CEC Hearing
Vivian Sands Project
MBEN/OLS
Hydrogeological Evidence Presentation

Louis-Charles Boutin, P. Eng.
Principal Groundwater Engineer
Technical Lead Numerical Modelling

8 March 2023

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Presentation Overview

- Introduction
- Evidence Summary
- Conclusions

Introduction

Office Locations (19)

British Columbia
Fort St. John

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Regina
Saskatoon
Swift Current
Weyburn

Ontario
Guelph
Kitchener
London
Mississauga

Introduction

- Hydrogeological and Geochemical Subject Matter Experts:
  - **Louis-Charles Boutin, P.Eng. (QC, ON ,MB, AB)**
    Principal Groundwater Engineer (20 years)
    Technical Lead Numerical Modelling
    Municipal Water Well Design and Testing
  - **Don Haley, M.Sc., B.Math.**
    Senior Groundwater Scientist (+20 years)
    Groundwater Flow and Transport Modelling
  - **Maurice Shevalier, M.Sc., P.Chem.**
    Senior Geochemist (+30 years)
    Geochemical Modelling

Evidence Summary

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Road map

- **Overview of concerns related to groundwater**
- Well completion and abandonment
- Matrix’s opinion on direct effects of proposed project
- Historical regional hydrogeological studies
- Long-term indirect effects
  - Connects aquifers and creates preferential pathways
  - Increases risk of contamination
- Review of the Southeast Groundwater Management Plan
- Cumulative impact
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- Conclusions

Overview of potential groundwater concerns

Impact Assessment Agency of Canada

Public concerns related to the groundwater was summarized by the Impact Assessment Agency of Canada (IAAC) as following (2020):

- new, unproven mining methods proposed for the extraction project
- **effect of the extraction project on local aquifer (Manitoba Formation), including water levels**
- sustainability of use, and composition including dissolved air and acid creation
- **feasibility of reclamation of the aquifer if it becomes contaminated**
- acid and heavy metal leaching and production of harmful by-products resulting from the extraction process and composition of the silica sand being extracted to the aquifer and the surface
- subsidence due to sand and water withdrawal from the extraction process, and **the potential to cause ground and surface water contamination** and sinkholes
- lack of trust in the Proponent related to their history of regional operations, including concern related to closure of boreholes and exploratory activities
- **splitting of a project into parts for provincial assessment and cumulative effects**

Section 7.1.2 from EAP

<u>Groundwater Quantity</u>:

- Pumping of groundwater during sand extraction may produce increased drawdown with resultant impacts on well yield for nearby groundwater users with wells completed in Winnipeg Sandstone and the Red River Carbonate aquifers.
- Degradation of the Winnipeg Shale as a result of project operations resulting in increased hydraulic connection between the Winnipeg Sandstone and Red River Carbonate with possible well yield reduction impacts on groundwater users in the Red River Carbonate. This may also result in reduced impacts on groundwater users in the Winnipeg Sandstone because extracted water would be derived from both aquifers rather than being derived almost entirely from the Winnipeg Sandstone if the Winnipeg Shale remained intact.

<u>Groundwater Quality</u>:

- Installation of numerous wells may create preferential flow pathways from surface to either the Red River Carbonate aquifer and/or the Winnipeg Sandstone aquifer, with resultant impacts on groundwater quality due to mixing of waters of different water quality and geochemical equilibration with prevailing oxidation-reduction conditions in each aquifer.
- Storage of bedrock cuttings derived from project operations on ground surface. Exposure of sulphidic minerals to oxygen may impact water quality as a result of possible ML/ARD processes, with possible impacts on groundwater or surface water quality.
- Degradation of the Winnipeg Shale as a result of project operations resulting in mixing of groundwaters om the Winnipeg Sandstone and Red River Carbonate with possible impacts on groundwater quality in one or more of the aquifers.

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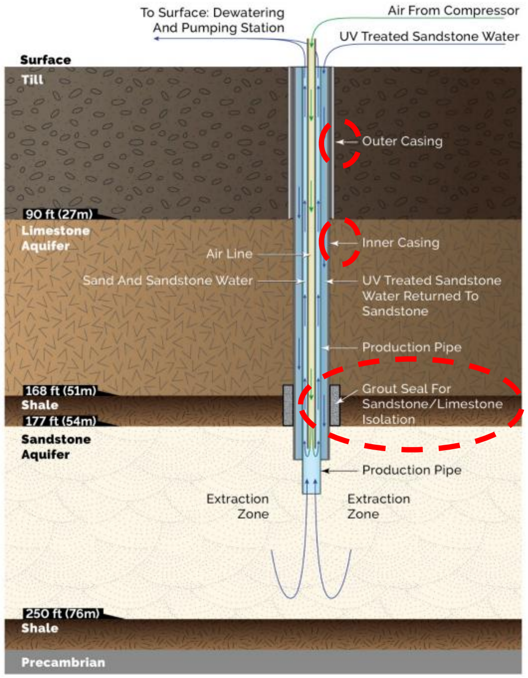
Well Completion, Sand Extraction Process, and Well Abandonment

INITIAL EAP WELL SCHEMATIC

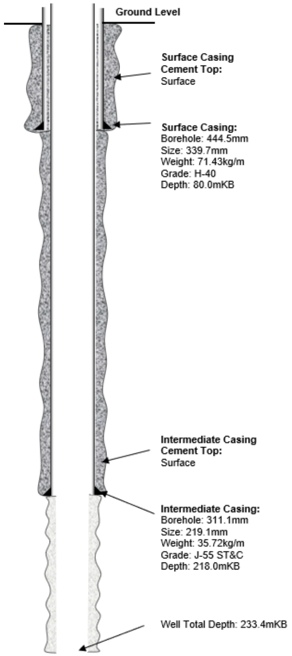


Example Only

IRs RESPONSES

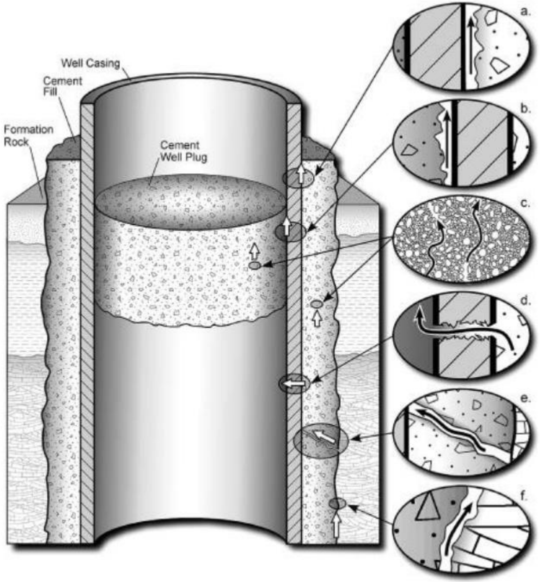
- A borehole is advanced through the glacial overburden sediments and an outer PVC casing is anchored in the limestone carbonates of the Red River Formation (i.e., Red River Carbonate Aquifer) to prevent collapse of unconsolidated deposits into the open borehole.
- Inside the outer PVC casing, a borehole would be advanced and an inner PVC casing installed through the Red River Carbonate Aquifer, through the Winnipeg Shale Aquitard, and into the top of the Winnipeg Sandstone Aquifer.
- The annular spaces between the outer PVC casing and the edge of the borehole as well as the inner PVC casing and the edge of the borehole would be cemented in place using a 1-inch tremie line (refer to proponent response to MBEN/OLS-IR-029 part b; MBEN/OLS 2023). The cement is expected to contain 5% bentonite additive to maintain some flexibility "*... in the event of any movement or fracture existence/ development*".
- A production pipe is installed inside the inner PVC casing and would be advanced to the bottom of the Winnipeg Sandstone Aquifer as mining progresses. Inside the production pipe, an air line would circulate air using an air compressor which would lift a mixture of air, water, and sand. This process is commonly named "airlifting".

STANDARD OIL&GAS OPERATIONS



Well Completion, Sand Extraction Process, and Well Abandonment

- **Why is it important?**
  - First phase years 1 to 5 of proposed Project:
    Number of wells estimated to 1,680 (Table 2-A); reduced by 400 (Jan 2023)
  - Proposed project's lifespan anticipated to be 24 years (many thousands)
  - Each well drilled through the Till and Winnipeg Carbonate Aquifer
  - Cement with bentonite in annulus space is the **main protection** against preferential pathways for fluids
  - Abandoned wells need to be **perpetual** (>>100 years)



Pathways (taken from Celia et al 2004)

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Direct Effects of the Proposed Project

GROUNDWATER QUANTITY

Matrix's Farvolden evaluation:

- First order conservative evaluation of long-term sustainable yield for each aquifer
- Standard screening level long-term sustainability assessment for supply wells
- Gain understanding lower range single well long-term sustainability for comparison to numerical model results

Result:

- Wells completed within the Winnipeg Sandstone and Red River Carbonate aquifers are expected to yield sufficient groundwater to meet the proposed project's water demand with conservative assumptions.
- Directionally consistent with AECOM numerical modelling results.

The long-term theoretical sustained yield is calculated using the **Farvolden Method**

$$Q_{20} = 0.68 * T * H_a * 0.7$$

$$T = K * b$$

Where: Q_{20} = the 20 year sustained yield (m^3/s)

Conservative Assumptions:

Confined aquifers
Homogeneous
20-year continuous pumping
70% safety factor

Direct Effects of the Proposed Project

GROUNDWATER QUALITY

<u>Addition of oxygen:</u>

- Minor effect on groundwater quality in magnitude
- Would contribute to precipitation of iron and manganese
- Local extent surrounding extraction wells

<u>Mixing of the waters from Winnipeg Sandstone and Red River Carbonate Aquifers:</u>

- PHREEQC modelling results and interpretations were validated
- Other aspects of the geochemical system were not reviewed as part of Matrix's scope (e.g., potential for acid rock drainage, shale collapse, or composition of the sandstone)

Direct Effects of the Proposed Project

PROPOSED PROJECT'S SHORT-TERM DIRECT EFFECTS

- In consideration of project's proposal and technical responses to supplemental information requests with regard to the hydrogeological component of the project:
  - Matrix's opinion is that the hydrogeological assessment with regard to the evaluation of project's short-term direct effects was **appropriate**.
  - Despite this conclusion, in the following sections, Matrix raises the following concerns on **potential long-term indirect effects** from the proposed project.

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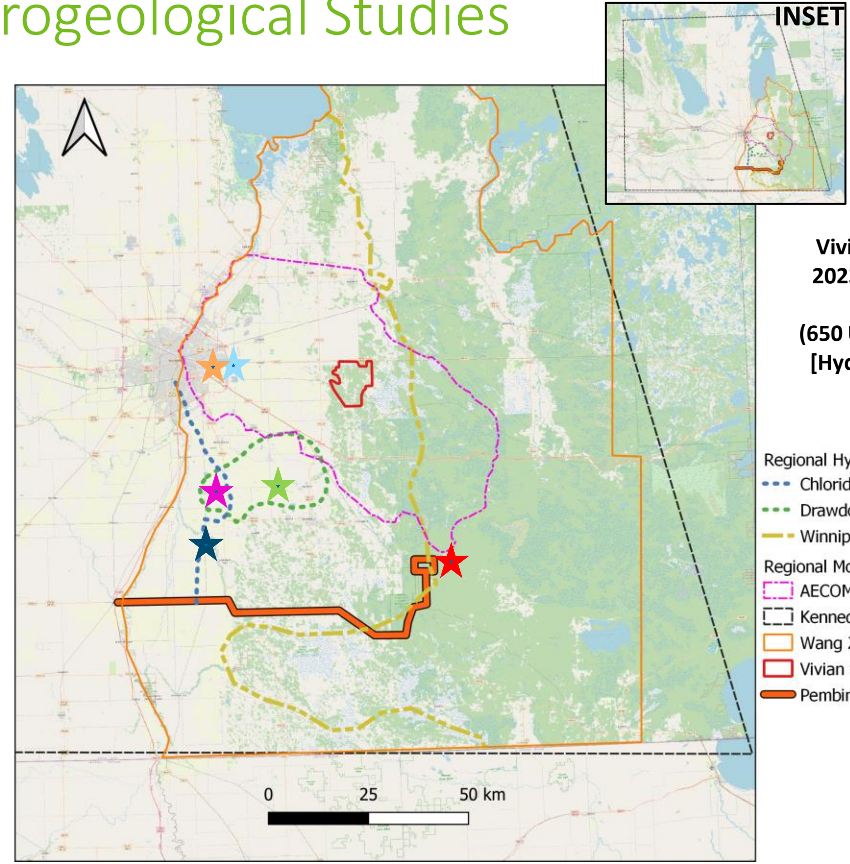
Historical Regional Hydrogeological Studies

- 1986 Betcher, Regional Hydrogeology of the Winnipeg Formation in Manitoba
- 1995 Betcher, Groundwater in Manitoba: Hydrogeology, Quality Concerns, Management
- 2002 Grasby and Betcher, Regional hydrogeochemistry of the carbonate rock aquifer, southern Manitoba
- 2002 Kennedy, Ph.D. Thesis, Groundwater Flow and Transport Model of the Red River/Interlake Area in Southern Manitoba
- 2003 Betcher and Ferguson, Impacts from Boreholes interconnecting multiple aquifers – a case study of Paleozoic aquifers in south-eastern
- 2005 Kennedy and Woodbury, Sustainability of the Bedrock Aquifer Systems in South-Central Manitoba: Implications for Large-Scale Modelling
- 2007 Ferguson and Betcher, Hydrogeology of the Winnipeg Formation in Manitoba, Canada
- 2008 Phipps, Geochemical and Isotopic Characterization of a Regional Bedrock / Surficial Aquifer System, Southeastern Manitoba
- 2008 Wang, Groundwater Resource Evaluation in Southeastern Manitoba
- 2010 Southeast Regional Groundwater Management Plan
- 2019 Friesen, Supplemental Municipal Groundwater Supply Rural Municipality of Springfield

Historical Regional Hydrogeological Studies

- 1964 Red River Floodway Construction
  - ***Groundwater levels decreased*** from 234 to 227 m asl (Wang 2008)
  - Large-scale dewatering below top of bedrock surface resulted in progression of the ***freshwater/saltwater front***.
- 2005 Red River Floodway Expansion
  - Proposed to cut into the regional Red River Carbonate Aquifer; potential increased groundwater discharge and pathways for contaminants
- 2007 Pembina Valley Water Cooperative
  - Supplemental Groundwater Supply System: **7,000 m³/day**
- 2008 Wang
  - 1991-2005 2 m Drawdown from urban development near Steinbach
- 2010 Southeastern Regional Groundwater Management Plan
- 2019 Supplemental Municipal Groundwater Supply Rural Municipality of Springfield
  - Population growth 8.73% per year
  - Demand projected: **2,500 m³/day**
  - Speculated Steinbach drawdown caused by 1970's Manning Canal – New Equilibrium (Supply for Ste. Agathe/Ile des Chenes)



Vivian Sands Proposed Project
2023 Groundwater Model – 0%
2,016 m³/day
(650 USGPM 200 days operations)
[Hydro. Feb. 28, 2023, Slide 24.]

Regional Hydrogeological Features
- Chloride >250ppm (Interp. from Phipps 2008 Fig.7)
- Drawdown 2 m (Wang 2008 Fig. 15)
- Winnipeg Sandstone Upper Contact

Regional Model Domains
- AECOM 2021
- Kennedy and Woodbury 2002
- Wang 2008
- Vivian Sands - Proposed Project Area
- Pembina Valley Water Coperative

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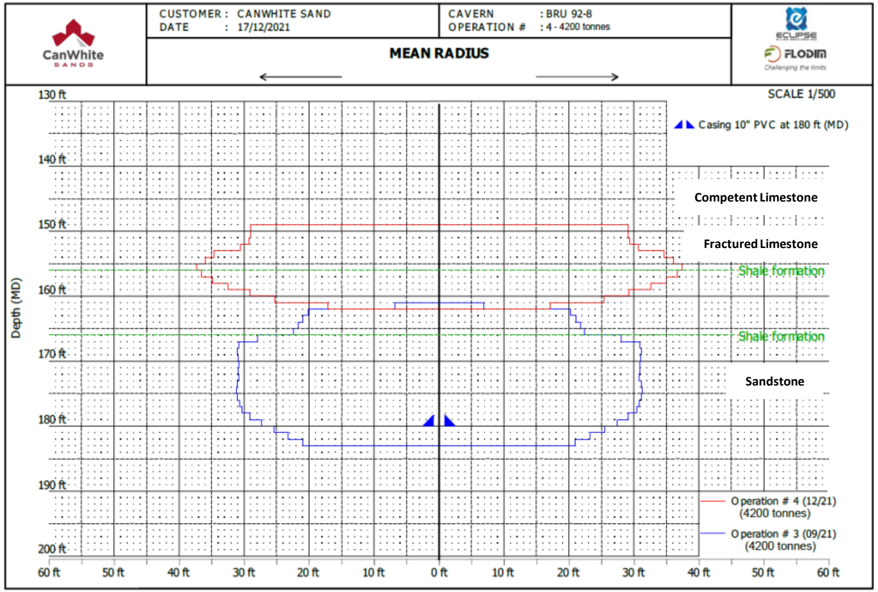
Indirect Effects of the Proposed Project

- **<u>Indirect effects:</u>** A secondary environmental effect that occurs as a result of a change that a project may cause in the environment. An indirect effect is at least one step removed from a project activity in terms of cause-effect linkages.

- **<u>Duration:</u>** Long-term (>10 years)

- **<u>Reversibility:</u>** Irreversible (Adverse effect is likely to not be reversed after project closure)

- In Matrix's opinion, there are the **two critical irreversible** effects the project has on the hydrogeological system that could lead to indirect effects in the long-term:
  1) degradation of the Winnipeg Shale Aquitard; and,
  2) increase in fracture density of the Red River Carbonate Aquifer.



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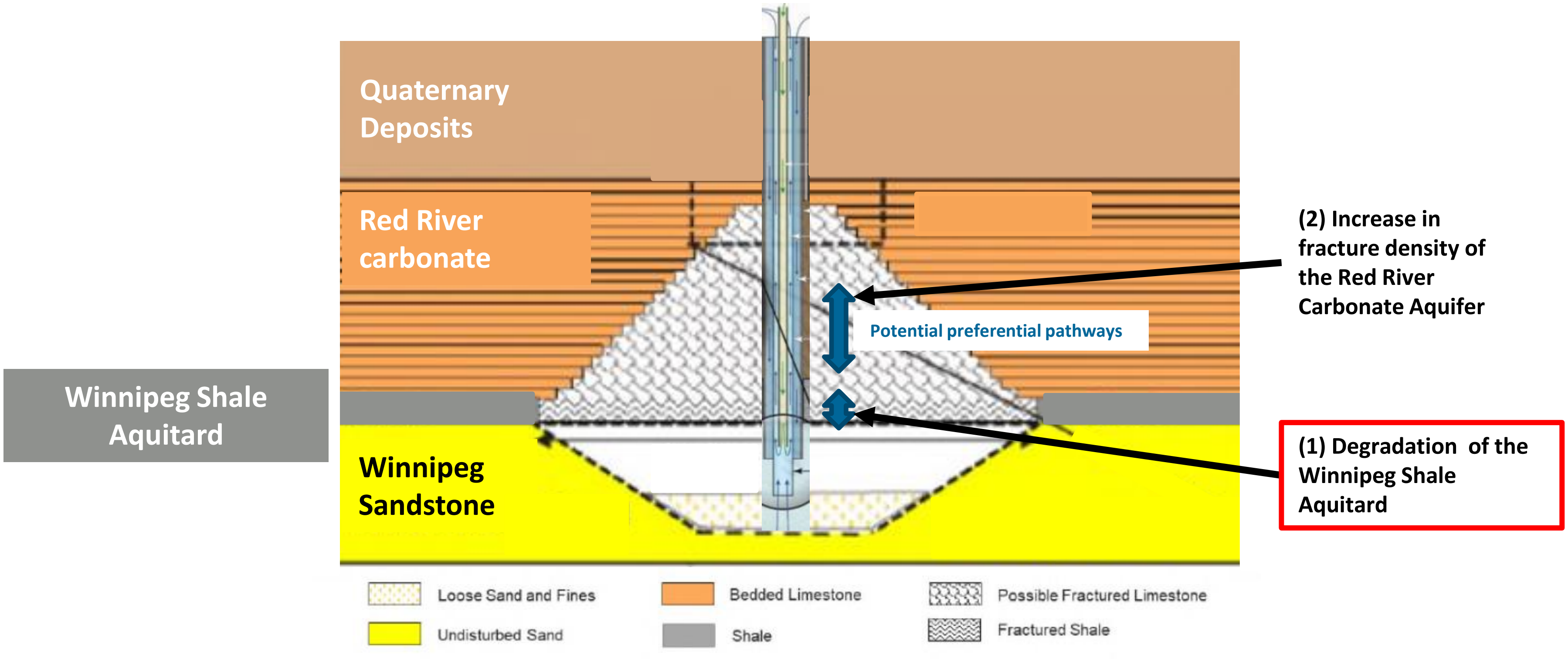
Indirect Effects of the Proposed Project



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Indirect Effects of the Proposed Project

Stantec

Geotechnical Analysis for Sio Silica Extraction Project

Project # 129500426

January 14, 2022

Prepared for:

Sio Silica Corporation

Prepared by:

Stantec Consulting Ltd.

Table 9: Allowable Extraction Disturbance Zone Dimensions

Competent Limestone Thickness (m)	Overburden Thickness (m)	Long-term Allowable Limestone Unsupported Span (Diameter) (m) (Notes 1 and 2)	Extraction Disturbance Zone Dimensions (Notes 3 and 4)	
			Top Diameter (m)	Bottom Diameter (m)
10	25	26	16	0 (Note 5)
	35	24	14	0 (Note 5)
15	25	35	25	6
	35	32	22	3
20	25	43	33	14
	35	40	30	11
25	25	50	40	21
	35	47	37	18

Notes:

1) Bending (Tensile) is the controlling failure mechanism to determine the long-term allowable span.

2) Single beam maximum long-term allowable span is 7 m. Average competent limestone bedding thickness is 0.7 m.

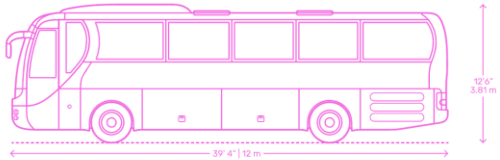
3) Extraction zone side wall slope of 65°.

4) Extraction depth is 20 m.

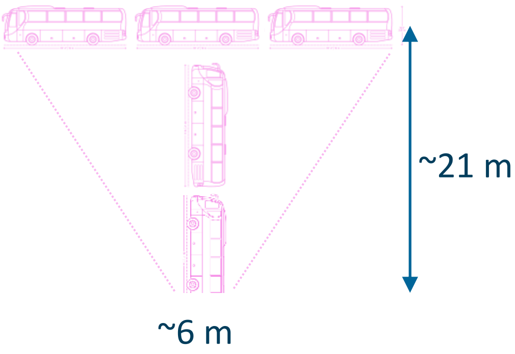
5) The long-term diameter of the extraction cavity is expected to be 10 m larger than the short-term diameter.

6) Due to possible long-term cavity expansion, limit the extraction zone to the long-term allowable unsupported span.

7) Extraction in areas with only 10 m of competent limestone is discouraged due to competency uncertainties.



~35 m Long-term allowable unsupported span



Volume disturbance zone per well: 6,735 m^3

Frustrum of right circular funnel of radii a, b and depth h

Volume = $1/3\pi h(a^2 + ab + b^2)$

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Indirect Effects of the Proposed Project

Why important?

- Local evaporation line suggest kinetic fractionation in Red River Carbonate (**recharge from different evaporation conditions throughout the year suggesting distributed recharge**)
- Winnipeg Sandstone all grouped around local meteoritic line (**single source of recharge not affected by evaporation fractionation**)

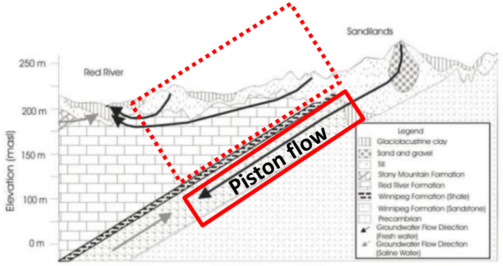

Figure 4 – Simple drawing of the groundwater recharge dynamics in the Southeastern Manitoba. (source – Betcher and Ferguson, 2003)

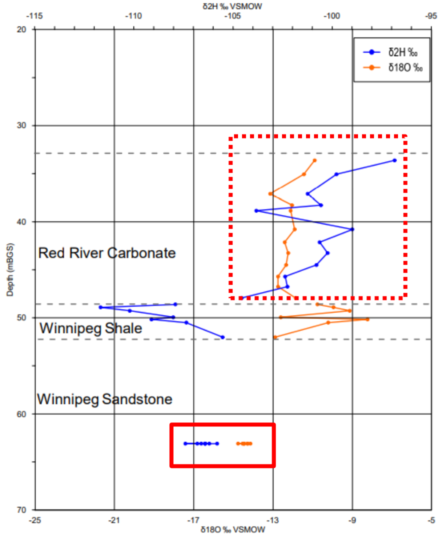

Figure 4-4. Depth Profile of Stable Isotopes - Oxygen-18 and Deuterium

AECOM

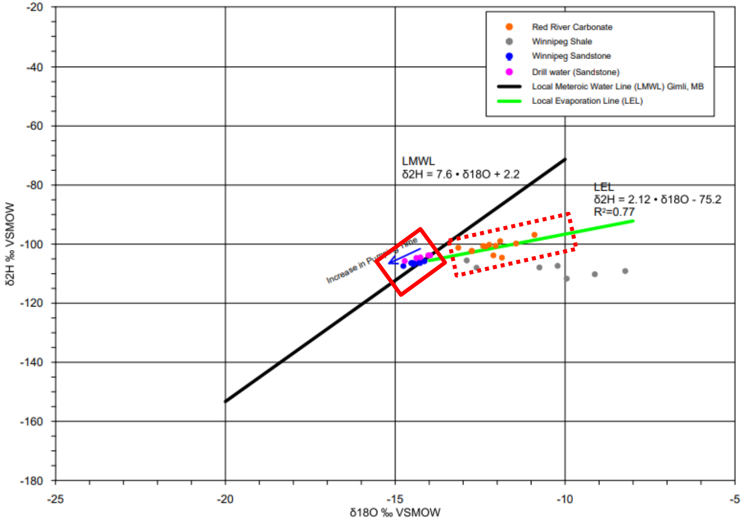

Figure 4-5. Stable Isotopes of Water in Carbonate, Sandstone and Shale Units

AECOM

Isotopes results are suggesting Red River Carbonate Aquifer groundwater recharge is more diffused than the Winnipeg Sandstone Aquifer.

<u>Two distinct water types based on isotopes.</u>

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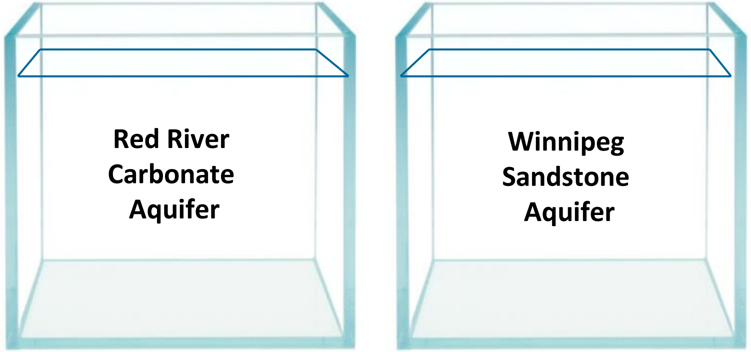
Indirect Effects of the Proposed Project

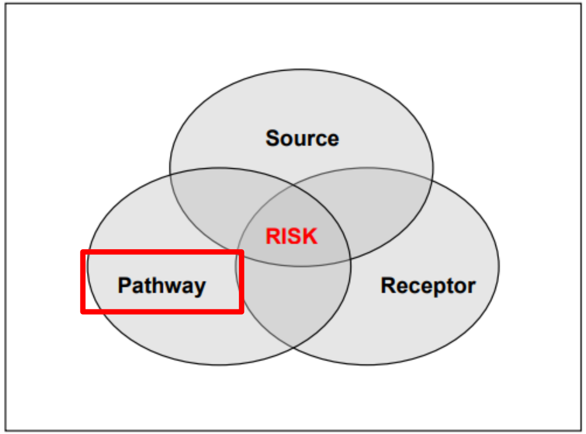
Why important?

– Winnipeg Shale Aquitard act as a **barrier** to groundwater flow
– Without the barrier, **creates a pathway**. It increases the vulnerability for both aquifers
– **Reduces ability to manage** aquifers individually (quantity and quality)



Winnipeg Shale Aquitard (barrier)

Conceptual Description of Environmental Risk



Indirect Effects of the Proposed Project

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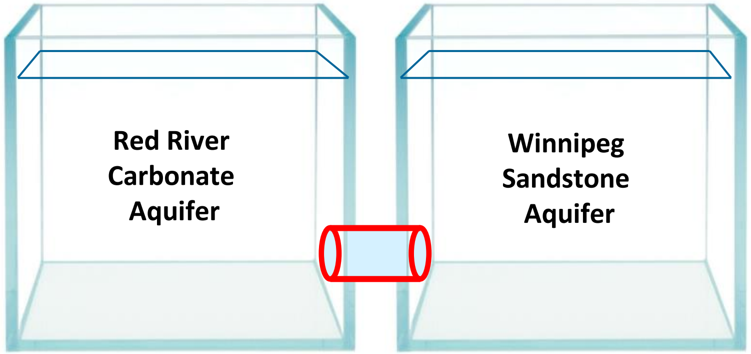
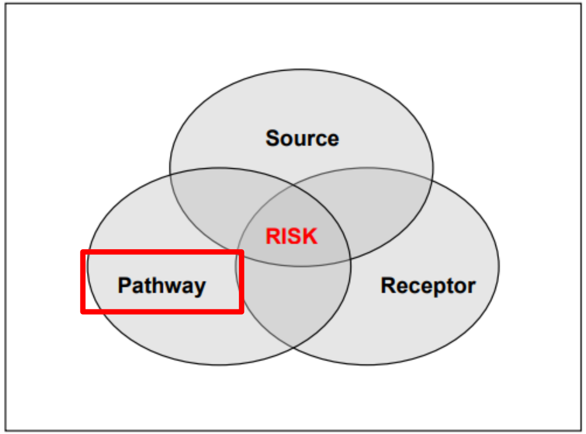


Post Sand Extraction

Conceptual Description of Environmental Risk



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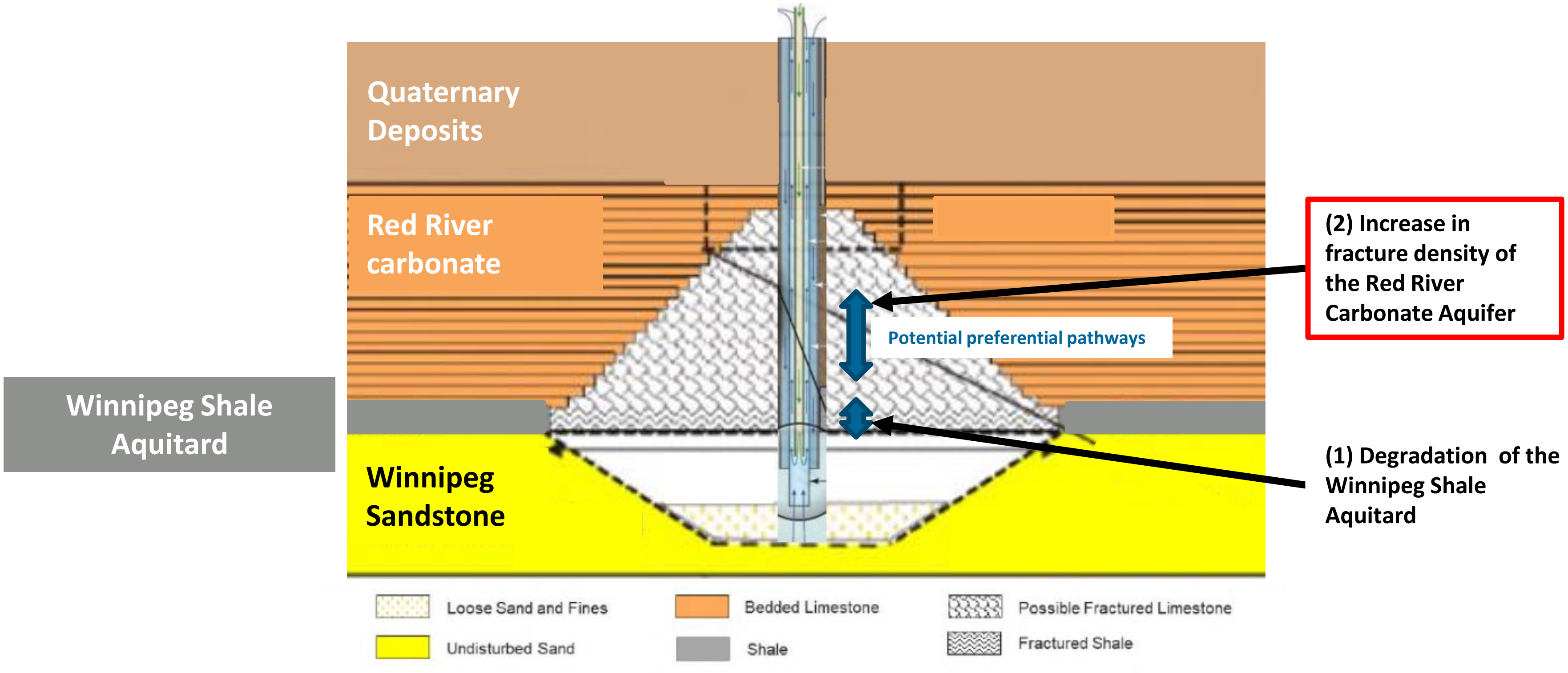
Indirect Effects of the Proposed Project



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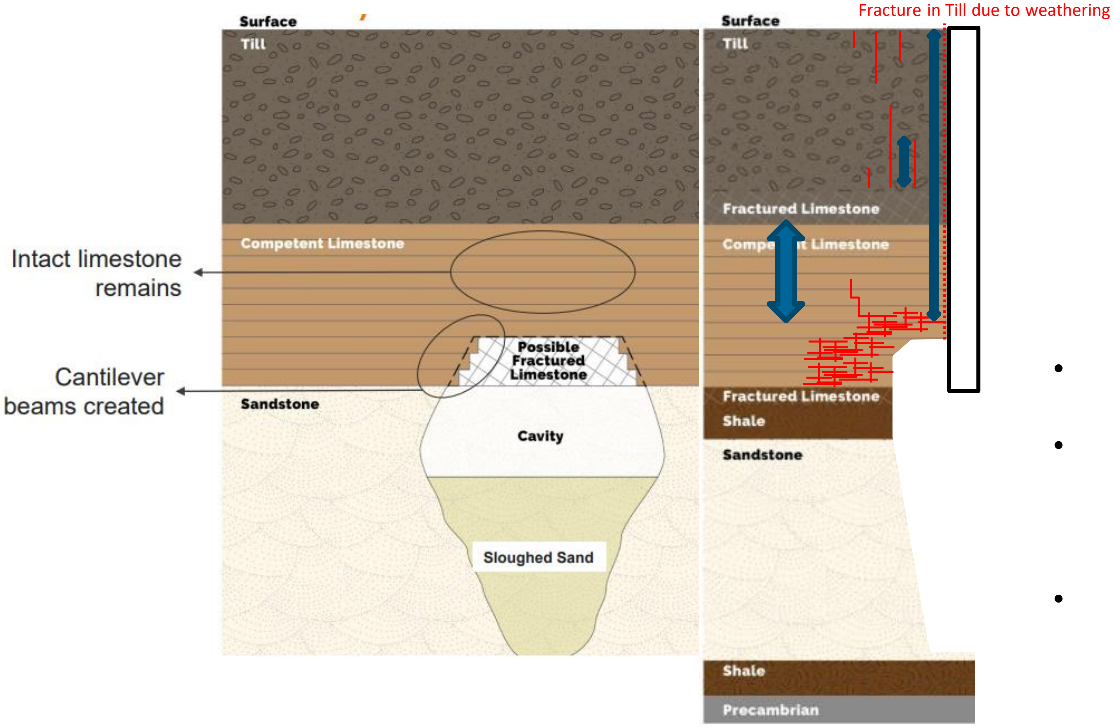
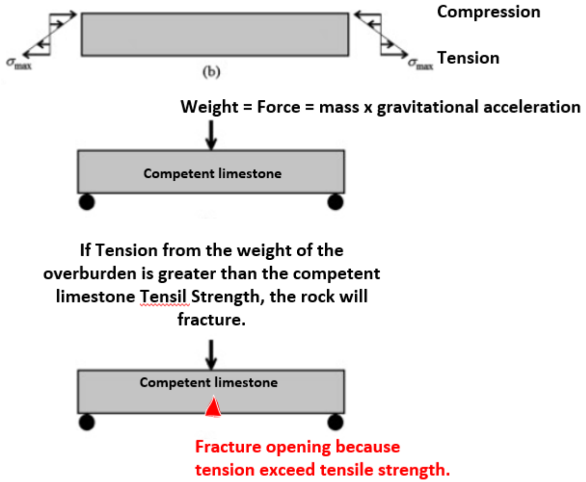


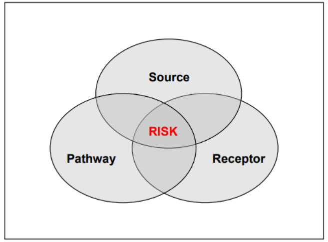


- Fractured porous network are highly **heterogeneous** and variability in fracture density should be expected.
- Increase in fracture density and/or increase in fracture apertures in the “Intact limestone” which could result in **increased vertical hydraulic permeability (e.g., pathways)**.
- Risk for preferential pathways increases with number of wells drilled (**hundreds/thousands**).

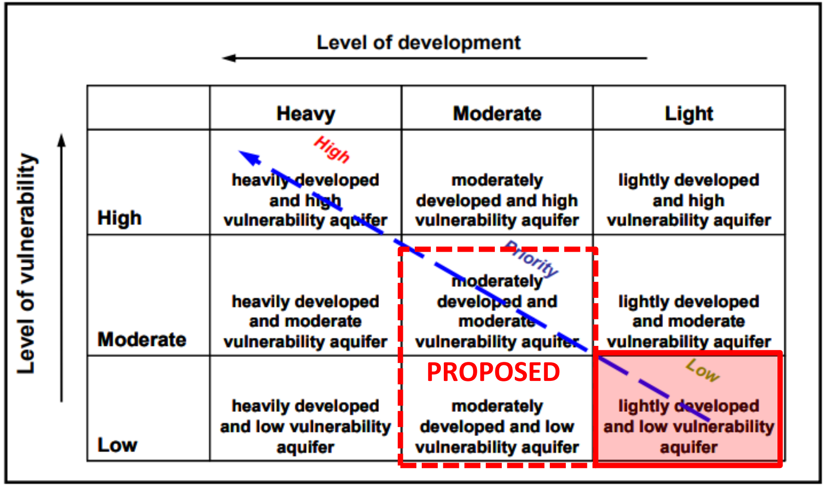
Indirect Effects of the Proposed Project

Why important?

- Project location hydraulically upgradient from most groundwater users
- Winnipeg Shale Aquitard act as a **barrier** to groundwater flow
- Without the barrier, **creates a pathway**. It increases the vulnerability for both aquifers
- **Reduces ability to manage** aquifers individually (quantity and quality)



Groundwater Risk Approach



Source: adapted from Berardinucci and Ronneseth 2002

BASELINE

Table 4-1: Land Cover in the Project Site and Regional Project Area

Cover Type	Project Site (2021 to 2025)		Regional Project Area		24-year Life of Project Area*	
	Hectares (ha)	Percent (± 1%)	Hectares (ha)	Percent (± 1%)	Hectares (ha)	Percent (± 1%)
Developed	87	13	2,777	6	637	8
Fields (Agriculture)	204	31	11,426	26	2,016	24
Forested	289	45	17,246	40	4,561	55
Marsh - Muskeg	0	0	4,789	11	0	0
Meadow	53	8	3,382	8	510	6
Other (Gaps in Forest Inventory Mapping)	0	0	36	0	0	0
Shelter Belts	0	0	7	0	0	0
Treed Muskeg	0	0	914	2	0	0
Water	0	0	26	0	0	0
Willow / Alder	15	2	2,775	6	511	6

Project Site = 649 ha; Regional Project Area = 43,378 ha; 24-year Life of Project Area = 8,235 ha
*Refer to **Figure 1-1** for the 24-year Life of Project Area
Source: Manitoba Land Initiative (2017)

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Indirect Effects of the Proposed Project

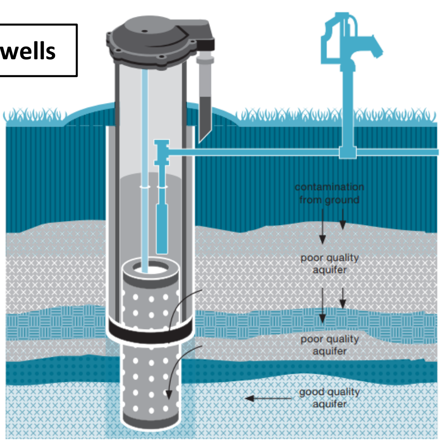
Why important?

– Winnipeg Shale and Fractured limestone collapse is **irreversible**

– Proponent response:
... considered to not be a concern should this occur: "Interconnection between the two aquifers is a common occurrence because many drinking water wells have been screened across the Red River Carbonate and the Winnipeg Sandstone."

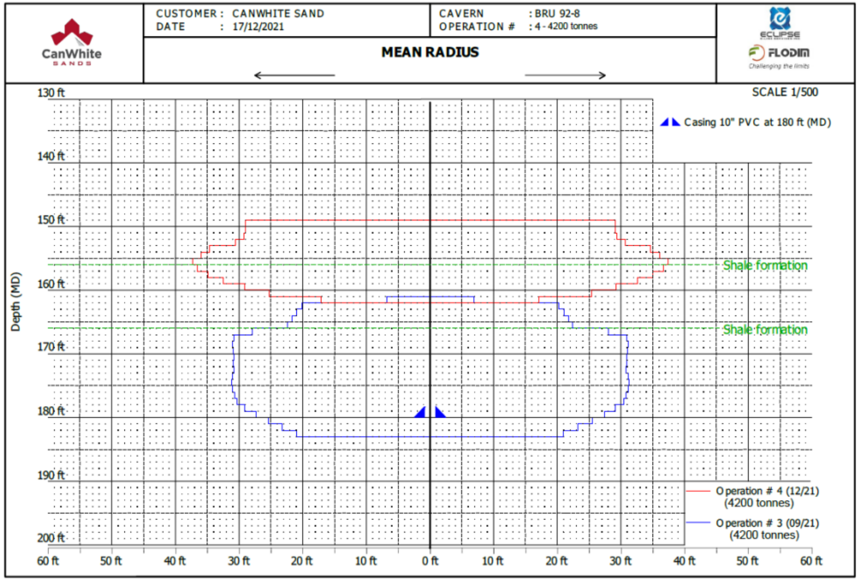
Assumption
Top Diameter Well: 25 m
Area: **491 m²**

FIGURE 2.0 EXAMPLE OF MULTIPLE AQUIFER COMPLETION



Hundreds of wells

Assumption
Diameter Well:
5 ½" (139 mm)
Area: **0.06 m²**



Hundreds to thousands of wells

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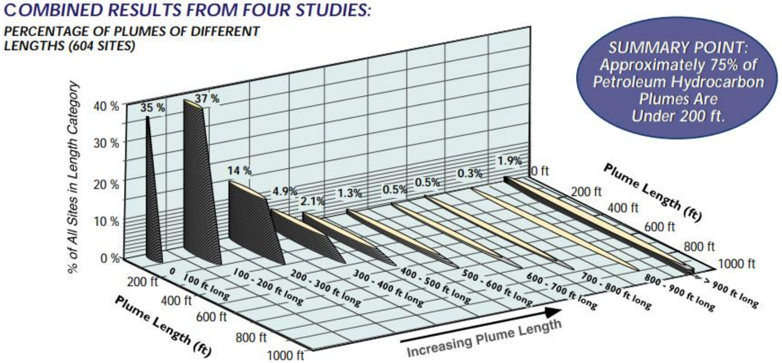
Indirect Effects of the Proposed Project

Risk for contamination?

– Human activities can lead to groundwater contamination.
– Point sources: landfills, leaking above/underground storage tanks, and accidental spills
– Diffuse sources: pesticides, fertilizers, and road/highway de-icing salt
– *"Shallow groundwater may be impacted by leaching of contaminants from the soil zone, but regional sampling programs have shown that most aquifers used in the area for household or municipal water **supply have not been affected to any significant degree**."* SRGMP 2010



^ 1.0 1.1 Newell, C.J. and Connor, J.A., 1998. Characteristics of Dissolved Petroleum Hydrocarbon Plumes, Results from Four Studies. American Petroleum Institute, Washington DC.

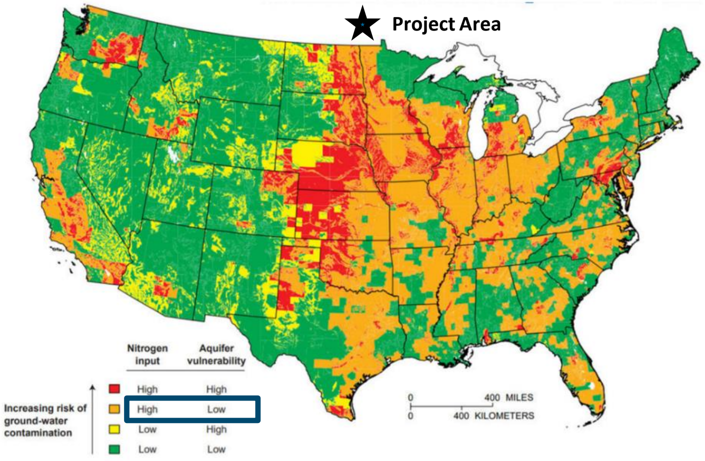


Fig. 6. Risk of nitrate pollution in groundwater aquifers in USA. Adapted from ("Groundwater Quality", 2019).

Indirect Effects of the Proposed Project

<u>Risk for contamination?</u>

- Red River Carbonate and Winnipeg Sandstone aquifers are assumed to have low DRASTIC index (vulnerability index)
- It is **unlikely** that contaminants migrate from ground surface to the Red River Carbonate Aquifer **<u>under current confined conditions</u>**
- Proposed activities during project's lifespan are **unlikely** to contaminate, if all mitigative measures are implemented

BUT

- It is **unlikely** that drilling and abandonments of **thousands of wells** be 100% compliant with proposed well design due to unforeseen technical issues which would result in preferential pathways (e.g., cement quality, casing failure, ...)
- Sand extraction could result in potential **enhanced vertical hydraulic connection** between ground surface and the Red River Carbonate Aquifer, and between Red River Carbonate and Winnipeg Sandstone Aquifer
- Future anthropogenic activities are unknowns (e.g., Ontario legacy wells problem)
- Since groundwater is the main source of potable water for thousands of Manitobans, **precautionary approach** is important

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- Concerns with the numerical model
- Conclusions

Groundwater Management Plan

- Aquifer management plans were developed between 1997 and 2005:
  - Winkler
  - Oak Lake
  - Assiniboine Delta
- Regional concerns overdevelopment and salt intrusion
- Southeast Regional Groundwater Management Plan was issued in 2010

SRGMP

Southeast Regional Groundwater Management Plan

Groundwater Management Plan

- The **sustainable yield** of a groundwater system has been defined in Manitoba as (SRGMP, Section 3.8 Sustainable Yield):

“the amount of water that can be removed on a long-term basis from an aquifer or aquifer system without compromising the ability of the aquifer or aquifer system to provide water to future generations and not imposing an unacceptable impact on parts of the ecosystem which depend on groundwater discharge, or causing other unacceptable impacts.”

- Example of implementation; annual water use licensing limited to sustainable yield as following:
  - **50% average annual recharge**
  - **15-30% average annual recharge, in sub-basins contained waterways with major reliance on aquifer discharge**

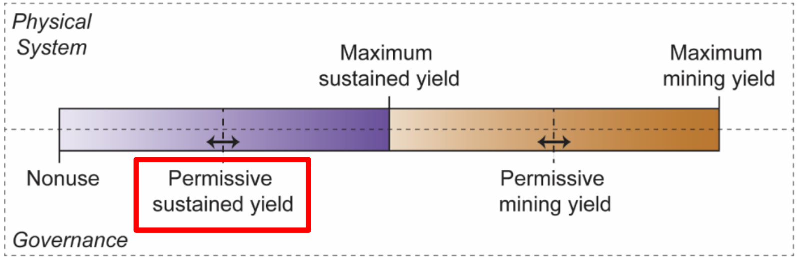


Figure 4. Aquifer yield classes, modified after Kalf and Woolley (2005) and Pierce et al. (2013).

Table 1. Equations used for calculating the yields for each aquifer yield class.

Nonuse	Permissive Sustained Yield	Maximum Sustained Yield	Permissive Mining Yield	Maximum Mining Yield
$P_{NU} = 0$	$P_{PSY} = R - D_x$	$P_{MSY} = R$	$P_{PMY} =$ $R + (V_0 - V_x)$	$P_{MMY} = R + V_0$

P = groundwater withdrawal (pumping)
R = inflow into the groundwater system (i.e., recharge)
D_x = desired discharge from the groundwater system (other than pumping)
V_0 = initial volume of water-saturated aquifer prior to the planning horizon
V_x = desired volume of water to remain in storage at the end of the planning horizon

Pierce, S.A., Sharp, J.M., Guillaume, J.H.A., Robert, E.M. and Eaton, D.J. (2013): Aquifer-yield continuum as a guide and typology for science-based groundwater management; Hydrogeology Journal, v. 21, no. 2, p. 331–340, doi:10.1007/s10040-012-0910-y

Kalf, F.R.P. and Woolley, D.R. (2005): Applicability and methodology of determining sustainable yield in groundwater systems; Hydrogeology Journal, v. 13, no. 1, p. 295–312, doi:10.1007/s10040-004-0401-x

Groundwater Management Plan

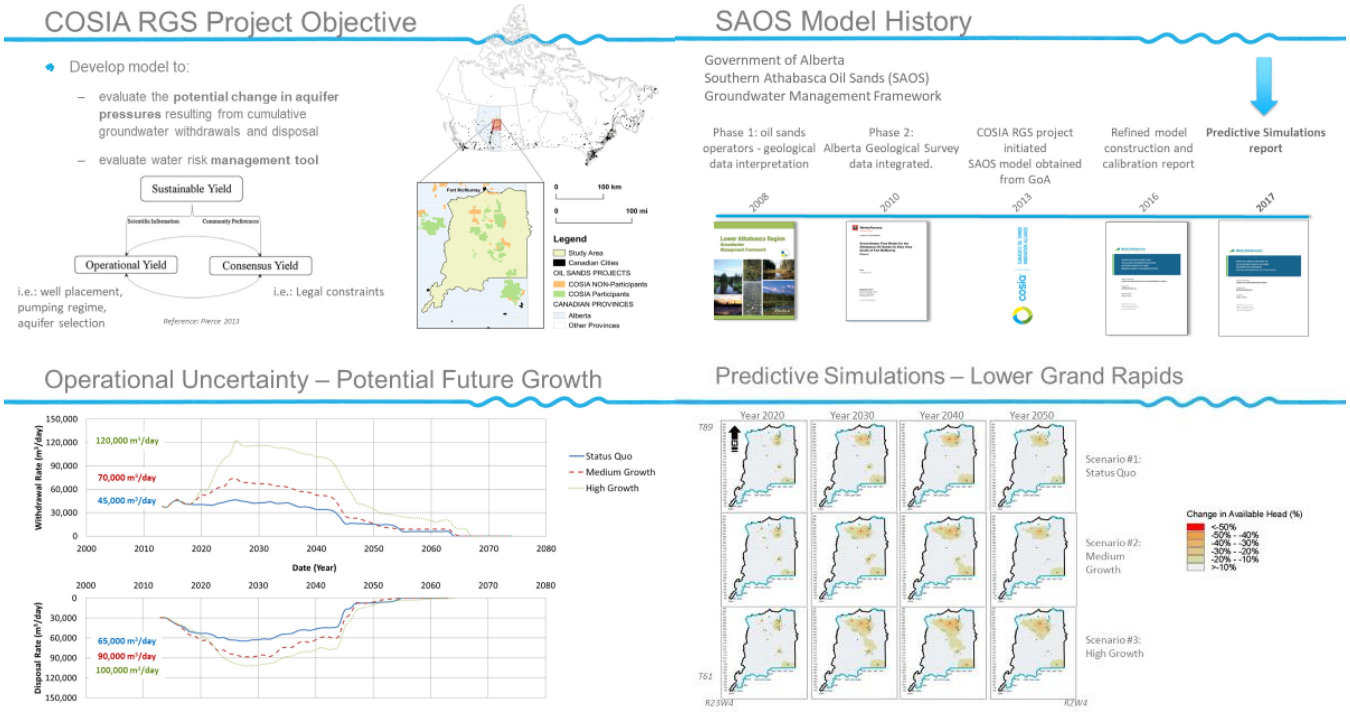
From SRGMP 2010:

- "The approach to sustainable yield and water use licensing limits in the study area needs to be more continuous, integrated and comprehensive. Such an approach has been initiated in the design of a **three-dimensional digital model for the groundwater flow regime**." → Wang 2008

- "**The model** is expected to be completed for initial use by 2011, at which time it will be **used to evaluate** recharge areas and volumes, local and regional water tables, potential water level **and water regime impacts from proposed developments**, adequacy of the monitoring network and as a key management tool to assess local, regional and regime **sustainable yield** values."

Groundwater Management Plan

- Example of a groundwater management plan that is consistent with the goal of SRGMP 2010:
  - SAOS: Southern Athabasca Oil Sands
  - COSIA: Canada's Oil Sands Innovation Alliance
  - RGS: Regional Groundwater Solutions Project
- Benefit of using a common numerical model:
  - Foster collaboration between stakeholders
  - Have a shared understanding of the water balance of the system
  - Gain understanding and confidence over time
  - Evaluate future use



https://cosia.ca/resources/project-research

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Road map

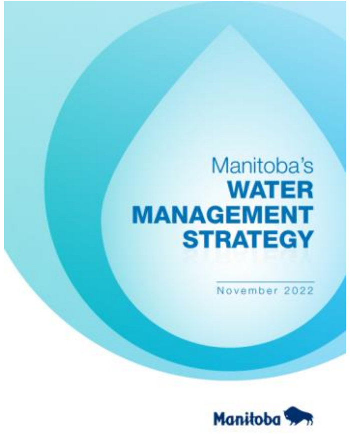
- Overview of concerns related to groundwater
- Well completion and abandonment
- Matrix's opinion on direct effects of proposed project
- Historical regional hydrogeological studies
- Long-term indirect effects
  - Connects aquifers and creates preferential pathways
  - Increases risk of contamination
- Review of the Southeast Groundwater Management Plan
- **Cumulative Impact**
- Concerns with the numerical model
- Conclusions

Cumulative Effects Assessment of the Full Project

- Back to the hearing subject ...

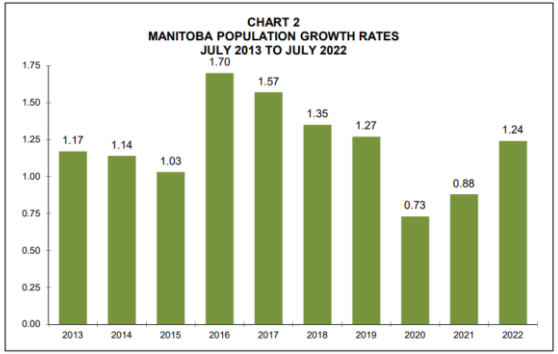
- Canadian Environmental Assessment Act defines a cumulative impact assessment (CIA) as following: *"any cumulative environmental effects that **<u>are likely</u>** to result from [a] designated project in combination with other physical activities that have been **<u>or will be carried out.</u>**"*

- **Cumulative impacts** – changes to the environment (positive or negative, direct and indirect, long-term and short-term) that are caused by an action in combination with other past, present and reasonably foreseeable future human actions. Each individual impact may not be significant if taken in isolation, but can be significant when considered as a whole.



Cumulative Effects Assessment of the Full Project

- In Matrix's opinion, CIA should consider effects from existing and **<u>foreseeable future activities</u>**.
  - Full Project: 24-year lifespan
  - Population growth
  - Agricultural and industry growth
- Manitoba population:
  - October 2022: 1,420,228 persons
  - 2013-2022 Average annual growth 1.21%
  - Yearly additional water consumption: **8,578 m³/day**
    (SRGMP 2010: 500 L/day per person)



DATA SOURCE: STATISTICS CANADA
(Table 17-10-0009-01)

MANITOBA BUREAU OF STATISTICS
SEPTEMBER 28, 2022

Cumulative Effects Assessment of the Full Project

- Future development plan from the Vivian Sands proposed project did not use the SRGMP numerical model for which the **model domain** was adopted by stakeholders and decision-makers.
  - Unclear if Wang (2008) model was approved by Manitoba Water Stewardship – Groundwater Management
  - Unclear if the use of this model was discussed at early stages of the EAP process

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Road map

- Overview of concerns related to groundwater
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- Historical regional hydrogeological studies
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  - Connects aquifers and creates preferential pathways
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- Cumulative Impact
- **Concerns with the numerical model**
- Conclusions

Cumulative Effects Assessment of the Full Project

- Concerns of using AECOM 2021 regional numerical model:
  - The model domain exclude regional areas of overdevelopment and salt intrusion concerns identified within the SRGMP that are key to cumulative effects assessment.
  - The domestic wells outside the regional project area were not considered.
  - Foreseeable population, industry, and agricultural growth was not considered.

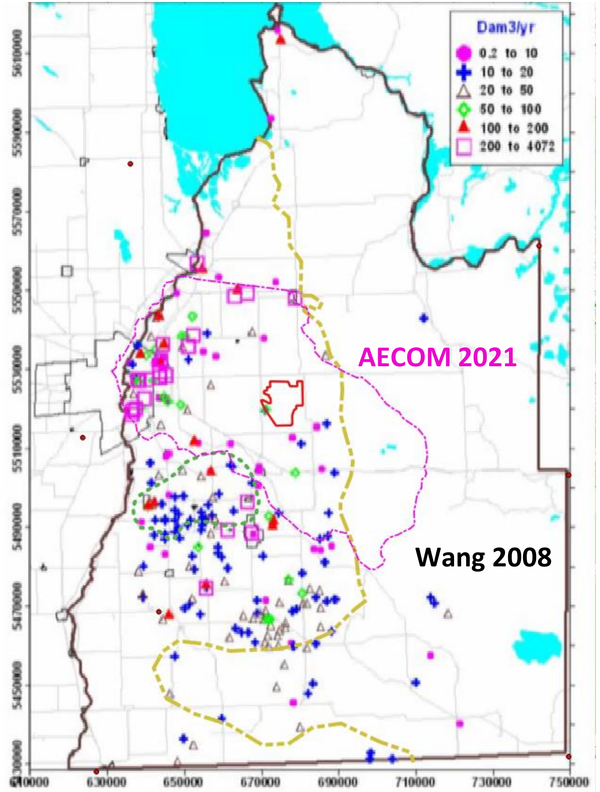

Figure 10 Groundwater License Location

From Wang 2008

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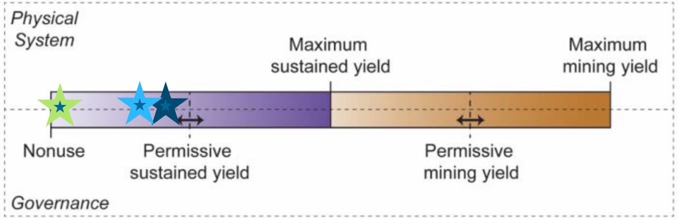
Cumulative Effects Assessment of the Full Project

Matrix notes that the domestic water use is inconsistent between historical studies:

- SRGMP 2010 — 500 L/day per person
- Friesen 2019 — 300 L/day per person
- AECOM 2021 — 200 L/day per person

Component of the Water Balance	AECOM 2021	Friesen 2019	SRGMP Wang 2008	Kennedy and Woodbury 2005
Model Domain Area (km²)	3,176	N/A	17,000	60,000
Recharge Applied (m³/day)	620,000	32,877	N/A	164,160
Groundwater Use (m³/day)	17,189	12,932	81,424	51,840
Groundwater Use (% of Recharge)	**2.8** ★	**39.0** ★	**N/A**	**32.0** ★

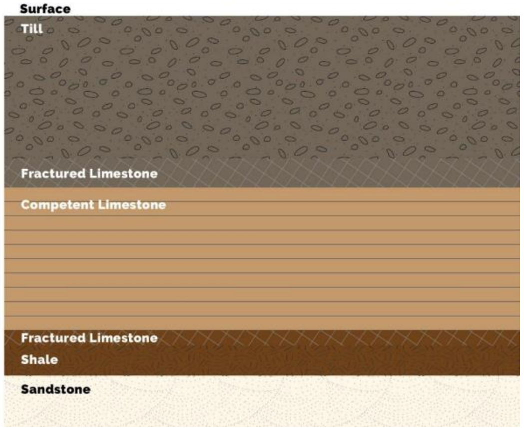


Groundwater Users	AECOM 2021 Consumptive Groundwater Use
Licensed water wells	5,241,820 m³/year (14,361 m³/day)
Domestic within Regional Project Area	439,000 m³/year (1,203 m³/day)
Domestic outside Regional Project Area	Not considered
Proposed Project (0% Re-Injection – Conservative)	593,000 m³/year (**1,625 m³/day**)
Total	6,273,820 m³/year (**17,189 m³/day**)

Prediction of Local Effects

- Concerns of using AECOM 2021 numerical model for the simulation of local scale effects:
  - The use of seven layers do not represent the conceptual site model in vicinity of extraction wells.
  - Higher hydraulic conductivity zones are found at the top and bottom of Red River Carbonate Aquifer, but not represented in AECOM model.
  - Vertical refinement is needed to simulate the effect of sand extraction and collapse of Winnipeg Shale and fractured limestone.

- Quaternary Sediments (Layers 1-3)
- Sedimentary Bedrock Layers (Layers 4-6)
  - Red River Carbonate
  - Winnipeg Shale
  - Winnipeg Sandstone



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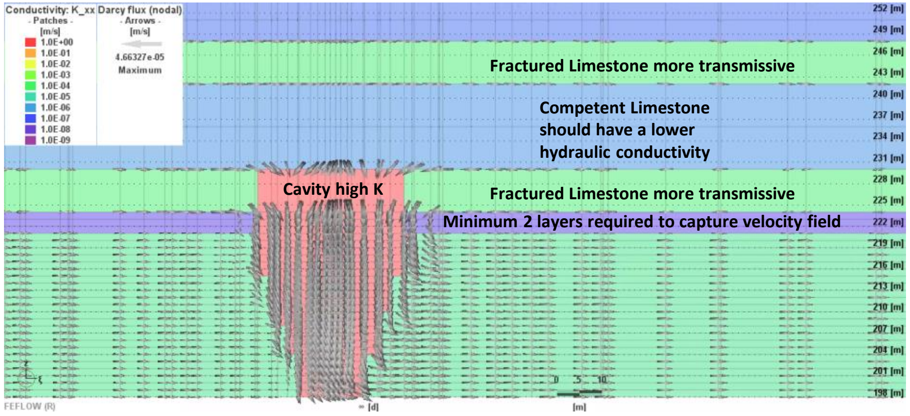

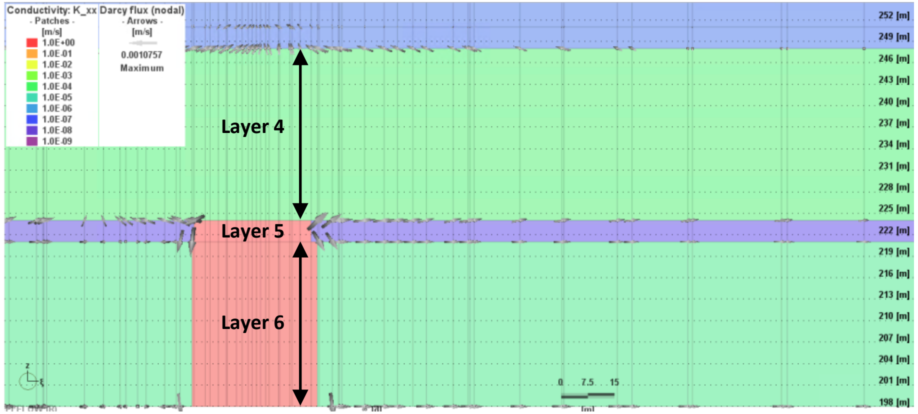

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Conclusions

Conclusions

- Overall, the assessment of the project potential (short-term) direct effects on the hydrogeological system respects industry standards for regional studies.

- Two critical irreversible effects the project has on the hydrogeological system that could lead to indirect effects in the long-term are the degradation of the Winnipeg Shale Aquitard and the increase in fracture density of the Red River Carbonate Aquifer.

- Several jurisdictions have adopted prohibitive measures to prevent the construction of water wells across multiple aquifers to prevent waters mixing and prevent the spread of contaminants. The effect of the proposed project is expected to systematically enhance the hydraulic connectivity between the Red River Carbonate and Winnipeg Sandstone aquifers due to degradation of the Winnipeg Shale Aquitard and increase in fracture density in the Red River Carbonate Aquifer, which increases both aquifers vulnerability.

- In Matrix's opinion, the irreversible and permanent indirect effects of the project should be considered not only based on potential accidental release of contaminant from the proponent's project, but also understanding that any future anthropogenic activities can lead to contaminated groundwater from either point or distributed sources. The indirect effect is the increase in vulnerability of both aquifers and should be evaluated by decision-makers (e.g., the CEC hearing), to determine if the project meets the objectives of the *Environment Act*, the *Groundwater and Water Well Act*, and the *Mines and Minerals Act* with respect to the preservation of these aquifers for the benefit of future generations of Manitobans.

Conclusions

- Future development plan from the proposed project did not use the SRGMP numerical model. It is unclear if Wang (2008) model was approved by Manitoba Water Stewardship – Groundwater Management, or if the use of this numerical model was discussed at early stages of the EAP process, for consistency with the SRGMP.

- Predictive simulation performed by AECOM does not include regional areas of overdevelopment and salt intrusion concerns identified within the SRGMP, it does not account for cumulative effects from foreseeable growth, and its estimated recharge seems to be significantly greater than previous studies.

- At a local scale, the numerical model cannot reproduce the heterogeneity within the Red River Carbonate, nor reproduce the change in material properties and geometries from the sand extraction process.

Contact Us

Louis-Charles Boutin, P.Eng.
Principal Groundwater Engineer
Technical Lead Numerical Modelling
lboutin@matrix-solutions.com
403-589-0477

matrix-solutions.com

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