who advocated the poisoning of water supplies, and provided instruction to members of his group. https://www.cbc.ca/news/canada/manitoba/patrik-mathews-reservist-accused-neo-nazi-group-1.5253212

In April, 2020, two Brokenhead RM officials noticed one of the well caps was off. On a closer look, they observed that foreign matter resembling feces was floating in the well, and the water was covered with a foamy substance (Figure 6). They took pictures and replaced the loose cap. It was only after another complaint that the wells were sealed more securely.

The very close proximity of the wellheads to the roadway raises the question of their fate in the event of a road accident: automobile, snowmobile, large truck, tractor, farm machinery. On page 13 of the EAP we read: "The new production wells will be equipped with pitless units, mechanized, and protected from surrounding runoff and vehicular traffic". Page 8 of the EAP promised "bollards to protect the well-head". Three rocks have now been placed around the West well (barely visible in Figure 9 below), but only after the above complaints. The East well is still completely unprotected. The EAP makes no further mention of exactly how the wells will be protected – will they be enclosed and locked?

The wells are located in approaches to agricultural fields, which were widened (see section 2.2.1 below). Farm machinery can be very wide, in some cases wider than the roadway, and many large tractor attachments can be lifted only to a limited height. The farmers will always have to ensure that they have adequate clearance so that the wellheads and rocks (in the case of the West well) are not clipped by their equipment, both while using the approaches, and while working near the edges of the fields. What are the legal liabilities in the event of mishap: can the Town sue the farmer for expensive damage to the wellhead, and/or can the farmer sue the Town/RM for expensive damage to her/his equipment?

The EAPHR (p. 76) briefly mentions: "The wells should be protected from vehicular impact and be secured against vandalism.", but gives no guidance or suggestions on how this will be accomplished.

Figure 6. Photograph inside unsecured well on Road 71N, taken by a Brokenhead RM official, who observed the well cap was off. Floating feces-like material has been dumped in the well. Third week of April, 2020.

Photo used by permission

2.2.0 Contamination potential

The EAP report (p. 21) admits the uncertainty of current knowledge with respect to aquitard integrity and surface water intrusion into the confined aquifer: "On-going testing in the future is recommended to affirm the effectiveness of the aquitards at preventing surface water intrusion into the aquifer."

The two source wells have been sited in a ditch that periodically floods, between a frequently travelled public road and agricultural fields. A number of concerns regarding contamination potential are identified below. While it may be argued that some of these concerns, for example agricultural pollution, exist in hundreds of other places on the aquifer, the difference here is that at this location, drawdown from intensive pumping will be greatest, and therefore contaminants near these sites will be drawn in from upper strata at an accelerated rate through fractures, boreholes and patches of permeable overburden. For these reasons, it is important to keep the area clean, dry and inaccessible, yet the unfortunate locations of these wells will preclude the ability to take these precautions to the desired or even necessary level.

2.2.1 Flooding

The two wells are located in a ditch, which by definition is designed to carry runoff water. This water originates as meltwater from the adjacent fields, or as runoff after rainfall from the fields and road. When the volume of water exceeds the drainage capacity of the ditch and culvert, flooding occurs, such that the water overflows onto the adjacent field (Figure 7). In spring, the culvert at the field access driveway at the West well may be frozen, or plugged with debris. This dirty contaminated water can encroach on the wellhead and casing (Figure 8). The concern is that this water may travel through the surrounding porous and fractured matrix to the well source. The wells are in a "confined aquifer and [are] not in artesian condition" (EAP, p. 14), i.e. the water is not under pressure. Thus contaminants may enter, particularly in conditions of drawdown at and around the pumping sites ("suction").

The EAP (p. 8) promised "mounding to ensure surface runoff from the surrounding area does not approach to the pitless unit and casing." Figures 7 and 8 clearly indicate that this was not done.

The aggregate around the wellheads has since been somewhat built up (after complaints), and the field access driveway has been widened to accommodate the passage of farm machinery. This widening has been accompanied by the installation of a longer culvert, but the flooding problem is likely to persist because the new culvert has a very small diameter (Figure 9), which will easily become plugged with debris and garbage, and its greater length will exacerbate problems with freezing.

Figure 7. Flooding of ditch and adjacent field, encroaching on West well casing in foreground.

Photo: E.Pip 29 March 2020

Figure 8. Dirty ditch water encroaching on West well casing.

Photo E.Pip 29 March 2020

Figure 9. New, longer culvert (bottom arrow) installed in widened field access driveway across ditch at West well. Note the ludicrously tiny culvert diameter. Wellhead is at top left of centre behind weeds (top arrow).

Photo E.Pip 12 July 2020

2.2.2 Beausejour Dog Nuisance Ditch

The section of ditch between and including the two wells is a primary traditional dog nuisance ground for Beausejour dog owners. Every day, year-round, numerous town residents bring their dogs here in their vehicles, and let their dogs out into the ditch. Many owners do not get out of their cars. Due to the lack of other suitable objects in the area, some dogs have adopted the well casings in lieu of fire hydrants.

The accumulated dog waste soaks in the water when water is present in the ditch. The proximity of this ditch water to the well casings is a concern, given the porous nature of the soils and the potential for pathogens to travel. While it has been argued that the treatment plant will remove pathogens, this will benefit only those users who are receiving treated water.

Other residents, who depend on private wells, will be drinking this water in its unfiltered and undisinfected state.

A large number of pathogens associated with dog feces and capable of transmission to humans have been found as contaminants in drinking water. These include, but are not limited to: various *Escherichia coli* serotypes, *Salmonella* (Procter et al., 2013), *Campylobacter* (Procter et al., 2013), *Arcobacter* (Houf et al., 2008), *Clostridium* (Ferguson et al., 2009), and the protozoan parasites *Giardia* (Liang et al., 2012; Procter et al., 2013; Sotiriadou et al., 2013) and *Cryptosporidium* (Ferguson et al., 2009; Sotiriadou et al., 2013). Dogs often do not exhibit symptoms of infection, yet can shed these organisms in their feces (Kozak et al., 2003; Procter et al., 2013). Significant microbial loads to the environment can result (Wright et al., 2009).

The EAP (p. 15) states: "The proposed membrane filtration process with primary and secondary disinfection through gaseous chlorine is effective in protecting against viruses and cysts such as Cryptosporidium oocysts and Giardia lamblia cysts." While filtration is indeed effective, chlorination is only partially effective for *Giardia,* requiring high concentrations and extended contact time, but **completely ineffective** for *Cryptosporidium* (Betancourt and Rose, 2004). Just small numbers of these parasites are enough to cause human illness (Wright and Collins, 1997).

The above EAP quoted statement (from p. 15) also touts membrane filtration and chlorine as effective against viruses. Again, membrane filtration is effective, but some percentage of viruses may persist after chlorination, particularly enteroviruses, including coxsackievirus, echovirus and picornavirus (Payment et al., 1985). According to Keswick et al. (1985), "Norwalk virus appears to be very resistant to chlorine". The concern here is that 20% of the finished water will consist of raw water that has bypassed the RO process, but has passed through the manganese greensand filter. In order to remove viruses, specialized filters are required, such as biosand amended with iron oxide to enable electrostatic absorption of negatively charged virion particles (Bradley et al., 2011).

Pathogenic bacteria vary in their vulnerability to chlorination, and exhibit extended survival times at low water temperatures (Flint, 1987). Groundwater typically averages 4^{o} C. year round. In groundwater, pathogens are not subject to inactivation by ultraviolet light from the sun (e.g. Pip, 2015).

Page 12 of the EAPHR states: "Surface water sources now require significantly more complex and expensive treatment to remove such things as giardia, crypto sporidium [sic], and various bacteria's [sic] and viruses that can be present in surface water." All of these "things" can and have been found in groundwater. Bacterium = singular, bacteria = plural.

Helminthic parasites (e.g. *Echinococcus, Dirofilaria, Toxocara*, *Baylisascaris* (Villeneuve et al., 2015; Baneth et al., 2016,) can also be transmitted to humans from dogs, and through well water. The eggs shed in feces can survive in the environment for many years (Villeneuve et al., 2015), during which time they may travel some distance from the source.

2.2.3 Agricultural pollution

The two wells are immediately adjacent to agricultural fields, and therefore are at potential risk from cropland management practices conducted thereon (Figure 10). Liquid ammonia as a fertilizer is extremely soluble. Manure contains ammonia, nitrite and nitrate, phosphates, as well as pharmaceuticals, vaccines and metals, a large array of organic compounds, and various pathogens (Pip, 2000c). Cropland spraying contributes numerous synthetic herbicides, fungicides and insecticides. These sprays contain not only the active ingredient, but also a host of other chemicals including adjuvants, surfactants, synergists and extenders. Some of these ancillary compounds may be more toxic to people than the active ingredient (e.g. the surfactant in Roundup, which is significantly more toxic than the active ingredient, glyphosate (Cox, 1998)). Since the formulations of pesticides are proprietary and protected under the Canada Trade Secrets Act, the ingredients are not listed. When the chemicals degrade, they may generate other toxic products, that may be just as or more toxic and persistent than the original substance (Kolpin et al., 1998). In groundwater, these substances may persist for long periods of time, due to the low temperature, lack of oxygen, and lack of exposure to the lytic effects of ultraviolet light from the sun.

Human health impacts of various herbicides and their breakdown products are an ubiquitous concern in drinking water. Some of these include:

Endocrine disruption (Gasnier et al., 2009)
Chromosomal damage (Biradar and Rayburn, 1995)
Cancer (Sterling and Arundel, 1986; Morrison et al., 1992)
Parkinson's disease (Rajout et al., 1987)(Canadian well water in agricultural areas)
Intrauterine growth retardation (Munger et al., 1997)
Birth defects (Sterling and Arundel, 1986)

The concern in the present instance is that these compounds may percolate or travel through the porous matrix in the vicinity of the wells to the source aquifer. Blanchard and Donald (1997) found that even where a claypan layer restricts percolation to groundwater beneath, herbicide (atrazine and alachor) application to agricultural fields still resulted in detection of the herbicides in the monitoring wells. Pionke and Glotfelty (1990) reported that atrazine applied to fields, and its breakdown products, subsequently "were found in most groundwaters including deep wells". Precipitation soon after application particularly facilitates movement of herbicides to groundwater, and field tillage vs. no-tillage makes little difference in herbicide movement (Ritter et al., 1994).

The location of the wells in a ditch beside the fields also raises the question of field edge losses, which are themselves important stressors on water quality (Leonard and Knisel, 1988). According to the latter authors, in regional aquifer systems, "no clear separation between surface water and groundwater can be made". In the present case, flooding may create a continuous body of water lying in the field and ditch (Figure 7); thus edge losses become moot, as materials from the field become directly dissolved/suspended in the water around the wells.

Figure 10. East well, showing proximity of staging ground for spraying adjacent agricultural field. Note the killed crop from chemical spillage behind the well.

Photo E.Pip 12 July 2020

Pathogens may enter surface and ground water from livestock enclosures, direct access of livestock to streams and ditches, or from the application of manure to cropland and pastureland. Hog and cattle manure may contain a variety of viruses, bacteria, protozoa, helminthic pathogens and possibly prions that may be transmitted to humans (see Pip, 2000c). Coliform bacteria have been documented in the Brokenhead River after application of manure to adjacent fields in the fall (Pip and Reinisch, 2012).

In 1993, more than 400,000 people in the Milwaukee, Wisconsin area became ill from *Cryptosporidium* in the treated water supply; 69 people died (Gradus, 2014). Cattle manure combined with precipitation and runoff was identified as a likely cause (MacKenzie et al., 1994).

Both *Cryptosporidium* and *Giardia* are present in Manitoba, and in Shoal Lake, the source of the City of Winnipeg's water supply (Pip, unpublished data; MacBride, 2000). In 1996 the public water supply of Dauphin was compromised by *Giardia* (MacBride, 2000): that well water source was also located in a municipal right-of-way (MEAP, 2014). In 2001 Dauphin was beleaguered again by an outbreak of *Cryptosporidium* (Macey et al., 2002).

The worst, but preventable, waterborne tragedy in Canada occurred in 2000 in Walkerton, Ontario. Nearly half of the residents of this community of 5000 became ill, and 7 people died as a result of contamination of their groundwater source with surface runoff, combined with treatment plant inadequacy and incompetence. "... the source of the contamination was most likely Well No. 5, a well which had been constructed in 1979 and supplied the town with about 60 per cent of its water. When the well was designed one of the original recommendations was that there should be a protected buffer zone, but this had not been implemented and livestock were grazing in the fields around the well. After heavy rainstorm floods in early May, bacteria-laden manure had probably run off the surface and entered the well or its aquifer. The chlorine disinfecting system had not been able to cope."
(https://www.canadianconsultingengineer.com/features/what-happened-in-walkerton/)

No protected buffer zone is in the offing for the Beausejour wells, according to the EAP. Given their location, in a ditch that carries dirty water, a suitable buffer zone is not even possible. Manure may be applied to the fields at any future time, and the unsanitary dog park remains. No lessons to be learned here, folks.

2.2.4 Ditch spraying

Intermittently, Agassiz Weed Control sprays municipal ditches with herbicides. On some occasions, ditches full of water have been sprayed. The location of the wells in a roadside ditch is a concern because of the elevated risk of persistent, toxic chemicals and their breakdown products being directly applied to the ditch and contaminating the water at its source. In a wider perspective, ditch spraying in general in the RM presents another risk of migration of contaminants to the aquifer. While some of these chemicals can be addressed by the water treatment plant, other stakeholders utilize the same aquifer, and they will not have the benefit of the treatment plant.

2.2.5 Road runoff

An unpaved road runs along the ditch between the two source wells. Such roads are a recognized source of environmental pollution (Colbert, 2003). When the road is dry, dust is raised by each passing vehicle and settles in the ditch. During rain and snowmelt, runoff from the road enters the ditch. Road dust and runoff are associated with a variety of pollutants, most of which originate from wear and tear of the vehicles and tires, as well as leakage of fluids. Contaminants that have been documented include Pb, Zn, Fe, Cu, Ni, Cd, Hg, Cr (Leitao, 2007; Helmreich et al., 2010). Oil, hydraulic fluid, coolants and various other substances such as corrosion inhibitors, lubricants, sealants, polyaromatic hydrocarbons, products of fuel combustion, fuel additives, paints, polishing compounds, etc. are also shed by vehicles.

The extreme proximity of the wells to a well travelled public road exposes them to the potential of contamination when these substances enter the soil or ditch water, that can subsequently percolate through the porous matrix. De-icing salts also easily enter groundwater (Howard and Haynes, 1993).

Aside from ongoing runoff, the potential for crashes and spills always exists on a well-used public road. Crashes and vehicles going off the road into the ditch carry the risks of gasoline and diesel oil spills, and loss of hydraulic fluids, antifreeze, transmission fluid and engine oils. Spills from pesticide tanks, liquid ammonia tanks, bulk fuel farm delivery tankers, and so on could jeopardize the water at its source. Is a plan in place for immediate response? Whose responsibility: the Town, the RM, or the Hazmat team from the Province, that would take some time to arrive?

2.2.6 Garbage

The section of Road 71N where the wells are located sustains a great deal of traffic, not only as an approach to the Town from the rural area to the west and southwest, but also for town residents who daily visit this section with their dogs. Sundry garbage, both loose and in garbage bags, is a common sight in the ditch between the two wells. Whether it “accidentally” fell off the truck into the ditch, or was tossed in passing, household trash contains almost every chemical contaminant imaginable, as well as microbial risks from diapers, tissues, and rotting or spoiled food.

Pet waste is a common component of garbage, although in the present case of dog waste it is vastly redundant. However pets can be of various other species: cats, rodents, birds, reptiles, each of which may bring their own set of zoonotic diseases capable of transmission to people through excrement and bedding, and occasionally the dead animals themselves placed in the garbage.

After the wells were drilled, the litter selection was augmented with debris at the two drilling sites: food wrappers, coffee cups, plastic bottles, plastic bags, tape roll ends, rags, various metal discards and sundry unidentified scraps. People seem to have little respect for their or somebody else’s environment.

When the ditch floods, the garbage soaks in the water and presents a potential for contamination. The location of the wells in such an open and communal place makes it difficult to keep the area clean, and to restrict public access in the vicinity of the wells.

3.0 Construction

Section 4.6 of the EAP (p. 31) states: "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." Several species of native orchids (for example 3 species of Lady Slippers, *Cypripedium*) may be found growing on the municipal rights-of-way in the immediate area (e.g. on Road 70N within a 2-mile radius of the wells), and they frequent disturbed areas, as well as grassed areas, despite occasional spraying if they are shielded by other vegetation. Habitat for Manitoba orchids is listed as: "**Habitat**: Ditches, deciduous and mixed forests, coniferous bogs, and tall-grass and mixed-grass prairie." http://www.nativeorchid.org/wordpress/manitoba-orchids/

The Western Silvery Aster (*Aster sericeus*) has a registered occurrence in the **immediate** area. "Western silvery aster is found in central North America, from Manitoba south to Texas. In Canada, Western silvery aster is found only in southeastern Manitoba and in the Rainy River area of northwestern Ontario. Most of Manitoba's Western silvery aster plants are found in three areas: Birds Hill Provincial Park and vicinity, Carlowrie and between Gardenton and the Manitoba-Minnesota border. Additional plants can be found near Beausejour, Grunthal and Zhoda" https://www.gov.mb.ca/sd/wildlife/sar/pdf/western_silvery_aster.pdf

This species is listed as Threatened under the Manitoba Endangered Species Act, as well as the national Committee on the Status of Endangered Wildlife in Canada.

It is irresponsible to prejudge "they are unlikely to contain rare plant species" without actually looking.

"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."(EAP, p. 34). A permit for such an operation is required. How will these species be recognized – who will be engaged to survey and identify them? Section 4.6 (see above) already assumed such species are unlikely.

Section 5.3 pertaining to surface water (EAP, p. 33) states: "Mitigation of surface water issues may be achieved by limiting open cut trenching to within 30 m ahead or behind the pipe laying, redirecting surface water runoff, pumping accumulated water to adjacent ditches and providing erosion control practices as required." Will erosion-control dams be used during the period of construction to prevent disturbed soil from entering ditches? Will erosion-control mats be installed on ditch slopes?

"Re-establishment of vegetation will occur as soon as possible on areas of disturbed soil." (EAP, p. 33). What is the plan to revegetate disturbed soil? Will it be seeded with native grasses? Will an appropriate contractor be hired to do this?

"The proponent will conduct long term monitoring of Brokenhead River to verify impacts on water quality." (EAP, p. 34). Proponent = Town of Beausejour. Will the Town hire a contractor to carry out monitoring? What is meant by "long term"? A few months, a year, 5 years, or….?

A similar observation applies to fish in the river: "Water quality monitoring on the Brokenhead River will provide data for the assessment of any water quality impacts affecting fish species." Who will do this monitoring, how often, and how long? Is the hope here that this duty will maybe be carried out by the Province, or maybe Fisheries and Oceans?

4.0 Non-town aquifer users

It must be emphasized that the aquifer in question is not the exclusive property of the Town, but that there are many additional users in the surrounding area that depend on the same water source, and who will be affected by the Town's requirements and the Town's wasteful practices. These include residential users as well as agricultural operations including livestock producers who have a large water demand for their animals. There is also at least one registered ecological reserve (i.e. my property) whose integrity depends on relatively stable water table levels to protect the established ecosystem and registered endangered species. "Due to the extremely high transmissive conditions observed for the area, it is common for influences from pumping to travel great distances."(EAPHR, p. 60), and "The high transmissive conditions in the carbonate aquifer result in drawdown cones that are shallow with a large areal extent." (EAPHR, p. 72). Thus the longterm impacts of pumping may affect many users.

In estimating the groundwater use in the area (section 15.4, EAPHR, p. 74-75), besides licensed users, "the value for domestic use was conservatively estimated by assuming each of the 6,500 wells in the GWDRILL database (2018) supplies groundwater for a family of four at the average rate of 250 L/day/person". Other living arrangements, such as communes and ethnic/religious colonies, would have substantially greater domestic usage per well, but do not seem to have been included.

For some reason, domestic animals were excluded. What about the cattle, pigs, horses, sheep, goats and so forth, kept by farmers and residential users? What is the animal population of the area, which is, after all, rural? How much of this water demand relies on wells vs. surface water? Sample estimates for daily water consumption by livestock are given in Table 6 (Ontario data) (OMAFRA, 2019). These values do not include additional water demands such as barn washing, and animal and equipment hygiene.

Table 6. Estimated maximum daily water consumption for livestock (OMAFRA, 2019).

Livestock type	**Daily water consumption L**
Dairy cow	Up to 155
Beef cow	Up to 67
Pig	Up to 22
Horse	Up to 59
Sheep	Up to 11
1000 chickens 5-8 weeks old	450-770 Dependent on temperature
1000 turkeys	Up to 1100 Dependent on temperature

On p. 71-72 of the EAPHR, "the large number of private water wells documented within and around the Town of Beausejour is of concern for groundwater quality and must be considered in a GUDI assessment. A review of GWDRILL (2018) revealed more than 124 wells within a two mile radius of the new well field site. It is further assumed that the GWDRILL database typically under represents the actual number of wells in a region, as the database effectively covers water wells completed from 1964 to present. Consequently, wells drilled before 1964 generally do no have a well log record. In the well log review, most of the wells were completed in the carbonate aquifer. It is unknown at this time how many of these wells are still in use or if they have been properly abandoned. The overall density of private wells within the area is cause for concern with regards to groundwater quality, as each additional well increases the potential for surface impacts to enter the aquifer." The EAPHR does not mention the large number of test drill cores at aggregate mining operations in the area of concern. In one example (adjacent to GO50J155 on EAP map, p. 40), four separate and independent series of cores by different contractors were reportedly drilled on this property in the winter of 2019-2020 alone, whereas this property had already been extensively test drilled at least once, more than a decade previously. This is of concern, since "In generally [sic], quarry operations often increase the potential for groundwater recharge and can impart some hydraulic influence on local groundwater dynamics" (EAPHR, p. 26), and "Quarry operations in the region further reduce the local overburden cover and also increase the potential for surface water impacts to reach the local groundwater aquifer"(EAPHR, Appendix A, p. 178 of total 332 EAP). Such a situation provides enormous potential for contamination, as the water table associated with the unconfined aquifer is exposed and unprotected at the pits, and this property has become a haven for garbage disposal, recreational vehicles, youth gatherings and partying, swimmers, dog walkers, target shooters, hunters, and has been cursed with oil and mechanical fluid leakage from abandoned mining equipment left on site, including in the water, that created slicks on the ponds. When the gravel pits were in all-day operation, for several years there were no toilet facilities on site, and currently the 'irregular' users often spend the entire day there.

On p. 21 of the EAP we see the statement: " the drawdown of the proposed wells will be within the historical natural groundwater fluctuation and no impacts on surrounding users is anticipated." This statement is based on the following EAPHR paragraph (p. 69): "The amount of addition [sic] drawdown calculated for the wellfield is within the historical range of natural groundwater level fluctuations observed in regional hydrograph stations. After one year of municipal pumping, the cumulative additional drawdown impact observed in the closest domestic wells is calculated to be 5.6 ft., or about six feet. The natural groundwater level fluctuations observed in regional hydrographs were up to approximately 7.5 feet. Thus, it is expected that existing wells in the area are already capable of handing this amount of water level change." This statement is misleading. First, the drawdown of 5.6 feet should be considered **in addition to, not within,** the existing fluctuations of 7.5 feet. The drawdown will be constant, and the simultaneous "natural groundwater fluctuation" will not cease. With climate change, the latter may even increase. Thus a drought year where the natural level is at its lowest will result in a total change of 13.1 feet from the natural condition at its maximum. And this is with the assumption for "wells that are perfectly efficient with no losses" (EAPHR, p. 66, bottom paragraph). We know that nothing is perfectly efficient, and that the numbers provided are the best possible case scenario, in other words, unlikely.

The above statement is paraphrased but hedged in the EAP (p. 31) as: "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." What monitoring will be in place, what will the "appropriate adjustments" for adverse effects consist of, and are they even possible? If groundwater levels turn out to be a problem, surely the amount of withdrawal will not be scaled back? Therefore what is the plan to help the people who will be affected?

The above statement also assumes that **recharge capacity of the aquifer will remain constant.** However the reality of climate change and changes in precipitation levels must be taken into account, and it must be acknowledged that drawdown levels will almost certainly be greater than those in the simulated model presented in the EAP. According to the EAPHR (p. 72) itself, "The carbonate aquifer is highly responsive to seasonal and climatic variations. Water levels in the carbonate aquifer appear to decline rapidly during prolonged dry periods. The aquifer appears to be similar to an open reservoir and pipe analogy; when the water level in the reservoir falls, the potential in the pipe declines very rapidly. This means that during prolonged dry periods, static water levels in the area will respond rapidly, and decline accordingly." Similarly, poorly considered drainage projects undertaken by the RM in recharge areas also worsen the longrange outlook.

The model also assumes that **demand on the aquifer will remain constant**. However the reality has been and will be that as development proceeds and more wells are drilled, the burden on the aquifer will concomitantly grow.

According to the EAP (p. 34), "The recommended groundwater level monitoring program would include the use of existing wells on the current WTP property." What about the surrounding rural users? Monitoring should include a suitably large number of diverse wells, not just a few monitoring wells that may or may not represent the broader picture.

I live just over 2 miles away from the West well. Drawdown changes on my property can be severe and catastrophic. In 1999, the RM CAO gave unauthorized permission to the aggregate mining operation (at Roads 70N and 39E) diagonally across the road from me to operate a high-speed pump in order to dewater their gravel pit. As a result, my well went dry, as did that of another neighbor to the north on Road 39E, at the same time. While I was away at work, my pump continued to pump air until it burned out. I was without water for several days, and the RM did not provide me with water. The cost to rectify the situation and install another pump amounted to thousands of dollars. To this day, **I have never been reimbursed by the RM** for the grief they inflicted on me, although the RM did tell me to save my receipt (as a memento, I suppose). The Province did, in response, install a monitoring well beside the gravel operation, but too little, too late.

Therefore it was of great interest to me to read the following paragraph in the EAPHR (p. 71), which impacts me directly: "The presence of quarries and gravel pits in the area present another concern for GUDI conditions. The expansion of the drawdown cone around the wellfield after long term pumping will likely extend under existing surface water features and gravel pits; most notably, the surface water feature located directly north of the wells in west Beausejour, and southwest of the wells along Rd 70 North between Rd 40 and 39 E. The locations of these features requries [sic] that monitoring be in place to observe for potential surface water-groundwater interactions under long term pumping conditions." My neighbor and I can already bitterly vouch for the fact that these interactions exist. If intensive pumping of the gravel pit can affect the immediate area of the aquifer, then pumping of the aquifer can affect the surface water. So, what remedy can monitoring provide?

The impacts on surface water features bring into question the issue of pastured livestock that depend on dugouts. In the event that a well must be drilled to replace the lost surface watering source, will the Town compensate the livestock owner? Oh, wait. They will be told to save their receipt.

The bottom line is that the matrix is very porous and water travels easily and quickly through it, as indicated in the EAPHR (p. 53). Contaminants also easily enter it, and this has been aggravated by the many drill holes through the top aquitard that facilitate intrusion from the surface stratum (unconfined aquifer) to the confined aquifer(s) beneath. Drawdown in the confined aquifer is expected to accelerate the vertical movement of contaminants from the unconfined to the confined strata via the numerous holes as well as natural areas of aquitard weakness. Contaminant plumes will be horizontally attracted to wells due to the hydraulic forces of pumping.

"As per the conditions of the Groundwater Exploration Permit, the Town of Beausejour, as the proponent of the water supply project, is responsible to correct any existing water supplies that are negatively impacted as a result of a new municipal groundwater supply." (EAPHR, p. 69). How will the Town be able to correct somebody's compromised water supply? It will take years and thousands of dollars of litigation for a resident to prove that the new municipal wells caused the problem, and indeed such proof may be impossible. Will the Town undertake to provide the unlucky residents with water in the meantime? Probably not. The unfortunate resident will be forced to undertake the drilling and installation of a new well on their own, and keep their receipts. Like myself (above), they will keep those receipts until they die. "The last sentence of section 14.3 (EAPHR, p. 69) states: "Long term monitoring and a well interference program will be required to address these concerns." There is no mention of what exactly the "well interference program" will entail or achieve, nor who will administer and conduct it.

Over the three decades that I have lived on my property, I have also documented declining water quality. After the spring melt, nitrogen spikes in my well water (Figure 1), and coliform bacteria now appear sporadically where in the 1990s there were none. Growing development, location of subdivisions and communities on recharge areas, the drilling of more wells, the failure of more septic fields, small residential lots where septic fields are embarrassingly close to wellheads, drilling of wells in livestock enclosures, abuse of land by greedy mining interests, leaking of abandoned well casings, increased application of manure, inappropriate RM and private drainage practices, and many other factors in my immediate area have contributed to the irreversible soiling of a once magnificent aquifer.

It is unsettling to see how much uncertainty and assumption blur the expectations concerning the impacts of this project, and the different slippery gambles that will be undertaken, with no useful fallback plan for any of them, other than "monitoring".

During the course of my career in the past 50+ years, I have reviewed and evaluated a great many environmental impact models in sewage and water treatment, industrial agriculture, mining, hydro dam flooding, cottage development, nuclear power installations, and so on. They have all had one thing in common: nobody is ever held accountable when the projections and models fail, and reality turns out to be very different. Who knew? Assertions. Assurances. Empty words.

5.0 Other remarks

- The EAP and EAPHR suffer from hundreds of typographical, spelling, grammar and syntax errors, as well as contradictions, indicating the reports were prepared in haste and not proofread.
- The present document was likewise prepared in haste. The time allotted between the publication of the Environment Act Proposal notice and the deadline for comment submissions was too short to prepare a more complete and organized response, given the complexity of the issue, the amount of data, and the magnitude of the consequences of this project.

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