CEC submission for Vivian Silica Sand Extraction Project

D.M. LeNeveu, M.Sc. (biophysics). B.Sc. (honours physics), B.Ed.

Feb. 13, 2023

Table of Contents

1 Introduction 6
1.1 List of Issues 6
1.2 Major issues 7
2 Air Entrainment 10
2.1 Air injected directly into the aquifer during the air lift extraction method 16
3 Sio Silica Extraction Well Design 17
4 Evidence that the combined Sio Silica re-injection and extraction well design is not functional 22
4.1 Re- Injected water interferes with sand extraction 23
4.2 Modelling of the re-injection of water with an Analytical Solution from Carslaw and Jaeger 24
5 Temporary Authorization Permits to Divert Water 29
6 Requirements of the injection well permits 31
7 Collapse of the Shale Aquitard 32
7.1 Mixing of aquifer waters - Manganese and Iron – oxidizing conditions in the sandstone 35
7.2 Pyrite and marcasite in the sand, concretions and oolite 36
7.3 Sample handling procedures 45
7.4 Other evidence of sulphide in the silica sand in the Project area 47
7.5 Shale 52
7.6 Selenium 54
7.7 Fluoride 56
7.8 Oxidizing Conditions in the Carbonate Aquifer 56
7.9 Evidence of aquifer contamination from Sio Silica Extraction activities 57
8 Sio Silica Groundwater drawdown and modelling study 58
9 Disposal of Year End Water reaming is Surface Vessels at the Extraction Site 60
10 Sand Purity 61
11 Well abandonment Waste Characterization and Management and Groundwater Monitoring Plans 61
12 Subsidence 62
12.1 Stantec limit of 15 limestone thickness 62
12.2 Maximum allowable log-term cavity span 63
12.3 Revised Extraction Plan 67
12.4 Sand Pillar Stability 70
12.5 Cover Collapse 71
12.6 Evidence for Subsidence 72
13 UV Radiation and Microbial Treatment 73
14 Aquifer contamination from operation of the air compressor 77
15 GHG cumulative Effects 80
16 Sio Silica Slurry Lines 82
16.1 Mass balance calculation of contaminant build-up in the slurry line loop and clarifier tank 85
16.2 Determination of the acrylamide content in the slurry water 85
16.3 Determination of selenium accumulation in the slurry loop 89
16.4 Acid and heavy metals in the slurry loop, dewatering station and UV filtration system 91
17 Cumulative Effects of Project Noise and Light Disturbance 91
18 Cumulative Exposure to silica dust 94

19 Infrastructure Disturbance 95
19.1 Hydro Lines, Roads and Drainage 95
19.2 The Winnipeg Aqueduct 98
20 Modeling of Sio Silica Wells using Carslaw and Jaeger Solution 14.9 99
21 Head Change in the Carbonate from water transferred from the sandstone by water re-injection 107
22 Feasibility of re-injection of excess water extracted with the sand 112
23 Geo-Mechanical calculations of the stability of the unsupported limestone spanning extraction cavities 113
24 Conclusion 114
25 Appendix 1. Equations 119
26 References 120

List of Figures

Figure 1. Air entrainment from three water jets and subsequent step down chute and from a plunging water jet [6,8] 11
Figure 2.Volume fraction from a water jet into a tank left and a stepped spillway right analogous to water gravity flow in a lower water re-injection tank from a main water and sand separation tank [6] 11
Figure 3. Air entrainment on a free turbulent water surface such as the Sio Silica water settling tank at the dewatering station [15] 12
Figure 4. Mechanisms of Water Entrainment [7] 12
Figure 5. Air Entrainment by a hydrocyclone.[13] 13
Figure 6. Air Entrainment and particulate separation from a dewatering screen.[14] 13
Figure 7. Sio Silica injection of extracted water and sand into tanks near Vivian Manitoba, Aug. 18 2021.. 14
Figure 8. Air entrained in by the overflow v notch weir and the receiving pool of a clarifier tank[100] 15
Figure 9. Sio Silica EAP design for combined extraction and injection wells. 17
Figure 10. Sio Silica air lifting well at Center Line Road for advanced exploration. 18
Figure 11. CWS permitted injection well Bru 92-8 at a quarry south west of Vivian 2021. 19
Figure 12. Bru 92-2 production well completed July 11, 2021 at a quarry south west of Vivian. 20
Figure 13. Bru 92-3 production well completed July 11, 2021 at a quarry south west of Vivian. 21
Figure 14. Drawing from Sio Silica airlift patent application. 23
Figure 15. Sio Silica Conceptual well cluster layout Sio Silica Supplemental Information June 2, 2022. 25
Figure 16. Head Change contours from three Sio Silica extraction wells after one day of operation. 26
Figure 17. Head Change contours from three Sio Silica extraction wells after three hours of operation. 28
Figure 18. Permit 2021.01.1 for the single purpose injection well Bru 92-8 at a quarry southwest of Vivian.31
Figure 19. Shale collected by concerned citizens near Vivian from Sio Silica extracted sand piles, spring 2020. 33
Figure 20. Extent of the Carman Sands.[21] 38
Figure 21. Orange coloured concretions and sand extracted by Sio Silica at Centre Line Road SW of Vivian. 39
Figure 22. Google Earth image of original Sio Silica extracted sand piles and photographs of the Sio Silica silica sand piles taken June 7, 2020 (left) and Nov.14 2020 41
Figure 23. Photograph of the Vivian site on Nov.18, 2020 showing the covered sand pile disturbed and silica sand spread on the ground. 41
Figure 24. Photograph Bru 95-3 sand sample collected on Nov.19, 2020 42
Figure 25. Bru 121-1 sand samples 42
Figure 26. Bru 146 sand samples 43
Figure 27. Acid base accounting results from Winnipeg formation sand at Seymourville. 48
Figure 28. Electron microscope pictures of marcasite in sand grains from the Winnipeg Formation near Seymourville. 49
Figure 29. Silica sand grains in the Winnipeg Formation showing imbedded marcasite and pyrite. 50
Figure 30. ALS acid base accounting and heavy metal results for silica sand sampled from a Sio Silica stockpile near Vivian Manitoba. Results received, 17-Jul-2020. 51
Figure 31. Sio Silica extracted sand pile near Vivian showing yellow/orange gelatinous deposits 51
Figure 32. Bru 146 shale sample exposed to air 53
Figure 33. Sio Silica borehole logs from Manitoba Mines Branch showing interbedded shale layers deeper in the sandstone 54
Figure 34. Limestone thickness for the Sio Silica extraction area. 63
Figure 35. Table 9 Stantec data for maximum long term allowable silica sand extraction cavity span compared to calculated values from equation 1. 64

Figure 36. Limestone and till thickness and maximum allowable long-term excavation cavity span over the Sio Silica 24 year project area. 65
Figure 37. Sio Silica revised Extraction Plan of Jan. 24, 2023. 68
Figure 38. FAC modelling of the slumping of a backfill pillar in a rock mined cavity [116] 70
Figure 39. Cover subsidence sinkhole into a cavity in limestone........ 71
Figure 40. Cover collapse sinkhole into a cavity in limestone. 72
Figure 41. Subsidence and sinkholes at Sheridan,Wyoming from an abandoned underground coal mine[40] ... 72
Figure 42. Cross section of a sand drying bed[113] 74
Figure 43. Acrylamide concentration in Sio Silica Slurry loop........ 89
Figure 44. Selenium concentration in the Sio Silica recycling loop water........ 90
Figure 45. Noise Enclosure for a drill rig [76] 92
Figure 46. Email response of Manitoba Workplace Health and Safety to a complaint of uncovered Sio Silica sand piles at the quarry south west of Vivian 94
Figure 47. Sio Silica sand extracted at a quarry southwest of Vivian May, 2021 of the left and south of Vivian spring 2020 on the right. 95
Figure 48. Planned location of Sio Silica well clusters up to 2025 from the Sio Silica HGR........ 96
Figure 49. Location of MB Hydro Pointe du Bois power line, the MB Hydro 500 kV international transmission line, Winnipeg aqueduct and CN mainline.[75] 97
Figure 50. C&J model geometry 99
Figure 51. Head drawdown in the sandstone for the C&J solution, observed head values obtained from pressure transducer data for Sio Silica 72 hour pump test, and head results from the Theis solution. 101
Figure 52. Head change at the top of the sandstone for one well in a cluster for increasing extraction times 106
Figure 53. Net water transfer to the carbonate for increasing transfer coefficient for 65% water and 50% water during withdrawal for 5 days of extraction over a radius extending to 27 meters from the extraction well. 107
Figure 54. Sandstone potentiometric surface........ 109
Figure 55. Simulated potentiometric surface in Springfield before Sio Silica extraction operations 110
Figure 56. Head Change in the Carbonate from water transferred from the sandstone by water re-injection. 111
Figure 57. Water transit time in fractures in the limestone and karst of fracture porosities of 0.001 and 0.003 112
Figure 58. Collapse of limestone in the Sio Silica extraction cavities. 114

List of Tables

Table 1. Sio Silica permitted injection wells from 2018 to the end of 2021 18
Table 2. Representative sandstone parameter values for the C&J solution for three Sio Silica re-injection wells 26
Table 3. Summary of the information in the temporary authorization letters from Manitoba Drainage and Water Rights Licensing Branch. 29
Table 4. Limestone and till thickness for Sio Silica wells in the Bru area 65
Table 5. NPRI emission factors [108] 78
Table 6. Estimated contaminant concentrations in the extraction cavity for 12.84 cubic meters of diesel fuel used for each well cluster air compressor and a cavity volume of 16970 cubic meters. 79
Table 7. Slurry loop acrylamide concentration and model parameter values 87
Table 8. Selenium concentration guidelines in mg/L (data from the SIO Silica extraction EAP) 90
Table 9. Calibrated Model Values 101
Table 10. Theis solution values for observed drawdown 101
Table 11. Data for figure 51 102
Table 12. Reference C&J parameter values for sandstone 104
Table 13. Water transfer to carbonate for various scenarios for the combined extraction and re-injection well of the EAP design. 104
Table 14. Validation of Theis Solution (Lower Paleozoic Aquifer, Alberta) 120

CEC submission for Vivian Silica Sand Extraction Project

D.M. LeNeveu, M.Sc. (biophysics). B.Sc. (honours physics), B.Ed.

June 10, 2022

1 Introduction

This participant submission for the Clean Environment Commission (CEC) Hearings into the Vivian Silica Sand Extraction Project addresses and mandate of the review and the list of issues with respect to the potential environmental detriment of the project. The mandate of the review is to conduct a technical review and a public hearing to consider the potential environmental effects of the proposed Sio Silica extraction project. This submission provides evidence, data and documented reasons why the project must not proceed due to deleterious environmental effects from the Project that would have no effective mitigation. The list of issues for the project is given in appendix I of the hearing directive of February 2022. The list of issues is reproduced below.

1.1 List of Issues

In reviewing the Proponent's project proposal, the Panel's assessment of the Project will include, but not be limited to, consideration of the following:

Public Involvement: The Proponent's process of consultation with the public and Indigenous groups on the Project.

Project Description: Suitability of the proposed design (including project components and geotechnical components), construction, operation and decommissioning of the project.

Regulatory Environmental Assessment: Consideration of the Proponent's approach to environmental assessment.

Environmental Effects Assessment: Potential effects on the environment including; groundwater (supply and quality); surface water fish and fish habitat; climate and greenhouse gas emissions; vegetation; wildlife; water, hydrology, and wetlands; soils, terrain and geology; air quality.

Potential effects on socio-economic matters including: labour force and employment; infrastructure and services; heritage resources; land resource use; human health; traffic; aesthetics; visual quality.

Environmental Effects on the Project: The effect of weather and other environmental factors on the physical and operational aspects of the Project.

Cumulative Effects Assessment: Potential effects of the Project, in combination with the effects of past and future projects and activities, on both the biophysical and socio-economic environment.

Monitoring and Follow-Up: Follow-up and monitoring plans for the Project, including consideration of draft plans.

Sustainability: The Project and long-term sustainability.

Recommendations: Terms and Conditions Recommendations to be included in the Panel report. Terms and conditions to be included in any advice the Panel may issue.

This submission describes omissions, inconsistencies, and non-disclosure in the proposed project design including project components and geotechnical components, construction, operation and decommissioning of the project. The submission provides comprehensive documented evidence for the deleterious environmental effects of the Project.

The proponent CanWhite Sands Corporation (Sio Silica) has changed its name to Sio Silica.

1.2 Major issues

Sio Silica has given no engineering specifications and detailed design of the dewatering facility including the volume and number of all vessels such as hydrocyclones, sand separators, sand screening collection vessels and tanks used to separate the sand and sediment. Sio Silica has been developing the extraction methodology since at least 2016 and has disclosed no data regarding pumping rates and volumes of re-injected water and sand extracted. Data on the ratio of sand to water extracted as a function of time during sand extraction has not been disclosed. Sio Silica has not demonstrated the methodology and design for transfer of water to slurry lines and regular movement of the lines. During advanced exploration activities Sio Silica has only performed small scale extraction of no more than one or at the most two wells simultaneously. Sio Silica has not implemented the well cluster design of up to five wells per cluster and simultaneous extraction of from seven or more wells. Sio Silica has not demonstrated the operation of dewatering facility or given engineering specification and detailed design for volume of sand and excess water produced during simultaneous extraction of many wells. The few injection well permits issued to Sio Silica since 2019 for advanced exploration activities required the monitoring and measurement of injection pressure on the formations and demonstration that formation damage would not occur. Sio Silica has not disclosed the formation pressure data required by the injection well permits. Sio Silica has tested the return of process water to the sandstone aquifer for only one well and has given no data or information to substantiate the gravity feed method of return is feasible on a production scale.

Sio Silica has failed to provide adequate engineering and design specifications and data for the processing plant and the extraction activities. Sio Silica should provide engineering designs giving the size and nature of all the vessels and the details of the beneficiation processes used to purify the sand to solar panel glass standards. The beneficiation processes normally entail the use of toxic chemicals requiring dedicated disposal.[128] Such disposal must be considered cumulatively with disposal of concretions and other wastes at both the processing plant and extraction sites and thus must be included in the Hearing.

Sio Silica has failed to disclose the amount of air that will be introduced into the sandstone aquifer during the extraction process through air entrainment in process water and air injection directly into the aquifer. In response to public comments regarding return of air and oxygen to the aquifer Sio Silica states in the project public registry 6119.00

"*Although a small amount of dissolved oxygen may occasionally enter the aquifer, it will not adversely impact the quality of the groundwater.*"

No evidence has been provided by Sio Silica to quantify the amount of dissolved oxygen returned to the aquifer. No mention is made by Sio Silica of air entrainment which could result in much more air in gaseous form than dissolved air sent into the sandstone aquifer. Sio Silica has stated that air used in the air lifting process remains in the production tube and does not enter the aquifer. The patent for the Sio Silica air extraction wells describes the injection of air outside the production tube to loosen the sand in the aquifer.[1] Sio Silica has failed to consider pollutants such as CO2, NO2, SO2, diesel fumes, oil vapours, benzene and microbes that would be draw in by extraction rig air compressors and injected into the aquifer and dissolved in the returned process water.

The Sio Silica extraction well patent shows that re-injected water would form curtain around the extraction well and be drawn into air lift production tube diluting and obstructing sand uptake. The formation curtain of water formed by re-injection of water near the top of the sandstone has been verified by modelling using an adapted heat conduction solution for Carslaw and Jaeger (C&J) solution.[43] This evidence establishes the return of water to the aquifer on the scale necessary during production is not likely feasible. The C&J solution reveals that the re-injected water causes a pressure that would force re-injected water into the carbonate once the aquitard degrades. The aquitard degradation is documented in the Sio Silica Hydrogeological Report and the third party technical review report by Arcadis Inc.

Sio Silica has dismissed the potential environmental effects of air introduction on the groundwater of the two major aquifers of Southeast Manitoba, the carbonate and sandstone aquifers. These aquifers are anaerobic with little or no dissolved oxygen as quantified in studies by Phipps et al. (2008).[98] Sio Silica has failed to account for major sources of sulphide in the sandstone aquifer such as shale interbeds, concretions and ooilite and failed to properly measure sulphide within the aquifer. Air would react with the sulphide to form acid and mobilize heavy metals.[9] Sio Silica has dismissed without evidence other potential sources of aquifer contamination measured by geochemical anlysis of core logs such as high levels of selenium and fluoride documented in the EAP. The geochemical studies in the Sio Silica Hydrogeological Report demonstrate that oxidizing conditions from air introduction would precipitate iron and manganese degrading well water quality. Sio Silica has claimed without evidence that the iron and manganese would be filtered and absorbed in the sandstone. Evidence is given here that effective absorption of iron and manganese on the sandstone will not occur. The oxidizing conditions caused by Sio Silica extraction activities would promote the growth of iron bacteria and other harmful microbes.

The supplemental document #4 filed with the CEC on June 29, 2022 describing methods of filtration of process to prevent scattering of UV light used for disinfection is fraught with unresolved issues documented herein.

I give evidence that harmful microbes and iron bacteria would enter the aquifer from the drilling of hundreds of extraction wells per year and from air injection even if the UV sterilization were effective.[55,78] Sio Silica has not given methods to sterilize air injection. I provide evidence the air compressor used for air injection would draw in and concentrate pollutants such as diesel exhaust, cooling oil vapour, and microbes. CO2, NO2, SO2, benzene and other pollutants would readily dissolve in the aquifer water. Dissolved CO2, SO2 and NO2 would form acids that would leach heavy metals into the aquifer. Gaseous air bubbles introduced into the sandstone aquifer from re-injected process water and from the air tube used in the airlift process would rise into the carbonate aquifer through the collapsed shale aquitard. The air bubbles would be carried rapidly in the larger water bearing carbonate fractures in the direction of the prevailing hydraulic gradient. The dissolved air, as documented in the EAP, would precipitate iron and manganese discolouring and degrading domestic well water quality. Iron bacteria introduced in the compressed air from airlift operating would proliferate in the newly oxidizing conditions in both aquifers fouling domestic wells.

Sio Silica has claimed that the re-injected water would be confined to the sandstone aquifer and not enter the carbonate aquifer despite evidence in their Extraction Environmental Act Proposal (EAP) that the aquitard could degrade and mixing of carbonate and sandstone aquifer waters would occur. Evidence is provided in this report of the large amount of air that would be introduced to the sandstone and carbonate aquifers and the repercussions of this air introduction. Sio Silica has not provided any documentation on the operation Sio Silica combined well sand extraction and water re-injection design given in the EAP and revised in the supplemental filing of document #1 on June 2, 2022 and revised again in the filing of Jan. 24, 2023. The Sio Silica extraction EAP and Sio Silica replies to participant information requests acknowledge the shale aquitard would be compromised by silica sand extraction operations leading to mixing of aquifer waters. The mixing of aquifer waters by Sio Silica extraction methods is prohibited by Manitoba Groundwater regulations. The regulations mandate that this project cannot proceed.

I give evidence from Sio Silica well information reports obtained from Manitoba Groundwater that the minimum limestone thickness to prevent subsidence specified by Stantec of 15 meters is not achieved in the area east of highway 302 and in many areas west. Information in Attachment A of the response to public comments of the project registry 6119.00 demonstrates more that 15.0 meters of competent limestone is required for stability. Sio Silica has consistently ignored the Stantec limit of 15 meters of limestone thickness documented repeatedly beginning with the public comments submitted for the Project and repeated in many submissions to the CEC. Well information reports obtained from Manitoba Groundwater provide evidence that the entire 24 year Sio Silica Bru project area is susceptible to subsidence due to insufficient limestone thickness. The revised extraction plan of Jan 24, 2023 uses variable number of wells per cluster up to a maximum of five. Five well per cluster would result in a cavity span of about sixty meters according to the information in the extraction plan of June 2, 2022. Analysis of the public version of the Stantec geotechnical data released in January 2022 demonstrates that a sixty meter cavity span is not viable for the limestone and overburden thickness in the Project are and would lead to collapse of the limestone and subsidence. The measures to adjust the number of wells per cluster and the spacing of the clusters during production activities to address the Stantec data given in January of 2022 has not been adequately described. The entire project is not viable based on the subsidence issue alone.

I provide evidence that Sio Silica did not protect the inadequate number of geochemical samples from air oxidation and weathering. I provide evidence that the quantified neutralization potential of the sand samples analyzed is invalid due to contamination and air exposure. Sio Silica did not follow federal MEND guidelines for geological sampling and handling of the samples to protect against oxidation and exposure to moisture. The geochemical analysis reported in Appendix A of the extraction EAP is therefore invalid and must be redone. I demonstrate acid potential of the sand measured by Sio Silica, underestimated due to the weathering of the sand samples that occurred, would cause significant acid formation in the dewatering plant, slurry recycle loop, and the aquifer sand. I provide evidence that the water in slurry lines recycle loop and clarifier tank will accumulate toxic acrylamide monomer and selenium concentrations. I provide evidence that both the carbonate and sandstone aquifers will become contaminated with heavy metals, selenium and fluoride.

No geochemical analysis or testing of samples was done in the area west of highway 302. Two of the samples for geochemical testing Bru 121-1 and Bru 146 were extracted south of the Project area. All geochemical testing must be redone with many representative samples from the western area that are taken to prevent any air exposure.

All these documented design and geochemical and geo-technical evidence given here falls within the, **"Environmental Effects Assessment",** in the list of issues**.**

This submission provides evidence of the substantial cumulative greenhouse gas emissions from both the Sio Silica processing plant, the extraction activities, from users of the new natural gas line for drying sand and from the fabrication of the large amount of casings required for the hundreds of wells per year required for the sand extraction. The cumulative greenhouse gas emissions fall within the scope of, **"Potential effects on socio-economic matters",** in the list of issues.

This submission gives evidence concerning the potential for silica dust exposure that would be detrimental to the health of both workers and the public. Silica dust exposure falls under the human health issue under, **"Potential effects on socio-economic matters",** in the list of issues.

Contaminant build up in the slurry lines and processing facility water could damage surface water fish and fish habitat upon leakage. Sio Silica has not properly addressed the risk of leakage and has not adequately specified leak detection measures. Such leakage would fall within the scope of, **"Environmental Effects Assessment",** in the list of issues.

Evidence for these and many other adverse environmental consequences are detailed in this submission.

2 Air Entrainment

In the Sio Silica/Sio extraction wells air would become entrained in the water during the air lift process. Further large amounts of air would be entrained during injection of the water into the settling tanks in the dewatering station by the water jets and by turbulence in the tank. [6,8,15]

Sio Silica in response to public comments about lack of specifications for the dewatering system stated,

"*The sand and water extracted from wells will first pass through a cyclone at the well cluster site to remove some water. Then the sand and water at 65% sand will pass over a dewatering screen. A dewatering screen is a one layer inclined screen. The screen catches the sand, and allows the water to pass through. The wet sand then travels off the inclined screen into a sump, and the water that flows out the bottom of the screen feeds into the UV light treatment system before reinjection (by gravity flow) back to the sandstone aquifer. When the wet sand enters the sump it is mixed with recycled water from the Processing Facility and is then transported (pumped) as a sand and recycled water slurry through a slurry line to the Processing Facility*."

This cursory description does do make up for the lack of design and engineering drawings that should have been part of the EAP.

Air would be entrained in the water to be returned to the aquifer in the hydrocyclone used for dewatering and fines removal and in the dewatering screen.[13] Figure 1 illustrates the air entrainment from a water jet directed into a tank. Figure 2 shows the air fraction, α, entrained by the water jet.[6] Figure 3 shows the water entrained by surface turbulence.[15] Figure 4 shows water entrainment mechanisms.[7] Figure 5 illustrates air entrainment in the central core of a dewatering hydrocylcone.[13] The overflow from the hydrocyclone would contain fine particulate and a large fraction of entrained air in the water that would be returned to the aquifer. Figure 6 illustrates further water entrainment in the dewatering screen.[14] Fine particulate and entrained air in the water below the screen would be returned to the aquifer. Figure 7 shows the pipe depositing extracted sand plus water into a grey tank of the dewatering station. Settled sand is extracted from the grey tank using a track hoe contrary to the description in the response to public comments that describes the wet sand travelling of the inclined dewatering screen to a sump pump. A red tank below the level of the grey tank has a gravity flow entry chute that would result in air entrainment as shown in figure 1. There are three red tanks to process the water and sand all of which have hose or chute entries that would entrain more air. The suspended black nozzles appear to be separators for fine sand that would be deposited in a red tank. The overflow from the black separators would contain water with entrained air. The water in all the tanks would be turbulent from the rapid rate of water flow during extraction. The surface turbulence would entrain more water as shown in figure 3. The water and sand from the extraction that enters the dewatering station will contain entrained air from the air lift operation.

The amount of air entrained in the sand slurry spray entering the grey tank shown in figure 7 can be estimated from the increase in the spray radius.[4,5] A study of the slurry spray from Trailing Suction Hopper Dredges (TSHD) that dredges sand and sediment from harbours by suction and sprays the slurry through the air from a hose to the destination. The spray radius increases significantly with spray distance due to air entrainment.[5] The volume of air entrainment is proportional to the square of the increase in spray radius. Figure 7 illustrates the increase in radius of the Sio Silica slurry spray into the receiving grey tank is at least a factor of 8. The final spray volume is at least 64 times greater from the entrained air. The sand separators and hydrocyclones would entrain more air. Tank turbulence would prevent air from escaping.

Fig. 6. Formation of vortex due to plunging jet (v_N = 3.2 m/s, d_N = 4 mm, H_N = 300 mm)

Figure 1. Air entrainment from three water jets and subsequent step down chute and from a plunging water jet [6,8]

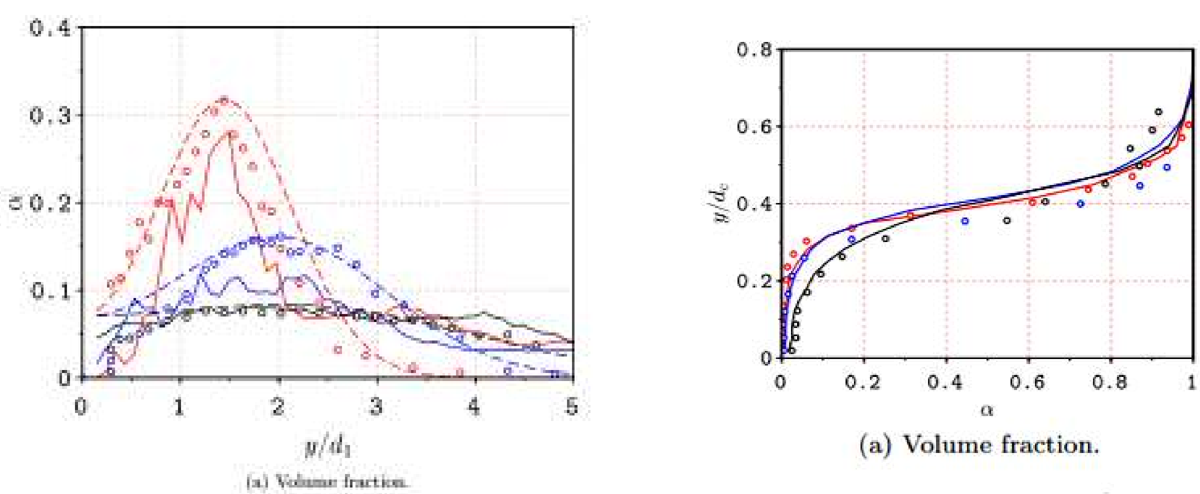


Figure 2. Volume fraction from a water jet into a tank left and a stepped spillway right analogous to water gravity flow in a lower water re-injection tank from a main water and sand separation tank [6]

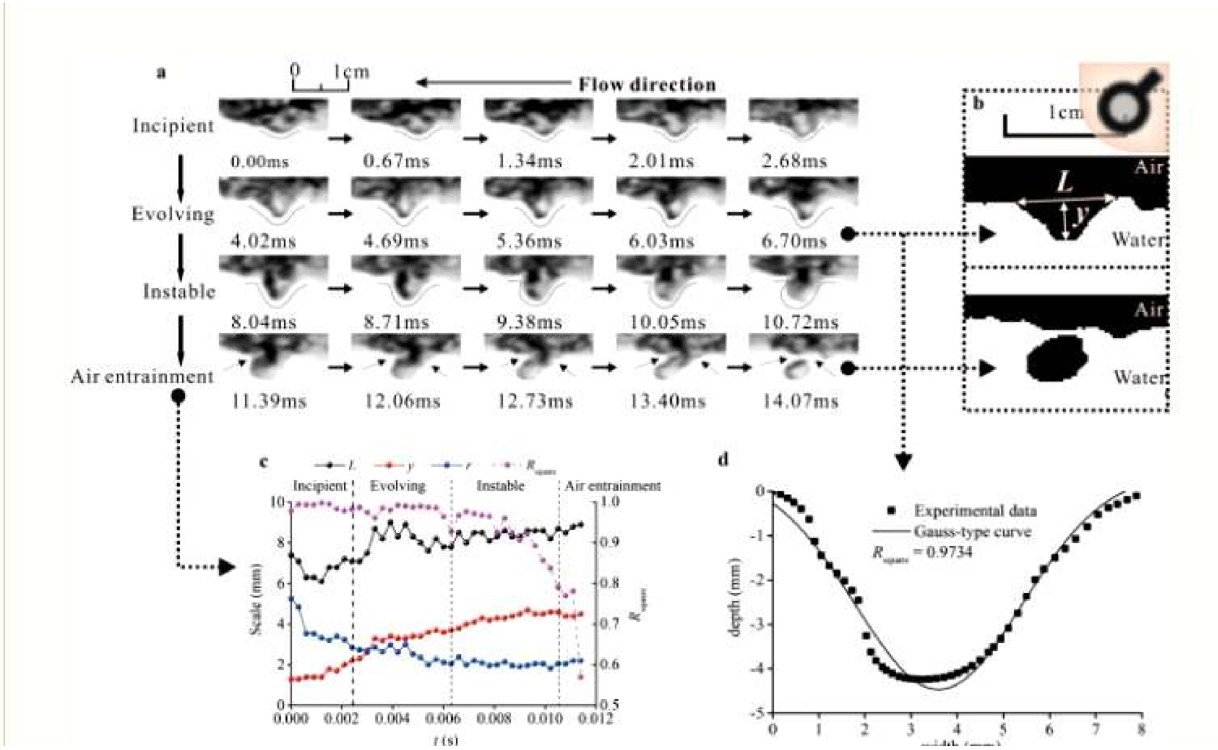


Figure 3. Air entrainment on a free turbulent water surface such as the Sio Silica water settling tank at the dewatering station [15]

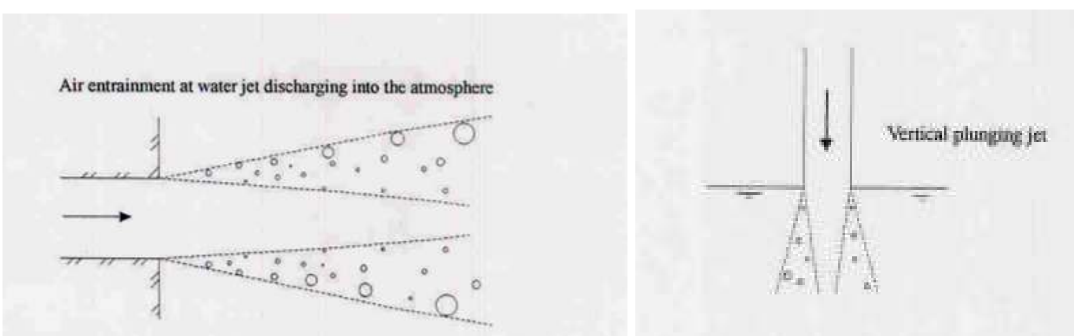


Figure 4. Mechanisms of Water Entrainment [7]

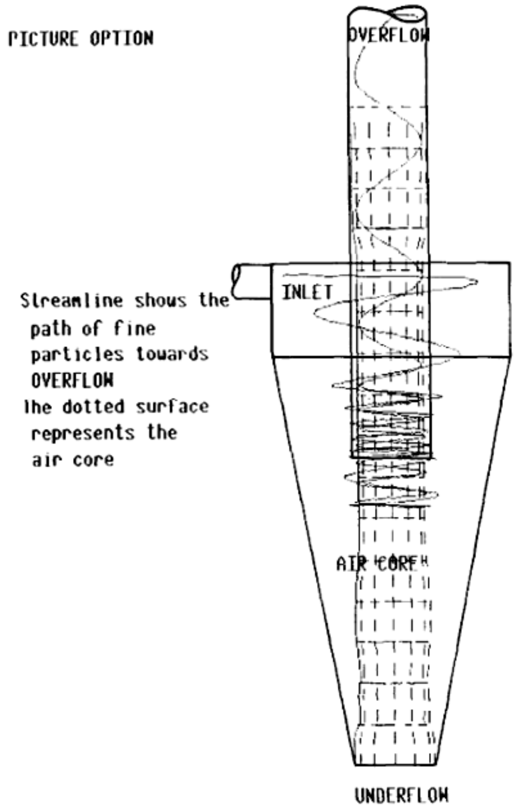


Figure 5. Air Entrainment by a hydrocyclone.[13]

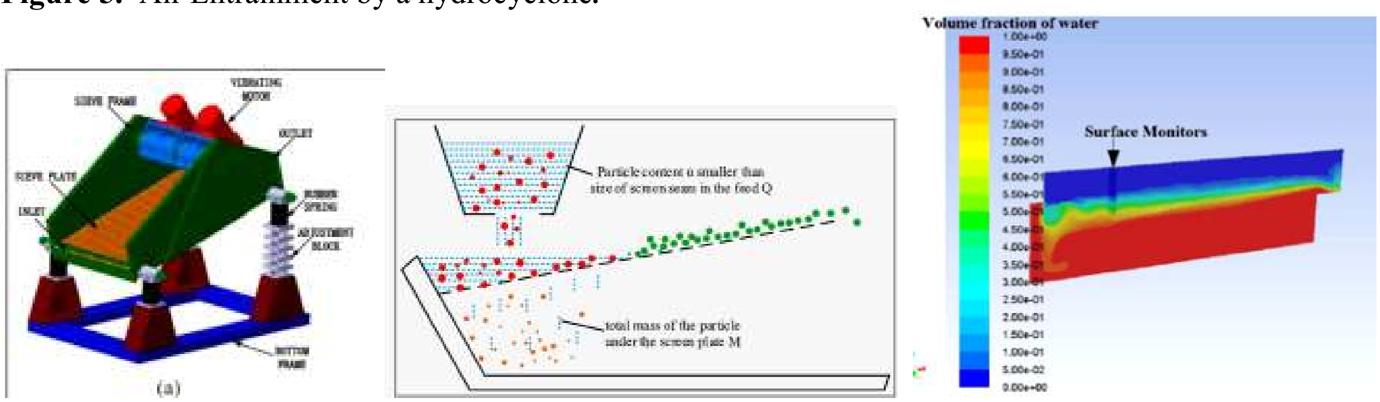


Figure 6. Air Entrainment and particulate separation from a dewatering screen.[14] On the right the volume fraction of air is one minus the volume fraction of water.

Figure 7. Sio Silica injection of extracted water and sand into tanks near Vivian Manitoba, Aug. 18 2021. The blue hydrocyclone is visible at the top on the right. *Images are used with the photographer's permission.*

The filtration system required for the UV sterilization process as described in the supplemental document #4 filed with the CEC on June 29, 2022 would result in more air entrainment. Evidence of air entrainment in a clarifier by the V notch overflow weir of the clarifier and in effluent water plunging into a process water receiving tank required in the UV filtration process is illustrated in figure 8.[101,102]

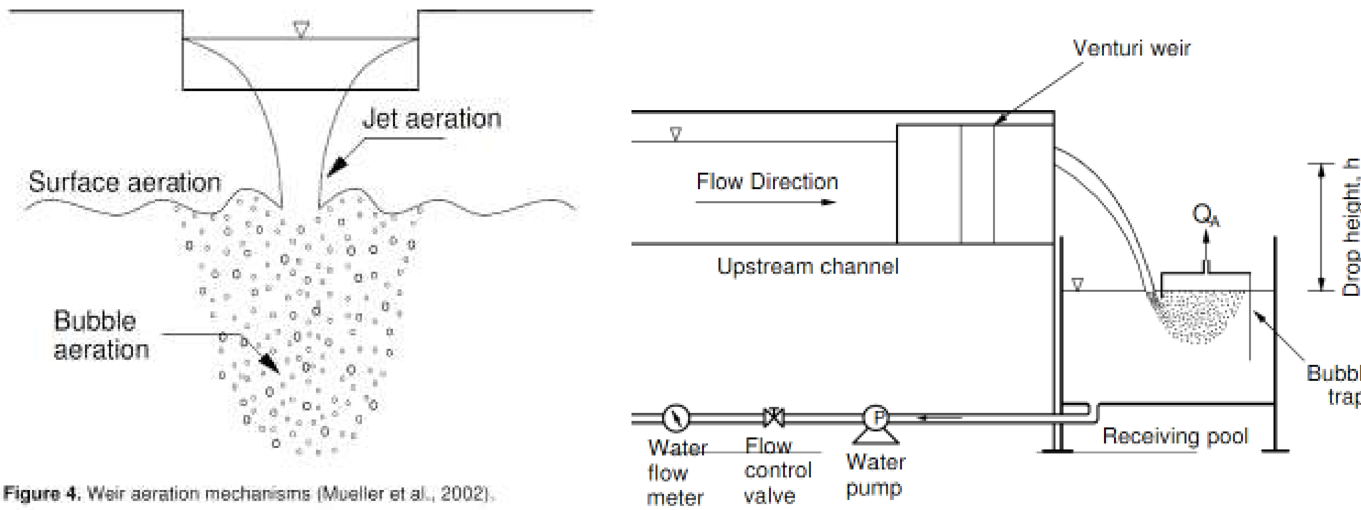


Figure 8. Air entrained in by the overflow v notch weir and the receiving pool of a clarifier tank[100]

How much air would be re-injected into the aquifer from water entrainment? Sio Silica in Appendix H uses average water to sand ratio of one to one by volume. Therefore the amount of returned water, using a dry sand density of 1.65 t/m^3 [99] for 1.36 million tonnes of sand per year, is 824,242 m^3. The fraction of entrained air can be as high as 40% as documented in DLN IR-002. For a small value of 5% air by volume of water, a one to one ratio of the volume of water to sand and for an air density of 1.3 kg/m3, the weight of air to aquifer per year would be 53,576 kg and the volume, 41212 m^3.

The oxidation of iron pyrite is often written as;[120]

FeS2 + H2O +7/2O2 -> Fe(SO4) + H2SO4

Thus 7 moles of O2 produces 2 moles of sulphuric acid. The molecular weight of O2 is 32 and H2SO4, 98.08. Using this data and a weight fraction of O2 in air of 0.23 the entrained air could produce 110,022 moles of sulphuric acid. The EPA recommends the pH of drinking water be in the range of 6.5 to 8.5.[121] Below pH 6.5 heavy metal release can be expected. Using only the first strong dissociation of H2SO4, for a pH of 6.0, 110 million cubic metres of aquifer water would be potentially contaminated per year. This is a calculation and ignores any bicarbonate or other neutralizing potential of the groundwater and reaction of the O2 with other minerals. However neutralization of sulphuric acid by CaCO3 or bicarbonate produces CO2 which would dissolve in water to form carbonic acid.[122,127] Oxygen reaction with other minerals would also be detrimental such as leaching of selenium and precipitation of iron and manganese. Thus the oxidation potential of the entrained air in the water returned to the aquifer is limited but enormous in terms of potential heavy metal leaching and drinking water acidification and other detrimental effects. This calculation does not include air introduced from the aquifer by the airlift air tube that would cause further acidification and heavy metal leaching of the aquifer water.

The density of air at the surface (1.3 g/L) is roughly 100 times the solubility (10 mg/L) of the air. Thus a certain volume of air injected would require about 100 times the volume of water for dissolution at the surface. At depth into the aquifer the solubility of air increases with pressure. A small amount of gaseous air entrained in the re-injected water would eventually result in a much larger volume of dissolved water saturated with air. The dissolved air has serious detrimental geochemical consequences for the aquifer as documented below. The potential detriment of re-injection of entrained air is enormous and has been neglected by Sio Silica.

The solubility of oxygen in water at atmospheric pressure at 15 Centigrade according to the online engineering tool box is 10 mg/litre. The solubility of a gas is proportional to the partial pressure. The re-injected gaseous oxygen would dissolve as it spreads out. The top of the sandstone is about 50 meters below ground surface with a hydrostatic pressure of 490 kPa or nearly 5 atmospheres. Thus the solubility would be about 5 times greater in the aquifer as confirmed by online data from the engineering tool box.[116] For 824,242 m^3 cubic meters of water re-injected the amount of dissolved oxygen would be another 8.2 tonnes of air and 1.89 tonnes of oxygen. This would be about 0.153 of the amount of the gaseous entrained air determined above resulting in a potential of 16.9 million cubic meters of water contaminated to a pH of 6.0 from the oxidation of iron sulphide just from dissolved air per year. Thus even if Sio Silica somehow managed to eliminate the gaseous entrained air from process water, the dissolved air has the potential to contaminate a limited but unacceptable amount of aquifer water.

Sio Silica should be required to deaerate and measure the air content of water before re-injection. Deaeration is an expensive time consuming process involving pressure reduction and heating.[83] For the high flow rate required for the Sio Silica extraction, deaeration is likely not feasible. The project must not proceed with out demonstration of the feasibility of deaeration and measurement to ensure entrained air has been removed from the re-injected water.

2.1 Air injected directly into the aquifer during the air lift extraction method

The patent for the CanWhite Sands Corporation air lift wells states;[1]

"*The gas injection line may also be lowered beyond the lower end of the conduit and into the sandstone formation to generate a pressure vibration or inject a pulse of air to agitate the sand from time to time*."[1]

The Sio Silica extraction process would inject air directly into the aquifer as described in their patent. How much air does the extraction process inject with pulses to loosen the sand? The patent states the air compressor will provide a flow rate of 300 to 600 cubic feet of air per minute or, on average, 12.7 m^3/min. The total amount injected directly into the aquifer would depend on the frequency and duration of the pulses air injection to loosen the sand. If air injection only occurred 1% of the time for about 220 operating days per year, with an average of 10 well operating simultaneously as shown in Table 6-3 of the extraction EAP, would result in a staggering 402,336 cubic meters of air injected into the aquifer per year at the average rate of injection. This 402,336 cubic meters of air is 9.76 times the amount of entrained air estimated above and would have the potential to contaminate more than one billion cubic meters of aquifer water to a pH of 6.0 from the oxidation of pyrite.

Local residents observing the well and the sand being extracted noted that the compressor operated in alternating pulses, off and on confirming pulsed air injection directly to the aquifer likely occurred. The injection of sand plus water from the slurry line pipe to the dewatering tanks was also pulsing resulting in airborne mist and carrying silica sand fines that would be a respiratory hazard. Even if the air tube were confined in the production tube some over pressurization of the air would cause air to enter the sandstone. Sio Silica has not documented the pressure used for injection and how that pressure is controlled and measured. Sio Silica cannot guarantee air would not enter directly into the sandstone.

The moving air would have created a suction to draw up the loosened sand. The amount of air retained in the sandstone is difficult to determine because some of the injected air would return to the surface with the extracted sand. Much of the large amount of injected buoyant gaseous air would have risen and spread out under the aquitard eventually dissolving in the groundwater and changing the geochemical conditions from anaerobic[98] to aerobic (oxidizing).

3 Sio Silica Extraction Well Design

The extraction well design from Sio Silica's Supplemental Filing #1 of June 3, 2022 is shown in figure 9

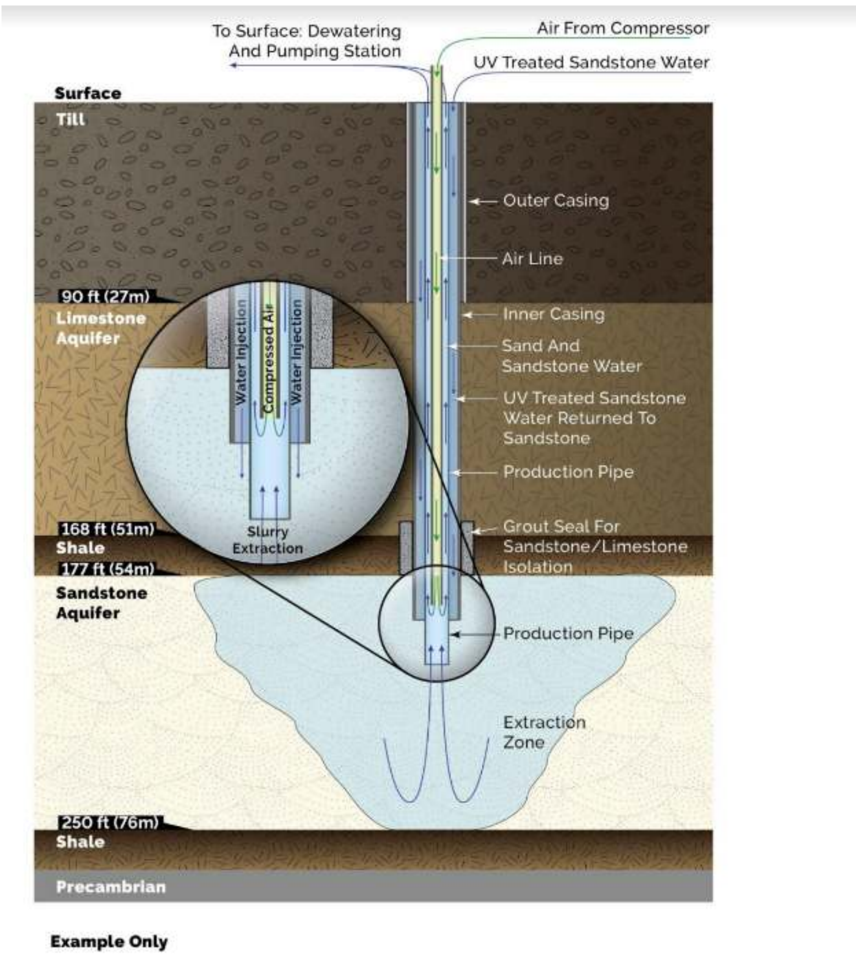


Figure 9. Sio Silica EAP design for combined extraction and injection wells.
Illustration was reproduced from the Sio Silica EAP.

In the EAP design shown in figure 9, excess water would be injected into the sandstone aquifer simultaneously with extraction of sand in the production pipe by means of airlift.

Sio Silica has withdrawn silica sand from at least four locations in the RM of Springfield since 2017 in advanced exploration operations, the Center Line Road Site at SW19-10-8E, the Vivian site at SW32-10-8E and two quarry sites at SW5-11-8E and SW29-10-8E. Of all the Sio Silica well information reports obtained from Manitoba groundwater for the Sio Silica sand extraction sites I have found only two wells prior to the wells at the quarry sites of 2021 partially conforming to the EAP design. These two wells, Bru 82-5/BH 6-18 and Bru 82-6/BH47-18, were completed in 2018 at the Center Line Road Site. Bru 82-5/BH 6-18 and Bru

82-6/BH47-18 completed Sept 28, 2018 and Nov.14, 2018 were concentric triple tube wells with the outer steel casing opening into the carbonate, the middle steel casing opening into the top of the sandstone and a deeper steel casing opening into the sandstone. The well construction of Bru 82-5 and the possible water re-injection and sand extraction routes is shown in figure 10. The air injection tube in the centre would be removable thus is not shown in the photograph of the well on the right. Bru 82-5 was sealed and cut off at two feet below ground surface on June 18, 2020, almost two years after completion. It should be noticed that well Bru 82-5 is one of many Sio Silica advanced exploration wells left open at the surface for long periods before sealing in violation of Manitoba groundwater regulations.

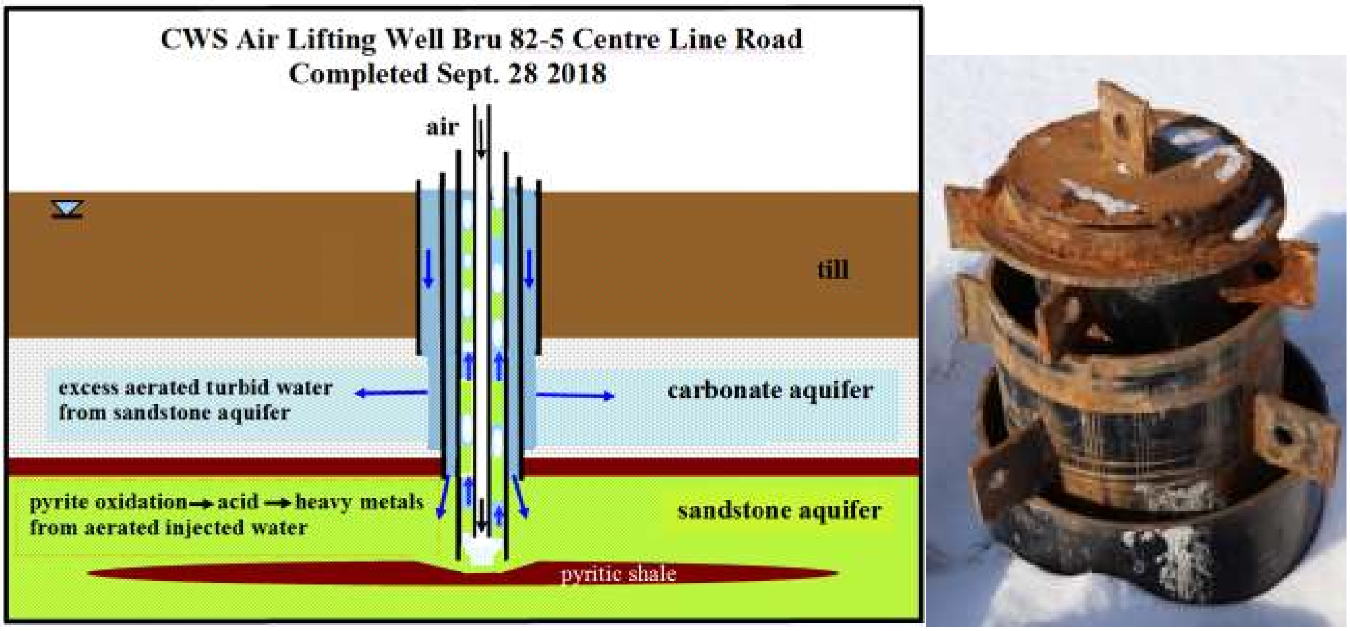


Figure 10. Sio Silica air lifting well at Center Line Road for advanced exploration.
Illustration is by D.M. LeNeveu. Image of well was used with photographer's permission.

Except for the outer steel casing opening into the carbonate Sio Silica wells Bru 82-5 and Bru 82-6 would conform to the EAP design. It could be that these triple tube wells were used to investigate the optimal well design for Sio Silica extraction and re-injection. The opening into the carbonate would allow for testing of the efficacy of re-injection of water into the carbonate rather than or in addition to the sandstone. The remarks section in the well information report stated "*air lifting*" confirming the Bru 82-5 triple tube well was used for air lifting and silica sand extraction testing. Sio Silica was not issued an injection well permit for Bru 82-5 or Bru 82-6; therefore water re-injection could not have been tested for these wells without violation of the Manitoba groundwater regulations. One other steel cased double tube well BH9-17 completed in June 13, 2018 at the Centre Line Road site was labelled "*air lifting*". However the outer tube for BH9 9-17 opened into the carbonate allowing re-injection only to the carbonate which is prohibited by regulations against mixing of aquifer water.

All the Sio Silica injection well permits and corresponding well names issued to Sio Silica by the Manitoba Water Branch since 2018 up to the end of 2021 are given in table 1.

Table 1. Sio Silica permitted injection wells from 2018 to the end of 2021

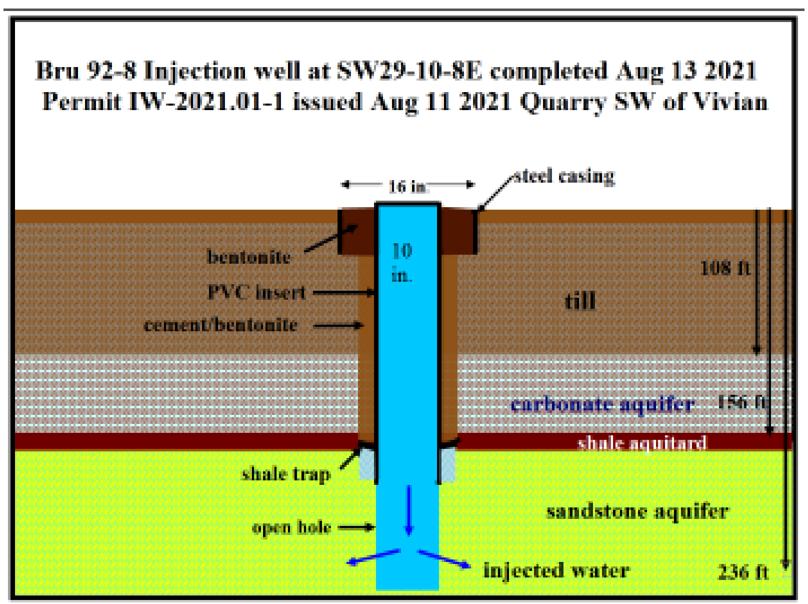
Sio Silica Injection Well	Sio Silica injection well	Sio Silica injection well	Injection formation	Well completion date	Injection well permit issue

Permit number	name	location			date
IW-2019.01-1	BH 9 B-17	SW19-10-8E1 Center Line Road site	carbonate	June 6, 2018	May 19,2019
IW-2019.02-1	Bru 95-2	SE32-10-8E1 south of Vivian	sandstone	June 16, 2019	May 19,2019
IW-2019.02-1	Bru 95-3	SE32-10-8E1 south of Vivian	sandstone		May 19, 2019
IW-2020.01.1	Den 304-1	SE32-07-08E1	sandstone		July 31,2020
IW-2021.01-1	Bru 92-8 and Bru 92-9	SW29-10-8E quarry south west of Vivian	sandstone	Aug. 13, 2021	Aug.11, 2021

Data was obtained from the Manitoba Groundwater Section.

According to the Manitoba Groundwater Section the wells BH 9B-17, Den 304-1, and Bru 92-9 were not used for water re-injection. In round 2 of the information requests Sio Silica stated Bru 95-2 and Bru 95-3 were not used for water re-injection. The only remaining well permitted for water re-injection is Bru 92-8.

Figure 11 shows that the permitted injection well Bru 92-8 at the quarry south west of Vivian. Injection well Bru 92-8 is missing the production pipe and therefore does not conform to the Sio Silica design in the EAP. Sio Silica has explained in the response clarification of the DLN Information Requests (IR) that the production tube was removed even though the well construction reports obtained from Manitoba Groundwater do not record the installation and removal of the production tube. The procedure for injection of water through a removal production tube remains unclear. There is no stated means to stabilize the production tube within the outer PVC annulus shown in figure 11 for Bru 92-8. Any well inserts to prevent the production tube from moving during sand extraction and water re-injection could interfere with the water re-injection.



2022 Feb 11
Well PID: 208473
Location: SW29-10-8E
UTMX:681631.6 UTMY:5526384.6 XY Accuracy:1 EXACT [<5M] [GPS]
UTMZ:275 Z Accuracy:4 FAIR - Shuttle at Centroid
Owner: CANWHITE SANDS
Driller: EARTH DRILLING CO. LTD.
Well Name: BRU 92-8
Date Completed: 2021 Aug 13
Well Use: INJECTION
WATER USE: Other
Well Status: ACTIVE Aquifer: SANDSTONE
WELL LOG (Imperial units)

From	To(ft.)	Log
0.0	108	GREY TILL
108.0	156	PURPLE/BEIGE LIMESTONE
156.0	166	RED/GREEN SHALE
166.0	236	WHITE SANDSTONE

WELL CONSTRUCTION

From	To(ft)	Const.Method	Inside Dia.(in)	Outside Dia.(in)	Type Material
0.0	20.0	CASING	15.0	16.0	T & C STEEL
0.0	180.0	BOREHOLE	13.8		
0.0	180.0	CASING	10.0	10.8	INSERT PVC
180.0	236.0	OPEN HOLE	9.8		
126.0	162.0	ANNULAR FILL	10.8	13.8	CEMENT/BENTONITE
0.0	126.0	SURFACE SEAL			BENTONITE
162.0	162.0	SHALE TRAP			OTHER

Top of Casing: 0.0 ft above ground

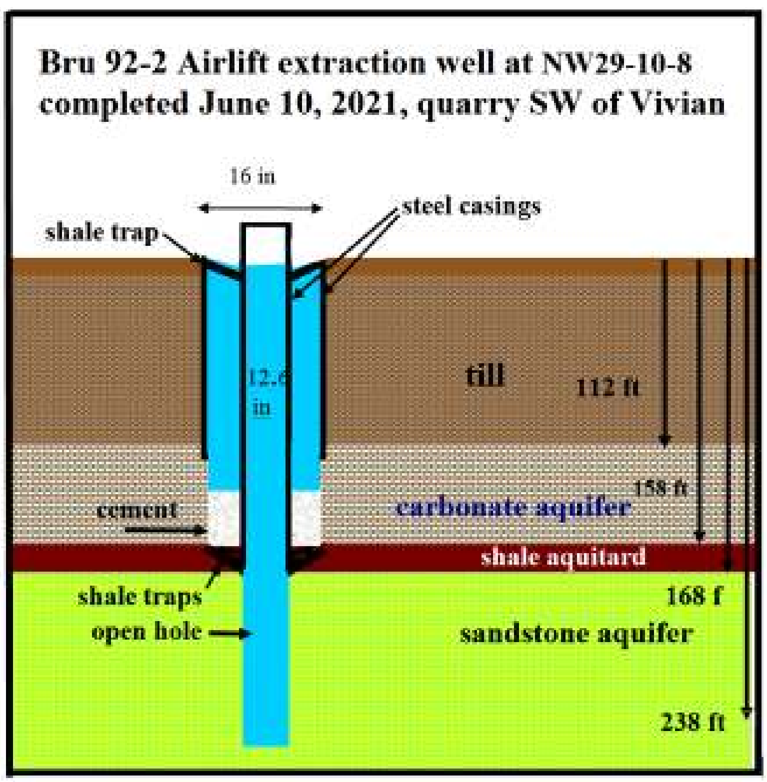
Figure 11. CWS permitted injection well Bru 92-8 at a quarry south west of Vivian 2021. *Illustration is by D. M. LeNeveu. Well information report was from Manitoba Groundwater*

In response to clarification information request about the gravity fed water return for Bru 92-8 Sio Silica stated;

"*Sio monitored water gravity feed to the well visually. If the gravity feed flow exceeded the ability for the well to receive water the feed would be reduced or shut off completely because the water could overflow around the wellbore as the wellbore is open to atmosphere. Please note, these are testing configurations and not necessarily the configuration of the proposed extraction operations*."

Sio Silica in this statement tacitly admits that the airlift well may no be able receive all the water required for re-injection. A visual method to monitor the re-injected water is not acceptable for production. No other method of monitoring the re-injection is given by Sio Silica. During production many wells will be receiving re-injected water. There will be a delay in re-injecting water withdrawn due to the retention time in clarifiers, hydrocyclones, chitosan filter and other vessels of the dewatering and UV filtration system. Some wells at the end of their extraction cycle would not be operable to provide the airlift drawdown for gravity feed re-injection. Managing all the water return for many wells operating simultaneously has not been described by Sio Silica and would likely present insurmountable water management problems.

Two other airlift extraction wells 92-2, 92-3 at the same extraction site as Bru 92-8 are illustrated in figures 12 and 13.



Location: NW29-10-8E
UTMX:681574.4 UTMY:5526460.6
UTMZ:282
Owner: CANWHITE SANDS
Driller: Friesen Driller
Well Name: BRU 92-2
Date Completed: 2021 Jun 10
Well Use: PRODUCTION/SOUR
WATER USE: Other
Well Status: ACTIVE
WELL LOG (Imperial units)

From	To(ft.)	Log
0.0	3	FILL
3.0	20	BROWN TILL
20.0	112	GREY TILL
112.0	158	LIMESTONE
158.0	168	SHALE
168.0	238	SANDSTONE

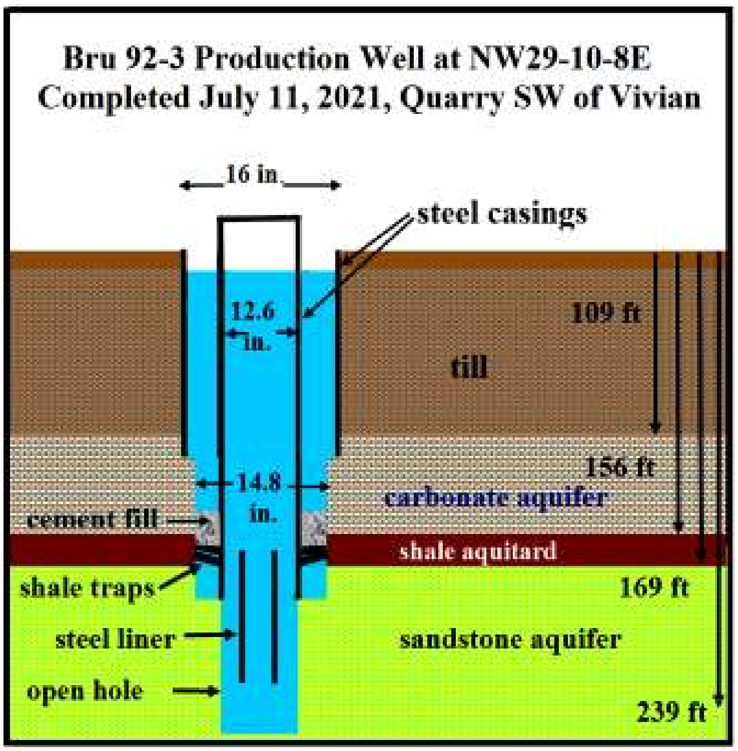
From	To(ft)	Const.Method	Inside Dia.(in)	Outside Dia.(in)	Material
0.0	115.0	CASING	15.5	16.0	STEEL
0.0	169.0	BOREHOLE	14.8		
0.0	168.0	CASING	12.0	12.6	STEEL
168.0	238.0	OPEN HOLE	11.0		
130.0	158.0	ANNULAR FILL	12.0	14.8	CEMENT
158.0	158.0	ATTACHMENT	12.0		K PACKER
158.0	158.0	ATTACHMENT	12.0		SHALE TRAP
0.0	0.0	ATTACHMENT	16.0		SHALE TRAP
158.0	158.0	ATTACHMENT	12.0		SHALE TRAP

Top of Casing: 2.0 ft above ground

Figure 12. Bru 92-2 production well completed July 11, 2021 at a quarry south west of Vivian. *Illustration by D.M. LeNeveu was based on the well information report received from Manitoba Groundwater shown on right. Photograph of well Bru 92-2 was reproduced with permission of photographer.*

The Bru 92-2 airlift well is designed such that the excess water extracted with the sand could be re-injected into the carbonate aquifer through the outer annulus. Injection of water into the carbonate aquifer of water taken from the sandstone aquifer is prohibited by Manitoba regulations. In addition Bru 92-2 is not permitted as an injection well thus water could not be re-injected in this well even though the well is designed for re-injection into the carbonate. The opening into the carbonate is protected at the surface with a shale trap. This is not a permanent seal. I must question why temporary shale trap would be used to seal the surface opening directly into the carbonate aquifer. A cloth skirt was affixed around the well with duct tape as shown in figure 12 for what purpose?   If a permanent seal is not placed to seal the opening in the outer annulus into the carbonate aquifer contamination could eventually occur from ingress of contaminated surface water.

Figure 13 for Bru 92-3 has steel liner penetrating into the sandstone and no sealing of the outer annulus.



Location: NW29-10-8E
Owner: CANWHITE SANDS
Driller: Friesen Drillers
Well Name: BRU 92-3
Date Completed: 2021 Jul 11
Well Use: PRODUCTION/SOURCE
WATER USE: Other
Well Status: ACTIVE

WELL LOG (Imperial units)

From	To(ft.)	Log
0.0	3	BROWN GRAVEL
3.0	8	BROWN TILL
8.0	25	GREY SANDY TILL
25.0	109	GREY TILL WITH BOU
109.0	156	BROWN LIMESTONE
156.0	169	GREY AND RED SHALE
169.0	239	WHITE SANDSTONE

WELL CONSTRUCTION

From	To(ft)	Const.Method	Inside Dia.(in)	Outside Dia.(in)	Material
0.0	115.0	CASING	15.5	16.0	STEEL
0.0	189.0	BOREHOLE	14.8		
0.0	188.0	CASING	12.0	12.6	STEEL
189.0	239.0	OPEN HOLE	11.0		
150.0	163.0	ANNULAR FILL			CEMENT
165.0	225.0	LINER	8.0	8.6	STEEL
163.0	163.0	ATTACHMENT			SHALE TRAP
168.0	168.0	ATTACHMENT			SHALE TRAP

Top of Casing: 2.0 ft above ground

Figure 13. Bru 92-3 production well completed July 11, 2021 at a quarry south west of Vivian. *Illustration by D.M. LeNeveu was based on the well information report received from Manitoba Groundwater shown on right. Photograph of well Bru 92-3 was reproduced with permission of photographer.*

In the Remarks field of the Bru 92-3 well information report shown in figure 13 the this statement was entered;

“*THREADED PIPE (REMOVABLE) STUCK IN SANDSTONE*”

This remark explains why the central steel liner appears to be unsupported in the illustration in figure 13.

Sio Silica in response to clarification information requests has stated that the threaded stuck pipe was the removable production pipe that had a failure at the connection thread. Sio Silica stated;

“*Bru 92-3 has a stuck production pipe left in it. It broke during extraction at approximately 165 ft down (TOF 166.5’).*”

The remainder of the production pipe extends to 225 feet, 14 feet above the bottom of the hole. To extract sand below 225 feet the moveable air tube would have likely been extended below the production pipe injecting air directly into the aquifer providing evidence that the aquifer would be thoroughly saturated with air and that oxidizing conditions would prevail. As described in the Sio Silica patent, the air injection tube could be extended below the production tube to loosen and mobilize the sand.[1] The air injection would be pulsed as described in the patent. Gaseous air would move upward into the carbonate aquifer establishing oxidizing conditions in the carbonate as well. The pulsed extraction of sand into the dewatering tank was observed at the quarry by local citizens.

It appears that in the Bru 92-2 airlift well, the steel liner, likely used in construction and airlifting to prevent sand collapse, was successfully removed.

The broken production pipe illustrates that many problems could occur in the installation and removal of the production pipes during operation. The Bru 92-3 well design does not conform to the design for extraction wells given in the Sio Silica EAP

Bru 92-3 like Bru 92-2 has an open outer annular region from the surface directly into the carbonate. The top of the outer casing is at ground level. Any run-off or snow melt would enter the annular region and could carry surface contamination directly into the carbonate aquifer. The shale trap at the top of the annular space of Bru 92-2 is not present in the well information report for Bru 92-3. The annular region appears to be unsealed and vulnerable to surface contamination in Bru 92-3. The picture of Bru 92-3 shows a cloth skirt duct taped onto the inner casing that extends above ground surface. The skirt extends downward mostly obscuring the open outer casing. Flanges attached to the inner casing rest on top of the outer casing. The chains looping through the flanges secure well Bru 92-3 against well tampering. For a well that has been left unsealed, opening directly to the carbonate aquifer, tamper protection would seem rather superfluous.

The Groundwater and Water Well Act (C.C.S.M. c. G110) Well Standards Regulation December 21, 2015 states;

"***Surface seal required for annular space***
31(1) Subject to subsection 30(3) and except as provided in sections 32 and 33, grout must be used to seal the upper annular space of a well as follows: (b) if the depth of the well casing is greater than 6 m (20 ft), the annular space above 6 m must be filled continuously to the established ground surface."

Well Bru 92-3 clearly violates the regulation 31(1). Well Bru 92-2 has a temporary shale trap seal at top of the annular space. Bru 92-2 also violates the regulation that the space above 6 m must be filled continuously with grout to the established ground surface.

Sio Silica has clearly violated regulation 31(1) for wells Bru 92-3 and Bru 92-2. The open annular spaces for Bru 92-3 and Bru 92-2 connect directly into the carbonate aquifer allowing any surface contamination and fecal matter to enter into the carbonate aquifer. If this has occurred in a small number of test extraction wells it is very likely to occur repeatedly in production when over 300 wells are to be drilled per year.

4 Evidence that the combined Sio Silica re-injection and extraction well design is not functional

Could it be that the investigations from the triple tube air lift extraction wells at Centre Line Road in 2018 showed water return by gravity feed was not possible? Without an injection permit Sio Silica could not have legitimately tested the EAP design in the wells at the Center Line Road site in 2018. The only well where gravity feed water return could have been tested with an injection permit is well Bru 92-8 in 2021. Sio Silica gives only verbal assurance that well Bru 92-8 was able to accept all the water extracted with the sand in well Bru 92-8 and no evidence that gravity fed would be viable during production with may operational wells being closed and opened with inherent system delays in the dewatering station, UV filtration and any possible water de-aeration procedures. Pressurized injection of waste water and produced water from oil and gas wells into saline aquifers is common in Western Canada.[131] Sio Silica has not documented any example of gravity fed injection of process waste water. Further evidence is provided below that re-injection would establish a water curtain next to the well interfering with sand uptake such that water is simply being re-circulated during injection and withdrawal.

4.1 Re- Injected water interferes with sand extraction

The Sio Silica patent describes how re-injected water would move downward in the extraction cavity (void) enveloping the extraction tube and being drawn in at the bottom of the production tube.[1] This recycling of re-injected water would form a barrier diluting sand being drawn into the production tube as illustrated in figure 14 reproduced from the Sio Silica patent description.[1]

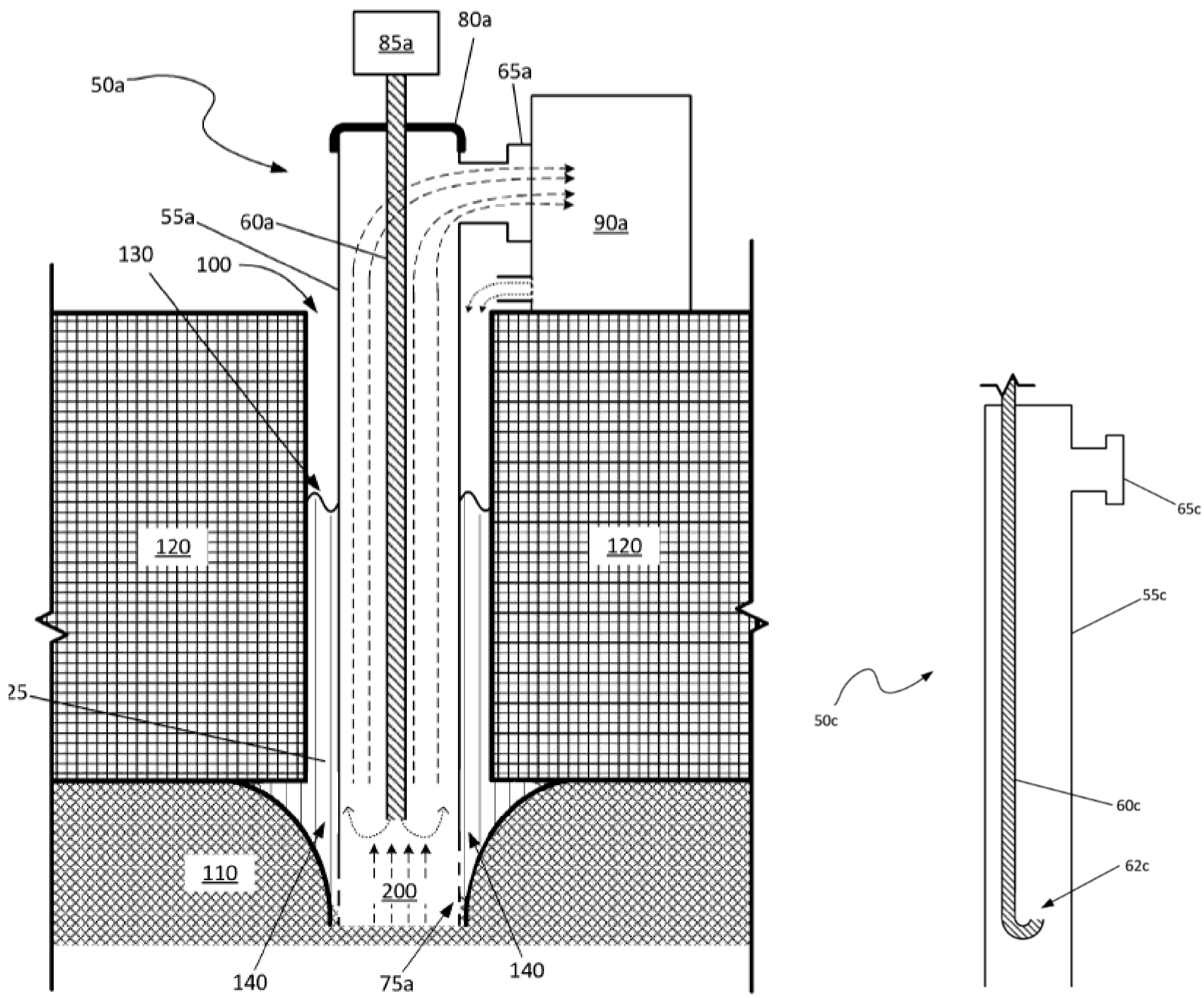


Figure 14. Drawing from Sio Silica airlift patent application.
Drawing was reproduced from the Sio Silica patent.[1]

Figure 14 shows the water barrier “140” formed from re-injected water around the withdrawal well inhibiting sand removal. The height of the re-injected water column labelled “130” in figure 14 is maintained to provide re-injection pressure.

The Sio Silica patent states;

“*In the present example a void 140 is formed and filled with water. It is to be appreciated as the void forms **and sand moves away from the perforated wall** 75a, the advantages of the perforated wall 75a are negated since the water may pass through the perforated wall. However in some examples the conduit 55a may be extended to maintain the perforated wall 75a below the sand to continue to receive the advantages of the perforated wall. Alternatively, the gas injection line 60a may be used to generate a pressure vibration or pulse air to agitate the sand such that the void 140 is partially filled by the settling of the sandstone formation 110a to cover the perforated wall 75a*.”

It must be appreciated that the interference of the re-injected water with sand extraction is a vicious cycle. As more and more water is extracted than sand, the injection rate of water must be increased. The increased water re-injection rate would act as more of a barrier to sand extraction. The water to sand ratio would keep increasing requiring ever larger water re-injection rates. The patent describes how injection of air directly into the sandstone could be used to alleviate the barrier to extraction of sand formed by the re-injected water. Sio Silica has not disclosed measurements of the sand to water ratio for any of their advanced exploration sand extraction operations.

Figure 14 illustrates that there will be a drawdown of the water level in the outer annulus used to return water caused by the suction of the air lift. The height of water in a tank or vessel at the surface draining returned water into the aquifer will provide a gravity pressure head helping to move water into the aquifer. This would be similar to the gravity pressure head forcing water down the drain in a bathtub from the height of water in the tub. It has not been demonstrated during production with many extraction wells operating simultaneously that a gravity fed water return would be able to keep pace with the amount of water withdrawn with the sand. Sio Silica has refused to measure the pressure from water re-injection that is a requirement of the injection well permit stating that no pressure is used to force the returned water into the aquifer. The height of returned water in a surface tank above the drawdown level in the outer annuls however would provide a pressure that would be manifest in the aquifer.

4.2 Modelling of the re-injection of water with an Analytical Solution from Carslaw and Jaeger

A heat conduction solution from section 14.9 of Conduction of Heat in Solids by Carslaw and Jaeger (C&J) has been implemented to further examine this issue.[43,77] The C&J solution is a Green’s function for instantaneous point sources or sinks in a three dimensional semi–infinite medium. The finite surface of the semi-infinite medium employs a transfer coefficient to allow movement of heat or water into a second external medium. The second medium in the application for this study would be the shale aquitard or the carbonate for a degraded aquitard. To model the no flow boundary at the bottom of the sandstone aquifer the method of images was used. An image solution with a source or sink of the same strength as pertaining to the injection and withdrawal was placed equidistant below the no flow boundary to obtain the no flow boundary condition.

The application of heat conduction equations for the modeling of groundwater flow is well established. For example the well-known Theis solution used to model well drawdown in a confined aquifer is taken from equation 10.4 (5) for a continuous line heat source (or sink) in Carslaw and Jaeger.[44,90,77] The details of the C&J solution and extensive modelling using this solution are given in further documentation. The results from the C&J solution are shown in figure 16 for three combined injection and extraction wells operating simultaneously in the well cluster configuration described in the Sio Silica EAP. Sio Silica revised the extraction design on Jun.3, 2023 and again on Jan. 24, 2023. The latest extraction design does not give the width of the cluster openings and cluster separation and varies the number of wells per cluster from one to five depending on an unspecified method that takes into account limestone and overburden thickness. The original well cluster layout from the EAP is reproduced in figure 15. No revised cluster layout has yet been provided by Sio Silica.

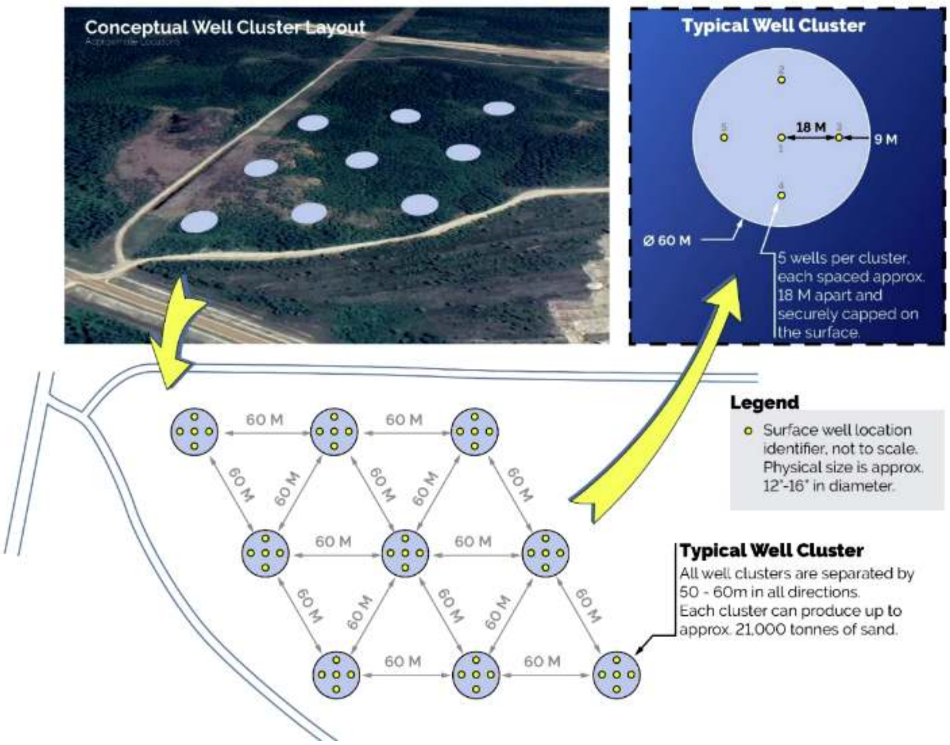


Figure 15. Sio Silica Conceptual well cluster layout Sio Silica Supplemental Information June 2, 2022. *Illustration was reproduced from Sio Silica Sio Silica Supplemental Information June 2, 2022 .*

Figure 16 illustrates the head change from the re-injection and withdrawal of water for three production wells after one day of pumping. The water flow direction is perpendicular to the head contours.

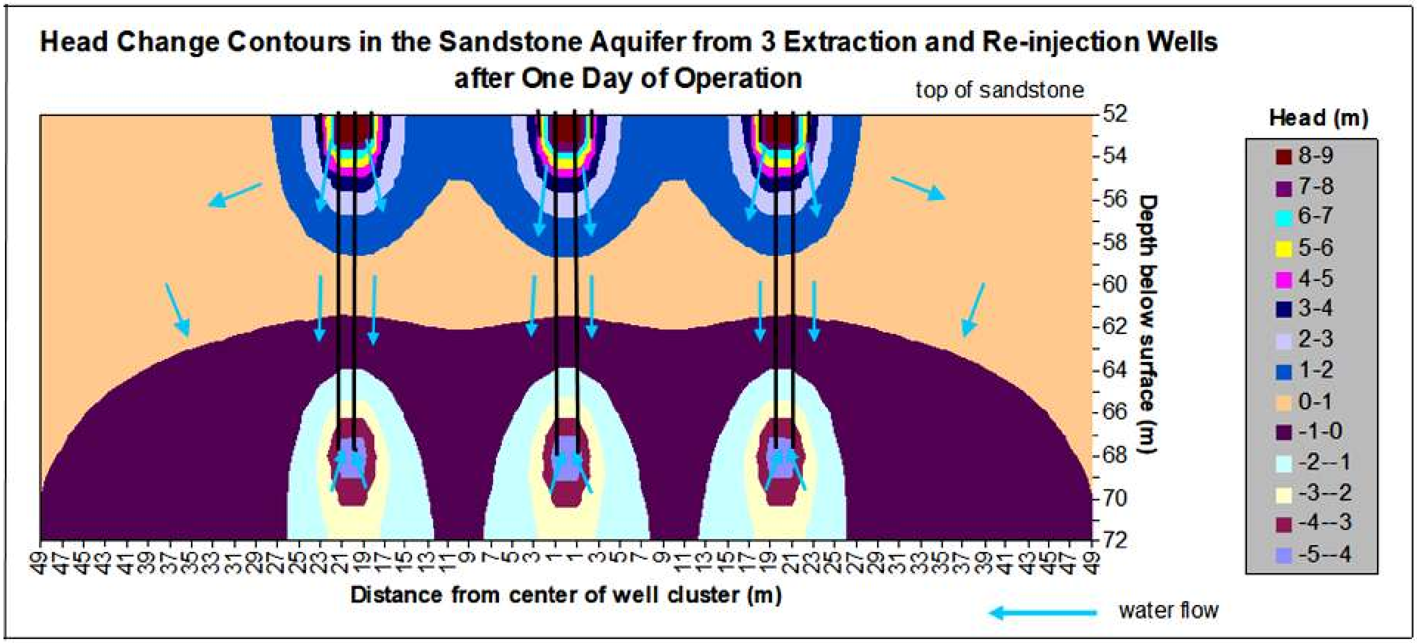


Figure 16. Head Change contours from three Sio Silica extraction wells after one day of operation. *Illustration from simulations by D.M. LeNeveu.*

For use in the three dimensional C&J solution the storativity and transmissivity from the Theis solution were divided by the aquifer thickness of 20.14 meters as specified for the models used in the Sio Silica study. The model parameter values for the C&J solution for three extraction wells are given in table 2. The transfer coefficient was set to zero to model an intact aquitard. Further modeling studies with the C&J solution use parameter values obtained by fitting to the measured head drawdown values given in the Sio Silica Hydrogeological study. Various values of the transfer coefficient have been used to model aquitard degradation where transfer of re-injected water into the carbonate would occur.

Table 2. Representative sandstone parameter values for the C&J solution for three Sio Silica re-injection wells

Storage coefficient m^{-1}	$6.0x10^{-6}$
Hydraulic conductivity m/s	$4.8x10^{-5}$
Water withdrawal rate per well m^3/s	$4.21\ x10^{-3}$
Water re-injection rate per well m^3/s	$4.12x10^{-3}$
Depth of re-injection in the sandstone (m)	1.0
Depth of withdrawal in the sandstone (m)	16.0
Thickness of sandstone aquifer (m)	20.14
Transfer coefficient (m^{-1})	0

The water re-injection rate was determined from the target production rate of 21000 tonnes of sand per cluster specified in the extraction EAP. With seven extraction wells per cluster 3000 tonnes of sand per extraction well are required. Using a dry density of sand of 1.65 tonnes per cubic meter,[99] 1818.2 cubic meters of sand would be withdrawn per well in the cluster. For five days of extraction and one to one water to sand ratio the water withdrawal rate would be $4.21\ x10^{-3}$ cubic meters per second or 66.7 US gallons per minute (gpm) for one well. The Hydrogeological study states each well would withdraw from 40 US gpm to a maximum of 120 US gpm. The water re-injection rate would be somewhat smaller than the withdrawal rate since according to the extraction EAP 10 US gpm per cluster is diverted to the slurry lines giving a re-injection rate of $4.12x10^{-3}\ m^3/s$. For this re-injection rate the head increase at one meter from the injection wells is about 9 meters as shown in figure 16. Sio Silica gives inconsistent extraction rates. The operational rate given by Sio Silica in the response to public comments is 270 US gpm. Sio Silica stated in the EAP that the sand to water ratio would vary with close to 70% sand at the start of extraction to as low as 20% sand later. Since the C&J modelling the number of extraction wells per cluster has been reduced to a maximum of five however the well injection rate used in the modelling would be representative given the uncertainty and inconsistencies in the Sio Silica stated well extraction rates. Sio Silica has not documented measured values of sand and water extraction rates. Larger water to sand ratios would give a higher increase in re-injection head increase in head manifest at the boundary with the carbonate aquifer and would result in more aerated water transferred to the carbonate following aquitard degradation. The lack of disclosure of measurements of water to sand ratios and sand extraction pumping rates carried out in advanced exploration activities is a major project deficiency.

The head gradients are largest next to the production tube thus the re-injected water concentrates around the tube as shown in figure 16. Results from the C&J solution verifies the description in the Sio Silica patent that the re-circulation of the re-injected water acts as a barrier to sand uptake.

In response to public comment Sio Silica stated in the project registry;

"*No pressure is applied to the well or the formation during re-injection of the water. Water is returned to the aquifer by gravity only via the wells in operation. Therefore, water returns to the aquifer passively and is not forced*."

Figure 16 shows that contrary to Sio Silica claims, pressure is exerted on the shale aquitard and the carbonate aquifer from the re-injection. It is important to understand the model input for the C&J solution is the withdrawal and injection rates not pressure. Thus pumping pressures are not required, only water injection and withdrawal rates. The positive pressure exerted by the re-injection is caused by the resistance to the movement of the injected water.

Figure 17 shows that after only three hours of operation the head change contours are virtually the same as after one day. Only a small decrease in the extent of the zero pressure head contour for three hours compared to one day of operation is visible. Steady state where re-injected water is simply being re-circulated is established very quickly. After the initial sand is extracted next to the well and a cavity (void) is formed around the well further uptake of sand is inhibited in less than 3 hours into operation.

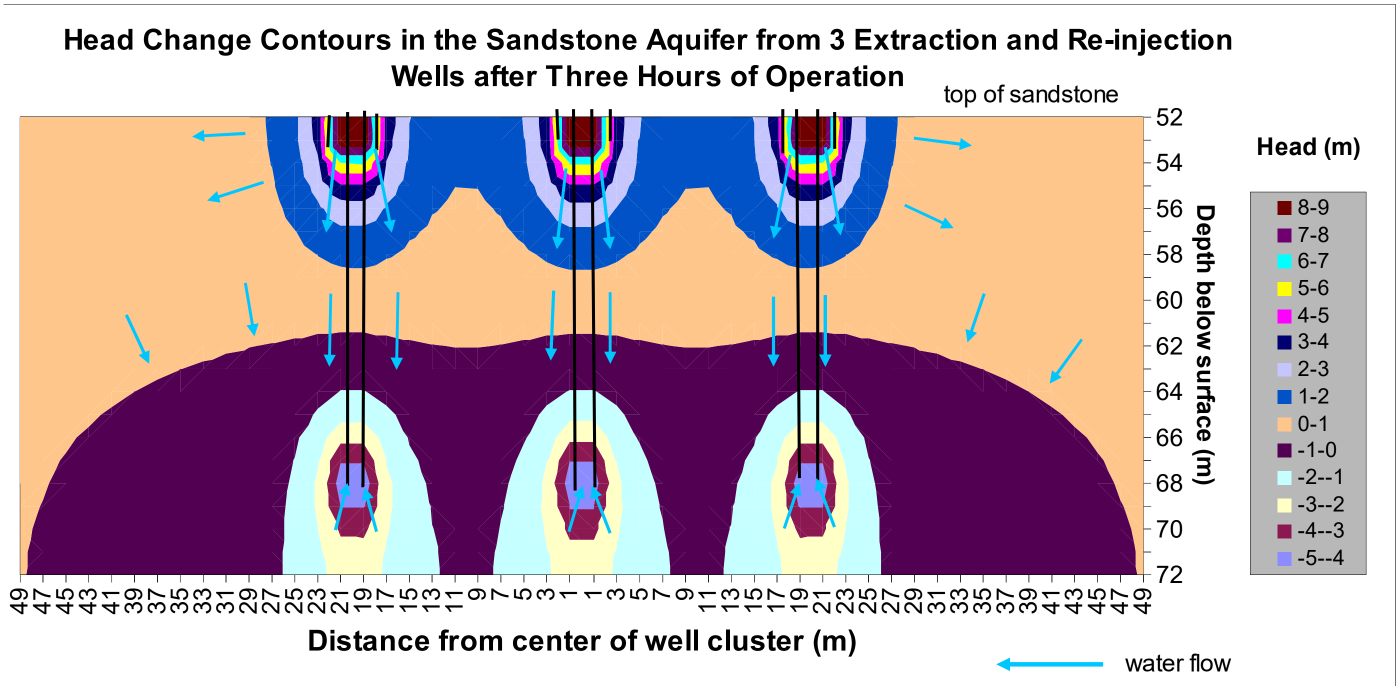


Figure 17. Head Change contours from three Sio Silica extraction wells after three hours of operation. *Source: simulations by D. M. LeNeveu.*

In the Sio Silica Hydrogeological Report only drawdown was measured and modeled. A modeled 50% re-injection scenario was done by simply reducing the pumping rate as shown by the following excerpt from the Hydrogeological report;

- "*Scenario 1 (0% re-injection): Pumping Rate = 2,998 m3/day (550 US GPM)*
- *Scenario 2 (50% re-injection): Pumping Rate = 1,526 m3/day (280 US GPM)*"

No re-injection occurred. The hydrogeological study concentrated on demonstrating drawdown from Sio Silica send extraction would not be detrimental. The study did not evaluate the effect of re-injection that could pressurize the sandstone aquifer driving contaminated water into the carbonate. This was either a deliberate deception or a gross oversight. Re-injection of water extracted with the sand is an essential process in the Sio Silica operation that can lead to detrimental effects. An example of detriment has already occurred at the Centre Line Road site where re-injection could be attributed to brown water at a nearby residential well.

The aquitard may not degrade immediately but would likely be fully degraded as cluster extraction continued permitting water from the re-injection to enter the sandstone. The C&J modelling illustrates that rather than downward hydraulic gradients that may temporarily draw water away from local wells during production as claimed by the Sio Silica modelling, when re-injection is considered, a positive pressure upward pressure would be created that would push water into the carbonate. This upward hydraulic pressure would occur simply because the re-injection of water would occur much closer to the carbonate than the withdrawal lower down in the sandstone. The C&J modelling demonstrates the Sio Silica modelling and Hydrogeological pumping tests where only water withdrawal occurred with no re-injection are misleading and of no value in determining the actual production conditions.

From the evidence presented here, the Sio Silica design for gravity fed water return to the aquifer simply does not work. Sio Silica gives no evidence that gravity feed water return has ever been used and established before. Sio Silica has claimed to have tested this unproven method in only one well Bru 92-8 and has given only assurances that this test was successful with no measured data. The evidence given here demonstrates Sio Silica has promulgated a design for gravity fed water return that is not viable. The evidence presented here demonstrates aerated water from re-injection would be forced into the carbonate, the opposite of what Sio Silica modelling and hydrogeological study that neglected water re-injection concluded.

5 Temporary Authorization Permits to Divert Water

Water extracted with the sand was returned to the aquifer only for well Bru 92-8 in 2021. Up to this time temporary authorization permits were issued for diversion of water by Sio Silica beginning in 2017 at many locations throughout the project area. The well complaint report quotes an email for the Manitoba Drainage and Water Licensing Water Branch dated Jan.19, 2020 that stated;

"*I can confirm that HD Minerals Ltd./CanWhite Sands has submitted 16 requests for Temporary Authorizations in order to complete a borehole and hydrogeological testing program as part of their mineral claims in various areas throughout the province since 2017. The Temporary Authorizations (not Water Rights Licenses) provided permission to drill exploration wells and conduct short-term pump testing. Authorizations were issued for time frames of several weeks to several months. Pumping rates ranged from 350 USgpm to 1500 USgpm. Only two (2) of these authorizations remain active and the remaining fourteen (14) are completed and have expired.*"

In all the temporary authorization permits the actual location of the diverted water was not specified. The well names, property owners, locations, rate, date and volume of water withdrawal for each well were not recorded. In response to a freedom of information request I was sent hard copies of temporary authorizations (TA) given to Sio Silica where for the most part the request from Sio Silica was simply echoed back with a signature from Water Licensing. It was noted in response to the request that some information had not been included to protect third party privacy. Whatever Sio Silica reported in the request was authorized with no additional requirements for information as to the well locations, property owners, or locations and dates of the water diversion. There appeared to be no electronic records or systematic record keeping of the TA's. This lack of record keeping, technical capability and oversight by the Manitoba Drainage and Water Rights Licensing Branch was documented by the Manitoba Ombudsman in a report in 2008.[97] It appears nothing has changed since then.

Sio Silica should be required to disclose the information of the water diversion in the TA's for the CEC hearings. This information should have been obtained by the Manitoba Drainage and Water Licensing Water Branch as part of issuance of the temporary authorization permits. The conditions of the authorization permits detailed above were left to Sio Silica to self regulate. A summary of most of the TAs issued to Sio Silica since 2017 is given in Table 3. In column four to the number of people who would consume the total amount of diverted water in 100 days based on average usage per person is given to provide perspective. The total amount withdrawn is also given.

Table 3. Summary of the information in the temporary authorization letters from Manitoba Drainage and Water Rights Licensing Branch.

Start Date	Expiry Date	Locations	Total allowed withdrawal (cubic	Maximum Withdrawal rate (Litres per	Number of boreholes

			meters/ (persons for100days))	minute/USGPM)	
June 13, 2017	Dec. 31, 2017	NE 19&24-10-8E, SW 27,18&7-10-8E	1365/41	378.5/100	5
June 13, 2017	Dec. 31, 2017	Extended to SE 18, SW 19 and NW 17-10-8 E and SW 14 and NE 15-10-7E	1365/41	378.5/100	Not given
Aug.4, 2017	Dec.13, 2017	NE 19&24 10-8E SW27,18 and 7-10-8E,SE18,SW19 and NW 17-10-8E and SW and NE 15-10-7E	Same as above	Same as above	Not given
May 3, 2018	May 3, 2019	Same as above	Same as above	Same as above	Not given
June 21, 2018	May 3, 2019	SE29-10-8E W1/2 29-10-8E	Same as above	Same as above	Not given
Oct.9, 2018	Apr. 30, 2019	La Broquerie (locations not given)	54,000/1641	3785.41/1000	9
March 26, 2019	Sept.30, 2019	S1/2 32-10-8E	24,000/729	3785.41/1000	4
April 11, 2019	Sept.30, 2019	Same as above	Same as above	5678.12/1500	Not given
May 21,2019	June 30, 2019	SW19-10-8E	182/5	3028.3/800	Not given
Aug. 16, 2019	Sept.30, 2019	SW19-10-8E	23,000/699	2650/700	5
Feb.20,2020	Aug.31, 2020	SW5-11-8E Q	25,000/760	2271.25/600	7
June 18,2020	Oct. 31, 2020	SE 32-10-8E	25,000/760	2271.25/600	3
Oct.5,2020	Apr. 30, 2021	SW5-11-8E Q	3,800/116	1514.16/400	2

The Temporary Authorizations require that Sio Silica correct any water supply problems or provide temporary water supply to anyone whose well(s) are negatively impacted as a result of pumping. Q indicates quarry near Vivian outside the Sio Silica mineral claim area. *Data was taken from information from the Manitoba Drainage and Water Rights Licensing Branch sent to fulfil a freedom of information request.*

The Nov. 5, 2020 Authorization for HD Minerals Ltd. to Divert and Use Groundwater for Testing and Analysis as Part of the Company's Hydrogeological Study for SW 32-10-8 EPM, and SW 33-10-8 EPM, posted Appendix A part 4 of the Hydrogeological study states,

"*The total amount of water that may be pumped from the well for testing and analysis is not to exceed 16,500 cubic metres (16,500,000 litres)*."

The Hydrogeological report states;

"*A total of approximately 6,880 m3 (1,818,700 US gallons) of groundwater was pumped from the aquifer over the duration of the step test and constant-rate pumping test, which is approximately 42% of the approved volume of 16,500 m3 (4,358,839 US gallons) under the authorization to divert and use water*"

This large amount of aerated water discharged to the land surface could have infiltrated into the aquifer.

The lack of oversight displayed in the discharge of water by Sio Silica over this long period from 2017 must be considered by the Hearing with respect to the oversight that would be exercised for the return of water to the aquifer and any disposal of process water and process waste from the Sio Silica extraction operations.

6 Requirements of the injection well permits

The injection well permits require that the injection pressure be measured in carbonate aquifer to ensure the injection formation is not over pressurized. Figure 18 gives the terms of the injection permit for Bru 92-8.

Sustainable Development

Water Science and Watershed Management Branch

Injection Well Permit

Pursuant to The Groundwater and Water Well Act PERMIT#: IW-2019.01.1

HD Minerals, Suite 2650 645 7th Ave. SW Calgary, AB

is hereby permitted to construct an injection well on the following described land, SW 19-10-08 E1 subject to the following conditions:

1. The permittee must have legal access to the site where the injection well is to be located.
2. This Authorization is not transferable or assignable to any other party.
3. The injection water will originate from the same strata as the injection zone.
4. The injection water will not contain any substances that will degrade the quality of the water in the receiving zone.
5. The injection well will be constructed with all annular space above the Winnipeg Formation sandstone fully tremie grouted with cement.
6. The injection well construction must be such that it completely hydraulically isolates the overlying carbonate aquifer from the Winnipeg Formation.
7. Continuous measurement of the water pressure in the carbonate aquifer must be conducted through the entire injection test and during any recovery to monitor the isolation between the Winnipeg sandstone aquifer and the overlying carbonate aquifer. The test must cease if breakthrough is evident in the monitoring.
8. The injection well will be continuously monitored to ensure the injection formation is not over-pressured.
9. The injection well must be sealed in full compliance with the Groundwater and Water Well Act Well Standards Regulation after testing is complete and within twelve (12) months of the issuance of this permit.
10. If the permittee has not commenced construction of the injection well within three (3) months of the issuance of this permit, the permit is revoked.

Figure 18. Permit 2021.01.1 for the single purpose injection well Bru 92-8 at a quarry southwest of Vivian. *Reproduced from information from Manitoba Sustainable Development*

Note condition 6 requires that the well must be sealed so that no injected water from the sandstone could enter the carbonate aquifer. Condition 5 requires the annular space of the well be fully grouted with cement above the Winnipeg Formation. The Groundwater and Water Well Act Wells Standard regulations define annular space as;[54]

“"annular space" means an open space between a casing or well screen and the hole used to construct the well, and includes space between overlapping casings within the well.”

Condition 5 therefore prohibits the EAP design for re-injection occurring in the overlapping cased annular region that extends into the Winnipeg Formation sandstone. During the time between installation of the outer annular casing and the time of sand extraction and return of water the outer annulus would remain open and endanger of being a conduit for surface contamination to enter the sandstone aquifer during rainfall or overland flooding events or other occurrences. Sio Silica has stated that the annular space is open such that excess returned water would spill on the surface implying that excess surface water or rainfall could enter the annular space. In regions of flowing wells sandstone aquifer water would overflow onto the ground surface through this outer annular space. Problematic issues regarding the open outer annulus during well operations have not been considered by Sio Silica.

Sio Silica was required to monitor the injection pressure. Sio Silica must disclose the measured injection pressures in all the injection wells implemented during advanced exploration at the CEC hearings.

In response to public comments in the project registry 6119.00 Sio Silica states;

“*borehole mining was ultimately not selected for this project due to the high volumes of injected water and injection pressure that would be required, which could impact the aquifer*.”

If all the Sio Silica permitted borehole injection wells were standalone injection wells of the kind used in borehole mining, these injection wells by Sio Silica own admission would require high pressure that could impact the aquifer.

The injection permit requires that the injection well must be continuously monitored to ensure injection formation is not over-pressurized. Manitoba Groundwater has not specified the maximum pressure allowed. Sio Silica replied to information requests that the requirement of the injection well permit for measurement of the formation water pressure during injection is not required since no pressure was applied during the gravity feed water return. Sio Silica cannot unilaterally decide to ignore requirements of a permit.

Well information reports from Manitoba Groundwater show Sio Silica completed a monitoring well Bru 92-4 opening into the sandstone aquifer near the injection well Bru 92-8. Sio Silica must submit any pressure data from this well. If in fact the gravity feed method produces no pressure, the pressure measurements would verify this. It is in Sio Silica’s interest to produce the pressure data during water return to the aquifer if gravity feed in fact produces no excess pressure. The Hearing must require Sio Silica to produce the pressure data as required by the injection well permit. A precedent must not be set that a proponent can simply ignore permit requirements. If Sio Silica continues to refuses to submit the pressure data from Bru 92-4, I request that the Panel subpoena this data. If no pressure data exists for gravity feed return of water tests must be done to provide this data.

7 Collapse of the Shale Aquitard

The most vulnerable formation is the shale aquitard. The hydrogeological study states;

“*The Winnipeg Shale is inferred to be considerably weathered and assumed to degrade (increased hydraulic conductivity) in Scenarios 1 and 2 when locally disturbed/unsupported from below due to extraction of the Winnipeg Sandstone.*”

One of the pathways for impact on the groundwater stated in the hydrogeological study is;

"*Degradation of the Winnipeg Shale as a result of project operations resulting in mixing of groundwaters of the Winnipeg Sandstone and Red River Carbonate with possible impacts on groundwater quality in one or more of the aquifers*."

The shale would experience a shear force due to the movement of water from the radial pressure gradient caused injection.[45,50] The shear, S is given by,

$$S = c' + (\sigma - p)\tan\phi' ,$$

where p is the pore pressure, c' is the modified cohesion, σ is the stress normal to the surface and ϕ' is the modified angle friction that must be determined under saturated conditions for the appropriate overburden pressure.[44,50]

The increase in pore pressure from injection would decrease the effective normal stress (σ - p) on the shale and decrease the modified friction angle and cohesion decreasing the shear strength. Shale is subject to slaking caused by changes in pore pressure.[45 50,51] The limestone over the cavity up to the point of collapse would be self-supporting thus the only normal stress on the shale would be the pore pressure (σ - p) would be zero or very small such that the shear strength would likely only be determined by the modified cohesion. The insertion of well casings and shale sealing would induce stresses that would affect the shale stability. All these effects must be quantified to determine the allowable injection pressure.

Shale fragments have been observed in the extracted sand piles at Vivian as shown in figure 19 verifying that the shale will not survive the Sio Silica extraction. Figure 19 shows that the shale is so fragile it can be crushed by hand pressure. The implementation of shale traps in many Sio Silica wells also illustrates that the shale easily crumbles.

Figure 19. Shale collected by concerned citizens near Vivian from Sio Silica extracted sand piles, spring 2020.
Images used with photographer's permission.

In the Hydrogeological Report Sio Silica acknowledges that mixing of aquifer waters may occur from degradation of the shale thereby confirming the evidence presented here.

The disintegration of the shale aquitard into the excavation cavity and subsequent mixing of aquifer waters is not addressed by the statement by Sio Silica in the response to public comments;

"*Proper sealing of extraction wells will prevent any mixing of water between aquifers. CanWhite's extraction wells will be sealed across the shale layer*."

Sio Silica is required by the injection permits to measure injection pressure, to determine if the injection formation is over-pressurized and to cease operation if breakthrough to the carbonate occurs. Sio Silica has not disclosed this required injection monitoring information. There is no documentation in the extraction EAP of the data measurements and shale stability determinations.

The geotechnical engineers of Stantec stated in Table 1 of their report in the response to public comments section of the extraction EAP that the shale aquitard is not supporting. Thus the geotechnical engineering study does give evidence that the shale aquitard is not a supporting member and therefore would be subject to collapse. The Arcadis third party technical review stated, "*Based on the geotechnical information presented, as well as technical discussions with Sio Silica (6 September 2022) it is understood by Arcadis that the shale aquitard has the potential to collapse into the sand extraction*." Arcadis conclusion#5 identifies shale aquitard collapse as a critical failure mode. I assert there is conclusive evidence from geotechnical experts including Stantec and Arcadis that shale collapse would occur.

The evidence presented here demonstrates that the protective shale layer separating the aquifers will be compromised by Sio Silica extraction. This evidence demonstrates that prohibited mixing of aquifer waters will occur in the Sio Silica extraction clusters through the degraded shale aquitard. For this reason alone the Sio Silica sand extraction is not viable and must be stopped.

Sio Silica should have publicly disclosed the monitoring data collected during injection in the EAP submitted for extraction. No actual injection of water occurred in the Hydrogeological study. Sio Silica was not issued an injection permit for the pumping that occurred for the Hydrogeological study but only a temporary authorization from Manitoba Drainage and Water Rights Licensing Branch to divert groundwater. Sio Silica has not documented in any form the re-injection of groundwater that would occur should this project be allowed to proceed and will not disclose the monitoring data collected during the actual re-injection that did occur during sand extraction in their advanced exploration activities.

From the evidence presented here Sio Silica would introduce large amounts of entrained and dissolved air in the water re-injected into the sandstone aquifer. Direct air injection used to loosen sand as described in the Sio Silica air lift well patent could introduce of the order of 18 million cubic meters of air per year into the aquifer in pulses used to loosen sand. The Sio Silica extraction activities will change the groundwater conditions in and around extraction clusters resulting in a whole-scale change in geochemical conditions from reducing[98] to oxidizing that will results in contamination of the aquifer with acid, heavy metals, fluoride, selenium, iron, manganese, iron bacteria and other microbes.

The evidence presented here makes a mockery of the Sio Silica statement in the response to public comments;

"*Geochemical modelling conservatively accounted for the exposure of minerals naturally occurring in the aquifer to an unlimited supply of oxygen (EAP, Appendix A). In reality, under actual conditions, the materials will remain in the water-saturated subsurface conditions and the concentrations of oxygen therefore will be much lower than simulated by the model. Thus, there was no need to calculate actual dissolved oxygen concentrations*."

The evidence provided here completely refutes the Sio Silica claim made by F. Somji, CEO of Sio Silica, in a letter to the Impact Assessment Agency of Canada (IAAC)[60] documented in the Vivian Sio Silica Processing Plant Project public registry 5029.00, that air injected for extraction remains in the production tube.

Sio Silica has not disclosed any monitoring data on the actual re-injection of water into the sandstone aquifer. The hydrogeological study was a deliberately misleading drawdown study and modelling exercise that gives no direct information on the critical re-injection of water into the aquifer. Sio Silica is deliberately not disclosing essential information on the re-injection of water that pertains to the detriment that could be caused by re-injection of aquifer water.

The collapse of the shale aquitard would result in mixing of aquifer waters that is disallowed by Manitoba groundwater regulations. Sio Silica justifies breaking the regulations through a PHREEQC equilibrium chemistry study in Appendix A of the EAP that shows iron and manganese concentrations would decrease. This claim is shown to be false in the sections below. Oxidizing conditions would lead to serious detriment in both the carbonate and sandstone aquifers. Sio Silica cannot be allowed to unilaterally contravene Manitoba groundwater regulations with false claims about the benefits of the mixing of aquifer waters.

7.1 Mixing of aquifer waters - Manganese and Iron – oxidizing conditions in the sandstone

The Sio Silica extraction EAP reports the results of the geochemical modeling software PHREEQC for the oxidizing conditions and mixing of aquifer water that could occur due to re-injection of aerated water. Sio Silica reports that there could be a reduction in the concentration of iron and manganese in the aquifer waters due to oxidizing conditions and portrays this decrease as beneficial. Sio Silica ignores the regulations that prohibit mixing of aquifer waters. Dr. E. Pip in her public comment submission to registry 6119.00 points out that iron and manganese reduction in concentration is caused by precipitation of iron and manganese under oxidizing conditions. Precipitation of iron and manganese causing discoloration and degradation of water quality is well known.[16] Iron bacteria that can thrive under the newly introduced oxidizing conditions can cause slime and clogging of wells and plumbing.[17] In response to public comments Sio Silica states;

"*Chemical reactions between iron, manganese and oxygen would produce less soluble mineral precipitates, which generally will attach to local substrate or will be filtered out of the water by the sandstone and not result in discoloration of water used by domestic well users*."

As usual Sio Silica does not provide any support or evidence for this statement. A report on the potential use of quartz sand to remove manganese states,

"*The quartz sand could adsorb manganese but easily became saturated*."[16]

A greensand filter using glauconite and sand can be used to remove iron and manganese.[16,17] The sandstone aquifer does not contain glauconite. The evidence presented here shows the aquifer sand will not effectively absorb manganese and iron precipitates. There will be deterioration of water quality from iron and manganese precipitation.

Iron bacteria and other potential detrimental organisms as documented the submission by Dr. E. Pip that would thrive under the introduced oxidizing conditions would enter the aquifer by multiple routes especially through the Sio Silica drilling, well casings and air injection.[19,78]The Sio Silica proposed deactivation of microorganisms by UV light would not prevent proliferation of iron bacteria and other microorganisms introduced by Sio Silica drilling and air injection. Manitoba well standards regulations do require use of chlorine during well drilling for disinfection. It is very unlikely that such disinfection could totally prevent introduction of iron bacteria for the over 320 Sio Silica wells planned per year.[19] Microbes would be introduced by the compressed air through the airlift air tube. The Sio Silica dismissal of the detrimental effect of oxidizing conditions and associated iron bacteria and other organisms is not credible and not supported by any evidence. Sio Silica drilling activities and air injection would contaminate both aquifers with iron bacteria and other detrimental microorganisms that would thrive in the aerobic environment caused by Sio Silica re-injection of water with entrained and dissolved air and by direct injection of air into the aquifer. The evidence submitted here refutes the Sio Silica dismissal of the detriment of oxidizing conditions created by Sio Silica extraction operations.

7.2 Pyrite and marcasite in the sand, concretions and oolite

Sio Silica in their response to public comments documented on the project registry 6119.00 finally admits the presence of pyritic oolite and concretions in the sandstone formation. Sio Silica states in response to public comments;

"*Oolites and concretions comprise a very small proportion (<5%) of the overall sandstone aquifer. Oolites are commonly composed of calcium carbonate and are not likely to negatively influence water quality. Due to their relatively large spherical shape, the oolites and concretions are likely to have a low reactivity in the subsurface. Some of these materials were contained within the sand samples submitted for geochemical analysis*"

Up to 5% oolites and concretions is very large with respect to acid generation potential. More than 1.36 million tonnes of aquifer material would be required to produce 1.36 million tonnes of sand per year. Thus, for example, 4% of oolite and concretions in the total aquifer material extracted with the sand would generate more than 54 thousand tonnes of acid generating sulphide minerals per year. Much more sulphide is waiting in the aquifer to become oxidized by huge amount of air introduced into the formation by sand extraction.

Sio Silica gives no evidence to support that oolite and concretions found near Vivian are composed of calcium carbonate. There has been no quantification of the amount of oolite and concretions in the sand in the Sio Silica Hydrogeological report.

Watson writes in Economic Geography ER-84-2;[2]

"*The next layer is 0.5 to 1 m in thickness and is composed of sand with numerous desiccation cracks and burrows. These structures are filled with either silty sand or pyrite oolites. Oolites are typical of the next 2 m layer. The pyrite oolites have been described by Genik (1952). The layer in which they occur consists of up to 75% pyrite with lesser amounts of sand and silty material. In some other areas the oolites are limonite.*"[2]

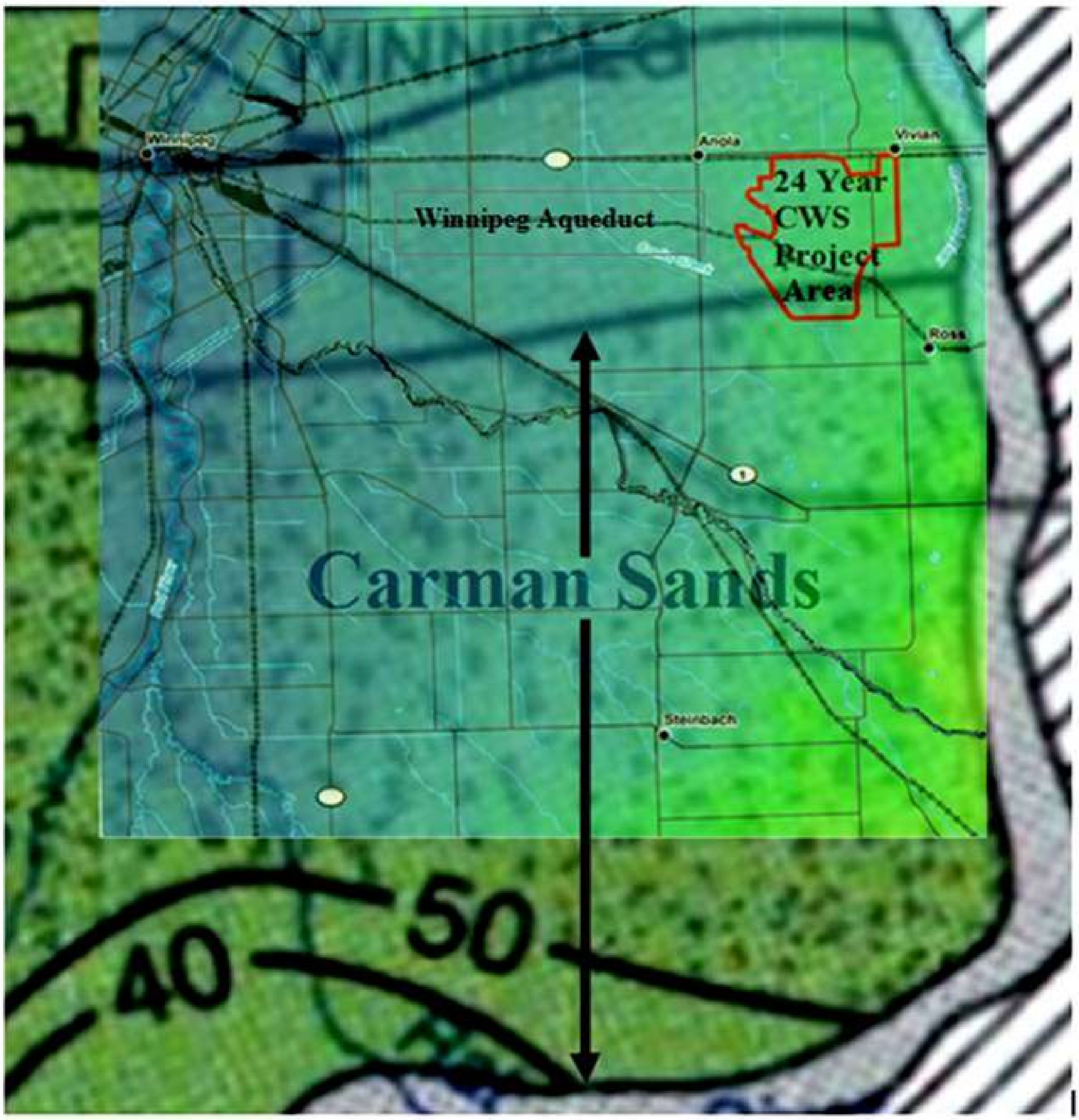
Limonite is a form of iron oxide/hydroxides not calcium carbonate.[3] The oolite in the Winnipeg formation is up to 75% pyrite with silt, sand and limonite as the remainder - not calcium carbonate.

A peer reviewed paper by Schieber and Riciputi (2005) on the diagenesis of pyrite and marcasite in the Winnipeg formation states; [20]

"*Throughout the Black Island Member I find irregular iron sulfide concretions that follow burrow trails. They consist of a mixture of pyrite and marcasite in clusters and coarse aggregates with rounded quartz grains ''floating'' in the sulfide matrix.*"

In both references the presence of calcium carbonate is not mentioned in oolite and concretions. Calcium carbonate is found in the limestone of the carbonate aquifer deposited more recently than the Winnipeg formation sandstone.[95]

The concretions at Vivian would have been formed under the same conditions as the Black Island Member. Sio Silica claims that the sand is to be extracted from the Carman sands. Sio Silica replied to key issue 8 in the response to public comments in the project registry 6119.00, that the Carman Sand does not contain marcasite. Evidence from the Manitoba compilation map series shows the Carman sands to be south of Vivian as shown in figure 20.[21,126] In any case the Ice Box and Black Island member shale mentioned in the Sio Silica response to public comments would be encountered at the bottom of the Sio Silica extraction wells as shown by the core logs reported in the Sio Silica Hydrogeological report.



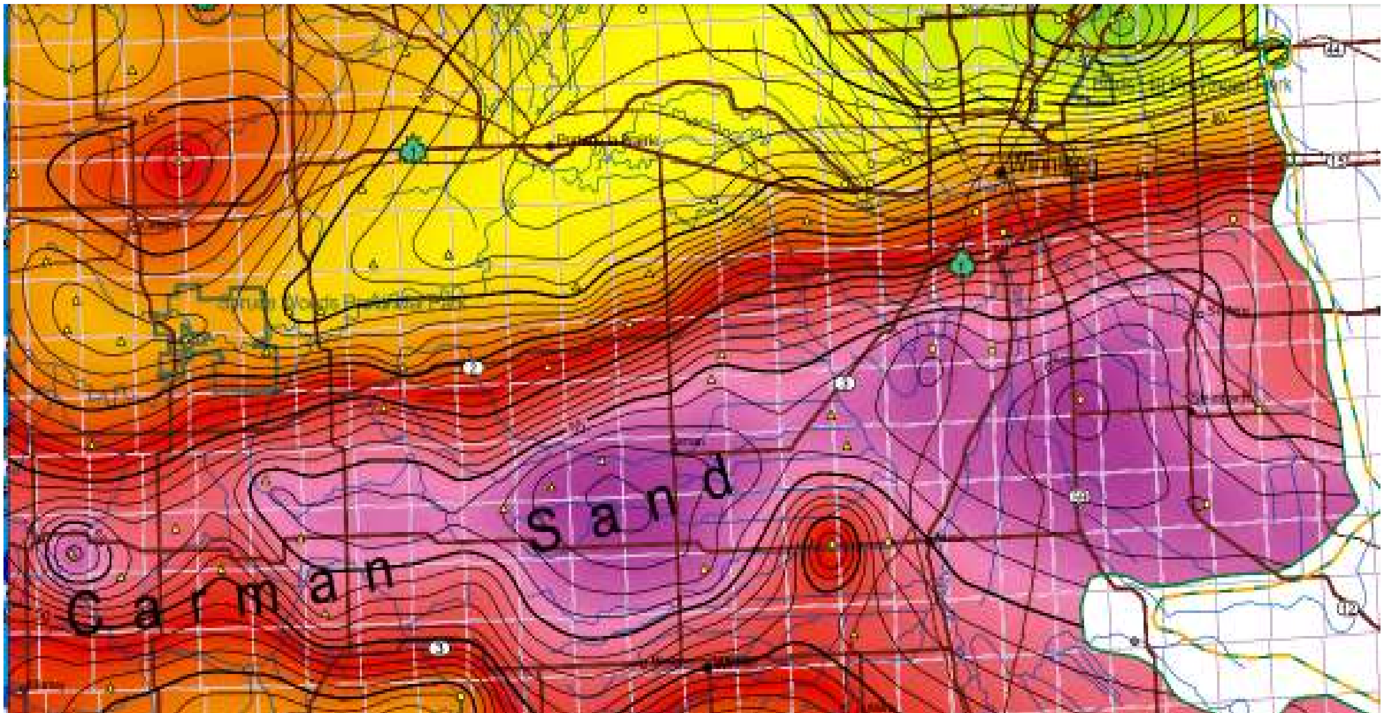


Figure 20. Extent of the Carman Sands.[21]
Project boundaries image was reproduced from the Sio Silica EAP. Overlay was created by D. M. LeNeveu. The Carman Sands Map above was reproduced from Manitoba Compilation map series.[21]The Carman Sands shown in purple on the below indicated by the 50 meter contour line was reproduced from the Manitoba Science, Technology, Energy and Mines Petroleum Ordovician Winnipeg Formation: Isopach map.[126]

The Carman sands impinge only on the very southern portion of the 24 year proposed Sio Silica extraction area as determined from the Manitoba Compilation map series and the NRC Isopach Map and illustrated in figure 20.[21,126] The evidence for the location of the Carman sands in my submission to the public comments for the Sio Silica extraction project was ignored.

In Economic Geology Report ER84·2 (1988), Watson writes:[2]

A thickened portion of the upper part of the Winnipeg sandstone near Ste. Anne was tested for possible mining by hydraulic methods. This unit, known as the Carman sand body, varies in thickness and extent. It is generally about 27 m thick and extends westward from Ste. Anne for about 240 km to Ninette. It ranges in width from 24 to 100 km. The sand in this body is similar to that in the lower Winnipeg at Black Island. It is a separate body, however, and is separated from the rest of the sand section elsewhere by shale-rich rocks. The body is probably a former offshore bar and the increased thickness of the Winnipeg section is due to the compaction of the sandstone being less than for the shale-rich sections elsewhere. In 1966, the deposit was drilled in the area east of Steinbach (Fig. 13) by Norlica Minerals Limited (Underwood McLellan and Associates Limited, 1967). The drill holes intersected silica sand intermixed with shale, with high quality sand beneath the upper sand-shale layer. The sand ranged from loose to well cemented. Various methods were tried to loosen the sand, including water jets, suction and a mechanical cutter, in order to pump it from drill holes These methods were unsuccessful largely due to the presence of hard sandstone and shale layers within the section."

This excerpt from Watson demonstrates the Carmen sands found near St. Anne Manitoba contains significant amount of shale known to contain pyrite. Thus the Carman sands have no advantage with respect to potential for acid generating material extracted with the sand.

Figure 21 shows concretions in sand extracted by Sio Silica during advanced exploration activities at the Centre Line Road site. The orange colour indicates oxidation of pyrite upon weathering and demonstrates pyritic concretions are within the sand extracted by Sio Silica.

Figure 21. Orange coloured concretions and sand extracted by Sio Silica at Centre Line Road SW of Vivian. *Images used with permission of the photographer.*

The Sio Silica Hydrogelogical report states;

"*Although the extraction process targets the removal of sand and groundwater, trace amounts of other unwanted material (referred to as "waste") could also be pumped to surface during the extraction process. This could include concretions (calcified sand), bedrock cuttings, and shale*"

The pictures in figure 21 illustrate that substantial amount of concretions are extracted with the sand.

Sio Silica admits up to 5% of the formation will contain this pyritic material. Some will be brought to the surface with the sand where it will produce acid in the dewatering tanks and get into the re-circulating slurry lines where it will accumulate.[52] Much of the acid formed and released heavy metals will be re-injected with water along with dissolved and gaseous oxygen.

The sand samples Sio Silica analyzed were taken from stockpiles that were exposed to weathering for more than a year. The weathering would have oxidized most of the sulphide. Pictures of the sand samples from Bru 95-3 in the Sio Silica Hydrogeological Report (HR) show no oolite or concretions as shown in figure 21. Thus the concretions and oolite were not analyzed in the Bru 95-3 sand samples.

The well information report obtained from MB Groundwater gives the date of completion for Bru 95-3 as June 28, 2019. The samples were gathered for analysis in November of 2020. The sand sample had been exposed to weathering outdoors for a year and a half. Despite the weathering the ALS results for Bru 95-3 in Appendix A part 6 of the Hydrogeological report gives the sulphide concentration as 0.02%, the same value as obtained from ALS lab results from Sio Silica Vivian sand sampled by concerned citizens in the spring of 2020. The XRD results from Bru 95-3 showed 0.2% calcite and 0.2% dolomite that can act to neutralize the acid whereas ALS lab results for sand samples collected by concerned citizens in the spring of 2020 showed no carbonate from calcite or dolomite as shown in figure 30. The reported 0.02% sulphide from the Sio Silica XRD results and the OLS results is consistent with marcasite in the sand and refutes the statement by Sio

Silica in response to public comments that the Carman sands that Sio Silica would extract does not contain marcasite.

The sand for Bru 95-3 was extracted by airlift. The documented presence of shale fragments in airlift extracted sand as shown in figure 19 establishes that the Bru 95-3 sand sample could have contamination from the shale aquitard and from the carbonate above. Calcite of the limestone strata is formed in a more recent epoch than the sandstone.[11,95]

The dolomite reported in the XRD results of the Bru 95-3 sand is even more indicative of contamination on the Bru 95-3 sand sample. Geological Report GR 93-1 on the Fort Garry Aquifer in Manitoba by Betcher et al. (1993) reports that limestone-dolomite-anhydrite deposition occurred near the end of the carbonate aquifer formation. Dolomite is reported only in the upper member of the Selkirk member of the carbonate aquifer found in eastern Manitoba.[95] Dolomite is not reported in the Bru 121-1 and Bru 146 sand samples shown in figures 24 and 25.

Following complaints in the spring of 2020 about silica dust from the exposed sand piles at Vivian, Sio Silica first covered the piles and then buried them. By November 18 of 2020 most of the sand piles had been removed and the sand spread on ground and buried as shown in figure 22. It is uncertain where the sand samples were collected on Nov. 19, 2020. The date of collection of the sand sample Bru 95-3 is illustrated in figure 24 and corroborated on page 3 of Appendix A part 6, ALS analytical results of the Sio Silica Hydrogeological Report where the sampling date and time for Bru 95-3 sand sample is given as 19-Nov-2020, 08:00.

In section 5.4 of the Sio Silica Hydrogeological report, limestone (primarily calcite) and dolomite are reported to occur in glacial till. The Bru 95-3 sand samples could have been contaminated with calcite and dolomite in surface till during movement and handling, as documented in figure 23. Previous pictures of the sand at Vivian are shown in figure 22. The Google Earth image of figure 22 shows that the original piles had been moved and reduced to one covered pile by Nov.19, 2021 the date of sampling.

Notice that the Google Earth image shows that sand extraction site was flooded by the Sio Silica extraction activities. The flooded area is confined to the extraction site and is therefore not due to rain as claimed by Sio Silica in a letter to the IAAC of Sept. 11, 2020. The letter to the IAAC is posted on the processing Vivian plant project registry 6057.00 in the Sio Silica response to public comments. The flooded water could have contaminated the sand piles with suspended surface material containing both calcite and dolomite as reported in the Sio Silica Hydrogeological Report. Thus there is copious evidence for contamination of the Bru 95-3 sand sample.

Notice the brown/orange coloured concretions on the photograph on the left of figure 22. The brown/orange colour on the sand pile on the bottom left of figure 22 is consistent with the oxidation of pyrite and marcasite in the concretions as reported by Schieber and Riciputi (2005).[20] The discoloured concretions at the Vivian site are consistent with those found at the Centre Line Road site demonstrating the pyrite and marcasite in extracted concretions would be found throughout the Bru extraction area. The covered sand pile of Nov.14, 2020 had been diminished by Nov.18, 2020 indicating disturbance.

Figure 22. Google Earth image of original Sio Silica extracted sand piles and photographs of the Sio Silica silica sand piles taken June 7, 2020 (left) and Nov.14 2020
Photographs were reproduced with permission of the photographer.


Figure 23. Photograph of the Vivian site on Nov.18, 2020 showing the covered sand pile disturbed and silica sand spread on the ground.
Photographs were reproduced with permission of the photographer.

The brown colour of the Bru 95-3 sand shown in Figure 24 is further indication of contamination. Other Sio Silica sand is pure white as shown in figures 24 and 25.

Photo No. 18

Description:

Sample ID: Bru 95-3
Depth: Unknown
Lithology: Sandstone

Grab Sample From Test Extraction Pile

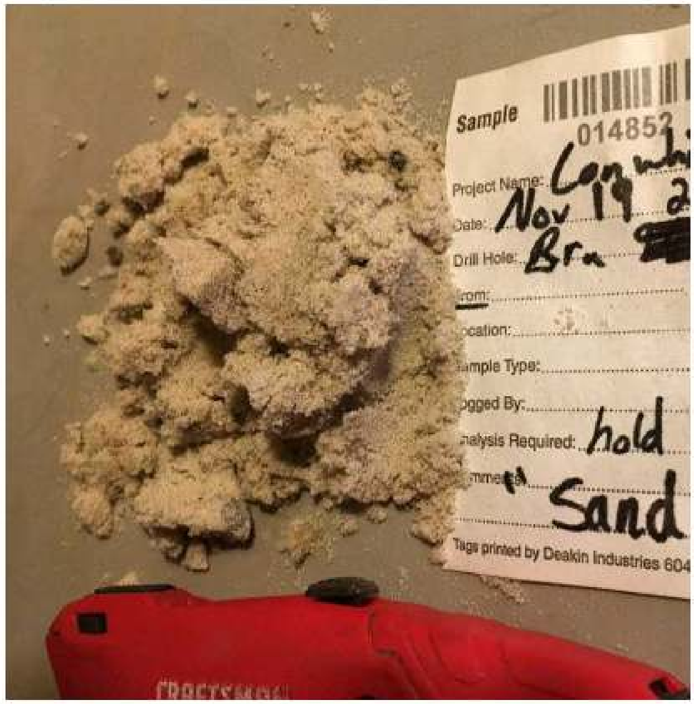


Figure 24. Photograph Bru 95-3 sand sample collected on Nov.19, 2020
The photograph was reproduced from the Sio Silica Hydrogeological report.

Airlift extraction exposes the extracted silica sand to air and water in the extraction tube. Pyrite and especially marcasite that is known to oxidize readily[62] would oxidize during extraction leading to an underestimate of the sulphide content of Bru 95-3 sand during acid base analysis.

Description:

Sample ID: Bru 121-1
Depth: 174 – 179m
Lithology: Sandstone

Grab Sample

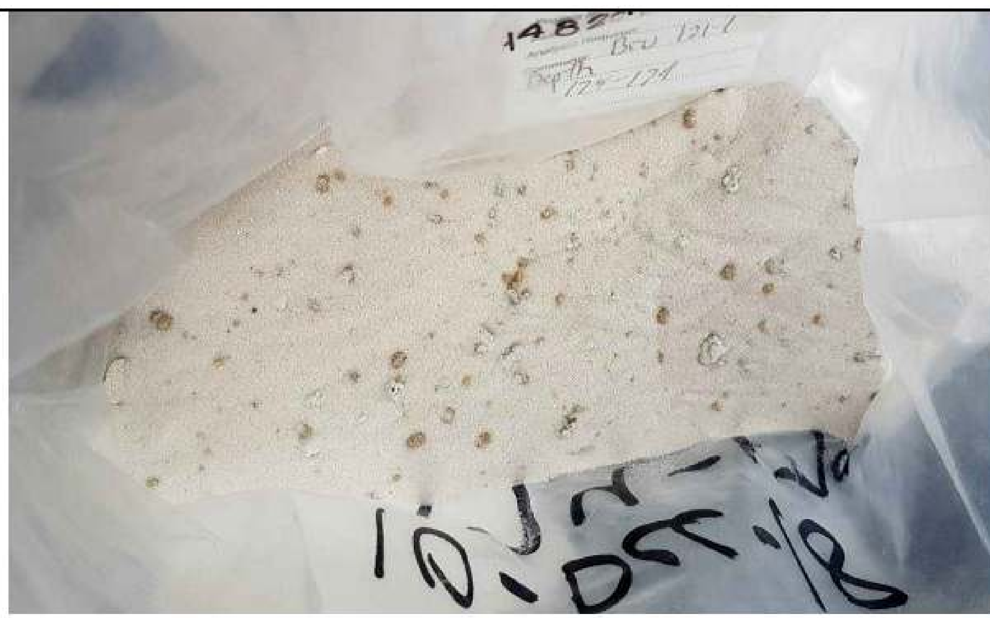


Figure 25. Bru 121-1 sand samples
The photograph was reproduced from Appendix A Part 5 of the Sio Silica Hydrogeological Report

Photo No. 6
Description: Sample ID: Bru 121-1 Depth: 174 – 179m Lithology: Sandstone Grab Sample

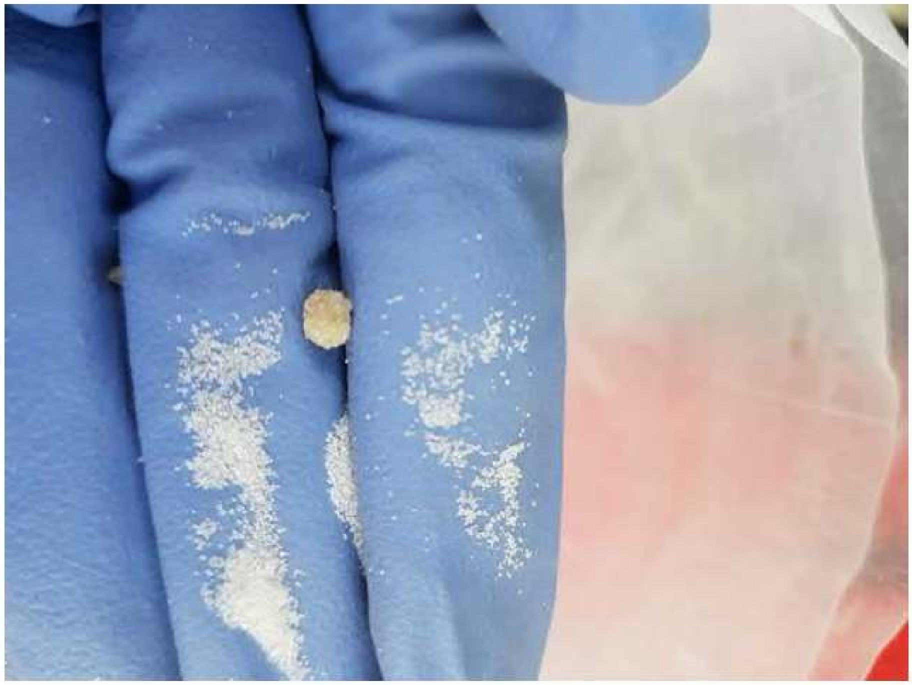


Figure 26. Bru 146 sand samples
The photograph was reproduced from Appendix A Part 5 of the Sio Silica Hydrogeological Report

The Sio Silica Hydrogeological report states;

"*Boreholes Bru 121-1 and Bru 146 were drilled as part of historical investigations. Samples of Red River Carbonate and Winnipeg Shale were collected from core boxes stored in CanWhite's core storage facility in Steinbach, and the samples of Winnipeg Sandstone associated with these locations had been previously collected and submitted by others to ALS Environmental Laboratories"*

As shown in figure 3-1 of the Sio Silica Hydrogeological Report both Bru 121-1 and Bru 146 are outside the intended Sio Silica 24 year extraction area. Thus the only relevant sand sample, Bru 95-3 was taken from a sand pile, exposed to weathering since July of 2019. The sand pile was and disturbed and potentially contaminated with glacial till before sampling as illustrated in figure 23.

According to the well information reports Bru 121-1 was completed at location NW22-9-8E on Feb.19, 2019. Borehole records obtained from Manitoba Mines show that Bru 146 was drilled on Nov.21-23, 2018 to the carbonate and extended into the sandstone on Dec. 10, 2018. Therefore, clear evidence demonstrates that the sand samples were corrupted by exposure to air during the long time after drilling. The well information report for Bru 121-1 states the well use as test well. Air lifting used to extract sand is not indicated. Open hole is reported extending into the sandstone with the casing terminating in the shale aquitard above the sandstone. The Sio Silica EAP reports that sand could not be extracted by normal core logging methods implying the Sio Silica sand samples were extracted by air lift wells that would expose the samples to air and water causing oxidation of sulphide in the samples. The Bru 121-1 well was flowing and left active. The well information report for Bru 121-1 states no sealing information was provided. A flowing well condition would have further complicated removal of a sand sample. It remains undocumented how the sand sample was retrieved from Bru 121-1.

Bru 146 was not reported in the well information reports received from Manitoba Groundwater although all Sio Silica well reports were requested. Borehole records for Bru146 were obtained from Manitoba Mines Branch. Bru 146 location is south of Bru 121-1 in the flowing well area.[32]

The work order chain of custody forms in Appendix A Part 6 of the Hydrogeological report give inconsistent sampling dates for Bru 121-1 and Bru 146. All samples were list as received in LDPE bags which are known not to be air tight.[123] The sampling dates for Bru 121-1 24.28 m to 37.0 m in the carbonate and shale aquitard were given as 11-Nov- 2020. The sampling date for Bru 121 -1 from 174 m to 179 m in the sandstone was 10-Dec-2018. The sampling date for Bru 146, 36.82 m to 50.29 m, was 11-Nov-2020. The sampling date for Bru 146 189 to194 m in the sandstone was 06-Dec- 2018. The chain of custody forms and work orders given in EAP Appendix A Part 6 verify these dates. Please note the work orders for the samples state; "*If samples are identified below as having been analyzed or extracted outside of recommended holding times, measurement uncertainties may be increased, and this should be taken into consideration when interpreting results*." The ALS report in Appendix A Part 6 gives the sampling date for the Bru 121-1 and Bru 146 sand as 18-Nov-2020 contradicting the Sio Silica statement that the samples had been previously collected and submitted by others to ALS. The collection time, the collector identity, collection method, and the storage containment of the Bru 121-1 and Bru 146 sand samples are not given and remain unspecified. To be valid samples the date, time, and method of collection and storage must be specified. The Bru 121 and Bru 146 dates of sampling in 2018 violate the hold times for the samples. Sio Silica has displayed negligence by lack of the documentation of the collection of the Bru 121-1 and Bru 146 sand samples.

Note that figure 26 of the Bru 146 sample shows a red colour indicating pyrite and/or marcasite oxidation.

The comments in the HR on the samples collected state:

"*Bru 121-1 Winnipeg sandstone sample contains concretions of brown color containing iron oxide minerals. Bru146_Winnipeg Sandstone sample contains concretions of brown color containing iron oxide minerals and remnants from overlying shale*"

These statements demonstrate that iron sulphide in the sand samples from Bru 121-1 and Bru 146 had oxidized to iron oxide minerals.

The XRD analysis of the Bru 121-1 and Bru 146 given in Table 4-2 of Appendix A part 4 of the Sio Silica Hydrogeological Report shows 0.1 weight % of α-Fe could be marcasite.[93] Other sources of iron such as pyrite, siderite, hematite, ankerite and goethite are given separate from the α-Fe. Marcasite is known to be composed of α-Fe while pyrite contains β-Fe.[93] Table 4-2 shows zero calcite for Bru 121-1 sand and 0.2% calcite for Bru 146 sand. Table 4-1 of Appendix A part 4 of the Sio Silica Hydrogeological Report reports the samples for Bru 121-1 contained concretions of brown colour containing iron oxide minerals. Table 4-1 states that the Bru 146 sample contained concretions of brown colour containing iron oxide minerals and remains from the overlying shale. The samples for Bru 146 were contaminated with shale. If shale fragments were present it is possible that fragments from the overlying carbonate were also present which would explain the presence of the calcite found. The presence of iron oxide from the concretions is consistent with oxidation of pyrite or marcasite known to occur in the concretions of the Winnipeg formation.[20]

The results for calcite are further complicated by the footnote of Table 4-1 which states CaCO3 Equivalency = Total Inorganic Carbon (TIC)*(100/12)*10. Total inorganic carbon can come from non acid generation minerals such as ankerite and siderite.[12] The total inorganic carbon for Bru 121-1 sandstone is given as 0.09% and for Bru 146 sandstone as 0.05% in Table 4-4. Using the formula in the footnote the CaCO3 equivalency for Bru 121-1 would be 7.5 tCaCO3/kt whereas the modified neutralization potential is reported as 3 tCaCO3/kt. Using the formula in the footnote the CaCO3 equivalency for Bru 146 would be 4.17 tCaCO3/kt whereas the modified neutralization potential is reported as 4 tCaCO3/kt. This is due to the adjustment made for the siderite content given in Table 4-2 for Bru 121-1 as 0.9% and for Bru 146 as 0.1%. However the inorganic carbon content fro Bru 121-1 of 0.09% is due entirely to the siderite content of 0.9% since the fraction of carbon in siderite (FeCO3) according the molecular weights is 0.1. Thus sample Bru 121-1 was given a net neutralization potential of 3 tCaCO3/kt even though all the inorganic carbon content was due to siderite which is not neutralizing.[12] This demonstrates that adjustment used for ankerite and siderite content to modify the neutralization potential is incorrect. The neutralization potential for samples containing ankerite and siderite are therefore invalid.

These results demonstrate that the silica sand is likely to contain no calcite for neutralization and potentially 0.1% marcasite reported as α-Fe. The results from Table 4-4 demonstrate that all three sand samples Bru 95-3, Bru 121-1 and Bru 146 have acid generating potentials of 0.6, 0.3 and 0.3 tCaCO3/kt even though all samples were exposed to oxidation and weathering. The calcite reported in sand samples from Bru 95-3 and Bru 146 can be attributed to documented contamination. The neutralization potential for Bru 121-1 was solely from siderite as non neutralizing mineral.[12] Thus the neutralization potential for all sand samples reported in the Sio Silica analysis must be disregarded. The Sio Silica analysis confirms the results from Wanipigow that the sand in the Vivian area contains acid generating sulphide. The acid generating capacity of the Vivian sand samples has been underestimated due to exposure of the samples to air for a long period of time.

7.3 Sample handling procedures

In the response to public comments regarding air exposure of the samples taken Sio Silica stated;

"*The environmental samples were not contaminated. Industry accepted methods for sampling, handling, preservation, and shipping of drill cuttings, water samples, and core samples were applied by the professional consultants retained by CanWhite* ."

Sio Sio Silica in response to information request DLN-IR-002c-26 concerning the handling and storage of geological samples states; "*Collection of samples for geochemical testing was completed in a manner that is consistent with industry standard practice as defined by the Guidelines for the Prediction of Acid Rock Drainage and Metal Leaching for Mines in British Columbia (Price 1997), the Metal Environment Neutral Drainage (MEND) Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials (MEND 2009) and the Global Acid Rock Drainage (GARD) Guide (INAP 2014).*"

The Guidelines for the Prediction of Acid Rock Drainage and Metal Leaching for Mines in British Columbia (Price 1997) state;[124]

> **6.8 Sample Preparation**
>
> **After being collected a sample should be air dried or oven dried at a low temperature. Oven drying at temperatures no higher than 40 °C will ensure most minerals are not altered. Prior to drying, the sample should be kept cool. However, drying will cause additional secondary minerals to precipitate during evaporation of the porewater, which could complicate testwork and predictions.**

The Guidelines for the Prediction of Acid Rock Drainage and Metal Leaching for

Mines in British Columbia (Price 1997), the Metal Environment Neutral Drainage (MEND) Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials (MEND 2009) states;[125]

125 **Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials** **Version 0 – Dec. 2009**

The geochemical conditions of the material in the field should be maintained within samples where changes will obscure or destroy the targeted properties and processes of the subsequent analyses and test work. A good example of this is the need to maintain anaerobic conditions during sampling and storage for samples from anaerobic sediments. Exposure to oxygen will change the composition of the pore water and the solubility of potential contaminants. Therefore, changes in geochemical conditions should be minimized where possible during storage. Nevertheless, some changes may be inevitable. Where differences occur they should be considered in the interpretation of the analyses and test work results.

The geochemical conditions of the material in the field should be maintained within samples where changes will obscure or destroy the targeted properties and processes of the subsequent analyses and test work. Nevertheless, some changes may be inevitable.

After being collected, samples of drill core, blast hole cuttings and unweathered or aerated waste materials and walls should be air dried or oven dried at a low temperature. Prior to and after drying, the sample should be kept cool. Drying at temperatures no higher than 40°C will ensure most minerals are not altered. However, the evaporation of the pore water will cause solutes in pore water to precipitate. Typically, the effect of solute precipitation is minimal because the solute concentration is not significant compared to the concentration of previously precipitated weathering products.

Some sulphide oxidation may occur during drying and storage. Approaches that will minimize oxidation after sampling include freezing the sample, minimizing the delay prior to drying and avoiding humid storage conditions. Anaerobic conditions may be maintained by storing the sample under nitrogen gas.

(*Reproduced from Prediction Manual for Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1, Dec. 2009*).[125]

Sio Silica has given no evidence that the core samples were air dried at temperatures no higher than 40 C and that prior to after drying the samples were kept cool. Sio Silica provides no evidence of freezing the samples before drying and maintaining anaerobic conditions by storing under nitrogen gas. The guidelines show that my stated concerns about oxidation of the samples by air exposure are valid. The references Sio Silica provides confirm the handling and storage of Sio Silica core samples was inadequate. Therefore I dispute the claim by Sio Silica in the IR response that; "*Collection of samples for geochemical testing was completed in a manner that is consistent with industry standard practice.*"

The MEND report gives the recommended initial sampling frequency based on the tonnage of disturbed ore as shown in the reproduced table 8.2 below.[125]

Table 8.2 Suggested initial sampling frequency based on tonnage when sampling without prior information (adapted from BCAMDTF, 1989).

Tonnage of Unit (metric tonnes)	Minimum Number of Samples
< 10,000	3
< 100,000	8
< 1,000,000	26
< 10,000,000	80

(*Reproduced from Prediction Manual for Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1, Dec. 2009*).[125]

In the 24 year Project period in excess of 24 million tonnes of aquifer sandstone (ore) would be disturbed. Thus the number of geochemical samples should be in excess of 80 collected throughout the Project area. Sio Silica collected only three sand samples that were inadequately handled. Bru 95-3 sand sample was taken from an outdoor stockpile exposed to weathering for one year from June 2019 to June 2020 before the stockpile was covered with a tarp as illustrated in figure 22. The other two samples were taken in 2018 from wells Bru 146 and Bru 121-1 south of the Project area as shown in figure 3-1 of appendix A Part 1 of the EAP. The Bru 146 and Bru 121-1 samples were held in storage without protection from oxidation by air exposure for two years before analysis. We must question why the Bru 146 and 121-1 samples were used as they are outside the project area and therefore are not relevant.

Sio Silica stated in response to DLN-IR-002c; "*The sand pile from which the Bru 94-3 sand sample was taken was covered by tarp and not exposed to weather for an extended period of time.*" This statement is false as illustrated in figures 21 and 22. The sand for the Bru 94-3 sample was extracted from wells at Vivian in June of 2019. The tarp was placed over the exposed sand piles following a complaint of June 28, 2020 to Manitoba Workplace Safety and Health that ATV operators and passers by were being exposed to silica dust from the sand piles.

The evidence I presented in my public comments submission to the project registry regarding industry standard methods of sampling for sulphide in core samples was not addressed.[26,27] The evidence I submitted on the oxidation of pyrite in shale samples exposed to air was ignored.[28]

The evidence from the references given by Sio Silica demonstrates that geochemical sampling must be redone with sampling methods, number of samples, and handling conforming to the stated guidelines. Samples of concretions, shale interbeds, and oolite must be taken and analyzed.

7.4 Other evidence of sulphide in the silica sand in the Project area

Acid base accounting results in the NI 43-101 technical report for the silica sand from Winnipeg formation at Wanipigow gave an acid to neutralizing ratio of 0.73 that indicates strong acid producing.[25] The net acid potential was 2.01 tonnes per 1000 tonnes of sand expressed as neutralizing potential $CaCO_3$. Assuming one mole of $CaCO_3$ neutralizes one mole of sulphuric acid, and using a molecular weight of CaCO3 of 100, the acid potential would be 0.02 million moles of acid per 1000 tonnes of sand for the Wanipigow sand.

The results of the acid base accounting test for the sand at Seymourville/Wanipigow is shown in figure 27 below.

Claim Post Resources Inc. – Seymourville – Project 14466-001 – Interim

Table 9: Standard Acid Base Accounting Test Results

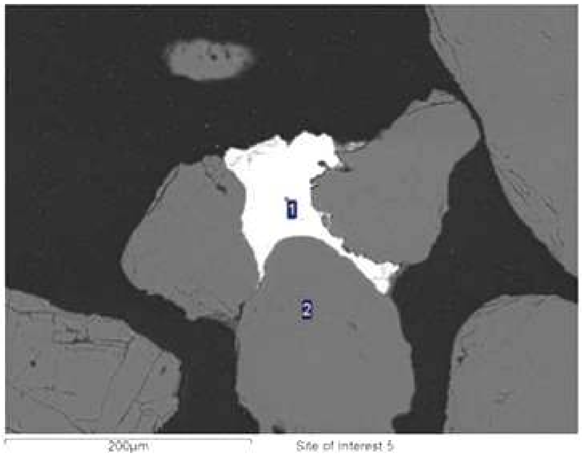
Parameter	Unit	Master Composite A
LIMS		12782-APR14
Paste pH		6.16
Fizz Rate	---	1
Sample weight	g	2.03
HCl added	mL	20.00
HCl	Normality	0.10
NaOH	Normality	0.10
Vol NaOH to pH=7.0	mL	13.41
Final pH		2.08
NP	t $CaCO_3$/1000 t	5.3
AP	t $CaCO_3$/1000 t	7.34
Net NP	t $CaCO_3$/1000 t	-2.01
NP/AP	ratio	0.73
S	%	0.235
Sulphide1	%	0.10
SO_4	%	0.3
C	%	0.044
CO_3	%	0.035
CO_3 NP	t $CaCO_3$/1000 t	0.58
CO_3 Net NP	t $CaCO_3$/1000 t	-6.76
CO_3 NP	ratio	-0.079

Figure 27. Acid base accounting results from Winnipeg formation sand at Seymourville.
The results were reproduced from the 2014 NI43-101 technical report of Claim Post Resources.[25]

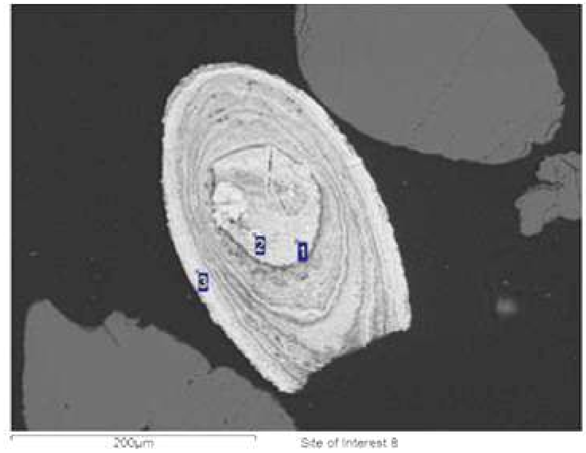
The acid base accounting test showed a sulphide content of 0.235% from the iron sulphide (pyrite, marcasite) in the sand. The sand also contained 0.035% $CaCO_3$ which could act to neutralize some of the acid formed from oxidation of the pyrite and marcasite. The sand deposit at Wanipigow is near surface and overlain by glacial till.[25] The sand at Wanipigow could contain some glacial till containing calcite. Even so the calcite found at Wanipigow was small. The small amount of calcite at Wanipigow sand that was collected directly from the formation by sonic drilling and protected from air exposure would indicate the calcite concentration of 0.2% for Bru 95-3 and 0.1% for Bru 146 could well be from contamination due the inadequate collection methods.

The acid potential is expressed in terms of $CaCO_3$ equivalent. A net neutralization potential of -2.01 expressed as CaCO3 equivalent with a molecular weight of 100 converts to a net acid potential of 20100 moles of sulphuric acid per 1000 tonnes of sand.

The marcasite in the sand is shown in microscope pictures from the 2014, NI 43-101 technical report of Claim Post Inc. reproduced in figure 28.[25]



Backscattered Electron Image of Master Composite
6 Minutes Non-Mag -50/+70 Mesh Quartz grains (grey)
are cemented together by pyrite/marcasite (white)



Backscattered Electron Image of Master Composite
6 Minutes Non-Mag -50/+75 Mesh Rounded
pyrite marcasite grains exhibit concentric layering

Figure 28. Electron microscope pictures of marcasite in sand grains from the Winnipeg Formation near Seymourville.
Pictures in figure 28 were reproduced from the 2014 NI43-101 technical report of Claim Post Resources.[25]

The marcasite in figure 28 is shown as white. Different forms of sulphide will oxidize at different rates. It is well known that marcasite and framboidal pyrite will oxidize quickly while crystalline pyrite will oxidize more slowly.[62]

The NI 43-101 report for Wanipigow describes how the sand was extracted using a sonic drilling method and immediately placed in air tight containers at the surface and sent for analysis.[25] This is the industry standard method to ensure that the sand was not exposed to air or moisture during extraction and transit for analysis. Sampling the sand from sand stockpiles exposed to the weathering for more than one year is simply not acceptable. The sand at Wanipigow was formed under the same conditions in the Ordovician age as at Vivian.[20]

The evidence for marcasite and pyrite in the sand throughout the Winnipeg Formation is not confined to the Wanipigow area. Figure 29 reproduced from the paper by Schieber and Riciputi (2005)[20] shows marcasite and pyrite grains in the sand at other locations in the Black Island member of the Winnipeg formation. Table 1 of the Stantec report in the response to public comments section of the EAP shows the target extraction zone as being in the Carman sands located above the Black Island Member. Figure 29 illustrates that in the extraction area of the first four years south of Vivian the Carman sands is further south and extraction would commence in the Black Island member where marcasite and pyrite is documented to occur. This does not mean that marcasite and pyrite would not be found in the Carman sands that were laid down in the same era under similar conditions.

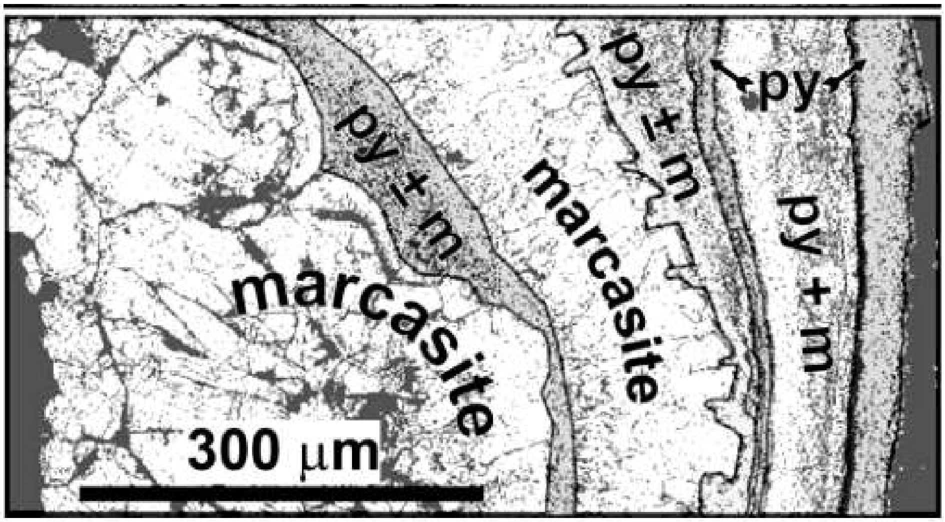


FIG. 6.—**A)** Detail view of grain shown in Figure 5B; showing a closeup of alternating marcasite and pyrite laminae. The radiating clusters of marcasite in the left third of the image belong to the core of the CIS grain, and the pyrite and marcasite laminae to the right belong to the cortex of the CIS grain. Different gray shades indicate variable crystal orientation of pyrite and marcasite grains. **B)** Same field of view as in A, showing distribution of pyrite and marcasite as mapped by EBSD.

Figure 29. Silica sand grains in the Winnipeg Formation showing imbedded marcasite and pyrite. *Reproduced from Schieber and Ricupiti, 2005*.[20]

Sio Silica attempts to discount evidence from Wanipigow and other locations in the Winnipeg formations being inapplicable. To properly evaluate this Proposal, information from other applicable Projects or situations can and must be used since so little information is supplied for this Project and this Project has not yet been implemented. Using information and data from other sources is standard and accepted practice. When I participated in the Seaborn Panel Environmental Review of the Canadian Concept for Canada's Nuclear High Level Nuclear Waste we continually used applicable information from other projects such as the Swedish SKB nuclear waste disposal project.[118] The evidence from Schieber and Riciputi applies to all of the Winnipeg formation that was laid down in the same Ordovician era under the same deposition environment. I therefore assert that results from Black Island member of the Winnipeg formation in Wanipigow and Saskatchewan are relevant and must be considered until conclusive evidence to the contrary is established.

Sand samples were collected by a concerned individual certified in sample collection from the Sio Silica sand stockpiles at Vivian in the spring of 2020. The Sio Silica extracted sand piles at Vivian had been exposed and weathered for over one year. Sand samples collected by concerned citizens were sent for analysis by ASL laboratories. The results showed the presence of 0.02% sulphide and no $CaCO_3$. This is consistent with all the $CaCO_3$ consumed by neutralization of the acid produced over a year of weathering. There was still sulphide present in the spring of 2020 conclusively establishing that the sand at Vivian contains pyrite. The 0.6 tonnes of acid potential is obtained by multiplying the sulphide content of 0.02 by 31.25.[92] The ALS report has rounded the MPA (maximum acid potential) to one significant figure of 0.6 tonnes acid potential expressed as tCaCO3 equivalent per kt of sample. The net neutralization potential ratio NNP of -1 was the result of no CaCO3 detected in the sample.

The acid base accounting results and trace metal analysis of the Vivian sand collected by concerned citizens in the spring of 2020 is given in figure 30.

ALS Canada Ltd.
2103 Dollarton Hwy
North Vancouver BC V7H 0A7
Phone: +1 604 984 0221 Fax: +1 604 984 0218
www.alsglobal.com/geochemistry

To: OUR LINE IN THE SAND
PO BOX 689, STATION
STEINBACH MB R5G 1M

CERTIFIC

Sample Description	Method / Analyte / Units / LOD	WEI-21 Recvd Wt. kg 0.02	OA-VOL08 MPA tCaCO3/1Kt 0.3	OA-VOL08 FIZZ RAT Unity 1	OA-VOL08 NNP tCaCO3/1Kt 1	OA-VOL08 NP tCaCO3/1Kt 1	OA-ELE07 pH Unity 0.1	OA-VOL08 Ratio IN Unity 0.01	S-IR08 S % 0.01	S-GRA06 S % 0.01
#4 sand		0.88	0.6	1	-1	0	8.0	0.00	0.02	<0.01
#7 sand		0.92								

Sample Description	Method / Analyte / Units / LOD	ME-MS61 As ppm 0.2	ME-MS61 Ba ppm 10	ME-MS61 Be ppm 0.05	ME-MS61 Bi ppm 0.01	ME-MS61 Ca % 0.01	ME-MS61 Cd ppm 0.02	ME-MS61 Ce ppm 0.01	ME-MS61 Co ppm 0.1	ME-MS61 Cr ppm 1
#4 sand										
#7 sand		0.9	10	<0.05	0.01	0.06	<0.02	5.07	0.5	5

ME-MS61 Cr ppm 1	ME-MS61 Cs ppm 0.05	ME-MS61 Cu ppm 0.2	ME-MS61 Fe % 0.01	ME-MS61 Ga ppm 0.05	ME-MS61 Ge ppm 0.05	ME-MS61 Hf ppm 0.1	ME-MS61 La ppm 0.5	ME-MS61 Li ppm 0.2	ME-MS61 Mg % 0.01	ME-MS61 Mn ppm 5	ME-MS61 Mo ppm 0.05
5	0.11	2.0	0.47	0.64	0.05	1.8	2.6	6.7	0.02	47	0.13

Figure 30. ALS acid base accounting and heavy metal results for silica sand sampled from a Sio Silica stockpile near Vivian Manitoba. Results received, 17-Jul-2020.
Figure 30 was reproduced from ALS report to Our Line in the Sand local group

The Our line in the Sand (OLS) certified lab results shown in figure 30, report the presence of heavy metals in the sand. Barium was particularly high at 10 ppm.

It is well known that iron bacteria can proliferate in sediment from acid mine drainage.[49] Iron bacteria cause gelatinous yellow or range coloured deposits to form that can plug wells and plumbing.[48]Yellow gelatinous blobs were documented by concerned citizens at the base of extracted sand piles near Vivian as show in figure 31.

Figure 31. Sio Silica extracted sand pile near Vivian showing yellow/orange gelatinous deposits
Image was used with permission of the photographer.

The deposits shown in figure 31 are consistent with bacterial action of the marcasite in the Vivian sand.[16,17,48] The iron bacteria deposits are further evidence confirming the presence of sulphide in the Vivian sand. The independent evidence of the sulphide includes results for the NI 43-101 report, the paper by Schieber and Riciputi (2005)[20] that marcasite and pyrite formed through the Winnipeg formation in the Ordovician age millions of year ago, lab reports from concerned citizen's showing sulphide present in the sand even after about 8 months of weathering, and Sio Silica extracted sand piles showing orange coloured concretions and sand. These compelling and corroboratory independent lines of evidence must not be dismissed.

The Sio Silica results of sand exposed to weathering for more than one year for Bru 95-3 showed the same 0.02% sulphide content as the sand sampled at Vivian by concerned citizens in the spring of 2020. What remains in doubt is the amount of calcite in the sand that could act to neutralize some or all of the acid produced from oxidation. The ALS results for Bru 121-1 and the OLS results for Vivian sand showed no calcite establishing that calcite neutralization cannot be relied upon. There is no doubt that the sulphide in the sand extracted by Sio Silica from the same sand pile sampled by concerned citizens had depleted after about seven months further weathering. Given that the sand sampling at Vivian was compromised, the results from Wanipigow would be the best estimate of the acid generating potential at Vivian. Until valid results are obtained for Vivian sand the results from Wanipigow showing marcasite and acid drainage potential should apply. Many more freshly collected sand samples that are immediately protected from air must be analyzed from the entire Bru 24 year project area.

7.5 Shale

The Sio Silica acid base accounting for the shale shows the presence of both pyrite and calcite. Calcite can act to neutralize the acid formed by oxidation of pyrite. The XRD results documented in table 4-2 of the Sio Silica Hydrogeological Report shows ankerite and siderite. Ankerite and siderite are sources of inorganic carbon that are not neutralizing.[12] The ankerite and siderite would contribute to the inorganic carbon used in acid base accounting to estimate the neutralizing potential and lead to an overestimate of the neutralizing potential.[12] In Bru 121-1 and Bru 146 the concentration of ankerite and siderite in the shale is larger than the calcite. The calcite is known to occur near the upper boundary of the shale and limestone. A peer reviewed paper by Ferguson et al. (2007) [11] on the Winnipeg formation states;

"*The shales are sometimes lightly calcareous near the contact with the overlying Red River Formation*."

This is supported by the Sio Silica core log for Bru 95-8 that shows interbedded shale and limestone at the interface with the limestone and shale layer and trace sulphides along the joint plane. The sulphide along the joint plane directly contradicts the statement in the Hydrogeological study;

"*Disseminated sulphides or visible minerals were not observed in any of Winnipeg Shale samples collected from the Project Area*."

These sulphides could have been oxidized in the analyzed core samples that were not protected from air exposure. A thin reddish brown shale layer is documented in the core logs of the Sio Silica Hydrogeological Report to lie above the main shale layer confirming the top shale layer shale is of a different composition than the lower shale.

The shale core sample of Bru 146 shown in figure 32 is exposed to air, shows dark red spots consistent with pyrite oxidation and is held by an un-gloved hand. Other core sample pictures show in Appendix A Part 5 of the Sio Silica Hydrogeological report show core samples exposed to air. Obviously proper care was not taken in the collection storage and handing of the Sio Silica core samples to protect against oxidation of sulphide.

Photo No. 10

Description:

Sample ID: Bru 146
Depth: 49.86 – 50.29m
Lithology: Shale

Core Sample

Figure 32. Bru 146 shale sample exposed to air
The photograph is reproduced from the Sio Silica Hydrogeological Report.

The shale aquitard would be exposed to aerated re-injected water from below during Sio Silica sand extraction such that the calcite would not encounter the air until much of the shale had already been oxidized to form acid and mobilize heavy metals.

The XRD results for Bru 95-8 report 1.3% pyrite by weight and list Bru 121-1 and Bru 95-8 shale samples as uncertain acid generating status. Uncertain protection of the aquifer must not be allowed.
The shale layer for Bru 95-8 is 3.3 meters thick. For a cluster radius of 27 meters and a shale dry density of 1.8 t/m^3,[99] the shale aquitard overlying the excavation in the sandstone would contain 176 tonnes of pyrite. The Sio Silica extraction EAP states the target amount of sand to be removed for each cluster is 21000 tonnes. Using a dry density of sand of 1.65 t/m3 and a sand fraction of 0.75 in the aquifer, the excavation cavity for the cluster would contain 16970 cubic meters of water. Assuming each mole of pyrite could generate as much as 2 moles of sulphuric acid and the molecular weight of FeS_2 as 120 g/mol, 1.47 million moles of acid could be produced in with a pH potential of 1.06 in the cluster cavity if all the pyrite were oxidized and no neutralization occurred. Only a small amount of heavy metals mobilized by this acid could contaminate the aquifer. For example, the allowable amount of arsenic is drinking water is only 10 micrograms per litre. If neutralization did occur the reaction of sulphuric acid and calcium carbonate produces carbon dioxide that would dissolve and form carbonic acid.[122,127]

This example calculation does not include all the other sources of pyrite in oolite, the concretions, shale interbeds and the marcasite and pyrite in the sand that cannot be dismissed based on the long exposure of the sand to weathering prior to analysis.

The Bru 95-7 core log documents thin shale interbeds from 72.2 meters to 74.7 meters occurring 20 meters into the sandstone aquifer. This is followed by a thick shale layer. Well information reports from Manitoba groundwater document numerous interbedded shale layers at lower depths in the sandstone as shown in Table 4 and figures 10 and 33. Sio Silica borehole logs obtained from Manitoba Mines also show interbedded shale at lower depths in the sandstone. Figure 33 illustrates two such Sio Silica borehole logs. The shale at this lower depth was not sampled and would most assuredly contain pyrite that would be exposed to air both from the re-injected water and the air injected directly into the sandstone to loosen the sand or as in the case of extraction well Bru 92-2 injected directly into an open hole in the sandstone to extract the sand.

From (ft)	To (ft)	Lithology	Date Drilled
0	118	Quaternary	18-Apr-19
118	148	Limestone	23-Apr-19
148	153	Shale	07-Jun-19
153	218	Sand	
218	228	Sand + Shale Layers	

TABLE 6: BRU 95-1 LOGGED SECTION

From (ft)	To (ft)	Lithology	Date Drilled
0	86	Quaternary	11-Dec-18
86	161	Limestone	14-Dec-18
161	170	Shale	
170	245	Sand	
245	258	Sand + Shale Layers	

TABLE 1: BRU 82-8 LOGGED SECTION

Figure 33. Sio Silica borehole logs from Manitoba Mines Branch showing interbedded shale layers deeper in the sandstone

Only a very small number of samples of shale were taken by Sio Silica. The shale lower in the sandstone was not analyzed. Much of the Sio Silica proposed extraction area was not sampled. The Sio Silica results confirm up to 1.3% pyrite content in the shale. Sio Silica has minimized and underestimated the risk of acid generation from shale. From the precautionary principle and the evidence presented here the shale in the aquitard and throughout the sandstone formation is at high risk to be acid generating. This aquifer is used as a drinking water source for a large number of residents and this risk for contamination cannot be dismissed based on the Sio Silica evidence. On the contrary the Sio Silica evidence confirms the risk of aquifer contamination from pyrite in the shale is very high.[24]

7.6 Selenium

Sio Silica in response to public comments states;

"*There will be no injection of aerated water into the carbonate aquifer and therefore, there is no potential for enhanced mobility of selenium in the carbonate aquifer. All reinjected groundwater will be injected into the sandstone aquifer.*"

According to the Hydrogeological report one of three shale samples, Bru 121-1 contained selenium and two of three samples in the carbonate, Bru 95-8 and Bru 146 contained selenium at more than five times the average crustal abundance.

Sio Silica response to public comments states;

"*Project operations will primarily interact with the sandstone aquifer, with very little interaction with the shale and carbonate aquifers. Any shale encountered within the sandstone aquifer will be brought to surface with the sand slurry and the resultant waste materials will be managed in accordance with the Material Characterization and Management Plan. Thus, any trace elements (including barium, selenium, arsenic and boron) contained in the shale will not pose a risk to groundwater quality in the aquifer*."

"*As shown in Table 4-3 of the Hydrogeology and Geochemistry Assessment Report (Appendix A to the EAP), concentrations of selenium in the sandstone aquifer (where sand extraction will occur) were found to be either very low or below the lowest concentrations that could be measured, indicating that the potential for leaching of selenium is low.*"

Sio Silica does not consider oxidation of selenium in the aquitard by re-injected aerated water. Sio Silica does admit that shale will be brought to the surface with the sand slurry but does not acknowledge that oxidation of selenium and mobilization of heavy metals would occur contaminating in the slurry line water.

The shake flask from Table 4-5 results for shale from Bru 121 show 1.64 mg/L selenium. The Canadian drinking water maximum level is given as 0.05 mg/L in Table 4-2. Table 4-3 gives the concentration of selenium in the shale core sample for Bru 121 as 13.1 ppm which is 22 times higher than the crustal abundance of 0.6 ppm given Price (1997) in Table 4-3. The large amount of air in the re-injected water and the air injected directly into the aquifer as documented here would oxidize and mobilize the selenium in the aquitard.

Pat 1 of Appendix A of the extraction EAP states; "*Selenium was identified as a contaminant of potential concern in samples of Red River Carbonate, Winnipeg Shale and one sample of Winnipeg Sandstone (perhaps due to presence of shale fragments).*"

The concentration of selenium in the sandstone from dissolution of the shale aquitard can be estimated from the thickness of the aquitard and the surface area and volume of the extraction cavity. The volume of sand for one cluster at 21000 tonnes of dry sand extraction using a density of 1.65 t/m3 dry sand would be 12727.3 m^3. Using the sand fraction in the sandstone of 0.75 (0.25 water) the total volume of the extracted cluster would be 16970 m^3. Using the equation for the volume of a cylinder and weight is the product of volume and density, the weight of a 3 meter thick shale aquitard of density 1.8 t/m^3, for a 60 meter diameter cluster, would be 15268 tonnes. Using the Bru 121-1 value 13.1 ppm selenium in the shale if all dissolved the concentration in the excavation cavity would be 15268×10^9 mg x 13.1×10^{-6} /16970 m3 = 11786 mg/ m^3 = 11.8 mg/L. According to the extraction EAP, the drinking water standard for selenium is 0.01 mg/L while the allowed concentration for agriculture is 0.001 mg/L. Even if only 0.1% of the selenium dissolved the concentration in the cavity would be above drinking water standards. This does not included selenium dissolution from interbedded shale deeper in the sandstone aquifer documented to occur from the Manitoba Groundwater well information reports, from the core logs given in the extraction EAP and from Sio Silica borehole records obtained from Manitoba Mines Branch. If the selenium concentration of sandstone aquifer water cannot be demonstrated conclusively to be below allowed limits the Project must be terminated.

Table 4-5 gives shake flasks results for selenium for Bru 95-8 in the carbonate of 0.0165 mg/L which is above the 0.01 mg/L maximum for Manitoba Water Quality Standards Objectives and Guidelines given in Table 4-5. The Sio Silica shake flask results establish that selenium can leach into the carbonate aquifer at toxic levels by oxidizing water transferred or directly injected into the carbonate from extraction operations.

The selenium level in three carbonate core samples listed in Table 4-3 are 0.3, 0.5 and 0.7 ppm. The concentration of selenium in and around coal deposits that have been identified with selenium contamination of groundwater varies from 0.1 to several ppm verifying that the levels of selenium found in shale and carbonate at Vivian can lead to groundwater contamination following oxidation to the soluble and mobile selenate SeO_4^{-2}.[23,24] The adsorption of selenate under oxidizing conditions including upon limestone is quite low however reduced species of selenium would precipitate and absorb.[24]

The aerated water injected into the sandstone would move to the carbonate driven by the injection pressure. Even if the double tube extraction method documented in the extraction EAP is implemented the C&J modeling show that injection pressure will be manifest. The oxidizing conditions in the aerated water transferred into the carbonate from the injection pressure would dissolve selenate from the limestone. In the highly fractured karst areas of the limestone the oxidized water carrying selenium in the form of selenate would move relatively rapidly tens to hundreds of meters per day.[31,32] Selenate would continue to dissolve and concentrate as the oxidizing front would move through the karst. This phenomenon is the well known redox roll front.[30] The movement of gaseous air entrained in the re-injected water and from the air injection tube of the airlift wells move faster than the water oxidizing and mobilizing selenium. The development of oxidizing conditions in the carbonate is discussed in more detail in section 7.8.

The acid from oxidation of sulphide in the sandstone would be neutralized by calcite in the limestone however the released heavy metals such as arsenic, chromium, barium in the sandstone would be transported in the carbonate aquifer. A plume of contamination containing heavy metals, and increasing amounts of selenium would be expected to migrate in the carbonate aquifer from the Sio Silica extraction operations moving at the rate of meters to hundreds of meters per day.[31]

7.7 Fluoride

The Sio Silica Hydrogeological report states;

"*Elevated concentrations of arsenic, fluoride and uranium have also been found in groundwater within the study area. Arsenic concentrations are typically below 0.025 mg/L but may be elevated in proximity to shales. Fluoride concentrations have also been found to be elevated (1-2 mg/L) within the study area and may be related to mixing between saline and fresh waters (Betcher et al. 2003) and are notably higher in the Winnipeg Sandstone*."

"*Fluoride concentrations in all water samples exceeded FIGQC for agricultural use. Fluoride concentrations in all water samples met CDWQ MAC of 1.5 mg/L*."

"*Under oxidizing conditions, most fluorides are present as inorganic F- or associated with calcium and sodium which are very water soluble.*"

Dissolution of fluorite (CaF_2) and/or fluorapatite (FAP) ($Ca_5(PO_4)_3F$), is thought to be the dominant mechanism responsible for groundwater fluoride (F^-) contamination.[41] Sulphuric acid formation from the oxidation of sulphide in the sandstone, shale, concretions and oolite could release more fluoride into the water by the following reactions; $H_2SO_4 + CaF_2 \rightarrow 2\ HF + CaSO_4$ and $Ca_5(PO_4)_3F + 5\ H_2SO_4 \rightarrow 5\ CaSO_4 + HF + 3\ H_3PO_4$. The HGR has failed to consider and assess the potential source of groundwater contamination from fluoride mobilized by acid dissolution of fluoride containing minerals such as fluorite and fluorapatite. Calcite is considered to be a sink for fluoride so that fluoride contamination from acid leaching is more likely in the sandstone aquifer.[42]

7.8 Oxidizing Conditions in the Carbonate Aquifer

Gaseous air bubbles introduced into the sandstone aquifer from re-injection of water containing entrained air and from the airlift tube would rise into the carbonate aquifer that would be exposed directly to the sandstone after the shale aquitard collapses into the sand extraction cavity. The air bubbles would move upwards in the carbonate from buoyancy and enter the larger water bearing karst near the top of the carbonate aquifer.[32] The bubbles would move laterally in the direction of the prevailing hydraulic gradient more rapidly than the water due to buoyancy and higher permeability. The high entry pressure caused by capillary forces in the clay and fine grained material of the glacial till overburden would prevent migration of the bubbles upward out of the carbonate.[103] The air bubbles moving in the fractures would result in oxidizing conditions that would cause the leaching of selenium as shown by the shake flask tests results of the Sio Silica Hydrogeological Report. Iron and manganese would precipitate discolouring and degrading domestic well water quality as documented by Dr. E. Pip in the public comments for the Extraction EAP. The oxidizing conditions would cause iron bacteria introduced in the air from the airlift tube to proliferate fouling domestic wells (Dr. E. Pip, public comments). The acid from the dissolution of CO2, NO2, SO2 in the compressed air from the airlift tube and from reaction of air with sulphide sources such as interbedded shale, oolite and concretions in the sandstone would leach heavy metals into the carbonate aquifer as documented above. Benzene from diesel fumes from the air compressor and other diesel powered extraction equipment injected into the aquifer by the extraction wells airlift tubes would contribute to the aquifer contamination. The carbonate aquifer would be rendered toxic and unusable.

7.9 Evidence of aquifer contamination from Sio Silica Extraction activities

A resident near Centre Line Road wrote in the public comments for the Manitoba licensing approval of Sio Silica Vivian sand processing facility;

"*The company states that the extraction process will be a closed loop system but little details are provided. They have suggested a slurry technique but have not provided any details as to how this method was going to work. They have injected air into the aquifer previously. As I reside approximately two kilometers from the Centre Line Road, when they were extracting the sand, my water had a brown discolouration from the outdoor tap, first time in thirteen years of living in RM of Springfield. I have not seen clear documentation as to the affects on our drinking water when introducing substances into the aquifer. Common sense suggests that when you have a sealed system like and aquifer, introducing substances that are not normally present or present to that concentration will affect the natural system to some extent*."

In limestone most of the water flow is through the fractures.[32]A study of a limestone quarry outcrop in England by Medici et al. (2019) determines water flow velocities ranging from 500 m/day to 9000 m/day in faulted zones. The driving force for water flow was rainfall infiltration.[31] The hydraulic gradient in the study by Medici et al varied from 0.005 to 0.0024 while the hydraulic gradient in the Springfield area in the carbonate aquifer is about 8.5×10^{-4}.[32] A Sio Silica injection well would provide a large driving force that would compensate for the somewhat smaller gradient in the Springfield area compared to the Medici study.

Fine silt and sand in the excess water injected to the carbonate aquifer could be expected to appear in a well two kilometres distant in a matter of a day or two given the fracture flow velocities of 500 to 9000 meters per day given in the report by Medici et al., (2019).[31,46] The aquifer studied by Medici et al. is similar in nature to the carbonate aquifer in Springfield. Both have karst near the surface and dolomite in the formation.[31,32]

Bubbles of entrained air from leakage from air injection and would rise into the karst of the carbonate aquifer and move more quickly than the water. Dissolution of the bubbles would lead to oxidizing conditions and precipitation of iron and manganese discolouring well water.

Oxidizing re-injected water containing gaseous air would be expected to move more slowly in the sandstone. However air injected directly into the sandstone aquifer under pressure from the airlift tube would move much faster and could be the cause of brown water in a well opening in the sandstone at a distance from the extraction. Domestic wells within a radius of two to three kilometres from industrial wells where hydraulic fracturing occurs are know to be in danger of contamination from the hydraulic pressure from these wells.[132]

Injection of nitrogen for opening of coal seams for coal bed methane extraction is suspected to have caused methane contamination of nearby domestic wells.[133] The injection pressure for airlift would normally be much smaller that used for hydraulic fracturing however Sio Silica has not disclosed the pressure used for loosening sand by extending the air tube below the production tube as described in the patent.[1]

On February 5, of 2021 a group of concerned citizen's in Springfield with my assistance submitted a formal complaint about suspected violations of the Manitoba Groundwater and Well Water Act pertaining to wells constructed since 2017 by HD Minerals/CanWhite Sands (Sio Silica). Several citizens near Vivian have experienced a reduction in water quality occurring in their wells near CanWhite sand extraction and borehole testing operations. The scenario of bubbles of air from Sio Silica extraction operations rising rapidly into the carbonate leading to discolouration of the water from oxidizing conditions would explain. The Director of Manitoba Water Branch dismissed the complaint without investigation of the well water discolouration stating, "*Our records show that issues related to iron do occur naturally in this area*."

Complaints of Sio Silica extraction wells unsealed for up to two years was also dismissed by the simple statement from the Director that the wells are now sealed. The improperly sealed and open annuli of wells Bru 92-2 and Bru 92-3 in 2021 illustrates that the problem of improperly sealed Sio Silica wells persists. Well annuli open at the surface exposed to surface contamination may be

The movement of air bubbles from Sio Silica operations is the most likely explanation of the discoloured water Centre Line Road and near Vivian. The evidence of well water discoloration illustrates widespread well contamination is likely to occur from Sio Silica operations.

8 Sio Silica Groundwater drawdown and modelling study

The IAAC, following requests for designation for the Sio Silica Vivian Sand project, opened a project registry site. On Nov.9, 2020 Sio Silica posted an announcement on the IAAC Vivian Sand Review Project Registry of the commencement of an independent environmental study. The announcement in reference 63 stated;[94]

"*Today's CanWhite announces the retention of AECOM, the world's premier environmental firm, to conduct an in depth hydrogeological study, including but not limited to testing and monitoring of the carbonate and sandstone aquifers and associated aquitards*."

The requests for project designation by the IAAC was refused despite all the evidence that has been provided here that was submitted to the IAAC regarding aquifer and surface water contamination and subsidence. Two requests for designation based on physical activity regulations that are automatic triggers for IAAC designation were also rejected. The first request was based on the physical activity for a metal mill. Sio Silica has claimed that the silica sand could be used for solar panels that require silicon. The Sio Silica project conformed to the requirement for ore production capacity of 5 000 t/day or more however the IAAC ruled that silicon is a metalloid not a metal. The second request was based on the size of the Sio Silica railway yard. The land acquired by Sio Silica for the railway yard was 96 hectares. The requirement for an IAAC physical activity is that the railway yard is 50 hectares or more. The IAAC interpreted the railway yard area as;

"When determining the area of a railway yard under paragraphs 54(b) and 55 of the Regulations, the Agency considers the surface area of each component, specifically required for carrying out the operations of the railway yard. This includes tracks, sidings, buildings, and related equipment used for storing,

maintaining, or joining engines and carriages, and for sorting, loading, unloading, forming and dispatching new trains. The determination of railway yard components does not include other potential project components such as access roads, parking, water retention areas, etc. that do not functionally form part of the core railway yard. Components that are not part of the railway yard and the areas in between components of the railway yard such as an area inside a rail loop are not included in the calculation of total area of the railway yard."

Under this determination of the area of a railway yard, that was not specified in the regulations, the Sio Silica railway yard is well under 50 hectares and was therefore not designated.

The Sio Silica hydrogeological study was commenced by Sio Silica in response to the IAAC designation assessment as illustrated by the announcement of the study on the IAAC Vivian Sand Project Registry. The hydrogeological part of the study included a field, 72 hour pumping test near the planned location of the Sio Silica processing plant south of Vivian. The head drawdown and recovery in the Winnipeg formation was measured and results recorded in the Sio Silica Hydrogeological Report. Draw down and recovery tests in the Winnipeg formation have been done previously. The estimates of aquifer properties from several of these pumping tests are given in Table 5-1 of the Sio Silica Hydrogeological Report.

Sio Silica implemented a regional scale finite element model that included several regional pumping wells listed in Table 6-A of the Sio Silica Hydrogeological Report. The objectives of the model were stated as;

• *Translate the conceptual hydrogeological model to a numerical model;*
• *Calibrate the numerical model to observed groundwater level information from long-term records and recent pumping tests; and*
• *Conduct predictive simulations to estimate the effect groundwater and sand extraction will have on groundwater levels in the area during the first four years of operations*

The model parameter values were calibrated to the best match to observed groundwater head values over the model domain. The model results were compared against the observed results of the field pumping tests. The results were not in full agreement but showed similar behaviour. I must question the value of this exercise. Previous studies drawdown studies in Springfield RM had been done. The reported relatively fast well recovery after drawdown has already been documented. It is well known that wells will recover quickly after temporary drawdown.

The Sio Silica finite-element model was used to predict several scenarios with no water re-injection and 50% water re-injection for a degraded and intact an aquitard. Sio Silica acknowledges the sand extraction can damage the aquitard leading to mixing of Winnipeg sandstone and carbonate aquifer waters. This mixing of aquifer waters is prohibited by Manitoba Groundwater regulations. Sio Silica has attempted to provide evidence that the mixing of aquifer waters is not detrimental.

The Sio Silica study did not inject any water. The finite element study did not model re-injection. Sio Silica gave the pretence that reducing the withdrawal rate by almost 50% during model studies was the equivalent of re-injection. This is absurd and illogical. Would the nearly 100% re-injection, that is required, result in zero pumping and no modelling results? Why did the finite- element model not incorporate re-injection in the same way as withdrawal by injecting water at specified grid cells rather than just removing water? Injection certainly would have been within the capabilities of the Sio Silica finite-element model by the same method that withdrawal was implemented. Could it be that Sio Silica deliberately avoided modeling of the essential water re-injection process to avoid revelation of any possible detriment from re-injection?

The Sio Silica claim that the finite-element modeling study showed aquifer drawdown from Sio Silica sand extraction would be temporary and benign, is misleading. Several drawdown studies had already established complete, rapid head recovery after drawdown in the Winnipeg formation. It is the permanent loss of aquifer water from Sio Silica extraction activities that is of concern for sustainability. The permanent loss of water from the sandstone aquifer would include the 15% water entrained in the sand stockpiles at the processing plant, water entrained in the waste sediments, water in filtrates from the UV sterilization process, and water used as road dust suppressant. Sio Silica has not acknowledged and quantified this permanent water loss to the aquifer nor modelled the sustainability of this water loss. The movement of withdrawal wells every four to seven days is difficult to model exactly. Representative wells distributed over the project area could have been used to represent the total projected yearly water loss. Each year, one representative well pumping at an average rate to sustain yearly loss could have been activated and the others turned off. Sio Silica has been negligent in not acknowledging and quantifying the sustainability of sandstone aquifer water loss from the Sio Silica extraction activities.

It is not the drawdown from the Sio Silica extraction wells that is a concern. Most of the water withdrawn is re-injected. The effect of Sio Silica extraction on drawing down the aquifer that has been discussed as being benign in the Sio Silica Hydrogeological Report is a red herring. It is re-injection that can lead to detriment. Sio Silica has avoided evaluating this issue.

The modelling of water re-injection has been implemented here by use of a heat equation from Carslaw and Jaeger (C&J). The results from the C&J equation demonstrate that re-injection would result in pressure build up at the top of the sandstone and subsequent movement of water into the carbonate through a degraded aquitard.

The Sio Silica injection well permits specify that the potential damage to the aquifer from re-injection must be determined. Sio Silica acknowledged in the Hydrogeological Report that aquitard degradation leading to mixing of aquifer waters could occur. Such mixing of aquifer waters is prohibited by Manitoba groundwater regulations. Evidence has been provided here that aerated re-injected water would cause dissolution of selenium in the aquitard, acid formation from oxidation of documented sulphide sources in the sandstone, release of heavy metals from the acid formation, and proliferation of iron bacteria and other microbes in the aquifer. The contaminated, aerated water would be transferred to the carbonate through the degraded aquitard. Dissolution of documented sources of selenium in the carbonate would occur from the widespread movement in the carbonate of the already contaminated water from the sandstone aquifer. Contamination of well water during Sio Silica extraction activities at Centre Line Road has already been reported. Residents in the Vivian area have formally reported under the Groundwater and Water Well Act deterioration in well water quality following Sio Silica extraction activities in that area. The well water complaints were consistent with proliferation of iron bacteria. The reported violations were never properly investigated. Enforcement of the Manitoba regulations prohibiting mixing of aquifer waters, and prohibiting contamination of groundwater from Sio Silica injection wells, should prevent this project from proceeding.

9 Disposal of Year End Water reaming is Surface Vessels at the Extraction Site

Silica in response to information request DLN-IR-002c-13 states; "*The remaining water in the system after extraction is complete will be taken to a water treatment facility for disposal.*" This is entirely new information not previously documented in the EAP and is introduced at an inappropriate stage in the approvals process with no prior TAC, public, and third party expert comment. The amount of remaining water in the system has not been quantified. The process waste water is likely to contain toxic pollutants such as selenium, heavy metals and acid that would require specialized disposal. A treatment plant would dispose of the water to the surface environment in some manner contradicting Sio Silica's assertions that their process would result in no surface discharge of process water. The disposed of remaining water would constitute a draw on the sandstone aquifer that may along with all the other sources of permanent removal of aquifer water, be unsustainable.

Sio Silica also states in the IR response; "*Where possible, water will be moved to a holding tank for the winter months to reduce the volume* Sio *of water taken to a treatment facility*." How big will this holding tank be at the extraction site? Would it be moveable to new sites each new extraction year? Would it be heated in winter? The holding tank is also entirely new information not previously documented in the EAP introduced at an inappropriate stage in the approvals process with no prior TAC, public, and third party expert comment.

The treatment of the remaining system water at a disposal facility and a remaining system water holding tank at the extraction site are major project alterations that would require an alteration to the EAP, TAC and public comments, review by the Hearing third party experts and suspension of the Hearings until this approvals process is complete. Delay of the Hearing is required until new project alterations pertaining to disposal of year end process water are adequately dealt with.

10 Sand Purity

Sio Silica has not disclosed the beneficiation methods required for high purity silica requirements. Toxic chemicals including acid could be required resulting in unidentified waste streams.[128] Sio Silica has not demonstrated that purification methods for the Vivian sand to meet high purity standards are feasible. Full disclosure of the chemicals used for beneficiation and the waste disposal requirements is essential for determination of the potential environmental effects and for fulfilment of the Hearing mandate.

11 Well abandonment Waste Characterization and Management and Groundwater Monitoring Plans

On Feb. 6, 2023 Sio Silica submitted draft Well abandonment, Waste Characterization and Management and Groundwater Monitoring and Impact Mitigation Plans. It is far too late in the approvals process for the submission of these plans. Sio Silica states; "*Final versions will be completed during the final design stage of the Project and prior to operations commencing. They will incorporate any applicable conditions in the Environment Act License and any other authorizations, permits and approvals issued for the Project*." There is no provision for technical review by the TAC, third party experts and the public for these plans. This is unacceptable.

Some major issues with these plans that must be resolved are outlined below.

The well abandonment plan specifies; "*Wells are to be constructed such that: It prevents the interconnection or mixing of groundwater having distinctively different characteristics within the same aquifer or different aquifers*." Collapse of the shale aquitard would prevent the sealing of wells in a cluster to prevent mixing of carbonate and sandstone aquifer waters. This is an irresolvable problem that should prevent this Project from being implemented.

The Waste Characterization plan specifies the guidelines for the characterization of the ore and mine waste including the Mend Report by Price (2009).[125] It has been established above that the guidelines were not followed for the silica sand ore. This Project must not proceed until the guidelines to characterize the silica sand ore body are completed according to the guidelines.

The waste streams do not include the Winnipeg sandstone. This is a blatant unacceptable oversight. The Winnipeg formation as acknowledged by Sio Silica in response to CEC information requests contains concretions, oolite and shale interbeds that are documented in the literature to contain marcasite and pyrite that would cause acid drainage on the surface.[2,9,20] The concretions, oolite and shale interbeds were not subject to geochemical analysis. The three sand samples geochemically analyzed were improperly handled resulting unacceptable exposure to air and moisture. Sample Bru 95-3 was taken from an outdoor sand pile exposed to weathering for a year and half. The other two sand samples were outside the project area as documented above. Extensive sand sampling over the entire Project area must be completed and analyzed. It is essential that the waste streams include the Winnipeg sandstone. Ongoing regular geochemical testing of Winnipeg formation samples must be carried out during production after the initial silica sand ore characterization. If the initial characterization reveals significant acid generation potential a detailed plan must be developed for the handling of acid generating silica sand and imbedded acid generating wastes. Significant acid generation potential of the silica sand may be unmanageable in a production operation resulting in necessary termination of this Project.

The groundwater monitoring plan specifies monitoring of groundwater water quality without specifying what measurements would be made. Normally conducted well water tests for bacteria hardness and iron would be insufficient. Measurements must include all heavy metals including selenium, pH, nitric acid, carbonic acid, sulphuric acid, entrained gaseous and dissolved oxygen, electrochemical potential, benzene, total organics, total dissolved species, and total suspended material. These measurements must be made not only for monitoring wells but also on re-injected water at regular intervals. All measurements must be reported publically including on an easily accessible online form.

12 Subsidence

The Sio Silica extraction cavities could cause widespread subsidence over the Project area as documented below.

12.1 Stantec limit of 15 limestone thickness

Attachment A, Geotechnical Analysis for Sio Silica Extraction Project - Public Version, of the Sio Silica response to public comments gives a Geotechnical Analysis for Sio Silica Extraction Project. One recommendation based on the Stantec geotechnical anlysis is;

"*Limit extraction areas with competent limestone thicker than 15 meters*."

Sio Silica/Stantec Table 9 of Attachment A gives the extraction disturbance zone dimensions and the long-term Allowable limestone unsupported span diameter. The initial extraction zone dimensions and the long term allowable diameters are no more than 50 meters for limestone and overburden thicknesses typically found in the Project area. The EAP refers to extraction zones of 60 meters in diameter; therefore 50 meters should be a minimum allowed excavation diameter.

Figure 34 shows the limestone thickness taken from 44 well information reports for Sio Silica wells obtained from MB Groundwater.

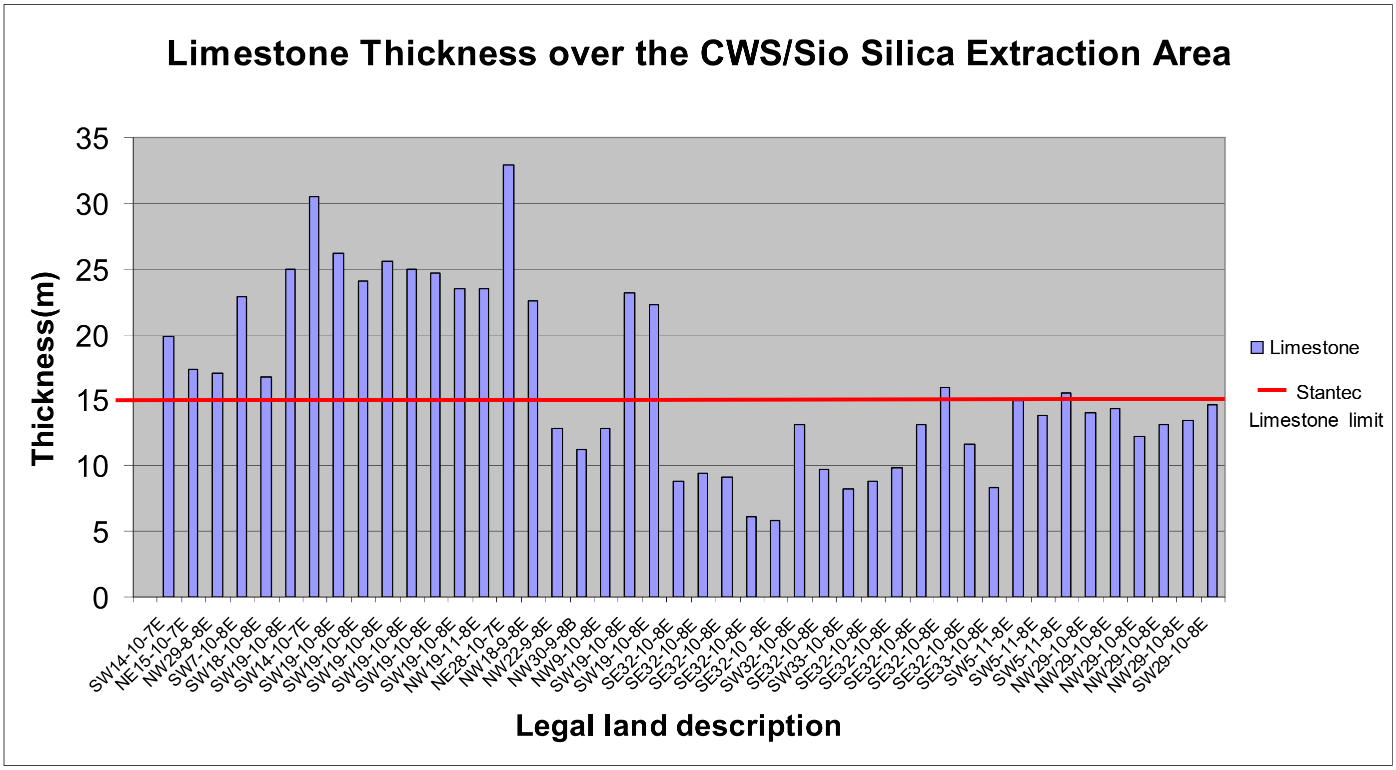


Figure 34. Limestone thickness for the Sio Silica extraction area.
Illustration from analysis by D. M. LeNeveu based on data from well information reports obtained from Manitoba Groundwater Section

All limestone thicknesses less than 15 meters on the right of figure 34 are in the area east of highway 302. Thus according to the Stantec recommendation to; "*Limit extraction areas with competent limestone thicker than 15 meters*," no extraction must occur east of highway 302,

12.2 Maximum allowable log-term cavity span

In the brief supporting the motions from DLN and WTFMB I used data from the public version of the Stantec geotechnical report of Jan. 14, 2022 posted in the response to public comments to develop equation 1 that predicts the long term maximum extraction cavity span based on the thickness of the limestone and overlying glacial till.

$$S = 1.5(L - 15) - 0.3(O - 25) + 35 \quad (1).$$

Equation 1 applies for limestone thickness greater than or equal to 15 m, the minimum allowable limestone thickness determined by Stantec. L is the limestone thickness in meters. O is the overburden thickness in meters. The cavity span calculated by equation 1 is compared in figure 35 to the Stantec maximum allowable cavity span from Table 9 in Attachment A of the Sio Silica Responses to Public comments in Project Registry 6119.00.

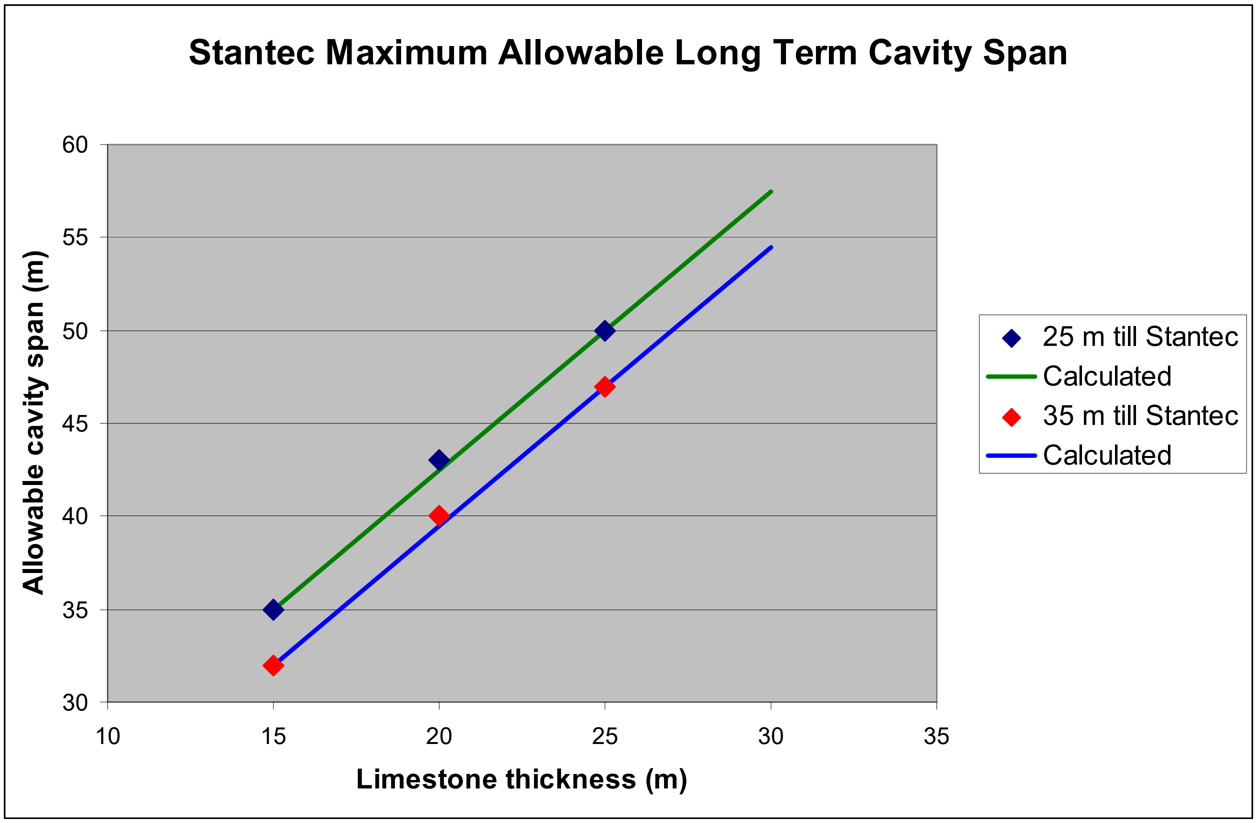


Table 9: Allowable Extraction Disturbance Zone Dimensions

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

Figure 35. Table 9 Stantec data for maximum long term allowable silica sand extraction cavity span compared to calculated values from equation 1.
Illustration from calculations by. D.M. LeNeveu based on Stantec Table 9 reproduced from Attachment A of the response to public documents in the project registry 6119.00

Figure 35 establishes that equation 1 provides accurate values for maximum allowable long term silica sand extraction cavity span for any limestone and glacial till thicknesses within the range of data over the 24-year Sio Silica Project area.

From equation 1 the long term minimum stable cavity span can be determined for any location within the 24-year Sio Silica Project area, given the till and limestone thickness. Using equation 1, and the Stantec limit of no extraction for limestone thickness less than 15 m, I determined the maximum allowable span diameters for the data obtained from the Manitoba Groundwater Section from 44 Sio Silica extraction wells over the 24 year project area as shown in the figure 36 below.

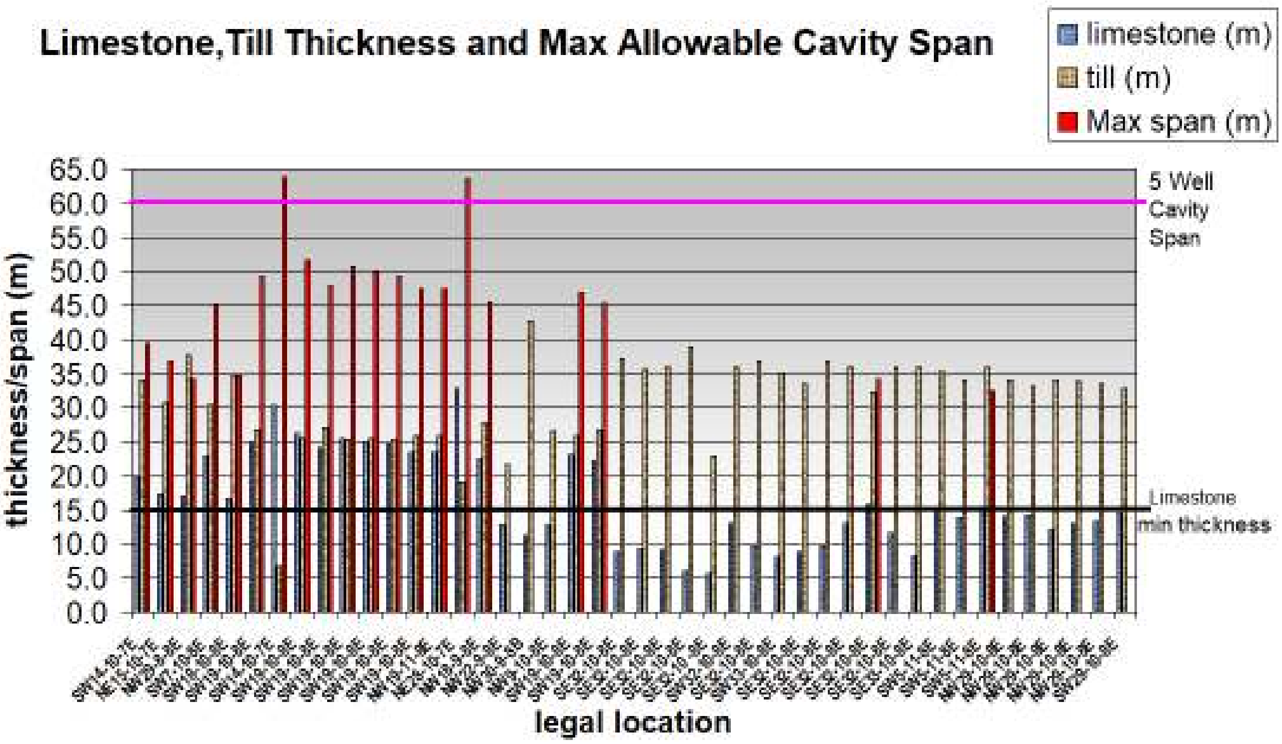


Figure 36. Limestone and till thickness and maximum allowable long-term excavation cavity span over the Sio Silica 24 year project area.
Illustration based on calculations by D.M. LeNeveu and data from Manitoba Groundwater well information reports and Stantec Table 9.

The data for figures 34 and 36 taken from Manitoba Groundwater well information reports, the Sio Silica Hydrogeological Report and calculated from equation 1 are given in table 4.

Table 4. Limestone and till thickness for Sio Silica wells in the Bru area

Well PID	Well name	Legal	Limestone thickness (ft)	Limestone thickness (m)	Till thickness (m)	Till thickness (ft)	Max Cavity Span (m)	Interbedded shale depth (ft)
197860	BH 10-17	SW14-10-7E	65.0	19.8	34.1	112.0	39.5	190-335
197858	BH 14-17	NE15-10-7E	57.0	17.4	30.8	101.0	36.8	
203674	BRU-154-2	NW29-8-8E	56.0	17.1	37.8	124.0	34.3	
197923	BH2-17	SW7-10-8E	75.0	22.9	30.5	100.0	45.1	253-232
197862	BH3-17	SW18-10-8E	55.0	16.8	34.7	114.0	34.7	237-277
200818	SITE 1 82-9	SW19-10-8E	82.0	25.0	26.8	88.0	49.4	

204171	BH 108-17	SW14-10-7E	100.0	30.5	6.7	22.0	63.7	122-192
204173	BH 9B-17	SW19-10-8E	86.0	26.2	25.6	84.0	51.6	
203688	BRU 82-11	SW19-10-8E	79.0	24.1	27.1	89.0	48.0	
199982	BRU 82-5	SW19-10-8E	84.0	25.6	25.3	83.0	50.8	244-250
197859	BRU9	SW19-10-8E	82.0	25.0	25.6	84.0	49.8	247-250
197863	BH9-17	SW19-10-8E	81.0	24.7	25.3	83.0	49.4	164-315
203678	BRU 82-14	SW19-10-8E	77.0	23.5	25.9	85.0	47.4	
203699	BRU 82-10	NW19-11-8E	77.0	23.5	25.9	85.0	47.4	
199984	BRU 28-1	NE28-10-7E	108.0	32.9	19.2	63.0	63.6	
199965	BRU 117-1	NW18-9-8E	74.0	22.6	27.7	91.0	45.5	
200861	BRU 121-1	NW22-9-8E	42.0	12.8	21.6	71.0	0.0	196-199
199972	BRU 126-1	NW30-9-8B	37.0	11.3	42.7	140.0	0.0	247-259
199980	BRU 73-1	NW9-10-8E	42.0	12.8	26.5	87.0	0.0	192-210
203682	BRU 82-8	SW19-10-8E	76.0	23.2	25.9	85.0	47.0	245-263
203691	BRU 82-6	SW19-10-8E	73.0	22.2	26.8	88.0	45.3	245-253
201401	BRU 95-3	SE32-10-8E	29.0	8.8	37.2	122.0	0.0	217-226
201400	BRU 95-2	SE32-10-8E	31.0	9.4	35.7	117.0	0.0	218-230
201399	BRU 95-1	SE32-10-8E	30.0	9.1	36.0	118.0	0.0	218-228
201159		SE32-10-8E	20.0	6.1	39.0	128.0	0.0	
201398	BRU 95-5	SE32-10 -8E	19.0	5.8	22.9	75.0	0.0	
205003	BRU 95-7	SW32-10-8E	43.0	13.1	36.0	118.0	0.0	237-245
205011	monitoring	SE32-10-8E	32.0	9.8	36.9	121.0	0.0	
205013	BRU 96-1	SW33-10-8E	27.0	8.2	35.1	115.0	0.0	
205016	BRU/MW20-01	SE32-10-8E	29.0	8.8	33.5	110.0	0.0	
HR*	BRU95-6	SE32-10-8E	32.2	9.8	36.9	121.1	0.0	
HR	BRU-95-7	SE32-10-8E	43.0	13.1	35.9	117.8	0.0	237- 246
HR	BRU95-8	SE32-10-8E	52.2	15.9	32.3	106.0	34.2	
HR	BRU95-9	SE32-10-8E	38.1	11.6	36.0	118.1	0.0	
HR	BRU96-1	SE33-10-8E	27.2	8.3	36.0	118.1	0.0	
205641		SW5-11-8E	49.0	14.9	35.4	116.0	0.0	
205588	BRU2020	SW5-11-8E	45.5	13.9	34.1	112.0	0.0	
205642	BH2C-20	SW5-11-8E	51.0	15.5	36.0	118.0	32.5	
206788	BRU92-2	NW29-10-8E	46.0	14.0	34.1	112.0	0.0	
207211	BRU92-3	NW29-10-8E	47.0	14.3	33.2	109.0	0.0	
206786	BRU92-4	NW29-10-8E	40.0	12.2	34.1	112.0	0.0	
207218	BRU92-6	NW29-10-8E	43.0	13.1	33.8	111.0	0.0	
207219	BRU92-7	NW29-10-8E	44.0	13.4	33.5	110.0	0.0	
208473	BRU92-8	SW29-10-8E	48.0	14.6	32.9	108.0	0.0	

* HR indicates data taken from the Sio Silica Hydrogeological Report

Note that all maximum long term cavity spans for limestone thickness less than 15 meters is set to zero in conformance with the Stantec condition that limestone thickness must be over 15 meters for extraction to occur.

For the documented limestone and till thicknesses a long term cavity span of 60 meters given in Document #1 – Silica Extraction Method of June 2, 2022 is too large for stability for almost all the wells in the 24-year Project Area. The design cavity span of 60 meters must be reduced considerably for the extraction design to be viable. The maximum allowable extraction cavity span must be determined anew for each extraction cluster location based on the local limestone and till thicknesses. The revised extraction plan of Jan 24, 2023 has variable number of wells per cluster up to a maximum of five. The revised long term allowable cavity spans for the clusters with different number of wells is not given. For the clusters with five wells, in the absence of further information the cavity span of 60 meters given in Document #1 would still apply.

However except for two locations SW14-10-7E and NE28-10-7E both north of the aqueduct about half way between highway 302 and highway 12, the cavity span of 60 meters for 5 wells would be unstable. The limit of 15 meters for limestone thickness would render only 20 locations of the 44 viable. Therefore over most of the project area figure 36 demonstrates that extraction cannot occur.

All the geochemical samples analyzed were taken east of highway 302 and are therefore not in the extraction area with limestone thickness greater than 15 meters. Numerous core samples and fresh silica sand samples, samples of concretions and shale samples taken lower in the sandstone area, and oolite samples must be taken from a wide area west of highway 302 where the limestone is thick enough to less the danger of subsidence. These samples must be protected from air during sampling and transport for laboratory anlysis.

In Attachment A, Sio Silica/Stantec Table 9 gives a long-term allowable limestone unsupported span diameter. The long term diameter is determined by arbitrarily increasing the initial short term diameter by 10 meters. No long term geotechnical engineering analysis of the slope stability has been given.

12.3 Revised Extraction Plan

On Jan. 24 2023 Sio Silica issued a revised extraction plan that is a wholesale departure from Document #1 – Silica Extraction Method submitted to the Hearing on June 2, 2022. The revised plan confirms my analysis of that 60 meter cavity spans are not viable based on the data from Table 9 of the Stantec report, given in the response to public comments section of the extraction EAP.

Attachment A of the revised extraction plan reproduced in Figure 37 does not contain information on the revised cluster cavity spans, cluster spacing, the year of extraction and the number of wells for each extraction year.

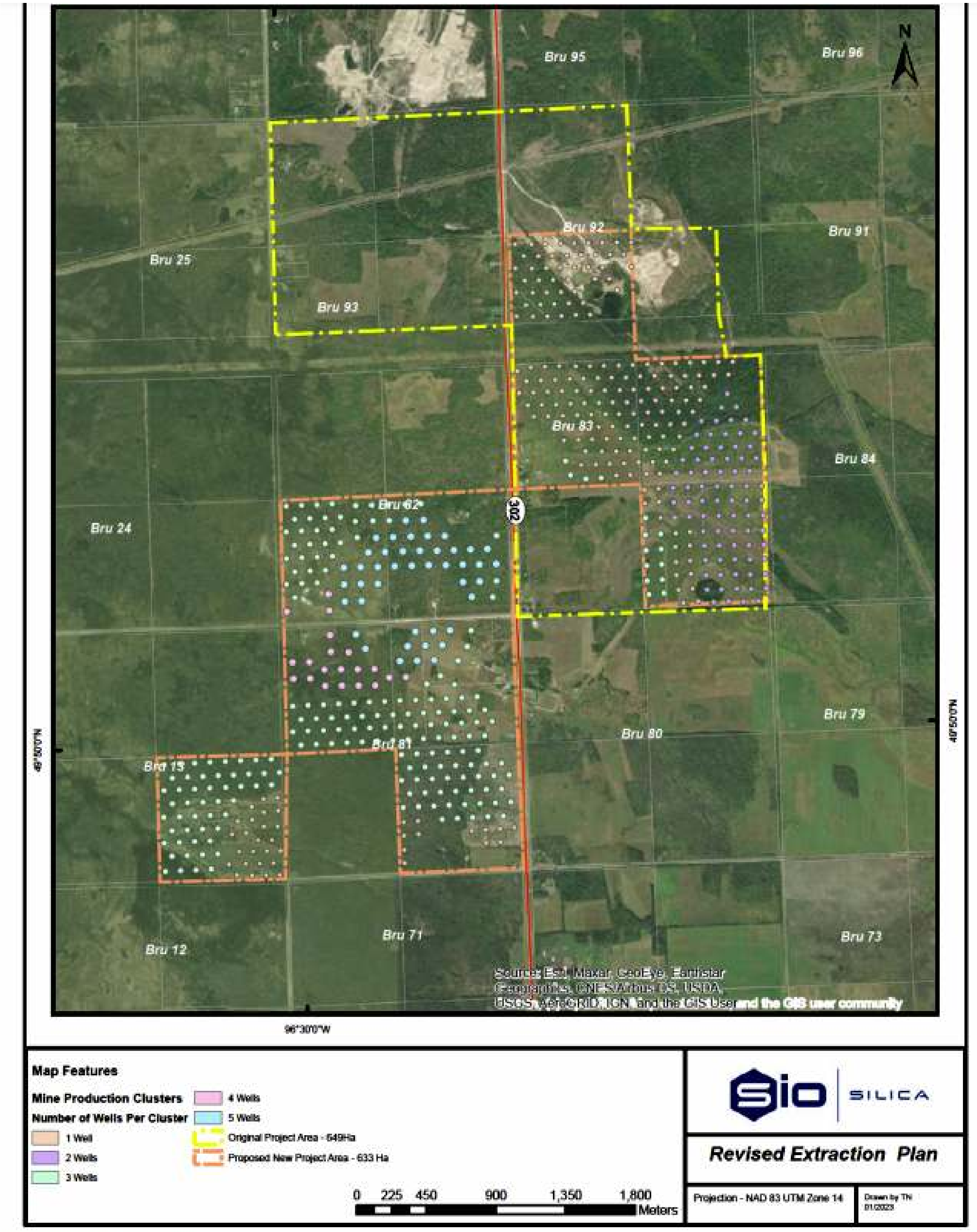


Figure 37. Sio Silica revised Extraction Plan of Jan. 24, 2023.
Reproduced from Sio Silica letter from Jesse Baker of Osler Law to the CEC.

The revised plan states;

"*The number of wells in each well cluster has also been reduced from seven wells to a variable number of wells, but less than six, depending upon cap rock thickness in the extraction area*;"

This statement is incorrect. The cluster size would depend on both the overburden thickness and the limestone thickness. The cluster sizes also depends on the geotechnical properties of the limestone and sand such as tensile and shear strength and the sand internal angle of friction and cohesion that are inherently variable and heterogeneous. The analysis used to determine the wells per cluster has not been disclosed by Sio Silica. It is essential that the geotechnical analysis for the revised plan of Jan. 24 be reviewed by the third party technical advisors and the participants. The introduction of a major project alteration for the essential extraction plan immediately before the Hearing with no expert review is unacceptable.

The Bru 82 area contains many clusters with five wells. The extraction plan of June 2, 2022 shows that five wells per cluster will result in cluster cavity spans of 60 meters. A 60 meter cavity span according to the analysis of the Stantec Table 9 data in the Bru 92 area is not viable area and would lead to limestone collapse as shown by the available data on the limestone thickness and overburden thickness in this area. The wells in area SW19-10-8E are within the Bru 92 area. According to the data in Table 4 these wells have maximum long term cavity spans of around 50 meters not 60 thus all 5 well clusters that would have cluster spans of 60 meters would be unstable and likely to collapse.

The clusters in Bru 92 area are all one well per cluster. Most of the wells in Bru 83 area are one or two wells per cluster with fifteen wells at three wells per cluster. The size of the dots designating wells are larger as the number of wells per cluster increase but no cluster dimensions are given and no rational or data is given as to the size of the clusters based on the cap rock thickness (limestone). The clusters with two wells per cluster in Bru 83 are primarily east and south of the wells with one well per cluster however the limestone thickness is known to increase in a westerly direction as shown in figure 5-B of the Appendix A Part 1 of the EAP. Thinner limestone should correspond to a decrease in wells per cluster. The eastern most clusters should have a lower number of wells. Similarly in Bru 82 most of the clusters with five wells per cluster are east of those with three or four wells per cluster. Sio Silica must provide the detailed data and analysis that support the number of wells per cluster in the revised cluster design of Attachment A.

There is no statement in the revised plan that the Stantec recommendation "*to limit extraction to areas with competent limestone thicker than 15 m*." is rescinded. All the well information reports east for Sio Silica wells east of highway 302 show limestone thickness less than 15 meters. The well information reports for Bru 92-8 Bru 92-2 and Bru 92-3 that are closest to area Bru 92 of the revised extraction plan have total limestone total thicknesses of 14.6, 14.0 and 14.2 m respectively. Thus according to the Stantec recommendation the wells in the revised extraction plan of east of highway 302 are not valid.

There is no information in the revised plan as to the methods that would be used in the field during production to determine the number of wells per cluster and cluster spacing. Asymmetric extraction cavity shapes must be considered in the geotechnical modeling for determination of cluster spacing in the field. There is no method to determine the cavity span breadth during the sand extraction operations to ascertain in maximum cluster spans are being adhered to. For instance cluster with 5 wells according to the extraction plan of June 2022 would normally result in cavity spans of 60 meters that would be unstable over almost the entire Project area as shown in figure 36. Thus stability of the extraction cavities cannot be assured. The incomplete revised cluster completed at an unacceptable late date is deeply flawed and must not be allowed to be the basis of production operation.

12.4 Sand Pillar Stability

Sio Silica has given no data on the determination of sand pillar stability. Sio Silica states that the FLAC two dimensional geotechnical software was used by Stantec in the stability analysis. The complex sand pillar geometry is inherently there dimensional, however online information on the FLAC software gives examples of how the FLAC and FLAC/Slope 2D models can be used to represent three dimensional room and pillar geometry.[117] The results of 2D analysis must be considered approximate given the inherent simplifications in reducing three dimensional complex geometry of numerous adjacent cavities with sand pillars between to a two dimensional approximation.

The FLAC/Slope software requires input data including bulk modulus, shear modulus cohesion, friction angle and tensile strength of the sand. Sio Silica has given no information on how these data were measured for the sand. Sio Silica must provide the information on the sand samples taken to provide this data and what tests were done and where, to obtain the required data.

Hollander and Woodbury's concern about liquefaction of the sand pillars has not been adequately addressed by Sio Silica. Sio Silica must give revised cluster spacing for the various sized clusters in the revised extraction plan and describe how the spacing was determined based on the FLAC modelling. An illustration of the FLAC/Slope analysis of a 2D pillar stability for a rock cavity that is being progressively mined is illustrated in figure 38.

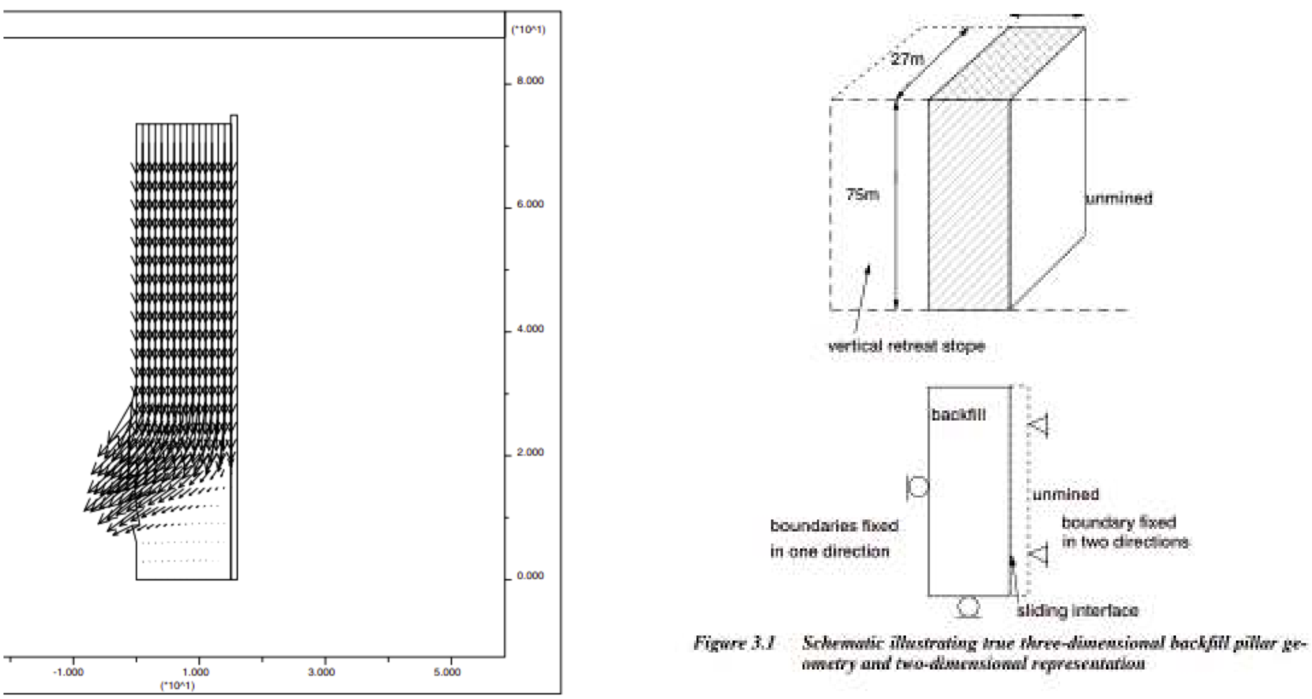


Figure 38. FAC modelling of the slumping of a backfill pillar in a rock mined cavity [116]
https://itasca-downloads.s3.amazonaws.com/software/applied-examples/BackfillPillar_Ex.pdf

It should be noted that the cavity in the illustration is rectangular in shape whereas the cavities from sand extraction would be approximately cylindrical with curved surfaces that would render any 2D approximation more uncertain. Sio Silica should provide a similar illustration for the revised extraction plan including an illustration of the evolution of the sand pillar slumping and the final stable pillar configuration. Such an illustration as shown above need not contain any proprietary information.

The departure from the extraction plan in the Sio Silica Document #1 – Silica Extraction Method of June 2, 2022 is a major alteration. Document #1 was issued long after the Stantec Table 9 data given in January of 2022 in the response to public comments of the extraction EAP. That Sio Silica has made a major alteration to the extraction plan of Document #1 at this late date, when the previous data from Stantec Table 9 illustrated cavity spans of 60 meters are not viable, demonstrates that Sio Silica's extraction plans and methods are not properly established. Sio Silica has provided no data on the revised cluster cavity span other than un-dimensioned size of dots on the attachment A of the revised extraction plan. Sio Silica must provide detailed data on the size of the cluster cavity span and the method of determination of this span length and cluster spacing based on a revised Stantec geotechnical analysis. This new Stantec analysis for cluster cavity span and cluster spacing must be reviewed by the third Party technical advisors since the technical review of the Stantec analysis for Document #1 is no longer valid.

Sio Silica should be required to supply the well and borehole data on the limestone and overburden thickness in the Bru areas shown in Attachment A of the revised extraction plan upon which the number of wells per cluster was based. This data is not proprietary. We have already obtained the well information data from Manitoba Groundwater on 44 Sio Silica wells and data from Mines on many Sio Silica boreholes

12.5 Cover Collapse

If there are any areas with competent limestone thick enough for stability cover collapse sinkholes and cover subsidence can occur as described by the USGS.[29] The unconsolidated till overburden can migrate through limestone fractures into the cavity in the sandstone created by silica sand extraction. Acid produced in the sandstone from oxidation of sulphide by re-injected water can enter the limestone after degradation of the shale aquitard. Acid is known to increase the width of fractures in the limestone contributing to the till migration through the fractures.[29] The stress of drilling seven wells in close proximity in the well clusters and the stress on the unsupported limestone above the excavation cavity could increase the limestone fracturing. Cover collapse and cover subsidence is illustrated in figures 39 and 40. The potential occurrence of cover subsidence and cover collapse sinkholes cannot be dismissed and should disqualify the entire project from being viable.

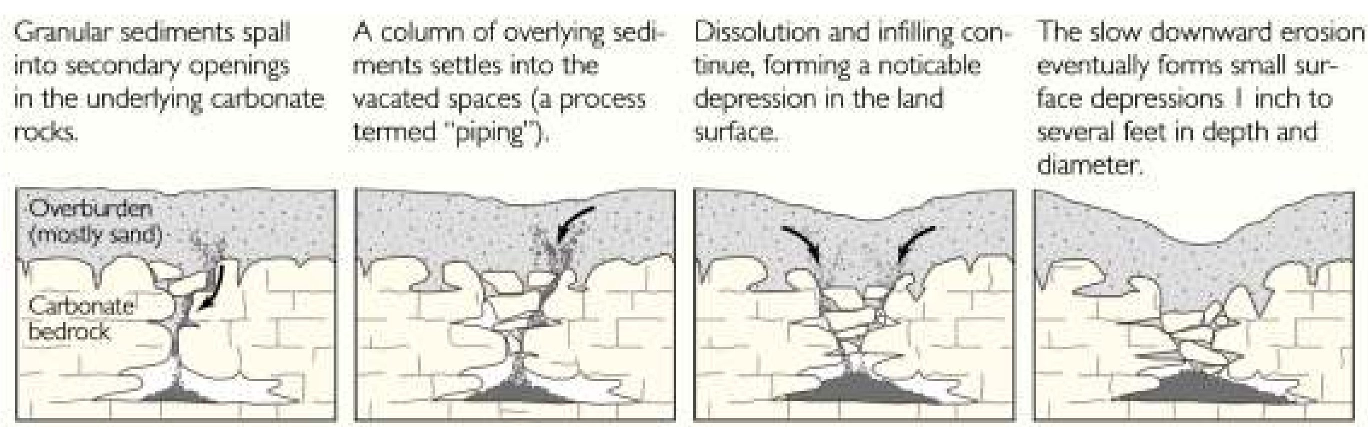


Figure 39. Cover subsidence sinkhole into a cavity in limestone.
The image is from US Geological Survey (USGS).[29]

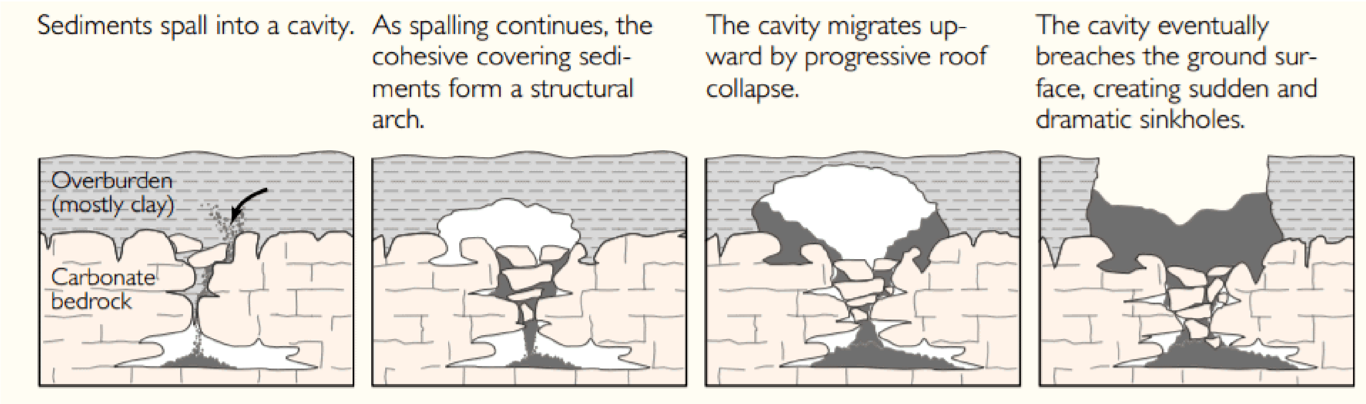


Figure 40. Cover collapse sinkhole into a cavity in limestone.
The image is from USGS.[29]

12.6 Evidence for Subsidence

An example of subsidence has occurred in Sheridan, Wyoming for an underground coal mine abandoned in 1921.[40] The mined coal cavities were under a solid supporting coal layer covered by overburden analogous to the Sio Silica sand extraction cavities under solid limestone covered by glacial till at Vivian. At Sheridan the cavities were supported laterally by solid coal pillars. At Vivian the cavities would be surrounded by unconsolidated sand that would not be supporting. Thus subsidence at Vivian would therefore be more likely than has occurred at Sheridan. The general subsidence is punctuated by deeper sinkholes at Sheridan as shown in figure 41 taken from the Geological Survey professional paper describing subsidence at Sheridan in the Powder River Basin.[40] Figure 41 foretells the future landscape at Vivian.


Figure 41. Subsidence and sinkholes at Sheridan,Wyoming from an abandoned underground coal mine[40]
The Figure was reproduced from Effects of Coal Mine Subsidence in the Sheridan, Wyoming, Area By C. Richard Dunrud and Frank W. Osterwald Geological Survey Professional Paper 1164, 1980

The carbonate and sandstone aquifers would be exposed to contamination from agricultural chemicals, animal fecal matter, septic tank seepage and surface that would runoff into the subsided depression and sinkholes.

The stability analysis including the potential for cover subsidence and cover collapse sinkholes should have been thoroughly investigated at the onset of the project as part of the mine closure report that is required under the Mines and Minerals Act of Manitoba prior to commencement of advanced exploration.[96] The

Manitoba Mines Branch and the Environmental Approvals and Licensing have been negligent in not requiring the mine closure analysis prior to commencement of advanced exploration activities. On July 22, 2020, Don Sullivan, Spokesperson for What the Frac Manitoba sent a letter to the Hon. Blaine Pedersen, Minister of Agriculture and Resource Development informing him of the requirement of the Mines and Minerals Act for a filing of a mine closure plan for advanced exploration stipulated under the act under the definition of advanced exploration regarding the removal of a bulk sample of at least 500 tones of material for testing. Sio Silica has removed far more than 500 tonnes of sand for testing running advanced exploration. The Minister did not and has not responded to the letter. In January of 2021, Don Sullivan and I submitted separate complaints to the Manitoba Ombudsman about the failure of the Agriculture and Resource Development and the Mines Branch to enforce the provisions of the Act. The Office of the Ombudsman accepted the complaints but has failed to act upon the complaints. The Mines Branch and Environmental Approvals and Licensing may be liable for loss investments that have occurred for a project that was not viable from the onset for geo-mechanical stability reasons. Should the project be licensed and subsidence eventually manifest as documented here the EAB and the Mines Branch could be liable for all damages incurred by subsidence caused by Sio Silica extraction operations.

13 UV Radiation and Microbial Treatment

Sio Silica in the extraction EAP claims a UV radiation will be used to destroy any potentially harmful microorganisms in the water that will be returned to the aquifer. No engineering drawings or detailed plans were given for this UV radiation process. In my submission to the public comments in the project registry I provided evidence that filtration must be used to remove suspended particles that would scatter UV light rendering the treatment ineffective.[33,34] on of June 24, 2022 Sio Silica submitted Supplemental Filing #3 to the CEC Hearing that describes the process wastewater treatment options to remove fine particulates hat would scatter UV light. The process water treatment options include, vortex grid removal, hydrocyclone solid separation, gravity clarifier, lamella clarifier, chitosan enhanced filtration (CESF), cloth filtration and filtrate and sludge drying beds.

The process treatment option report states;

"*CESF system consists of two parts: settling basin where the polymer precipitates the solids that settle out and a sand filter where the remaining solids are retained. It is equipped with automatic recirculation of non-compliant discharge water to keep water discharge in compliance and comes with an enclosed sand filter complete with automatic and manual backwash functions. The CESF can only accommodate an influent of approximately 1,000 mg TSS/L. That necessitates an additional treatment step prior to CESF. SECURE offers additional clarification module equipped with turbidity curtain that could be installed prior to CESF and could treat the effluent coming from the hydrocyclones for example. The effluent from CESF is expected to meet 75 mg TSS/L. A bag filter system with 5 or 1 micron filter bags would be able to remove the residual suspended solids from the water and meet the water quality goal needed for UV treatment*."

According to information from the US EPA the filters typically must be backwashed approximately every 30 hours of operation.[35] The effluent from the backwash must be disposed of. The city of Winnipeg has a UV radiation system project managed by AECOM.[38] The effluent from backwash is sent to a settling pond and the settled sludge is transported to landfill.[37] The liquid from the pond is sent to the sewage plant for disinfection and treatment before release.[37] The process treatment option report does not describe the filter back washing fluid and used filter disposal requirements. The water required for backwashing of filters could be filtered water from the aquifer. A settling pond would contain a large amount of aquifer water that if not returned would be a drain on the aquifer.

The Process Water Treatment Options technical memorandum states;

"*The raw process wastewater is expected to have a solids concentration of 18,500 mg TSS/L, which will then be reduced to approximately 10,000 mg/L and directed for treatment. This is a relatively high concentration. The flow is expected to range from 1,100 m^3/d to a peak of approximately 6,000 m^3/d.*"

Appendix H of the Hydrogeological report gives the average water to sand extraction ratio as 50% and the extraction time at full production of 1.36 million tones of dry sand as 224 days. The average water flow rate assuming a dry density of sand of 1.65 t/m^3 would be $1.36x10^6$ t/1.65t/m^3/224d = 3,679 m^3/d which is within the range of 1,100 m^3/d to 6,000 m^3/d given in the technical memorandum. The concentration of solids for treatment of 10,000 mg/L is equivalent to 10 kg/m^3. Using a water flow rate of 3,679 m^3/d, the solids to be removed before UV treatment would be an expected maximum 10kg/m^3 x 3679 m^3/d = 36,790 kg/d. For 224 extraction days 8,241 tonnes of solid sludge per year would be required to be removed prior to UV filtration.

The removed solids are to be spread on drying beds as is conventionally done to dry municipal wastewater sludge as illustrated below.[113]

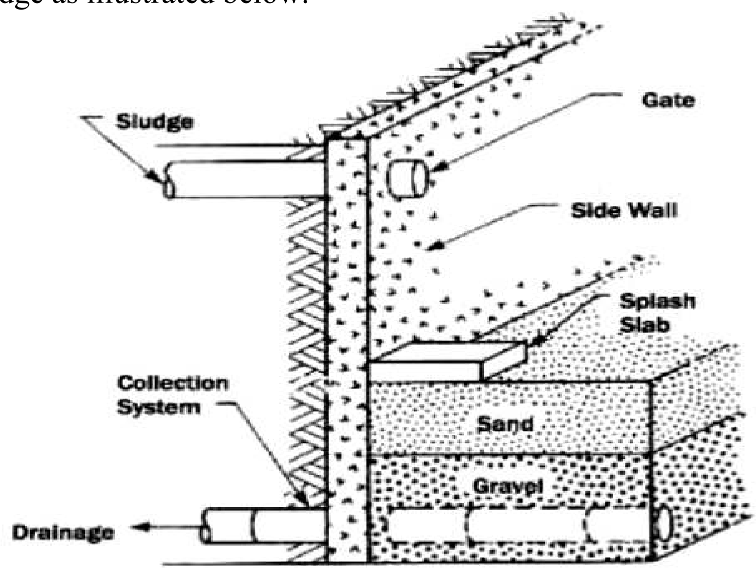


Figure 3.23 Conventional sand drying bed. (Plan from Metcalf & Eddy, 2003.)

Figure 42. Cross section of a sand drying bed[113]

Presumably the drying bed area will be reused several times per year. The total mass of solids spread on the drying bed for each drying cycle can be determined from the total mass of solids per year divided by the number of drying cycles per year. The number of drying cycles can be determined from the total number of drying days per year divided by the average recycling time for the drying bed. The average recycling time would include the bed drying time, the spreading time and the solid sludge removal time. If two beds of the same size are used one bed can be prepared during the drying time of 3 to 4 days given in the technical memorandum. The process water treatment options memorandum states;

"*Draining time is typically 3 to 4 days. Applied sludge depth should be 200 mm to 750 mm for coagulant sludges*."

Using a recycling time of 4 days for one of the beds, 56 cycling periods would be required in 224 days of sand extraction. The mass of solids per bed would be 8241t/56=147.2 tonnes. The actual total mass of solids could be larger than 8241 tonnes depending on the amount of water extracted with the sand for which CWS/SS has not provided measured data. The number of drying bed cycles would be considerably less that 56 due to rainfall. Using the solid loading rate of $2.4kg/m^2$ from the technical memorandum, the area of each bed would be $147200kg/2.4kg/m^2 = 61{,}333\ m^2$ or 6.1 hectares. For two beds the area would be 12.2 hectares.

The drying beds are typically constructed with impermeable sides and bottom with layer of gravel containing drainage pipes with a layer of sand about 0.3 meters thick on top.[110,111] The mass of dry sand required for one drying bed at $1.65\ t/m^3$ density would be $61{,}333m^2 \times 0.3m \times 1.65t/m^3 = 30{,}360$ tonnes. Some of this sand would be removed with the fine silica sand sludge on top. About 2.5 to 5 cm of sand would be removed along with the solids sludge when the bed is cleaned for the next drying cycle.[114] Using 3 cm of underlying sand removed for 56 drying cycles another $61{,}333m^2 \times 0.03m \times 1.65t/m^3 \times 56 = 554{,}400$ tonnes of sand would be required per year for a total of 170,015 tonnes of sand to be disposed of per year which is 12.5 % of the total amount of silica sand extracted per year. The size of the drying beds required according to the example calculation and the amount of sand disposed of and replenished for the drying beds per year is clearly unfeasible.

The example analysis performed here for drying bed size assumes optimal drying conditions. Periods of rain and lower evaporation rates in the cool weather of spring and fall would increase drying times, decrease available drying days and increase the required size of the drying beds and the amount of underlying sand disposed of. Measurements of the actual amount of water withdrawn with the sand have never been documented by Sio Silica. An increase of the average water content withdrawn with the sand over 50% would also increase the size of the beds and amount of underlying waste sand. The example calculations given here are an underestimate of the resources required for the drying beds. Clearly the drying bed requirements are unfeasible.

In response to the DLN IR 007 on process water treatment Sio Silica stated;

"Sio *is also exploring other options such as a filter press which have a far smaller footprint*."

This implies that Sio Silica has recognized and accepted that drying beds are impractical and cannot be used.

One disadvantage of filer presses is the chemicals that must be used to coagulate fine particle for the filter press to operate efficiently.[110,111] Ferric chloride is commonly used for chemical treatment of filter presses however ferric chloride cannot be used for drinking water sources due to its toxicity.[112] Polyelectrolyte such as polyacrylamide are also used for flocculants in filter presses[110] however the acrylamide monomer that appear as a manufacturing residual and from degradation is extremely toxic as documented in DLN IR 003. For this reason, the Process Wastewater Treatment Options, Technical Memorandum states, "*chemicals aiding in the treatment process used commonly for coagulation and flocculation of solids are not allowed*."

The non toxic chitosan polymer recommended for use in the Wastewater Treatment Options, Technical Memorandum states is a polysaccharide composed of glucosamine monomers. Residual glucosamine from manufacturing or degradation is soluble and would be transferred into the aquifer as documented in DLN IR 007.[115] The clarifier removes only suspended solids not dissolved. Dissolved components would be sent into the sandstone aquifer with the process wastewater. Glucosamine and soluble degradation products in the aerated re-injected water would promote the growth of microbes that could be harmful. Glucosamine itself is not toxic could adversely affect the water quality.

Dr. Matt Kowalski, author of the Sio Silica Supplemental Filing #3 of June 24, 2022 establishes the requirement for pilot testing of the process wastewater treatment options. Dr. Kowalski recommends;

"*Due to uncertainty in the settling ability of the solids and unique characteristic of the wastewater it is recommended to pilot some of the recommended treatment options in order to assess the efficiency of the equipment treating the process water before proceeding with final equipment selection. It is especially recommended to pilot trial test the hydrocyclones and mobile/lamella clarifiers*."

The pilot testing must include measurement of the process water quality to be re-injected into the sandstone aquifer following treatment. Suspended and dissolved contaminant concentrations including, total suspended solids, including iron, manganese, organics and remaining sand fines, total dissolved material including selenium, heavy metals, acid, benzene, PAHs, chitosan monomer (glucosamine), and other dissolved organics, dissolved oxygen, entrained air, and total microbes including fungi and fungal spores should be measured in the process water and reported before and after treatment.

The amount and properties of all waste streams for the process water treatment should be recorded and determined as a function of the amount of sand extracted. Comprehensive geochemical testing and contaminant content of the waste streams should be completed and reported. The pilot testing of the process water treatment should be done in conjunction with the field testing of silica sand extraction.

It would be necessary to measure the effluent from the filtration and overs for acid drainage potential. Should the effluent and overs have acid drainage potential specialized disposal such as for the waste ore at Snow Lake that is deposited in Anderson Lake.[39] Sio Silica has been negligent in not considering and designing the filtration and effluent disposal system for the UV filtration system. The engineering specifications and design cannot be left to future development and must be completed prior to receipt of a licence. It may well be filtration and disposal required for the UV system is not feasible for this project with the high throughput of water and the large volume of suspended sand that must be filtered and disposed of.

It would also be necessary to test all the water returned to aquifer for acid and other contaminates such as heavy metals. It may well be that return of aquifer water is not feasible due to the large amount of sulphide in the sandstone aquifer documented in this report.

Even if the UV treatment could be made feasible microbial contamination could be introduced into the aquifer through the over 342 extraction wells per year and the injected air.[19] Manitoba Groundwater and Water Well regulations require chlorination of well drilling operations however complete disinfection of hundreds of all the well casings, rotary drills and drill mud used in the extraction operations is dubious.[54]

The City of Winnipeg uses chlorination to disinfect the water. The Manitoba Groundwater and Water Well regulations require the water discharged from open loop geothermal operations to be chlorinated.[54] Sio Silica could be required to chlorinate the re-injected water as well as expose it to UV light. Introduction of large amounts of chlorine to disinfect drilling operations and re-injected well water would have a detrimental effect of water quality. Chlorine is known to lower the pH and promote release of heavy metals such as arsenic.[47]

The large amount of air introduced into the aquifers as documented here would provide an ideal environment for introduced iron bacteria and other harmful microbes to thrive.[17] This project must not be allowed to proceed based on the harmful microbial activity that would be introduced through Sio Silica operations.

14 Aquifer contamination from operation of the air compressor

My public comments submission for the processing plant, registry 6059.00 documented how air compressors can contaminate the compressed air from oil leakage. In the response to public comments for the processing plant project Sio Silica stated;

"*The air from compressors are used daily in water well drilling throughout Manitoba with no leaking of oil. The air is scrubbed of all particles and materials and oil less dry screw compressors are available*."

Sio Silica did not state that they used oil free compressors in their advance exploration activities.

In an article in the Carillon of Nov. 16, 2021, Mark Wowchuk, former site manger for the CanWhite project reported that oil from the compressor leaked into the aquifer.[53] B. Bullen, Chief Operating Officer of CanWhite denied that contamination occurred.

Introduction of contaminants into the aquifers is forbidden by Part 3 section 28 and 29 of the Manitoba Groundwater and Water Well Act.[54] Sio Silica has been injecting air into the aquifers since 2017 or perhaps earlier.

In the response to public comments Sio Silica states;

"Air compressors used to facilitate sand extraction will be oil-less and therefore will not introduce any oil contaminants. All wells comprising a 'cluster' will be serviced by one rotary screw, oil-free compressor for the duration of operation."

A white paper by M. White, Parker Company Compressed Air Treatment Manager, describes that oil free compressors require oil external to the compression chamber for cooling.[55] Vaporized oil from the oil breather will be sucked into the compressor and concentrated. Therefore the air output from oil free air compressor is not oil free. Exhaust vapours from nearby diesel powered drill rigs and Sio Silica vehicles, slurry line handling equipment and vacuum trucks would be drawn into the compressor and concentrated. According to the white paper the concentration of vapours is a factor of 8 at 7 bar compression and a factor of 40 at 40 bar compression.[55] Sio Silica has not disclosed the air pressure required for the air lift extraction. The pressure would have to be greater than the hydrostatic pressure of the aquifer which would be at least 5 bar. More pressure would be required to generate pulses to loosen the sand or for direct air injection to the sandstone to mobilize the sand as described in the Sio Silica patent.[1] When equipment exhaust is drawn in from nearby equipment the outlet air contamination would be very high.

The white paper describes how as the compressed outlet air cools vapour condenses into liquid water and oil. Some compressors have a water separator or wet air receiver for liquid reduction. These waste liquids would require disposal. The white paper notes that water separators reduce liquids only and are not effective at reducing vapours and gases and would not remove 100% of the liquid. The vapour would include carbon monoxide, diesel fumes, unburned diesel fuel, nitrous oxides and many other toxic organic vapours from the diesel drill rigs, the compressor trailer, and other Sio Silica equipment. Table 6-3 of the Sio Silica extraction EAP gives the total GHG equivalent emissions from all the sources at the drill site to be 6.8 kt tonnes per year demonstrating that there will be significant exhaust emissions drawn into the air compressors, concentrated by a factor of 8 or more and injected into the aquifer.

There is industry literature on complex systems to remove organic vapours, particulate and liquids from compressed air systems to protect employees that could breathe the air.[56] These are multistage filters such as, a coalescing filter to remove liquid oil droplets from the air stream, a catalytic converter to convert any CO present into CO_2, an activated carbon filter to remove aerosolized oils and/or hydrocarbons from the air stream, and a final filter to remove any remaining solid particulates from the gas stream. Such complex multistage filters requiring continual maintenance and production of filtration wastes are likely not feasible for the large scale high through put air injection system required for the Sio Silica extraction operations. Sio Silica has certainly not developed or demonstrated the feasibility of such filtration systems that would be required for their operation.

The Sio Silica EAP states;

"*Project activities are expected to affect air quality due to dust generated by movement of drilling rigs and other mobile equipment, and due to exhaust emissions including nitrogen dioxide (NO_2), carbon monoxide (CO) and sulfur dioxide (SO_2). The exhaust emissions and dust generated from mobile equipment can have adverse effects on human health, wildlife and vegetation.*"

According to Table 6-3 of the extraction EAP the air lift extraction method uses an Oil Free Rotary Screw Air Compressor. Industrial literature documents that the compressed air from oil-free air compressors can contain contaminants such as microbes, organic vapours such as diesel fumes and oil vapours from the compressor oil breather and particulate. The compressor concentrates contaminants found in the ambient air around the compressor.[104,105] The extraction EAP states that a diesel powered air compressor will be used.

A typical air compressor is rated at 90 kW for up to 125 psi.[106] The compressed air must be at least 125 psi to overcome aquifer fluid pressure at depth and to provide extra pressure to loosen sand as described in the Sio Silica patent reproduced in Supplementary Information, Silica Extraction June 2, 2022.

The diesel fuel consumption for a rotary screw compressor can be calculated by 0.238 L/(kW.h) x 90 kW= 21.4L/hr.[107] Using 0.0214 m^3/hr one air compressor for a well cluster operating for 5 days would consume about 2.568 cubic meters of diesel fuel. Each cluster has five extraction/injection wells. Assuming one compressor per well the total diesel fuel consumption for one extraction cluster would be 12.84 cubic meters

The Canadian NPRI emission factors are given in the table below. [108]

Table 5. NPRI emission factors [108]

Substance	NPRI emission factor (kg/m^3 of diesel fuel)
SO_2	4.761
NO_2	72.396
benzene	1.532×10^{-2}

The Sio Silica target sand production for one well cluster is 21000 tonnes. Using a density of the sand of 1.65 tonnes/cubic meter and a porosity of the sandstone of 0.25, the volume of the extraction cavity is estimated to be 21000 tonnes /1.65 tonnes/cubic meter /0.75 = 16970 cubic meters. Note Sio Silica has not specified the value for the sand dry density. The value of 1.65 tonnes/cubic meter is used as a reference example.

The concentration of the contaminant in the well cavity would depend on the capture fraction transferred to the aquifer of the air compressor for diesel emissions which is unknown. The capture fraction would be enhanced by the compressor action of concentrating the concentration of contaminants in the air. It is well known that both SO_2 and NO_2 in water will form acid, hence acid rain. Nitrous oxide (NO_2) will dissolve in the water in the excavation cavity to form nitric acid and nitric oxide according to the formula,[109]

$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$.

Nitric acid, HNO_3, is a strong acid that will almost completely dissociate. Three moles of NO_2 forms two moles of nitric acid in water.[109] Microbes can denitrify NO_3^- to produce N_2O and N_2 gasses that may decrease the amount of nitric acid over time.[129] However nitrates could act to stimulate harmful microbial growth.

The overall chemical formula for production of sulphuric acid in water is;[109]

$2SO_2+O_2+2H_2O \rightarrow 2H_2SO_4$.

One mole of SO_2 would produce one mole of H_2SO_4. Air injection in the air-lift silica sand extraction process would provide the source of oxygen required for the formation of sulphuric acid.

Carbon dioxide from the burning of the diesel would also be transferred to the aquifer according to the conversion ratio of 2.7 kg of CO_2 per litre of diesel fuel. CO_2 will form carbonic acid in water. Only a small portion of the CO_2 dissolved forms carbonic acid that may be buffered by bicarbonate in solution, therefore the pH cannot from CO_2 dissolution cannot be determined.

Acid production would be buffered by the bicarbonate concentration in the sandstone aquifer that ranges from 226 to 532 mg/L, however the dissolved CO_2 could diminish the buffering capacity of the groundwater.[98] A detailed chemical speciation calculation is required to estimate the resulting acid concentration in the aquifer.

Table 6 gives the estimated acid and benzene concentration in an extraction cavity from air injection

Table 6. **Estimated contaminant concentrations in the extraction cavity for 12.84 cubic meters of diesel fuel used for each well cluster air compressor and a cavity volume of 16970 cubic meters.**

Substance	Capture fraction	Aquifer Concentration (mg/L)	pH for $3M\ NO_2 \rightarrow 2M\ HNO_3$ and $1M\ SO_2 \rightarrow 1M\ H_2SO_4$	Capture fraction	Aquifer Concentration (µg/L)	pH
SO_2	0.1	3.60	4.25	0.01	360	5.25
NO_2	0.1	54.8	3.10	0.01	5480	4.10
CO_2	0.1	204	-	0.01	20400	-
benzene	0.1	1.16×10^{-2}	-	0.01	1.16	-

The allowed limit of benzene in drinking water is 5µg/L.[130] An air compressor capture fraction transferred to the aquifer of about 4.3% could result in benzene contamination. Even a very low 0.1% of capture of NO_2 from the exhaust fumes of the diesel generator for the air compressor could result in a strong acid depending on the amount of buffering in solution. Dissolution of heavy metals such as arsenic into the excavation cavity would occur with acidification of the groundwater of the aquifer. These calculations do not include emissions from the drill rigs and Sio Silica vehicles and equipment which would increase the contamination of the aquifer. Contamination by microbes is also not included.

These calculations and references establish that filtration of the air injected into the sandstone aquifer is required.

In response to information request DLN IR001 concerning the contamination of the aquifer by diesel fumes from Sio Silica extraction equipment Sio Silica replied,

"*With respect to air emissions, the vehicles and equipment used for Project activities (listed in Table 2-1 of the EAP) would not all be operating simultaneously and will move around the Project Site as extraction wells are drilled and progressively decommissioned. This equipment is also not all concentrated in one small location, nor is there a large volume of equipment. Where possible, equipment will be electrified thereby further reducing the potential for emissions. For these reasons, Sio concluded that this equipment and activity would not cause significant air quality impacts*."

The total GHG emissions for the equipment and vehicles at the processing facility given in Table 9 of the EAP for the processing facility are 1088 tonnes CO2e per year. The total GHG yearly GHG emissions for an extraction site from Sio Silica equipment exclusive of indirect emissions from hydro power given in table 6-3 of the extraction EAP is 6785 tonnes CO2e per year, 6.24 times the emissions from the processing facility. An air quality study was completed for the processing facility that has about the same surface area as a yearly extraction site. The maximum NO2concentration at the edge of the processing facility from the air quality modelling study was 95 $\mu g/m^3$. Thus the expected NO2 concentration at the edge of the extraction site would be expected to be 95x6.24 = 593 $\mu g/m^3$, which is well above the allowed limit of 200 $\mu g/m^3$. The concentration near the emitters especially the extraction rigs housing the diesel powered compressors would be much higher. Thus the contention by Sio that there would not be significant air quality impacts within the extraction site is contradicted by a direct analogy to their own air modelling studies for the processing facility. This is another example of Sio Silica's habit of issuing unsupported statements with no evidence that are contradicted by the available evidence.

Compressed air can also introduce microbes into the aquifer. Moisture concentrates in the compressor. The warmth and moisture provide an ideal environment for microbial proliferation. The heat of the compressor chamber would not necessarily kill all microbes and spores.[55,56] The air injection tube could harbour microbes. Continual disinfection of the air tube may not be practical. Large air drier systems can be used to minimize the microbial content of the compressed air.[78] Such systems are expensive and require continuous maintenance that might not be practical in the continuous outdoor high flow operation of the well clusters. Sio Silica has not addressed the potential microbial contamination from the continuous use of air compressors. Sio Silica has no mitigation measures planned to eliminate this risk.

Without adequate counter measures contaminants and microbes would enter the aquifer continuously from compressed air injection for several Sio Silica clusters operating simultaneously 24/7 all year excluding only the winter months. Sio Silica must be required to develop and demonstrate the feasibility of an effective system to remove all potential contaminants and microbes from the compressed air before this project can proceed. The compressed air decontamination must be engineered to operate effectively at all temperatures including during winter extraction that Sio Silica has stated may occur. Documented tests and measurements must be done and disclosed on the level of residual air contamination and microbes from such tests. Tests must include nearby exhaust emissions of various concentrations.

15 GHG cumulative Effects

The Sio Silica extraction EAP states;

"*Overall, the Project is estimated to generate 0.006797411 tonnes (Mt) of CO2e annually with the application of the above mitigation measures, which is 0.0296% of the reported Manitoba emissions in 2019 which were 23 Mt CO2e, about 0.000931% of the reported 730 Mt CO2e from Canada in 2019*."

The estimate of 6.87 kt of CO2e per year is for the extraction sites and does not include total cumulative project emissions. The estimated 34 kt of emissions for the processing plant is one of the cumulative contributions omitted. Most of processing plant emissions would be from a natural gas fired sand drier.

No estimate is given for the increase in GHG from the customers of the new natural gas line that must be constructed for the drier. Sio Silica in the response to public comments concerning this issue stated;

"*A new industrial user of natural gas who comes forward in the future would be subject to such Manitoba environmental approvals as apply at that time. Similarly, any new residential use would be subject to such review processes as might apply at that time*."

The Sio Silica response is totally inadequate. The Sio Silica response does not quantify the GHG emitted by new users that would be directly attributable to the Sio Silica natural gas line. The new user emissions would continue long after the stated 24 year Sio Silica project timeline and must be accounted for in the Sio Silica emissions.

The Sio Silica processing facility has already received a licence from Environmental Approvals and Licensing. The licence was issued despite the fact that the Extraction Project is under review by the CEC and there are substantive cumulative effects of the two projects. There is no regulatory requirement in the licence to mitigate the GHG emissions through electrification of sand drying. Cumulative Sio Silica GHG emissions were included in my request for designation of the Sio Silica extraction project to the Impact Assessment Agency of Canada.[60] In denying the request for designation the IAAC accepted Sio Silica estimates for emissions for the extraction project. The IAAC analysis did not consider cumulative GHG including the processing plant and ignored the GHG calculations in my request for designation. The IAAC did not involve the Strategic Assessment for Climate Change (SACC) which is mandated to develop programs for 2050 net zero emissions.[61] Regulators, both federal and provincial, are not serious about 2050 net zero greenhouse gas targets. The regulators allow projects with new substantial GHG emissions to proceed with no GHG plans for net zero.

The Sio Silica Extraction EAP states;

"*The dewatering and pump station will be powered via direct mainline from Manitoba Hydro to reduce diesel consumption. It is expected that the dewatering and pump station will require 1460 connected hp to operate*."

Sio Silica has not documented a commitment from Manitoba Hydro to provide to hydro installation nor documented the cost that would be born by Sio Silica for installation. The dewatering station must be moved each year greatly complicating the installation of the hydro power. The cost to Sio Silica for hydro may be much more than the cost of diesel. In my submission to the public comments I provided an estimation for CO2 emissions for diesel powered dewatering station and slurry line pumping based on the 1460 hp requirement. Initially when the slurry lines are close to the processing plant the CO2e estimate is about 6.7 kt rising to about 40 kt as the dewatering stations move further from the processing plant. Without documentation of a commitment from Manitoba Hydro to provide power the GHG emissions from diesel powered the dewatering and slurry pump station must be included.

The indirect CO2e emission from the fabrication of the steel or PVC for the Sio Silica extraction wells has not been determined.

Dr. E. Pip in her extraction project public submission commented that Sio Silica did not determine the GHG from land clearing. In the response to public comments Sio Silica estimated the yearly GHG from land clearing to be 494 tonnes of CO2e. The clearing of land for hydro poles for the Hydro transmission lines that would be moved every year is not included in the 494 tonnes of CO2e. The GHG from the removal of waste from the extraction site to landfill has not been determined. Up to eleven dump trucks per day could be required to transport the waste from the required UV filtration system. The GHG emissions from the required sand bed drying and fines removal by filtration and clarifying for the UV purification system has not been determined. The omission in the Sio Silica EAP of the GHG from land clearing, waste transportation, fine sand filtration and removal for the UV system and from new users of the Sio Silica natural gas line repeats the pattern of Sio Silica omissions of significant factors contributing to project detriment.

Sio Silica attempts minimize the GHG be not stating cumulative GHG from all project contributions and by expressing the GHG as a percent of the total provincial GHG emissions. It is a wonder that Sio Silica did not use the Sio Silica percentage of total Canadian GHG or world GHG to further disguise and minimize the project impact.

The cumulative GHG from the project without considering the likely GHG from diesel powered dewatering station would be 61.5 kt. Including the likely eventual 40 kt from the dewatering stations and slurry pumping the total GHG would rise to over 100 kt CO2e. One hundred kilotonnes CO2e is about 0.4% of the provincial total GHG emissions for 2019. But that is not a large concern since 100 kt would be about 0.00027% of global GHG emissions and after all GHG is a global problem.[57] Such as excuse can be and is used by any potential GHG emitter. We cannot allow such subterfuge. Our future depends on significant climate action now.

The threshold for GHG reporting requirements nationally is 10 kt.[58] Manitoba considers a facility emitting more than 50 kt CO2e per year to be a large final emitter (LFE). In 2018 there were only eight LFE's.[59] At over 100 kt, using 2018 data, Sio Silica would have ranked number five. This does not include emissions from the new users of the natural gas line. Even with hydro powered dewatering stations and without consideration of new gas users Sio Silica would be a large final provincial emitter, within the top ten in the province. The GHG emissions for the Sio Silica project are significant despite Sio Silica attempts to omit and minimize the contributions. Sio Silica should be required to achieve net zero emissions by electrification of all operations.

16 Sio Silica Slurry Lines

In the response to public comments Sio Silica states;

"As described in the EAP (Section 2.2, Silica Sand Extraction Process), the slurry line contains only water and sand and therefore poses no risk of contamination caused by a spill of toxic chemicals … there is no risk of toxic chemical or heavy metal contamination associated with the accidental release of water to a surface water body from the slurry line.

"*The slurry line connecting the extraction sites with the Processing Facility will only contain a sand/water slurry and a residual amount of a non-toxic biodegradable flocculant (from recycled water as described in the Facility project EAP).*"

The slurry line will be inspected on a daily basis, and after extreme weather events, to check for leaks and/or breaks in the line. Additionally, an automated pressure transducer for leak detection will be installed along the slurry line. If any leaks or breaks in the line that require repair are detected, flow to the line will be shut *down, and appropriate spill containment and clean-up measures will be applied, and the line will be repaired or replaced*."

"*The slurry line will be made of HDPE (high density polyethylene) which is not prone to leakage*."

"*Note that none of the extraction sites proposed in this application approach or cross the aqueduct. Any future Notice of Alteration for operations that might fall within the proximity of the aqueduct will consider potential environmental effects on the aqueduct."*

"*Water in the slurry loop system will be drained into appropriate portable tanks to hold water over the winter months for re-use in the spring. These temporary water storage tanks will be large volume modular tanks (lined) which will vary in size from 1,300 m3 to 6,000+ m3 , as needed*."

"*Slurry lines are fused for sectional length and flanged together through the length of the system which allows for easy access for inspection and maintenance, and substantially reduces the risk of a leak*."

"*During the winter months and prior to start up of the slurry line each season, a full inspection for wear of seals and connections will be conducted*."

"*The HDPE type slurry lines are used in many industries and are utilized to move abrasive materials. This type of HDPE material was purposely selected for robustness and wear resistance*."

The extraction EAP states;

"*If access is required to the slurry line or water return lines, the flanged connections can be used as access points in addition to specific access points that will be built into the line periodically and close to major wear areas such as corners. The specific section of the line will be closed off with valves, and water/sand in the line will be removed prior to the line being opened. To do this, access points will be equipped with vacuum truck connections to void the line of material. Material removed from this section of line will be returned into the system with the water at the dewatering and pumping station.*"

There is no adequate documentation and evidence or engineering drawings provided to support the Sio Silica statements regarding the slurry lines. The EAP does not mention automated leak detection. The simplistic statement in the response to public comments about automated pressure transducers is unacceptable method to document such an important required feature. The EAP includes a tacit acknowledgement about the significant risk of leakage at susceptible wear locations such as slurry line corners or bends but provides no quantification, analysis and mitigation for this risk. There has been no quantification of the pipeline flow velocities that must be known to evaluate wear and risk of failure. The inspection of slurry lines after winter operation only mentions seals and connections. No essential inline measurement of pipe thickness and abrasion is mentioned.

Pressure transducers to measure leaks would not detect small continuous leakage that can result in more volume spillage than a large detected leak. Volume conservation measurements for the input and output water in the slurry line would be one method of detection of small leaks. Such volume control measurement of water is not planned.

The use of vacuum trucks for ongoing emptying of cluster slurry lines is not adequately explained and documented. For instance, are cluster slurry lines flushed to remove the sand content before emptying or is sand left in the water? Residual water and sand in each emptied line could spill. This potential spillage is not quantified or addressed. The method of return of the water and sand in the vacuum truck to the dewatering station is not documented.

The assertion that the slurry lines will contain only sand and water and no toxic contaminants is not supported by any measurements or direct evidence. The evidence presented here shows that shale fragments will be present in the extracted sand. Fragments of concretions that are not screened out will also be present in the sand. Sio Silica did not geochemically analyze concretions. The paper by Schieber and Riciputi, 2005, documents that concretions contain marcasite and pyrite that would oxidize to form acid that would in turn mobilize heavy metals into the slurry lines.[20] The Sio Silica geochemical analysis shows significant selenium content in the shale. The selenium would oxidize to a mobile selenate form into the slurry lines. Sio Silica admits in a response to an information request that a residual amount of the polyacrylamide flocculent would be in the slurry line. Sio Silica does not reveal that small amounts of extremely toxic acrylamide monomer from manufacturing residual and from polyacrylamide degradation from exposure to slurry line acid would also be present.

In my public submission for processing plant project I documented an industrial example of the methods that must be used to maintain acid and water balance in a recycling loop system. This evidence was ignored.

On Jan.22, 2021 (posted on the project registry on Feb.16, 2021) Sio Silica submitted a notice of a minor project alteration to document French drain system that would capture run off from the sand stockpiles at the processing plant. The capture water likely contain contamination would be returned to the recycled slurry line loop system. Engineering specifications for the French drain system were not given. Critiques of this French drain system by me and a local resident are entered in the registry.[52] The critiques describe how addition of large amounts of run off to a closed loop slurry line is not feasible without a storage and gradual feed in mechanism. The critiques also describe how contamination would build up in the slurry line water that is reused for at least 24 years. Sio Silica did not adequately respond to the critiques stating;

"*Wastewater and stormwater collection systems will be designed in accordance with acceptable industry standards and specifications*."

No engineering specifications were provided by Sio Silica to support this meaningless statement. Qualified engineers were not engaged for the processing plant, slurry line and French drain designs. Sio Silica used a minor alteration procedure that does not require TAC review for the major French drain design change. The Environmental Licensing and Approvals Branch (EAB) ignored the requests in the critiques that this design change should be treated as a major alteration requiring resubmission and full review by both the TAC and the public. The licence deficiencies include specification of conditions that are at the discretion of the Director.

Sio Silica's response to the information request DLN-IR-003c-35&36 about the ability of the slurry loop system to accept a large amount of water from a deluge collected by the French drain system is faulty. Sio Silica responded to the IR, "*The French drain system will drain into the water recycling system. This means the first stop of the water is the clarifier, not the slurry line*." In the request DLN-IR-003c-35&36 the clarifier was meant to be included in the slurry line loop. Returning a large amount of water to the clarifier tank as stipulated in the Sio Silica response to the information request is not possible. The rate of return of water from a deluge collected by the French drain system is estimated in the comments about the notice of alteration on the facility registry to be more than 50 m^3/min. The maximum flow rate of the clarifier given in the processing facility EAP is 24.4 m^3/min. The clarifier tank has a water overflow at the top to remove the clarified water. The tank must be always full, to this level. The only way a significant quantity of water could be added to the tank would be to increase the flow rate. Increasing the flow rate would decrease the detention time of the clarifier. The detention time cannot be decreased to below design levels. The flow rate to the clarifier could not possibly be raised by 50 m^3/min. The inability of the slurry loop system including the clarifier to accept deluge water from the French drain system has been raised repeatedly from April 8, 2021 as documented in the Facility Project registry, and again in the IRs. Sio Silica is still responding inadequately. I dispute the statement by Sio Silica that deluge water from the French drain can be added to the clarifier. The fate of the water from the French drain has serious environmental consequences. Sio Silica's unfeasible plan to add this water to the slurry line loop and clarifier system was to avoid the environmental consequence of releasing this water to the surface. Before the Hearings commence Sio Silica must specify a feasible discharge from the French drain system that would not be detrimental to the environment.

I have completed an analysis of the potential build up of contamination in the slurry lines using a compartment model. This analysis is an extension of the model used by a qualified engineer of Great Plains Sand to determine the acrylamide content in the closed loop system for the silica sand processing facility. Sio Silica should be required to perform an anlysis of this nature for this important aspect of the project. Sio Silica has so far provided only unsupported statements and no certified engineering analysis of the slurry line system. This inadequate documentation is grossly negligent and must be addressed. This is another example of deliberate avoidance of and non-disclosure by Sio Silica of essential issues. The analysis below makes assumptions due to lack of data that must be provided by Sio Silica for a comprehensive analysis.

16.1 Mass balance calculation of contaminant build-up in the slurry line loop and clarifier tank

A technical memorandum of March 9 2012, by T. Holstrom of Great Plains Sand describes the method of determination of the potential concentration of acrylamide monomer in the recycling water loop of the Great Plains Silica Sand plant in Jordan Minnesota.[64] Using a mass balance equation the concentration of the acrylamide monomer, C_a , is determined from the following equation,[64]

$$C_a = \frac{M_a}{(Q_L + \lambda_a V_P)} ,$$

where M_a is the mass loading rate of the acrylamide monomer into the clarifier tank, Q_L is the loss rate of water in the water recycling system system, λ_a is the first order rate constant and V_p is the total volume of water in the water recycling system including the clarifier tank and slurry loop.

16.2 Determination of the acrylamide content in the slurry water

The volume of the clarifier and water in the slurry loop is not given in the Sio Silica EAP. The volume can be estimated by a typical detention time from the relationship that the volume of the tank is equal to the product of the detention time and the volume flow rate in to the tank. Clarifier retention times are typically 2-3 hours for wastewater sewage plants however frac sand plant clarifier tank retention times may be as low as 80 minutes.[65,66] From the volume flow rate of 24.416 cubic meters per minute given in the Sio Silica EAP for the processing plant and a representative detention time of 2 hours, the volume of the clarifier tank at the Vivian processing plant would be 3000 cubic meters. To transport the sand slurry to the processing plant 14-inch (35.6 cm) HDPE lines would be used according to the Sio Silica EAP. The thickness of the slurry pipes is not given. Thick walled pipe can be about 5 cm.[68] The Sio Silica EAP for the processing plant gives a water flow rate from the clarifier tank to be 24.4 cubic meter per minute minimum. For a slurry line with an inside diameter of 30.6 cm the water volume per kilometre in the sand would be 294 cubic meters ignoring the sand which is stated to be 15% by Sio Silica. Thus the volume of water in the slurry lines is small compared to the clarifier tank. The Sio Silica draft water management plan of June 17, 2022 for Vivian states;"*The slurry loop system needs approximately 1,325 m^3 (350,500 U.S. gallons) of water to operate*." This is comparable to the volume of 1700 m^3 given for the Great Plains Sand study for acrylamide concentration from the water recycling system.[64] A water volume for the Vivian clarifier and slurry loop of 1325 m^3 was used here. It must be noted that this volume is smaller than would be expected for the specified clarifier tank flow rate.

The CEC Participant RMSF in RMFSF IR 009 asked the origin of the 10 US gpm of water that Sio Silica states enters the slurry line with the sand. Sio Silica replied that based on literature values of dewatering methods the average water content of the sand entering the slurry lines after the dewatering process is 3.6%. The processing plant EAP states the water content of the sand exiting the slurry line loop at the processing facility is 15%. Thus more water leaves the loop than enters and the slurry line would eventually dry up and be inoperable. On average water balance in the slurry loop must be maintained. This inconsistency has not been resolved by Sio Silica.

The water loss from the water recirculation system at Vivian is dominated by the 15% water entrained in the sand stockpiles to prevent silica dust exposure. Assuming 15% water refers to water by volume of the sand, using sand production target of 1.36 million tonnes per year and a sand dry density of 1.65 tonnes per cubic meter,[99] the volume of water lost to the sand piles per year would be 123,636 cubic meters. At 220 operating days the loss rate from the slurry loop would be 23.4 m^3/hr. Using the value of 3.6% water entering the slurry line with the sand would result in higher concentrations of accumulated toxins in the slurry line thus the modelled concentrations reported here would be an underestimate if the 3.6% value were applied in production.

The Sio Silica supplementary information #3 for process wastewater treatment posted June 24, 2022 states;

"*The raw process wastewater is expected to have a solids concentration of 18,500 mg TSS/L, which will then be reduced to approximately 10,000 mg/L and directed for treatment*."

The concentration of 10,000 mg/L refers to the fines that for the re-injected water must be removed before UV treatment. Based on this information it is assumed that the fines content entering the slurry line at the extraction site would be 10,000 mg/L.

Using a slurry loop/clarifier tank water flow rate of 24.416 m^3/min and a fines concentration of 10 kg/m3 the clarifier fines loading rate for Vivian would be 14.65 tonnes/hr.

The Great Plains study uses a solid loading rate to the clarifier tank of 7 tons (6.35 metric tonnes) per hour and a polyacrylamide loading rate of 0.5 lb. per ton (0.25 kg/tonne) of solids for a total polyacrylamide loading of 1.587 kg/hr. The comparable Sio Silica polyacrylamide loading rate would be 3.66 kg/hr.

The Great Plains study used a manufacturing residual weight fraction of $2x10^{-4}$ of acrylamide monomer in the polyacrylamide. All polyacrylamide in the European Union contain less than 0.1% ($1x10^{-3}$) w/w free acrylamide monomer to avoid being considered as a category 2 carcinogen.[63] The monomer content of the polyacrylamide to be used for the Sio Silica operation is not disclosed.

The paper by Xiong et al., 2018,[67] states;

"Many previous studies have demonstrated the importance of dissolved oxygen and Fe2+ in the chemical degradation of PAM under environmental conditions. Fe2+ can be released by oxidative dissolution of pyrite minerals or other iron-bearing clays, which simultaneously acidifies the fluid."

The slurry line water will almost certainly have pyrite minerals from the collapsed shale layer, interbedded shale as documented in table 4 and pyritic concretions[20] that will release Fe2+ by the oxidation dissolution of these sources of pyrite in the slurry line sand and cause degradation of the polyacrylamide to the toxic acrylamide monomer. The degradation of the polyacrylamide would increase the toxic acrylamide monomer concentration however the degradation rate remains unknown therefore the increase in the toxic acrylamide monomer from degradation was ignored. Thus the acrylamide monomer concentration calculated here would be an underestimate.

A peer reviewed paper in NPJ Clean Water Nature Partner Journal by Xiong et al., 2018,[67] states,

"*Several studies support the hypothesis that naturally occurring microbes in soils, sediments, and water systems can degrade acrylamide to the nontoxic products ammonia and acrylic acid over periods of days to months. In aquatic systems, complete degradation of acrylamide likely occurs within 2 weeks. However, in tap water, acrylamide can persist for more than 2 months"*

Using a half time of 2 months the first order rate constant for the acrylamide monomer in the water recycling system and clarifier tank λ_a would be 4.74x10^{-4} hr^{-1} as opposed to the value of 0.125 hr^{-1} used in the Great Plains study. The EU study gives a half life in surface waters with biodegradation of 2.0 x10^{-3}hr^{-1}. Biodegradation in the slurry water should be less than surface water given the high flow rates in the slurry lines and likely less organic and microbial content.

Using λ_a of 4.74x10^{-4} hr^{-1}, Q_L of 23.7 m^3/hr, V_p of 1325 m^3, and an acrylamide weight fraction of 0.1% of the polyacrylamide giving an acrylamide monomer loading rate, M_s, of 3.66 g/hr, the steady state acrylamide concentration in the Sio Silica slurry loop, C_s , at Vivian would be 151 µg/litre which is far above the allowed limit from the Great Plains study of 0.5µg/liter or 0.5 ppb. The allowed limit of acrylamide has been lowered in most jurisdictions sine the Great Plains study. The allowed limit in Minnesota is 0.2 parts per billion (ppb).[119] For an acrylamide weight fraction of 2x10^{-4} as used in the Great Plains study C_s for Vivian would be 30.1µg/litre, which is still much above the allowed limit of 0.5µg/liter. Finally for a λ_a of 0.125 hr^{-1} and a acrylamide loading factor of 2x10^{-4} as was used in the Great Plains study C_s for Vivian would be 3.87µg/litre which is also above the allowed limit of 0.5µg/liter. Sio Silica has ignored the potential for acrylamide contamination of the slurry water that could poison surface waters or the aquifer upon leakage of the slurry lines or processing facility water. According to this analysis the steady state Sio Silica slurry line concentration of toxic acrylamide monomer would be well above allowed limits. The results and parameter values for the steady state analysis of the acrylamide concentration in the slurry loop water are summarized in table 7.

Table 7. Slurry loop acrylamide concentration and model parameter values

Water Loss Q_L m^3/hr	Recycle Volume V_p m^3	Acrylamide Loading M_s g/hr	Decay Rate λ_a hr^{-1}	Acrylamide Con. C_s µg/litre	GP Allowed Limit µg/litre	Minnesota allowed limit µg/litre
23.7	1325	3.66	4.74x10^{-4}	151	0.5	0.2
23.7	1325	0.732	4.74x10^{-4}	30.1	0.5	0.2
23.7	1325	0.732	0.125	3.87	0.5	0.2

The mass balance equation for the accumulation of contaminants in the recycling water system is given by,

$$V_p \frac{dC(t)}{dt} = Q_L C_i(t) - Q_L C(t) + M_s - \lambda_a V_p C(t) + C_o V_p \delta(t). \qquad (2)$$

$C_i(t)$ is the concentration of contaminant entering the recycle recycling water loop. M_s is the mass input rate of contaminants in the loop (assumed to be constant). C_o is the initial concentration of contaminant present in the wash water of the loop. δ is the kronecker delta function. Q_L is the loss rate of water in the slurry loop system. λ_a is the first order rate constant for degradation of the contaminant and V_p is the total volume of the slurry loop including the clarifier tank, vessels of recycling water system. C_i is the initial concentration of contaminant in the water entering the loop.

Assuming the initial concentration of contaminant in the loop is zero, the solution to equation (2) is,

$$C(t) = \left(\frac{M_s}{Q_L + \lambda_a V_p}\right)\left[1 - \exp\left\{-\left(\frac{Q_L + \lambda_a V_p}{V_p}\right)t\right\}\right] + \frac{Q_L}{V_p}\int_0^t C_i(t') \exp\left\{-\left(\frac{Q_L + \lambda_a V_p}{V_p}\right)(t - t')\right\} dt'. \qquad (3)$$

The initial concentration, C_i , is the concentration entering the loop from the extraction dewatering tanks and the airlifting and includes any contaminants from the French drain input. The flow of water entering the loop, Q_L, must be the same as the flow of water exiting the loop for water balance. The flow of water input from the French drain cannot change the Q_L or water balance would not be maintained. Sio Silica has not acknowledged this requirement. Sio Silica must address how water balance can be maintained during a large precipitation event that generates flow rates from the French drain much larger than Q_L.

When $C_i(t)$is zero and for long times when steady state is reached the above mass balance equation reduces to the steady state equation from the Great Plains study.

$$C_s = \left(\frac{M_s}{Q_L + \lambda_a V_p}\right) \text{ for } t >> V_p/(Q_L + \lambda_a V_p) \qquad (4)$$

If the initial contamination entering the slurry loop from the pumping stations or from the French drain system is a constant, at steady state, the last term of equation 3 reduces to $Q_L C_i / (Q_L + \lambda_a V_p)$. Any initial concentration of contaminant entering the loop would increase the level of contamination in the slurry loop.

A question remains as to the time required to reach steady state. Using equation 3 the approach to steady state for the Vivian slurry like loop is given in figure 43 for a range of parameter values used for the steady state calculations.

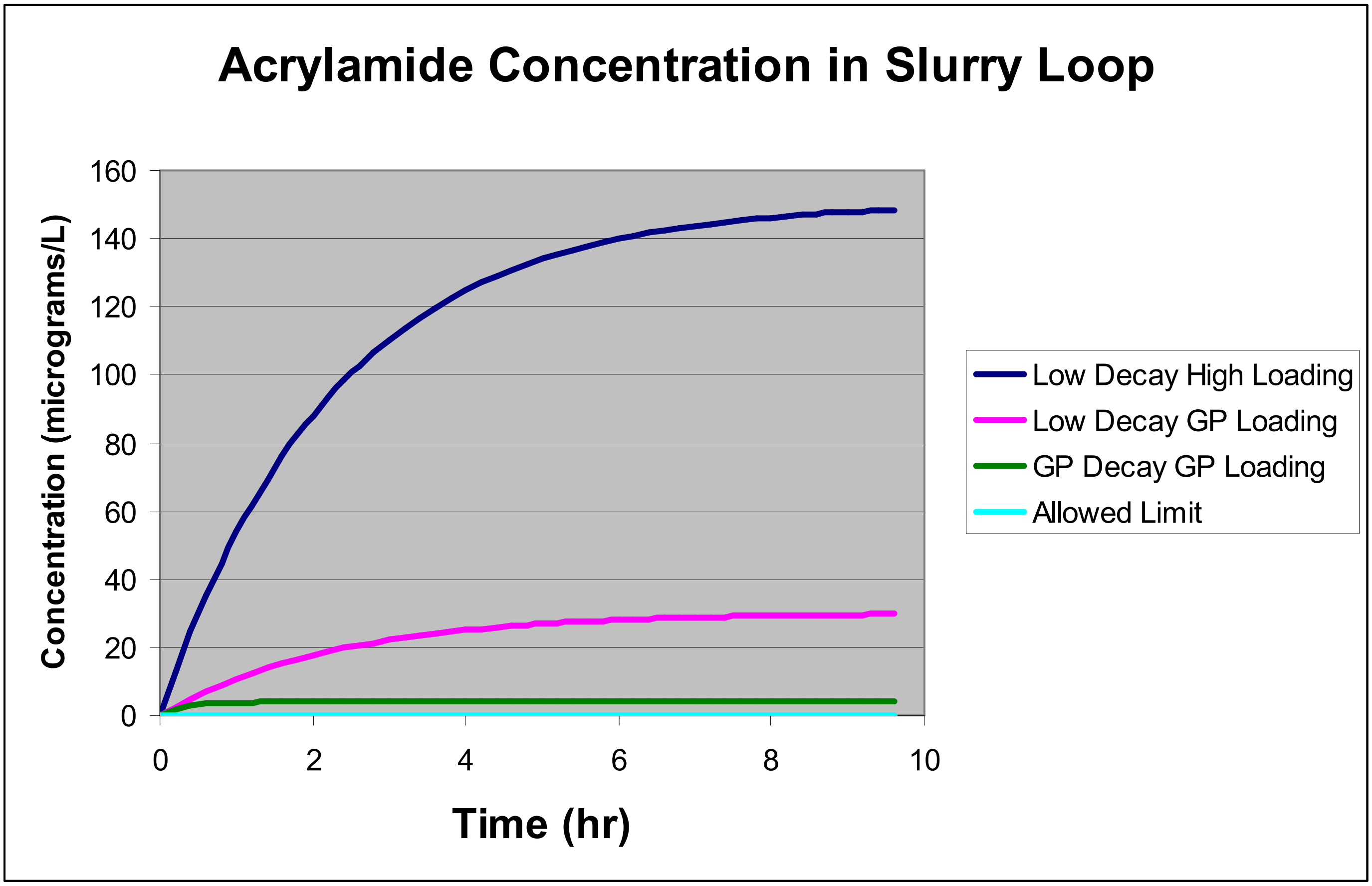


Figure 43. Acrylamide concentration in Sio Silica Slurry loop
Illustration from modelling by D. M. LeNeveu

16.3 Determination of selenium accumulation in the slurry loop

It has been established in the Sio Silica EAP Hydrogeological shake flask tests that shale contains selenium that would dissolve as selenate when exposed to oxidizing conditions introduced by the Sio Silica sand extraction. Sources of selenium from interbedded shale in the sandstone and other potential selenium from oolite and concretions have not been included in the evaluation. In the slurry line sloop selenium would be present in the sand and in fragments of shale from the collapsed aquitard and from interbedded shale in the sandstone formation.

The amount of shale withdrawn with the sand in each extraction cavity using an aquitard thickness of 3 meters, radius of 27 meters and density of shale of 2 tonnes cubic meter would be 13,741 tonnes. If 10% of the shale aquitard were extracted with the 21,000 tonnes of sand per cluster the shale fraction in the sand would be 0.065.

The maximum concentration for Bru 121-1 shale in the 24 hour shake flask tests was 1.64 mg/L for a liquid to solid ratio by weight of 3 to 1. In the shake flask test 37.6% of the available 13.1 ppm selenium dissolved per litre.

The mass rate of sand delivered in the slurry loop to meet the production target of 1.36 million tonnes of sand per year, for 220 days of operation per year, would be 257.6 tonnes per hour. The maximum selenium rate of discharge to the slurry line water, M_s, at a shale fraction of 0.0654 and a fraction dissolved of 0.02 is estimated to be $257.6x0.0654x13.1x10^{-6}x0.02 = 4.41x10^{-6}$ tonnes per hour

Using equation 4 with a first order degradation rate for shale of zero, Q_L of 23.7m^3/hr and M_s of 4.41 grams per hour, the steady state Sio Silica slurry line loop concentration of selenium would be 0.186 mg/L. Note that a very small dissolved fraction of selenium of 2% was used for this analysis and only 10% of collapsed shale aquitard. The concentration guidelines for selenium taken from the Sio Silica EAP Hydrogeological Report are shown in table 8. The steady state concentration of selenium in the slurry loop water far exceeds all guidelines.

Table 8. Selenium concentration guidelines in mg/L (data from the SIO Silica extraction EAP)

CCME FAL Acute and Chronic (aquatic life)	0.001
CCME Livestock and MWQSOG Livestock	0.05
CCME Irrigation and MWQSOG Irrigation	0.02-0.05
FIGQG Agricultural	0.001
MWQSOG MAC (Manitoba drinking water)	0.01
CDWQ MAC (Canadian drinking water)	0.05

Figure 44 illustrates the selenium concentration in the slurry line loop as a function of time for a zero initial concentration of selenium in the water entering the slurry line, Q_L of 23.7 m^3/hr , M_s of 4.41 g/hr and V_p of 1325 m^3 for the water loss, Q_L, determined for 15% water loss to sand stockpiles.

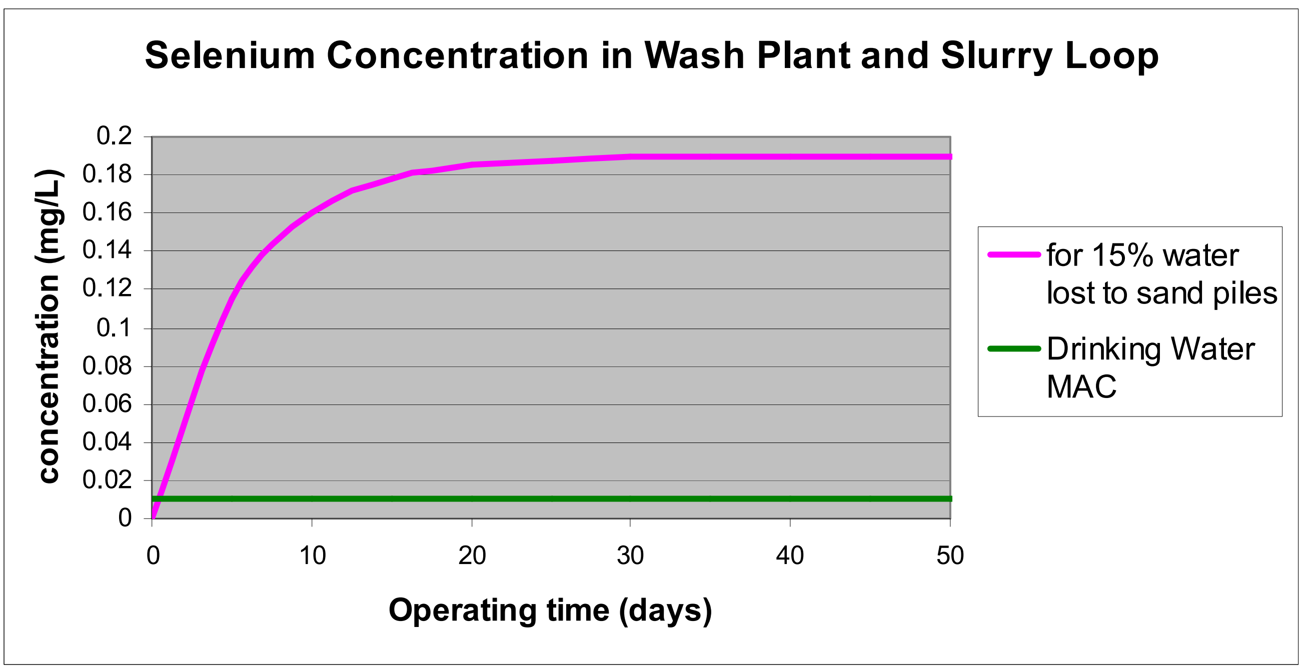


Figure 44. Selenium concentration in the Sio Silica recycling loop water
Illustration from modelling by D.M. LeNeveu

Figure 44 illustrates that the selenium concentration would rise to steady state in the water recycling loop in about 20 days and would exceed drinking, irrigation and aquatic life water guidelines in a matter of hours. Remediation by a contaminant removal process such as reverse osmosis would be required to operate continuously. Sio Silica must specify the volume, disposal method and disposal location of the concentrated selenium waste stream.

It is essential that geochemical analysis from numerous samples of sand, interbedded shale, concretions and oolites throughout the project area be completed by Sio Silica to determine the risk of aquifer and slurry line contamination. The selenium concentration in the slurry line water could only increase with more information from comprehensive sampling.

A further consideration is dissolved contaminants from the slurry loop would be in the 15% water in the sand stockpiles. These dissolved contaminants will be baked onto the sand in the dry plant and lost to the water loop. The contaminants baked onto the sand would degrade the quality of the sand rendering the sand unsuitable high purity applications such as solar panel glass. Sio Silica must account for the contamination of the sand by accumulated dissolved contaminants from the slurry loop.

16.4 Acid and heavy metals in the slurry loop, dewatering station and UV filtration system

The sulphide documented to occur in the concretions, oolite, and shale interbedded in the sandstone that would be extracted with the sand in the slurry loop would dissolve in the slurry loop and vessels of the de watering system and UV filtration system forming acid that would leach heavy metals. Acid base accounting testes were not done by Sio Silica on samples containing concretions, oolite, and shale interbedded in the sandstone to determine the acid potential. The Winnipeg formation sand at Wanipigow has been measured to contain 0.235 % sulphide with a net acid potential 2.01 tonnes of $CaCO_3$ equivalent per 1000 tonnes of sand.[25] The evidence given here shows that Sio Silica sand from the Vivian area was exposed to weathering for a long period before sampling. The geochemical results for sulphide content are therefore invalid. The potential for acid accumulation in the slurry loop cannot be estimated due to the lack of adequate data from the Sio Silica geochemical sampling and analysis. Accumulation of acid and heavy metals can be expected to occur in the slurry loop.

Sio Silica has not properly determined the marcasite and pyrite content in the sand. Other sources of sulphide in the sandstone such as the concretions, oolite and interbedded shale were not measured by Sio Silica. The evidence given here for unacceptable levels of sulphide extracted with the sand is overwhelming, cannot be dismissed, and conclusively demonstrates the project is not viable.

Sio Silica has been negligent in not addressing the potential for contamination build up in the recycle water loop. The method of calculating the contamination build up has been used for the Great Plains silica plant and is well established. The amount of acrylamide monomer and large amounts of contamination of selenium, acid and subsequent heavy metal contamination shows the recycling loop is not feasible without some method of contaminant removal such as reverse osmosis. The selenium, acid and subsequent heavy metal contamination in the frac tanks and vessels of the UV filtration system will render all the waste including overs, fines and UV filtrates toxic and acidic and would require specialized disposal at a disposal facility licensed for toxic acidic waste. Acid tailings waste disposal such as done at Anderson Lake near Snow Lake Manitoba would be required.[39]

17 Cumulative Effects of Project Noise and Light Disturbance

Sio Silica has not adequately quantified the light disturbance from 24 hour drilling and slurry line operations and have not measured the noise levels.

The EAP states;

“*The impact of the Project on noise levels at nearest points of reception (e.g. nearest residences) is assessed as minor to moderate with intermittent duration and short-term frequency. Example noise sources associated with Project activities include mobilization of extraction well drilling equipment, drilling of wells and operation of pump stations. The following measures will be implemented to reduce noise generated from Project activities: • Vegetation clearing will be minimized to the extent feasible. • Project activities will setback a minimum of 100 m from nearest residences. • Mobile equipment and vehicles will be kept well maintained and will be fitted with mufflers, and other noise mitigation equipment as required. • Unnecessary idling and revving of engines will be avoided. • Additional noise mitigation measures will be applied (e.g. portable noise barriers) as required. In consideration of the above measures to minimize noise levels due to Project activities, it is anticipated that noise levels will be adequately attenuated*.”

Mitigation measures such as, setbacks, mufflers, portable noise barriers are vague and the effects of such mitigation have not been quantified. Additional noise mitigation measures are not specified and are meaningless. Sio Silica has completed many drilling and sand extraction operations during the advanced exploration since 2017. Sio Silica should have measured the sound levels from these activities and the reduction in levels from various mitigation measures. Acoustics studies should have been completed to extrapolate these measurements and mitigation strategies to the production scenario of at least ten extraction wells operation simultaneously. The added noise from the dewatering station, clearing activities, waste collection treatment and movement, and slurry line movement and handing should have been factored in. Complete enclosure of all drill rigs and extraction equipment in noise barriers may be necessary as shown in figure 45.[76]

The construction and dismantling of such barriers every four to six days as cluster operations move may be unfeasible.

Figure 45. Noise Enclosure for a drill rig [76]
Figure was reproduced from reference 76.

Residents in the town of Vivian have complained about noise levels from Sio Silica sand extraction activities in the LSL quarry pit about two kilometres south west of Vivian that have occurred since the spring of 2021. The noise was from one drill rig and sand extraction from one well, not at least ten operating at once as would occur for the Sio Silica operational well cluster extraction. This is definitive evidence that a 100 meter setback and intervening bush would be ineffective noise attenuation of Sio Silica extraction activities.

The EAP states;

“*Fully shielded directional lighting fixtures will be used to focus light specifically to work areas to minimize the dispersal of light to the surrounding Project Site.*”

This appears to be the only reference to light pollution and mitigation of the effects to residents. The drilling rigs would be lit 24-7. Slurry lines and equipment with lights are to operate day and night. There is no quantification of the amount of light disturbance that would occur or any determination of the effect of this minimal mitigation measure of focus light. Focus light may not be feasible for drill rigs. Residents have witnessed intense yard night time lighting occurring at quarry sand extraction activities carried out near Vivian by Sio Silica.

Sio Silica did complete a noise study estimate for the processing plant EAP however this study was not reviewed and certified by CN who must approve the railway yard and all the engineered features including noise mitigation. The study did not include all project cumulative effects on noise and light.

On Nov.2, 2021, I sent a request to the Canadian Transportation Agency (CTA) requesting a ruling on CTA requirement for approval of the Sio Silica railway yard and rail loop connection to the CN mainline. Under the CTA regulations a railway line that requires approval must conform to many conditions such as community engagement, provision of engineering plans, assessment of noise and vibration and other environmental effects. Sio Silica in the processing plant EAP dismissed the need for a vibration study. All of the assessments and engineering plans must be approved by CN. None of these CTA conditions have been met and CN has had no formal rail participation in the railway project.

The CTA is required to act upon the condition in the guideline that the application for approval must contain;

"*a detailed description of the proposed line construction activities. Include the following:*
1. Construction activities, including a description of:
the phases of construction, including any preliminary works (clearing, grubbing, demolition, pre-loading, etc.);

Sio Silica has cleared the area for the rail bed loop in April of 2021 without approval of the CTA.

On Nov.2, 2021 I submitted a formal complaint under the Canada Transportation Act that Sio Silica cleared the railway loop without CTA approval. Under Section 116 of the Act a ruling on the complaint is required within 90 days. The CTA replied that Sio Silica is not considered a railway company therefore the provisions of the Act do not apply. Sio Silica has already received a licence for the processing plant from the Manitoba Environmental Approvals so could start using the railway line at any time. If and when the railway loop is connected to the CN mainline the CTA approval requirements would have to be revisited.

Manitoba Infrastructure requires that to initiate a short line railway in Manitoba the Railway Safety Officer must be contacted. [100] To operate the railway a railway operating licence, engineer's certificate of fitness, a safety fitness certificate and if the railway will be operating on federally-regulated track, an application must be sent to Transport Canada for a railway operating certificate.[100] By contacting the Manitoba Railway Safety Officer I was informed that Sio Silica had not initiated the procedure to operate a short line railway in Manitoba. When I contacted Ron Schuler, Minister of Infrastructure, I was sent the following reply On Sept.15, 2021, by Richard Danis, Director of Manitoba Infrastructure;

"*The Vivian Sand Processing Facility proposal must undergo the formal environmental assessment review described by The Environment Act. The environmental review process is ongoing and a licensing decision has not yet been reached. In the event the proponent is issued a license, like with any other commercial enterprise, all other applicable federal, provincial and municipal regulations and by-laws would need full compliance. The onus and responsibility is on any commercial enterprise doing business in the province to undertake the necessary due diligence to determine and then achieve its overall regulatory obligations relating to all facets of its enterprise at appropriate federal, provincial and municipal levels. In this respect, Manitoba Infrastructure maintains that should CanWhite determine an obligation to make an application to the Superintendent of Railways regarding construction, operation and related licensing or certification of the proposed rail loop within the auspices of the Provincial Railways Act, I will be pleased to assess the application at that time.*"

In response to a request from the IAAC on what approvals federal, provincial or municipal approvals, licences, permits, authorizations would be required for the Project F. Somji, CEO of Sio Silica replied in a Sept. 11, 2020 letter to the IAAC that no federal approval would be required and did not mention any requirement for provincial approval of the Sio Silica railway line.

The cumulative effects of the railway yard, processing plant operation, and extraction operations of both light disturbance and noise must be completed. This must take into account the cumulative effects on wildlife, residents, and domestic animals from the combined effects of noise light and loss of habitat from all the clearing activities for the entire project.

18 Cumulative Exposure to silica dust

Aerosols from the sand-water spray from the sand slurry entry pipe shown in figure 7 would contain fine sand that would be a respiratory hazard for the operators.[4,80] Fine sand sprayed into the red tank from the separators would also create fine silica dust that would contribute to the respiratory hazard.[4,80] Extracted sand piles at the drill site as shown in figure 7 could dry and further contribute to wind blown silica fines. Sio Silica may eliminate the need for sand stockpiles at the drill site however this has yet to be demonstrated in any detailed engineering plans. Stockpiles that could generate airborne silica dust exposure to both workers and residents would occur at the Sio Silica processing plant. The licence for the processing facility include a definition of the respirable PM 2.5 and PM10 silica dust but no requirements in the licence for measurement of respirable silica dust or for worker protection measures to prevent exposure to respirable silica dust. Aerosols from the sand-water spray from the sand slurry entry pipe would contain fine sand that would be a respiratory hazard for the operators.[4,80] Fine sand sprayed into the red tank from the separators would also create silica dust that would contribute to the respiratory hazard.[4,80]

Figure 47 shows ATV tracks on Sio Silica extracted sand piles south of Vivian. The youth driving the ATV and public who frequent the area would have been exposed to silica dust from the piles. The Sio Silica sand piles were not protected against entry and no signage was posted. According to well information reports from Manitoba Groundwater, the sand was extracted in July of 2019. The sand at Vivian was covered following a complaint to Manitoba Workplace Health and Safety on June 28, 2020. In the spring of 2021 another large sand pile was extracted at the quarry southwest of Vivian. Sand was observed blowing from the extracted sand piles toward nearby residences. The quarry pit operators and drillers were not wearing any respiratory protection. It was not until the hazard was reported to Manitoba Workplace Health and Safety on May 10, 2021 that the sand piles were covered as shown in figure 46.[84] The email response to the complaint from Manitoba Workplace Health and Safety is reproduced below.

+WPG112 - Wshcompl (FIN) <wshcompl@gov.mb.ca> May 10, 2021, 1:18 PM
to me

Good Day,

The information has been assigned to the Hygiene Team.

Figure 46. Email response of Manitoba Workplace Health and Safety to a complaint of uncovered Sio Silica sand piles at the quarry south west of Vivian

On June 11, 2020, Steinbach-on-line reported Brent Bullen, Chief Operating Officer of Sio Silica claimed that stockpiles of silica sand, derived by mining directly from the Sandstone aquifer, pose roughly the same threat as the sand along Grand Beach.[85] In response to a question from Interlake Eastern Manitoba Health on

July 28, 2020, Sio Silica posted in the response to TAC comments on the public registry 6057.00 for the Vivian Sands Processing Project;

"*Two samples of raw sand slurry material were analysed by a third-party laboratory. Results showed 0.67% and 0.45% of particulates less than 11 micrometers in size*"

Appendix B of the Sio Silica processing plant EAP gives maximum 24 hour exposure limit to particulate with diameter less than 10 microns (PM10) as 50 micrograms per cubic meter. At a production target of 1.36 million tonnes per year, according to the Sio Silica laboratory analysis, there would be up to 9,112 tonnes of silica sand extracted per year with particulate less than 11 microns in diameter. The laboratory analysis of Sio Silica sand slurry directly contradicts the statement of B. Bullen as to the respirable hazard of Sio Silica extracted sand.

Figure 47. Sio Silica sand extracted at a quarry southwest of Vivian May, 2021 of the left and south of Vivian spring 2020 on the right.
Photographs are reproduced with permission of the photographer

In August of 2021 more sand was extracted from the quarry south west of Vivian. As shown in figure 7 the freshly extracted sand piles were again left uncovered and workers were again observed without respiratory protection. The lack of adequate precautions for silica dust exposure in previous sand extraction activities was reported in an article to the Steinbach Carillon by M. Wowchuk, former Sio Silica onsite manager.[53]

Worker exposure to silica dust would also occur at the sand processing facility during the handling and movement of the silica sand from the stockpiles into the processing facility and during loading operations. Given the history of neglect of adequate protection and concern for silica dust exposure chronically demonstrated by Sio Silica, inadequate protection for both workers and the public would be expected to continue at the extraction sites and the processing plant.

19 Infrastructure Disturbance

Infrastructure disturbance from the Sio Silica extraction operation includes roads, drainage, hydro lines and the Winnipeg aqueduct.

19.1 Hydro Lines, Roads and Drainage

The Sio Silica slurry lines and return recycling water lines would cross two Manitoba Hydro transmission lines one of which is an international 500 kV transmission line falling under the federal jurisdiction of the

Canada Energy Regulator Act (S.C. 2019, c. 28, s. 10).[74] Sio Silica well clusters would be drilled on either side of the transmission lines as shown in the original extraction plan of the EAP in figure 48. The well clusters may cause ground disturbance of the transmission lines. Sio Silica vehicles, equipment and slurry lines would cross the transmission lines. The new extraction plan of Jan. 24, 2023 has moved the extraction further from the Pointe du Bois power line but is till close to the 500 kV transmission line.

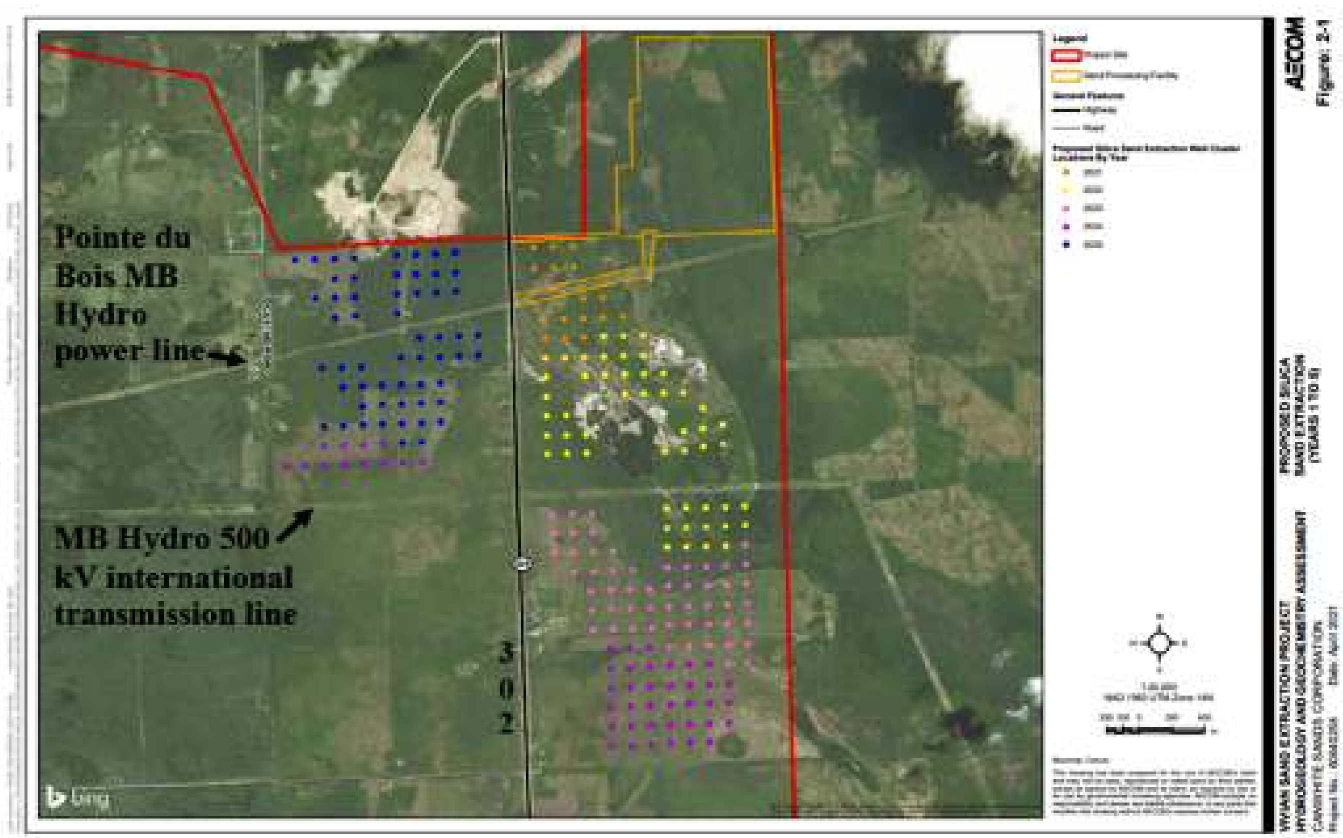


Figure 48. Planned location of Sio Silica well clusters up to 2025 from the Sio Silica HGR
Illustration was reproduced from the Sio Silica Hydrogeological Report.

Section 273 of the Canada Regulator Act states;[74]

"*Prohibition — construction or ground disturbance*

273 (1) It is prohibited for any person to construct a facility across, on, along or under an international or interprovincial power line or engage in an activity that causes a ground disturbance within the prescribed area unless the construction or activity is authorized by the orders or regulations made under section 275 and done in accordance with them.

Marginal note:Prohibition — vehicles and mobile equipment

(2) It is prohibited for any person to operate a vehicle or mobile equipment across an international or interprovincial power line unless
(a) that operation is authorized by orders or regulations made under section 275 and done in accordance with them;

Orders
275 (1) The Commission may, by order, give directions
(a) governing the design, construction, operation and abandonment of facilities constructed across, on, along or under an international or interprovincial power line;
(b) prescribing the area for the purposes of subsection 273(1);
(c) authorizing the construction of facilities across, on, along or under an international or interprovincial power line;
(d) authorizing ground disturbances within the prescribed area;
(e) governing the measures to be taken in relation to
(i) the construction of facilities across, on, along or under an international or interprovincial power line,
(ii) the construction of an international or interprovincial power line across, on, along or under facilities, other than railways, and
(iii) ground disturbances within the prescribed area;
(f) authorizing the operation of vehicles or mobile equipment across an international or interprovincial power line and governing the measures to be taken in relation to that operation;"

The location of the MB Hydro Pointe du Bois power line and the 500 kV International Transmission Line to Minnesota as well as the Winnipeg aqueduct and the CN mainline railway are shown in figure 49.

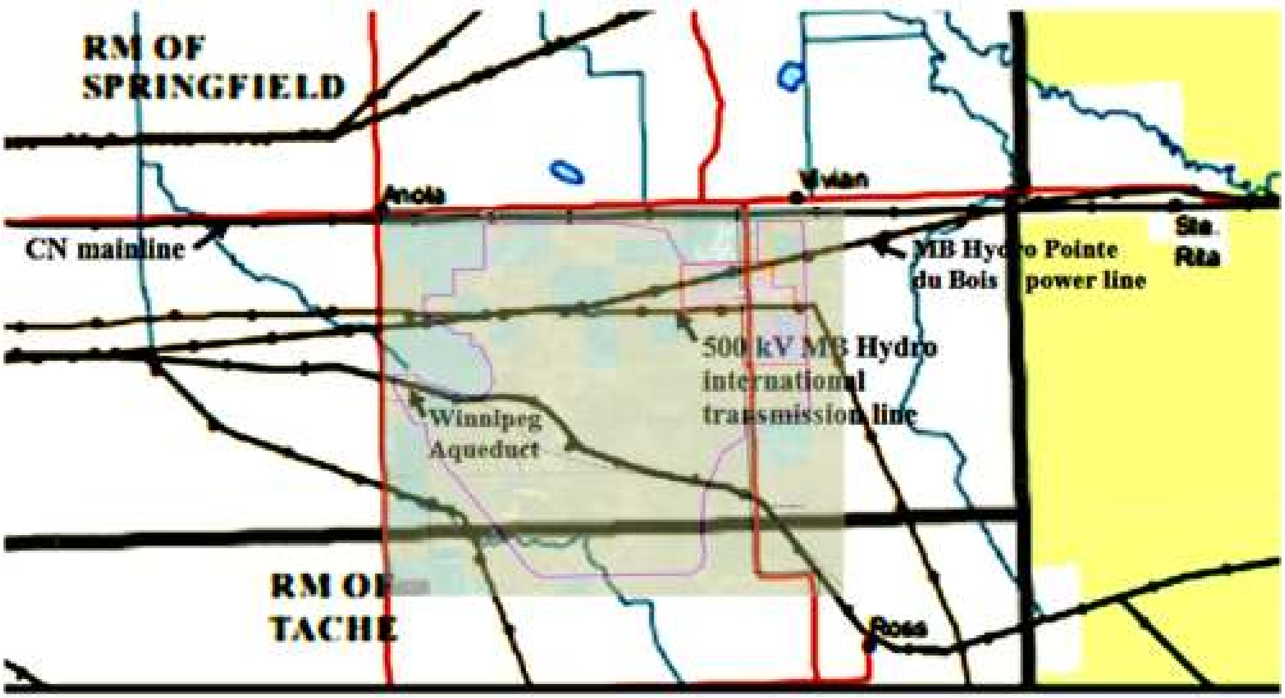


Figure 49. Location of MB Hydro Pointe du Bois power line, the MB Hydro 500 kV international transmission line, Winnipeg aqueduct and CN mainline.[75]
Illustration was reproduced from reference 75. The Bru outline was obtained from the Sio Silica Hydrogeological Report and overlain on the infrastructure map by. D. M. LeNeveu

The Sio Silica project boundary is shown by the purple line

Fourteen and six inch diameter HDPE slurry lines that would carry the extracted sand to the Vivian Sand Processing Plant and recycled return water lines would cross the Hydro lines multiple times. The six inch sand slurry HDPE lines would be emptied into vacuum trucks and moved every five to seven days each time crossing the hydro lines anew when extraction is in that vicinity. The fourteen inch main slurry line and the return recycle water lines would have to be moved, crossing the hydro lines repeatedly in different locations.

Figure 49 illustrates the land disturbance that would affect the international 500kV transmission line and the Pointe du Bois power line due to land subsidence. The unconsolidated sand around the cavities would slump into the cavities gradually enlarging the area of the unsupported shale and limestone above. The limestone is not thick enough to support the cavities that would increase in size as the sand slumps. The land subsidence could cause the formation of swamps or wetlands around and crossing the hydro corridors. The subsidence would cause land depression and instability within and adjacent to the corridors and transmission lines.

As shown in figure 49 the Sio Silica well clusters up until 2025 would be on either side of the provincial highway 302. Sio Silica slurry lines and heavy equipment such as vacuum trucks and drill rigs would be required to cross highway 302. To our knowledge Sio Silica has not notified Manitoba Infrastructure nor obtained permission for the disturbance to highway 302. The land subsidence that could occur from the well clusters could destabilize the road bed and would affect road drainage. Sio Silica should have identified these engineering issues and documented the risks and planned mitigation.

In response to DLN-IR-003 concerning Manitoba Hydro approval of the slurry line crossing the hydro lines and silica sand extraction near the lines Sio Silica stated; "*Sio and Manitoba Hydro have been working towards securing approval and discussions remain ongoing*." Sio Silica has not received approval for the crossing of the slurry lines or approval for extraction near the lines. The Project cannot advance until approval from Manitoba Hydro is obtained.

19.2 The Winnipeg Aqueduct

As shown in figure 49 the Winnipeg aqueduct traverses the entire Sio Silica project area. Eventually the slurry lines and return recycled water loops would eventually likely have to cross the aqueduct multiple times. The aqueduct is known to have cracks that allow infiltration of surface water.[73] Slurry line spills near the aqueduct could contaminate Winnipeg's drinking water supply with harmful microbes, arsenic, selenium, other heavy metals and the highly toxic acrylamide monomer. A major break of the slurry line would leak at a rate of up to 24 cubic meters per minute as documented in the Sio Silica processing plant EAP. The aqueduct could be submerged with a volume of about an Olympic sized swimming pool in two hours. A gradual undetected leak could infiltrate the aqueduct undetected for a long time. The land subsidence and wetlands created by the well clusters on either side of the aqueduct could destabilize the aqueduct and adversely affect drainage around the aqueduct. Flooding of the aqueduct from subsidence wet lands could occur.

Sio Silica is applying for a licence up to 2025. The excavations are not planned to reach the aqueduct by 2025. Project alterations after 2025 such as crossing of the Winnipeg aqueduct could be approved by an alteration request under the Environment Act with no consultation with the City of Winnipeg or the federal government. Sio Silica has failed to consider the potential detriment of the extraction project on the Winnipeg aqueduct. Sio Silica has failed to notify the City of Winnipeg of this eventual disturbance of the aqueduct and has not participated in or initiated a legal agreement with the City of Winnipeg for the Sio Silica slurry operations to cross or be in the vicinity of the aqueduct. Failure to consider the eventual risk to the Winnipeg aquifer and to devise a method to avoid notification and approval by the City of Winnipeg for aqueduct crossing is deliberate avoidance of responsibility by Sio Silica.

20 Modeling of Sio Silica Wells using Carslaw and Jaeger Solution 14.9

An analytical solution from section 14.9 of Conduction of Heat in Solids by Carslaw and Jaeger (C&J) has been used to independently analyze the drawdown and head contours for the Sio Silica pumping and sand extraction activities.[77] The use of heat conduction equations to model head distribution for groundwater flow modelling is well established. The well known Theis solution used to model well drawdown in a confined aquifer is taken from equation 10.4 (5) for a continuous line source (or sink) in Carlslaw and Jaeger.[44,77] The C&J solution used here is for a semi infinite domain bounded on top by plane surface with heat transfer into a medium above. The semi-infinite medium pertains to the Winnipeg sandstone and the medium above is either a shale aquitard overlying the Winnipeg sandstone or the carbonate aquifer in the case where the drilling activities have resulted in disintegration of the shale aquitard. Solution 14.9 from C&J is for an impulse point source or sink of unit strength in the semi-infinite medium. The point source or sink is used to represent the withdrawal or injection of fluid into the Winnipeg Formation from Sio Silica wells. The C&J impulse solution (Green's function) is convoluted with the time dependent well injection or withdrawal rate to represent a continuous time varying source or sink rather than an impulse source or sink.

To represent the finite thickness of the Winnipeg Formation the method of images is used.[77] In this method an image source of equal strength to the injection or withdrawal source is placed beneath the bottom no flow boundary of the model at the same vertical distance below the no flow boundary pane as the source or sink is above the plane. The no flow boundary plane represents the top surface of the granite bedrock. The C&J solution with the same mass transfer boundary condition is used for the image source. The model domain is illustrated in figure 50. For a well with a line input such as through a well screen, a series of point sources can be used. The number of point sources can be increased until the results from the solution converge.

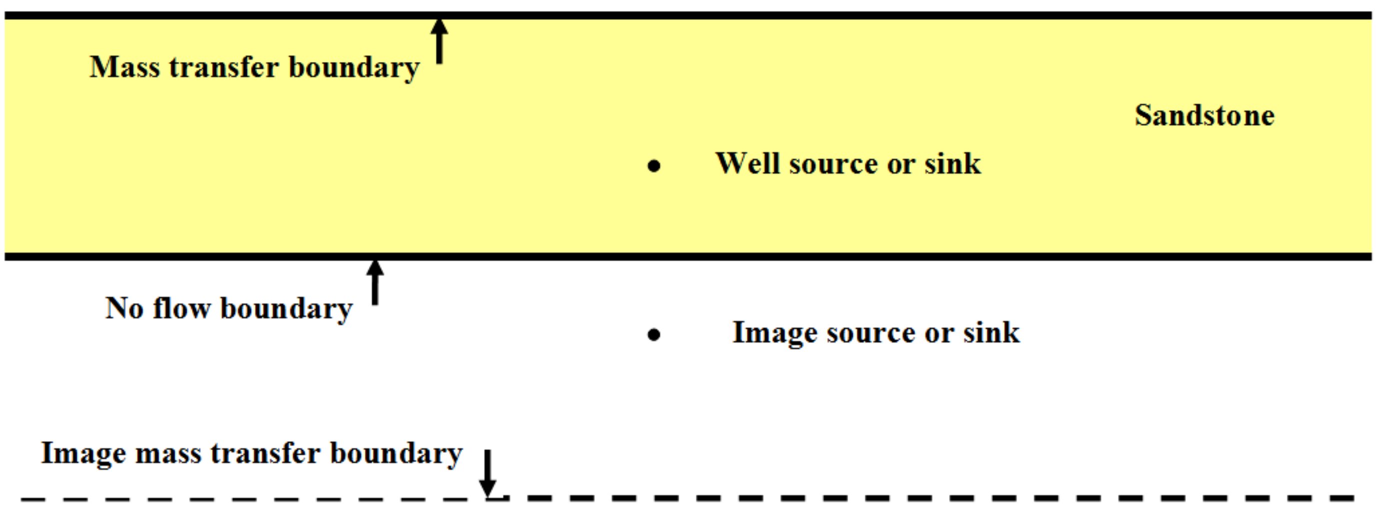


Figure 50. C&J model geometry
Illustration by D. M. LeNeveu

The value of the mass transfer coefficient, h, was estimated according to information from Carslaw and Jaeger $h = H_a/(H_s)/d$ where H_a is the hydraulic conductivity of the aquitard, H_s is the hydraulic conductivity of the sandstone and d is the thickness of the aquitard. The use of an image source below the no flow boundary plane introduces an extra discharge through the mass transfer boundary from the image source. Since the mass transfer coefficient must be estimated and parameter values calibrated to observed values, the extra discharge from the image point source should not impact the veracity of the model. A no-flow boundary into the carbonate or shale can be modelled by setting the mass transfer coefficient to zero. The effect of this model perturbation is examined by comparing the results from the C&J solution with image sources to the Theis solution. The Theis solution applies to a confined aquifer bounded above and below by no flow boundaries with a uniform line source in the aquifer. The line source is modelled in the C&J solution by a vertical series of point sources.

Parameter values for the C&J solution for the Vivian area were obtained by calibration of C&J model results to best fit the head measurements from the Sio Silica Vivian Hydrogeological Study and results from the Theis solution are shown in figure 51.

A non zero mass transfer coefficient was used for the best fit to the observed head values in figure 51. The non zero but small value for the mass transfer coefficient used in figure 51 is consistent with the observed small head drawdown in the carbonate aquifer in response to pumping in the sandstone. The shale aquitard is therefore not a perfect no flow boundary consistent with a small drawdown response in the carbonate requiring a small but non zero mass.

The results of a single point sink and a series of point sources used to represent the pumping well are almost identical as shown in table 11 demonstrating that a single point source for the pumping well is a good approximation. The depth of the single source below the aquitard was 18 meters and the depth of the zero concentration boundary was 20.14 meters consistent with the Sio Silica Hydrogeological modeling study.

In the Hydrogeological study the Theis solution was fit to the observed groundwater head values. Best fit parameters for the Theis solution are given in Table 3-C of the Hydrogeological study.

The results the observed drawdown in the sandstone aquifer compared to the C&J solution and the Theis solution is given in figure 51. The head values for the Theis solution were obtained using the parameter values from the Hydrogeological and an implementation of the Theis solution using Excel VBA. For comparison to the Theis solution a zero mass transfer coefficient was used for the C&J solution to mimic the no flow boundary conditions of the Theis solution. The hydraulic conductivity and storage coefficient values were changed from those used for figure 51 to obtain a best fit for the Theis solution.

The parameter values for the Theis solution, the C&J solution and parameter values used for the finite element model of the Sio Silica Hydrogeological study are given in tables 9 and 10.

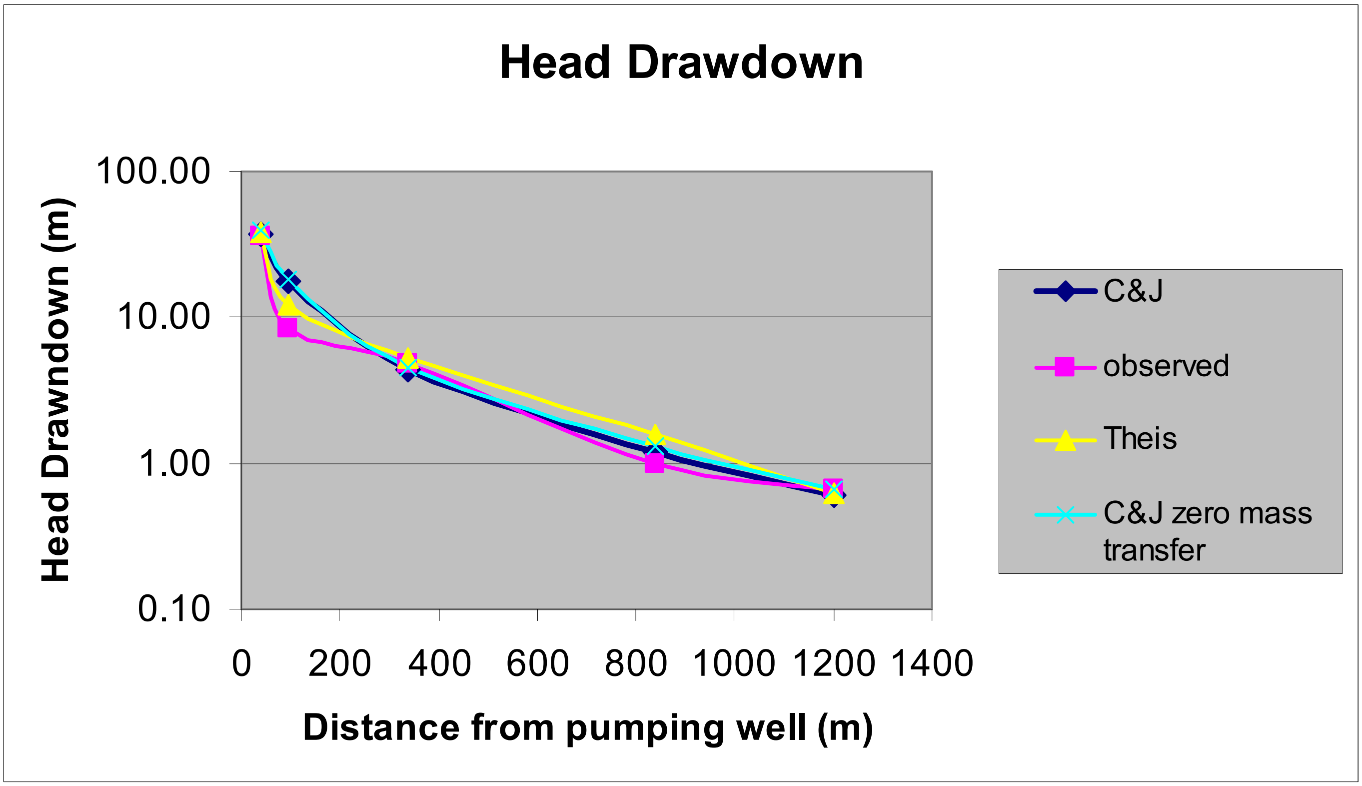


Figure 51. Head drawdown in the sandstone for the C&J solution, observed head values obtained from pressure transducer data for Sio Silica 72 hour pump test, and head results from the Theis solution. *Illustration was produced from analysis by D.M. LeNeveu*

The observed maximum drawdown in the sandstone as a function of distance for the 72 hour pump test obtained from figure 3-4 of the Sio Silica Hydrogeological Report is shown in table 9.
The best fit values to the observed pumping head drawdown values for the C&J solution, and Theis solution and the calibrated value for the Sio Silica finite element model values are given in tables 9 and 10.

Table 9. Calibrated Model Values

Parameters	C&J calibrated	Sio Silica finite element model calibrated
sandstone specific storage (m^{-1})	1.0E-6	7.0E-6
sandstone hydraulic conductivity (m/s)	4.2E-6	1.01E-5 (GM)
sandstone thickness (m)	20.14	20.14
mass transfer coefficient (m^{-1})	7.4E-05	
pumping rate (m^3/s)	0.0252	
aquitard hydraulic conductivity vertical (m/s)		7.27E-9 (GM)
carbonate hydraulic conductivity (m/s)		$6.9x10^{-5}$

(GM is the geometric mean)

Table 10. Theis solution values for observed drawdown

Storativity	5.3E-4
Transmisivity (m^2/s)	8.0E-4
pumping rate (m^3/s)	0.0252

The transmissivity and storativity values for the Theis solution values used for best fit given in table are within the somewhat smaller values given in Hydrogeological report for various scenarios but within the range of variability. The pumping rate used was 400 US gpm or 0.0252 m^3/sec.

The data from figure 51 are shown in table 11.

Table 11. Data for figure 51

Radius from well (m)	Head from C&J one point source (m)	Observed head (m)	Head from C&J line source – 10 points (m)	Head from Theis (m)	Head from C&J zero mass transfer coeff. (m)
40	37.62	36.3	38.61	37.83	39.03
95	17.73	8.5	17.64	12.06	17.97
340	4.38	4.8	4.38	5.27	4.57
840	1.20	1	1.20	1.57	1.29
1200	0.61	0.67	0.61	0.63	0.66

The lack of exact match between the C&J solution and those of the finite element model are to be expected and consistent with the lack of match of the Theis solution parameter values and the equivalent finite element model values. The C&J parameter values are within the range of values quoted in studies by Friesen Drillers.[32] The specific storage for the C&J best fit value is within the range given by Freeze and Cherry for sand from about 10^{-6} to 10^{-8} m^{-1}.[44] Friesen Drillers gives the hydraulic conductivity of the sandstone in the Springfield area as 2.5 x 10^{-5} m/s. The C&J fitted value for hydraulic conductivity of the sandstone is between the Sio Silica calibrated values and the Friesen Drillers value.[32] Thus the C&J parameter values are within the range of other modelling and experimental values.

The results illustrated in table 11 demonstrate that a singe point source used to represent a pumping well of finite length is a good approximation. The small difference between the C&J solution with a small best fit value for the mass transfer coefficient and a zero mass transfer coefficient verifies that the sandstone can be adequately represented as a confined aquifer. The ability of the C&J solution to reasonably fit the observed head drawdown results and results form the Theis solution verifies the use of the C&J model for this study.

The implementation of both point sinks and sources in the C&J solution allows for the modeling of a combined extraction and re-injection well specified in the Sio Silica EAP design. The finite element modeling in the Hydrogeological study used only pumping. No re-injection was modeled with the finite element model. This could be due to the very fine discretization that would normally be required in the finite element methodology to model point sources and sinks so close together.[79] The C&J solution is a Green's function for an impulse point source or sink. The C&J solution is not subject to the inherent numerical discretization errors associated with small point sources and sinks for most numerical finite element or finite difference models. The mass transfer coefficient of the C&J solution allows for the modeling of a diverse set of conditions pertaining to the state of the aquitard. As a cavity develops under the carbonate the shale layer is likely to degrade as documented in the Hydrogeological report. A low value of the mass transfer coefficient of the C&J solution would pertain to an intact aquitard and a higher value a degraded aquitard. The C&J solution can be used to estimate and quantify the amount of water transferred into the carbonate from the sandstone for various states of the aquitard. The C&J solution is semi-infinite in nature and therefore not subject to artificial boundary conditions that must be applied to the finite element solution. For a continuous pumping source numerical integration of the C&J solution of the pumping rate over time is required. The integration is implemented with a time step size that increases with time. The number of time steps is increased until convergence is obtained thus minimizing and quantifying the potential numerical error from numerical time integration.

The well information reports obtained from Manitoba Groundwater demonstrate that the Winnipeg Formation aquifer extend much deeper than the 20.14 meters used in the Sio Silica finite-element model. Well BH2-17 further west at township range and section identifier SW7-10-8E extends to the granite bedrock. The well log for BH2-17 records a sand layer 20.4 meters deep beneath the 3.35 m thick shale aquitard, followed by a layer 2.4 m thick layer of sand with shale layers, followed by 21.6 m thick shale layer. The final layer above the granite bedrock is 1.5 m thick layer of white sand. The total depth from the bottom of shale aquitard to the top of the granite is 46 m. The core log for Well BH9-17 at SW19-10-8E records no distinct white sandstone layer. Multi- shale and mixed shale and sandstone extend almost from the shale aquitard to the granite. A 3 meter thick black sandstone layer overlies the granite. The depth from the top of the shale aquitard to the granite is 49 meters. The two wells that extend to granite indicate about 47 meters would be a more appropriate model depth for the Winnipeg sandstone than the 20.14 m aquifer thickness used in the Sio Silica HR. The well information reports from Manitoba Groundwater show the extractable sand layer, under the shale aquitard is typically is not more than 20 meters thick over the entire Bru area. Shale stringers or beds are often recorded within the 20 meter thick sandstone layer particularly at larger depths. Beneath the extractable sand layer, shale layers are consistently recorded. These deeper shale layers are consistent with the Black Island members described in the Sio Silica Hydrogeological report as containing pyrite. The Hydrogeological report states

"*The Winnipeg Formation has been subdivided into stratigraphically distinct units with subdivisions generally consisting of a lower sandstone unit (Black Island Member) and overlying units consisting of sandstone and shale layers (Icebox Member). A third unit (Carman Sand Member) is a clean very-fine-to-medium-grained sandstone zone that is up to 30 m thick in the upper portion of the Winnipeg Formation in Southeastern Manitoba*."

However the maps of figure 20 demonstrate that most of the Bru Project area is north of the Carmans sands.

This deeper pyritic shale would be exposed to aerated re-injected water and injected air during the Sio Silica extraction operations when the sandstone layer above is removed. The deeper shale layers were not sampled and subject to geo-chemical analysis by Sio Silica. The potential oxidation of pyrite to form acid in the deeper Black Island members has been ignored by Sio Silica.

It must be emphasized that the finite element modeling used in the Hydrogeological study never addressed the essential and required feature of the Sio Silica operation of re-injection of aquifer water. Extensive drawdown studies and aquifer modeling studies have already been carried out in the Springfield area around near Glass and Steinbach.[81,82] The well pumping and modelling done by Sio Silica is simply one more drawdown study. The results of the C&J model for combined extraction and re-injection wells in a cluster are given in figures 16 and 17 above. The parameter values used for the C&J studies in figures 16 and 17 are given in table 2.

The amount of water transferred from the sandstone aquifer to the carbonate during re-injection for a degraded aquitard can be determined from the C&J model. To simulate the flow rate of water transferred to the carbonate from the sandstone into the carbonate from re-injection F_w is calculated by integrating the head, H_B at the top of the sandstone over a 27 meter well radius, r, multiplied by the hydraulic conductivity of the sandstone, K_S and the transfer coefficient, h after a steady state head contour has been achieved.

$$F_w = 2\pi \int K_S h H_B(r) r dr$$

Figure 52 shows steady state is achieved in less than 3 hours of extraction for one well in a cluster for a degraded aquitard. The smaller mass transfer rate before this time is an insignificant fraction of the total water transferred across the boundary during the reference extraction time per well of 5 days. The C&J simulations for a degraded aquitard show a small amount of water transferred from the carbonate back into the sandstone for a radius greater than 27 meters however the aquitard is likely to remain intact outside the area of the cluster at least until such time as the sand external to the cluster slumps into the cavity formed by extraction. By the time slumping would occur and the radius of the extraction cavity would increase extraction may well have halted for a given cluster. For an intact aquitard beyond the cluster boundary an insignificant amount of water would be transferred across the boundary. For the intact aquitard in the Vivian area, the head in the carbonate is about 3 meters high than in the sandstone. To determine the water transfer across the boundary the head at the sandstone aquitard boundary caused by re-injection is decreased by 3 meters. It is assumed for the degraded aquitard the head differential across the boundary will equalize.

Numeric integration of the equation for water flow using reference parameter values for the C&J simulation and a radius of 27 meters corresponding to the radius of the well cluster gives a water transfer rate from the sandstone to the carbonate of 86 cubic meters per day for one well. For 455 wells per year, used for these simulations, would result in 195,650 cubic meters per year transferred into the carbonate from the sandstone from the water re-injection. The reference parameter values for the sandstone are given in Table 12

Table 12. Reference C&J parameter values for sandstone

Specific storage (m^{-1})	Hydraulic conductivity (m/s)	Total thickness (m)	Depth below aquitard of re-injection (m)	Depth below aquitard of withdrawal (m)
$1.0x10^{-6}$	$4.2x10^{-6}$	44	4	18

The depth of the sandstone aquifer was set to 44 meters in accordance with the deeper Sio Silica wells that extend to the bedrock as recorded in the well information reports obtained from Manitoba Groundwater that captured the entire geological feature of the Winnipeg Formation. The amount of water transferred across the boundary for a diameter of 54 meters from the extraction well for 5 days of extraction per well and 455 wells per year for alternative scenarios of a degraded aquitard and intact aquitard with 65% water during extraction and 35% water during extraction is shown in table 13 along with the relevant parameter values. The last row of table 13 gives the results for a degraded aquitard for the re-inject point moved from 4 meters below the aquitard to 1 meter. The further the separation of the re-injection point and the withdrawal, the less water re-injected is drawn back into the withdrawal tube and the more is transferred to the carbonate. Re-injected water being drawn into the withdrawal would interfere with and dilute sand extraction. The incentive to maximize sand extraction would be to move the re-injection directly to the carbonate aquifer. The perturbation of local well water would be much greater with direct re-injection into the carbonate for wells completed in the carbonate.

Table 13. Water transfer to carbonate for various scenarios for the combined extraction and re-injection well of the EAP design.

Case	Transfer coefficient (m^{-1})	Water fraction in extraction	Water withdrawal rate per well (m^3/day), (USgpm)	Water re-injection rate per well (m^3/day)	Water transferred to carbonate for one well in 5 days (m^3)	Water transferred to carbonate in one year (m^3)	Water re-injected in one year (m^3)

Intact aquitard	$7.4x10^{-5}$	0.65	675.3,123.8	611.15	0.608	276	$1.39x10^6$
Degraded aquitard	0.047	0.65	675.3,123.8	611.15	454	206,577	$1.39x10^6$
Degraded aquitard	0.047	0.50	363.64,66.6	299.23	174	79,077	680,748
Degraded aquitard re-injection 0.1 m below aquitard	0.047	0.65	675.3,123.8	611.15	686	312,429	$1.39x10^6$
Re-injection for zero head increase at 5 m after 1 hour	0.047	0.65	675.3,123.8	117.0	-3.38	-1539	$1.39x10^6$

The amount transferred to the carbonate over the area of the cluster for a degraded aquitard is non-linear with respect to the transfer coefficient. For a high transfer coefficient the water transfer into the carbonate is restricted to a small region around the re-injection well. Water from the carbonate is drawn back into the sandstone from the carbonate at larger distances from the injection well so that the net transfer can be from the carbonate to the sandstone. Figure 52 illustrates the negative head change at distances further from the combined extraction and injection wells for the Sio Silica EAP design that would result in water transferred to the carbonate being drawn back into the sandstone for degraded aquitard. However the aquitard is likely to be damaged only over the excavation cavity. Thus the movement of water back into the carbonate at distances beyond the extraction cavity in unlikely to occur.

The evidence given here demonstrates that the Sio Silica combined extraction and injection well design is not viable. The production well configuration that would be implemented remains unspecified by Sio Silica. Sio Silica has stated that dedicated injection wells permitted by Sio Silica during advanced exploration would not be used since the injection pressure from such wells would damage the formation. The only other option would appear to be re-injection of water into the carbonate as per the design of the Sio Silica permitted injection well at Centre Line Road. The airlift extraction wells at the two quarries near Vivian where sand was extracted were designed to allow combined extraction and re-injection of water through the outer annulus into the carbonate aquifer. Re-injection into the carbonate of water taken from the sandstone is prohibited by Manitoba Groundwater regulations. The huge amount of water per year required for re-injection given in table 13 would cause a major perturbation of the carbonate aquifer and destruction of water quality over a wide area.

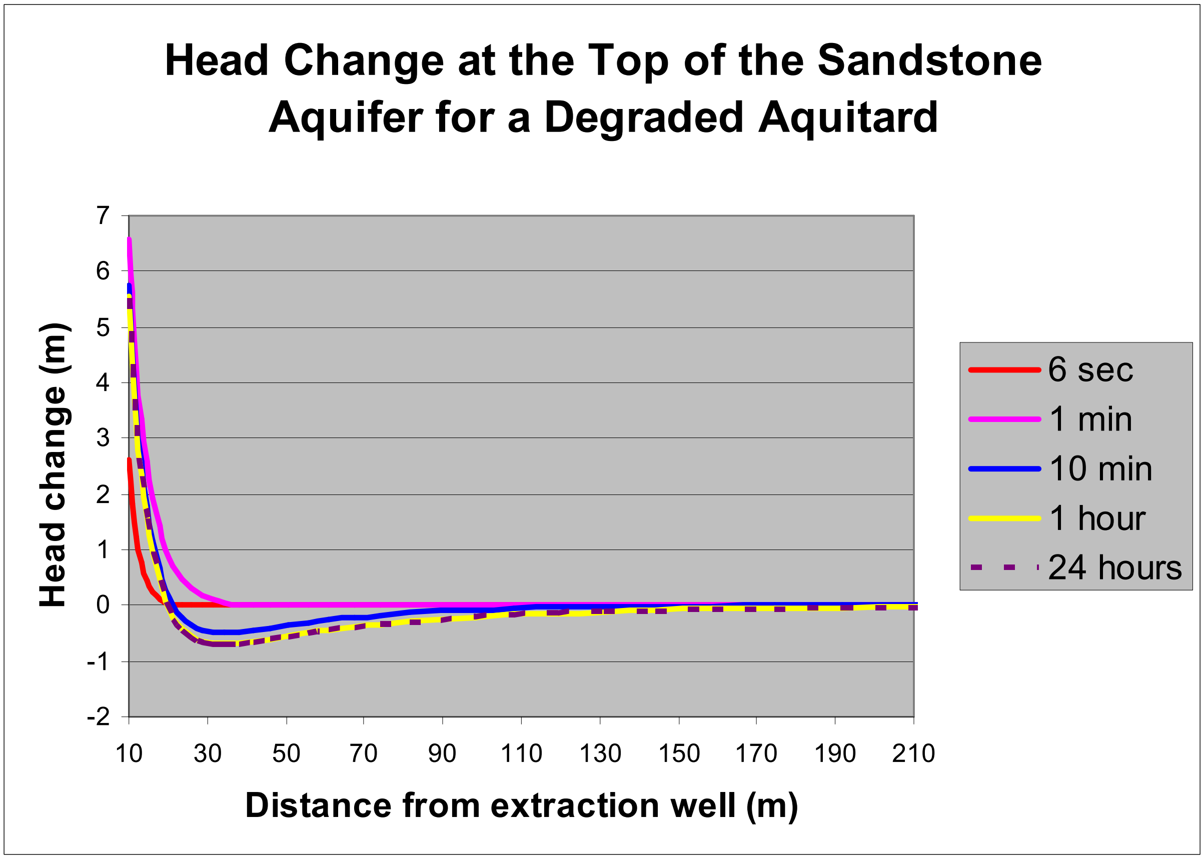


Figure 52. Head change at the top of the sandstone for one well in a cluster for increasing extraction times
Illustration is from analysis by D.M. LeNeveu

The movement of water into the carbonate and then back into the sandstone would result in a mixing of aquifer waters and would still result in contamination from oxidation of sulphide in the sandstone being transferred to the carbonate. The degradation of the aquitard caused by extraction activities would allow continued mixing of aquifer waters such that contamination migration in both aquifers would occur after extraction. A complex situation could occur where water first spread laterally across the top of the aquitard initially when the aquitard would be intact. As the aquitard degraded more water would be transferred to the carbonate. The percent of water in the extraction would be expected to increase with time of extraction resulting in more water transfer to the carbonate. As the aquitard degraded further more of the water transferred to the carbonate would move back to the sandstone at distances further from the well. Such a complex situation cannot be modelled exactly by the C&J solution however the overall results can be illustrated by variation in parameter values.

The net water transferred to the carbonate over a radius extending to 27 meters from the extraction well as a function of increasing transfer coefficient for two average water percents during the extraction is illustrated in figure 53.

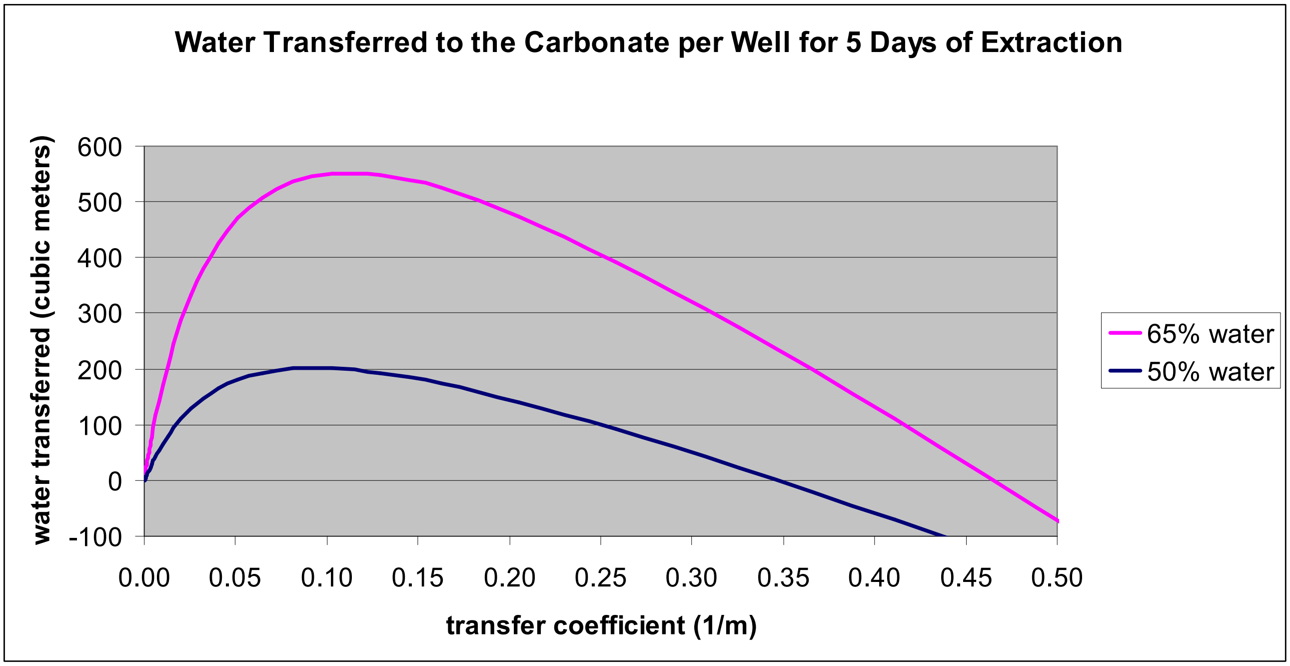


Figure 53. Net water transfer to the carbonate for increasing transfer coefficient for 65% water and 50% water during withdrawal for 5 days of extraction over a radius extending to 27 meters from the extraction well.
Illustration is from analysis by D.M. LeNeveu

As the value of the transfer coefficient increases the amount of water transferred to the carbonate over the cluster area first increases then decreases. The decrease at larger mass transfer values is caused by water draw back from the carbonate into the sandstone near the wells. In this situation almost all the water re-injected is recycled back into the withdrawal wells greatly inhibiting sand uptake. This phenomenon illustrates the unfeasibility of the combined extraction and injection wells and explains why Sio Silica abandoned this extraction method in the advanced exploration operations even though the method remains as the operational design given in the EAP.

21 Head Change in the Carbonate from water transferred from the sandstone by water re-injection

The Theis solution can be used to model the head increase in the carbonate from the water transferred from the sandstone by re-injection. The Sio Silica hydrogeological study did not model water re-injection, only water withdrawal. The effect of water re-injection transferring water from the sandstone to the carbonate, thereby increasing head in the carbonate was completely missed in the Sio Silica modelling study. This is a major potential consequence of the Sio Silica extraction operation that has been ignored by Sio Silica.

To model the head increase in the carbonate from re-injection a single average discharge point at the centre of the cluster is used injecting at an average rate of 3.5 wells x 90.8 cubic meters per day =317.8 cubic meters per day (58.3 US gallons per minute) for ten days. This corresponds to the second scenario of 65% water 35% sand with water extraction rate of 124 US gpm per well and total sand plus water extraction rate of 190.5 US gpm per well. Three clusters operating simultaneously at the average cluster injection rate injecting at a total cluster rate of 953.4 cubic meters a day (174.9 US gallons per minute) were modelled for a single injection point into the carbonate. As the distance from the clusters increases this approximation improves. For yearly production the position of the operating clusters would move. The modelling shown in figure 56 would be representative of three clusters operating simultaneously for ten days that would move as operations continued.

If the head from the Theis solution is given by $T_h(r,t)$, the head from each cluster is given by $T_h(r,t-T_s)H_s(T_s) - T_h(r,t-T_e)H_s(T_e)$ where, r, is the radius from the centre of the cluster, T_s is the operating start time for the cluster, T_e is the operating end time for the cluster and H_s is the Heaviside step function. The total head at any point and time is determined by superposition.

According to the Sio Silica Hydrogeological Report;

"*The transmissivity values of the upper carbonate aquifer range from 28 m^2/day to 2,840 m^2/day and the storage coefficient varies from 1 x 10^{-6} to 1 x 10^{-3}. The lower carbonate aquifer has lower permeability due to less frequent interception of fracture sets and groundwater flow is reduced. The maximum probable transmissivity of this aquifer was estimated by Render (1970) to be less than 62 m^2/day*"

Friesen Driller gives the average transmissivity of the carbonate to be 50,000 US gallons per day per foot or 7.2×10^{-3} m^2/s or 621 m^2/day.[81,82]

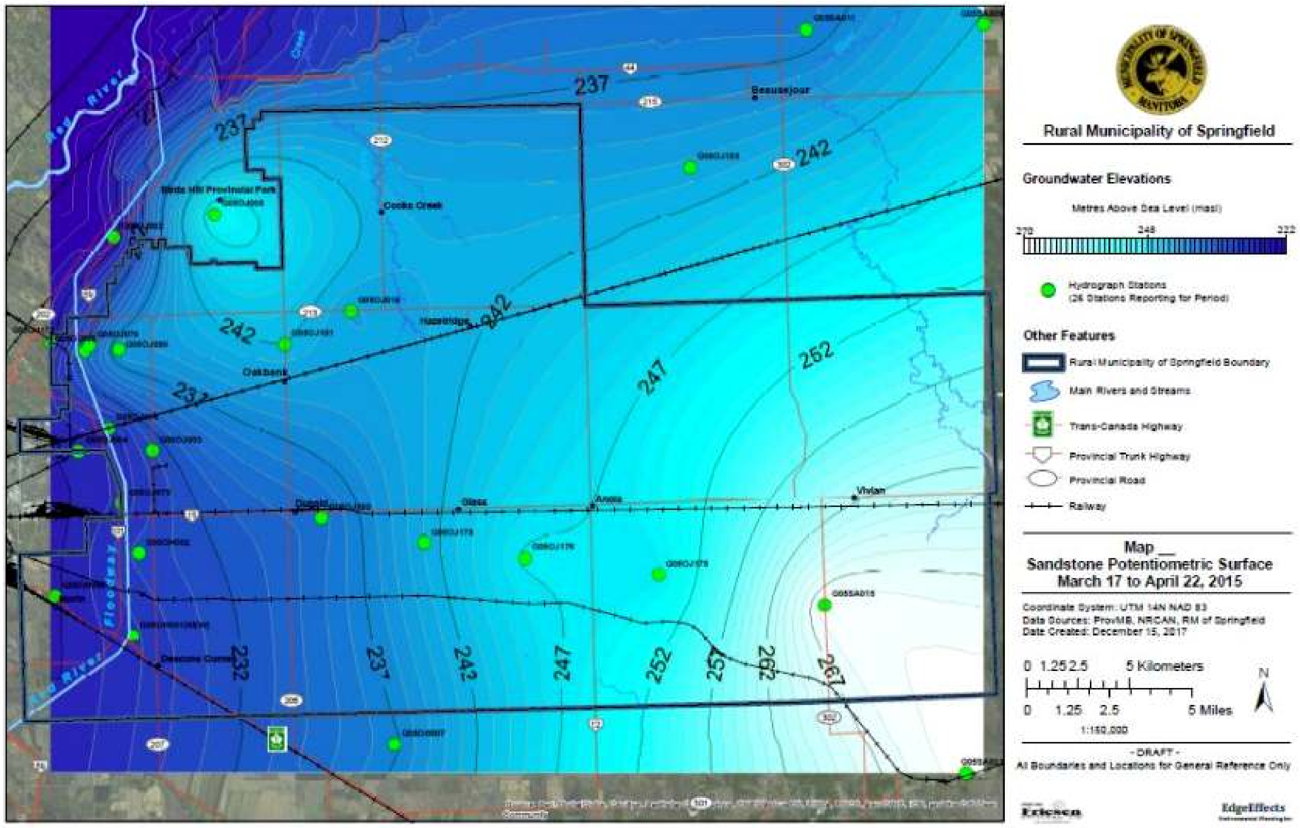
Table 6-C of the HR gives the specific storage of the carbonate to be 1.0×10^{-6} m^{-1}. According to the core logs the limestone thicknesses are for Bru 95-6, 9.7 m; Bru 95-7, 13.2 m; Bru 95-8, 15.9 m; Bru 95-9 11.6 m; and Bru 96-1, 8.3 m for an average of 11.74 m

Thus from the HR data the storativity of the carbonate would be 1.0×10^{-6} m$^{-1} \times 11.74 = 1.174 \times 10^{-5}$.

The reference values used for the Theis simulation for the water transfer into the carbonate are, transmissivity, 621 m^2/day and storativity, 1.174×10^{-5}.

The initial head distribution in the Bru area was modelled by adjusting curve fitting equations to match the head distribution in the sandstone reported by Friesen Drillers.[32] The data for the initial head distribution reproduced in figure 54. The head distribution obtained by curve fitting is illustrated in figure 55.

Figure 9 – Groundwater Flow in the Sandstone Aquifer – RM of Springfield.



(Data source: MSD, 2018)

Figure 54. Sandstone potentiometric surface**.**
Original data from Manitoba Sustainable Development (MSD) groundwater observation wells was reproduced from reference 32 .

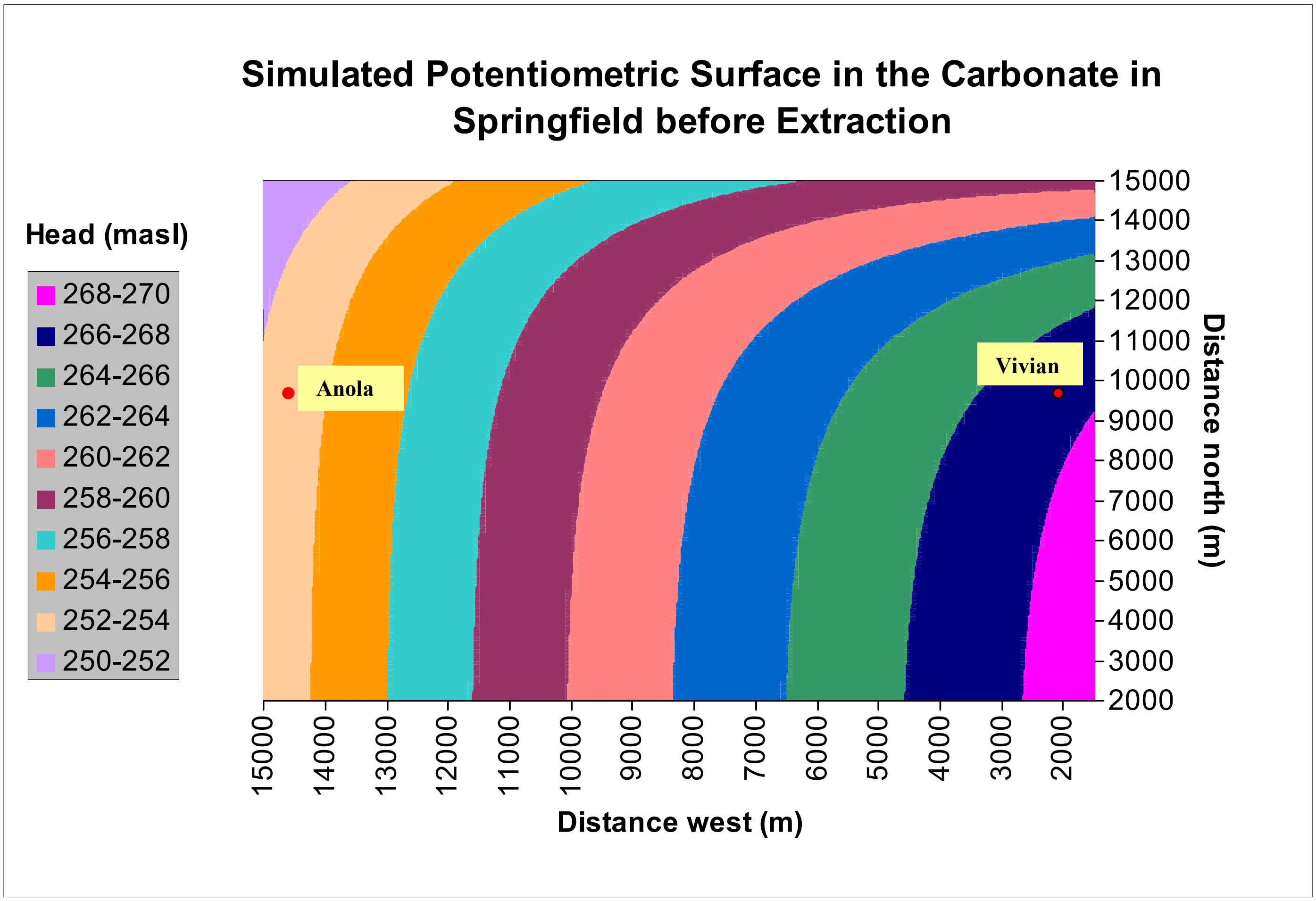


Figure 55. Simulated potentiometric surface in Springfield before Sio Silica extraction operations
Illustration is from anlysis by D. M. LeNeveu

The total head distribution obtained by adding the head change obtained from the Theis solution for a three cluster Sio Silica extraction unit, to the initial simulated head distribution, is shown in figure 56.

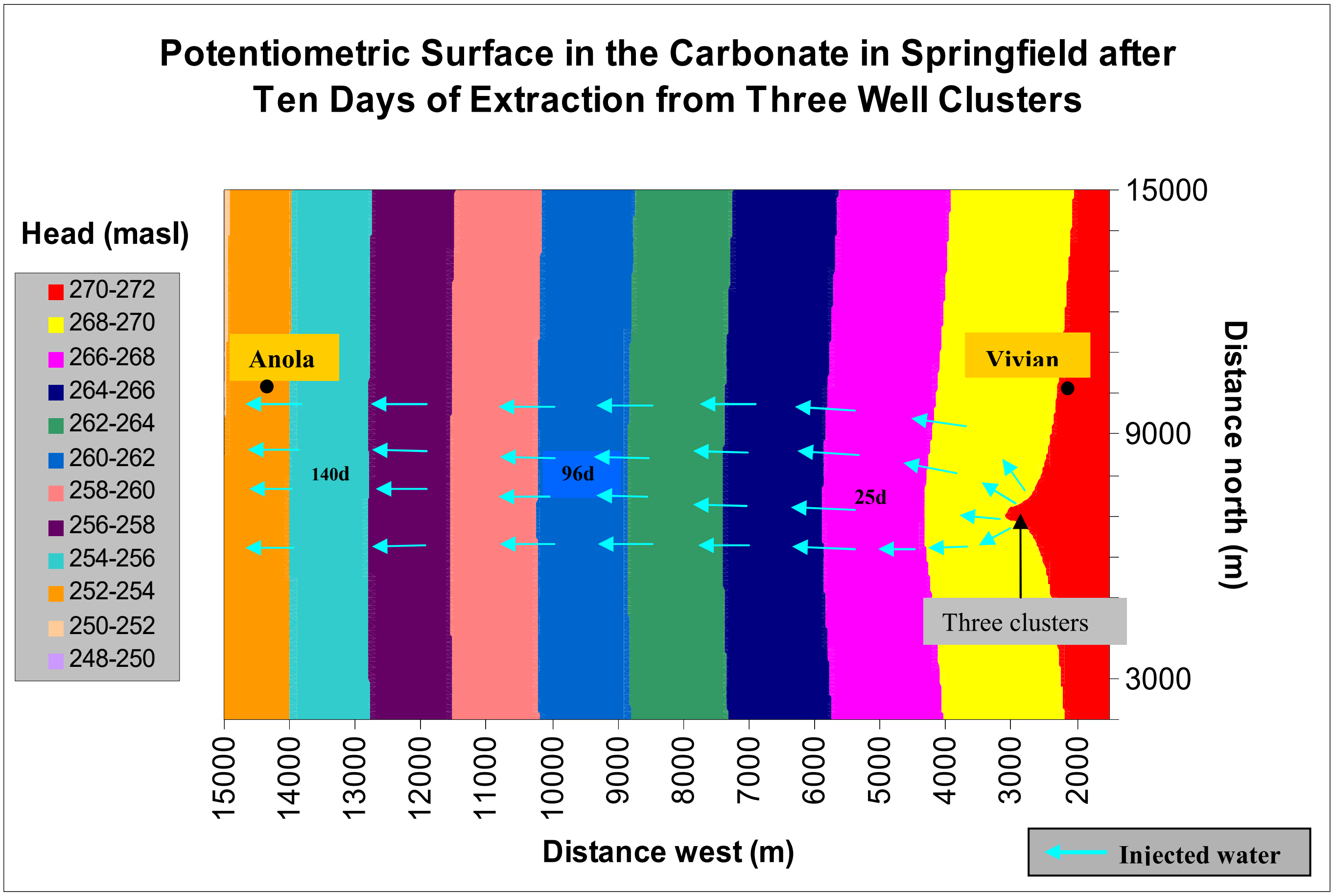


Figure 56. Head Change in the Carbonate from water transferred from the sandstone by water re-injection. *Illustration is from analysis by D. M. LeNeveu*

The water transit time is given in figure 57 for fracture porosities of 0.003 and 0.001. The "natural" transit times refer to conditions before extraction. Medici et al. suggest using a facture porosity in limestone of 0.0001 for water transit time. Such a small porosity would decrease transit times by an order of magnitude compared to the 0.001 porosity values.

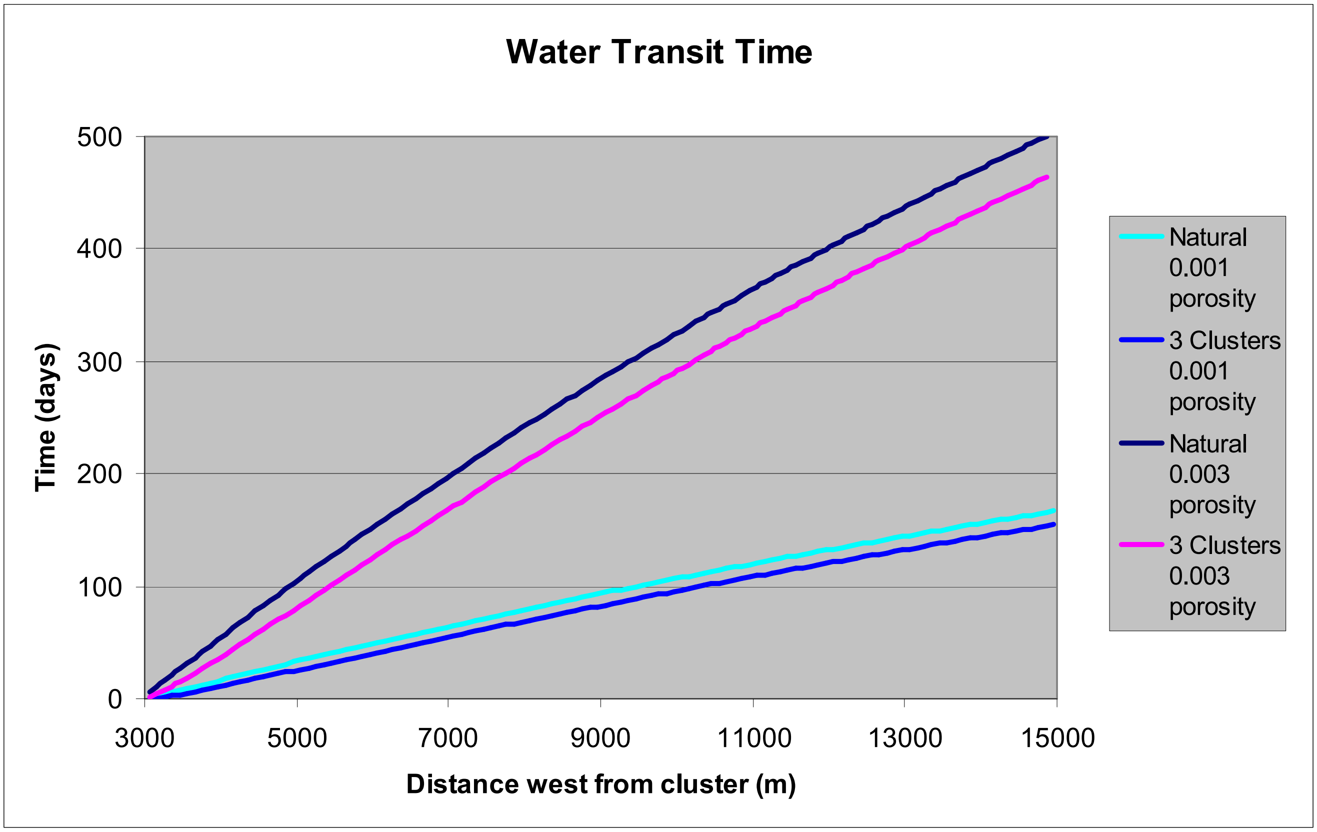


Figure 57. Water transit time in fractures in the limestone and karst of fracture porosities of 0.001 and 0.003
Illustration is from analysis by D. M. LeNeveu

The results of the Theis simulations for movement into the carbonate of re-injected water from the sandstone by Sio Silica sand extraction operations demonstrate large detrimental changes in water quality would be expected to occur. The aerated water in the carbonate would mobilize selenium measured to be in the sandstone. Acid formed by aerated water oxidizing documented sulphide sources in the sandstone would mobilize heavy metals. The acid carried into carbonate aquifer would dissolve limestone opening fractures leading to cover collapse sinkholes and cover subsidence as documented by USGS studies.[29] The acid would contribute to collapse of the unsupported limestone span over excavation cavities. Such collapse would destroy both aquifers and cause long term widespread detrimental effects to the land surface. The aerated water and microbes introduced by well drilling and air injection would deteriorate water quality from the action of iron bacteria and potentially cause sickness. Sio Silica has neglected the potential microbial introduction from the injected air. Sio Silica has not demonstrated the effectiveness or viability of UV sterilization of re-injected water and drilling of hundreds of wells per year. Suspended fine particulate from the sandstone would further degrade water quality. Brown water was reported in nearby carbonate water well following Sio Silica extraction activities. Residents in the area of Vivian lodged an official complaint of deterioration of water quality consistent with the action of iron bacteria following Sio Silica extraction activities in the area corroborating such detrimental effects will occur.

22 Feasibility of re-injection of excess water extracted with the sand

The evidence presented here demonstrates that the Sio Silica EAP design of a combined extraction and re-injection well is not feasible. The well information reports of Sio Silica extraction wells since 2018, obtained from Manitoba Groundwater, corroborates this evidence. Following degradation of the shale aquitard, movement of water into the carbonate, from re-injection into the sandstone, would occur. Sio Silica has not demonstrated that the shale aquitard would retain its ability to isolate the aquifers following extraction activities. The evidence presented here demonstrates that the aquitard above extraction cavities would be degraded with subsequent movement into the carbonate of water re-injected to the sandstone. The Sio Silica Hydrogeological report acknowledges the risk of aquitard degradation due to Sio Silica extraction activities. Sio Silica models the geochemical consequence of aquitard degradation even though mixing is prohibited by Manitoba regulations. The only viable option would appear to be remote re-injection of water far from the extraction site. Nearby re-injection could compromise the sand support between excavation cavities referred to as "*room and pillar style*" extraction in the Sio Silica EAP. Such remote injection in dedicated injection wells would escalate the cost of the operation and may still damage the aquitard, due to the injection pressure. Over three hundred re-injection wells per year may be required. Sio Silica has already stated that they will not use dedicated re-injection wells due to the risk of injection pressure damaging the formation. The risk of transfer of water from the sandstone to the carbonate from Sio Silica extraction activities alone renders the entire project unfeasible.

23 Geo-Mechanical calculations of the stability of the unsupported limestone spanning extraction cavities

The well clusters for the Sio Silica extraction wells are expected to leave a cavity of at least 54 m for five wells that is expected to grow as sand slumps into the cavity as documented in Sio Silica/Stantec Attachment A of the response to public comments in the project registry 6119.00. The shale is expected to degrade into the cavity leaving a layer of unsupported limestone above as is acknowledged in the Sio Silica Hydrogeological Report. Sio Silica/Stantec Attachment A reports that the shale is not a supporting layer, further confirming that degradation would occur. The eventual collapse of the limestone as the excavation cavity opening increases due to sand slumping is illustrated in figure 58.

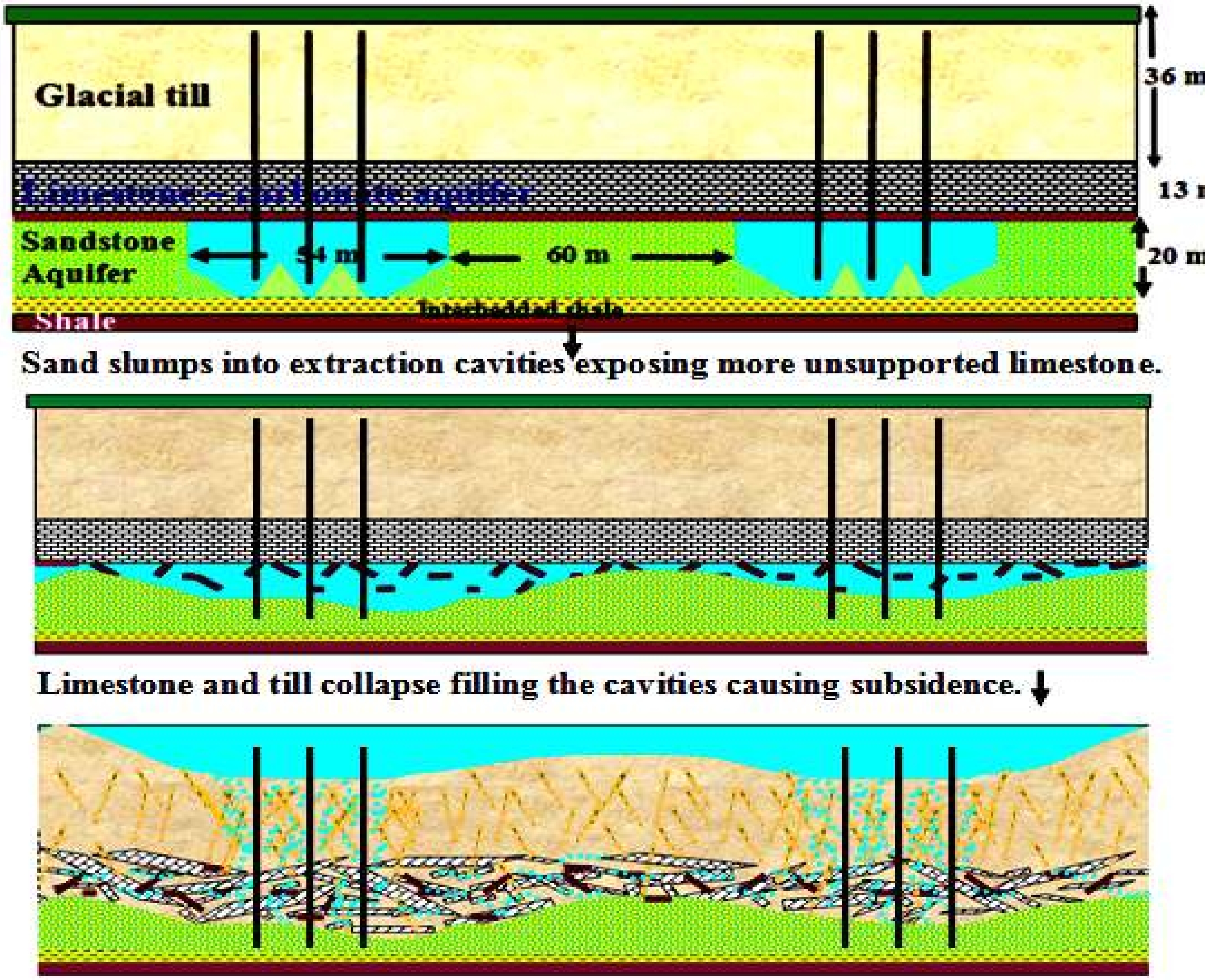


Figure 58. Collapse of limestone in the Sio Silica extraction cavities.
Illustration was produced by D.M. LeNeveu including figures reproduced from Sio Silica Hydrogeological Report

24 Conclusion

Sio Silica has failed to disclose essential information required to assess the environmental effects of the project. Sio Silica has not given detailed engineering specifications drawings measurements and data many processes including the processing facility, dewatering plant, connection of the processing facility and dewatering plant to the recycling slurry loop, French drain system at the processing plant, UV radiation and filtration, leak detection systems for the slurry loop, CN approved specifications for the Sio Silica railway loop, waste management facilities, processing facility and slurry loop water storage tank. Sio Silica has failed to disclose essential process, data and measurements including the rate and volume of water and sand extracted from the sandstone, the rate and volume of water re-injected, the water to sand extraction ratio as a function of extraction time, the water pressure in the sandstone and carbonate during extraction and water re-injection, analysis of the damage to the aquitard and the formation during extraction, the volume of waste as a function of sand extracted at the extraction site including concretions, sediments, overs and fines, the amount of air and contaminants in the re-injected water, the pressure, rate and volume of air injected directly and indirectly into the aquifer during extraction, methods of determinations of extraction well cluster size and spacing, beneficiation measures in the processing facility, and processes for removal of accumulated dissolved contaminants in the recycle slurry loop,.

Data on the formation pressure and analysis of damage to the aquitard and the formation during re-injection of water as required by the injection well permits has not been disclosed. Sio Silica has tested the re-injection of process water at only one well Bru 92-8 in the summer of 2021 and has given only assurances that all the water extracted with the sand was returned to the aquifer with no data to support this assurance. No detail has been given on how the process water return would be implemented during production when many wells are operating, closing down and starting up with many process water flow delays in the surface vessels of the dewatering station, UV filtration and tanks for possible removal of entrained air. No examples have been given of successful gravity fed re-injection processes on an industrial scale.

Sio Silica has ignored the presence of entrained gaseous air in the re-injected water that evidence given here demonstrates is very significant. Sio Silica has claimed that all the air injected into sandstone remains in the production tube however evidence given here establishes that air would likely be injected directly into the aquifer.

Sio Silica has failed to adequately address all the potential microbial sources of aquifer contamination. Sio Silica has not considered the injected air as a source of microbial contamination of the aquifer as documented by evidence given here. Sio Silica has not considered sterilization methods for compressed air injection. Sio Silica has failed to consider contaminants including diesel exhaust and oil vapours for the compressor cooling that would be concentrated in the oil-free air compressor to be used by Sio Silica. Sio Silica has not documented the effect on the aquifer water quality of large amounts of chlorine that would be required for drilling sterilization required by the regulations of the Manitoba Groundwater and Water Well Act.[54] Sio Silica has acknowledged that filtration of particulate that would scatter the UV light would be required but has not given final specifications on how this would be implemented.

The required re-injection of water is a major perturbation to the aquifers. Sio Silica has deliberately suppressed the adverse effects of re-injected water through deceptive modeling and groundwater field pumping and measurement tests that considered only drawdown. The C&J and Theis modeling results presented here demonstrate that re-injected water penetrating the carbonate from the sandstone through a damage aquitard has the potential to contaminate a huge area of the carbonate aquifer with acid, heavy metals transferred from the sandstone, iron bacteria and other harmful microbes, dissolved diesel fumes and other contaminants from the compressed air. The Sio Silica modeling did not consider the aquifer sustainability with respect to loss of water from the sandstone to entrained water in the sand stockpiles at the processing plant and in waste management activities. Sio Silica has acknowledged that mixing of aquifer water could occur from degradation of the aquitard caused by sand extraction activities. Mixing of aquifer waters is prohibited by Manitoba groundwater regulations. Sio Silica used geochemical modeling to attempt to construe this mixing of aquifer waters as benign despite evidence from Dr. E. Pip to the contrary. Assertions that increase in iron and manganese precipitates caused from Sio Silica induced oxidizing conditions, would be filtered out by the sandstone has not been supported by evidence. I have provided evidence that effective filtration of iron and manganese by the sandstone will not occur. Sio Silica assumes the right to unilaterally ignore regulations on aquifer mixing and formation pressure measurement during extraction. The Sio Silica acknowledgement that mixing of aquifer waters could occur should in itself prevent this project from proceeding. The injection of contaminants of air in the through the injection water and air into the aquifer is prohibited by the Manitoba Groundwater and Water Well Act.[54] This violation of the Act should as well prevent this project from Proceeding.

Sio Silica has suppressed information on the sulphide content of the sandstone aquifer. Sio Silica did not measure the sulphide content of concretions or of the lower shale of the Black Island members exposed during excavation. Sio Silica has falsely claimed that extraction would be solely in the Carman sands that are found only in a small southern portion of the 24 year project area. The majority of the extraction would occur in the Black island member of the Winnipeg formation. The well information report obtained from Manitoba groundwater reveal the presence of the lower shale interbeds in all wells penetrating to depth in the sandstone. The geological literature consistently reports the presence of sulphide in the lower shale of the Winnipeg formation and in concretions and oolite also found in the Winnipeg formation.

The Sio Silica geochemical results recorded levels of selenium and fluoride above accepted limits in shake flask tests but did not evaluate the contamination that could result from the release of these contaminants caused by re-injection of aerated water into the aquifer.

The Sio Silica core samples were insufficient, did not cover representative areas of the entire 24 year Bru project area and were not protected from air exposure as required by MEND guidelines. Two of the three analyzed core sample locations, Bru 146 and Bru 121-1 were outside the Bru area and taken from historical core storage at Steinbach that had been air exposed since 2108. The collection method, date of sampling, identity of samplers and the storage for the Bru 121-1 and Bru 146 sand samples was not recorded. The Bru 95-3 sand sample near Vivian was extracted by airlift that would oxidize sulphide in the sand. The samples were taken from outdoor stockpiles exposed to weathering since June of 2019. The stockpiles were likely contaminated with till containing calcite and dolomite by movement and burial operations on site. Sio Silica did not follow the federal MEND guidelines for handing and storage samples taken for geochemical analysis that Sio Silica claimed in a response to an information request they did follow.

All the measured carbonate neutralizing potentials for the sand samples have been shown to be invalid. All three sand samples were measured to have significant acid potential. The measured acid potential for the Bru 95-3 sand sample matched that of the OLS sand sample. The Sio Silica geochemical results for the sand in fact demonstrated significant acid potential, the opposite of what Sio Silica has claimed. All the Sio Silica sand and core samples have been shown to be air exposed. MEND sample handling and storage guidelines were not followed. The geochemical analysis would have seriously underestimated the acid potential of all samples.

The inadequate sampling methods and inadequate number and locations of samples mandates a complete independent re-sampling and geochemical re-analysis of the carbonate, shale and sandstone formations in the entire 24 year Bru project area.

An analysis done here of the acrylamide, selenium, and acid accumulation in the slurry recycle loop and clarifier tank waters demonstrates unacceptable levels of contamination would occur. Sio Silica has ignored this problem. In response to public comments on the minor alteration pertaining to the French drain system of the processing facility, submitted Feb.16, 2021, Sio Silica gave the inadequate response that standard industry practices would be applied. Evidence submitted demonstrated that the slurry line and clarifier tank recycling system could not absorb a large quantity of water collected by the French drain system from a deluge. No engineering data, design specifications and analysis was given by Sio Silica. This inadequate response was allowed to stand by the Manitoba Environmental Approvals Branch and the processing plant was granted a licence. Leakage of the slurry line or processing facility water would cause serious surface water pollution and must be addressed as part of the cumulative effects in the CEC list of issues.

Participants have not been given access to the complete Stantec geotechnical analysis of the extraction system without signing of a non-disclosure agreement that puts them in legal jeopardy for any disclosure. It is essential that Sio Silica produce the complete Stantec geo-mechanical analysis for the CEC hearings for all participants to review. One of the Stantec recommendations of Attachment A of the Sio Silica response to pubic comments in the project registry 6119.00 was limiting extraction to areas with competent limestone thicker than 15 meters. Histograms produced from Manitoba Groundwater well information reports show that almost all the wells east of highway 302 would not meet this Stantec requirement. Many wells west of highway 302 also showed limestone thickness less than 15 meters thus severely restricting the extraction capability throughout the Project area. Sio Silica and the Approvals Branch have ignored the Stantec recommendation concerning the limestone thickness of 15 meters required for extraction. The revised extraction plan of Jan. 24, 2023 specifies extraction east of highway 302 in the area with insufficient limestone thickness. The revised extraction design of Jan.24, 2023 corroborated my analysis that the cluster design submitted to the Hearing on June 2, 2022 was faulty and contradicted the earlier results of public version the Stantec report released in January of 2022. The revised cluster design gave no detailed information on the data and calculations used to determine the number of wells per cluster. No information was given on the cluster spacing and the geotechnical analysis for sand pillar stability in the revised report. Sio Silica gave only a vague description of the methods that would be used to determine the number of wells per cluster, cluster span and cluster spacing during production. Certainly a detailed geotechnical modelling to determine the cluster parameters during production would not be feasible.

Even without collapse of the limestone, cover collapse and cover subsidence as documented by USGS studies are likely to occur. In this form of subsidence the limestone remains intact. The glacial till would migrate through fractures in the limestone to fill the extraction cavities. The limestone fractures would be expected to increase in aperture from stress effects of extraction drilling and acid dissolution of limestone from acid water transferred into the carbonate from the sandstone through the aquitard, degraded by Sio Silica extraction activities. Each year subsidence, that would expose the carbonate aquifer to surface contamination and destroy property values, would grow in extent eventually covering much of the 43,000 hectare Sio Silica regional project area. This massive damage is not acceptable. Stantec used only a two dimensional model FLAC in geotechnical analysis that is inappropriate for the complex three dimensional geometry of the well clusters and extraction cavities. A thorough state of the art three dimensional geo-mechanical analysis on the stability of the extraction cavities must be submitted by Sio Silica and subject to independent expert review. The extraction plan must be revised to avoid all areas with limestone thickness less than 15 meters. This project must not proceed before the 3D geotechnical analysis and revisions are completed.

In two EAP's produced by Sio Silica and in the response to TAC ands public comments Sio Silica has consistently given simple assertions without adequate evidence on critical issues regarding the environmental consequences of this project. The evidence presented here has been supported with literature reports, literature data, photographs, mathematical analysis, data provided by Manitoba Groundwater and data taken from what little information Sio Silica supplied, has conclusively demonstrated that this project cannot proceed. The evidence given here establishes that extensive aquifer contamination will result from acid, selenium, fluoride, heavy metals, microbes, iron, manganese, chlorine, and toxic organics such a diesel fumes and oil vapours introduced to the aquifer by Sio Silica operations. Mixing of aquifer waters and massive subsidence would occur. Irreparable damage will be done to the regional carbonate and sandstone aquifers, to the surface environment. The provisions of the Mines and Minerals Act requiring a mine closure plan to be submitted prior to commencement of advanced exploration was not enforced.[96] The mine closure plan would have required the assessment of project environmental damage such as the aquifer contamination and the subsidence, documented here. Had this assessment prior to a mine closure plan being performed and properly and subject to expert review as earlier as project outset in 2016 this project would not have been allowed to proceed. A very large investment in an untenable project would have been avoided. The intent of the provisions of the Act pertaining to advanced exploration was to avoid this unwarranted expenditure of resources.

A formal report of violations under section 67(1) of the Groundwater and Water Well Act,[54] from Springfield residents, of damage to water quality from Sio Silica activities during advanced exploration was dismissed without proper formal investigation. Complaints and pictures in the report of Sio Silica wells left open and unsealed at Center Line Road and south of Vivian were dismissed with no action taken.

Temporary Authorizations for Sio Silica to divert large amounts of water since 2106 were handed out to Sio Silica with no proper oversight or detailed documentation of even where the diversion of water would occur. Provisions of the Groundwater and Water Well Act prohibiting aquifer contamination and regulations prohibiting mixing of aquifer waters have not been considered. Provisions of injection well permit for pressure measurement have not been enforced. Well information reports showing insufficient sealing of wells including Bru 92-2, Bru 92-2 and Bru 121-1 have been ignored by the Manitoba Groundwater Section and Water Branch.

There has been a failure at all regulatory levels to assess and regulate this Project. The IAAC has refused all designation requests for the Vivian Sand Project.[60] The IAAC has not engaged the SACC in planning for 250 net zero GHG for this project. The Mines Branch has not enforced the Mines and Minerals Act requirement s for submission of a mine closure plan for advanced exploration. The Ministry of Agriculture and Resource Development overseeing the Mines Branch did not respond to a request enforce the Mines Act. The Manitoba Ombudsman did not act on a complaint of the failure to administer the Mines Act. No indigenous consultation has been initiated by the province. Manitoba Infrastructure has not implemented its guidelines for a short line railway. The CTA has not implemented guidelines for the establishment of the Sio Silica railway loop. The EAB has provided no oversight to inadequate responses by Sio Silica to public and TAC comments. Simple assertions by Sio Silica dismissing comments with no corroborating evidence have been allowed to stand. Sio Silica has been allowed to ignore comments such as the violation of the Stantec recommendation for nom extraction for limestone thickness less than 15 meters. Provisions of the licence for the processing facility were discretionary subject to implementation by the Director. No requirement was specified for the measurement or worker protection from exposure to respirable silica dust. Manitoba Water Branch dismissed a formal complaint from residents without investigation. The Manitoba Water Branch has not enforced well sealing and aquifer mixing regulations and injection well permit requirements. This experience has illustrated that the licensing process and subsequent regulatory oversight for the Vivian Sand Project cannot be relied upon to mitigate and protect against environmental and public detriment.

The CEC hearings should be postponed until full and complete indigenous consultation has been carried out.

There has been a total systemic failure in proper environmental assessment and a failure of enforcement environmental regulations up to this time at all levels. The CEC hearings have been convened largely due to pressure from rural RM's and residents who are concerned about the aquifer and the lack of proper environmental assessment and enforcement of regulations to assessment to date. The CEC hearings are the last measure of hope of the local residents to avoid destruction of their aquifer and damage to their property. The economic and irreversible environmental damage from the effects of this project if allowed to proceed would far outweigh any benefit.

25 Appendix 1. Equations

The Green's function of Carslaw and Jaeger, Section 14.9 $G(x,y,z,x',y',z',t,t')$ for a point source at, x',y',z' into a semi–infinite region with transfer at z = 0 into a medium at zero is given by;

$$G = \frac{1}{8[\pi\kappa(t-t')]^{3/2}}\left\{\exp\left[-\left(\frac{z-z'}{4\kappa(t-t')}\right)\right] + \exp\left[-\left(\frac{z-z'}{4\kappa(t-t'}\right)\right]\right\}\exp\left\langle-\left[\frac{[(y-y')^2+(x-x')^2]}{4\kappa(t-t')}\right]\right\rangle -$$

$$\frac{h}{4\pi\kappa(t-t')}\operatorname{erfc}\left\{\frac{z+z'}{2\sqrt{[\kappa(t-t')]}} + h\sqrt{[\kappa(t-t')]}\right\}\exp\left\{h(z+z') + \kappa h^2(t-t') - \left[\frac{(y-y')^2+(x-x')^2}{4\kappa(t-t')}\right]\right\}$$

The Green's function in Carslaw and Jaeger is for heat conduction problems. To apply the equation to determine head, the hydraulic diffusivity and a water transfer coefficient must be used instead of thermal diffusivity and a heat transfer coefficient. The hydraulic diffusivity is the given by *K/S* where *K* is the thermal conductivity and *S* is the specific storage. The transfer coefficient is given by *h* and has dimensions of inverse length. The head change *H(x,y,z,t)* is given by convolution with the ratio of rate a point source water input or withdrawal at position x',y',z', *Q*(*t*), and the specific storage *S*;

$$H(x,y,z,t) = \int_0^t \frac{Q(t-t')}{S} G(x,y,z,x',y',z',t')dt'$$

For a constant rate of water input or withdrawal the convolution integral reduces to an ordinary integral over time that is evaluated numerically using trapezoidal integration and time steps that increase with time. The number of time steps is increased until convergence is obtained. For water withdrawal from a pumping well, *Q* is negative. For an injection well, *Q* is positive. As explained in the text, to model a no flow boundary at *z* = *d*, below the water transfer boundary at *z* = 0, the method of images is used. The thickness of the aquifer is *d.*

To evaluate the last term involving the complementary error function, erfc, the flowing algorithm by S.Chevillard, 2012, is employed;[89]

$$\operatorname{erfc}(x) = \frac{e^{-x^2}}{x\sqrt{\pi}}\left(1 + \sum_{n=1}^{N-1}(-1)^n \frac{1\cdot3\cdot5\cdots(2n-1)}{(2x^2)^n}\right) + \varepsilon_N^{(3)}(x)$$

$$\text{where } \left|\varepsilon_N^{(3)}(x)\right| \leqslant \frac{e^{-x^2}}{x\sqrt{\pi}}\cdot\frac{1\cdot3\cdot5\cdots(2N-1)}{(2x^2)^N}.$$

The Theis solution used here has been implemented in Excel Visual Basic. The Theis solution used a heat conduction equation developed by H.S. Carslaw in 1921 as documented in by Theis, C.V., 1935.[90] The implementation of the Theis solution is verified by comparison to literature values.

The Theis solution was used to predict the head from waste injection into the lower Paleozoic aquifer. The Theis solution implemented here was executed and compared with the results from OFR-1996-02 for an injection rate of 1000 m^3/day.[91] The lower Paleozoic aquifer at the BP injection site was assigned a hydraulic conductivity of 0.11 m/d and a specific storage of 2.8×10^{-4} m^{-1}. The transmissivity used for the Theis solution here was 3.83×10^{-3} m^2/d and the storativity is 9.74×10^{-3}. The value for the aquifer thickness used here to obtain the best fit was 34.75 m whereas the OFR-1996-02 specified an aquifer thickness of 34.5 m. The heads were determined at a distance of one meter from the injection well. The comparison is shown in table15. Small discrepancies are likely due to differences small differences in the significant figures used for parameter values and different in convergence conditions used for the Theis equation.

Table 14. Validation of Theis Solution (Lower Paleozoic Aquifer, Alberta)

Time (days)	This Implementation Head (m)	OFR-1996-02 Head (m)
1	140.9	141.1
5	174.4	174.6
10	188.8	189.0
30	211.7	211.8
60	226.1	226.2
180	249.0	249.0
270	257.5	257.5
365	263.7	263.7
547.5	272.2	272.2

The Theis solution was used in OFR-1996-02 to examine the potential environmental effects of injection of residual water obtained from the extraction of bitumen. Sio Silica was required by the conditions of well injection permits ensure that the Sio SilicaW injection would not damage the formations. Sio Silica has not disclosed the analysis done to conform to the conditions of the well injection permits.

The head equations used to fit the initial head distribution in the Vivian area were;

$$H_I(x,y) = h_o + a(x - x_o)b^{(x-x_o)/100} + cd^{(x-x_o)/100}\left[1 - f^{\{(y-y_o)/100-g\}}\right],$$

with h_o = 250 m, x_o = 15000 m, y_o =15000 m, a = 0.00173, b = 0.998, c = 2, d = 1.0019, f = 0.969 and g = 104.

26 References

1. Patent 3080017 Application Summary, Air Lifting Sand, Government of Canada Patent Data Base, Inventors: L.A. Weedon and B.R. Bullen, Owners: CanWhite Sands Corp. Filed: 2020-05-01 https://www.ic.gc.ca/opic-cipo/cpd/eng/patent/3080017/summary.html?query=CanWhite+sands+corp&type=basic_search
2. Economic Geology Report ER84-2 Silica in Manitoba By D.M .Watson Manitoba Energy and Mines Geological Services Report, 1985 http://www.manitoba.ca/iem/info/libmin/ER84-2.pdf
3. Geoscience News and Information, Limonite, https://geology.com/minerals/limonite.shtml

4. Methods for Describing Airborne Fractions of Free Fall Spills of Powders and Liquids, NUREG/CR-4997 PNL-6300, y M. Y. Ballinger, J. W. Buck, P. C. Owczarski, J. E. Ayer, Jan. 19, 1988, https://www.osti.gov/servlets/purl/5539197
5. Hydraulic Engineering V: Proceedings of the 5th International Technical Conference on Hydraulic Engineering, (CHE V) 15-17 December 2017 Shanghai China, edited by Guojun Hong, Gongxun Liu, Liquan Xie, A Method for calculating the trajectory and extension of bow-spray for the TSHD, F. Wang, J. Yin and Q. Zhang https://books.google.ca/books?id=iXFQDwAAQBAJ&pg=PA8&lpg=PA8&dq=slurry+spray+trajectory+gravity&source=bl&ots=AGsDWkj0nR&sig=ACfU3U1aDuCrCOEqXcv1kKYCvpPz4gds7A&hl=en&sa=X&ved=2ahUKEwizsKuWqP72AhUCG80KHduDDvkQ6AF6BAg2EAM#v=onepage&q=slurry%20spray%20trajectory%20gravity&f=false
6. Air entrainment modeling in the SPH method: a two-phase mixture formulation with open boundaries. Flow, Turbulence and Combustion, Thomas Fonty, Martin Ferrand, Agnès Leroy, Damien Violeau. Springer Verlag (Germany), 2020, 105 (4), pp.1149-1195. ff10.1007/s10494-020-00165-7ff. ffhal03248993f
7. Air Bubble Entrainment in Free Surface Turbulent Flows, Depratment of Civil Enginering, Queensland, H. Chanson, University, Report 46/95, June 1995, https://espace.library.uq.edu.au › view › UQ:8290
8. Visualisation of air entrainment by a plunging jet, 5th BSME International Conference on Thermal Engineering, A. K. Roy, B. Maiti, P.K. Das, Procedia Engineering 56 (2013) 468 – 473, https://www.sciencedirect.com/science/article/pii/S187770581300502X
9. What on Earth, Acid mine drainage: past present … future? M.C. Moncur, March 1 2006 https://uwaterloo.ca/wat-on-earth/news/acid-mine-drainage-past-presentfuture?fbclid=IwAR3ae45-IX-fMPuxGehGOXGno1xTiG73OyyUbwPzsGoAO6WOJCd5sQdtHWk
10. Toppr : https://www.toppr.com/ask/question/how-many-kilograms-of-pure-h2so4-could-be-obtained-from3/
11. Hydrogeology of the Winnipeg Formation in Manitoba, Canada, Grant Ferguson, Robert N. Betcher,Stephen E. Grasby, May 2007, Hydrogeology Journal 15(3):573-587 https://www.researchgate.net/publication/226439310_Hydrogeology_of_the_Winnipeg_Formation_in_Manitoba_Canada
12. Siderite Masking, a factor to consider in overburden acid - base balancing, Vance P. Wiram , 2015 https://wvmdtaskforce.files.wordpress.com/2015/12/92-wiram.pdf
13. Mathematical simulation of hydrocyclones K. A. Pericleous CHAM Limited, Bakery House, Wimbledon, London, SW19 SAU, UK (Received February 1986; revised November 1986) 242 Appl. Math. Modelling, 1987, Vol. 11, August, PII: 0307-904X(87)90139-9
14. Study on screening performance and parameter optimization of vibrating-dewatering screen, Zhanfu Li, Peiyu Jia, Kunyuan Li, Xin Tong, and Zhihong Wu, Advances in Mechanical Engineering, 2021, Vol. 13(9) 1–15 https://www.researchgate.net/publication/354788728_Study_on_screening_performance_and_parameter_optimization_of_vibrating-dewatering_screen [accessed Feb 10 2022].
15. Bubble formation and scale dependence in free-surface air entrainment, Wangru Wei, Weilin Xu, Jun Deng, Zhong Tian, and Faxing Zhang, Sci Rep. 2019; 9: 11008. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6662671/
16. Mechanism of Removing Iron and Manganese from Drinking Water Using Manganese Ore Sand and Quartz Sand as Filtering Material, Cai YA, Bi XJ, Zhang JN, He J, Dong Y, Wang HG. Feb 8;40(2):717-723. Chinese. doi: 10.13227/j.hjkx.201806223. PMID: 30628335. https://pubmed.ncbi.nlm.nih.gov/30628335/
17. North Dakota State University Publications, Iron and Manganese Removal, WQ 1030, May 2019, https://www.ag.ndsu.edu/publications/environment-natural-resources/iron-and-manganese-removal-1

18. Science Madness, Wiki, Dichlorine heptoxide http://www.sciencemadness.org/smwiki/index.php/Dichlorine_heptoxide
19. Investigation into the Cause of Iron-Related Clogging of Groundwater Bores Used for Viticulture in the Limestone Coast, South Australia by Birte Moser et al., Water 2021, 13(5), 683; https://doi.org/10.3390/w13050683, 3 March 2021 https://www.mdpi.com/2073-4441/13/5/683/htm
20. Pyrite and Marcasite Coated Grains in the Ordovician Winnipeg Formation, Canada: an intertwined record of surface conditions, stratigraphic condensation, geochemical ''reworking,'' and microbial activity, Jurgen Schieber and Lee Riciputi, Journal of Sedimentary Research, 2005, v. 75, 907–920, https://www.semanticscholar.org/paper/Pyrite-and-Marcasite-Coated-Grains-in-the-Winnipeg-Schieber-Riciputi/c7260c14eefc435745019d169ed8f741ed4da6df
21. Manitoba Energy and Mines Bedrock Geology Compilation Map Series - Winnipeg, NTS 62H Bezys R. and McCabe H.R.,1998 https://www.gov.mb.ca/sd/eal/registries/6119/appendix_a_part1.pdf
22. The geochemistry of selenium associated with coal waste in the Elk River Valley, Canada, C. Lussier, V. Veiga, Susan A Baldwin, January 2003, Environmental Earth Sciences 44(8):905-913
23. Response to Comments regarding Spruce No. 1 Mine under CWA Section 404 (Appendix 6), EPA, United States Environmental Protection Agency, 2002 https://www.epa.gov/sites/default/files/2015-05/documents/spruce_no_1_mine_appendix_4.pdf
24. Sorption of Selected Radionuclides on Sedimentary Rocks in Saline Conditions – Updated Sorption Values, Peter Vilks, Tammy Yang, Atomic Energy of Canada Limited 2Nuclear Waste Management Organization, NWMO-TR-2018-03 August 2018, https://www.nwmo.ca/~/media/Site/Reports/2018/10/29/18/49/NWMOTR201803.ashx?la=en
25. Technical report and preliminary economic assessment on the Seymourville Silica Sand Project, Manitoba, Canada for Claim Post Resources Inc., NI-43-101 & 43-101F1, Eugene Puritch, P.Eng., Richard Sutcliffe, P.Geo., Ph.D.,Yungang Wu, P.Geo., David Burga, P.Geo., Jarita Barry, P.Geo., Kenneth Kuchling P.Eng., David Orava, P.Eng., David Anthony, P.Eng., Michael Esposito, P.E., P&E Mining Consultants Inc., Report No. 292, November 1, 2014 sedar.com
26. Best Practices for Shale Core Handling: Transportation, Sampling and Storage for Conduction of Analyses. February 2020, Journal of Marine Science and Engineering 8(2):136,S. Basu, Adrian P Jones, Pedram, Mahzari, https://www.researchgate.net/publication/339426332_Best_Practices_for_Shale_Core_Handling_Transportation_Sampling_and_Storage_for_Conduction_of_Analyses
27. Core alteration and preservation, From AAPG Wiki, https://wiki.aapg.org/Core_alteration_and_preservation
28. Iron oxidation in sediment cores (Site 1062) during six months of storage in the Ocean Drilling Program archive, September 2000, Proceedings of the Ocean Drilling Program: Scientific Results 172:1-11, I. König et al. https://www.researchgate.net/publication/262791290_Iron_oxidation_in_sediment_cores_Site_1062_during_six_months_of_storage_in_the_Ocean_Drilling_Program_archive
29. USGS Water Science School, Sinkholes, https://www.usgs.gov/special-topic/water-science-school/science/sinkholes?qt-science_center_objects=0#qt-science_center_objects
30. Selenium and molybdenum enrichment in uranium roll-front deposits of Wyoming and Colorado, USA, Liam A.Bullock, JohnParnell, Journal of Geochemical Exploration Volume 180, September 2017, Pages 101-112, https://www.researchgate.net/publication/317718361_Selenium_and_molybdenum_enrichment_in_uranium_roll-front_deposits_of_Wyoming_and_Colorado_USA
31. Medici, G., West, L.J., Chapman, P.J. et al. Prediction of contaminant transport in fractured carbonate aquifer types: a case study of the Permian Magnesian Limestone Group (NE England, UK). Environ Sci Pollut Res 26, 24863–24884 (2019). https://link.springer.com/article/10.1007/s11356-019-05525-z

32. Supplemental Municipal Groundwater Supply Rural Municipality of Springfield, Friesen Drillers, May 2019 https://www.gov.mb.ca/sd/eal/registries/6013springfield/EAPspringfield.pdf
33. Health Canada Page 6: Guidelines for Canadian Drinking Water Quality: Guideline Technical Document - Enteric Protozoa: Giardia and Cryptosporidium https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-enteric-protozoa-giardia-cryptosporidium/page-6-guidelines-canadian-drinking-water-quality-guideline-technical-document-enteric-protozoa-giardia-cryptosporidium.html
34. Health Canada, Guidelines for Canadian Drinking Water Quality Guideline Technical Document Turbidity, https://www.canada.ca/content/dam/canada/health-canada/migration/healthy-canadians/publications/healthy-living-vie-saine/water-turbidity-turbidite-eau/alt/water-turbidity-turbidite-eau-eng.pdf
35. EPA Fiter Backwash Recycling Rule, Technical Guidance Manual, Office of Ground Water and Drinking Water (4606M) EPA 816-R-02-014 www.epa.gov/safewater December 2002, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=200025V5.txt
36. The Sizing and Selection of Hydrocyclones, Richard A. Arterburn, 2001, Environmental Science https://www.911metallurgist.com/blog/wp-content/uploads/2015/10/SIZING-AND-SELECTION-OF-HYDROCYCLONES.pdf
37. City of Winnipeg, Water and Waste Department, https://winnipeg.ca/waterandwaste/water/treatment/plant.stm
38. Winnipeg Water Treatment Plant, https://www.water-technology.net/projects/winnipeg-treatment/
39. NI 43-101 Technical Report, Lalor And Snow Lake Operations, Manitoba, Canada Olivier Tavchandjian, P. Geo. Vice President, Exploration and Geology Hudbay Minerals Inc. March 28, 2019, effective as of January 1, 2019 https://s23.q4cdn.com/405985100/files/doc_downloads/tech_reports/canada/Lalor-NI-43-101-Technical-Report-2019-03-28.pdf
40. Effects of Coal Mine Subsidence In the Sheridan, Wyoming, Area By C. Richard Dunrud and Frank W. Osterwald Geological Survey Professional Paper 1164, 1980
41. Geoscience Frontiers Groundwater fluoride contamination: A reappraisal, Amlan Banerjee, Volume 6, Issue 2, March 2015, Pages 277I284 https://www.sciencedirect.com/science/article/pii/S1674987114000371
42. Food and Nutritional Components in Focus, CHAPTER 1:Fluoride in the Context of the Environment , in Fluorine: Chemistry, Analysis, Function and Effects María Gabriela García and Laura Borgnino, 2015, pp. 3-21 DOI: 10.1039/9781782628507-00003, eISBN: 978-1-78262-850-7, https://pubs.rsc.org/en/content/chapterhtml/2015/bk9781849738880-00003?isbn=978-1-84973-888-0&sercode=bk
43. Conduction of Heat in Solids, H.S. Carslaw and J. C. Jaeger, Second Edition, Oxford at the Clarendon Press, 1959
44. Groundwater, R.A. Freeze and J. A, Cherry, Prentice Hall Inc. Englewood Cliffs New Jersey, 1979 Aquifer Capability and Groundwater
45. Seepage Pressure and Quick Sand Condition, Civil Engineering Notes 08/03/2021, https://civilengineeringnotes.com/seepage-pressure-formula-quick-sand-condition/
46. Solute and colloid transport in karst conduits under low- and high-flow conditions, Nadine Göppert, Nico Goldscheider, GroundWater Jan-Feb 2008;46(1):61-8. https://pubmed.ncbi.nlm.nih.gov/18181865/
47. Metals releases and disinfection by product formation in domestic wells following shock chlorination Mark Walker, J. Newman, January 2011, Drinking Water Engineering and Science 4(1) DOI: 10.5194/dwes-4-1-2011, https://www.researchgate.net/publication/307664306_Metals_releases_and_disinfection_byproduct_formation_in_domestic_wells_following_shock_chlorination
48. Iron Bacteria in Minnesota Well Water, Minnesota Department of Health https://www.health.state.mn.us/communities/environment/water/wells/waterquality/ironbacteria.html

49. Perimeter Water technologies, 7887 Fuller Rd Suite 106, Eden Prairie, MN 55344 https://www.premierwatermn.com/water-quality/water-contaminants/iron-bacteria/
50. Introduction to Rock Mechanics, Second Edition, R.E. Goodman, John Wiley and Sons, 1989
51. The behaviour of clay shales in water, Ross Seedsman, Can. Geotech. J. 23, 18-22 (1986) https://cdnsciencepub.com/doi/pdf/10.1139/t86-003
52. Critique of CanWhite Sands Minor Notice of Alteration,, D.M. LeNeveu, B.Sc. (hons. phys.), M.Sc. (biophysics) B.Ed. On Behalf of What the Frack Manitoba, posted April 8, 2021 on registry 6057.00, submitted Feb. 23, 2021, https://www.gov.mb.ca/sd/eal/registries/6057canwhite/canwhite_sands_minor_noticeofalteration.pdf
53. Former CanWhite employee alleges well contamination, lax site safety, The Carillon, Jordan Ross, Nov. 16, 2021, https://www.winnipegfreepress.com/the-carillon/local/Former-CanWhite-employee-alleges--well-contamination-lax-site-safety-575758671.html?fbclid=IwAR1wQgKrFbedWhNs8rVtP_2eVZfRSZgla_wxSDS3bproL7jHi58RHDLfyzk
54. The Groundwater and Water Well Act (c.c.s.m. c. g110) Well Standards Regulation, https://web2.gov.mb.ca/laws/regs/current/_pdf-regs.php?reg=215/2015
55. How to Get Clean, Dry, Oil Free Compressed Air From Any Compressor A White Paper By Mark White - Compressed Air Treatment Applications Manager, Parker Manufacturing Ltd
Gas Separation & Filtration Division EMEA, Dukesway, Team Valley Trading Estate
Gateshead, Tyne & Wear, NE11 0PZ United Kingdom
https://www.parker.com/Literature/Hiross%20Zander%20Division/PDF%20Files/Brochures/WPCDOAAC-00-EN.pdf
56. Compressed air systems, Breathing air Filtration, https://www.compressedairsystems.com/breathing-air-filtration/
57. Statistica, https://www.statista.com/statistics/276629/global-co2-emissions/
58. Facility Greenhouse Gas Reporting. Technical Guidance on Reporting Greenhouse Gas Emissions, Environment and Climate Change Canada, https://publications.gc.ca/collections/collection_2021/eccc/En81-29-2020-eng.pdf
59. Climate Change Connection, Manitoba Large Final Emitters (LFE), https://climatechangeconnection.org/emissions/manitoba-ghg-emissions/manitoba-large-final-emitters-lfe/#:~:text=Large%20Final%20Emitters%20(LFEs)%20are,GHG)%20emissions%20to%20Statistics%20Canada.
60. Impact Assessment Agency of Canada, Vivian Sands Project, https://iaac-aeic.gc.ca/050/evaluations/proj/80974
61. Strategic Assessment of Climate Change, Revised, October 2020, https://www.canada.ca/en/services/environment/conservation/assessments/strategic-assessments/climate-change.html
62. Technical Document Acid Mine Drainage Prediction, EPA 530-R-94-036 NTIS PB94-201829, December 199, https://www.epa.gov/sites/default/files/2015-09/documents/amd.pdf
63. European Union Risk Assessment Report, Acrylamide CAS No: 79-06-1, 2002 https://echa.europa.eu/documents/10162/50218bf9-ba0f-4254-a0d9-d577a5504ca7
64. Technical Memorandum, Great Plains Sand, T.Holstrom, March 9,2012 https://www.scottcountymn.gov/DocumentCenter/View/880/Exhibit-M-PDF?bidId=
65. Clarifier Calculation prepared by Michigan Department of Environmental Quality Operator Training and Certification Unit https://www.michigan.gov › documents › deq › w...
66. Where the frac sand goes CST Follows May/June issue of Shale Water Management Magazine https://www.cstindustries.com/where-the-frac-sand-goes-cst-follows
67. Polyacrylamide degradation and its implications in environmental systems. NPJ Clean Water 1, 17 (2018), Xiong, B., Loss, R.D., Shields, D. et al, https://doi.org/10.1038/s41545-018-0016-8

https://www.nature.com/articles/s41545-018-0016-8#:~:text=The%20presence%20of%20degraded%20polyacrylamide,degradation%20under%20various%20environmental%20conditions.
68. Pars Ethylene Kish Co. PE and HDPE pipe specifications https://www.parsethylene-kish.com/separsekish/default.aspx?page=Document&app=Documents&docId=12576&docParId=11736
69. Analysis of Erosion Rate on Discharge Slurry HDPE Pipe in Canal Water Intake PLTGU Grati using CFD Simulation, I. J. Meir, 2018, International Journal of Marine Engineering Innovation and Research, https://www.academia.edu/39292863/Analysis_of_Erosion_Rate_on_Discharge_Slurry_HDPE_Pipe_in_Canal_Water_Intake_PLTGU_Grati_using_CFD_Simulation
70. Manitoba Environmental Assessment and Licensing, Public Registry File: 5991.00 - Canadian Premium Sand Inc. - Wanipigow Sand Extraction Project https://www.gov.mb.ca/sd/eal/registries/5991wanipigow/index.html
71. Schlumberger Oil Field Glossary https://glossary.oilfield.slb.com/en/terms/l/liner_hanger
72. Minnesota Administrative Rules, 4725.4250 Limestone or Dolomite Water-Supply Wells, https://www.revisor.mn.gov/rules/4725.4250/
73. Winnipeg Aqueduct Water-Leakage Repair Winnipeg, MB, Canada Submitted by Vector Construction Ltd. November/December 2013 Concrete Repair Bulletin https://cdn.ymaws.com/www.icri.org/resource/resmgr/crb/2013novdec/CRBNovDec13-WinnipegAqueduct.pdf
74. Canada Energy Regulator Act (S.C. 2019, c. 28, s. 10). https://laws-lois.justice.gc.ca/eng/acts/C-15.1/
75. Pointe du Bois Transmission Project Environmental Assessment Report Prepared By: Transmission Planning and Design Division Licensing and Environmental Assessment 4/11/2014 Prepared for: Manitoba Conservation and Water Stewardship, Environmental Approvals Branch https://www.gov.mb.ca/sd/eal/registries/5716mbhydropointedubois/eap/chapt1.intro.pdf
76. Drill Rig Noise Control, eNoise Control, https://www.enoisecontrol.com/contact/
77. Conduction of Heat in Solids, H.S. Carslaw and J. C. Jaeger, Second Edition, Oxford at the Clarendon Press, 1959
78. Controlling Micro-organism Growth in Compressed Air, A White Paper By Mark White Compressed Air Treatment Applications Manager, https://www.parker.com/Literature/IGFG/PDF-Files/WPCMGICA-00-NA-012021_POST.pdf
79. Simulation of Unconfined Aquifer Flow Based on Parallel Adaptive Mesh Refinement, Georgios Kourakos and Thomas Harter, Water Resources Research, 57, e2020WR029354. https://doi.org/10.1029/2020WR029354, Received 21 Dec. 2020, Accepted 29 Nov. 2021, https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2020WR029354
80. U.S. Department of Energy Pressurized Spray Release Technical Report, AU-30-RPT-02, April 2019, https://www.standards.doe.gov/related-items/u-s-department-of-energy-pressurized-spray-release-technical-report
81. Vulnerability in the Rural Municipality of Springfield, Manitoba, Friesen Drillers, prepared by J.E. Neufeld and J.J. Bell, July 25, 2019
82. Municipal Groundwater Field Investigation NW ¼ 3-7-6 EPM Proposed Park Road Municipal Supply Well Field, Environment Act Proposal, City of Steinbach –Manitoba, Friesen Drillers, Nov. 24, 2015, https://www.manitoba.ca/sd/eal/registries/5403.1steinbach/eap.pdf
83. Water Conditioning, Industrial, II.G Deaeration, John M. Donohue, in Encyclopaedia of Physical Science and Technology (Third Edition), 2003, https://www.sciencedirect.com/topics/engineering/deaeration
84. Ernst Versus Encana, Vivian Silica Sands, https://www.ernstversusencana.ca/vivian-silica-sands-extraction-wells-manitoba/
85. Steinbach Online. Springfield Residents Protest Potentially Hazardous Mine, June 11,2020 https://steinbachonline.com/local/springfield-residents-protest-potentially-hazardous-mine

86. Soil mechanics Effective and total stresses, Budhu, Muni, D. Soil Mechanics & Foundations. New York; John Wiley & Sons, Inc, 2000, Schroeder, W.L., Dickenson, S.E, Warrington, Don, C. Soils in Construction. Fifth Edition. Upper Saddle River, New Jersey; Prentice Hall, 2004. http://www.learncivilengineering.com/wp-content/uploads/2014/06/Effective-and-Total-Stress.pdf
87. What Are Frac Tanks? Six Kinds Of Frac Tanks Explained, Alder Truck Rentals, MARCH 28, 2018 BY NICOLE TARGOWSKI, https://www.adlertankrentals.com/blog/what-are-frac-tanks-six-kinds-frac-tanks-explained
88. Theory of Slope Stability, K.M. Cruikshank, Portland State University, 2002 https://web.pdx.edu/~i1kc/programming/slopes/LandslideNotes.pdf
89. The functions erf and erfc computed with arbitrary precision and explicit error bounds, S.Chevillard, Information and Computation,Volume 216, July 2012, Pages 72-95, https://www.sciencedirect.com/science/article/pii/S0890540112000697
90. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, C.V. Theis Am. Geophys. Union Trans., vol. 16, pp. 519-524. https://water.usgs.gov/ogw/pubs/Theis-1935.pdf
91. OFR-1996-02, Evaluation of Deep Waste Disposal Cold Lake Area, Stephan Bachu Manager 1988-08-31, https://static.ags.aer.ca/files/document/OFR/OFR_1996_02.pdf
92. Acid Rock Drainage Prediction Manual, Prepared for Department of Energy Mines and Resources, Canada by Coastech Research Inc., 80 Niobe St., North Vancouver, March 1991, http://mend-nedem.org/wp-content/uploads/2013/01/1.16.1b.pdf
93. Surfaces, Interfaces and Crystal Growth of Marcasite FeS2, Corinne Arrouvela, Materials Research. 2021; 24(1): e20200383, https://www.scielo.br/j/mr/a/ntc9NC9S3WwppS5yFFRmzSJ/?lang=en&format=pdf
94. Impact Assessment Agency of Canada, Vivian Sand Project, https://iaac-aeic.gc.ca/050/evaluations/proj/80974
95. Geological Report GR93-1, The Fort Garry Aquifer in Manitoba, Manitoba Energy and Mines Geological Services, R.N. Betcher, H.R. McCabe, and F.W. Render, 1993, https://www.manitoba.ca/iem/info/libmin/GR93-1.pdf
96. Manitoba Laws, The Mines and Minerals Act, Assented to July 26, 1991, https://web2.gov.mb.ca/laws/statutes/ccsm/m162e.php
97. Manitoba Ombudsman, Report on the Licensing and Enforcement Practices of Manitoba Water Stewardship, April, 2008, https://www.ombudsman.mb.ca/uploads/document/files/report-licensing-enforcement-water-stewardship-2008-en.pdf
98. Geochemical and Isotopic Characterization of a Regional Bedrock/Surficial Aquifer System, Southeastern Manitoba, Graham Phipps Manitoba Water Stewardship, Winnipeg, MB, Canada R.N. Betcher and J. Wang Manitoba Water Stewardship, Winnipeg, MB, Canada Geo Edmonton Conference 2008, https://www.gov.mb.ca/water/pubs/water-science-management/groundwater/publication/2008_phipps_geochemical_isotopic_characterization_regional_aquifer_system_southeastern_manitoba.pdf
99. Grain Size Analysis and Maximum and Minimum Dry Density Testing of Ottawa F-65 Sand for LEAP-UCD-2017. In: Kutter, B., Manzari, M., Zeghal, M. (eds) Model Tests and Numerical Simulations of Liquefaction and Lateral Spreading. Carey, T.J., Stone, N., Kutter, B.L. (2020). https://link.springer.com/chapter/10.1007/978-3-030-22818-7_2#chapter-info
100. Manitoba Infrastructure, Operating a Shortline Railway in Manitoba, https://www.gov.mb.ca/mit/mcd/shortline_rail/operator.html
101. Study of the influence of Venturi weir type on air bubble entrainment, Scientific Research and Essays 4(11):1184-1193, December 2009, Fahri Ozkan et al., https://www.researchgate.net/publication/228537632_Study_of_the_influence_of_venturi_weir_type_on_air_bubble_entrainment

102. Introduction to Wastewater Clarifier Design, N. Voutchkov, A SunCam Continuing Education Course, https://s3.amazonaws.com/suncam/docs/278.pdf
103. The Role of the Upper Geosphere in Mitigating CO_2 Surface Releases in Wellbore Leakage Scenarios, **LeNeveu, D.M.**, Walton, F.B., Tait and J.C. Haug, K, In, Proceedings of the Fifth Annual Conference on, Carbon Capture and Sequestration, Alexandria Mark Center, Alexandria Virginia, May 8-11, 2006. https://www.researchgate.net/profile/Susan-Hovorka/publication/237326201_Fifth_Annual_Conference_on_Carbon_Capture_Sequestration/links/54dbbfca0cf28d3de65c7fd8/Fifth-Annual-Conference-on-Carbon-Capture-Sequestration.pdf
104. Controlling Micro-organism Growth in Compressed Air A White Paper By Mark White Compressed Air Treatment Applications Manager, https://www.parker.com/Literature/IGFG/PDF-Files/WPCMGICA-00-NA-012021_POST.pdf https://www.parker.com/Literature/Hiross%20Zander%20Division/PDF%20Files/Brochures/WPCAC-EN_00.pdf
105. 32 Myths of Oil-free Compressed Air, Mattei, https://www.matteicomp.com/32-myths-of-oil-free-compressors-mattei
106. Plant Services Home Blog, Compressor power - Actual vs nameplate https://www.plantservices.com/home/blog/11314044/compressor-power-actual-vs-nameplate
107. Rotocomp Screw Compressor Co. Ltd. Calculation Method of Fuel Consumption for Diesel Air Power Compressor, http://www.rotorcompressor.com/calculation-method-of-fuel-consumption-for-diesel-air-power-compressor.html#:~:text=The%20ratio%20of%20water%20to,L)%20equals%20to%20fuel%20consumption.
108. Government of Canada, Environment and Natural Resources, Pollution and Waste Management, National Pollutant Release Inventory, Diesel fuel generator – fuel usage. https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/report/tools-calculating-emissions/diesel-fuel-generator-fuel-usage.html
109. Chemistry School, https://www.chemistryscl.com/reactions/nitrogen-dioxide+water/index.php
110. Sludge dewatering with different coagulants, University of Groningen, Marte Sveistrup, July2, 2013, https://fse.studenttheses.ub.rug.nl/11040/1/BA_Marte_Sveistrup_final_versi_1.pdf
111. Sludge Press Conditioning, Universal Filtration and Pumping, http://automaticfilterpress.com/sludge-conditioning/
112. Emergency do not consume/do not use concentrations for ferric chloride in drinking water, Hum Exp Toxicol, https://pubmed.ncbi.nlm.nih.gov/?term=%22Hum+Exp+Toxicol%22%5Bjour%5D&sort=date&sort_order=desc2013 Mar;32(3):260-74, C. C. Willhite, G. L. Ball, V. S. Bhat, https://pubmed.ncbi.nlm.nih.gov/23111879/
113. Climate Policy Watcher, The Main Advantages of Sludge Drying Beds, 14 Nov 2022, https://www.climate-policy-watcher.org/wastewater-sludge/drying-beds.html
114. Innovative Sludge Drying Bed Design, Case Study, GWLS GeoWeb, https://2y2qpw2op3o93ygu164frm9z-wpengine.netdna-ssl.com/wp-content/uploads/2016/10/GWLS-Geoweb-Sludge-Drying-Bed.pdf
115. Stability of Chitosan—A Challenge for Pharmaceutical and Biomedical Applications, Emilia Szymańska and Katarzyna Winnicka, Mar Drugs 2015 Apr; 13(4)
116. Engineering tool box, Solubility of air in water https://www.engineeringtoolbox.com/air-solubility-water-d_639.html
117. FLAC/Slope Version 8.1 Explicit Continuum Factor of Safety Model Analysis of Slope Stability in 2D https://itasca-int.objects.frb.io/assets/docs/about/ICG20-LFT-FLACSlope-810-A4-01.pdf
118. Disposal of Canada's nuclear fuel waste: The vault model for postclosure assessment. Atomic Energy of Canada Ltd., Pinawa, MB (Canada). Whiteshell Labs. Feb. 4, 1994. ed, Authors: Johnson, L

H; LeNeveu, D M; Shoesmith, D W; Oscarson, D W; Gray, M N, https://www.osti.gov/etdeweb/biblio/6962111
119. Acrylamide in drinking water, Minnesota Department of Health, Aug. 2014, https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/acrylainfo.pdf
120. Oxidation of Pyrite by A. Bergholm, U.S. GEOLOGICAL SURVEY Open-File Report 95-389, 1995 https://pubs.usgs.gov/of/1995/0389/report.pdf
121. What Is the Best pH Level for Drinking Water, MedicineNet, Dr. Sruthi M., MBBS, https://www.medicinenet.com/what_is_the_best_ph_level_for_drinking_water/article.htmChemical
122. PH of CO2 saturated water and CO2 saturated brines: Experimental measurements and modelling, Haghi, RK, Chapoy, A, Peirera, LMC, Yang, J & Tohidi, B 2017, , International Journal of Greenhouse Gas Control, vol. 66, pp. 190-203. https://doi.org/10.1016/j.jiggc.2017.10.001 https://pure.hw.ac.uk/ws/portalfiles/portal/16060209/pH_of_CO2_saturated_water_and_CO2_saturated_brines.pdf
123. Core alteration and preservation From AAPG Wiki from Methods in Exploration, Wellsite methods, Core alteration and preservation, AAPG special Volumes, 1992, Caroline J. Bajsarowicz https://wiki.aapg.org/Core_alteration_and_preservation
124. Draft Guidelines and Recommendations for Prediction of Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia, Ministry of Employment and Investment, B.C., Price, 1997, https://docs2.cer-rec.gc.ca/ll-eng/llisapi.dll/fetch/2000/90464/90552/384192/620327/624910/695919/747519/D122-4-5_-_Living_Oceans_Society%2C_Raincoast_Conservation_Foundation_and_ForestEthics_-_Schedule_C%2C_Part_1_-_Price%2C_1997__A2H0D8_.pdf?nodeid=747523&vernum=-2
125. Prediction Manual for Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1, Dec. 2009, https://mend-nedem.org/wp-content/uploads/1.20.1_PredictionManual.pdf
126. Natural Resources Canada, Manitoba Science, Technology, Energy and Mines Petroleum Ordovician Winnipeg Formation: Isopach map, https://www.gov.mb.ca/iem/geo/willistontgi/mapfiles/pdfs/055_ord_winnipeg_fm_iso.pdf
127. Libre Texts Chemistry, Acid Base and Gas Evolution Reactions, https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Introductory_Chemistry/07%3A_Chemical_Reactions/7.08%3A_AcidBase_and_Gas_Evolution_Reactions
128. NI 43-101 Technical Report, Inferred Resource Estimate on Canadian Premium Sand Inc.'s Wanipigow Silica Sand Glass Project in Manitoba, Canada, Prepared For: Canadian Premium Sand Inc D. Roy Eccles, M.Sc., P. Geol. Rachelle Hough, B.Sc., P. Geo. Effective Date: 14 October 2021, sedar.com
129. Denitrification- an overview Science Direct, https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/denitrification
130. Guidelines for Canadian Drinking Water Quality https://www.canada.ca/content/dam/canada/health-canada/migration/healthy-canadians/publications/healthy-living-vie-saine/water-benzene-eau/alt/water-benzene-eau-eng.pdf
131. Deep Injection of Waste Water in the Western Canada Sedimentary Basin, Grant Andrew George Ferguson,Ground Water 53(2),April 2014, https://www.researchgate.net/publication/262417411_Deep_Injection_of_Waste_Water_in_the_Western_Canada_Sedimentary_Basin
132. How Close is Too Close for Hydraulic Fracturing?, Sarah Derouin, November 27, 2017, Water in the West , News, https://waterinthewest.stanford.edu/news-events/news-insights/how-close-too-close-hydraulic-fracturing
133. Oh, Canada's Become a Home for Record Fracking, ProPublica, Nicholas Kusnetz Dec. 28, 2011, https://www.propublica.org/article/oh-canadas-become-a-home-for-record-fracking