Vivian Sand Extraction Project

Clean Environment Commission Hearing Rebuttal

March 14, 2023

Outline

1. General Clarifications
2. Geotechnical
3. Pumping Test
4. Groundwater Modelling
5. Aquifer Sustainability
6. Water Quality
7. Pilot Test Details

Clarifications

Issue or Statement:

- Industry Standard vs. State of Art (Academic Research) (Dr. Hollander)

Rebuttal:

- Industry standard is not bare minimum. Industry standard relies on proven approaches to collect and analyze data that others can follow and repeat.
- State of Art (Academic Research) is about testing new ideas or trying to develop new methods to collect and analyze data to expand the knowledge base. Research is intentionally novel but is not trusted or proven until it has been validated by others and applied.
- Regulatory agencies typically do not allow for State of Art (Academic Research). Need to utilize/apply proven technologies and approaches to mitigate any project impacts.
- Key Differentiator: Every one of the Technical Experts engaged by Sio has a professional designation and is bound by a Code of Ethics and Professional Conduct to protect the public interest.

We all risk loss of our license, credibility, disciplinary action and our livelihoods if we do not abide by these requirements.

Clarifications

Issue or Statement:

- Shale collapse was not considered by groundwater modelling. (Dr. Hollander)
- Alleged that the information provided was only provided the first week of the CEC hearing and therefore had not been reviewed. (Dr. Hollander)

Rebuttal:

- Shale collapse was considered in all groundwater modelling conducted to date by assuming it was not present and therefore took on the properties of the sandstone, which will permit the flow of water to the void and the exchange of water between the aquifers.
- This was explained in detail during a virtual meeting attended by Dr. Hollander, Gerd Wiatzka, Tony Brown, Doug McLachlin, Taesang Ahn, Cliff Samoiloff, Arash Eshraghian, Steve Bundrock and Sio Silica's representatives on September 6, 2022 prior to finalization of their review. Approximately 21 minutes and 10 seconds into the recorded meeting we specifically discussed the assumed 200m radius of possible shale collapse and how that was addressed in the numerical groundwater model. It was explained that the analysis explicitly analyzed a scenario that contemplated shale failure.
- We were surprised and disappointed to learn that that those facts were not considered in the finalized version of comments provided by PorousTec.

Clarifications

Issue or Statement:

- Method of modelling shale collapse is not appropriate. (Dr. Hollander)

Rebuttal:

- This has been discussed in detail over the past two weeks.
- Water must flow through the sandstone to enter the void before it can migrate between the aquifers.
- The hydraulic conductivity of the sand was assigned to the shale within the numerical groundwater model as it will provide resistance to groundwater flow. You cannot assign an infinite hydraulic conductivity in a model.
- The hydraulic conductivity of the void is of little relevance to the overall regional groundwater flow patterns.

Clarifications

Issue or Statement:

- “Overall, this information suggests the Winnipeg Shale is an effective hydraulic barrier to interaction between the two aquifers at this location” (AECOM Report)

Rebuttal:

- Statement was intended to describe function of Winnipeg Shale regionally, but there was no intention to apply this statement to the Winnipeg Shale across the model domain as there are clear differences.
- Winnipeg Shale does provide some resistance to the exchange of groundwater between the Red River Carbonate and Winnipeg Sandstone aquifers, but it is clearly not a perfect hydraulic barrier:
  - Leaky aquitard response during pumping test.
  - Abundant (>1,000) wells interconnecting the two aquifers.
  - Observed degree of natural weathering in core.
  - Natural variability in thickness regionally.

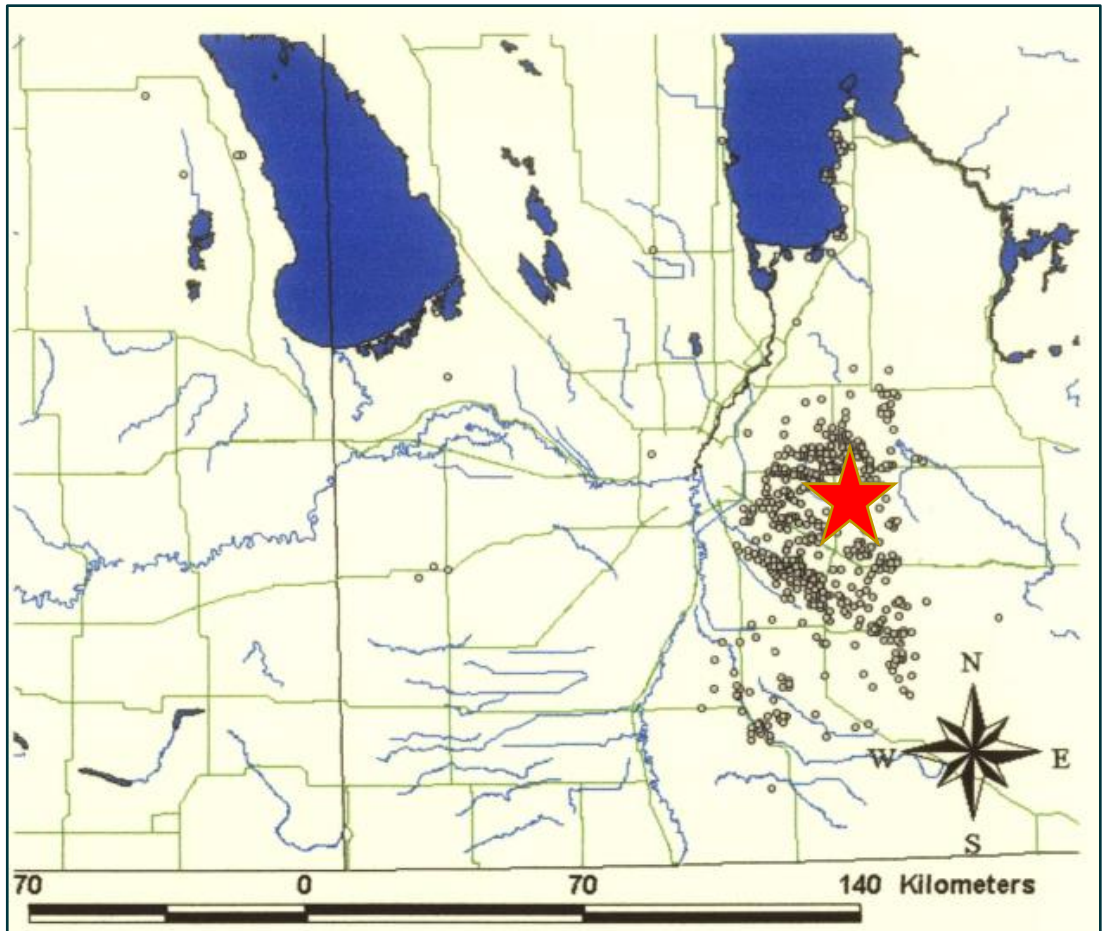


Figure 4.24 – Map showing location of wells screened over both the Carbonate and Sandstone Aquifers.

Clarifications

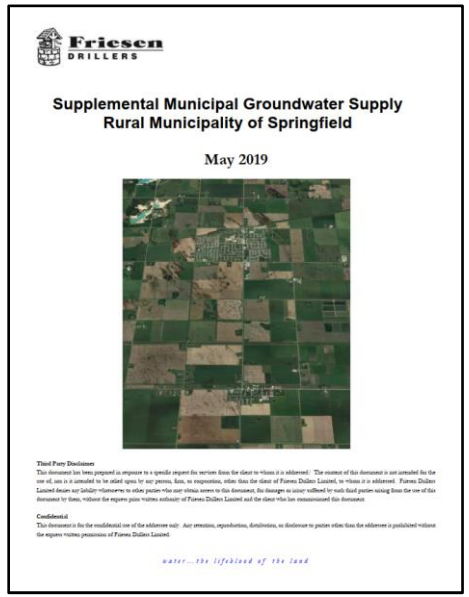
Issue or Statement:

- Matrix suggested that 200 L per person per day may not be an appropriate assumption.

Rebuttal:

- AECOM relied on EAP for Rural Municipality of Springfield (Friesen, 2019).
- Therefore, AECOM assumptions are appropriate and may be overly conservative.

"*Currently, water use in both Oakbank and Dugald is approximately 200 L/person/day (WSP, 2018), with the average use dropping per year over the last several years.*"



Friesen DRILLERS

Supplemental Municipal Groundwater Supply
Rural Municipality of Springfield

May 2019

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water...the lifeblood of the land

Currently, water use in both Oakbank and Dugald is approximately 200 L/person/day (WSP, 2018), with the average use dropping per year over the last several years. This is significantly below the Canadian average (Government of Canada, 2019). The low per capita water consumption rates are reflective of active programs by the RM to curtail water use. It should also be noted that nationally, per capita water rates are dropping. In the future, the RM plans to implement a study on further conservation efforts, and subsequently to implement an aggressive water conservation program, in the aim of obtaining additional water use reductions. These measures may include:

- A program for the installation of low-flow toilets within the town
- Lawn watering restrictions on certain days for properties
- Programs aimed at reducing water consumption within the town by major water users
- Additional digital real time monitoring of flows for the advanced detection of major water leaks.

Additional details are contained within the Master Plan for the RM water supply as prepared by Stantec Consulting (2016).

Clarifications

Issue or Statement:

- The integrity of sample Bru 96-1 collected in November 2020 is questionable because there was a significant delay between sampling and testing. (Dr. Hollander)

Rebuttal:

- All water quality samples were collected and stored following Standard Operating Procedures and delivered to ALS laboratory by trained professionals under standard Chain of Custody procedures.
- Bru 96-1 was collected on November 13, 2020, stored on ice and delivered to the laboratory on November 17, 2020. Four days between sampling and delivery to the laboratory are routine.
- Laboratory tests were completed within the recommended hold time.
- Water quality results were similar to Bru 96-1 sample collected on December 02, 2020.

Clarifications

Issue or Statement:

- Sio has not been controlling access to extraction sites or implementing health and safety protocols.

Rebuttal:

- Extraction wells are located on private property.
- Gates and signage have been repeatedly installed and removed by vandals on more than one location.
- Example: Gate installed at Bru-95 facility site prior to extraction activities occurring in June/July 2019. Gate installed in May 2019. Wells drilled mid-June 2019.
- Tarps utilized to cover sand piles following public concerns.

From: Mark Wowchuk [redacted]
Sent: Tuesday, May 14, 2019 1:42 PM
To: Brent Bullen <bbullen@canwhitesands.com>; Feisal Somji <fsomji@canwh
<lweeden@canwhitesands.com>; Tom Pierce <tpierce@canwhitesands.com>;
Subject: New Site Gate

All
Access gate installed .

Combination to the lock is TANK

Thanks

Mark

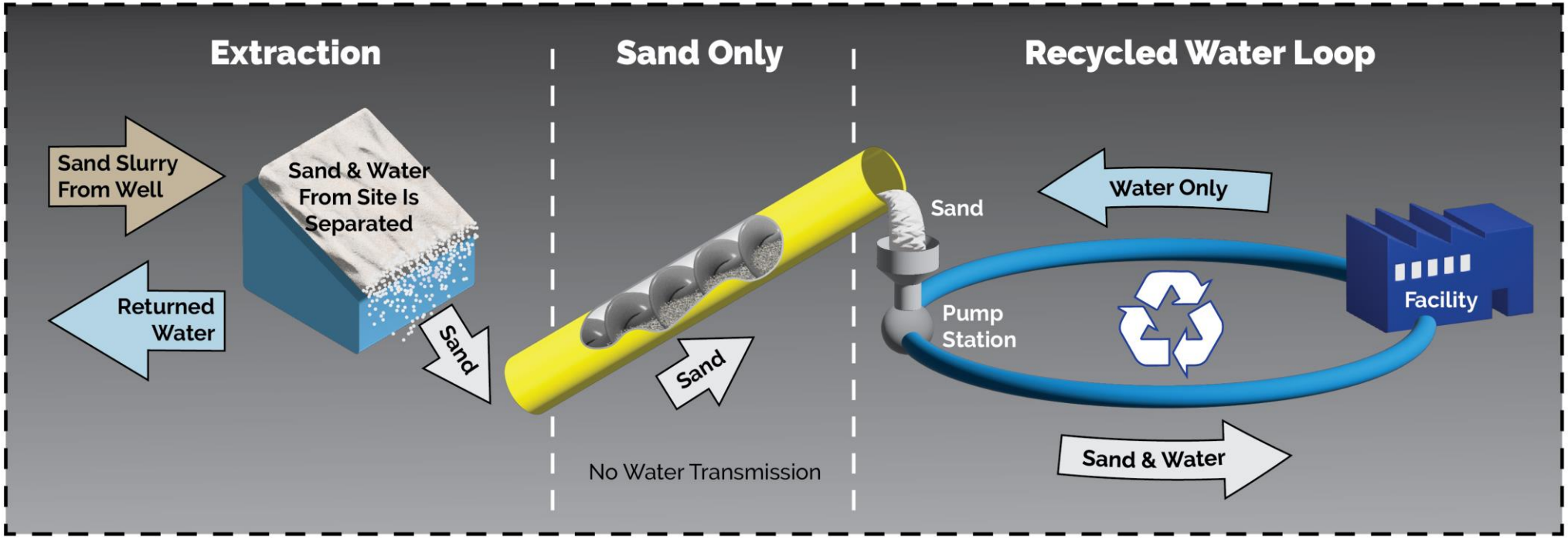
Clarifications

Issue or Statement:

- Concerns over connection between slurry loop and reinjection of water.

Rebuttal:

- There is no connection between the two systems.



Clarifications

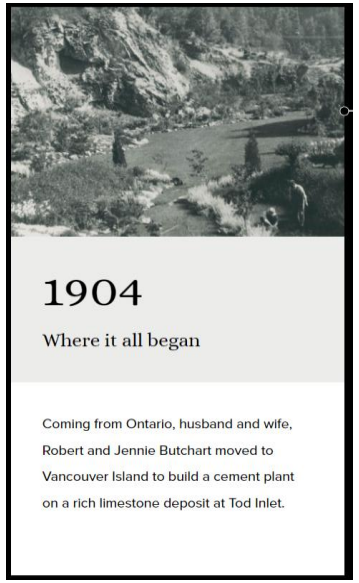
Issue or Statement:

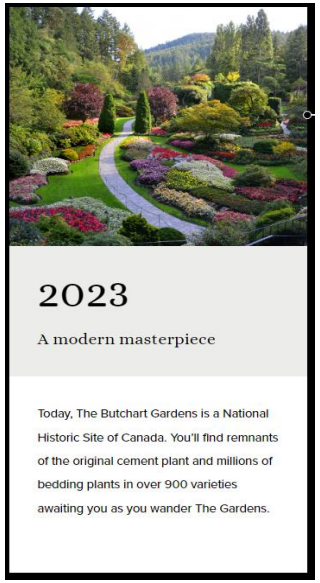
- There are no examples of mining in proximity to developed areas. (Matrix)

Rebuttal:

- There are hundreds of examples of mining near communities and water supplies, including many mining towns:
  - **RM of Springfield, MB**: Long history of sand/gravel mining.
  - **Flin Flon, MB**: Over 100 years of open pit and underground mining.
  - **Snow Lake, MB**: Over 50 years of underground mining.
  - **Thompson, MB**: Over 67 years of underground and open pit mining.
- **K&S Potash Mine** (b/w Regina and Moose Jaw, SK): Potash
- Chaplin Lake Mine (Chaplin Lake, SK): Sodium Sulphate
- Graymont Mine (Lac Des Arcs, AB): Limestone
- **Butchart Gardens** (Victoria, BC): Limestone quarry that is a tourist destination.
- Queen Elizabeth Park (Vancouver, BC): Rock quarry that is a tourist destination.
- Sullivan Mine (Kimberley, BC): Over 100 years of underground mining that has been redeveloped as a ski town and a solar panel generating station for power.
- Elkview Operations (Sparwood, BC): Metallurgical coal

Butchart Gardens





Clarifications

Issue or Statement:

- Chitosan absorption is effective only under acid conditions with pH <6 where it is soluble - becomes insoluble after absorption.
- Flocculant is required for filter presses.

Rebuttal:

- **This is incorrect.** Chitosan works without any adjustment between pH of 6.5 and 9.0. Outside of this range requires neutralization. Sio's operations are within this range.
- The paper cited by Mr. LeNevue was for a different chitosan mechanism then what is proposed.
- No coagulant or flocculant needs to be used or is proposed for the contemplated filter presses.

Geotechnical Clarifications

Issue or Statement:

- Vertical overhanging and cohesion values used are unacceptable.
- Other subsidence modes could be possible.

Rebuttal:

- Vertical overhanging sand is clearly shown in the side scan sonar results.
- Sand strength – The strength of sand was based upon standard penetration testing and side scan sonar survey. These are measurements showing that sand is very dense and cemented (sandstone). The sand strength values used for the stability analysis are reasonable.
- Use of 220 kPa for sand cohesion – The sonar survey and standard penetration testing measured very dense and weakly cemented rock properties. Weakly cemented rock cohesion often exceeds 1,000 kPa, and so 220 kPa is reasonably conservative.
- A strain weakening model was used that reduces cohesion from 220 kPa to 0 during deformation and over time.
- Cover subsidence – This is not a probable failure mode as sufficient competent limestone is present and provides a factor of safety of 2.0 as shown in Table 9 of Stantec's report.

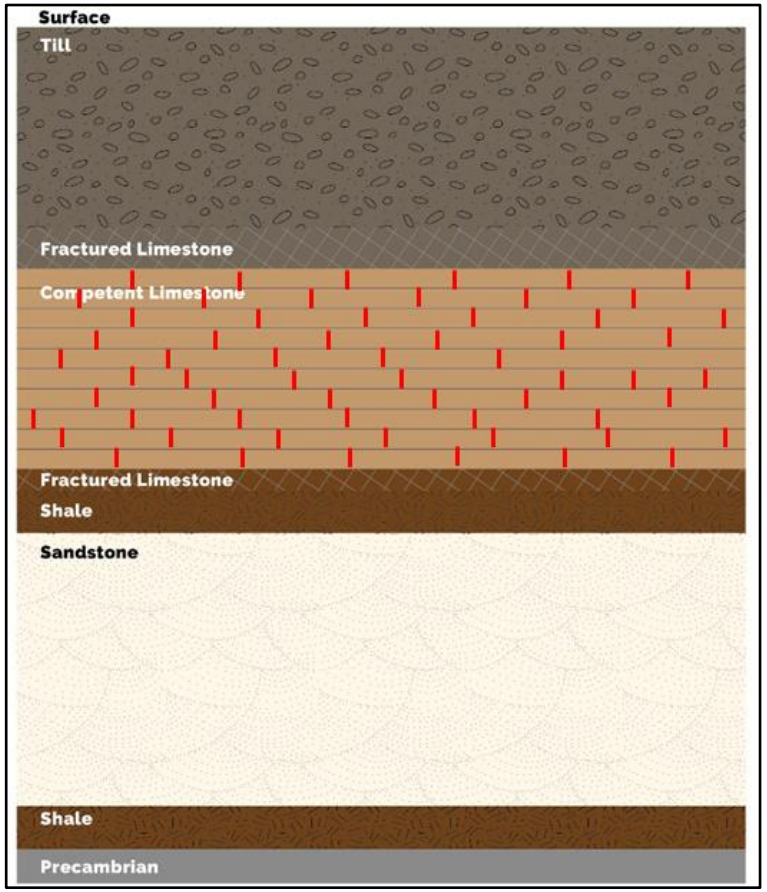
Competent Limestone Structure and Stability

Issue or Statement:

- Limestone structure competency due to vertical fractures.

Rebuttal:

- Stantec assessed the potential for competent limestone vertical joints and determined that they are likely randomly distributed and are not closely spaced or very continuous.
- Limestone is dolomitized which is typically more competent than other types of limestone.
- Logged Rock Quality Designations (RQD) are typically high (80-100%) demonstrating that limited jointing is present in the competent zones.
- If vertical joints are found, the graphic at right presents a reasonably conservative interpretation of their presence in competent limestone. The bending failure mode remains valid with this case.



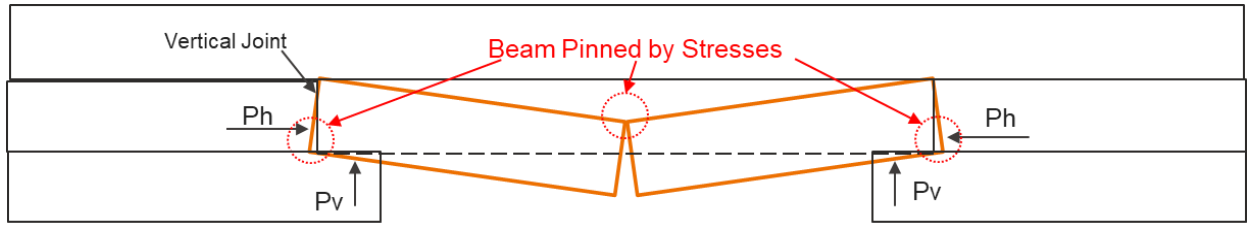
Competent Limestone Structure and Stability

Issue or Statement:

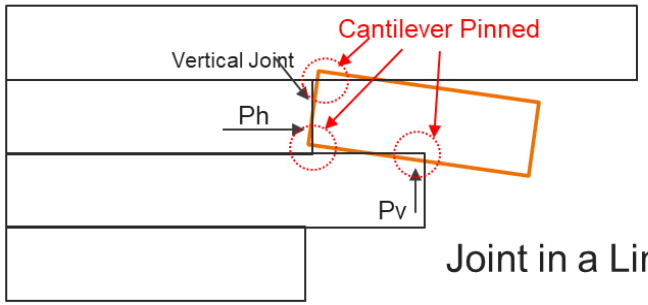
- Possible presence of vertical joints and impacts.

Rebuttal:

- If vertical joints are present, the bending failure mode remains valid. Based upon logging and other results, jointing is not common in the competent limestone.
- Vertical joints at spacings greater than the required span of beams and cantilevers (7 m and 0.7 m, respectively) are not expected to impact bending strength. Beams and cantilevers should remain in place.
- Limestone beams are held in place by confining forces on each end of the beam. See the graphics below.



Joint in a Limestone Beam

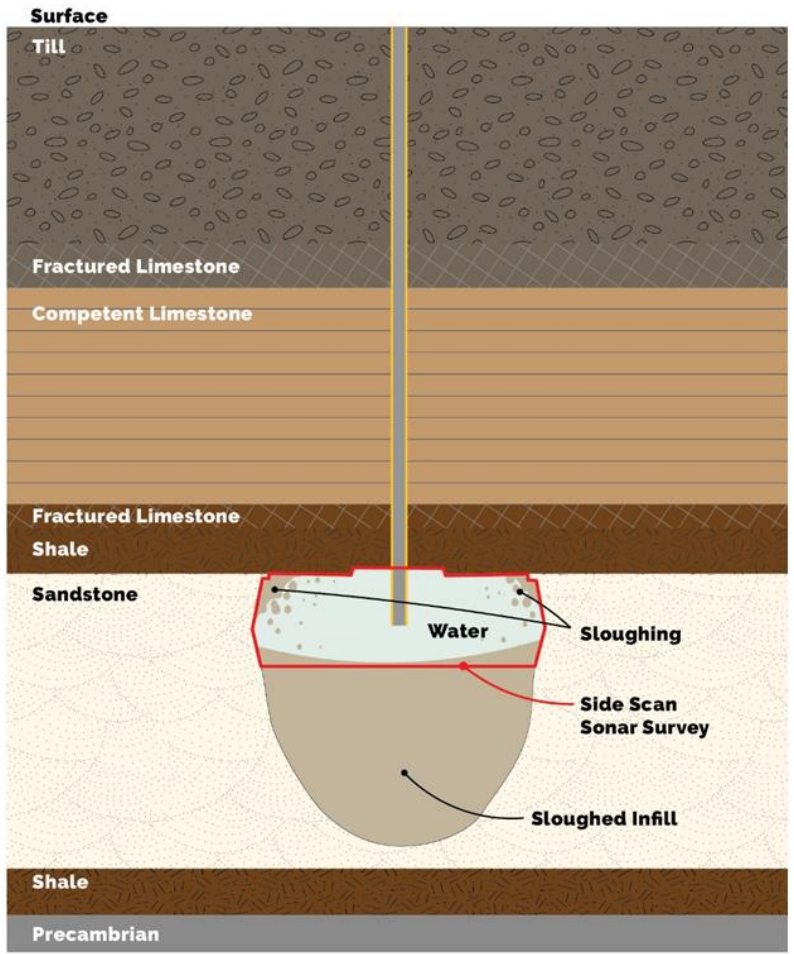


Joint in a Limestone Cantilever

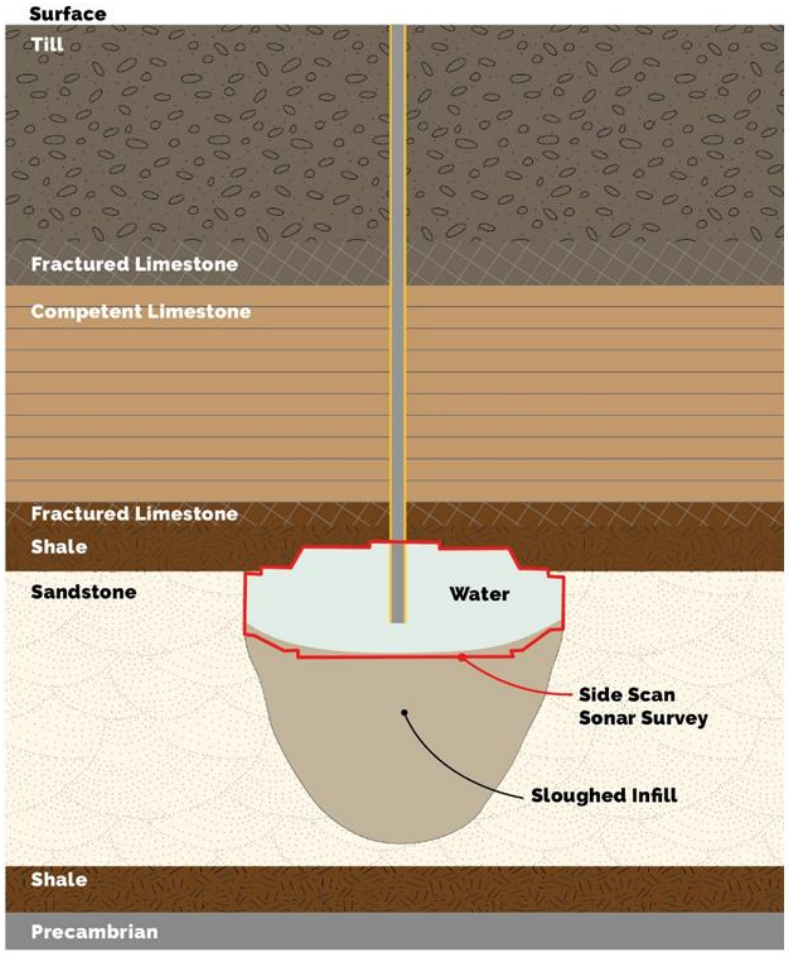
Not to scale, example only.

Cavity Development Over Time

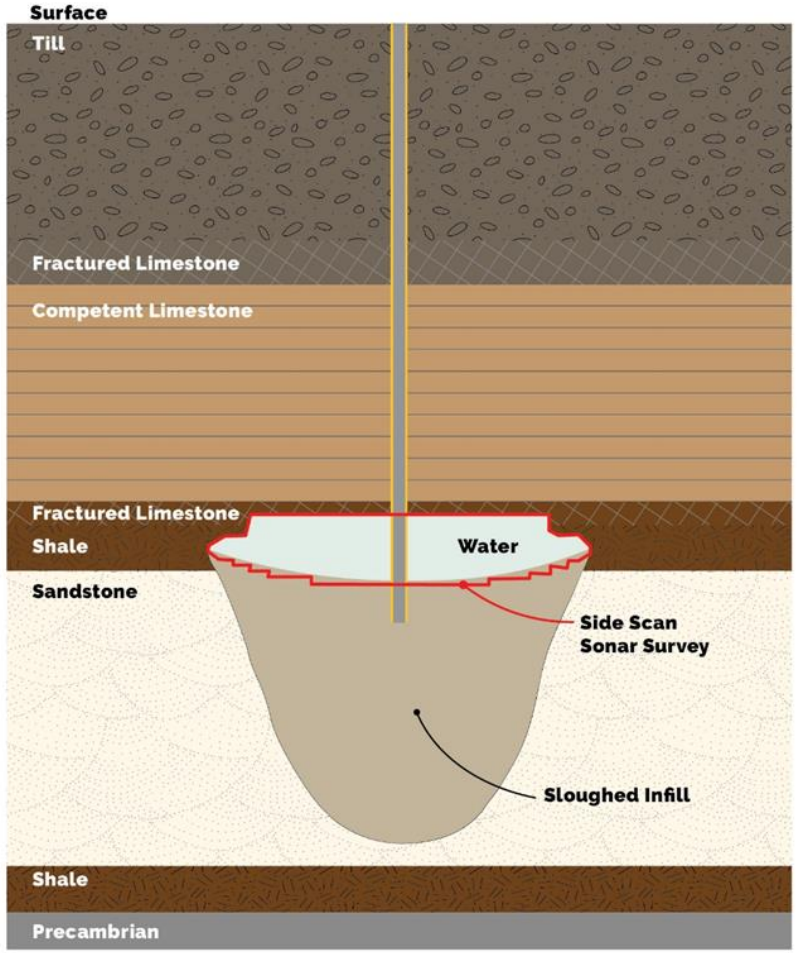
Issue or Statement: Unclear on development of cavity over time.



POST EXTRACTION



1 MONTH POST EXTRACTION



4 MONTHS POST EXTRACTION

Sensitivity Analyses

Issue or Statement:

- Suggestion that there was no sensitivity analysis completed.

Rebuttal:

- Sensitivity analyses were carried out to assess varying design parameters to determine their impact on results. This process helps to identify risk related to uncertainty.
- Stantec completed sensitivity analysis throughout this project that included:
  - Informal sensitivity analysis carried out when designing site investigations.
  - Collected data is analyzed separately and in groups to consider overall and individual results and to identify the most representative conditions.
  - Most recent stability assessments included sensitivity analysis of limestone and till thicknesses as well as material strength properties.
  - Other input parameters were also considered for their probable impact on overall results.

Expert Geotechnical Review

Issue or Statement:

- Suggestion by KGS that Arcadis did not thoroughly review the Geotechnical report and underlying assumptions.

Rebuttal:

- Over the past year Arcadis requested additional information from Stantec and AECOM including drilling information and logs for all geotechnical boreholes.
- Arcadis confirmed their review in the hearing testimony of Gerd Wiatzka as follows:
  - *"We looked at it both in terms of the actual detailed assumptions used and how they were -- the modelling results that came out from that".*
  - *"For those that didn't read the report, we also looked at all their underlying assumptions. We asked for additional information on borehole logs where we questioned how they got their -- their strength factors, et cetera, et cetera and our technical people who were looking at that were satisfied that these were reasonable and appropriate assessments."*
  - Arcadis also stated during the hearing *"Fundamentally the concern about subsidence to surface I think has been adequately addressed".*

Analysis of Pumping Test

Issue or Statement:

- Pumping test not interpreted using all possible analytical solutions to consider leaky shale aquitard.

Rebuttal:

- **Agreed.** Pumping test data was re-evaluated last week using leaky aquitard methods.
- Derivative solution indicates leaky aquitard. All methods produce essentially the same result.

Aquifer	Data Fit To	Analytical Solution Used	Storativity Results	Transmissivity Results	Hydraulic Conductivity Results	Hydraulic Conductivity Geometric Mean
	(-)	(-)	(-)	(m^2/s)	(m/s)	(m/s)
Sandstone	Pumping Well	Theis	1.2×10^{-4}	9.7×10^{-4}	4.82×10^{-5}	4.82×10^{-5}
	Observation Point	Theis	1.7×10^{-4}	2.2×10^{-3}	1.09×10^{-4}	9.52×10^{-5}
	Observation Point	Theis Distance Drawdown	1.6×10^{-4}	2.3×10^{-3}	1.14×10^{-4}	
	Observation Point	Theis Recovery	-	1.2×10^{-3}	5.96×10^{-5}	
	Observation Point	Cooper Jacob	1.1×10^{-4}	2.2×10^{-3}	1.11×10^{-4}	
Reanalysis of Same Data						
Sandstone	Observation Wells	Neuman-Whitherspoon (1969)	9.8×10^{-6}	2.2×10^{-3}	1.9×10^{-4}	9.89×10^{-5}
	Observation Wells	Moench (1985)	1.7×10^{-6}	1.9×10^{-3}	9.6×10^{-5}	
	Pumping Well	Hantush (1960)	1.4×10^{-4}	1.5×10^{-3}	7.4×10^{-5}	
	Observation Well 96-1	Hantush (1960)	9.0×10^{-5}	2.4×10^{-3}	1.1×10^{-4}	
	Observation Well 95-6	Hantush (1960)	1.7×10^{-4}	1.3×10^{-3}	6.4×10^{-5}	

Characterization of Aquifer

Issue or Statement:

- A single pumping test is not adequate to characterize the aquifer. (Hollander)

Rebuttal:

- Thousands of aquifer tests have been conducted to characterize the aquifers and they are very well characterized.
- Several publications (Wang, Kennedy, Betcher, Render, etc.) acknowledge the hydraulic conductivity of the pumped aquifer (Winnipeg Sandstone) is relatively uniform, and overlying carbonate is more variable.
- Other experts agreed there were no issues with the pumping test.
- Several slug tests and one pumping test were conducted locally, and the results are consistent with those reported in the literature.
- Additional pumping tests are proposed in advance of development when the groundwater monitoring well network is established.
- Results will be used to inform updates to the numerical groundwater flow model.

Table 4.1 – Number of measured transmissivity data obtained from each source and type of test used.

Source/Test Type	Hydrogeological Unit								
	Carbonate	*Lower Carbonate*	*Sandstone*	*Shale*	*Sand and Gravel*	*Till*	*Silt*	*Clay*	*Granite*
GWDrill									
Total	**2258**	--	**76**	**592**	**1846**	**20**	**5**	**33**	**39**
Multiple-well drawdown	--	--	--	--	--	--	--	--	--
Single-well drawdown	43	--	28	--	--	--	--	--	--
From specific capacity	2215	--	48	592	1846	20	5	33	39
Consultants' Reports/Thesis									
Total	**275**	**6**	--	--	--	**7**	--	**66**	--
Multiple-well drawdown	198	4	--	--	--	--	--	--	--
Single-well drawdown	33	2	--	--	--	--	--	--	--
From specific capacity	--	--	--	--	--	--	--	--	--
Unknown	44	--	--	--	--	--	--	--	--
Water Licensing Files									
Total	**154**	--	**2**	--	--	--	--	--	--
Multiple-well drawdown	27	--	--	--	--	--	--	--	--
Single-well drawdown	35	--	--	--	--	--	--	--	--
From specific capacity	46	--	2	--	--	--	--	--	--
Unknown	46	--	--	--	--	--	--	--	--
TOTAL	**2708**	**6**	**78**	**592**	**1846**	**27**	**5**	**99**	**429**

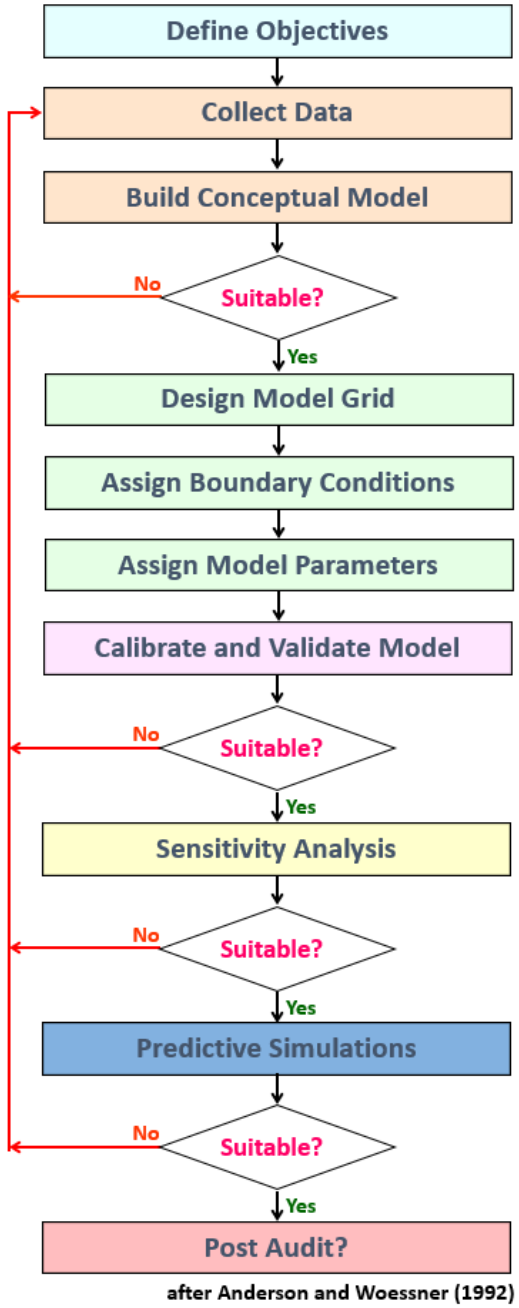
Groundwater Modelling

Issue or Statement:

- Groundwater model is not properly calibrated, and results cannot be relied upon. (Hollander)

Rebuttal:

- **Equifinality or Non-Uniqueness of the Model:**
  - This is completely false.
  - While it is true that many possible combinations of parameters could result in an acceptable calibration, this applies to ***every groundwater model*** that has ever been developed, including those developed by Kennedy (2002), Wang (2008) and Stafford and Hollander (2018).
  - However, there are methods within the ***modeling process*** to address this.
    - The model reasonably replicates regional and local aquifer behaviour at the scale of the impacts which helps constrain the parameters.
    - Calibration statistics are reasonable for a regional groundwater model.
    - Calibrated aquifer properties are well within the range of literature values.
    - A sensitivity analysis was completed on the calibrated model.
    - Predictive scenarios include conservative assumptions.



after Anderson and Woessner (1992)

Groundwater Modelling

Rebuttal (cont'd):

- **Definition of Industry Standard:**
  - Many peer reviewers (Dr. Ferguson, Matrix, KGS) agreed that AECOM followed industry standard protocols.
  - Dr. Hollander did not agree with the others, but he is holding the project to academic research standards (or State of the Art) which is not reasonable or achievable at the scale of the project.
  - It is ***not reasonable*** to hold this project to higher standards than his own work (which did not report calibration statistics) or other projects.
  - This project has gone above and beyond what has been completed for other EAPs in the area.

Groundwater Modelling

Rebuttal (cont'd):

- **Recharge:**
  - Recharge is one of the most difficult parameters to measure.
  - Although recharge values were higher than those employed in some of the other groundwater models, it should be recognized that recharge was assigned as an input parameter to the Sandilands Area based on academic studies by Ferguson (2003) and Cherry (2000).
  - The other models had different objectives, encompassed different study areas with different geology. It is of no consequence to prediction of local scale impacts and is only relevant to regional scale aquifer sustainability assessments.
  - This model was not intended to evaluate regional scale sustainability of the groundwater supply across southeastern Manitoba.

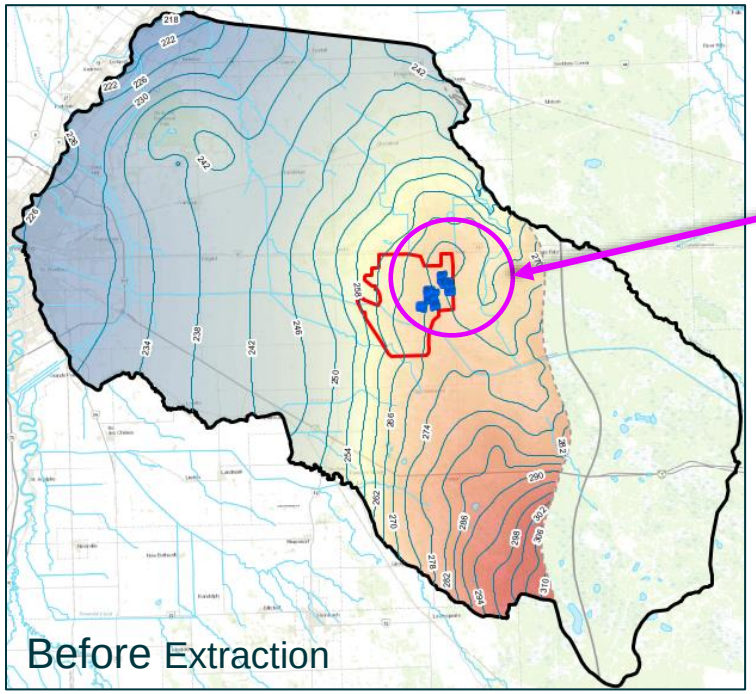
Groundwater Modelling

Issue or Statement:

- Groundwater flow system will change as a result of void spaces and shale collapse. (Hollander)

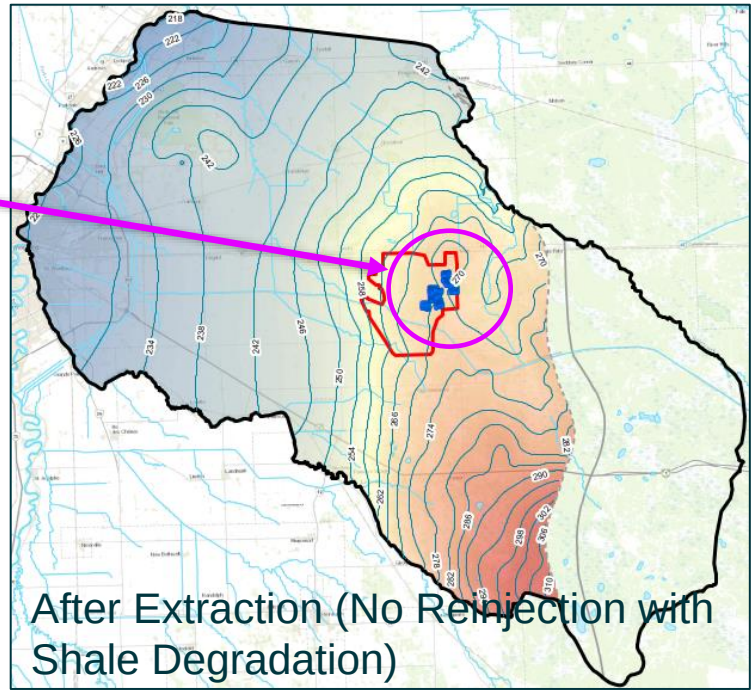
Rebuttal:

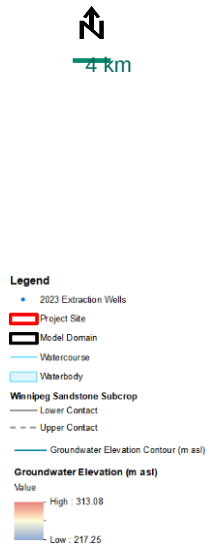
- No, the overall groundwater flow system will NOT change. The governing boundary conditions and aquifer system will be largely unaffected by the project.



Very Small Differences

Red River Carbonate





Groundwater Modelling

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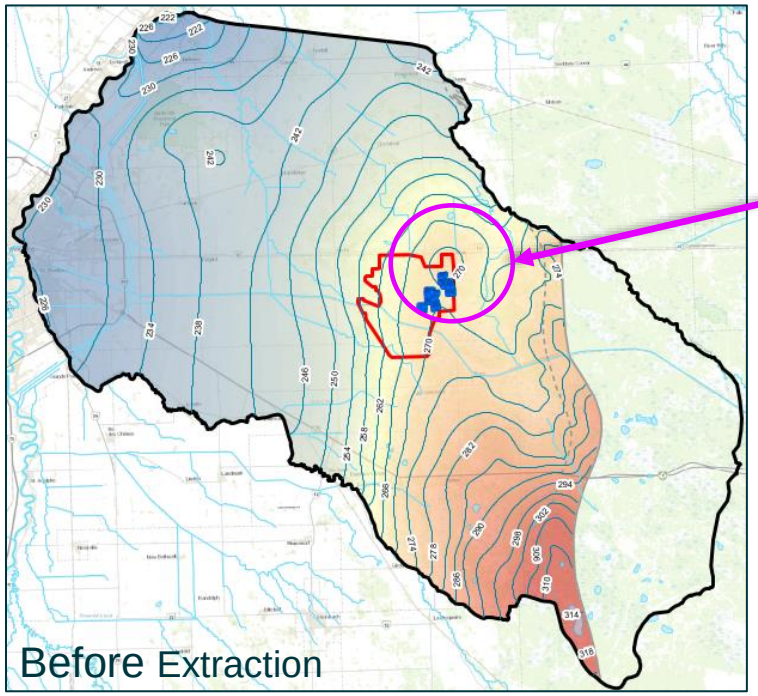
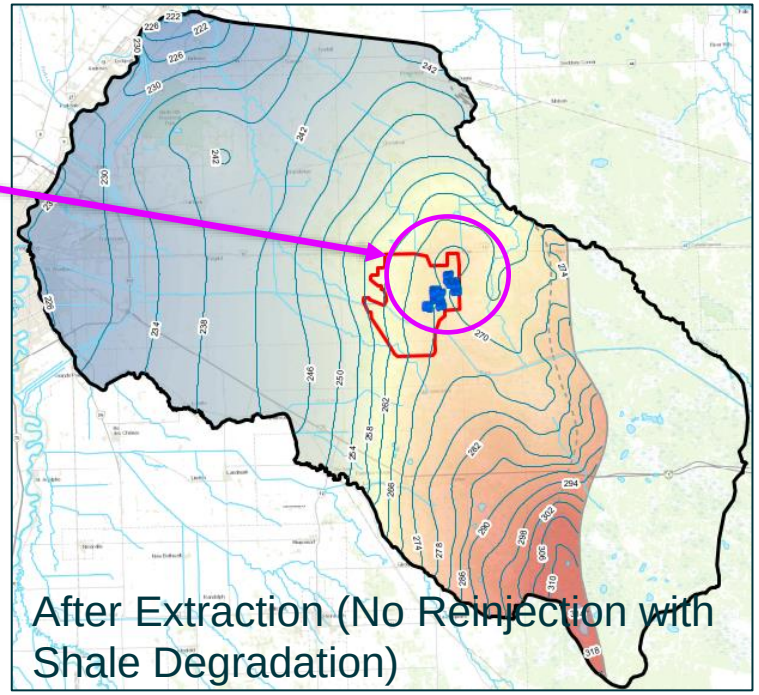
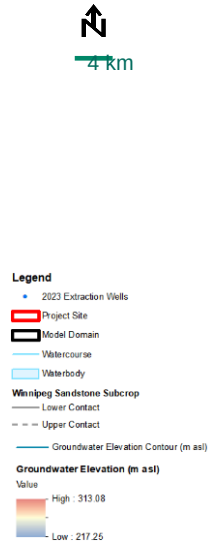


Very Small Differences

Winnipeg Sandstone





Density Dependent Flow

Issue or Statement:

- Density-dependent modelling is required to simulate groundwater flow within the Project area. (Hollander)

Rebuttal:

- Red River Carbonate, Winnipeg Shale and Winnipeg Sandstone contain fresh water with low TDS concentrations except near the Red River.
- Effects of variability in TDS is negligible within Project area.
- Supported by conclusions of Kennedy (2002), Wang et al. (2008) and even Stafford and Hollander (2011).
- Many of the models did not include density dependent flow. Those that did concluded the effect was relatively minor as the water is fresh.

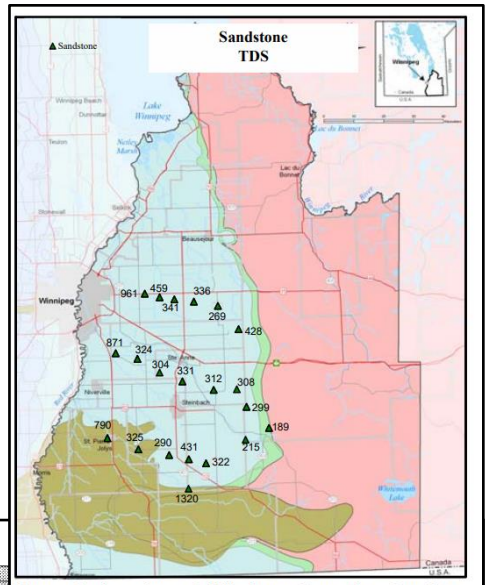
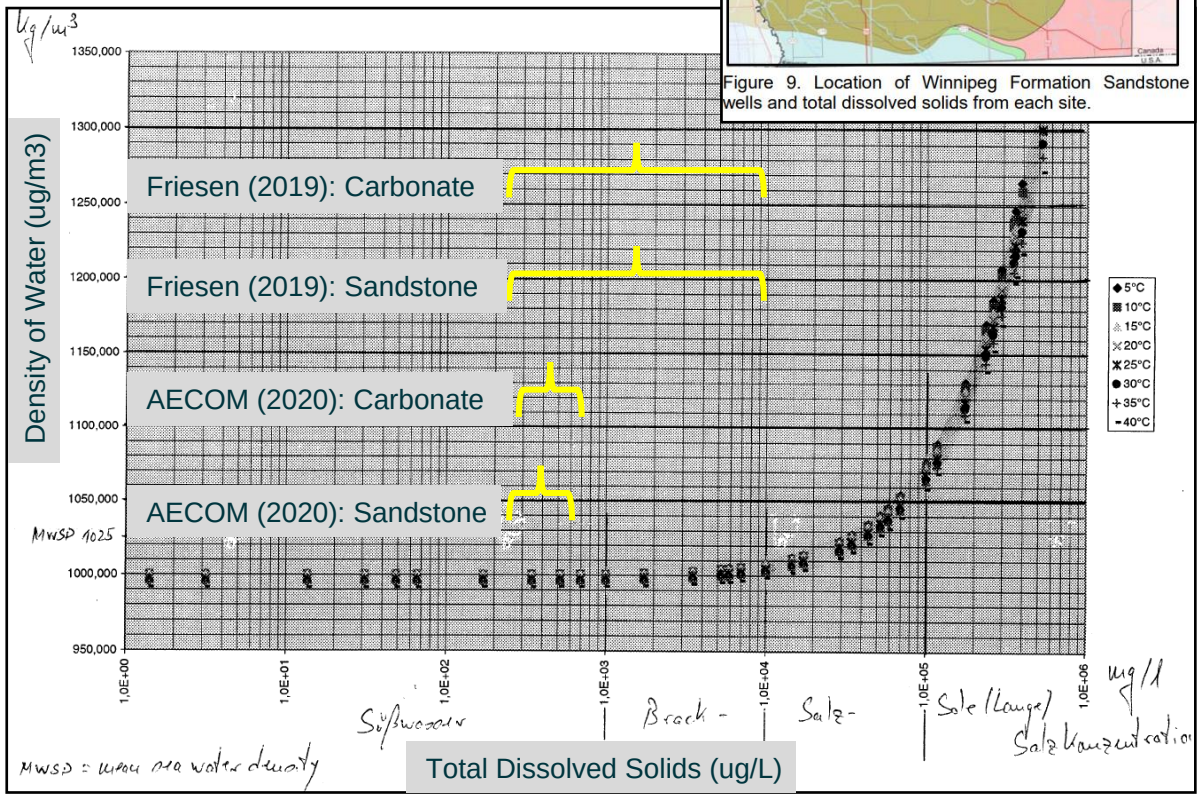


Figure 9. Location of Winnipeg Formation Sandstone wells and total dissolved solids from each site.



Aquifer Sustainability

Issue or Statement:

- Cumulative effects and sustainability of the aquifer is important and has not been assessed. (Matrix)

Rebuttal:

- The responsibility for sustainable yield of an aquifer is with Manitoba Water Stewardship (Groundwater Management Section).
- The use of groundwater by the project is relatively small in comparison to other users.
- The focus of an EAP is related to how an individual project (rather than all projects) will affect groundwater quantity. This is what was assessed, and the effects were assessed to be minor.

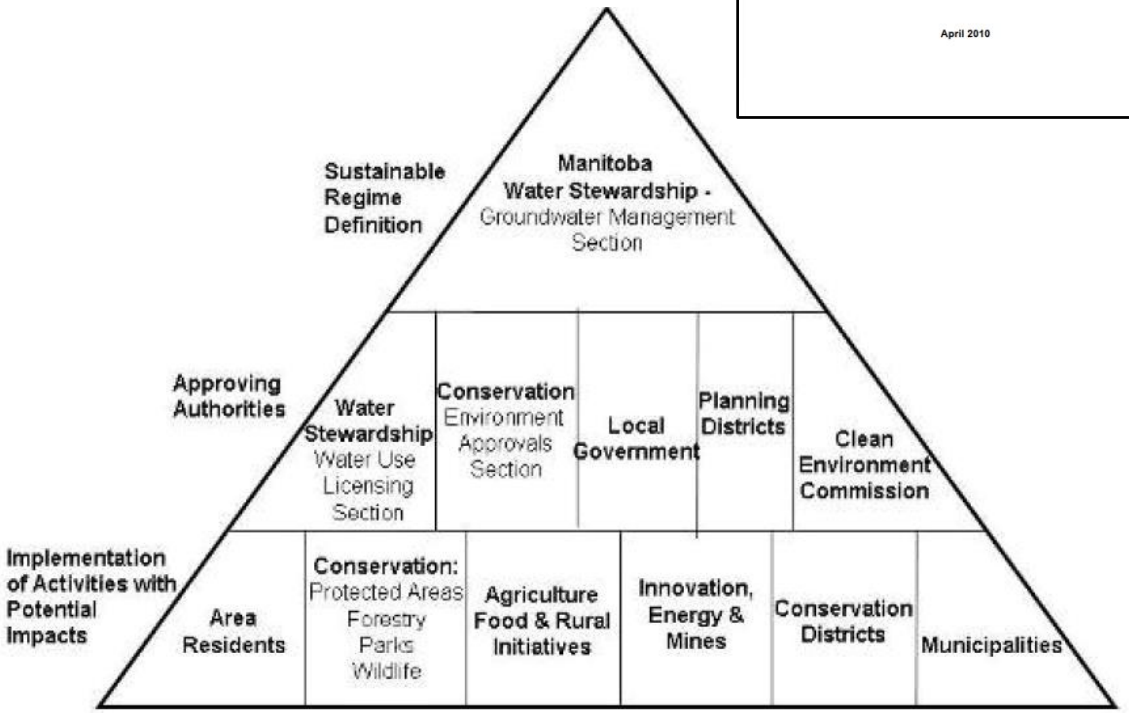


Figure 22: Groundwater Management Responsibilities Pyramid

Aquifer Sustainability

Rebuttal (cont'd):

- Other *Environment Act* Proposals (EAPs) for Springfield (2019) and Park Road (2015):
  - Requested much larger volumes of groundwater.
  - They did not include development of a numerical groundwater model.
  - They did not evaluate cumulative effects on groundwater quantity and quality.
  - All EAPs approved and issued Environment Act License and Water Rights License.
- Sand extraction over full 24 years of mining is NOT cumulative:
  - Sand extraction is seasonal (approx. 224 days/year).
  - Majority of extracted groundwater is reinjected to the same aquifer.
  - Water levels have been demonstrated to fully recover following operations each year.
  - Only change is the location of project activities associated with sand extraction. Expect similar drawdown and radius of influence for wells installed in the same aquifer.
  - Had we completed the 24 year assessment, it is likely that there would not have been any changes to the conclusions and recommendations.

Aquifer Sustainability

Issue or Statement:

- Concerned about impacts on water quantity and availability of groundwater.

Rebuttal:

- The use of groundwater by the project is small, especially in comparison to other users.
- Impacts of sand extraction are temporary in nature and full recovery occurred following pilot tests and pumping tests.
- Minor impacts to water levels in private wells, but no effect on availability of water (no complaints received).
- Groundwater modelling predictions support those field observations.
- Extensive monitoring proposed before, during and after operations to confirm findings.

Table 4
Water Use Licenses – Groundwater Users
RM of Springfield, Manitoba

License Category	Number of Licenses	Annual Allotment (dam^3/year)
Industrial-mining	1	4070.00
Heat/Cool	4	3508.00
Other Industrial	1	1100.00
Municipal	5	750.30
Irrigation	5	380.59
Other	3	272.00
Agricultural	3	99.60
Domestic	1	7.40
Fire Fighting	3	3.42
Total	**26**	**10191.3**

Table 4 – Licensed groundwater users within the RM of Springfield. (source – MSD-WUL, 2017)

0% Reinjection

100% Reinjection of Available 85%

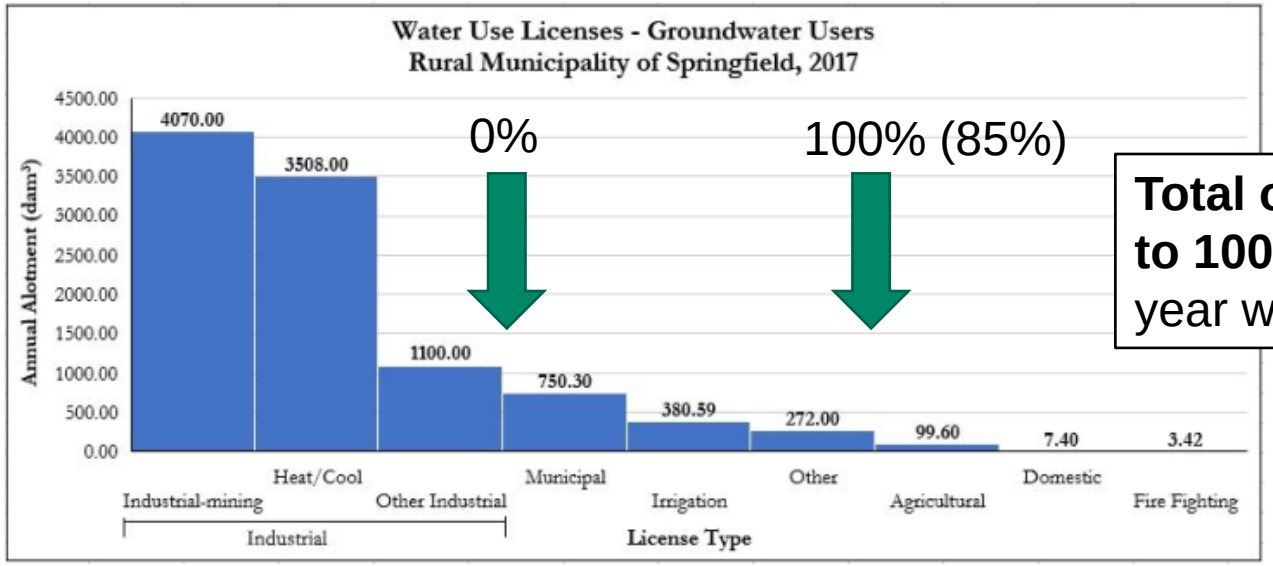


Figure 24 – Distribution of groundwater users by license type; RM of Springfield. (source – MSD-WUL, 2017)

Total of 80,000 m^3 to 100,000 m^3 per year water volume

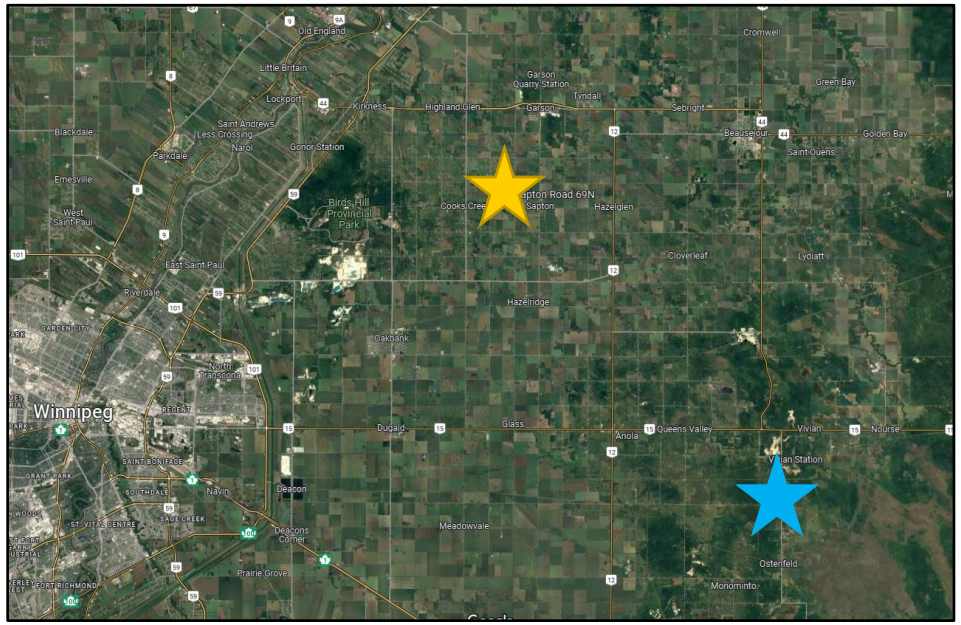
Corrosion of Plumbing

Issue or Statement:

- Plumbing fixtures corroded at childhood farm (yellow star) due to presence of acid rock drainage in aquifer.
- Inferred it was related to development of area and the reaction of pyrite to the sand in the area.

Rebuttal:

- Acid rock drainage can not be initiated in the subsurface because an infinite source of oxygen and abundant sulphide minerals (pyrite) are required and are not present.
- The corrosion of plumbing fixtures in that area is likely due to the presence of saline water (not acidic water) as has been documented in the literature for decades. Salt water is also known to rust metal, which would cause orange discoloration.
- Due to slower flushing of saline water from that portion of the Winnipeg Sandstone aquifer and is totally unrelated to development or ARD.
- Project area (blue star) is a long way from the saline groundwater interface and there will be no impacts on salinity or ARD.



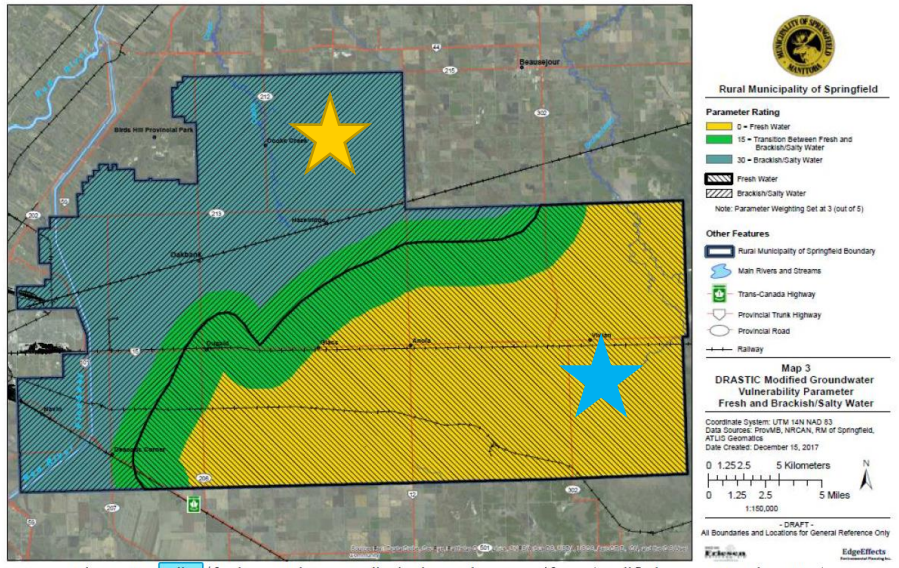


Figure 29 – Saline/fresh groundwater quality in the sandstone aquifer. – (modified source - Betcher, 1986)

Vulnerability of Aquifers to Contamination

Issue or Statement:

- Collapse of Winnipeg Shale aquitard will increase the vulnerability of the aquifers to surface contamination.

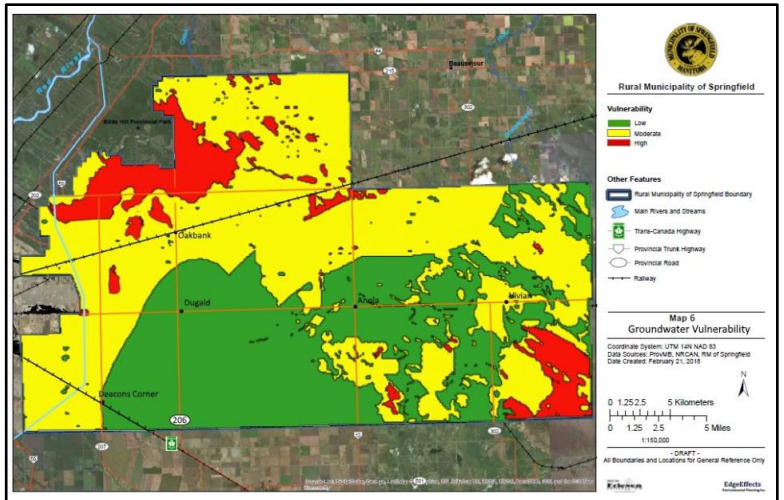


Figure 32 – Composite vulnerability map showing areas of low, moderate and high intrinsic vulnerability.

Rebuttal:

- There are thick (~ 100 ft) fine-grained Quaternary sediments overlying all bedrock aquifers in the area, which provides substantial protection to all underlying aquifers.
- Geotechnical modelling and subsidence monitoring indicates sand extraction will not cause failure of the limestone caprock or Quaternary sediments.
- The vertical groundwater gradients do not promote flow between the two aquifers now, and this will not change.
- Collapse of the shale will have no bearing on the vulnerability of the carbonate aquifer, and only minor influence on the vulnerability of the underlying sandstone aquifer.
- Well abandonment will preserve level of protection from surface contamination.

Intermixing of Aquifers

Issue or Statement:

- It is critical that Red River Carbonate and Winnipeg Sandstone aquifers remain separated.

Rebuttal:

- This is not true where both aquifers are fresh. They are not separated now. There are already over 1,000 wells within the area that interconnect the two aquifers. They are both fed by the same source of recharge.
- Water in Project area in both aquifers is fresh and potable, but much more variable spatially within each aquifer. Variability in water quality is common within aquifers.
- There are no reported water quality impacts from interconnection of the aquifers over the past 100 years in areas where the aquifers are fresh. All historical issues with saline water are located much further west, where historically strong upward hydraulic gradients forced saline water from the Winnipeg Sandstone aquifer upward through interconnected boreholes into the overlying Red River Carbonate aquifer.
- The water in both aquifers is fresh within the Project area, so mixing is of little to no consequence.

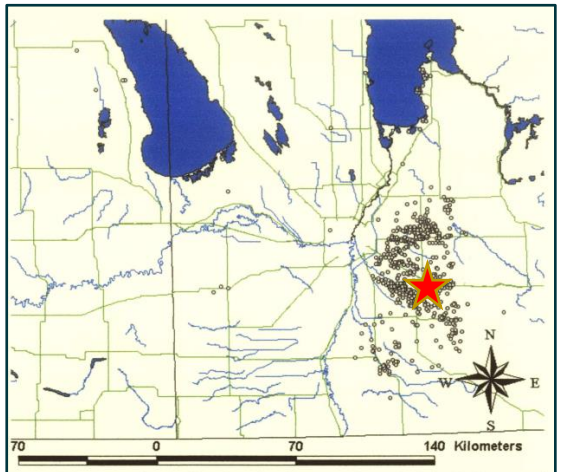


Figure 4.24 – Map showing location of wells screened over both the Carbonate and Sandstone Aquifers.

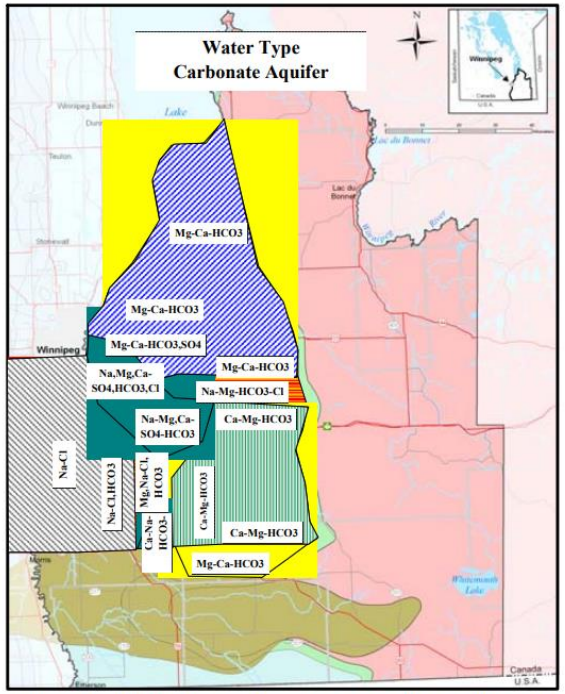
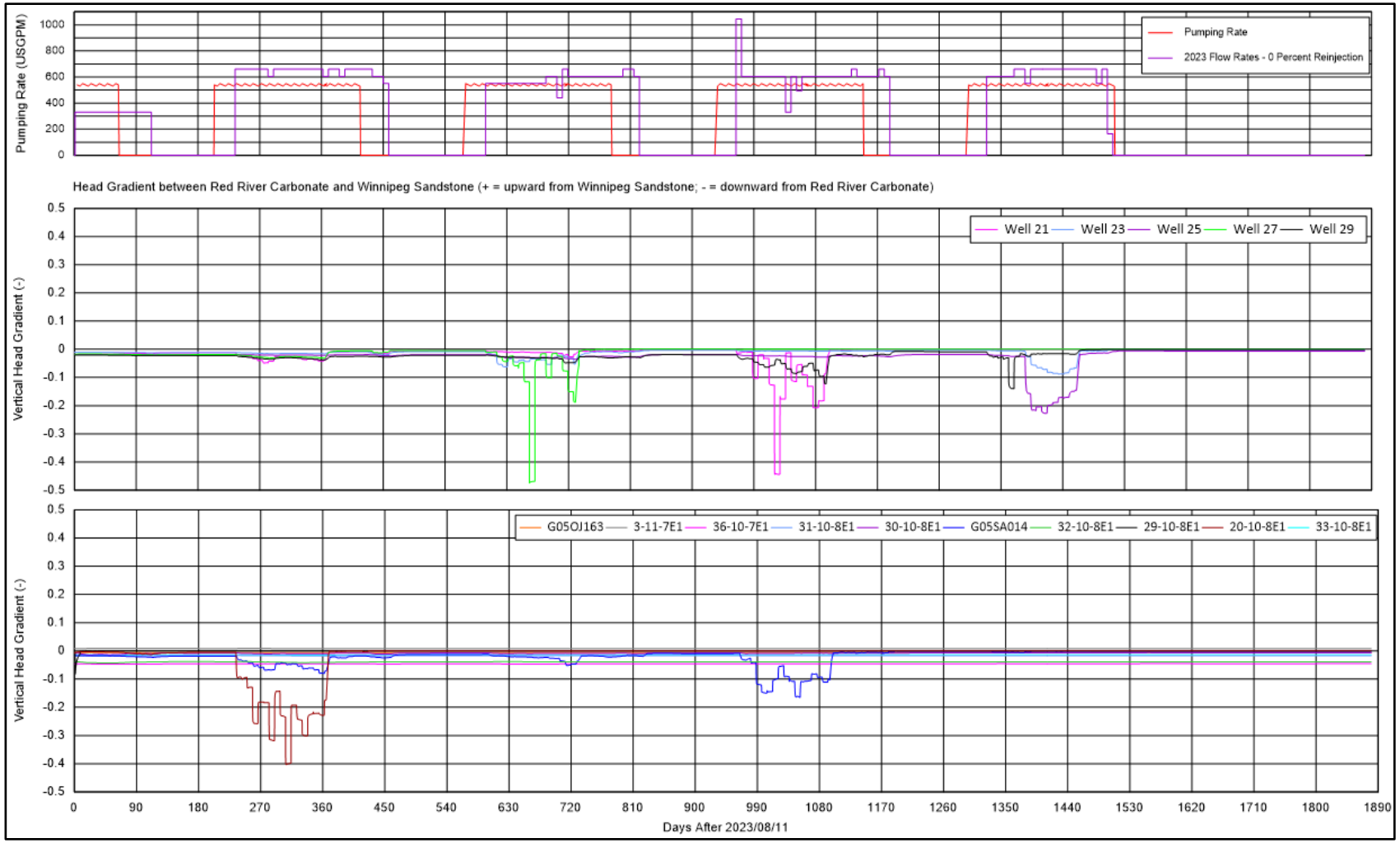


Figure 12. Distribution of major water types within the carbonate aquifer.

Intermixing of Aquifers

Rebuttal (cont'd):

- The primary effect has been equilibration of water levels, which will reduce or eliminate vertical hydraulic gradients and limit the bulk exchange of waters between the aquifers.
- Vertical groundwater gradients are presently neutral to slightly downward and are simulated to reduce even further following operations.
- No vertical gradient, no exchange of water.



Water Quality

Issue or Statement:

- Concerned about impacts on water quality due to mixing with porewater from Winnipeg Shale.

Rebuttal:

- Porewater in Red River Carbonate, Winnipeg Shale and Winnipeg Sandstone is fresh: < 500 mg/L TDS, Cl & SO_4 < 40 mg/L, Na < 100 mg/L.
- Volume of water in shale is very small.
- No material change in water quality in any of the aquifers.

Unit	Total Dissolved Solids (mg/L)	
	AECOM 2021	Friesen 2019
Carbonate Aquifer	217 - 277	240 -1,800
Shale Aquitard	269 - 489	-
Sandstone Aquifer	239 - 358	270 - 2,000
CDWQ/MWQSOG AO	500	
Fresh Water	<2,000	
Brackish Water	2,000 - 10,000	

Unit	Chloride (mg/L)	
	AECOM 2021	Friesen 2019
Carbonate Aquifer	1.01 - 14.4	0.87 -12
Shale Aquitard	2.84 - 37.2	-
Sandstone Aquifer	5.2 -33.5	12 - 310
CDWQ / MWQSOG AO	250	

CDWQ: Canadian Drinking Water Quality (CDWQ)

MWQSOG: Manitoba Water Quality Standards, Objectives, and Guidelines (Tier III) - Protection of Drinking Water Use - Aesthetic Objectives

AO: Aesthetic Objective

Water Quality

Issue or Statement:

- Concerned about impacts on water quality due to mixing with porewater from Winnipeg Shale.

Rebuttal:

- Groundwater in Red River Carbonate and Winnipeg Sandstone and Winnipeg Shale porewater met drinking water guidelines except turbidity (MAC), iron and manganese (AO)
- Many constituents in the Red River Carbonate, Winnipeg Sandstone and Winnipeg Shale were below the detection limit including selenium (16/20 < DL).
- Low concentrations of arsenic, selenium and uranium in Winnipeg Shale porewater.

	Maximum Concentration in Carbonate (mg/L)	Maximum Concentration in Shale Porewater (mg/L)	Maximum Concentration in Sandstone (mg/L)	CDWQ / MWQSOG MAC
Arsenic	0.00155	0.00179	0.00063	0.01
Selenium	0.00023	0.00091	0.0001	0.01
Uranium	0.00014	0.00121	0.00099	0.02

CDWQ: Canadian Drinking Water Quality (CDWQ) Aesthetic Objective (AO)

MWQSOG: Manitoba Water Quality Standards, Objectives, and Guidelines (Tier III) - Protection of Drinking Water Use - Aesthetic Objectives

MAC: Maximum Acceptable Concentration

Geochemical Testing

Issue or Statement:

- Concern that water quality has not been directly measured following pilot test.

Rebuttal:

- This is False. Water quality has been measured in the groundwater monitoring wells near historical extraction tests. Groundwater quality has not shown material changes.
- Samples directly from the void have not been collected to date.

Proposed Ongoing Testing:

- Sample groundwater from existing and future voids after shale collapse to directly measure water quality and validate modelling.
- Conduct additional water quality modelling to validate impact of shale collapse.

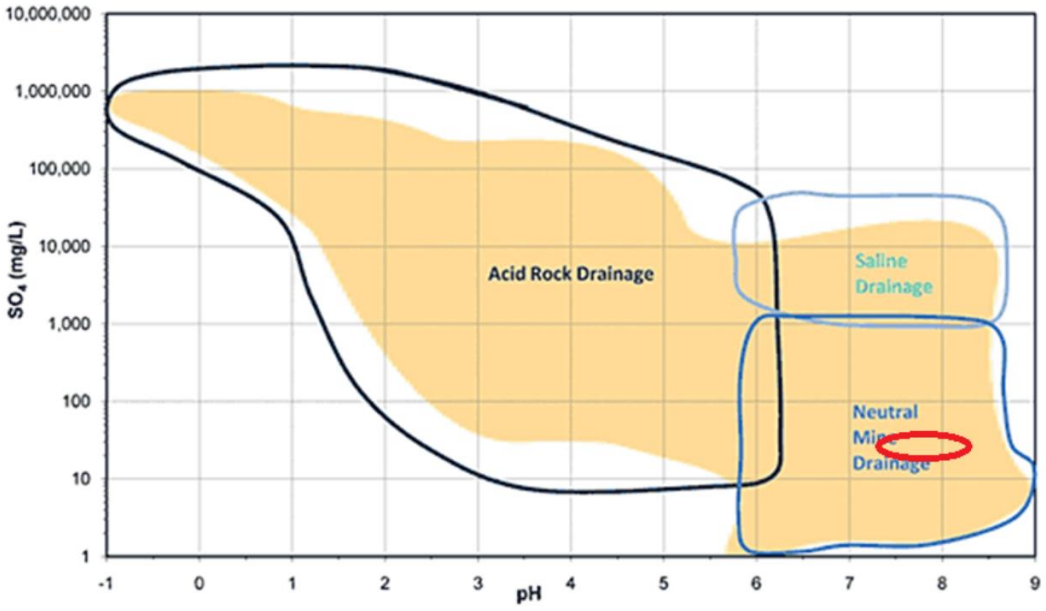
Acid Rock Drainage (ARD)

Issue or Statement:

- Concern that ARD/ML will proceed in the subsurface.

Rebuttal:

- ARD/ML will not occur in a subsurface saturated environment:
  - ARD does not initiate under water cover due to very low oxygen content in water (4 - 8 mg/L) and low diffusion.
  - Subaqueous waste disposal is a proven ARD/ML mitigation technology in mining.
  - No measurable sulphides available for oxidation in Red River Carbonate or Winnipeg Sandstone.
  - Low and finite amount of sulphides in Winnipeg Shale (max 0.6 wt.% sulfide sulfur).
  - Red River Carbonate contains a large reservoir of neutralization potential.



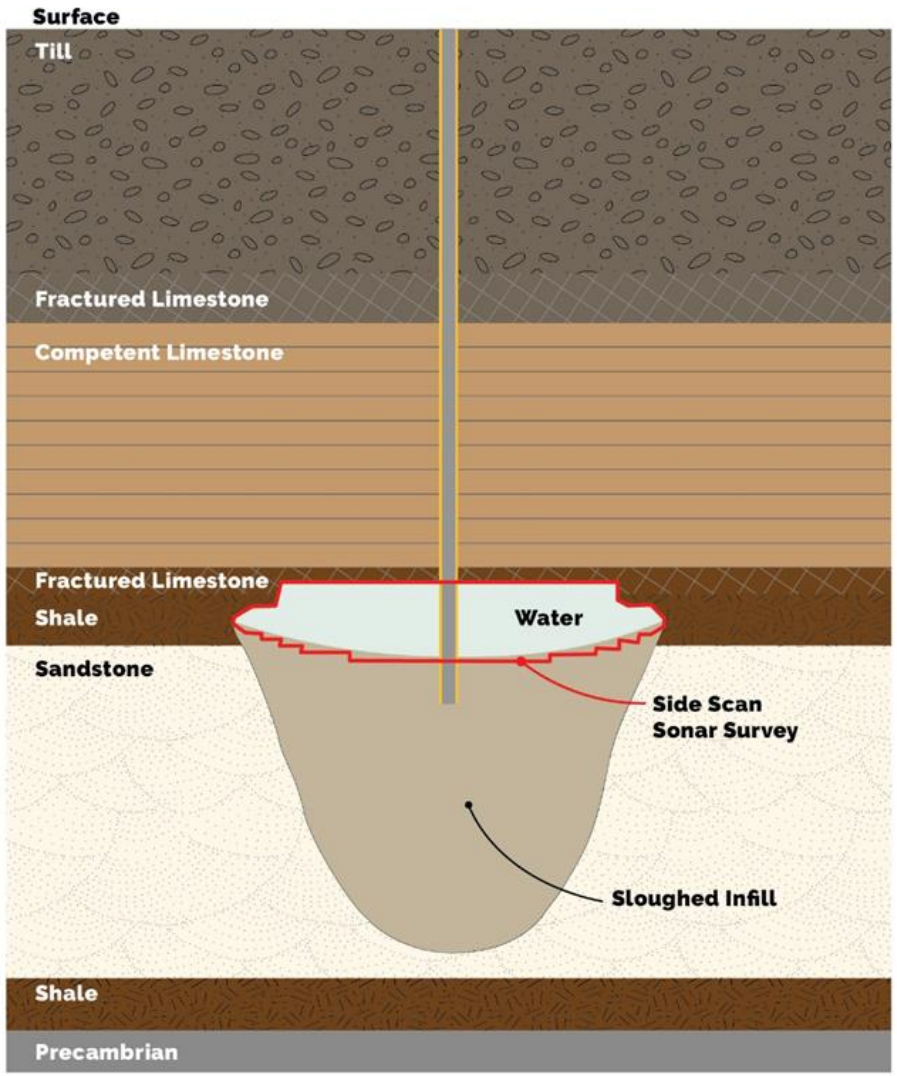
Effects of Shale Collapse on Metal Leaching

Issue or Statement:

- Concern that the proponent has not evaluated the following:
    - Impact of shale collapse on groundwater quality.
    - Arsenic (As), selenium (Se) and uranium (U) leaching.
    - Influence of changing redox conditions.

Rebuttal:

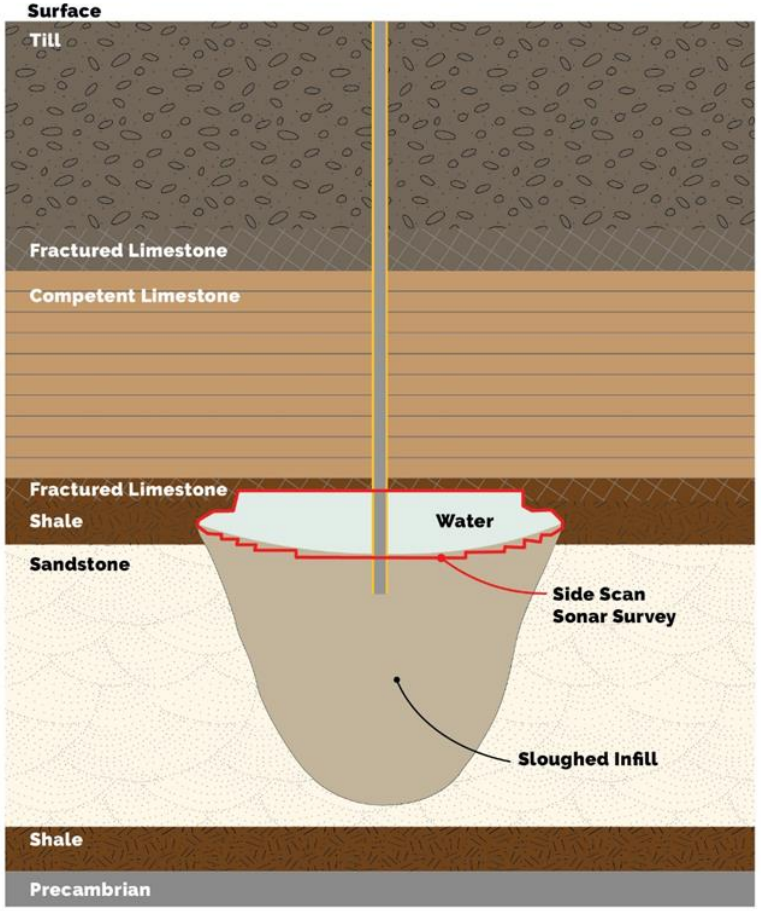
- **All three have been evaluated**
- The proportion of porewaters mixing in the void is estimated:
    - Limestone (7%)
    - Shale (2%)
    - Sandstone (91%)
- Evaluated assumes that there is additional flushing from fractured rock in the void (SFE results).



Effects of Shale Collapse on Metal Leaching

Rebuttal (cont'd):

- Conducted geochemical analysis to evaluate key mechanisms controlling concentrations of parameters in groundwater:
  - Dilution in the void.
  - Sorption to dissolved iron that readily precipitates from water.
- These two mechanisms will reduce concentrations of trace metals of concern U) to concentrations below drinking water quality guidelines *in the void*.
- Residual Se affected by subsurface **redox conditions**:
  - If some oxygen remains dissolved in water (up to ~5 mg/L; **oxic conditions**), selen will adsorb to additional iron *along the groundwater flow pathway*.
  - As oxygen is depleted (**anoxic**), the aquifer returns to natural conditions, Se will rec from Se6 (selenate) to Se4 (selenite) and precipitate out of solution.
- Several levels of conservatism in the analysis:
  - Assumed very defensible mixing ratios.
  - Assumed all shale and limestone directly above the void will collapse.
  - Allowed for a very limited number of geochemical attenuation mechanisms that were limited to sorption to iron (but not manganese or aluminum).
  - No allowance for advection (further dilution) or dispersion (further dilution).



Pilot Testing and Inclined Boreholes

Issue or Statement:

- No pilot test has been completed to date.
- Re-injection of water using gravity drainage is not possible.
- No inclined boreholes advanced to characterize any subvertical discontinuities in the limestone caprock.

Rebuttal:

- It is false that no pilot testing has been completed to date. Sio has conducted multiple extraction tests to refine the design including a test involving extraction from two wells simultaneously.
- They have successfully re-injected produced water during extraction using gravity drainage.
- They are committed to a full-scale pilot test for multi-well extraction and a maximum void space not exceeding 50 m long term allowable span based on the recommendations of Stantec (2022).
- They are committed to confirmatory drilling of inclined boreholes based on the recommendations of Stantec.

Expanded Pilot Testing and Inclined Boreholes

Proposed additional testing would include a multi-well test to remove maximum tonnage not exceeding 50 m long term allowable span with the least number of wells (1-5) with water re-injection:

Geotechnical Monitoring:

- Advancement / logging of three targeted inclined boreholes and ATV/OTV survey to characterize sub-vertical discontinuities.
- Monitoring of void space using sonar during and after extraction including long-term monitoring (after 1 year).
- Installation of subsidence monitoring network including; underground extensometer anchored to the caprock top surface, and piezometers within the overburden and at the top of the caprock surface within 5 m of the centre of extraction.
- Confirmation of competent limestone thickness and ongoing core sampling to confirm strength.

Groundwater and Geochemistry Monitoring:

- Completion of borehole packer testing to determine variability in hydraulic conductivity of Red River Carbonate.
- Collection of additional solid and aqueous phase samples for geochemical testing.
- Install groundwater monitoring network (monitoring wells, vibrating wire piezometers, etc.).
- Monitoring of groundwater levels and groundwater quality before, during and after pilot testing.

Follow Up:

- Update of geotechnical and groundwater models based on results of extraction.
- Validate and update design criteria based on results of extraction tests and supplemental modelling.
- Development and finalization of TARP and approval by Regulators.
- Confirmatory geotechnical drilling including an additional three inclined boreholes across Extraction Plan footprint to validate pilot test information.

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