SIO Silica Sand Extraction Project - Vivian, MB

MSSAC Presentation

Geology, Geotechnical, Groundwater, and Management Plans

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Personnel

- J. Bert Smith, M.Sc., P.Eng., FEC
- Jason Mann, M.Sc., P.Geo., FGC
- Tim Packulak, Ph.D., (candidate), P.Eng., P.Geo.

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Overview

Geology and Geotechnical Stability
Groundwater – Well Extraction Operations
Groundwater – Water Quality/Levels
Groundwater Monitoring and Mitigation Plan
Progressive Well Abandonment Plan
Waste Characterization and Management Plan

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Geology and Geotechnical Stability

Data collection process is important. Observation at multiple scales is important. Addressing natural variability is important.

- Look at exposures, analogues, large scale examples.
- Look at the Literature (papers, maps, etc.)
- Design a data collection program.
- Collect the details:
  - Drilling
  - Core logging
  - Televiewer
  - Lab data
  - Test wells/pumping tests/sand extraction tests
  - Sonar of voidspaces

Geology and Geotechnical Stability

Modeled geotechnical failure modes of shear mode and bending failure mode.
Assumption is a massive predominantly horizontally bedded caprock, without vertical jointing. This is not representative of typical and well-known Manitoba geological structure within these carbonate strata. These failure modes do not represent how the carbonate strata may behave in the field.

- Carbonate bedrock in Manitoba is characterized by horizontal bedding planes and vertical to subvertical jointing, as reflected by geolgical history:
  - Basin wide uplift/tectonism
  - Exposure, erosion, and karst processes (paleokarst)
  - Glaciation/glaciotectonism
  - Isostatic rebound

Geology and Geotechnical

An exposure of the Ordovician aged Dog Head Member weathering out in outcrop at Hecla/Grindstone Provincial Park – note the vertical joint faces

Geology and Geotechnical

An exposure of the Ordovician aged Dog Head Member weathering out in outcrop at Hecla/Grindstone Provincial Park – note the horizontal bedding planes

Geology and Geotechnical

An exposure of the Ordovician aged Dog Head Member weathering out in outcrop at Hecla/Grindstone Provincial Park – note the blocks defined by horizontal bedding planes and vertical joint sets

Geology and Geotechnical

An exposure of the Ordovician aged Dog Head Member on quarry floor/outcrop at Hecla/Grindstone Provincial Park – note the blocks defined by vertical joint sets

Imagery Sources:

Manitoba Geo Tour 41

https://www.youtube.com/watch?v=sgyk9V1t0jE

Manitoba Geo Tour 42

https://www.youtube.com/watch?v=c-1E3nejBPg&t=163s

Manitoba Geo Tour 43

https://www.youtube.com/watch?v=baj20ZAteqA

Geology and Geotechnical

“design was based on the sequence of competent (predominantly unfractured) caprock which was found to be present.”

Modeled geotechnical failure modes thus are shear mode and bending failure mode of relatively planar and continuous strata. Vertical joints, which will exist in the carbonate rock in the project area, are not addressed or accounted for the geotechnical model.

Multibeam cantilevers of 7 m, as modeled in beam analysis, may not be valid, with vertical joint spacing that likely occurs, in places, at spacing of less than 7 m, for an example.

Important: All investigation boreholes, and reviewed water well boreholes etc. are vertical. Vertical features within the bedrock are not resolved by vertical boreholes unless they are directly drilled into. The lack of data (“gap”) regarding vertical jointing in the carbonate bedrock was noted in the hearing discussions, by the SIO geotechnical panel. The potential for an additional failure mode (i.e. discrete blocks of bedrock defined by bedding planes and vertical joints subject to displacement by gravity), was discussed. However, there is not a commitment to revise or revisit the geotechnical modeling approach, and assess this failure mode that honors the observed discontinuity structures within the carbonate bedrock.

Geology and Geotechnical

65 degree sand slope geometry:

Vertical to overhanging sand is imaged in the sonar data within the upper portions of test well void spaces.

Significant voids of variable geometry were created by single well extraction tests which imply variability in sand formation cementation/cohesion, vertically and horizontally.

It is unclear if the cementation state/cohesion of the sand is consistent from top to bottom of the formation, and whether the interpretation of an effective 65 degree slope geometry is valid in the long term.

Sonar approaches in imaging void spaces are "blind" to the lower void space either due to loose sand slough, turbid waters, or a combination thereof.

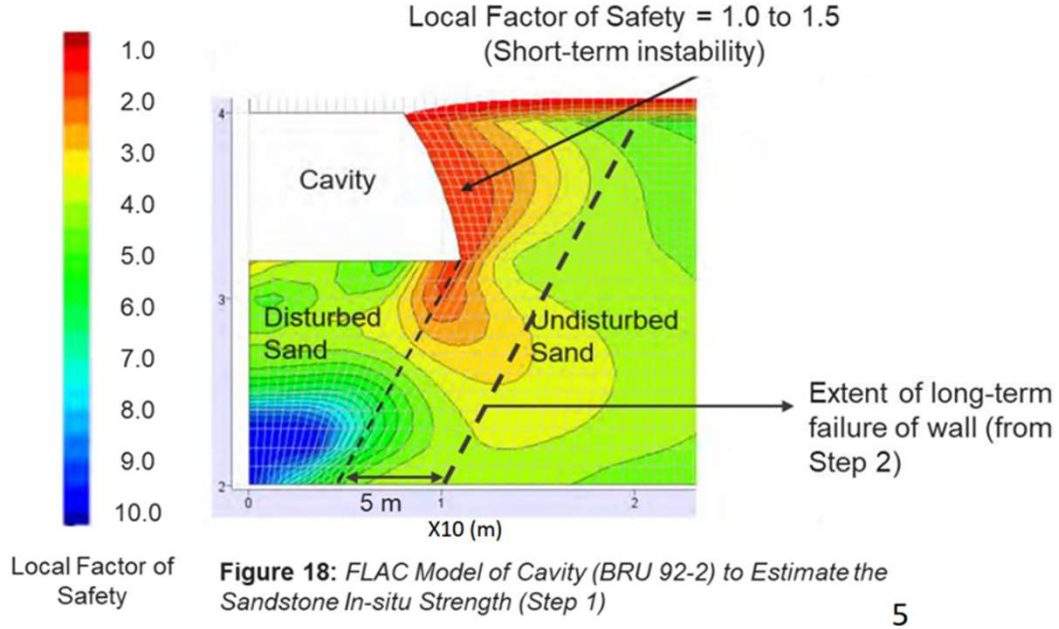

Figure 18: *FLAC Model of Cavity (BRU 92-2) to Estimate the Sandstone In-situ Strength (Step 1)*

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Geotechnical – Well Extraction Operations

"SIO has elected to start its operations at a location that allows for a reduced number of wells in a cluster, some as small as 1-2 wells. SIO will also conduct a multi-well test after the issuance of an Environment Act Licence while starting with single well production. Therefore, a ramp up period will occur with the initial phase of operations limited to smaller well clusters, where the design assumptions and Stantec's modeling will be confirmed by monitoring and minor adjustments might be required to the design. Should results of testing yield requirements for parameter changes, SIO will provide this to the Approvals Branch for review."

This plan of well cluster execution, and associated/governing Trigger Action Response Plan (TARP), are currently undefined.

Important: Sand extraction on a cluster scale must be executed, with a rigorous geotechnical and groundwater monitoring program, defined in the TARP, to demonstrate at a full cluster extraction scale, that the various geological, geotechnical, and groundwater interpretations made at this stage of the project, are valid.

The well cluster execution/TARP plan must include the means and methods to re-stabilize underground void spaces should subsidence or settlements occur that are beyond the allowable thresholds set in the geotechnical analyses and TARP.

Stakeholder input and review is necessary, and completion of this plan must be a requirement for issuance of the project License.

Groundwater – Well Extraction Operations

"10 US gpm was the anticipated effective pumping rate at the time that the assessment was conducted, however this rate does vary. During operations, actual rates will be measured and documented to confirm assumptions and allow for refinements of the extraction process. The water loss is accounted for by the wet sand that will move from the extraction, be dewatered and then enter the slurry loop because the sand is not 100% dry when it moves from the wellbore to the slurry loop. Please note that the 270 US gpm and 260 US gpm referenced is per cluster, not per well. Well flow rates vary over time from approximately 40 - 120 US gpm."

Does it remain that approximately 10 USgpm is the net loss to the aquifer?

Important: While these groundwater flows have been modeled, they have not been demonstrated in the field, on a full-scale cluster production well basis. Seasonal variability in aquifer recharge rates and overall water levels is important, and there is a lag time for seasonal recharge to be realized within the aquifer as water level responses, with a lag as much as approximately 8 months in this area of the province. Depending on SIO operations, this could have an enhanced overall effect on the aquifer resource and its water levels.

3rd party well inventory, response plans, and 24/7/365 coverage is necessary, and must be an integrated component of the Groundwater Monitoring and Mitigation Plan.

Stakeholder input and review is necessary, and completion of this plan must be a requirement for issuance of the project License.

Groundwater – Water Quality and Water Levels

"In accordance with Sio's Groundwater Monitoring and Impact Mitigation Plan, water quality in the sandstone and carbonate aquifers will be monitored before, during and following operations to confirm that water quantity and quality is preserved in both aquifers. The results will be evaluated by a professional hydrogeologist or geochemist with experience evaluating water quality, with results provided to regulatory agencies for review. In summary, the Project will not contaminate the sandstone or carbonate aquifers, and water quality is not anticipated to be materially affected by Project operations."

There will be loss of the shale aquitard that separates the carbonate and sandstone aquifers. The creation of these interconnections is irreversible.

Important: There has been much discussion with the panel and reviewers regarding the consequences with loss of the aquitard and mixing of the aquifer groundwaters. In most cases vertical gradients will change, and in some cases equilibrate; but there will certainly be an exchange of groundwaters between the aquifers. There will be an irreversible change where mixing of these two aquifers will occur.

The Groundwater Monitoring and Mitigation Plan is intended to manage the residual uncertainties surrounding this risk.

Stakeholder input and review is necessary, and completion of this plan must be a requirement for issuance of the project License.

Groundwater – Water Quality and Water Levels

"Based on the findings of the hydrogeology and geochemical assessment, groundwater quantity will be largely preserved within the project area due to the seasonal operation of sand extraction wells and reinjection of surplus groundwater following separation of solids. Based on the results of field testing, water levels were simulated to recover relatively rapidly, with approximately 80% recovery approximately two days following the end of production at each well cluster. Groundwater levels are anticipated to return to static water level conditions approximately 20-80 days after production ceases at each well cluster." "

As mentioned prior, the aquifer recharge that occurs on an annual basis to the aquifer in this region of Manitoba undergoes a time lag until the recharge is measured within the aquifer water levels.

Important: SIO operations are proposed to be seasonal, this lag time response for recharge, should there be a series of wetter than average, or drier than average years (in terms of aquifer recharge) could have an enhanced overall effect on the aquifer resource. It will be important to discuss what this may look like for long term aquifer water levels, and for any needs to adjust trigger levels within the Groundwater Monitoring and Mitigation plan.

The Groundwater Monitoring and Mitigation Plan is intended to manage the residual uncertainties surrounding this risk.

Stakeholder input and review is necessary, and completion of this plan must be a requirement for issuance of the project License.

Groundwater Monitoring and Mitigation Plan

This plan is a key document that will govern how the uncertainties and risk associated with the groundwater aquifer resources will be managed and protected. It requires stakeholder involvement in development and approvals.

This plan must be robust, and be updated/adapted as necessary.

- Well inventories and baseline water quality and water levels
- Add monitoring wells outside "Zone of Influence" to verify assumptions.
- Monitor the shale aquitard
- Establish trigger levels for quantity and quality that reflect ongoing variability
- Commit to 24/7/365 3rd party well and water supply support
- Include completed and approved plan and as condition for granting of License.

Progressive Well Abandonment Plan

This plan is a second key document that will govern how the uncertainties and risk associated with the long-term groundwater aquifer resources will be protected. It requires stakeholder involvement in development and approvals.

This plan must be robust, and be updated/adapted as necessary.

- There is no plan for backfilling of void spaces.
- Only well casings will be sealed.
- It is unclear what annular space seal will remain between the drilled formations and installed well casings with vertical losses of up to 3 m or more of shale/lower carbonate in the roof of the void spaces, which may affect the originally installed well seal, and cannot be addressed with internal well casing abandonment.
- Minimizing time between production and abandonment is important, unless wells are being used for monitoring or performance measurement purposes.
- Include completed and approved plan and as condition for granting of License.

Waste Characterization and Management Plan

This plan is a third key document that will govern how the uncertainties and risk associated with the long-term groundwater aquifer resources will be protected. It requires stakeholder involvement in development and approvals.

This plan must be robust, and be updated/adapted as necessary.

- Engineered containment/drainage for all material stockpile areas must be detailed as part of this plan. This allows for an additional level of environmental protection, and adds some ease in sampling effectiveness and methods for monitoring surface water runoff.
- The testing proposed is required to be sure that there is an understanding about how the geological materials will behave geochemically when produced and stored on surface, and whether there are any risks to an adverse environmental result should there be any geochemical changes that occur at surface with the produced materials.
- Planned laboratory testing program is generally appropriate for this scale of project, however tonnage justification for the 1 sample testing protocol per 500 tonnes of shale produced could be modified since the tonnage of shale produced within the project may vary widely.
- Procedural mitigation measure of segregating and separately storing shale produced from drilling of various project boreholes will be an important mitigation component
- Include completed and approved plan and as condition for granting of License.

Summary

There is a need to revise or revisit the geotechnical modeling approach, and assess the failure mode that honors the observed vertical discontinuity structures within the carbonate bedrock.

It is unclear if the cementation state/cohesion of the sand is consistent from top to bottom of the formation, and whether the interpretation of an effective 65 degree slope geometry is valid in the long term. Closer examination of what the sonar scanning may be "blind" to is necessary.

There will be loss of the shale aquitard that separates the carbonate and sandstone aquifers. The creation of these interconnections is irreversible. There will certainly be an exchange of groundwaters between the aquifers. There will be an irreversible change where mixing of these two aquifers will occur.

3rd party well inventory, response plans, and 24/7/365 coverage is necessary, and must be an integrated component of the Groundwater Monitoring and Mitigation Plan.

The management plans (TARP, Groundwater Monitoring and Mitigation, Well Abandonment, Waste Characterization and Management, other) are key documents that will govern how the uncertainties and risk associated with the long-term groundwater aquifer resources, and environment in general, will be protected. Stakeholder involvement in development and approvals is required.

Any and all management/mitigation plans must be included, completed, and approved as a condition for granting of any License.

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