Vivian Sand Extraction Project

Groundwater Monitoring and Impact Mitigation Plan

Sio Silica

Project number: 60640258

February 6, 2023

DRAFT

Delivering a better world

Statement of Qualifications and Limitations

The attached Report (the “Report”) has been prepared by AECOM Canada Ltd. (“AECOM”) for the benefit of the Client (“Client”) in accordance with the agreement between AECOM and Client, including the scope of work detailed therein (the “Agreement”).

The information, data, recommendations and conclusions contained in the Report (collectively, the “Information”):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the “Limitations”);
- represents AECOM’s professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time..

AECOM shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. AECOM accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

AECOM agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but AECOM makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

Without in any way limiting the generality of the foregoing, any estimates or opinions regarding probable construction costs or construction schedule provided by AECOM represent AECOM’s professional judgement in light of its experience and the knowledge and information available to it at the time of preparation. Since AECOM has no control over market or economic conditions, prices for construction labour, equipment or materials or bidding procedures, AECOM, its directors, officers and employees are not able to, nor do they, make any representations, warranties or guarantees whatsoever, whether express or implied, with respect to such estimates or opinions, or their variance from actual construction costs or schedules, and accept no responsibility for any loss or damage arising therefrom or in any way related thereto. Persons relying on such estimates or opinions do so at their own risk.

Except (1) as agreed to in writing by AECOM and Client; (2) as required by-law; or (3) to the extent used by governmental reviewing agencies for the purpose of obtaining permits or approvals, the Report and the Information may be used and relied upon only by Client.

AECOM accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information (“improper use of the Report”), except to the extent those parties have obtained the prior written consent of AECOM to use and rely upon the Report and the Information. Any injury, loss or damages arising from improper use of the Report shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

AECOM: 2015-04-13

Quality information

Prepared by	Checked by	Verified by	Approved by
Kun Jia, M.Sc., P.Geo. Hydrogeologist/Geochemist	Xinglong Ran, Ph.D., P.Geo. Senior Hydrogeologist	Ryan Mills, M.Sc., P.Geo. Senior Hydrogeologist	Ryan Mills, M.Sc., P.Geo. Senior Hydrogeologist

Revision History

Revision	Revision date	Details	Authorized	Name	Position
Draft for Review	February 6, 2023	Draft	RM	Ryan Mills	Senior Hydrogeologist

Distribution List

# Hard Copies	PDF Required	Association / Company Name
0	1	Sio Slica
0	1	AECOM

Prepared for:

Sio Silica
440 2 Ave SW #1930
Calgary, AB, T2P 5E9
Canada

Prepared by:

AECOM Canada Ltd.
99 Commerce Drive
Winnipeg, MB R3P 0Y7
Canada

T: 204.477.5381
F: 431.800.1210
aecom.com

Table of Contents

Tables (In-Text)

Tables (Back of Report)

Figures (Back of Report)

1. Introduction

1.1 Initiation

AECOM Canada Ltd. (AECOM) was retained by Sio Silica Corporation (Sio Silica) to develop a Groundwater Monitoring and Impact Mitigation Plan for use during the operation of the Vivian Sand Project located near Vivian, Manitoba. The project involves extraction of silica sand from the Carman Sand Member of the Winnipeg Formation using a series of boreholes (extraction wells) over a period of five years. The Groundwater Monitoring and Impact Mitigation Plan was a recommendation of the Hydrogeology and Geochemistry Assessment (AECOM 2021) and is required to confirm the findings of the Hydrogeology and Geochemistry Assessment (AECOM 2021) with respect to the zone of influence around project operations and any impacts on groundwater quantity and groundwater quality. Furthermore, the Groundwater Monitoring and Impact Mitigation Plan will ensure the project meets regulatory requirements and protects groundwater quantity and groundwater quality.

1.2 Objectives

The objectives of the Groundwater Monitoring and Impact Mitigation Plan are to:

- Establish protocols for determining the location of the existing water supply wells in advance of operations each year.
- Establish protocols for monitoring of groundwater quantity and quality before, during and after project operations, including monitoring well locations, the parameters that will be monitored, and the frequency of monitoring.
- Describe methods for assessing field performance against the design goals and objectives of this Groundwater Monitoring and Impact Mitigation Plan, the Waste Characterization and Management Plan, the Water Management Plan and the Progressive Well Abandonment Plan. This will direct the continuous improvement of monitoring networks and groundwater evaluation tools including the numerical groundwater model over time.
- Establish protocols for receiving and responding to well owner complaints and establish a Trigger Action Response Plan (TARP) that identifies mitigation measures and guides their implementation to avoid and/or mitigate any unacceptable impacts to groundwater levels, well yield or groundwater quality.
- Establish protocols for assessing the effectiveness of the mitigation measures over time.
- Establish a framework for reporting findings to the community and regulatory agencies.

1.3 Background

Sio Silica intends to develop and operate an in-situ sand extraction operation in southeastern Manitoba, and approximately 35 km east of Winnipeg. It will involve extraction of sand resources of the Carman Sand Member of the Winnipeg Formation for commercial and industrial use. The location of the project is shown on **Figure 1-1**.

In 2020, AECOM conducted a detailed Hydrogeology and Geochemistry Assessment (AECOM 2021) of the proposed *in-situ* silica sand extraction operation. This assessment included an environmental impact assessment and supported the overall environmental assessment of the extraction component of the project, focusing on aspects that have the potential to impact the quantity or quality of groundwater in the Red River Carbonate or Winnipeg Formation aquifers. The potential for surface water quality impacts due to extraction and storage of other geologic materials (e.g. drill cuttings) was also evaluated.

A three-dimensional regional scale groundwater model was developed to simulate the influence of the project on groundwater levels and groundwater quantity over the life of the project. Overall, project activities were found to have only a minor, short-term and reversible impact on groundwater quantity and quality provided the following monitoring and mitigation plans were implemented:

1. Waste Characterization and Management Plan

2. Water Management Plan
3. Progressive Well Abandonment Plan
4. Groundwater Monitoring and Mitigation Plan

This Groundwater Monitoring and Mitigation Plan (the Plan) is a core mitigation measure that is required to meet regulatory requirements, protect the groundwater resource and monitor the performance of mitigation measures. It is intended to provide a framework for groundwater quantity and quality monitoring prior to, during and following project operations and guide responses to events and conditions beyond those predicted or expected. Data collected during operational groundwater monitoring will be used to determine the need for further mitigation measures and then guide their implementation in accordance with a Trigger Action Response Plan (TARP). This Plan describes a phased, adaptive management approach for implementation of mitigation measures. The Plan identifies the actions that must be taken in advance of operations to establish a monitoring network and collect the required information to confirm background groundwater levels and groundwater quality in advance of operations.

1.4 Existing Groundwater Use

A water well inventory for the study area (defined as the area encompassing the Project Site, Local Project Area and Regional Project Area) was obtained from the Groundwater Information Network (GIN) data base. The locations of all registered water wells within the study area are presented according to aquifer and water use type on **Figure 1-2** and **Figure 1-3**, respectively. There are 10,879 water wells registered within the groundwater model domain discussed in **Section 6** of the Hydrogeology and Geochemistry Assessment. Of those, a total of 1,612 lie within the Regional Project Area and 406 wells are within the Local Project Area.

As shown on **Figure 1-2**, groundwater wells have been installed by private well owners and government agencies in multiple aquifers present within the groundwater model domain. According to the conceptual model stratigraphy detailed in **Section 5** of the Hydrogeology and Geochemistry Assessment, there are 562 wells completed in the Quaternary Sediments, 3,845 wells installed in the Red River Carbonate, and a further 565 wells installed in the Winnipeg Sandstone. Wells completed in the Red River Carbonate aquifer range from 13 m to 60 m in depth, with groundwater levels generally within 15 m of ground surface. Wells completed in the Winnipeg Sandstone aquifer range from 39 m to 75 m in depth, with groundwater levels generally within 10 m of ground surface.

Groundwater is used primarily for domestic purposes, but also supports other uses. Among the total number of wells within the Regional Project Area, 1,505 water wells are licenced for domestic use, 22 for air conditioning, three (3) for industrial use, two (2) for irrigation use, 54 for livestock watering use, three (3) for municipal water supply and five (5) for other uses as shown on **Figure 1-3**. The water use was not reported for 18 wells in the Regional Project Area.

The location of pumps within each water supply well is not known. It is industry best practice to install pumps near the bottom of the steel casing immediately above the well screen in confined aquifers to maximize the total available drawdown, but alternative pump configurations are often implemented for a variety of reasons.

Because groundwater wells continue to be installed in the area to meet the needs of the community, it will be important to routinely review the water well inventory to confirm the state of knowledge is current and the approximate location of all sensitive receptors is known. The exact location of wells within the zone of influence of project operations will need to be verified by completion of a well reconnaissance survey in advance of operations each year as described in **Section 4.3** of this Plan.

1.5 Hydrogeological Setting

The detailed surficial geology and bedrock geology was presented in Hydrogeology and Geochemical Assessment (AECOM 2021). Overall, Quaternary sediments include organic deposits, till, alluvial, glaciofluvial and glaciolacustrine sediments dominate the surficial geology of southern Manitoba. Precambrian igneous and metamorphic rocks form the basal geologic unit within the study area and consist of granite and tonalite gneiss. The Winnipeg Formation overlies the Precambrian basement, and consisting of a very fine silica sand that is poorly consolidated to unconsolidated. The Winnipeg Formation is subdivided into a lower sandstone unit and overlying units consisting of sandstone and shale layers. The Winnipeg Formation is overlain by a thick sequence of Ordovician carbonate rocks (limestone and dolostone) of the Red River Formation.

The following hydrostratigraphic units were encountered during 2020 field investigation (AECOM 2021):

- Quaternary Sediments
- Red River Carbonate (Aquifer)
- Winnipeg Shale (Aquitard)
- Winnipeg Sandstone (Aquifer)
- Precambrian Bedrock / Lower Shale (Aquitard)

The primary aquifers utilized to meet water needs in the area are the Red River Carbonate Aquifer and the Winnipeg Sandstone Aquifer, with far fewer wells accessing localized sand and gravel aquifers hosted within the Quaternary Sediments.

1.6 Proposed Site Activities

The proposed project will consist of the following key activities and components proposed to be permitted under an *Environment Act* Licence:

- Establishment of temporary access trails to annual sand extraction areas to accommodate water well drill rigs.
- Extraction well drilling and installment of sand and water slurry piping infrastructure within each extraction well for several wells per year.
- Construction of above-ground piping, and construction and operation of pumping stations to transport the sand and water slurry directly to the adjacent sand processing facility.
- Dismantling and relocating the above-ground piping and pumping stations to the subsequent annual sand extraction area.
- Return of excess groundwater through the extraction wells to the aquifer following appropriate treatment.
- Progressive decommissioning of annual extraction wells using a concrete cap, bentonite grout and permeable backfill layers in accordance with the Groundwater and Water Well Act.
- Progressive annual rehabilitation of well clusters, temporary drill rig access trails, slurry pipe routes and groundwater return pipe routes.

Figure 1-4 illustrates the location of extraction wells and well clusters over a five year operational timeframe. Sand extraction wells will be sequentially drilled, operated and progressively decommissioned over time. Extraction wells will be used to extract sand and groundwater from the Carman Sand Member of the Winnipeg Formation at an approximate depth of 51 m to 76 m (170 ft to 200 ft) below ground surface. Extraction wells will be drilled using dual rotary drilling methods. The Winnipeg Formation is located below thick overburden deposits and the Red River Formation which is comprised of a carbonate aquifer and an underlying shale aquitard that forms the boundary between the Red River Formation and the underlying Winnipeg Formation.

The sequence of activities during sand extraction is presented in Hydrogeology and Geochemistry Assessment (AECOM 2021). Extraction wells will be utlilized to extract the sand and groundwater slurry which will be conveyed to a surface collection tank to allow for screening and separation of the majority of the groundwater from the sand. The surplus groundwater will then be passed through an ultraviolet (UV) treatment system to destroy any bacteria prior to reinjection into the aquifer. Following operations, the extraction wells will be decommissioned.

Boreholes will be advanced during the project to investigate geotechnical and hydrogeological conditions in advance of extraction activities. Boreholes and monitoring wells will advanced using mud rotary drilling methods through the overburden. Air rotary drilling methods will be utilized to advance the boreholes through the Red River Carbonate aquifer. Mud rotary drilling will resume in the Winnipeg Shale and Winnipeg Sandstone.

Some boreholes will be completed as monitoring wells to allow for hydrogeological testing, and monitoring of groundwater levels and groundwater quality prior to, during and following extraction activities as described in the

Groundwater Monitoring and Mitigation Plan. All monitoring wells will be constructed using a combination of naturally developed filter packs (Winnipeg Sandstone aquifer) and introduced filter packs (Overburden Aquifer and Red River Carbonate Aquifer).

Boreholes will otherwise be backfilled with cement/bentonite grout to establish a hydraulic seal and prevent migration of surface water and/or groundwater along the borehole annulus as described herein. A locked protective steel surface monument will be installed to maintain the integrity of monitoring wells to allow for groundwater monitoring as described in the Groundwater Monitoring and Mitigation Plan.

2. Regulatory Context

2.1 The Groundwater and Well Act

The installation, operation and abandonment of groundwater wells in Manitoba is governed by *The Groundwater and Water Well Act (C.C.S.M. C. G110).* The purpose of the act includes protection and stewardship of Manitoba's aquifers and groundwater and to ensure that the construction, maintenance and sealing of wells and test holes meet standards that protect Manitoba's aquifers and groundwater.

The *Groundwater and Water Well Act* has exclusions for wells or test hole to which *The Mines and Minerals Act (C.C.S.M. C. M162)* applies. Because the Vivian Sand Project is licensed under *The Mines and Minerals Act* and is utilizing groundwater, both acts will be considered in this Progressive Well Abandonment Plan.

The Groundwater and Water Well Regulation establishes the requirements for licensing of well drilling contractors, insurance, permitting, license and renewal fees, well construction and sealing reports, and protocols for emergency response. It defines saline water as "*water that has (a) a concentration of total dissolved solids in excess of 3,500 mg/l; or (b) an equivalent electrical conductivity in excess of 5,000 micro-Siemens/cm.*"

The Well Standards Regulation establishes the requirements for construction and sealing of wells or test holes, interconnection of geologic formations, review of artesian conditions, construction or sealing of flowing artesian wells or test holes, covering of wells or test holes during construction or sealing, materials and additives used in the construction, sealing, rehabilitation, maintenance, or servicing of a well or test hole.

2.1.1 Well Construction Requirements

Well construction is regulated by the *Well Standards Regulation 215/2015* of G110.

Wells are to be constructed such that:

- They are suitable for the geologic and groundwater conditions existing at the site of the well.
- It prevents surface water from entering the well or test hole.
- It prevents contaminants from entering the well.
- It seals off water bearing formations that contain contaminants except in the case of an environmental well or environmental test hole.
- It prevents the interconnection or mixing of groundwater having distinctively different characteristics within the same aquifer or different aquifers.
- It is located at least 1.5 m (5 ft) from any property boundary.
- It is located such that upon completion of construction it is accessible for cleaning, treatment, maintenance, repair, testing, inspection, and visual examination.
- Wells will not be built with well pits if the water is intended for domestic purposes.
- Well casings will be a minimum of 6 m (20 ft) below the surface and a minimum of 30 cm (1 ft) above the ground surface or final constructed surface and be constructed from new watertight materials.
- The well is vented to the outside atmosphere in a manner that will safely disperse all gases.

2.2 Water Rights Act

Manitoba's *Water Rights Act* (the Act) gives all property owners equal access to water on a priority basis. Manitoba's Water Rights Licensing process intends to ensure sustainable allocation of water resources and protection of the interests of licensees, existing domestic users, the general public and the environment with respect to the use or diversion of water. Key objectives include:

- To ensure fair and equitable allocation of water for beneficial uses.
- To provide for optimal allocation of water within the sustainable limits of the resource base.
- To assess and license appropriate water use proposals.
- To provide clients with high quality, timely service and information.
- To ensure that the potential for negative impacts of water use projects are minimized.

Water users that use more than 25,000 L/day (4.6 US gpm) for municipal, industrial, agricultural, irrigation and other purposes must obtain a Water Rights License to extract and use groundwater under the *Water Rights Act*. Water withdrawals of less than 25,000 L/day generally do not require licensing. The Manitoba *Water Rights Act* prohibits connecting two aquifers within a single well completion to minimize hydraulic communication between saline and freshwater portions of drinking water aquifers. As described in Section 2.1 of this Plan, The Groundwater and Water Well Regulation defines saline water as "*water that has (a) a concentration of total dissolved solids in excess of 3,500 mg/l; or (b) an equivalent electrical conductivity in excess of 5,000 micro-Siemens/cm.*"

An *Environment Act* License is also required for groundwater withdrawals in excess of 200 dam^3/year. A groundwater exploration permit is required to drill and test groundwater wells. As part of the licensing process, the possibility of interference with other groundwater users is evaluated.

A Borehole License is required to advance boreholes for the purposes of mineral exploration or mineral extraction under *The Mines and Minerals* Act.

2.3 Groundwater Quality Standards

The Manitoba Environment Act and The *Water Protection* Act and its supporting regulations define groundwater criteria under the Manitoba Water Quality Standards, Objectives, and Guidelines for application in Manitoba. Guidance from Manitoba Sustainable Development Information Bulletin of June 2016 "Assessment Criteria for Groundwater" was used to determine the recommended criteria for groundwater quality evaluation.

Because groundwater in the project area is used for drinking water and may discharge to aquatic receiving environments, groundwater analytical results should be compared to the groundwater guidelines and standards as a screening assessment based on potential groundwater exposure pathways as follows:

- Canadian Drinking Water Quality (CDWQ, updated in September 2020 Version)
- Manitoba Water Quality Standards, Objectives, and Guideline (MWQSOG, Tier III) for the protection of Drinking Water
- Manitoba Water Quality Standards, Objectives, and Guideline (MWQSOG,Tier II) for the protection of Aquatic life and Wildlife
- Canadian Council of Ministers of the Environment (CCME), Water Quality Guidelines for the Protection of Aquatic Life

2.4 The Mines and Minerals Act

The object and purpose of *The Mines and Minerals Act (C.C.S.M. C. M162)* is to provide for, encourage, promote and facilitate exploration, development and production of minerals and mineral product in Manitoba, consistent with the principles of sustainable development. Part 6 of the *The Mines and Minerals Act* outlines requirements of drilling including the requirements for a Borehole License. Section 98 requires that "*The holder of a borehole licence shall*

drill and abandon a borehole in accordance with the regulations and in compliance with such other stipulations and conditions that the director specifies."

The Drilling Regulation is administered under *The Mines and Minerals Act* and outlines the requirements that must be addressed when drilling, including licensing of boreholes, managing waste, abandoning boreholes and requirements around movement of fluids between aquifers.

3. Water Well Inventory

Groundwater wells are typically assigned a coordinate that corresponds to the centre of a section or the centre of a quarter section. Further, the existing water well databases (e.g. GWDrill, GIN, etc.) are known to be out of date and new wells are continuously installed. As such, the location of water supply wells is not always known or accurate. Reported locations may be up to 1.5 km away from the physical location of the well based on the approximate distance from the centre of a section of land to each corner.

Proposed site activities for the year will be reviewed annually to estimate the zone of influence that may be affected by project operations based on previous numerical groundwater modelling and professional judgment. The proposed site activities will be advertised publicly and directly mailed to property owners within the estimated zone of influence to inform owners and solicit feedback on the existence and location of any known water supply wells on their property.

An updated water well inventory from the GWDrill database, GIN database, Sio Silica's database and other available information will be obtained annually, and Sio will consult with the Water Use License Section to determine if new Water Rights Licenses in excess of 50 dam^3/year have been issued within or near the zone of influence. This will confirm if there are any new users or times of year that require special consideration.

A site walkover of the zone of influence will be conducted to determine whether any additional water wells should be added to the well inventory. Based on the results, survey property owners with land within the estimated zone of influence will be asked to participate in a Water Well Survey prior to project operations.

Well owners who agree to participate in the water well survey will undergo an in-person interview to discuss the history and demand of the well. The well owner(s) will be canvassed for input on:

- Location of the well
- Age of the well
- Depth of the well
- Well yield
- Number of users serviced by the well
- Type of use (i.e. domestic, commercial, livestock watering, irrigation, municipal, etc.)
- Pump installation depth
- Pump age and condition
- Current water quality information
- Historical taste/odour issues
- The presence of water treatment (e.g. water softener, etc.) and type of plumbing (i.e. copper, PVC, etc.) will be documented to aid in interpretation of water quality results.

During the water well survey, the following will be completed:

- Measurement of groundwater levels under static and/or pumping conditions.
- Select wells will be outfitted with a pressure transducer to facilitate collection of continuous groundwater level measurements during operations if permitted by the well owner.
- Wells will be inspected for damage and the need for any repairs will be identified.

- A water sample will be collected from wells following industry standard methods to assess the baseline water quality. If a sample can not be collected directly from the well due to existing pump infrastructure, a sample will be collected from a hose bib or indoor tap. The water sample will be analyzed by a laboratory certified by the Canadian Association for Environmental Analytical Laboratories (CAEAL).

Information collected during survey, including water level and quality results, will be provided to the well owner annually through establishment of a data sharing portal or other method.

A comprehensive borehole, well, water level and water quality database will be established to document known boreholes, water supply wells, sand extraction wells and groundwater monitoring wells and the associated water level and water quality data. The database will be updated annually to reflect the current status of wells that have been installed, operated or decommissioned for future consultation. It will also host the results of the site visit including photographs, well coordinates, measured groundwater elevations and water quality sampling results.

4. Groundwater Monitoring Plan

4.1 Standard Operating Procedures

Groundwater monitoring will be conducted in accordance with the accepted procedures for collecting groundwater levels, collecting groundwater samples, collecting field measurements, recording field notes, and maintaining quality assurance/ quality control measures. The methodology is described in detail in the following reference documents:

- ASTM Standard D4448-01: Standard Guide for Sampling Groundwater Monitoring Wells
- ASTM Standard D6452-99: Guide for Purging Methods Used for Groundwater Quality Investigations
- British Columbia Field Sampling Manual (2003 Edition)

4.2 Proposed Groundwater Monitoring Network

The distribution of the existing groundwater monitoring wells installed in each hydrostratigraphic unit are shown on **Figure 4-1** (Red River Carbonate and Winnipeg Shale) and **Figure 4-2** (Winnipeg Sandstone). **Table 4-2** summarizes the existing groundwater monitoring well details. **Figure 4-1** and **Figure 4-2** also show the location of proposed multilevel monitoring wells that will be installed in advance of project operations. The groundwater monitoring wells will be located at the corner of each section of land where sand extraction wells are proposed. The monitoring network will extend to encapsulate the zone of influence associated with simulated one metre of drawdown (i.e. Local Groundwater Monitoring Zone) and the surrounding lands where drawdown impacts may be realized (i.e. Regional Groundwater Monitoring Zone) and where private water supply wells are known to be present. Groundwater monitoring wells able to monitor groundwater levels and groundwater quality outside the area that could be influenced by project operations will be established in consultation with regulatory agencies (i.e. Background Groundwater Monitoring Zone).

Three monitoring wells will be established at each location (shown in blue) in advance of project operations, with one well screened in the Quaternary Sediments, a second well screened in the Red River Carbonate Aquifer, and a third well screened in the Winnipeg Sandstone Aquifer to allow for monitoring of water levels and water quality before, during and after project operations.

Proposed project activities will be evaluated in advance of each operational year to determine the zone of influence and water supply wells that may be impacted by project operations. The completeness of the monitoring well network will be reviewed each year following the Water Well Inventory in advance of project operations to confirm it is adequate and able to monitor the impacts of sand extraction on all private water supply wells.

At least one monitoring well will be installed in between extraction wells and any private water supply wells (i.e. Operational Performance Monitoring Zone) to allow for early detection of impacts to groundwater quantity or quality for each year of operations and adjustment of operational procedures to avoid water supply well impacts. The monitoring network will be expanded to include private water wells within the simulated zone of influence with the permission of well owners.

Under direction from professional hydrogeologists, additional monitoring wells will be installed to satisfy any data gaps in the regional and local groundwater monitoring well network, following the completion of a water well survey. All groundwater monitoring wells, private water supply wells and sand extraction wells will be surveyed to determine their northing, easting and the geodetic elevation of ground surface.

4.3 Groundwater Monitoring Zones

Groundwater modelling (AECOM 2021) illustrated that the simulated zone of influence as defined by a drawdown of less than one metre in the Winnipeg Sandstone does not extend beyond 1,500 m from the active sand extraction wells if 50% of pumped slurry is re-injected to the Winnipeg Sandstone aquifer through the operating sand extraction wells. The simulated extent of drawdown in the Red River Carbonate does not extend beyond 800 m from the active sand extraction wells if 50% of pumped slurry is re-injected to the Winnipeg Sandstone aquifer through the operating sand extraction wells. The magnitude of drawdown is greatest in proximity to active sand extraction wells, and rapidly diminishes with distance. Drawdown was simulated to be greatest when multiple wells are operating in close proximity, but water levels were simulated to rapidly recover following operations each year.

Based on the results of field investigations and groundwater modelling, groundwater monitoring zones were established to guide development of a groundwater monitoring well network aimed at monitoring groundwater levels and groundwater quality in the Quaternary Sediments, Red River Carbonate Aquifer and Winnipeg Sandstone Aquifer. The local, regional and background groundwater monitoring zones are estimated based on modelling results and limited groundwater data. The configuration of the Local and Regional Groundwater Monitoring Zones should be adjusted after initial monitoring data are received and may require expansion over time.

4.3.1 Background Groundwater Monitoring Zone

The Background Groundwater Monitoring Zone will include monitoring wells that are able to monitor natural changes in groundwater quantity and quality that are not related to project activities. Background wells are required to establish background groundwater quality within the aquifer for a full suite of parameters of interest using scientifically defensible statistical evaluation methods. Once established, baseline groundwater quality may be useful for evaluating future data and gaining an understanding of the impact of seasonal variability on groundwater quantity and quality. It is anticipated that background monitoring wells will be selected from Manitoba's Provincial Groundwater Observation Well Network and will be located outside the Regional Groundwater Monitoring Zone. Wells located upgradient and downgradient of project activities will be incorporated at distances of five kilometers or more from the nearest sand extraction wells.

4.3.2 Operational Performance Monitoring Zone

In addition to the long-term groundwater monitoring zones identified above, additional groundwater monitoring will be conducted in close proximity to sand extraction activities monitoring wells to confirm operational parameters and monitor groundwater levels and groundwater quality between sand extraction wells and any identified water supply wells. Where required, monitoring wells will be established within this zone, which extends 100-250 m around the footprint of sand extraction activities.

4.3.3 Local Groundwater Monitoring Zone

The local groundwater monitoring zone is illustrated in **Figure 4-1**. It roughly encapsulates the simulated extents of the one metre drawdown cones in the Red River Carbonate and Winnipeg Sandstone aquifers during the five-year operational period for the scenario where 50% of the slurry is reinjected to the Winnipeg Sandstone Aquifer. The magnitude of drawdown impacts is anticipated to be between 1 m and 5 m for the majority of the licensed water supply wells within the local monitoring zone (AECOM 2021). However, it should be noted Sio Silica will re-inject majority of water removed during extraction back into the aquifer under the proposed operational condition, and therefore the overall lower net withdrawal rates will reduce the depth and spatial extent of drawdown impacts.

4.3.4 Regional Groundwater Monitoring Zone

The regional groundwater monitoring zone is illustrated in **Figure 4-2**. It was established by applying a 2,000 m buffer around the Local Groundwater Monitoring Zone established for the Winnipeg Sandstone Aquifer and by applying a 1,000m buffer around the Local Groundwater Monitoring Zone in the Red River Carbonate Aquifer. Beyond the

regional monitoring zones, the magnitude of impacts to groundwater quantity and quality induced by operational activities is anticipated to be negligible.

4.4 Methods

4.4.1 Groundwater Level Monitoring

Groundwater level monitoring will be conducted using a combination of manual data collection methods and automated high frequency data collection methods to monitor groundwater levels before, during and after project operations.

Prior to collection of groundwater levels, monitoring wells will be physically inspected, and the well condition will be documented. The depth to groundwater will subsequently be measured in units of metres below top of pipe (m btop) using an electronic water level meter. Water levels will be measured twice to verify the accuracy of the reading. The depth to the bottom of the well will also be measured in m btop. Finally, the height of each well above ground surface (known as the stickup) will be measured in units of metres above ground surface (m ags). All measurements of water levels, depth to bottom of the well, and well stickup will be recorded to the millimetre level (e.g., 1.201 m btop). The well name, date, time of collection, and weather will be recorded at each station. The electronic water level meter will be decontaminated between each monitoring well using Alconox detergent and de-ionized water.

Selected monitoring wells will be monitored continuously on an hourly (or more frequent) basis using pressure transducers and automated dataloggers that may also be outfitted with telemetry systems to allow for live reading of groundwater elevations during operations. Prior to installation, dataloggers will be confirmed to be in good working order and rated for their submergence depth. They will be capable of recording groundwater pressures to an accuracy of 0.01% of full scale or better. The dataloggers will be programmed to record measurements at a minimum frequency of one reading per hour. Manual water level measurements will be recorded at the time of deployment, and in advance of removal to allow for determination of geodetic groundwater elevations. A barometric pressure logger programmed to record measurements at same time interval setting will be deployed above the water table in at least two monitoring wells to monitor barometric pressure fluctuations and enable subsequent corrections to groundwater monitoring data. All dataloggers will be downloaded at a frequency of at least once per week or outfitted with telemetry to allow for live readout and data archiving in a digital framework.

Groundwater levels will be corrected to remove the influence of barometric pressure fluctuations and converted to geodetic groundwater elevations to produce hydrographs and evaluate groundwater elevation fluctuations in response to seasonal changes in groundwater recharge, groundwater use and project operations.

The frequency of groundwater monitoring is presented in **Table A.**

Table A. Groundwater Level Monitoring Frequency

Well Type	Frequency Prior to Operations	Frequency During Operations	Frequency for Year 1 Post-Operations	Frequency for Years 2-5 Post-Operations
Background Groundwater Monitoring Zone	Continuous (Once Per Hour)	Continuous (Once Per Hour)	Continuous (Once Per Hour)	Continuous (Once Per Day)
Operational Performance Monitoring Zone	Continuous (Once Per Minute)	Continuous (Once Per Minute)	Continuous (Once Per Minute)	Continuous (Once Per Day)
Local Groundwater Monitoring Zone	Continuous (Once Per Day)	Continuous (Once Per Day)	Continuous (Once Per Day)	Continuous (Once Per Day)
Regional Groundwater Monitoring Zone	Continuous (Once Per Hour)	Continuous (Once Per Hour)	Continuous (Once Per Hour)	Continuous (Once Per Day)

4.4.2 Groundwater Sampling

Groundwater samples will be collected to monitor any changes in groundwater quality before, during and after project operations. Groundwater sampling involves purging (**Section 4.4.2**), field parameters measurement (**Section 4.4.3**) and sample collection and analysis (**Section 4.4.4**).

The frequency of groundwater quality monitoring is presented in **Table B**.

Table B. Summary of Groundwater Quality Monitoring Frequency

Groundwater Monitoring Zone	Frequency Prior to Operations	Frequency During Operations	Frequency for Year 1 Post-Operations	Frequency for Years 2-5 Post-Operations
Background Groundwater Monitoring Zone	Twice	Once Per Quarter	Once Per Quarter	Once Per Quarter
Operational Performance Monitoring Zone	Twice	Once Per Month	Once Per Month	Once Per Quarter
Local Groundwater Monitoring Zone	Twice	Once Per Quarter	Once Per Quarter	Once Per Quarter
Regional Groundwater Monitoring Zone	Twice	Once Per Quarter	Twice Per Year	Once Per Year

4.4.3 Purging of Groundwater Monitoring Wells

Prior to collection of groundwater samples, each monitoring well will be purged of stagnant water to ensure field measurements and groundwater quality samples are representative of conditions present within the geologic formation. Groundwater purging will be conducted in accordance with industry standard practices, with the method selected based on the configuration of the well, the depth to water, and the objectives of monitoring.

Monitoring wells will be purged until at least three wellbore volumes of water have been removed or at least three field water quality parameters have stabilized. Field measurements of pH, temperature (°C), specific conductivity (µS/cm), oxidation reduction potential (mV), and dissolved oxygen (mg/L and% saturation) will be measured during purging using a multi-parameter water quality meter (e.g., YSI-556 or YSI Professional Plus) that is calibrated at least once daily throughout the duration of the sampling program. Water quality parameters will be recorded every five minutes during purging. Field parameters will be considered to be stable when at least three consecutive readings collected at least five minutes apart are within tolerance limits for temperature, pH, conductivity, oxidation reduction potential, and dissolved oxygen.

Wells that do not yield sufficient quantities of water will be purged dry at least once prior to sampling. The volume of water purged from each well will be measured using a graduated plastic pail. Purge water will be stored in drums for follow up testing and disposed of in accordance with testing results, or conservatively managed by transport and disposal at an appropriately licensed facility. The time/date, purge method, purge rate, purged volume, field parameters, and the location of water disposal will be recorded.

4.4.4 Field Parameter Measurements

Field parameter measurements will be collected from the same location as the groundwater quality sample after purging of the well is complete. For monitoring wells that are purged using a peristaltic pump, field water quality measurements will be made using a water quality probe installed in a flow-through cell. For monitoring wells that are purged using an inertial footvalve pump, field water quality measurements will be collected from a container holding enough water to fully submerge the water quality probe.

Stabilized field measurements of pH, temperature (°C), specific conductivity (µS/cm), oxidation reduction potential (mV), and dissolved oxygen (mg/L and% saturation) will be measured during purging using a multi-parameter water quality meter (e.g., YSI-556 or YSI Professional Plus) that is calibrated at least once daily throughout the duration of the sampling program.

Stabilized field measurements of pH, temperature (°C), specific conductivity (µS/cm), oxidation-reduction potential (mV), and dissolved oxygen (mg/L and% saturation) will be recorded in advance of sample collection using the same multi-parameter water quality meter (e.g., YSI-556 or YSI Professional Plus) used to document field parameter stabilization. As noted above, it will be calibrated at least once daily throughout the duration of the sampling program.

The water quality probe and flow through cell (or container) will be cleaned between sampling using Alconox detergent and de-ionized water. Field parameters measurements will be recorded.

Select groundwater monitoring wells within the Operational Performance Monitoring Zone will be outfitted with water quality probes capable of monitoring water levels and water quality (e.g. pH, temperature, conductivity, turbidity, dissolved oxygen and oxidation reduction potential) to allow for real-time monitoring of water quality in proximity to sand extraction wells.

4.4.5 Sample Collection and Analysis

Groundwater quality samples will be collected following purging of monitoring wells and recording of stabilized field parameters. Samples will be collected directly into laboratory-supplied bottles. Sample collection, filtration, and preservation methods will follow analytical laboratory recommendations. Select analytes will require field filtration and/or preservation. Samples requiring filtration will be filtered in the field using 0.45 µm inline filters. Any samples requiring preservation will be preserved in the field using laboratory-supplied preservatives at the time of sampling. Samples will be stored on ice in laboratory supplied coolers until they are submitted to the analytical laboratory for analysis.

Groundwater samples will be submitted to an analytical laboratory accredited by CAEAL under standard chain of custody procedures on a daily basis. Samples will be collected and analyzed for the following parameters:

- Physical and Conventional Parameters (pH, specific conductivity, alkalinity, hardness, acidity, total suspended solids)
- Nutrients (nitrate, nitrate and ammonia)
- Dissolved Organic Carbon
- Major Anions
- Dissolved Metals
- Total Metals

Laboratory analytical reports will be provided electronically for incorporation into a water quality database for review and analysis as discussed in **Section 4.6** of this Groundwater Monitoring and Mitigation Plan.

4.4.6 Data Analysis

Monitoring data collected from the monitoring programs will be analyzed to:

1. Establish baseline groundwater levels and groundwater quality for each monitoring zone.
2. Evaluate the impacts of project operations on groundwater levels and quality.
3. Inform the need for implementation of any mitigation measures described in **Section 5** of this Groundwater Monitoring and Impact Mitigation Plan.
4. Evaluate whether the findings of the Hydrogeology and Geochemistry Assessment remain valid.
5. Meet regulatory requirements.

<u>Baseline Groundwater Levels</u>

Baseline groundwater levels will be established by plotting long-term groundwater elevations measured in wells around the project area that are part of the Provincial Groundwater Observation Well Network. Many of these wells

have a long-term record that spans several decades. This will be supplemented with measurements from all wells in all zones that form the groundwater monitoring network (Background, Local and Regional) described in **Section 4.2** of this Groundwater Monitoring and Mitigation Plan. Baseline data collection will be expanded upon establishment of the Groundwater Monitoring Network in advance of project operations. The baseline phase will end when sand extraction commences in the first year of operations and baseline groundwater elevations will be the basis for comparison of future groundwater elevations.

The results of groundwater level monitoring will be continually added to the database and monitoring during and following operations to evaluate impacts on groundwater levels and inform the possibility of unforeseen impacts to other groundwater users so they can be avoided.

Baseline Groundwater Quality

Baseline groundwater quality will be established by plotting long-term groundwater quality measured in wells around the project area that are part of the Provincial Groundwater Observation Well Network. Many of these wells have a long-term record that spans several decades. This will be supplemented with sampling results from all wells in all zones that form the groundwater monitoring network (Background, Local and Regional) described in **Section 4.2** of this Groundwater Monitoring and Mitigation Plan. Baseline data collection will be expanded upon establishment of the Groundwater Monitoring Network in advance of project operations. The baseline phase will end when sand extraction commences in the first year of operations and baseline groundwater quality will be the basis for comparison of future groundwater quality data.

The results of groundwater quality monitoring will be continually added to the database and monitoring during and following operations to evaluate impacts on groundwater quality and inform the possibility of unforeseen impacts to other groundwater users so they can be avoided.

Water quality results collected to date indicate that groundwater quality is very good in both the Red River Carbonate and Winnipeg Sandstone aquifers and well below the applicable drinking water standards/guidelines. However, naturally elevated concentrations of iron and manganese exceeded drinking water aesthetic criteria as is commonly found in natural systems and within these aquifers (AECOM 2021). West of the proposed project operations near the Red River, groundwater in the Winnipeg Sandstone Aquifer is known to be brackish to saline.

Evaluation of Impacts to Groundwater Quantity

Groundwater level monitoring data will be evaluated to determine whether there is a potential for impacts to other groundwater users. During operations, groundwater levels will be intensively and continuously monitored in the vicinity of sand extraction activities to allow for real-time monitoring and operational adjustments to avoid unforeseen impacts to groundwater users. The evaluation will involve development of a real-time groundwater elevation monitoring system that leverages the use of telemetry to convey water level measurements to a centralized data repository (e.g. SCADA system) for plotting. Real-time water level measurements will be compared to estimated or simulated drawdown at individual private wells. If measured groundwater levels suggest the possibility of unacceptable impacts to nearby private wells, mitigation measures will be implemented as described in **Section 5**.

Evaluation of Impacts to Groundwater Quality

Groundwater quality data will be evaluated via water quality probes in real time and on a regular basis based on groundwater quality sampling results to determine whether there is a potential for impacts to water quality in the aquifer or other groundwater users. During operations, groundwater quality will be monitored in the vicinity of sand extraction activities to confirm groundwater quality has not been negatively impacted. The evaluation will involve development of a water quality database that allows for rapid comparison of groundwater quality data to regulatory criteria as described in **Section 2.3** of this Groundwater Monitoring and Mitigation Plan. If measured groundwater quality suggests the possibility of unacceptable impacts to nearby private wells, mitigation measures will be implemented as described in **Section 5**.

5. Impact Mitigation Plan

The Groundwater Monitoring Plan and groundwater monitoring data collected from the monitoring networks will be used to monitor the impact of operation performance on groundwater quantity and quality and provide the data required to inform this Impact Mitigation Plan. Changes in monitoring results will trigger changes in project operations to avoid unacceptable impacts to groundwater quantity and quality.

5.1 Trigger Events

This Impact Mitigation Plan is specifically designed to identify the indicators and triggers for actions or responses. Responses to the exceedance of a threshold or set of trigger conditions are designed to follow a staged approach, with stages differing depending on the type or location of an event. For the purposes of this report, four (4) potential events were established:

Event 1 – Low Groundwater Levels in Monitoring Well Network

Event 2 – Low Groundwater Levels / Inadequate Yield in Private Water Wells

Event 3 – Degraded Water Quality in Monitoring Well Network

Event 4 – Degraded Water Quality in Private Water Wells

5.2 Response Stages

In general, there are three response stages for events: Stage 1, 2, and 3. The response stages (and event status) are described in general as follows:

Stage 1 (No Action Required): Stage 1 is intended to confirm that conditions (water levels and water quality) are stable or are not changing in unexpected ways. For instance, low water levels in monitoring wells can be caused by short-term low precipitation, or within normal natural fluctuation range. For water quality, Stage 1 thresholds are not tied to applicable groundwater standards, but rather existing data are compared to temporal trends or baseline groundwater quality in each aquifer. Changes in water quality and water levels would lead to further evaluation to confirm results and possible improvements to system performance, or escalation of the event status to Stage 2.

Stage 2 (Early Warning): Stage 2 is intended to identify if water levels and/or water quality conditions that have diverged from the established baseline pattern and the changes are likely resulted from sand extraction operations. Unexpected low water levels or deteriorated water quality could lead to escalation of the event from Stage 2 to Stage 3, and appropriate actions/responses should be taken.

Stage 3 (Immediate Risk): Stage 3 is intended to identify water level or water quality conditions that require immediate attention. For water levels, a Stage 3 event would include measured water levels in private water wells that exceed Safe Available Drawdown of the well or have resulted in complaints regarding changes in water supply well performance. For water quality, a Stage 3 event involves water quality that exceeded applicable standard/guidelines and background water quality and may have the potential to cause harmful effects to human health and aquatic life in the receiving environment.

5.3 Threshold Development

Thresholds (or “trigger values”) are defined as numeric or specific conditions for the change in water levels or water quality result in a trigger event. Thresholds are developed for water levels and water quality, based on current monitoring data, or temporal or spatial trends.

5.3.1 Water Levels (Well Yield)

Trigger values for water levels were derived based on the range of natural groundwater level fluctuations and the simulated Zone of Influence during operations. Groundwater levels will be continuously monitored from background wells and the remaining wells in the Groundwater Monitoring Network. Background wells will be used to characterize seasonal groundwater variations, and therefore refine the threshold values in proximity to the project area.

An extensive Provincial Groundwater Observation Well Network (PGOWN) has been established by the Government of Manitoba to monitor groundwater elevations and groundwater quality in the Red River Carbonate and Winnipeg Sandstone aquifers in the study area. Long-term (2007-2021) observed groundwater elevations in three (3) well pairs outside of but nearby the project property boundary (G05SA003 / G05SA013, GO5SA014 / GO5SA015, GO50J175 / GO50J163) were used to evaluate the temporal and spatial pattern of natural groundwater fluctuations in Red River Carbonate Aquifer and Winnipeg Sandstone Aquifer in proximity to the project area. The detailed groundwater elevation data for the three pairs of wells was provided in Hydrogeology and Geochemistry Assessment (AECOM 2021).

Review of the time-series groundwater elevation data for the three pairs of wells indicated that groundwater fluctuations in the Red River Carbonate and Winnipeg Sandstone exhibited consistent pattern, as summarized below:

- Groundwater fluctuations in the Red River Carbonate and Winnipeg Sandstone exhibit multi-year cycles (every 4 to 6 years), which are closely related to the precipitation.
- Within each multi-year cycle, groundwater elevations exhibit seasonal fluctuations but have generally been increasing over time.
- By the end of the multi-year cycle, groundwater levels dramatically decrease within short period of time, and then enter the next multi-year cycle.
- The magnitude of groundwater level fluctuations within each multi-year cycle are generally consistent.

The long-term groundwater elevation data indicate that year 2021 is at the beginning of a new multi-year cycle following the dramatic decrease in water levels observed in July 2020. Therefore, the range of groundwater level fluctuations during the proposed operation is anticipated to be within the seasonal variation observed within previous multi-year cycles. The range of water level fluctuations will be reviewed and established in advance of operations, with particular attention to the influence of dry summer weather in 2021 on groundwater elevations in the aquifers. **Table C** summarizes the seasonal groundwater fluctuations within multi-year cycles and the maximum decrease in water levels when transitioning between multi-year cycles as represented by the 90th percentiles. It should be noted that the maximum decrease in water levels were usually observed at end of the multi-year cycle, within a short period of time (60-90 days).

Table C. Summary of Groundwater Fluctuations in Red River Carbonate and Winnipeg Sandstone Aquifers (2007-2021)

Hydrostratigraphic Unit	Well ID	Groundwater Fluctuations (m)	
		Seasonal Variations (90th percentile)	Max. Multi-Year Variations (90th percentile)
Red River Carbonate Aquifer	G05OJ163	0.1 - 1.48	1.94
	G05SA003	0.4 - 0.91	1.38
	G05SA014	0.1 - 1.76	2.56
Winnipeg Sandstone Aquifer	G05OJ175	0.2 - 1.25	1.74
	G05SA013	0.13 - 0.97	1.27
	G05SA015	0.18 - 1.13	1.68
Maximum Fluctuation - Red River Carbonate	-	1.8	1.38 - 2.56
Maximum Fluctuation - Winnipeg Sandstone	-	1.3	1.27 - 1.74

For regional groundwater monitoring and water supply wells, threshold values are derived based on long-term (2007-2021) seasonal variations within multi-year cycles. The maximum decrease in water levels at end of the multi-year cycle was not considered because it is unlikely to occur for the next 4-6 years. The thresholds for the Red River Carbonate and Winnipeg Sandstone were dependent on stages, and are summarized in **Table D**.

For private water supply wells installed near the piezometric surface within the Local Groundwater Monitoring Zone, water levels and specific well yields may be affected by local operation activities over the short-term operational period of each cluster. Therefore, the water level threshold values are determined based on specific well capacity/yield evaluation prior to operation as informed by the Water Well Inventory.

Water levels will be measured on daily basis for at least one month prior to operation to determine the maximum available drawdown (Ho), which is distance between the baseline static groundwater elevation and the top of the pump intake. Water levels in the water supply well should be continuously monitored to ensure water levels are at least 25% higher than the total available drawdown and a minimum of two (2) metres above the pump intake.

Thresholds for response Stages 1, 2 and 3 for water supply well and monitoring wells are summarized in **Table D**.

For groundwater monitoring wells within local monitoring zone, drawdown is simulated to be range from one (1) to five (5) metres dependent on the distance to the operational extraction well cluster and the duration of extraction operations. Measured groundwater levels will be compared with simulated modelling results at the same location, and the results will be used to provide appropriate warning and trigger mitigation measures if necessary. Threshold values at different stages are summarized in **Table D**.

5.3.2 Water Quality

Groundwater quality indicator parameters were selected based on evaluation of concentrations at existing monitoring stations and constituents of potential concern in solid materials identified in the Hydrogeology and Geochemistry Assessment Report (AECOM 2021).

The indicator parameters are grouped into two categories as follows:

Primary Indicators: Dissolved Selenium, Arsenic and Uranium. These constituents were identified as potential contaminants of concern in one or more samples of Red River Carbonate, Winnipeg Sandstone and Winnipeg Shale analyzed during solid phase geochemical testing that have the potential to change water quality.

Secondary Indicators: pH, Alkalinity, Conductivity, Sulphate, Aluminum, Iron and Manganese. These constituents either do not have a WQG, or can provide important supporting information for overall water quality. Iron and manganese were selected because they are elevated at some, but not all stations, and exceeded drinking water aesthetic criteria in present day as is commonly found in natural systems and within these aquifers.

The water quality threshold was developed by:

- Comparing groundwater quality data to Canadian Drinking Water Quality Maximum Acceptable Concentration Guidelines and Manitoba Water Quality Standards, Objectives, and Guidelines (Tier III) - Protection of Drinking Water Use – Maximum Acceptable Concentration
- Evaluating if key and secondary indicator concentrations increased or decreased relative to measured water quality prior to operations.

Thresholds and analyses required are dependent on both the stages and the indicator constituents as summarized in **Table E**.

Table D. Water Level Threshold Values in Stages 1, 2 and 3

Response Stage	Local Monitoring Zone				Regional Monitoring Zone	
	Private Water Supply Wells		Monitoring Wells		Water Supply and Monitoring Wells	
	Red River Carbonate	Winnipeg Sandstone	Red River Carbonate	Winnipeg Sandstone	Red River Carbonate	Winnipeg Sandstone
Stage 1	Decrease in water level <= 25% of Ho AND Distance between water levels and pump intake >= 2 m		Decrease in water level is 25% greater than simulated drawdown results		Water levels exhibit decreasing trend, but decrease in water level <= 1.8 m	Water levels exhibit decreasing trend, but decrease in water level <= 1.3 m
Stage 2	Decrease in water level <= 50% of Ho AND Distance between water levels and pump intake >= 2 m		Decrease in water level is 50% greater than simulated drawdown results		Decrease in water level is above 1.8 m but below 2.7m	Decrease in water level is above 1.3 m but below 2.0m
Stage 3	Decrease in water level <= 75% of Ho OR Distance between water levels and pump intake <= 2 m		Decrease in water level is 75% greater than simulated drawdown results		Decrease in water level is 50% greater than threshold value (2.7 m) OR Decrease in water level is 50% greater than seasonal fluctuations in upgradient and downgradient background monitoring wells outside of the regional groundwater network.	Decrease in water level is 50% greater than threshold value (2.0 m) OR Decrease in water level is 50% greater than seasonal fluctuations in upgradient and downgradient background monitoring wells outside of the regional groundwater network.

Table E. Water Quality Thresholds in Stages 1, 2 and 3

Response Stage	Description	Threshold
Stage 1	Water quality meets CDWQ MAC and MWQSOG MAC or is similar to baseline groundwater quality	Concentrations of Primary and Secondary Indicators continue to increase during two consecutive sampling events; OR All samples report results for indicators that are less than 10% higher than pre-operation maxima
Stage 2	Water quality meets CDWQ MAC and MWQSOG MAC or is similar to baseline groundwater quality	Two consecutive samples report results for any indicator that are more than 50% higher than pre-operation maxima OR Concentrations of primary indicators in one sample greater than 75% CDWQ MAC or MWQSOG MAC
Stage 3	Water quality exceeds CDWQ MAC and MWQSOG MAC	Two consecutive samples reporting concentrations of any primary indicator parameter that exceeds 100% CDWQ MAC or MWQSOG MAC

5.4 Mitigation Plans

Table F below presents the mitigation measures that will be put in place during site development, operation and for five years post-operation. Mitigation measures will be assessed and proactively applied following review of routinely collected groundwater monitoring data and/or receipt of any complaints from the public.

Table F. Trigger Events and Mitigation Measures

Trigger Event	Trigger for Application of Mitigation Measure	Mitigation Measure
Low Groundwater Levels in Regional Observation Well Network	Measured water levels in Regional Observation Well Network decrease to levels below established thresholds that have the potential to exceed well-specific Safe Available Drawdown in nearby private water wells.	Stage 1: Water level information evaluated on an ongoing basis by a qualified hydrogeologist, with results shared publicly. Stage 2: Confirm groundwater levels manually. Proactively adjust location and number of extraction wells, or rate of sand extraction to reduce impact of operations on water levels in nearby private water wells so they do not exceed Safe Available Drawdown. Stage 2: Confirm groundwater levels manually. Private Well Owners notified in the event there are deemed to be risks to water quantity in private wells. Implement increased monitoring frequency and/or Well Interference Response Plan. Stage 3: In extreme cases, provide potable water to any affected parties via certified water purveyor until the situation is assessed and rectified if impacts deemed related to Project operations or cease sand extraction from that well.

Trigger Event	Trigger for Application of Mitigation Measure	Mitigation Measure
Low Groundwater Levels / Inadequate Yield in Private Water Wells	Measured water levels in private water wells decrease to levels that exceed well-specific Safe Available Drawdown in nearby private water wells. Public complaints specific to changes in water supply well performance.	Stage 1: Water level information from monitored private wells evaluated on an ongoing basis by a qualified hydrogeologist, with results shared directly with well owner. Stage 2: Confirm groundwater levels manually. Reduce number of sand extraction wells that are operating concurrently, and/or the rate of extraction to reduce impact of operations on water levels in nearby private water wells so they do not exceed Safe Available Drawdown. Implement increased monitoring frequency and/or Well Interference Response Plan. Stage 3: In extreme cases, provide potable water and/or water treatment system to the affected party via certified water purveyor until the situation is assessed and rectified if impacts deemed related to Project operations. Alternatively, cease sand extraction from that well.
Degraded Groundwater Quality in Regional Observation Well Network	Water quality in Regional Observation Well Network significantly degraded relative to measured water quality prior to operations. Newly identified exceedances of applicable regulatory criteria based on water use.	Stage 1: Water quality evaluated quarterly by qualified hydrogeologist and/or geochemist, with results shared publicly. Stage 2: Conduct follow up sampling. Private Well Owners notified in the event there are deemed to be risks to water quality in private wells. Implement increased monitoring frequency. Stage 3: In extreme cases, provide potable water and/or water treatment system to the affected party via certified water purveyor until the situation is assessed and rectified if impacts deemed related to Project operations. Alternatively, cease sand extraction from that well.
Degraded Groundwater Quality in Private Water Wells	Water quality in Regional Observation Well Network significantly degraded relative to measured water quality prior to operations. Newly identified exceedances of applicable regulatory criteria based on water use. Public complaints specific to changes in water quality, taste or odour of well water.	Stage 1: Water quality information from monitored private wells evaluated following each sampling event by qualified hydrogeologist and/or geochemist, with results shared directly with well owner. Stage 2: Conduct follow up sampling. Nearby Private Well Owners notified in the event there are deemed to be risks to water quality in private wells. Implement increased monitoring frequency. Stage 3: In extreme cases, provide potable water and/or water treatment system to the affected party via certified water purveyor until the situation is assessed and rectified if impacts deemed related to Project operations. Alternatively, cease sand extraction from that well.

6. Data Review and Reporting

The Monitoring and Impact Mitigation Plan covers monitoring and impact mitigation measures required pre, during and post operation activities, particularly related to groundwater levels and quality. It will be reviewed on a monthly and annual basis including data quality assurance/quality control and adjusted, as required.

6.1 Monthly Data Review

Groundwater quality results will be reviewed for all monitoring stations on a monthly basis. This review will compare the results to the thresholds identified in this report. Water quality results will be compared to applicable criteria, with any exceedances flagged. Time series plots of water levels in the Regional Observation Well Network will be summarized. A monthly report will be prepared to summarize the results of this analysis. If the exceedance of a threshold is noted, Sio Silica will discuss and implement the required mitigation measures described in **Section 5.4**.

6.2 Annual Data Review and Reporting

A more detailed review will occur on an annual basis. An annual groundwater monitoring report will be prepared to present the results of ongoing monitoring of groundwater levels and groundwater quality. As part of the annual reporting, temporal plots will be prepared for selected key indicator constituents and any additional constituents identified from screening the newly collected data against applicable WQGs. Temporal plots for each constituent were qualitatively analyzed (i.e., visually examined) to identify increasing or decreasing trends in concentrations over the past sampling events, and this information was considered in development of appropriate threshold values. A general qualitative trend evaluation will also be completed on an annual basis, to identify if and when trends are projected to intersect threshold values.

The results of the data analysis will be presented in an Annual Groundwater Monitoring Report including:

a. Location of private water supply wells within the Local Groundwater Monitoring Zone each year.
b. Location and operational status of sand extraction wells
c. Configuration and status of the groundwater monitoring network.
d. Results of groundwater monitoring activities.
e. Tabulated groundwater quality data compared to appropriate provincial and federal guidelines described in **Section 2** of this Groundwater Monitoring and Mitigation Plan.
f. Time series plots of groundwater elevations and groundwater quality.
g. Time series plots of sand and groundwater extraction volumes.
h. Time series plots of groundwater reinjection volumes.
i. A water balance summary highlighting the volumes of sand and water that have been extracted and reinjected.
j. A clear statement on whether the project has impacted groundwater quantity and quality, including the magnitude and spatial extent.
k. A summary of the status of trigger events, including the current status of each event and any mitigation measures that were implemented.
l. A summary of well owner complaints received and how they were addressed.

This Groundwater Monitoring and Impact Mitigation Plan will be updated in consultation with the community and regulatory agencies as required. The annual monitoring report will be provided to regulatory agencies to fulfill license conditions. A summary of data will also be prepared and made available to interested members of the public.

7. References

AECOM, 2021. Vivian Sand Extraction Project – Hydrogeology and Geochemistry Assessment Report. AECOM Canada Ltd., July, 2021.

Health Canada (2022). Guidelines for Canadian Drinking Water Quality—Summary Tables. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario (updated in September 2020 Version)

Water Science and Management Branch Manitoba Water Stewardship (2011). Manitoba Water Quality Standards, Objectives, and Guideline.

Environment Canada. 2020. Canadian Climate Normals 1981-2010 Station Data. Online at: https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnName&txtStationName=ostenfeld&searchMethod=contains&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=3715&dispBack=1

Tables

Table 4-1. Existing Groundwater Monitoring Details

Well ID	Easting, m	Northing, m	Surveyed? (Y/N)	Monitoring Network?	Active Status	Potential Background Monitoring Well	Hydrostratigraphic Unit	Elevations (m ASL)				Depth (mbgs)		
								Ground Surface	Top of Pipe	Top of Screen	Bottom of Screen	Borehole Depth	Depth to Top of Screen or open interval	Depth to Bottom of Screen or open interval
Groundwater Monitoring Wells														
Bru 95-5	682208	5527628	Y	Regional	Active	-	Carbonate	275.193	276.225	237.38	230.94	44.25	37.81	44.25
Bru 95-6	682199	5527624	Y	Regional	Active	-	Sandstone	275.041	275.843	222.59	219.54	57.00	52.45	55.50
Bru 95-9	682203	5527621	Y	Regional	Active	-	Shale	275.191	275.844	227.34	227.03	48.16	47.85	48.16
Bru 96-1	683064	5527787	Y	Regional	Active	-	Sandstone	273.215	273.799	223.99	220.94	53.34	49.23	52.28
Bru 96-2	683062	5527791	Y	-	Active	Yes	Carbonate	273.304	274.005	237.34	231.55	41.76	35.97	41.76
Bru 92-1[3]	681479	5526513	Y	Local	Active	-	Carbonate	275.594	276.284	-	-	75.59	-	-
Bru 92-2	681566	5526457	Y	Local	Active	-	Sandstone	275.185	275.653	223.98	202.64	72.54	51.21	72.54
Bru 92-6	681601	5526428	Y	Local	Active	-	Shale	274.852	275.863	227.61	225.78	49.07	47.24	49.07
Bru 92-12	682109	5525979	Y	Local	Active	-	Sandstone	279.113	279.571	220.29	212.05	67.06	58.82	67.06
Bru 95-4[4]	682210	5527634	Y	Regional	Inactive	-	Carbonate	-	-	-	-	54.25	49.38	52.43
Water Supply Wells/Domestic Wells														
Bru 95-7	681863	5527616	Y	Regional	Active	-	Sandstone	277.120	277.927	223.17	204.88	74.98	53.95	72.24
Bru 92-8	681631	5526384	Y	Local	Active	-	Sandstone	274.982	274.828	219.72	202.65	71.93	54.86	71.93
66124	681445	5527842	Y	Regional	Active	-	Shale	-	-	-	-	-	54.9[2]	61[2]
23901	681236	5527685	Y	Regional	Active	-	Carbonate	-	-	-	-	36.42	-	36.42
Unknown	682732	5528117	Y	Regional	Active	-	Sandstone	-	-	-	-	54.88	-	54.88
Vibrating Wire Piezometers														
Bru 95-8_VW1	681953	5527630	Y	Regional	Active	-	Carbonate	277.271	278.387	N/A	N/A	55.09	N/A	N/A
Bru 95-8_VW2	681953	5527630	Y	Regional	Active	-	Carbonate	277.271	278.387	N/A	N/A	55.09	N/A	N/A
Bru 95-8_VW3	681953	5527630	Y	Regional	Active	-	Shale	277.271	278.387	N/A	N/A	55.09	N/A	N/A
Bru 95-8_VW4	681953	5527630	Y	Regional	Active	-	Sandstone	277.271	278.387	N/A	N/A	55.09	N/A	N/A

Notes:

m BGS = meters below ground surface.

m AGS = meters above ground surface.

m ASL = meters above sea level.

m BTOP = meters below top of piezometer pipe.

1 - Pre-existing monitoring well installed by Canwhite

2 - Reported by well owner

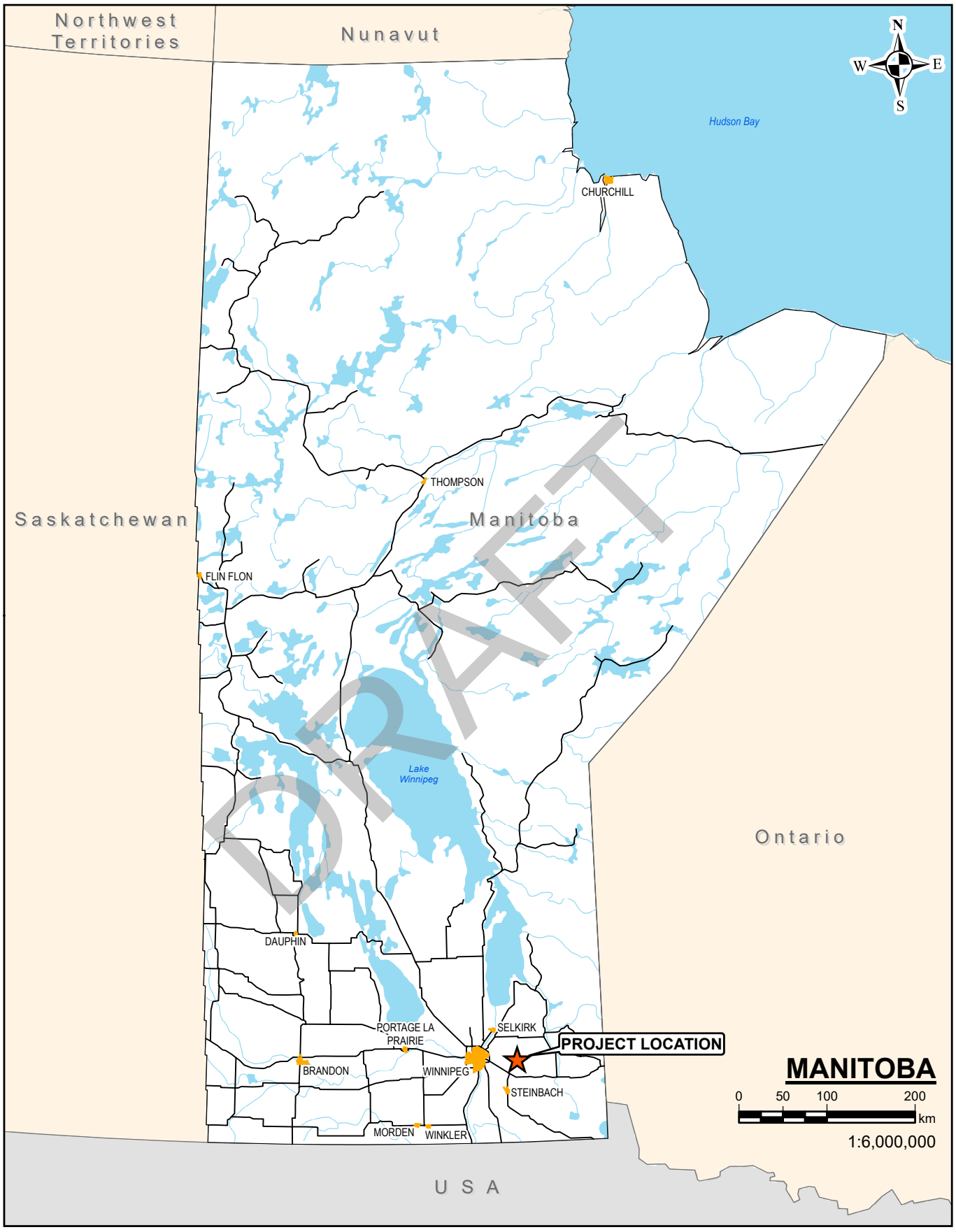
3 - Well construction detail is not available

4 - Well is decommissioned

- unknown

Survey data taken on Dec 1, 2020 by David Atkinson (AECOM).

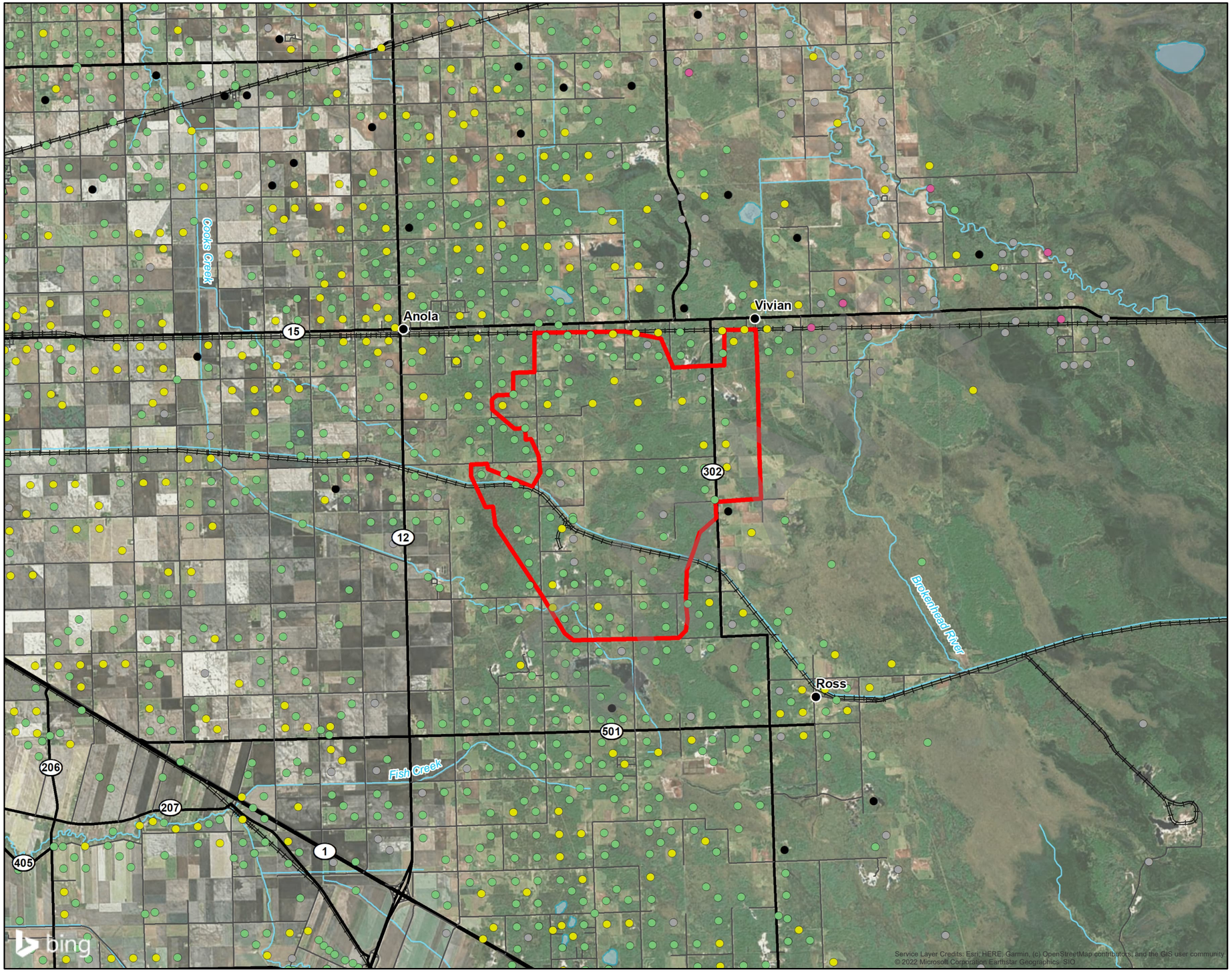
Figures



VIVIAN SAND EXTRACTION PROJECT **PROJECT LOCATION**
GROUNDWATER MONITORING AND IMPACT MITIGATION PLAN
SIO SILICA INC.
Project No.: 60640258 Date: 2022-10-12

AECOM

Figure: 1-1



Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
© 2022 Microsoft Corporation Earthstar Geographics SIO

Legend

- Project Site

General Features

- Highway
- Road
- Railway
- Watercourse
- Waterbody

Existing Groundwater Users by Aquifer

- Quaternary Sediments
- Red River Carbonate
- Winnipeg Shale
- Winnipeg Sandstone
- Lower Shale / Precambrian

DRAFT

N
W E
S

1:145,000
NAD 1983 UTM Zone 14N

2 1 0 2 4 km

Basemap: Canvec

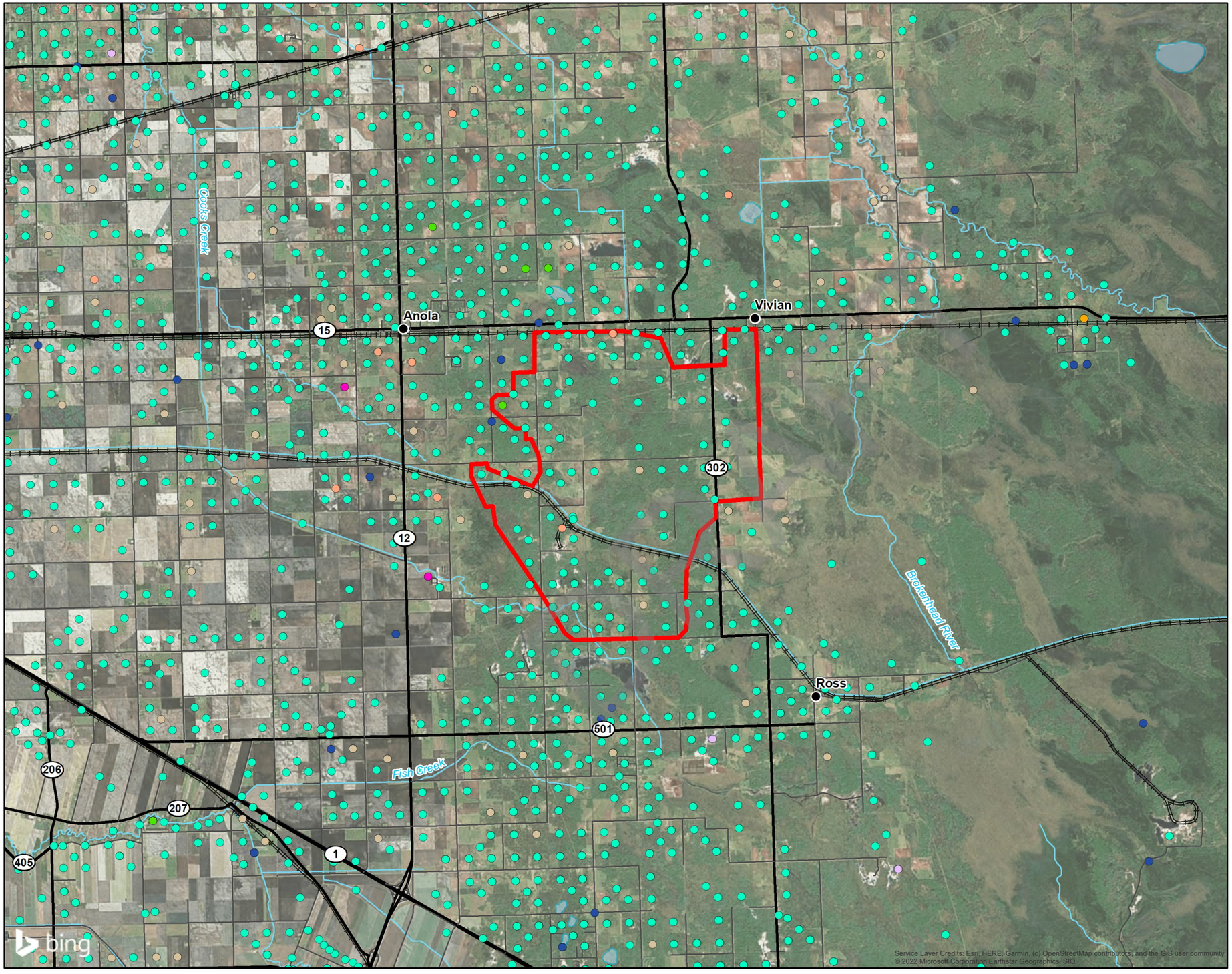
AECOM

Figure: 1-2

EXISTING GROUNDWATER USERS BY AQUIFER

VIVIAN SAND EXTRACTION PROJECT
GROUNDWATER MONITORING AND IMPACT MITIGATION PLAN
SIO SILICA INC.
Project No.: 60640258 Date: October 2022

Last saved by: PAIGE.CROSSMAN (2022-10-12)
Filename: B:\PAIGE CROSSMAN\WEST\WINNIPEG\60640258\900_CAD_GIS\920_929_GIS_GRAPHICS\02_MXDS\HYDRO 2022\H001-2_60640258_EXISTINGGROUNDWATERWELLS.MXD
Last Plotted: Mon Apr 05, 2022
Project Management Initials: Designer: Checked: Approved:
ANSI B 279.4mm x 431.8mm



Legend

- Project Site

General Features

- Highway
- Road
- Railway
- Watercourse
- Waterbody

Existing Groundwater Users by Type

- Air Conditioning
- Domestic
- Industrial
- Irrigation
- Livestock
- Missing
- Municipal
- Other

DRAFT

N
W E
S

1:145,000
NAD 1983 UTM Zone 14N

2 1 0 2 4
km

Basemap: Canvec

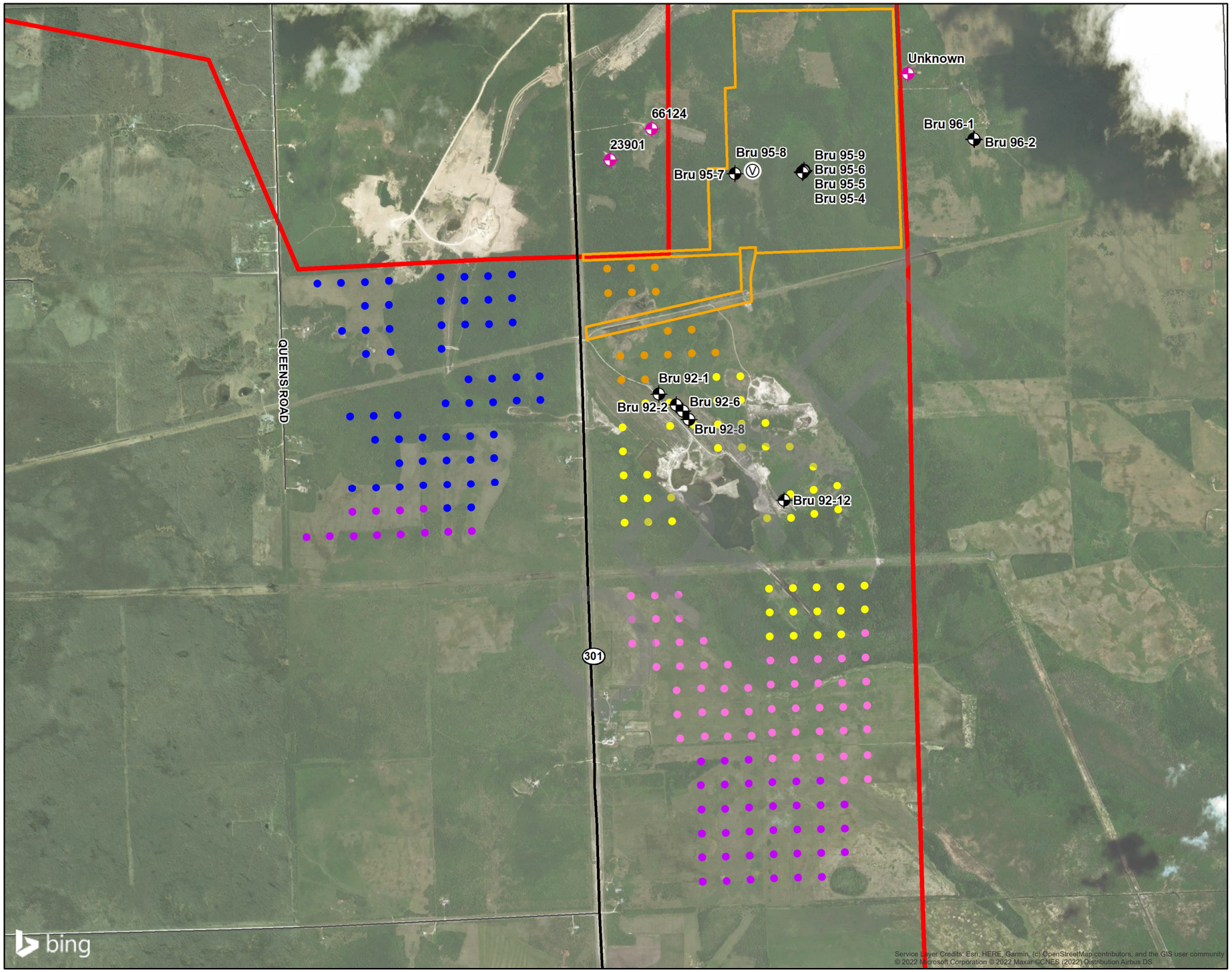
AECOM

Figure: 1-3

EXISTING GROUNDWATER USERS BY TYPE

VIVIAN SAND EXTRACTION PROJECT
GROUNDWATER MONITORING AND IMPACT MITIGATION PLAN
SIO SILICA INC.
Project No.: 60640258 Date: October 2022

Last saved by: PAIGE.CROSSMAN (2022-10-12) Last Plotted: Mon Apr 05, 2022
Filename: B:\PAIGE.CROSSMAN\WEST\WINNIPEG\60640258\900_CAD_GIS\920_929_GIS_GRAPHICS\02_MXDS\HYDRO 2022\H001-3_60640258_EXISTINGGROUNDWATERWELLS_USERTYPE.MXD
Project Management Initials: Designer: Checked: Approved: ANSI B 279.4mm x 431.8mm



Legend

- Project Site
- Sand Processing Facility Area
- Groundwater Monitoring Well (Sio Silica)
- Vibrating Wire Piezometers (Sio Silica)
- Surveyed Domestic Well (Sio Silica)

General Features

- Highway
- Road

Proposed Silica Sand Extraction Well Cluster Locations By Year

- 2021
- 2022
- 2023
- 2024
- 2025

N
W E
S

1:20,000
NAD 1983 UTM Zone 14N

200 100 0 200 400 600
m

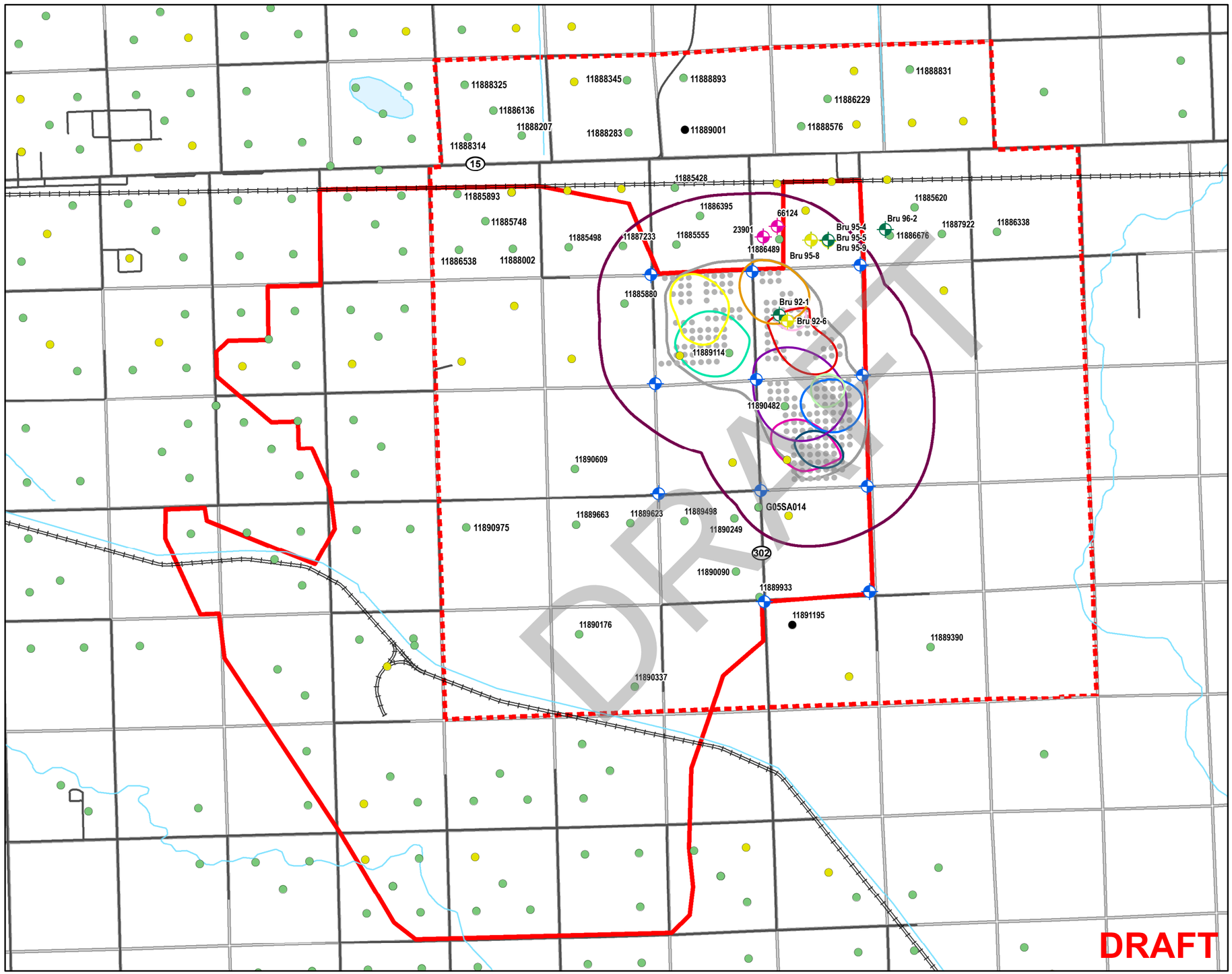
Basemap: Canvec

AECOM

Figure: 1-4

PROPOSED SILICA SAND EXTRACTION (YEARS 1 TO 5)

VIVIAN SAND EXTRACTION PROJECT
GROUNDWATER MONITORING AND IMPACT MITIGATION PLAN SAN
CANWHITE SANDS CORPORATION
Project No.: 60640258 Date: October 2022



Legend

- Five Year Plan Production Well
- Project Site
- Water Well Survey Boundary
- Local Monitoring Zone
- Regional Monitoring Zone

General Features

- Highway
- Railway
- Sections
- Watercourse
- Waterbody
- Proposed Groundwater Monitoring Well (Carbonate)

Existing Groundwater Monitoring Well (Surveyed)

- Carbonate
- Sandstone
- Shale
- Domestic Well

Existing Groundwater Users by Aquifer (Unsurveyed)

- Red River Carbonate
- Winnipeg Shale
- Winnipeg Sandstone

1-m Drawdown

- Day 30
- Day 270
- Day 360
- Day 540
- Day 630
- Day 720
- Day 990
- Day 1080
- Day 1350
- Day 1440

N
W E
S

1:60,000
NAD 1983 UTM Zone 14N

500 0 500 1,000 1,500 2,000 m

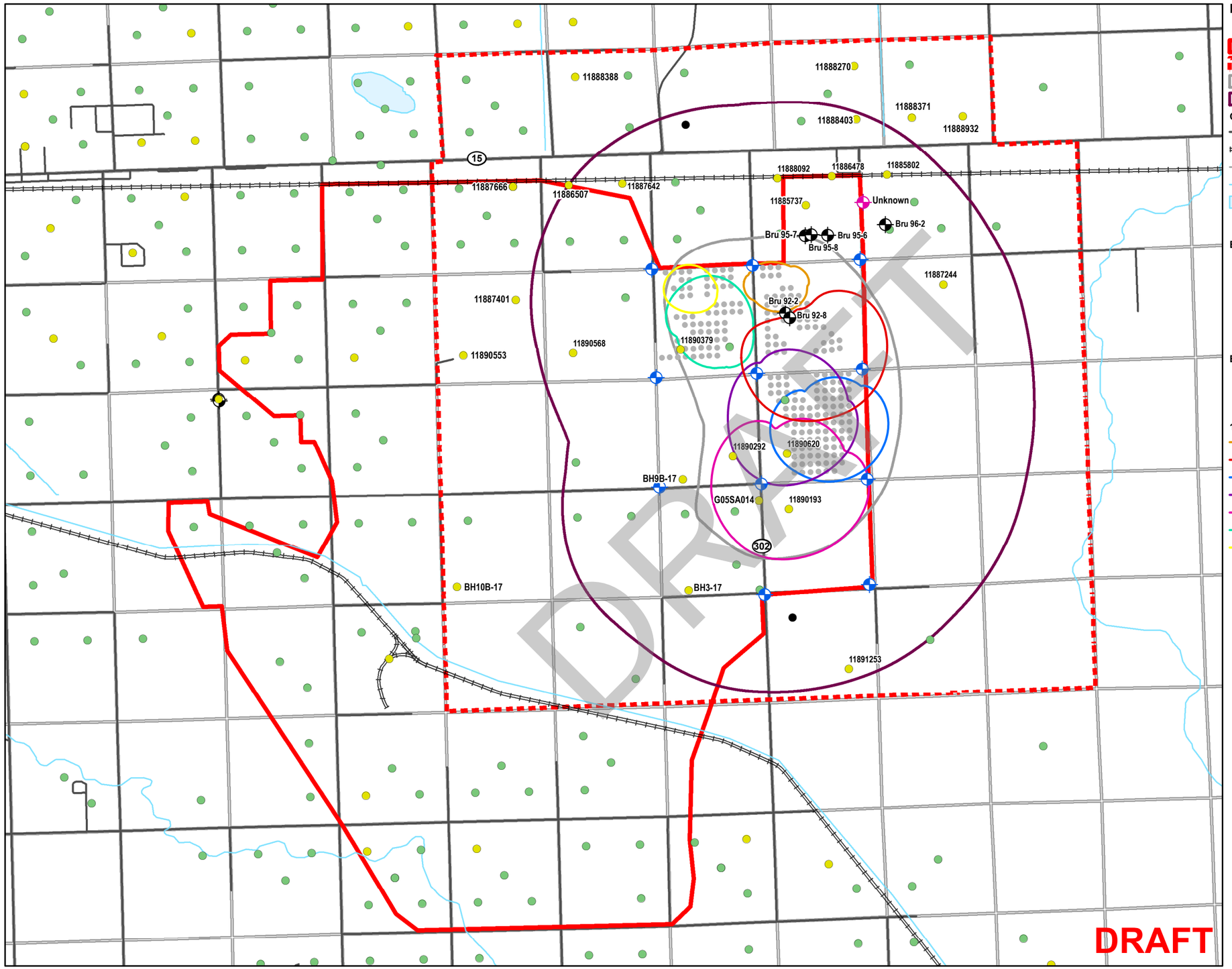
Basemap: Canvec, Manitoba Land Initiative

AECOM

Figure: 4-1

LOCAL AND REGIONAL GROUNDWATER MONITORING ZONES - RED RIVER CARBONATE AND SHALE

VIVIAN SAND EXTRACTION PROJECT
GROUNDWATER MONITORING AND IMPACT MITIGATION PLAN
SIO SILICA INC.
Project No.: 60640258
Date: February 2023



Legend

- Five Year Plan Production Well
- Project Site
- Water Well Survey Boundary
- Local Monitoring Zone
- Regional Monitoring Zone

General Features

- Highway
- Railway
- Sections
- Watercourse
- Waterbody
- Proposed Groundwater Monitoring Well (Sandstone)

Existing Groundwater Monitoring Well (Surveyed)

- Carbonate
- Sandstone
- Shale
- Domestic Well

Existing Groundwater Users by Aquifer (Unsurveyed)

- Red River Carbonate
- Winnipeg Shale
- Winnipeg Sandstone

1-m Drawdown

- Day 30
- Day 360
- Day 630
- Day 720
- Day 1080
- Day 1350
- Day 1440

N
W E
S

1:60,000
NAD 1983 UTM Zone 14N

500 0 500 1,000 1,500 2,000 m

Basemap: Canvec, Manitoba Land Initiative

AECOM

Figure: 4-2

LOCAL AND REGIONAL GROUNDWATER MONITORING ZONES - WINNIPEG SANDSTONE

VIVIAN SAND EXTRACTION PROJECT
GROUNDWATER MONITORING AND IMPACT MITIGATION PLAN
SIO SILICA INC.
Project No.: 60640258 Date: February 2023