GOVERNMENT OF NUNAVUT

Grise Fiord Water Treatment Plant Schematic Design Report

Grise Fiord, Nunavut (Final Report)

November 2023 – 23-5971

DILLON CONSULTING

December 5, 2023

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Grise Fiord Water Treatment Plant Schematic Design Report

Dillon Consulting Limited is pleased to submit our final schematic design report for the Grise Fiord Water Treatment Plant.

Should you have any questions, please contact the undersigned at your convenience.

Sincerely,

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1.0 Introduction

Dillon Consulting Ltd was retained by the Government of Nunavut (GN), Community and Government Services (CGS) to complete the detailed design for a new water treatment plant (WTP) in Grise Fiord, Nunavut. The field investigations and Business Case development for the new WTP took place in 2021-22, and was completed by EXP.

The overall objective of the schematic design phase of this project is to review the results of the Business Case (2022), and to outline design components to allow continuation into the detailed design phase for the new WTP. The new WTP and associated infrastructure will include a new seasonal raw water resupply system, year-around raw water storage within tanks, a WTP that meets treatment objectives from the *Guidelines for Canadian Drinking Water Quality* (GCDWQ), treated water storage tank, and truck fill system. The following sections provide background into the project and community water needs, in addition to providing the schematic design requirements for the proposed infrastructure, in preparation for advancing to detailed design.

2.0 Background

Grise Fiord is located on the southern side of Ellesmere Island, at 76°25' N latitude and 82°53' W longitude. It is the most northernly inhabited community in Canada and has a current population of 144 residents (*Statistics Canada, Census 2021*). The average annual temperature is -16.5°C and is one of the coldest populated communities in the world.

The primary water source in Grise Fiord currently comes from snow melt and surface runoff to a small basin located within the town. An alternative water source that has been used as a supplemental water supply is the Airport River that runs between the airport and the main portion of the town, which is fed by a combination of surface runoff with potential contributions from glacier runoff. Historically, the community has exclusively withdrawn water from the catchment basin; however, this basin has been shown to be an unsustainable water source into the future, and the new primary water source has changed to the Airport River (the River) in 2023, and will remain the primary water source for the new WTP. There are no other identified sources of potable water within reach of the community, and during the winter there are no accessible freshwater sources at all. The annual water supply must be captured and stored each summer within tanks to provide potable water for the community for the remainder of the year.

The existing water treatment plant is located within the center of the community, where it provides annual water storage within welded steel tanks, and disinfection by chlorine that is injected into the raw water while filling water delivery trucks. These trucks then deliver water to residential water tanks at all buildings within Town. The current water treatment process does not meet the minimum requirements for surface water sources from Health Canada's *Guidelines for Canadian Drinking Water Quality* (GCDWQ), and the infrastructure is outdated and has suffered significant failures over recent years, including structural failure of one of the water storage tanks, corrosion and pitting within another tank, and overall degradation of most electrical and mechanical components within the WTP itself. Based on the condition of the existing tanks and emergency repairs, it has been decided that full replacement of the water storage tanks and WTP is the preferred approach to meet federal treatment standards and reduce risk of future failures of the existing tanks.

The new WTP and associated infrastructure will include a new resupply system, new water storage tanks, a new WTP to meet GCDWQ treatment objectives, a treated water storage tank, and truck fill station, along with all required mechanical and electrical equipment for power, instrumentation and controls, SCADA, building heat, and freeze protection of exterior equipment. The following sections describe the work that was done in the Business Case development and outlines the schematic design details for the new infrastructure.

2.1 Planning Study

The planning study was undertaken in 2021-2022 and resulted in a Business Case (2022) that provided recommended schematic design features, including sizing, siting, foundation details, and recommended treatment process for the new water treatment plant in Grise Fiord. The Business Case included the following tasks:

- Hydrological and Water Balance Study;
- Geotechnical Investigations, including both field study and foundation recommendations;
- Phase 1 Environmental Site Assessment;
- Topographic Survey;
- Snow Drifting Study;
- Water Quality Data Review;
- Development of WTP components, including treatment process (based on Standardized Water Treatment Train approach), water storage requirements, power considerations, building considerations and geotechnical considerations;
- Development of schematic design;
- Preparation of a Class D cost estimate; and
- Evaluation and final WTP site selection for the new WTP.

The following subsections describe the results from the Business Case. Many of these items have since been modified or updated, which is described in section 4 below.

2.1.1 Water Source Hydrology

The Airport River will provide a sustainable water source for the design horizon of the WTP (2047) and was recommended to become the primary water source. At the time of the Business Case, no sampling or flow monitoring of the River had been undertaken, and the water source was not yet approved by the Department of Health as a community water source. It was recommended to complete quality sampling and flow monitoring prior to completing detailed design to confirm characteristics of the River water source. Flow monitors were installed by Dillon during the initial site visit in July 2023, as well as sampling of Airport River water quality. Results from flow monitoring will be summarized in a subsequent memo after the meters have been removed from the River and the results analyzed.

2.1.2 Geotechnical Investigation

The geotechnical study included the drilling of 10 boreholes and nine (9) test pits in the vicinity of the three sites considered for the WTP during the planning study. It concluded that the geotechnical conditions in this area are highly consistent, with the area being underlain by granular soils varying from sand and gravel to sand and silt with randomly distributed clayey silt to silty clay layers. Bedrock was not encountered at any of the boreholes. Drainage infrastructure to promote proper drainage of surface runoff away from the infrastructure foundations was recommended.

The WTP foundation was recommended as spread and strip footings set at a shallow depth on an engineered fill pad with thermosyphons. Water tank foundations were recommended as elevated engineered fill pads with provision of insulation under the tank slabs.

2.1.3 Treatment Process

The recommended treatment train, based on the SWTT approach, was as shown below in **Figure 2-1**. The recommended treatment included coarse screening and UV disinfection prior to the raw water storage tanks, followed by pH adjustment and coagulant, a contact tank, membrane filtration, UV disinfection, chlorine addition, and treated water storage. It was recommended that based on low levels of organics within the historical water sampling, that Dissolved Air Floatation (DAF) was not required. Based on the Business Case, there were no historical exceedances of other contaminants of concern that would require additional treatment steps; however, water chemistry sampling of the River was recommended prior to detailed design of the system to confirm water quality characteristics. This has since been completed.

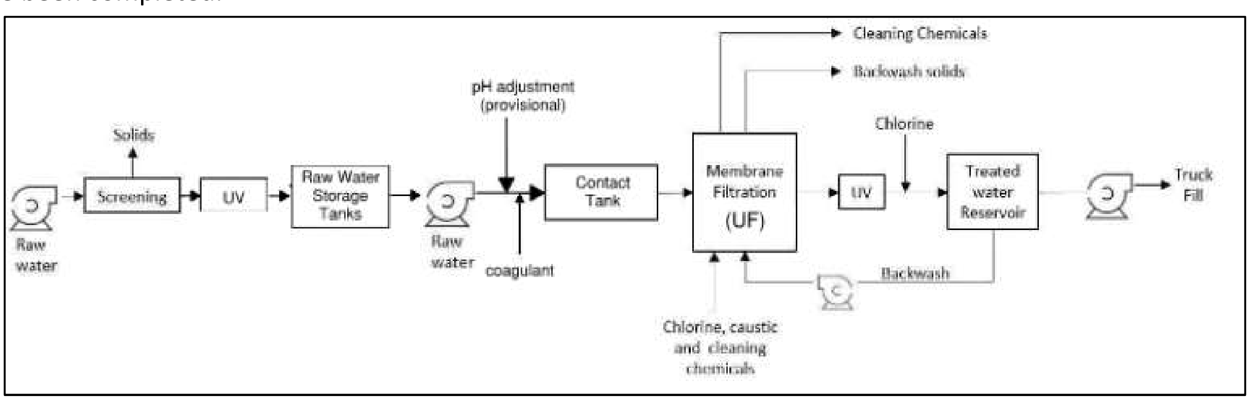


Figure 2-1: Business Case Proposed Treatment Process

2.1.4 Business Case Design Basis

The Business Case proposed the following parameters for the basis of design of the WTP, as shown in **Table 2-1**.

Table 2-1: Business Case Design Parameters

Parameter	Grise Fiord WTP Value
Population (2043)[1]	200 people
Design Consumption Rate	120 Lpcd
Annual Consumption Rate	8,760 m^3/year
Average Daily Demand	24,000 L/day
Peak Daily Demand (2.5 Factor)	60,000 L/day
Design WTP flow in 12 hr day	83 L/min

[1]The Business Case used the 2016 Census to project population which displayed a decrease from 2011. Therefore, a future population of 200 in 2043 was selected as a conservative estimate for the design basis (EXP, 2022)

2.1.5 Intake and Site Location

The Business Case completed a site scouting study to determine the preferred WTP site and seasonal intake location. **Figure 2-2** displays the recommended sites from the Business Case.

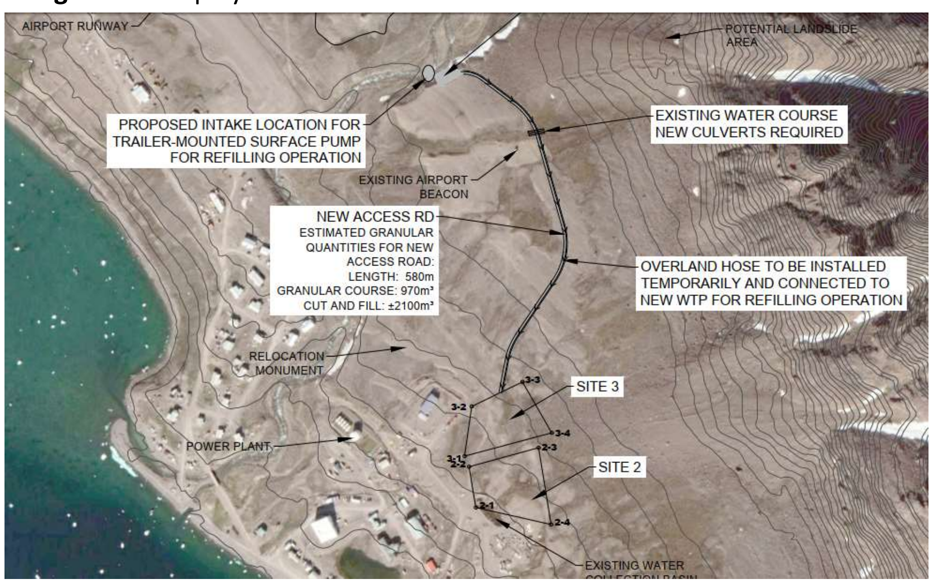


Figure 2-2: Business Case (exp. 2022) Proposed Siting

3.0 Regulatory Review and Approvals

There are several regulatory, approval, and notice requirements for the construction and commissioning of the new WTP in Grise Fiord. Many regulatory, code, and guideline requirements will be considered as part of the detailed design of WTP components, while others require early coordination.

3.1 Applicable Regulations, Codes and Guidelines

Dillon will follow the most up to date and relevant regulations, codes and guidelines applicable to the project and design will meet or exceed the following regulations codes and guidelines:

- Federal, Territorial and Municipal Safety Act;
- Health Canada Guidelines for Canadian Drinking Water Quality;
- Federal, Territorial and Municipal Public Health Act;
- Canadian Environment Protection Act (CEPA);
- Indigenous and Northern Affairs Canada (INAC) Water and Wastewater Policy and Level of Services Standard (Corporate Manual Systems);
- Guidelines for Spill Contingency Planning;
- Nunavut Municipal Infrastructure Capital Standards and Criteria Manual;
- Hamlet of Grise Fiord Zoning Bylaws;
- Northern Infrastructure Standardization Initiative (NISI) standards;
- American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE);
- National Energy Code of Canada;
- National Fire Protection Association (NFPA) Standards;
- Canadian Standards Association (CSA International) Standards;
- ARI Standards;
- National Plumbing Code of Canada;
- National Energy Code of Canada;
- National Building Code 2015, 1st printing;
- GN Good Building Practices Guideline;
- Authorities Having Jurisdiction (AHJ);
- Office of the Chief Electrical Inspector (OCEI). The OCEI provides information and services regarding plan reviews, permits, inspections, and registration for Electrical services. All electrical work shall be compliant to the requirements of the Electrical Protection Act and Regulations. Note: The Electrical Act is in the process of being repealed and replaced by the Technical Standards & Safety Act;
- Canadian Electrical Manufacturers Association (CEMA);
- National Electrical Manufacturers Association (NEMA);
- Underwriters Laboratory (UL and cUL);
- American Society for Testing and Materials (ASTM);
- American National Standard Institute (ANSI);
- Electrical and Electronic Manufacturing Assoc. of Canada (EEMAC);
- Canadian Electrical Code (CEC);
- Nunavut Electrical Protection Act and Regulations;
- Nunavut Building Code Regulations, latest edition; and
- Municipal ordinance governing electric work.

3.2 Regulatory Approvals and Permits

Various regulatory approvals and permits are needed for the construction and commissioning of the new WTP facility and structures. **Table 3-1** outlines several that need to be considered throughout the design process, with recommended timelines for submission. The following subsequent sections outline various agencies and application processes.

Table 3-1: Regulatory Submission Guideline

Regulatory Submission	Agency	Submission Date	Design Stage
Water License/Regulatory Application	Nunavut Water Board, Nunavut Impact Review Board, Nunavut Planning Commission	October 2023	50%-75% Design Submission
Airport Approvals	NavCanada, Transport Canada and Nunavut Airports	June 2023 (submitted)	Schematic Design
Municipal Development Permit	Municipality	November 2023	75% Design Submission
Municipal Land Use Bylaw Amendment	Municipality	November 2023	75% Design Submission
Electrical Inspector Approval	CGS Electrical Inspector; Office of the Chief Electrical Inspector	Summer 2024	Issued for construction set; by Contractor
Fire Marshall Approval	Office of the Chief Building Official	November 2023	75% Design Submission

3.2.1 Water License

The Municipality of Grise Fiord is licensed through the Nunavut Water Board to operate the Municipal water withdrawal, wastewater, and solid waste facilities within the community under water license 3BM-GRI2025. The license outlines the requirements for water withdrawal, waste discharge, and monitoring and inspection for the licensed facilities.

Airport River and the Basin are both approved water sources in the current water license, to a maximum annual water withdrawal quantity of 8,000 m^3, and a daily maximum of 299 m^3. There are no requirements for screening on the river intake infrastructure, but there are requirements to protect the river banks against erosion due to withdrawal activities.

An amendment will be necessary to this water license for the addition of the new infrastructure, and to increase water withdrawal volume to meet the new storage volume, currently estimated at 13,200 m^3 annually. The daily flowrate of seasonal withdrawal governs whether or not an increase above the daily limit is required; however, it is understood that exceeding the daily limit of 299 m^3 will require the license to move to a type A license, which will lead to an increase in license administration and monitoring requirements. As the new facility will include a fully redundant tank at the design horizon, it is not expected that this full volume would need to be resupplied under normal operating years, and would only be required during the commissioning year and the year(s) following a tank being taken offline for maintenance. Dillon will design the seasonal intake based on the 299 m^3/day limit. Based on conversations with CGS, should an exceptional circumstance occur where the 299 m^3/day limit need to be exceeded, it is intended that CGS would apply for a temporary/emergency permit rather than applying for a type A water license. Based on the anticipated resupply at the 20-year horizon of approximately two tanks at 8,800 m^3, it is not anticipated that withdrawal will exceed the 299 m^3/day limit during normal years. It is recommended that this license amendment could begin at the 50% - 75 % design stage.

During the year that the new WTP is commissioned, it is expected that additional water will be required for pressure testing and cleaning the tanks, in addition to potential emergency reserve water to be recommended to be stored within the existing storage tanks to protect against scheduling risks/delays. It is recommended that a temporary allowance for increased daily and annual water withdrawal be requested closer to construction, when an estimate can be made for cleaning/emergency storage requirements.

3.2.2 Department of Health

The Department of Health is the regulator for Municipal water supplies, through the Public Health Act and Consolidation of Public Water Supply Regulations (1990). These water regulations have been supplemented by formal Direction Notices from the Chief Public Health Officer (CPHO) for Nunavut to address outdated monitoring requirements within the 1990 document. In addition to the notices, the Department of Health is actively working on an update to the 1990 Regulations, which will require public water supply facilities to meet the treatment objectives outlined in the GCDWQ. As such, minimum treatment requirements are governed by the GCDWQ. The Department of Health also has regulatory authority over approving source water for potable use and a duty to review design and monitoring plans for water treatment facilities.

Airport River has recently been approved as the primary water source for the community of Grise Fiord by the CPHO. Beyond that it is understood that while the SWTT process has been reviewed previously by the Department of Health, any modification to this treatment process would be provided to the Department for their review. This process is anticipated to be review only, provided that treatment, redundancy, and operational recommendations of the GCDWQ are followed with the new process.

The Department of Health will also be communicated with prior to construction of the new facility to coordinate timing of construction and commissioning, and any impacts to community water delivery schedules. Since this new WTP will be completely independent of the existing facility, there is not expected to be an impact to water deliveries within the community.

3.2.3 Office of the Chief Building Official

The Office of the Chief Building Official (OCBO) is the Authority Having Jurisdiction (AHJ) in charge of all the Building Permits issued throughout the territory of Nunavut. Its mandate is to review and confirm the project's compliance with the applicable National, Territorial, and Hamlet Building Codes and regulations. Regulatory approvals from the AHJ required prior to construction include: a Development Permit (DP) from the Hamlet of Grise Fiord, a Building Permit, Boiler Permit, Electrical Permit, CSA A277 Certification from the Modular Manufacturer, and Department of Health and Fire Marshal plan reviews. The OCBO building permit application requires "Issued for Construction", stamped, and signed drawings, as well as completed Schedules 3A and 3B.

Prior to occupancy a letter of occupancy approval is required from the Fire Marshal along with OCBO Schedules 3C and 3D, and a letter from the Architect confirming final completion and compliance with the construction documents.

Modular construction manufacturers in Canada are required to submit proof of CSA A277 certification per the National Building Code for code compliance. The Government of Nunavut (GN) has required factory pre-rough-in inspections for compliance with CSA A277 and the GN Good Building Practices Guidelines in their standard GN/Prime Consultant contract agreements.

3.2.4 Office of the Chief Electrical Inspector

The Chief Electrical Inspector (CEI) provides mandatory plan reviews, permits, inspections, and registration for Electrical services. Permits must be obtained prior to any electrical work taking place, and in-person inspections by the CEI will need to be scheduled throughout the building's construction. Once the installation is approved by the CEI, it is the CEI who grants the necessary permit for the building to be connected to the Qulliq Energy Corporation (QEC) power grid.

3.2.5 Other Permits/Requirements

Permits from other agencies may be required throughout the project execution. Most of these permits could be applied by and managed by the Contractor during the Construction stage of the project, as part of their scope of work. Other permits include but are not limited to:

- Boiler permit (delivered by the Office of the Chief Boiler and Gas Inspector/GN);
- Gas permit (delivered by the Office of the Chief Boiler and Gas Inspector/GN); and
- Permit for power connection (delivered by QEC).

4.0 Schematic Design

4.1 Population Projections and Consumption

The new Grise Fiord WTP is intended to service the community for a 20-year design horizon. There are no major industrial or commercial water users in Grise Fiord, so the water demand is driven by residential population only. The Business Case indicated that based on historical information, Grise Fiord is anticipated to experience negative growth, but that a conservative future population of 200 people was recommended for use. Dillon has looked into Statistics Canada Population data for 2011, 2016, and 2021, and has determined that while 2011-2016 experienced a decline of -0.8% (1-person reduction), 2016-2021 experienced an annual growth of 2.3% (15-person increase). Dillon recommends for the purposes of the future planning for the WTP, that a projected 2047 population of 200 people, which equates to an annual growth of 1.3% is an appropriate and conservative assumption given historic growth averages.

Average per capita consumption has been conservatively set at 120 litres per capita per day (Lpcd) within the Business Case, which has been an established average to use for future planning in communities that use truck fill operations based on the SWTT Project. This means that annual consumption at the design horizon is anticipated to be 8,760 m^3, as indicated in the Business Case.

In the Business Case, it was recommended that storage volume be increased to provide a minimum of 3,500 m^3 within each of three tanks, which will provide a fully redundant tank at the current (2023) consumption scenario, but not at the design horizon. CGS requested that Dillon increase tank size to provide a single fully redundant tank at the design horizon (Oct 5th, 2023), which will increase each tank to a minimum of 4,400 m^3. This would equate to a total operational storage of 13,200 m^3 total within the three tanks. This would allow for a tank to be offline at any given year for maintenance and repairs.

4.2 Operational Scenarios

The Business Case was based on the following water production scenario (year around treatment):

1. Resupply raw water from Airport River seasonally into 3-large storage tanks.
2. Treat water, as needed, through the treatment process, and store daily water demand in treated water storage tank.
3. Truck fills from treated water storage tank.

Following several water infrastructure emergencies in Grise Fiord within the last couple of years, CGS has requested that the treatment plant be designed with the flexibility to treat all water as it is resupplied, and store the treated water for the year (seasonal treatment). This scenario includes the following key steps:

1. Resupply raw water from Airport River into the small tank (process tank).

2. From the process tank, pump water through the treatment train, and into the three large water storage tanks.
3. Treated water will circulate from the water storage tanks through boilers for freeze protection.
4. Chlorine residual will be maintained through a top-up injection point located on the recirculation system
5. Trucks will fill from the large storage tanks.

To provide flexibility for the WTP to be operated in either of the two scenarios described above, Dillon proposed the following:

- The treated water tank becomes a "process tank". It will be used as a settling/break tank in the seasonal scenario, and a treated water storage tank during the year around scenario.
- Tank cleaning will need to occur when changing from the year around to seasonal operations and vice-versa. Tanks that provided storage to raw water will need to be cleaned prior to storing treated water.
- Dillon proposed the use of flexible hose to directly connect to each tank during resupply operations to eliminate chances of cross-connections and to mitigate risk of filling the wrong tank unintentionally. Following this concept presentation, it was decided by CGS to instead bring the raw water into the WTP building to a single header, and then using valve controls direct the flow into the correct tank using the recirculation lines.

4.3 Treatment Design Parameters

Design parameters for the WTP are included in **Table 4-1** below. Most of the parameters are consistent with the Business Case, while others have been updated based on the site visit and schematic design to date. Treatment and storage details are provided in the subsequent sections below.

Table 4-1: Treatment Design Parameters

Parameter	Design Value
Current Population (Statistics Canada Census 2021)	144
Design Population (2047)	200
Design Consumption Rate	120 Lpcd
Peaking Factor	2.5
Peak Daily Demand	60,000 L/day
WTP Design Flow for seasonal treatment[2]	210 L/min (299 m^3/day)
Hours of operation required to meet daily demand for year-around scenario	5 hrs
Truck fill Rate	1,000 L/min
Intake Operation	Seasonal using trailer-mounted pumps, flexible hose to hill crest, buried pipe from hill crest into WTP to single raw water intake header.
Intake Screen	Attached directly at River Intake pump skid

# Truck Fill Arms	1
# Truck Fill Pumps	2 (1 duty, 1 spare)
# Treatment Trains	2; fully redundant system
Cartridge Filters	Coarse, Medium, and fine sequential filter train, with final step LT2 approved 1-micron absolute cartridges
UV	2 @ 100% design capacity
Chlorination	Sodium hypochlorite to be used. Primary chlorination of filtered water into the treated storage tank(s), chlorine top-up included on recirculation line and truck fill.
Fluoridation	Provisional; leave space for future addition.
Process Water Storage	210 m^3. Sized for chlorine contact time during year around treatment scenario. Fire water to be provided by emergency bypass.
Tank Freeze Protection	Water recirculation, consideration for internal mixer/heater during detailed design phase
Wastewater Storage[1]	1,500 Gallons; ~5.7 m^3
Water Storage	Fully redundant tank required 3 tanks @ 4,400 m^3 (minimum)

[1]Wastewater storage tank sized for 3 days of analyzer flow plus 25%.

[2]At this rate the seasonal resupply would take approximately 7.5 weeks during the commissioning year to fill all three tanks, and would take approximately 4.5 weeks in normal years to resupply two tanks, operating 24 hrs/day.

4.4 Treatment Process

Dillon has issued a treatment memo following Airport River water sampling undertaken by Dillon during the 2023 site visit. Water analyses have demonstrated that considerable cost savings and operational simplicity can be achieved by replacing the SWTT process with a cartridge filtration and ultra-violet disinfection process, while still maintaining water quality to achieve the goals of the GCDWQ. This treatment process memo has been included in **Appendix B.** Based on the findings presented within the memo, Dillon recommends adopting the simplified treatment process for the Grise Fiord WTP.

The following is the summary of treatment unit processes that are recommended for the new Grise Fiord WTP:

- Pre-treatment/screening will take place at the resupply pump at Airport Creek intake. Large solids elimination will be a function of the screening system utilized on the intake pipe and quiescent area that will be utilized to place the intake. All of this is intended to minimize the uptake of solids from the diesel driven pump that will be in operation directly at the River bank. The most likely design will incorporate a naturally occurring pool that provides a reduced velocity zone for the intake pipe to be placed. The intake screen is proposed to be sized with 2.54 mm spacing to promote rejection of large debris.
- Depending on the operational scenario (year around or seasonal treatment), the raw water will be directed from the raw water header within the WTP into the first tank. During the seasonal scenario, this will be the smaller process tank, whereas during the year around scenario water would be

directed into the three large storage tanks. The pre-treatment tank(s) will promote settling of particles that have entered the system from the raw water supply. A floating intake suction will be incorporated into the design that will allow for decanted “top water” to be withdrawn, and allow for maximum undisturbed settling of particles to occur within the tanks. The intent is not to design an optimized clarification tank, but rather to take advantage of the large hydraulic capacity for storage purposes and resultant settling that will naturally occur.

- The proposed core WTP treatment process is a progressively restricted cartridge filtration system. The final filtration step will be a certified USEPA LT2 filter that is effective to an absolute size of 1-micron particle removal, per GCDWQ requirements for log-removal credits for Cryptosporidium and Giardia. The multi size/stage filters installed upstream of the LT2 filters are lower cost and intended to remove larger bulk solids in order to promote the lifecycle of the costly LT2 filters. This system will be fully redundant to allow maintenance and filter changes to occur without impeding water treatment.
- Primary disinfection for virus and protozoa inactivation, as well as secondary disinfection are a requirement of the GCDWQ. For this application, a UV disinfection system is to be utilized that will provide log removal credits for Cryptosporidium and Giardia, which is in addition to the log-removal credits provided by physical rejection by the LT2 filters. The UV system will be provided with a fully redundant unit, and operated in series, with the ability to bypass either unit as needed for maintenance. The chlorine residual and treated water storage tank will be designed to provide a minimum of 4-log inactivation for virus. The chlorine residual in treated water filling delivery trucks will promote antimicrobial resistance for storage cisterns in the delivery system and homes of the users. The chlorine injection system will have a minimum of two (2) injection locations (tank recirculation and truck fill piping), each with 2 lead/lag pumps. An optional third chlorine injection upstream of the cartridge filters can be provided to reduce the risk of biofilm growth within the cartridge filters, especially if they are not needed to be changed frequently. The chlorine residual will be monitored online with continuous monitoring analysers on the treated water tank recirculation line. The chlorination system will be for sodium hypochlorite only, as directed by CGS. In the seasonal treatment scenario, chlorine residual will be maintained in the large storage tanks to protect against biological activity, but will be kept lower than in the normal year-around treatment scenario. In this scenario, treated water would be topped-up on the truck fill line to maintain the residual in the delivery trucks and home water tanks.
- Fluoridation is to be included as a provisional process. Space allowance for future addition of a fluoridation system will be provided in the WTP.

4.5 Annual, Process, and Wastewater Storage Tanks

The WTP will include the following storage tanks:

Annual Storage Tanks: These three tanks will provide storage for the annual water supply at the 20-year design horizon. They are proposed to have a volume of 4,400 m^3 (minimum) each. Depending on the treatment scenario (seasonal or year-around) these tanks may store raw water or treated water. Water will be continuously circulated through a boiler system, where it will also receive chlorine top-up in the seasonal treatment scenario when treated water is stored.

Process Storage Tank: This tank was initially to be the treated water storage tank, but is now referred to as the process tank. This tank is proposed to be 180 m^3 to provide chlorine contact time. During the seasonal treatment scenario, it will receive raw water through the raw water intake header. In the year-around treatment scenario it will be used to provide daily storage of treated water. This tank will also be heated by recirculating water through a boiler system and will receive chlorine top-up if storing treated water.

Wastewater Storage Tank: This tank is proposed to be 1,500 gallons, or roughly 5.7 m^3, and will be located within the WTP itself to provide wastewater storage for analyzer flow and domestic use. The wastewater tank will need periodic hauling by vacuum truck to the Municipal lagoon.

All exterior tanks will be glass lined, bolted steel construction, with panels fabricated at the manufacturer's facility, and then packaged for shipment to Grise Fiord on the annual sealift. The packaged components will be winterized and protected from exterior elements in case they need to be stored over winter in Grise Fiord after arrival, which is anticipated based on current schedule, as discussed further in section 5.0. Tank erection will be by the manufacturer.

4.6 Raw Water Intake and Pipeline

Historically, the community uses pumps and overland pipes to convey river water to a small earthen basin located slightly north and up gradient of the existing WTP, and then transfers water from the basin by gravity into the existing raw water storage tanks. The process to fill the community's existing raw water storage tanks generally takes 2-3 weeks (annually) to complete. One transfer pump is set up at the river, and another is located inline approximately 100 m southeast of the first pump to boost pressure. The existing river intake is located just east of the airport runway. Water from the River was not used prior to 2022.

Historically, natural surface runoff from the catchment area flowing to the basin was used as the sole water source. As the basin filled naturally during the summer, the Municipality would then transfer the water to the raw storage tanks. The duration of this operation was highly dependent on the surface runoff volume experienced in a given year. The sustainability of this method carried an associated risk of inadequate resupply during low precipitation years. In contrast, the Airport River watershed is significantly larger, with prolonged flow during the summer season. Based on this risk, it was decided that the River will be the sole water supply for the community.

During the July 2023 site visit, the project team walked the river to determine a preferred location for the intake. Consideration was given to the distance to the proposed WTP facility, the terrain for river access and hose layout, the availability of deeper, quiescent water pool in the river, and general constructability. During the reconnaissance work with CGS, it was apparent that the river showed evidence of meandering, and that the channel location could shift with time. Based on this observation, it was agreed that a permanent intake structure would not be the best option for Grise Fiord, and the preferred option would be a mobile intake that had the flexibility to be easily relocated.

The shortest route for the river intake (approximately 312 m) is from the west of the new WTP facility; however, it was noted that the east river bank at that location is 12-14 m higher than the river's edge, and the banks have steep slopes (2H:1V). This topography would make accessing the river and grading a pad for the pump more challenging. It was also noted that the shorter route to the west could potentially align the intake hose close to the culturally important Grise Fiord monument. For these reasons, this route was not recommended.

The current intake location is approximately 80 m east of the airport runway, and 570 m northwest of the proposed WTP facility. The area around the existing intake location has less challenging topography in terms of access and grading in comparison to the 'shortest' route. The pump at the current location is required to overcome a maximum 4000 mm of vertical elevation difference along the pipe route to the basin. The current route to this location from the proposed WTP facility is fairly consistent in terms of topography. Much of the river has turbulent, shallow flow. The area around the current intake has several locations where naturally occurring deeper pools are present, which are beneficial to the effectiveness of the intake.

The intake site identified in the New Water Treatment Facilities & Associated Infrastructure at Grise Fiord Business Case report (EXP, 2022) was also evaluated during the site visit. This area is 160m further east (upstream) of the current intake location. The river bank is approximately 8m high at that location and the slopes are in the range of 2.5H:1V. This terrain would also be challenging from an access and grading perspective. Further, there is an existing mountain to the northeast of the Grise Fiord town site and there is evidence of rock fall at the toe of the mountain which could present risks related to infrastructure damage. The location noted in the Business Case report does not offer any added benefit in comparison to the existing intake site.

Considering the aforementioned factors, the area around the existing intake was assessed as being the most suitable location for the proposed intake. Specifically, approximately 20 m upstream of the existing intake, there is a natural deep pool with good access. This location is slightly upstream of the airport runway. The proposed intake location and hose alignment is illustrated on **Figure 4-2**.

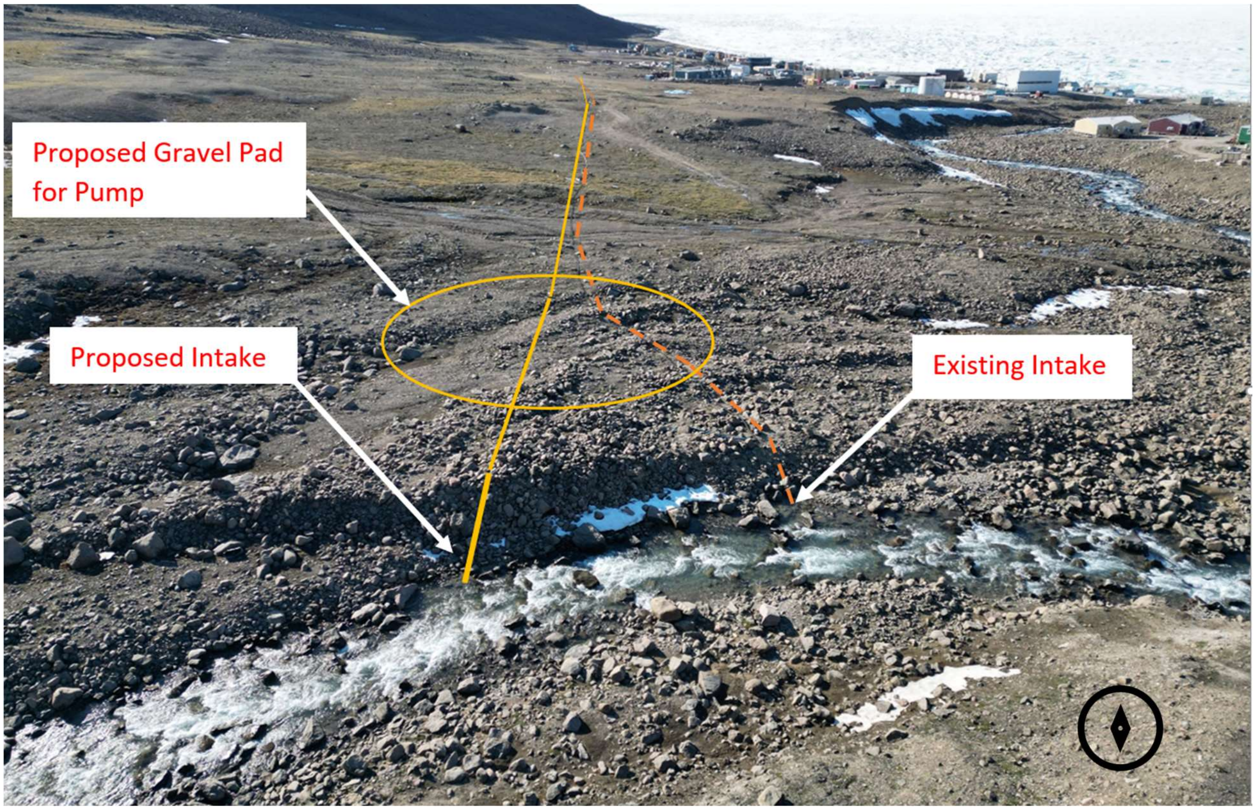


Figure 4-1: Existing and Proposed Intake Locations, Facing Southeast

Having the intake upstream of the airport runway is also beneficial from a water quality/security perspective. In the event of a fuel spill at the airport, the water supply would be unaffected. The current water source approval from the Department of Health is for a location upstream of the airport.

4.6.1 Resupply Access Road

An access road from the community in the vicinity of the WTP to the river intake location is required for pump/pipeline deployment and maintenance throughout the pumping season. An existing gravel trail already extends from the proposed WTP facility towards the existing/proposed intake location for approximately 250m. A portion of the trail is used to access the community monument site, as well as accessing the land north of the community. The proposed intake hose can parallel this trail, and is recommended to remain on the southern side of the trail as to mitigate risk of damage to the pipeline throughout the pumping season by ATV traffic. By utilizing the trail for the new intake access, some cost saving may be realized as there will be less grading and aggregate required. The existing trail will be extended to the new intake location and a new gravel pad will be constructed near the river to facilitate pump and intake deployment. Vehicular access to the intake, including turn-around space, will simplify pump deployment and monitoring. The road would be intended for use by a truck, that would pull a trailer containing the hoses and pumps. Some minor earthworks will be required for trail construction, and to provide a relatively smooth surface for the intake hose to lay on. Fill material may need to be procured from the existing quarry, which is northeast of the airport runway. Section 4.6.2 discusses further details about the granular requirements for the project. To facilitate access to the river intake, it is recommended that the trail be constructed to a minimum width of 3.0 m to provide adequate clearance for truck.

During the site visit, it was noted that there are several areas of concentrated runoff along the proposed hose alignment. Culverts should be installed across the trail/hose alignment to facilitate drainage. These areas are easily identifiable via the topographic survey and aerial photography, and have been illustrated on Figure A-1, in Appendix A. Further details on culvert sizing will be included in the proceeding design phases. Alternatively, the pipe route can be rough graded in these areas every year prior to hose deployment, as necessary.

4.6.2 River Intake

The gravel pad at the intake location is recommended to be constructed approximately 2m higher than the river for ease of construction and to limit any impact to the river bed. Some grading at the river bank will be required for this construction, including removal of large boulders located along the river bank. It is anticipated that the intake suction hose will need to be 8-10m long.

The existing river is fed by runoff and snow melt. Glacier melt may also contribute to the river flow near the outer edges of the catchment area, as suggested in the 2022 Business Case; however, this was not confirmed while Dillon was onsite. As the river is not expected to be fish-bearing (to be confirmed by the Department of Fisheries and Oceans Canada, (DFO)) the intake screen size should not need to comply with DFO regulations for the prevention of passage of fish into the intake (Section 30 of the Fisheries Act). The primary purpose of the intake screen for this project is to reduce the likelihood of larger debris materials from entering the intake, which could damage the pumping infrastructure. **Figure 4-3** displays an example of a recommended intake screen.

The intake screen will be sized to accommodate the pump suction flow. The screen will be constructed from stainless steel and will have cam-lock fittings for ease of attachment to the suction hose.

Figure 4-2: Example Intake Screen

During the site visit, the naturally occurring pool at the proposed intake was measured at approximately 500mm depth. Larger boulders can also be strategically placed around the pool to reduce the water's energy as it moves across the pool, allowing the pool's depth to be maintained, or to increase the depth of the pool. Infrequent maintenance at the pool may be required in the future to ensure the pool depth is maintained.

The design flow rate for the intake pump and resupply pipeline will be contingent on the river flow monitoring data collected throughout this season. It will be developed in subsequent design submittals.

4.6.3 Resupply Pipeline

In evaluating whether the piping from the river to the new WTP facility should be permanent or temporary, it is important to consider the labor effort required to deploy the system, the potential for damage from weather exposure and vehicle strikes, the capital cost, the ease of repair and maintenance, reliability, and the effect of the piping system on the quality of the harvested water. A permanent piping installation could be installed overland or could be buried in a trench. A temporary piping system could be installed overland annually and stored when not in use. **Table 4-2** describes the advantages and disadvantages of each option:

Table 4-2: Pipeline Installation Advantages and Disadvantages

	Advantage	Disadvantage
Permanent, Buried piping	• Lowest labor effort required annually. • Low maintenance cost. • Less exposure to weather. • Unlikely to be damaged by vehicles.	• High capital cost. • Requires installation of air release valves and drainage ports, which would be difficult to replace. • Requires highest level of technical training for repairs, and for purging of air and water. • Damaged piping would require more time to repair than other options. Logistics may be an issue, and a back-up overland piping system would be recommended.
Permanent, Overland piping	• Redundant pipe lengths can be stored and used if repair required. • Very little technical training required.	• Susceptible to bio-film build up. • Highest chance of damage from vehicles.

	Advantage	Disadvantage
	• Some labor effort required annually. Would need to drain pipes after tanks filled. • Low annual maintenance cost. • Low capital cost. Pipe protection costs would need to be considered.	• Weather exposure would lessen the useful service life of pipe considerably, thereby adding maintenance labor and cost. • Some technical knowledge required for pipe repair.
Temporary, Overland	• Simplest and cheapest approach. • Redundant hose lengths can be stored and used if required. Damaged hoses can be replaced with new over time. • Very little technical training required for deployment. • Hoses are drained and stored when not in use, which prevents damage and exposure to weather. • Lay-flat hoses are less susceptible to damage from vehicles. • Hoses can be rolled up and drained, which mitigates biofilm growth. • Lowest annual maintenance cost. • Lowest capital cost. • ATV or truck trailer can be used to mobilize/demobilize pumps and hoses. • Flexibility in operation if the intake location changes in the future	• Annual deployment and storage required. • Highest labor effort of three options. • If hoses are not removed for the winter, life expectancy will be reduced.

Given the low capital and maintenance costs and the relative simplicity of deployment and maintenance and factoring that the piping will be used for only a short period each year, Dillon recommends that the intake piping be a system of temporary overland hoses. Extra hoses should be stored (indoors) in case damage occurs and replacements are needed rapidly.

Based on direction from CGS, the temporary hose will terminate at the crest of the hill, directly north of the WTP site. From this point, a buried tie-in chamber is to be installed to drop the intake into a buried pipe to the WTP.

For the lay-flat hose portion of the intake line, a trailer with a hose reel is recommended to reduce the labor effort required for hose deployment/removal/storage. The trailer can be pulled by a truck or ATV. The pumps should also be mounted to a trailer for ease of deployment and storage. We recommend that the pumps be stored indoors when not in use for protection from the harsh climate. A fuel tank should also be mounted on the trailer to reduce labor effort involved with the pumping operation.

4.7 WTP Site Civil Schematic Design

The 2022 Business Case report identified “Site 3” as the recommended site for the new WTP facility. Site 3 is situated just east of the existing power plant. Prior to the July 2023 site visit, Dillon had considered a modification to the site location that would adjust the facility slightly southwest. The rationale for this modification was Site 3’s proximity to the airport runway approach path, and to move the site closer to existing roads.

The proposed site (modified Site 3) is currently designated as “Open Space” in the Hamlet of Grise Fiord’s 2016 Community Plan. The proposed WTP does not currently align with the permitted uses under the Open Space designation. An application for amendment to the zoning bylaw is required to rezone the land as “Industrial” to align with the community plan and local bylaws. During the July 2023 site visit, Dillon met with the Municipal Council and presented the Modified Site 3, and there were no objections to the proposed location. **Figure 4-4** below illustrates the proposed WTP site relative to the Community Plan. The proposed WTP lot should be registered by a land surveyor.

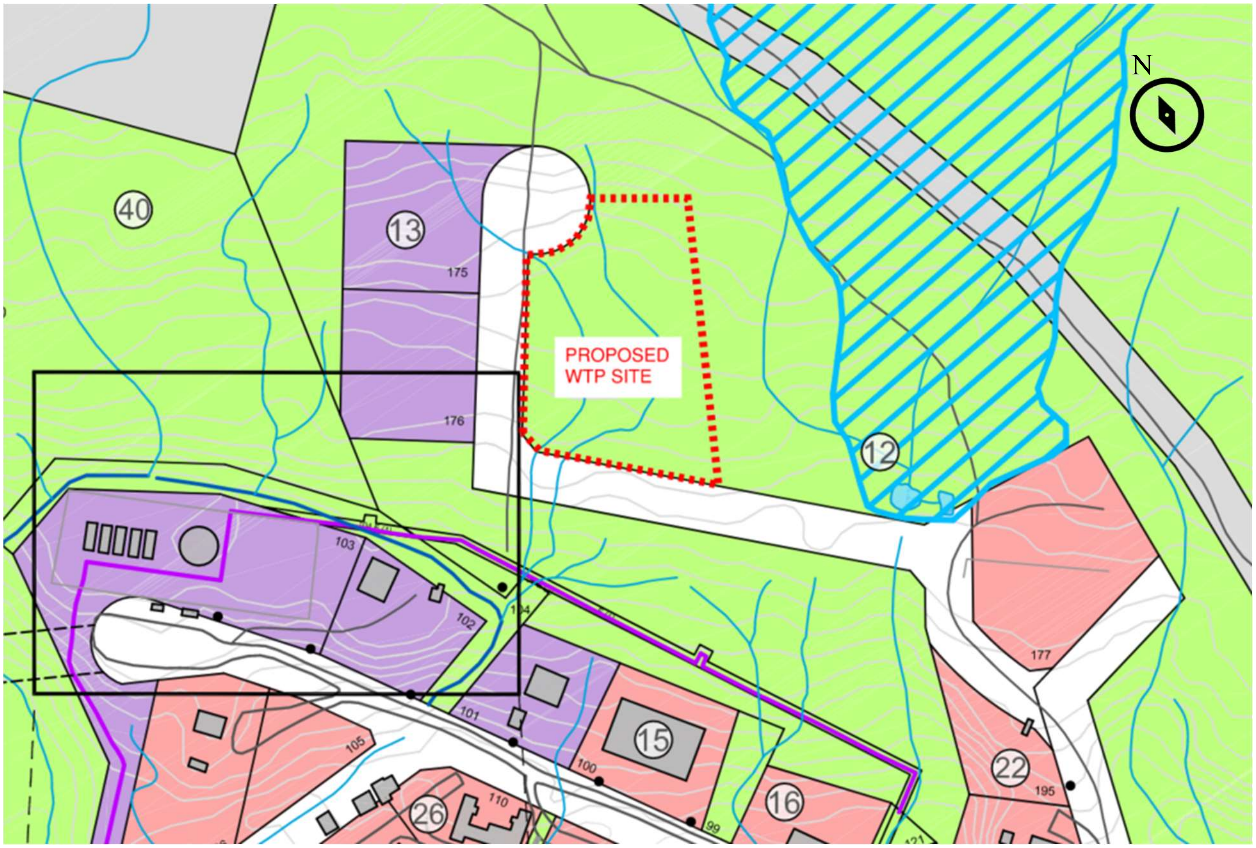


Figure 4-3: Proposed WTP Site Overlaid onto the Grise Fiord 2016 Community Plan

During the July 2023 site visit an assessment of the modified Site 3 and surrounding area was completed. The proposed site is at an elevation of approximately 21-26m above sea level and slopes from northeast to southwest at approximately 5%. There is an existing gravel road at the southwest and west sides which services the power plant. There is a gravel trail at the east and northeast sides of the site. **Figure 4-5** displays an aerial view of the site, with the approximate site shown in blue.

Figure 4-4: Proposed WTP Site Facing West

A drainage path runs through the site. During construction of the adjacent power plant, runoff water which previously flowed towards the power plant, was re-routed to the east, around the power plant, and south through the proposed WTP site. There is a culvert at the south side of the site which conveys water further south. Overland runoff will need to be addressed in the site development.

A large number of boulders were observed north of the proposed site during the site visit, as can be seen in **Figure 4-6**. These boulders seem to indicate that there are rock slides occurring from the adjacent mountain. The original Site 3 location was further northeast, closer to the mountain. The modified Site 3 location will provide an additional buffer from the mountain, reducing the risk associated with rock slides.

Figure 4-5: Rock and Boulder Accumulation at the Base of Mountains

If a large boulder were to hit the plant building or a storage tank, there is potential for significant damage. Protection measures around the northeast side of the site should be implemented to prevent a boulder from entering the WTP site. The adjacent power plant building is protected against boulder strikes via the inclusion of a berm, a moat, and a row of large boulders.

Early in the conceptual design stage, Dillon's design team discussed the option of positioning the tanks down-gradient of the plant building, with the thought process being that a strike from a boulder would be less catastrophic to the WTP building than a strike to a tank. Upon further review, it was noted that if the tanks were to be positioned down-gradient of the plant building, the tanks would not be able to fully drain via gravity, and thus pumps would be required at each tank. The inclusion of pumps to drain the tanks was considered more operationally complex than desired, and in the event of a pump failure, water in the bottom of the tank would not be accessible for use. Further, with the plant on the down-gradient end of the site, the manifold piping and the supply piping would not need to cross the truck-fill access roadway. With these factors in mind, a subsequent decision was made to position the WTP building on the down-gradient side of the site. To mitigate the risk of damage to the tanks from a boulder strike, robust rockslide impact mitigation measures will be implemented. A combination of measures, such as the inclusion of a berm, row of large boulders, moat, sacrificial structures, piles and railings, and/or commercially available rockslide fencing, will be reviewed during the detailed design stage.

During the site visit, the site soils were observed as gravelly sand, which is consistent with the findings noted in the Feasibility Study Geotechnical Investigation report (exp, 2022).

As the existing grade is around 5%, it is anticipated that fill material will need to be imported to the site (from the local quarry) to raise the southwest side. Drainage will need to be accommodated via the provision of ditches around the perimeter, to move water from the northeast to the southwest. The ground at the tanks will be designed to keep the tanks at a consistent grade. The site should be graded to ensure that there is no standing water. Grades in the range of 3-4% are preferred. A preliminary site layout is included on Figures A1-A3, included in **Appendix A**.

The existing road at the southwest and west sides of the site will be shared use with the power plant operations staff. Water tank trucks will make a loop for filling. The trucks will enter the site from the northwest and exit the site towards the northeast via a road through the site, adjacent to the WTP building. The existing gravel trail will be upgraded to accommodate the water trucks.

From a review of the Wind & Snow Assessment Water Treatment Plant Options report (SLR, 2022) completed as part of the Business Case, it appears that medium to heavy snow drifts may accumulate at the north and west sides of buildings. This may result in increased snow removal during winter months.

4.7.1 Final Grade of WTP Site

From an assessment of existing site topography, we anticipate that the finished grade around the three storage tanks will be set at an elevation of 25.30 m. The finished grade at the plant building will be set at an elevation of 24.50 m. Sub-surface foundation and granular depths need to be subtracted from the finished grade elevations to calculate subgrade elevations. These elevations are subject to change during the detailed design process.

4.7.2 Project Granular Requirements

During the 2023 site visit, Dillon visited the quarry site, located northeast of the airport runway. From a cursory review, there appears to be an adequate volume of aggregate available for construction of the intake trail, the intake pad and the WTP facility. It is understood the Government of Nunavut is in the process of undertaking an aggregate resource study for the community. That report will provide further information on the quality and quantity of local aggregates.

From the Feasibility Study Geotechnical Investigation, Water Treatment Plant, Grise Fiord, Nunavut (exp, 2022), the engineered fill should consist of frost stable sand and gravel placed in small lifts compacted to 100 percent SPMDD. The fill should be quarry processed into 25mm (nominal) crush, meeting the gradation noted in the following table. **Table 4-3** displays fill gradation requirements from the Business Case.

Table 4-3: Fill Gradation Requirements

Engineered Fill Gradation Requirements (Reproduced from 2021 Business Case)	
Sieve Size	**Percent Passing**
25mm	100
19mm	75 - 100
9.5mm	50 – 85
4.75mm	35 – 65
2.0mm	25 – 50
0.42mm	15 – 30
0.75mm	5 – 10

It is recommended that the processing of aggregate start as early as possible to ensure the volume of material required can be produced. Quality assurance gradation testing should be performed on the material during processing.

It is anticipated that the following engineered fill quantities will be required for each of the following project components:

Intake Hose/Access Trail/Intake Pad: 400 m^3
WTP site (includes tanks and buildings): 4300 m^3

The maximum depth of engineered fill under the tanks is expected to be 1.5 m.

A 50 mm thick sand bedding layer should be installed below any board insulation installed under the tanks and plant building to reduce the likelihood of coarse-grained particles from puncturing the insulation. Use of board insulation will be determined during detailed design when the foundation requirements are confirmed.

Prior to placing engineered fill, a proof-roll should be conducted on the native material/subgrade to identify any soft areas in the presence of a geotechnical professional. Soft areas should be over-excavated and backfilled with engineered fill.

The presence of surface and subsurface water flow could impact the performance of building and tank foundation systems. Runoff towards the site should be intercepted by ditches around the perimeter of the property to mitigate foundation stabilization issues.

4.8 Foundations

Foundations are required for the WTP, as well as all storage tanks. A geotechnical investigation was undertaken during the Business Case, followed by subsequent recommendations for foundation design. As part of this schematic design, the results of the earlier investigation, as well as results from geotechnical analysis completed on nearby, recent developments have been reviewed to develop a proposed foundation concept for each structure. The below sections outline the recommended approach, which is supplemented by a letter, included in **Appendix C**.

4.8.1 Water Treatment Plant

It was proposed within the feasibility study geotechnical report (EXP, 2021) for this project that the WTP building should be founded atop an engineered fill pad with thermosyphons. Furthermore, it was noted within Section 5.5.1.2 of the report that adfreeze piles "cannot be relied upon to perform satisfactorily during the life of the structure" given that "climate change is expected to result in degradation of the permafrost and increase the thickness of the active layer". It is our opinion that this conclusion is not accurate and the WTP building can be elevated up off the ground (1.0 m or more) and founded atop steel pipe pile foundations. To support this concept, our team has prepared a supplemental geotechnical letter reviewing the findings from the 2021 report, as well as information from other adjacent areas, and providing further recommendations to support design and construction of adfreeze piles at the site, while taking climate change into account per current standards (CSA PLUS 4011-19).

Adfreeze piles are used where bedrock is very deep or non-existent. Bond capacity for adfreeze piles relies on freezing of the permafrost to the pile, requiring embedment of at least 11 metres below grade (mbg). The WTP foundation system will be a grid pattern of strategically located adfreeze piles which will accommodate the strength and serviceability requirements of the superstructure, with the bond between the steel pipe pile and the permafrost providing the load bearing system to transfer the building loads to the ground.

The primary benefit of a pile foundation includes impact on overall schedule, as this foundation type can often be installed prior to sealift using local equipment and stockpiles (to be confirmed) or shortly after sealift arrival. The building can be installed upon completion of the pile foundation installation. By comparison, a thermosyphon fill pad must be constructed and allowed to freeze for a full winter prior to construction continuing on top of the pad. Both foundation types are permafrost dependant and the adfreeze piles can be designed to include additional conservatism (extra embedment depth) as desired.

4.8.2 Water Storage Tanks

The water storage tanks will bear on individual reinforced concrete raft slabs founded atop 1.2 m thick engineered fill pad including a 100 mm thick layer of horizontal insulation extending at least 2.0 m beyond the perimeter of each tank, in accordance with EXP's geothermal analyses and geotechnical recommendations. The reinforced concrete raft slabs will act to span over any localized settlements should they occur, providing rigid support to the tank bottoms at all times. The raft slabs will be constructed for each tank individually to fully isolate each tank. This will also simplify the process of jacking and grouting voids under the slab in the future if necessary. Thermosyphons will not be required beneath any of the tanks.

This foundation type is typical for other communities across the territory and should perform well so long as site grading/drainage is designed to ensure seasonal drainage does not flow or gather against the pads. Furthermore, it is critical that the temperature of the water being stored in the tanks does not exceed that temperature assumed by EXP within their thermal models (5°C to 10°C). The use of monitoring systems to ensure the water temperature is maintained as required is recommended.

4.9 Building Components

4.9.1 Building Access

A water treatment plant building per the 2015 National Building Code (NBC) is classified as a Group F Division 2 Medium-hazard industrial occupancy. NBC Table 3.4.2.1.-A – A Group F Division 2 major occupancy requires two exits in a non-sprinklered building if the maximum floor area is greater than 150m² or the maximum travel distance to one exit is greater than 10m. Exit doors from a Group F-2 occupancy need to swing out in the direction of exit.

The WTP will have two entries, one for the main entry on the south side, and the second one located on the west side of the building for the code required second exit and weather/emergency building access.

The roof will have two rows of snow/ice guards centered with the main entry door and a small eave gutter to prevent falling snow/ice or rain.

Arctic entryways are required per the GN Good Building Practices Guidelines to minimize building heat loss and prevent blowing snow and/or rain intrusion, also known as a vestibule. Each Arctic entry will have a weather-tight exterior insulated metal door and frame and an interior door. A gypsum board ceiling, or a suspended acoustical panel ceiling with hold-down clips is recommended in the Arctic Entry Vestibules to withstand the pressure changes on windy days when the exterior door is opened. This space ensures the temperature of other conditioned spaces in the building are not severely affected by people going through the door. This is in line with the energy code and the temperature of the vestibule will be limited to a maximum of 15°C.

4.9.2 Building Systems

The building envelope shall meet all applicable building codes and shall be suitable for installation in an Arctic environment. The building roof and wall assemblies shall consist of metal cladding with a factory applied corrosion resistant, 25-year warranty finish over high-density mineral wool semi-rigid insulation on structural insulated panels constructed on expanded polystyrene foam insulation sandwiched between structural steel studs installed parallel with the panel edges. The building envelope will be designed and constructed to exceed the 2017 National Energy Code (NEC) required minimum effective R-values.

Walls between the electrical room, mechanical room and the main process room and walls around the Chlorine room will be fire-rated per code.

The WTP modular building shall be constructed in sections for ease of shipping and erection. All building components shall be designed to optimize/reduce heat loss based on materials commercially available. Dimensional and weight limits for all shipped components shall be confirmed as part of design activities. The modular sections will be protected from impact damage, wrapped and sealed watertight for shipping and handling in Grise Fiord to the job site.

4.9.3 Main Process Room

The main process room will be the main portion of the WTP, where the treatment process is located. This will be open concept with ceiling heights such that overhead piping can be accommodated. Flooring will be waterproofed and fitted with drainage to accommodate spills, upsets or overflows as they occur. Ample floor drains or sumps as well as tapered floors will be utilized to minimize accumulated water. In this room there will be treatment equipment, pumps with motors, piping and valves as well as heat exchangers. The various liquids that will be conveyed in this room include raw water, clean water, glycol and hypochlorite (chlorine solution). As such all lines will be labeled as per industry standard. Filter vessels and heat exchangers will be the largest equipment in the room, and doors and travel routes must be accommodated for removal of these equipment components in the future.

The main process room will include the required second exit located in the west exterior wall at the end of the hallway, with vestibule. This will provide a clear, direct means of egress in an emergency. The east wall of the main process room will be fire-rated as required around the mechanical and electrical rooms.

4.9.4 Office and Laboratory

The WTP will include an office/laboratory room for completing sampling and reporting. A desk/workstation with chair and bookshelf will be provided for this space. The laboratory area will include a fridge with freezer for water samples and ice packs, a sink, cabinets with working countertop, storage cupboards and standard water chemistry testing equipment.

The walls around the Office/Laboratory will be constructed to provide a sound transmission coefficient (STC) STC-54 for a comfortable work environment. The laboratory countertop will be chemical and stain resistant.

4.9.5 Chemical Room

The chemical room will house all chlorination equipment and chemicals. The Business Case identified calcium hypochlorite (granular) as the preferred chlorination type, which would include a mix tank for preparing the chlorine solution and a 'day tank', however CGS has provided direction for the removal of this option, for only sodium hypochlorite (chlorine solution) to be used.

Ventilation for the chlorine room will be provided, with intake located at floor level. A shower/eyewash will be provided, in close proximity to the chemicals. Hot and cold-water taps are to be located in this room for mixing and cleanup purposes. A water fill pipe will be provided for each mix tank.

4.9.6 Mechanical and Boiler Room

The WTP shall include a separate room to contain the diesel-fired boilers used for building heat. The interior walls will be fire-rated as required for code. The walls also will be constructed to reduce noise transmission to adjacent rooms. The boiler room ventilation shall be designed to operate under negative pressure, so the atmosphere of the room is exhausted to the outside and will not migrate to other areas of the building. Exhaust intakes shall be located near floor level. The boiler room area shall be sized to house the boilers, with adequate access to perform maintenance on one boiler, while all other boilers are operating.

Domestic hot water heater and distribution piping shall be provided for the washroom, lab sink, mop sink, chemical line flushing system and emergency shower/eyewash. A tempering valve will be provided to ensure a consistent flow of water at a temperature that meets health and safety standards for emergency shower/eyewash systems. The hot water system shall be designed to meet the required emergency shower flow duration.

4.9.7 Electrical Room

A dedicated room will be provided to house primary electrical distribution equipment, including the service entrance, automatic transfer switch, splitter panels, programmable logic controllers (PLCs), variable frequency drives (VFDs), starters and main disconnect. VFDs and motor starters can be located next to the process equipment in the process area or in the electrical room in the MCC or as individual units. The room will be ventilated to prevent overheating of electrical equipment. The room shall be large enough to provide the minimum working space in front of panels by code (1.0 m in most instances). The interior walls around the Electrical room will be fire-rated as required per code and insulated to reduce sound transmission to adjacent rooms. The interior finishes will be the same as the Mechanical room. The power supply for the WTP will be coordinated with the local electrical utility (QEC).

4.9.8 PLC and SCADA

Telephone and internet services will be provided for the WTP. A complete SCADA system for the entire facility will be designed including, building automation (BAS), heat tracing, treatment equipment vendor supplied controls, storage tanks, chemical systems, truck fill pumping, and standby power systems. The Plant SCADA system shall utilize an Ethernet backbone for communications between individual PLC processors and communications between PLC processors and Operator Interfaces. The Ethernet backbone will be CAT6. The SCADA platform shall have remote connectivity capability. A Wonderware System Platform 2020, 1000 I/O tag package will be used. A system platform consisting of operator workstation, historian, active factory, OI Servers, monitors, printer will be provided. Remote alarm notification shall be provided which incorporates text messaging, voice messaging, radio phone, and email messaging. Notification system shall utilize a cellular modem complete with SIM card, Win911, or approved equal. Separate security callout system shall be sourced from “Arctic Alarms”. The PLC control system will provide unattended automatic operation of the facility. Communication protocol for the PLC processor network to be MBTCP or EtherNetIP. I/O signal voltage to be based on the following: Digital inputs and outputs: 120 VAC. Analog inputs and outputs: 4 to 20 mA, 24 VDC. Each PLC panel assembly is to include a UPS supply unit sized to carry the entire control panel load together with associated OIT.

Also, to be included in design are supplemental cooling for equipment heat load, in addition to surge protection and electromagnetic protection.

4.9.9 Electrical Supply

Primary electrical service shall be 600 VAC, 3 PH, 4 Wire. Service size in amps to be based on demand and connected load and to be confirmed with all equipment suppliers. Electrical supply requirements will be coordinated with Qulliq Energy Corporation (QEC) to confirm service availability. Power surge protection device upstream of the main panel will be provided to protect the entire electrical system for the WTP.

It is recommended that communication begin with QEC as early as possible to determine if upgrades are required at the power plant, and what service connection fees are to be expected.

4.9.10 Generator

The primary power source for the WTP shall be the local electrical grid, and the facility will have automatic transfer emergency power capabilities to a new diesel-powered generator at the site that will run the full WTP. A weatherproof, sound attenuated walk in-type generator enclosure with sub-base fuel tank will be provided for the generator and permit the operator to walk in and complete work on the generator. The exhaust shall be located so as to prevent the intake of generator exhaust into the WTP building ventilation system.

Fuel tanks shall be provided for day storage and bulk storage of diesel. The tanks shall be equipped with high- and low-level alarm switches, and a level transmitter. Fuel tank levels will be monitored at the main plant control panel.

Containment systems related to the generator and fuel tanks shall meet all applicable codes. At a minimum, tanks shall be installed on containment pads to prevent the accidental release of diesel to the environment associated with tank filling or minor drips. A risk assessment is required where diesel spilled to ground can reach the water source through various pathways including surface runoff and groundwater contamination. However, this risk is deemed low at this site due to distance from water bodies.

Generator module will be oriented in relation to prevailing winds for optimal separation of exhaust air, and fresh air supply intake for the building.

4.9.11 Washroom

The WTP shall include a washroom with a toilet, sink and accessories. The waste from the washroom will be transferred to the wastewater tank within the WTP building. A janitor-style mop sink will be located in the Mechanical Room for general cleaning tasks.

4.9.12 Security

Security will be provided for by the following design features:

- no windows in exterior doors;
- video surveillance cameras;
- electronic access control system on exterior doors; and
- cyber/firewall.

4.9.13 Mechanical Systems

The mechanical systems in the building will be divided into two parts: Heating system and Ventilation system. The heating system handles all equipment used to raise and maintain space temperature during the winter season. The ventilation system involves equipment that bring in fresh air to the space and exhaust stale air from spaces, where required.

4.9.13.1 Heating System

The main energy source for heating the building will be fuel. This is used to power boilers that supply hot water to the mechanical equipment and also heat exterior water tanks. Hydronic equipment considered for providing heat include baseboard heaters and unit heaters. Backup electrical coils will be considered for unit heaters. The outdoor design conditions used in calculating the envelop losses of the building can be found in **Table 4-4** below:

Table 4-4: Mechanical Design Conditions

Grise Fiord Design Conditions				
	Winter (Heating) 99.6%		Summer (Cooling) 1%	
	(°F)	(°C)	(°F)	(°C)
Design Temperature, Td	-43.2	-41.78	50	10

4.9.13.2 Ventilation System

Providing outdoor air is required to maintain the air quality of the building. The fresh air required for each space and also the air needed to be exhausted is calculated using ASHRAE 62.1. The space pressurization and air change rate required also plays a role in the amount of air exhausted and brought into each space. Ventilation equipment to be considered include exhaust and supply fans, air makeup units, heating coils, Heat Recovery Ventilator and Energy Recovery Ventilators.

4.9.14 Sanitary Drainage

The drainage system will service all plumbing fixtures, process waste streams, and floor drains in the building. This waste will be stored in an interior waste holding tank and periodically pumped out by a vacuum truck. The holding tank is to be fitted with a high-level alarm, and a light indicator, that alerts workers when the water level in the tank is high.

5.0 Construction Considerations

5.1 Tender and Construction Schedule

Currently the following schedule is anticipated for tendering and construction. This is dependent on funding availability.

Milestone	Date	Note
Tender GC Contract	February 2024	
Mobilize equipment to Grise Fiord	Summer 2024	
Civil Site works begins	Summer 2025	
Mobilize Tanks and WTP to site	Summer 2025	
Erect Tanks	Summer 2026	It is anticipated that two seasons will be required for this work.
Connect WTP	Summer 2026	
Final Commissioning	Summer 2026/2027	If tank erection is compressed into a single season or a phased approach is taken, 2026 commissioning may be feasible.

Grise Fiord receives only a single sealift in September, which is the only means of mobilizing equipment and prefabricated facilities. In Grise Fiord temperatures begin declining in late August – early September, seeing negative temperatures increasing by the end of September, meaning the construction season is limited into the fall, and the water source is only available until approximately early September. Therefore, the first year (2024) of construction will be limited to mobilization, and preparation of storing equipment for the winter. In the second year (2025), civil site work and foundation preparation will take place. The WTP will be manufactured at a southern factory and shipped to Grise Fiord in year two (2025). Finally, in year 3 (2026), final tank construction and WTP connections and commissioning will take place. Based on tender award schedules, availability of equipment and southern component fabrication delays, final commissioning could be delayed to 2027. This is due to the extremely short construction season, and shipment challenges.

It is anticipated that the General Contractor (GC) tender award will take place in spring 2024, with the aim that equipment will mobilize on the 2024 sealift, for work beginning in 2025. Due to limited availability of accommodations in Grise Fiord, it is recommended that a camp be provided by the GC.

5.2 Phasing and Commissioning

As the new WTP is a fully independent facility, there is not expected to be significant coordination of commissioning/decommissioning. The general phasing and commissioning sequence is listed below:

- Granular/crusher assignment to be facilitated;
- Shipment of tank components, civil equipment and camp accommodations;
- Civil site works, roadway construction and foundation preparation;
- Creek Intake modifications and construction (during end of season low water);
- Tank construction, hydrostatic test and disinfect;
- WTP fabrication, shipment and delivery;
- WTP exterior piping, module internal connections; and
- Final fill of water storage tanks.

During the final construction year, it will be preferred for the new water tanks to be filled directly from the River, as per WTP design. However, there could be a risk that the tank commissioning will still be ongoing when the River is flowing. In this case, it will be recommended to fill the existing raw water tanks, and transfer once the new tanks are ready.

Ultimately the General Contractor will determine schedule and coordinate with any specialty disciplines as required.

Once the new WTP is commissioned and servicing the community, it is recommended that the existing facility remain heated and maintained for the first year, after which a decommissioning plan can be undertaken. A decommissioning plan will be developed to issue to the Nunavut Water Board 60 days prior to construction.

5.3 Risks and Mitigation Measures

Dillon has developed and maintained a list of project risks and mitigation measures. The biggest risk for this project is the schedule. Due to mobilization challenges and the short construction season, small delays throughout design and construction can lead to massive delays in the date of final commissioning. Availability and scheduling of tank and WTP manufacturers, and GCs to undertake this work will also have an impact on the final commissioning schedule.

Staging and storage of modular units over winter prior to construction will require temporary heat and ventilation to minimize damage to interior finishes, fixtures, furniture, and equipment.

Modular units will be transported from the beach to the job site on low profile trailer wheel dollies towed by heavy equipment. Contractor will coordinate with the Hamlet for the best road route through town with the least number of overhead power and voice/data lines.

Risks and mitigation measures are listed in **Table 5-1** below.

Table 5-1: Risks and Mitigation Measures

Category	Risk Item	Impact	Mitigation
Permitting	Transport and Navigation Canada Approval	Construction delay	Applications have been submitted and followed-up on.
Permitting	Building Approval(s) Delay	Construction delay	Indicate to GC to communicate with regulators and apply early.
Design	Lack of river flow data to design intake	Inadequate intake design	River flow meters were installed and available data will be analyzed to inform intake design.
Construction	Tender overbudget	Tender award delay	Cost estimates and contingency added.
Construction	Supply and delivery time for water tanks	Construction delay	Advance tank tender as early as possible.
Construction	Tender delays	Construction delay	Advance tenders as early as possible, reserve space on 2024 sealift.
Construction	Mobilization delay	Construction delay	Reserve space on 2024 sealift to ensure GC will have access to space to mobilize equipment and materials.
Construction	Lack of accommodations in Grise Fiord	Construction/commissioning delay	Include provision for a contractor camp in GC tender.
Construction	Vandalism of equipment stored in Grise Fiord over Winter	Delayed construction while waiting for replacements, increased cost to replace damaged equipment	Require GC to properly winterize and store equipment to protect again vandalism.
Construction	Schedule to commission tanks to resupply from River	Delay in final commissioning	Maintain updated schedule with GC to understand potential delays. Fill existing tanks during commissioning year to hold water if new tanks are not ready for refill

6.0 Operator Requirements

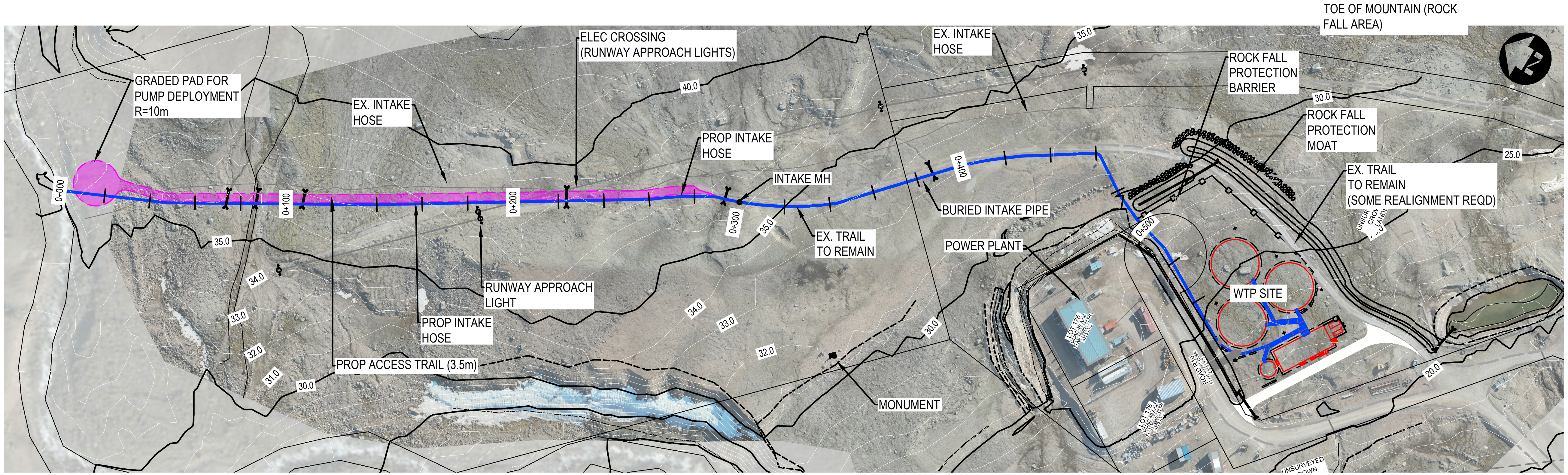
The proposed Grise Fiord WTP classifies as a Class 1 WTP, using the Nunavut WTP Classification System. It is recommended that a lead operator with Class 1 certification be established within the community, with 1-2 back-up trained operators to assist with continuous operations.

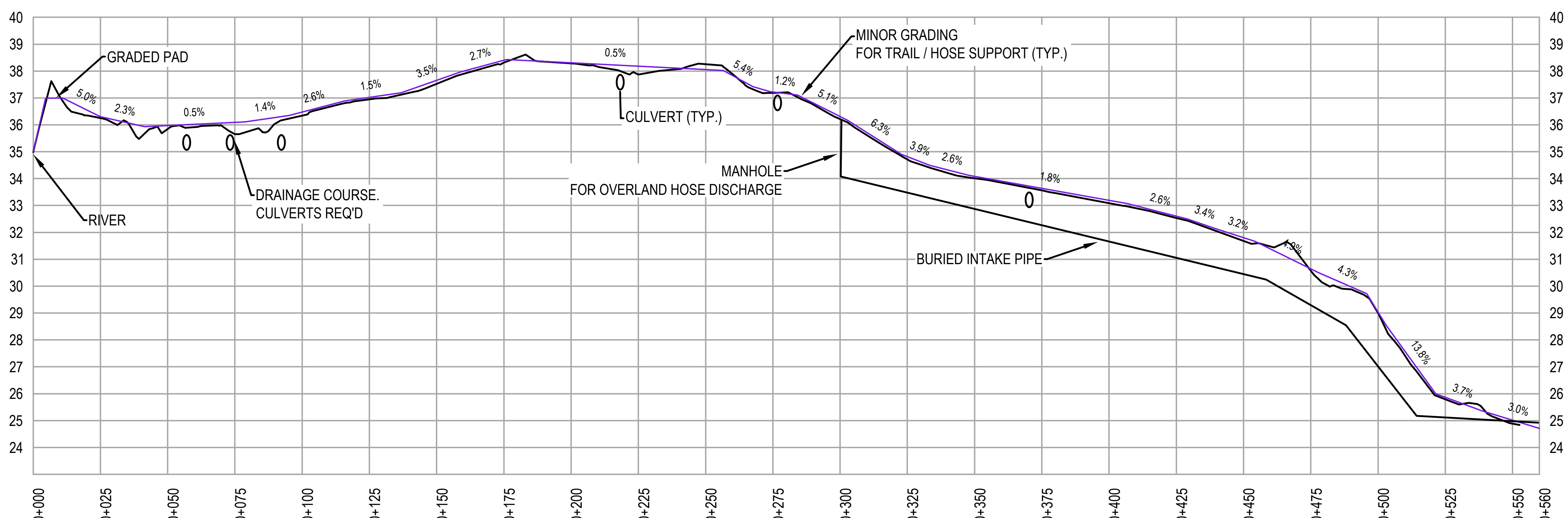
7.0 Closure

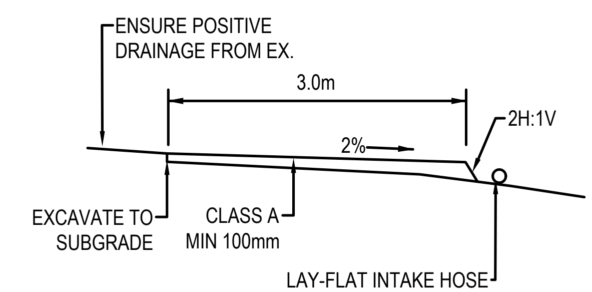
This report is intended to present Dillon's review the findings from the Business Case and to capture the key elements required to enter the detailed design stage. Following acceptance of the details within this report, Dillon will proceed to the 50% design stage where design drawings will be developed, with detail appropriate for this stage, in addition to specifications.

Appendix A

Schematic Figures







ACCESS ROAD & INTAKE HOSE
NOT TO SCALE

GRISE FIORD WATER TREATMENT PLANT

FIGURE A-1
PROPOSED RIVER INTAKE AND HOSE ALIGNMENT

SCALE : 1:750

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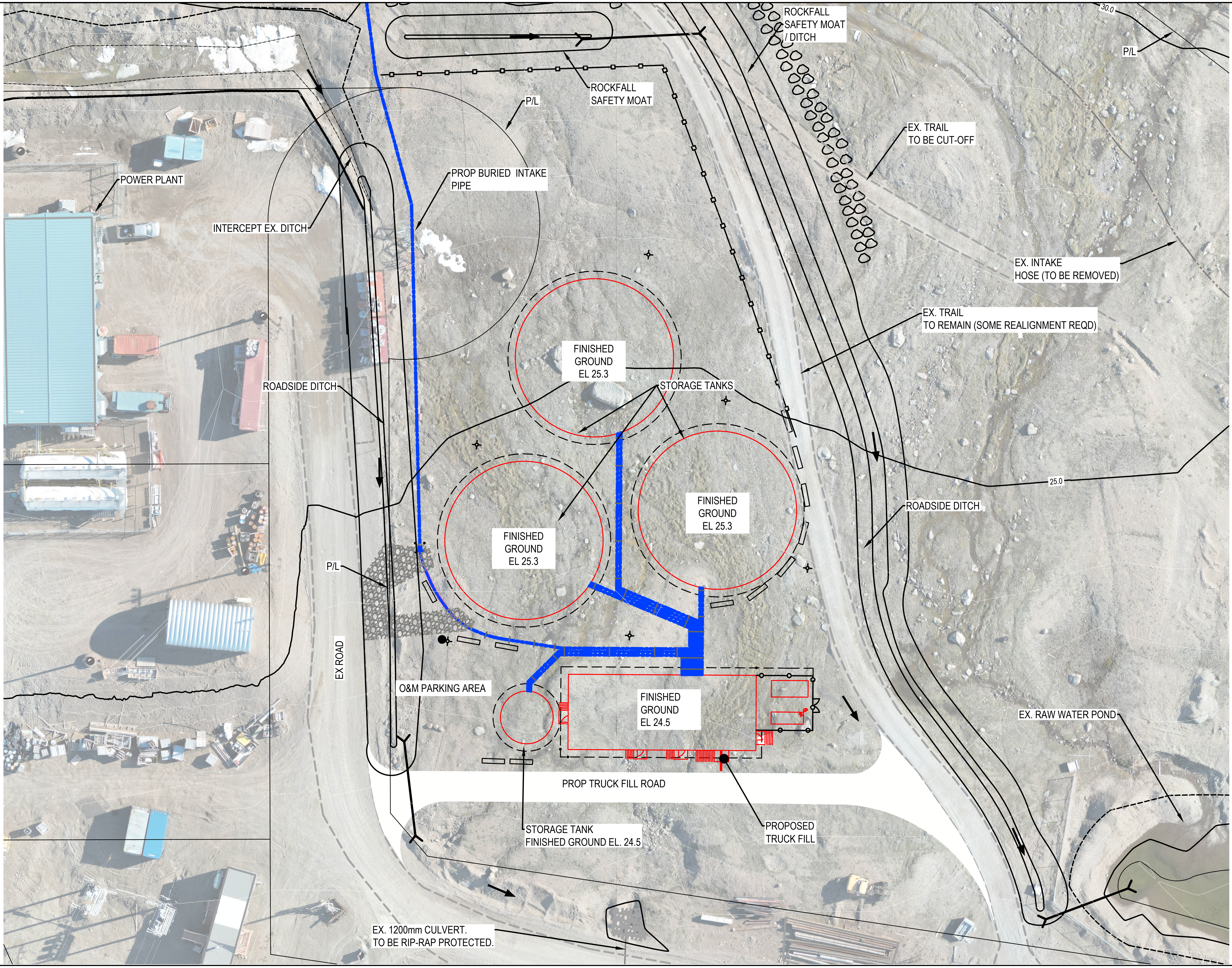

NOTE:
ELEVATIONS & SITE LAYOUT SUBJECT TO CHANGE

GRISE FIORD WATER TREATMENT PLANT

FIGURE A-2
PROPOSED WATER TREATMENT PLANT SITE

SCALE : 1:500

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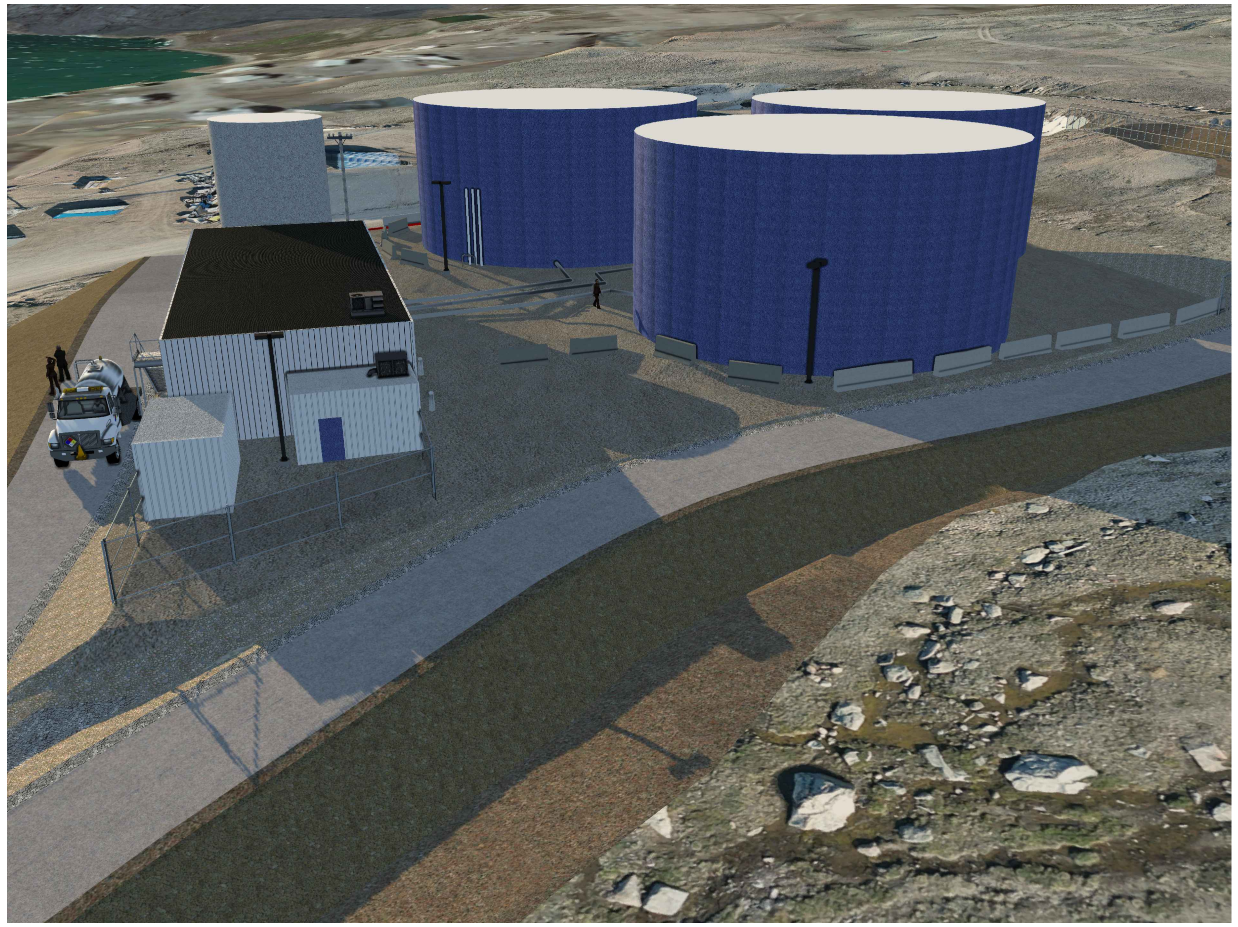
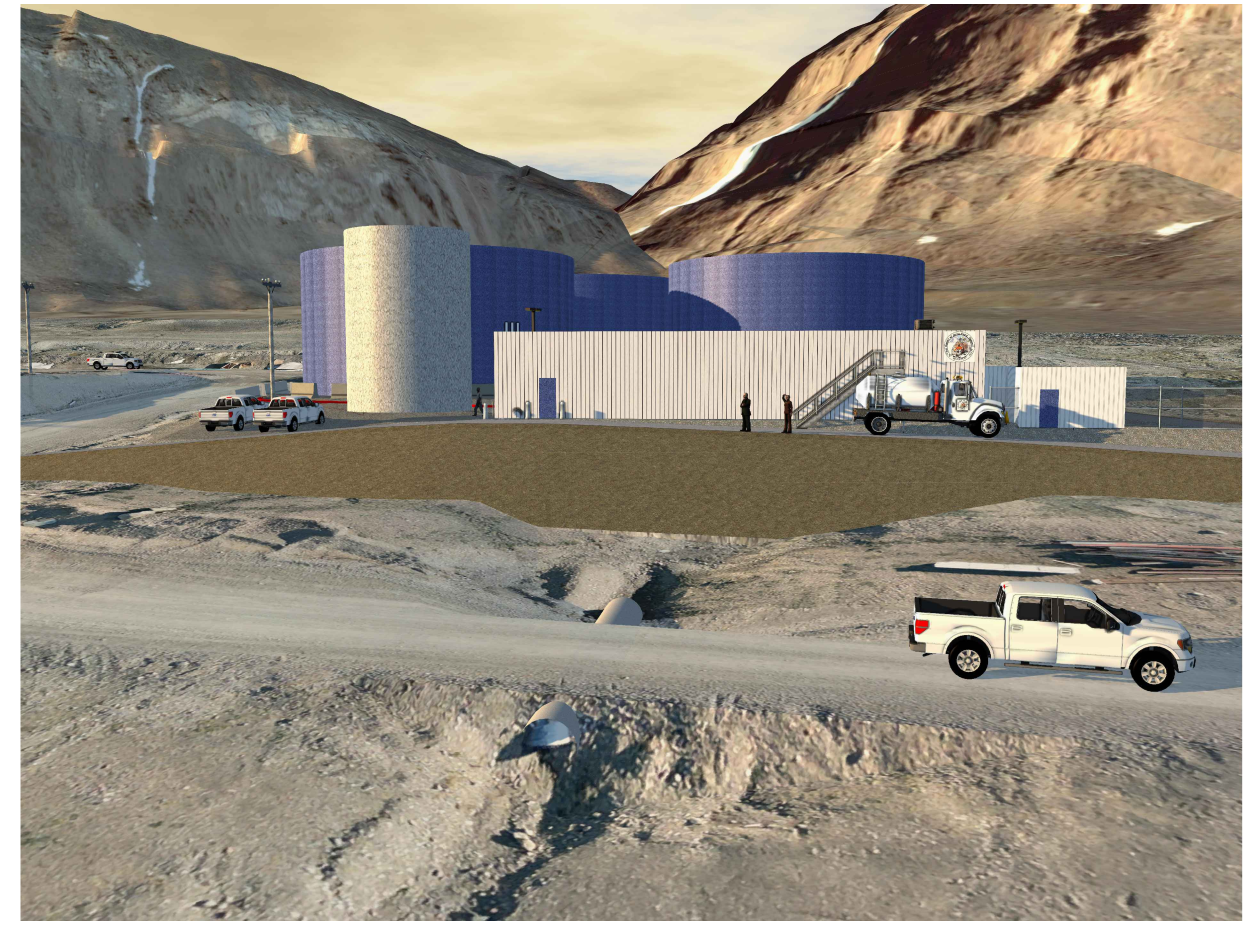
Note:
Tank dimensions are for general illustrative purposes only. Refer to detailed design drawings for actual heights and diameters.





GRISE FIORD WATER TREATMENT PLANT

FIGURE A-3
PLANT SITE RENDERINGS

NOT TO SCALE

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Appendix B

Grise Fiord New WTP Treatment Process Recommendation (August, 2023)

Memo

To: Francis Dubé – CGS Project Manager

From: Kyle MacIntyre, P.Eng.

Date: September 8, 2023

Subject: Grise Fiord New Water Treatment Plant
Treatment Process Recommendation

Our File: File #23-5971

1.0 Introduction

The Business Case study for the Grise Fiord water treatment plant (WTP) took place in 2021-2022, where field studies and infrastructure planning were completed to develop a schematic design, based on the Nunavut 'Standardized Water Treatment Train' (SWTT) process. The original scope of work was structured around the use of SWTT for the new WTP, and there was no direction from the GN to investigate alternative treatment options. No water quality data for the new water source, Airport River, was available at the time of the planning study.

The SWTT process was developed in an earlier project executed by the GN, which developed a common standardized water treatment process that met Health Canada's *Guidelines for Canadian Drinking Water Quality* (GCDWQ), and could be deployed at multiple Nunavut communities that used surface water sources. Grise Fiord was one of the communities that was evaluated during the development of SWTT, and it was confirmed based on source water characteristics that a SWTT process deployed to Grise Fiord would successfully treat the water to GCDWQ requirements.

The SWTT project did not, however, consider unique water supply operations in Grise Fiord, whereby an entire year's supply of water for the community will be harvested from Airport River and stored in large covered tanks. As part of the initial activities for this current detailed design project, Dillon evaluated the Airport River water source, which is considered a high quality seasonal source generated from upslope snow and ice melt, and considered the clarification effect that will occur in the water storage tanks whereby particulates will settle over time to the tank bottom. The thought is that clarified water from the top level of the stored water will have very low particulate levels, and would be an excellent candidate raw water for use of cartridge filtration.

Substituting cartridge filtration for the membrane filtration system included in SWTT will greatly simplify operations, which is considered a significant benefit for Grise Fiord, where training and retention of operators is a significant concern, and the remote location makes access for operational support challenging. Further potential benefits include reduced capital and operational cost of the new treatment system. It should be noted that the use of cartridge filtration at Grise Fiord as a substitute for SWTT is not recommended for other communities evaluated in the SWTT project; the unique water supply storage and resulting clarification, and high quality water supply are unique to Grise Fiord.

To validate whether the cartridge filtration option could be successfully deployed at Grise Fiord, Dillon executed a field program that included additional source water quality testing, and field settling tests. The results of the field testing and assessment regarding the feasibility of using cartridge filtration at Grise Fiord is discussed in this memorandum. The goal is to confirm whether Community and Government Services (CGS) can advance the design of the new WTP with a simplified treatment system, meeting federal and territorial regulations and guidelines.

This memo serves to describe in more detail the results of the 2023 water quality sampling program, and provide a recommendation to the Government of Nunavut for the treatment process to be adopted at the new Grise Fiord WTP.

2.0 Field Sampling Program

Dillon evaluated water quality data from two sampling events that took place late in 2022. Samples were collected from the existing water storage tanks in Grise Fiord, which included a blend of source water from both Airport River (the River), and from the historical water source (the Basin). The historical water source is seasonal overland snow melt that is generated from the local mountain slope above the existing storage tanks, collected in a dugout pond, from where the tanks are filled. The surface runoff reaches the dugout pond via a series of small streams that develop over the lower slopes during the melt season. Dillon considered this historic water source as a worst case quality compared to the new water source (Airport River) which is an established deeper seasonal river with relatively high flow, with a lower risk of dissolved organics that could lead to disinfection by-products (DBPs) following chlorination of the drinking water as part of the treatment process.

Dillon performed additional Airport River sampling and testing on July 17-19, 2023. Analytical results from 2022 sampling suggested that the blended water quality could be successfully treated using cartridge filtration process. However, there was no data on settling characteristics of the source water, and there was limited DBP analyses. To confirm the application of cartridge filtration, Dillon recommended additional field investigation including comprehensive water sampling from the Airport River (including DBPs), and settling tests. The field program was planned for July 2023 to avoid impacting project schedule relative to establishing the preferred treatment process for the new Grise Fiord WTP. Key to the 2023 water testing was to confirm that the risk of dissolved organics that are DBP precursors is low; the presence of DBPs would suggest cartridge filtration is not a good candidate process for Grise Fiord, and SWTT may be necessary.

3.0 Airport River Water Quality

Grise Fiord differs from all other communities in Nunavut in several ways. Beyond being the most northernly community in Canada, with limited access by aircraft and boat, the water source is also significantly different. Airport River will be a new water source for the proposed WTP. The River is described in detail in the Business Case report (*Grise Fiord WTP Business Case, EXP., 2021*). The River flows seasonally between mid-June to early-September, and is fed by snow melt and runoff, in addition to what appears to be glacier caps in the far reaches of the catchment area. It is not fed from any other significant water bodies, such as lakes or rivers, and based on visual inspection, the flow path is not habited by vegetation. The water moves quickly, and does not become stagnant in any areas along the flow path. The resulting water is of extremely high quality, with low to non-detectable organics and other contaminants.

While climate change and weather events into the future may impact the water supply, due to the characteristics of the river and lack of contributary water bodies, it is not expected that water quality will change drastically. The community noted that the River turbidity increases during and following rain events, based on visual observations; however, the turbidity quickly clears up. Based on this information, there will be periods around rain events where it is not recommended to harvest water from the River, subject to threshold turbidity verified by turbidity measurements. However, if withdrawal continues during these turbid periods, it is anticipated to only impact sediment accumulation in the bottom of the storage tanks, where the particles will settle prior to entering the treatment process through a proposed floating intake. Periodic inspections and tank cleaning will be recommended to clean sediment from the bottom of the tanks.

In addition to the specific characteristics of the source water, the raw water is stored year around in large tanks, instead of open earth reservoirs as is the case in many other Nunavut communities. This impacts water quality, because the tanks act as clarifiers, where sediment will settle through the water column to the tank floor over time. Dillon expects that the top water layer in the storage tanks will contain highly clarified/low suspended solids content water, and use of a floating intake inside the tanks will ensure the delivery of the lowest particulate water to the WTP filtration system. This will ensure sediments will settle through the tank, without being disturbed and resuspended.

The following sections will provide an overview of the water sampling analysis, and then move into a description of the recommended treatment process.

3.1 Water Analyses

Historically the primary water source in Grise Fiord was a small dugout basin within town, north of the existing WTP and storage tanks, which naturally collects surface runoff from a localized area. The catchment area to the Basin does become populated with native vegetation during the summer months. During 2022 and 2023, water from the River was pumped to this basin, where it would mix with runoff water naturally filling the basin, before the blended water was transferred to the existing storage tanks for refilling. Once the new WTP and associated infrastructure is constructed, the River will be the only water supply, with water being pumped directly from the river into the new storage tanks, and the basin will no longer be used as a water source. For this reason, historical water quality data is not considered fully representative of the future water quality for the new WTP.

To appropriately analyze the expected future water quality, Dillon undertook a round of water quality sampling while onsite on July 17-19, 2023. Raw water samples were taken from the river, in the location of the proposed new intake, upstream of the airport runway. See Figure 3-1 displaying the location where the samples were taken.

Six samples were taken for general chemistry, total and dissolved metals, hydrocarbons, and disinfection by-products from the River. Dillon also collected one sample from the treated water truck fill pipe as a comparable to 2022 data on July 19. The full water quality results summary is included in Appendix A and has been supplemented with three sampling events from 2022 from the water truck. The 2022 samples are a mix of Basin and River water. The water analysis showed that all analytes are below GCDWQ aesthetic objectives and maximum allowable concentrations.

Figure 3-1: 2023 Sample Location

In addition to analyzing GCDWQ maximum allowable parameters to determine if there were any contaminants in the source water that would require specialized treatment steps, Dillon also reviewed water quality parameters to determine if cartridge filtration could be implemented. **Table 3-1** below outlines results from the laboratory sampling analysis that were assessed to determine suitability of the simplified treatment system, and **Table 2-2** outlines field turbidity testing completed during the sampling events.

Table 3-1: 2023 Water Analysis Laboratory Results Summary

Parameters	Raw River 1	Raw River 2	Raw River 3	0 Hour Settled River	24 Hour Settled River	48 Hour Settled River	Treated Truck [1]	GCDWQ Guideline
Dissolved Organic Carbon (DOC) mg/L	<0.2	<0.2	<0.2	<0.2	0.8	<0.2	2	NA
DBP - Total Trihalomethanes[2] (THMs) µg/L	10.0	<6	<6	11.0	Blank	<6	52.0	MAC: 100 µg/L
DBP - Total Haloacetic Acids[2] (HAA5) µg/L	6.0	6.7	<5.3	<5.3	Blank	<5.3	14.1	MAC: 80.0 µg/L
Turbidity (NTU)	1.4	2.7	1.4	1.3	1.2	1.2	1.1	MAC: <0.3 NTU
TSS (Total Suspended Solids) mg/L	<3	<3	<3	<3	<3	<3	<3	NA
TDS (Total Dissolved Solids) mg/L	57.0	57.0	58.0	57.0	58.0	58.0	52.0	MAC: <500 mg/L
Ultra-Violet Transmittance (UVT) %	98.9	98.9	99.1	99.3	99.3	99.1	97.1	NA

[1]The treated water truck includes water from both the basin and the river. The basin is more susceptible to increased organics due to its overland flow path.

[2]Raw water samples from the river were site chlorinated to test for THMs and HAA5.

3.1.1 Organics and DBPs

Results indicate that the Airport River water has lower levels of dissolved organics and DBPs compared to the historic water quality, and DBPs are well below GCDWQ limits.

DOC, and DBPs (THMs + HAA5) are used to evaluate the potential for disinfection by-product (DBP) formation in the treated water. DBPs form from the reaction of chlorine with specific dissolved organic compounds, typically associated with rotting plant material and leaves. While DOC is an indicator on the level of organics present in the water, the THMs and HAA5 are direct measurements of DBPs forming after chlorinating this sampled water. As there is no treated water in Grise Fiord produced solely from the River water, River samples were chlorinated as part of the 2023 sampling program, with a free available chlorine target concentration between 1.0-1.5 mg/L after 20 minutes to simulate DBP production in the future WTP. Based on the results, the River source water has low to non-detectable amounts of dissolved organics, and DBPs that are significantly lower than the mixed basin-river water obtained from the treated water truck.

The results suggest that DBPs associated with River water following treatment are very low relative to the GCDWQ, and treatment for dissolved organics is not required at the new WTP. These findings indicate that the Airport River water source is an acceptable candidate for cartridge filtration, since removal of dissolved organics that may be DBP precursors is not a concern. These results support the conclusion that the SWTT coagulation/membrane filtration process at Grise Fiord can be replaced with simple cartridge filtration.

3.1.2 Turbidity

Analytical results suggest that the Airport River water supply has slightly higher turbidity relative to the treated water collected from the treated truck; however, it should be noted that the treated water that was sampled had been allowed to settle (clarify) in the tank for almost a year, and would be expected to have lower turbidity compared to a fresh river sample. It is also unknown if the lab agitated the river water samples as per standard, or if decomposition of particles may have occurred prior to turbidity measurement, to resuspend any settled particulate.

Field turbidity testing of the Airport River water revealed turbidity levels between 1.7-2.0 NTU on July 19, 2023. It was noted during measurement of samples in the portable turbidimeter that turbidity in the sample cell dropped each successive measurement, indicating that particulates were rapidly settling in the sample vial in the turbidimeter. This adds to the evidence that some of the particulate material in the water is higher density inorganic particulates (sand/grit/dust) that may be suspended in the turbulent river flow, but will quickly settle out of the water column. The bucket settling test shows a top water level turbidity of 1.4 NTU after 27 hours of settling, compared to treated truck turbidity of 1.3 NTU following 11 months of settling time. Table 3-2 summarizes results of the field turbidity and column settling testing.

The field turbidity tests suggest that water taken from the top of the storage tanks after a minimal settling period will have a turbidity of less than 1.4 NTU, which would be expected to improve with additional settling time. The ‘top of tank’ water is considered a good candidate for cartridge filtration.

Table 3-2: Field Turbidity Measurements

Sample	Turbidity (NTU)
River A – July 19	**2.00**
River B – July 19	**1.88**
River C – July 19	**1.70**
River D – July 19	**1.86**
Storage Tank 1	**1.31**
Column settling test – start (0 hours)	**3.3**
Column settling test – top water (22 hours)	**1.7**
Bucket settling test – start (0 hours)	**3.3**
Bucket settling test – top water (27 hours)	**1.4**

While the Municipal Council indicated concerns with turbid water associated with rain events, a recommendation will be made to pause water withdrawal during turbid periods, when the turbidity reading on a handheld device exceeds 5.0 NTUs. Although the cartridge filters can treat this water, much of the turbidity associated with high river flow and runoff is anticipated to be sediments that will rapidly settle out tin the storage tanks; however, avoiding the harvesting of this higher turbidity water from the river will reduce the accumulation of settled sediment on the tank bottoms. Based on anecdotal information from the community about the historic frequency and duration of elevated River turbidity through a typical River flow season, this is not anticipated to occur frequently and should not significantly impact capabilities to resupply storage tanks during the freshet season. There may be short periods following a rain event where water harvesting from the River must be suspended, until the water clears up.

The low turbidity of the River water indicates that cartridge filters will not suffer from frequent clogging, as is seen in communities with elevated turbidity levels and high organics. In addition to water chemistry, River water samples were analyzed for particle size distribution (PSD) to support the design/configuration of a potential cartridge filtration system. PSD will indicate what size cartridges are best suited for series orientation. Results of PSD analyses were not available at the time of this memo, but will be used to select appropriate cartridge filter sizes during detailed design to prolong life of each cartridge element in an effort to reduce operational effort and cost.

3.1.3 UV Transmittance

The UV Transmittance (UVT) analyses indicate that the raw river water will be easily treated by UV light disinfection. UVT represents the ability of UV light to travel through the water without obstruction, in order to reach bacteria particles, and is directly correlated with UV disinfection treatment of water.

The UVT from the 2023 water sampling analyses indicate an average UVT of about 99%, which is very favorable. The UVT is expected to improve further relative to the River water analytical results, after the water is filtered through cartridge filters. Most UV systems for drinking water treatment are certified for UVT between 81%-91%, with smaller systems certified down to as low as 71%. Based on the 2023 sample results, we do not expect to see any issues with the operation of a standard UV disinfection system.

4.0 Design Treatment Objectives

The selected treatment process must meet the GCDWQ for treatment objectives and treated water quality. While this is the principle basis for design of the new Grise Fiord WTP, the treatment process should also be energy efficient, simplistic operation, and designed to align with the characteristics of the specific source water quality in Grise Fiord. At a minimum, the GCDWQ requires approved filtration and disinfection processes. **Table 4-1** outlines minimum treatment performance objectives for the new WTP, as dictated by the GCDWQ.

Table 4-1: Treatment Objectives for GCDWQ

Parameter	Minimum Treatment Objective[1]
Cryptosporidium	3-Log Removal
Giardia	3-Log Removal
Virus	4-Log-Removal

[1]It is important to note that these treatment objectives are considered a minimum only. Without source water characterization, it is recommended that 5.5-Log Removal of both *Cryptosporidium* and *Giardia* be targeted.

4.1 Standardized Water Treatment Train Approach

The SWTT treatment process was developed as a common design standard to be deployed across Nunavut communities to facilitate consistency in operations, maintenance practices, and training for water infrastructure. During development of the SWTT design, communities were looked at for commonalities for treatment and water infrastructure requirements, in addition to operability, to establish a common treatment process.

The SWTT process includes the following treatment processes, as shown visually in figure 4-1 below:

- Raw water pre-filtration;
- Chemical Coagulation;
- Dissolved air flotation;
- Membrane filtration using Ultrafiltration membranes;
- Ultraviolet (UV) light disinfection;
- Primary Chlorination; and
- Secondary Chlorination (treated water tank recirculation).

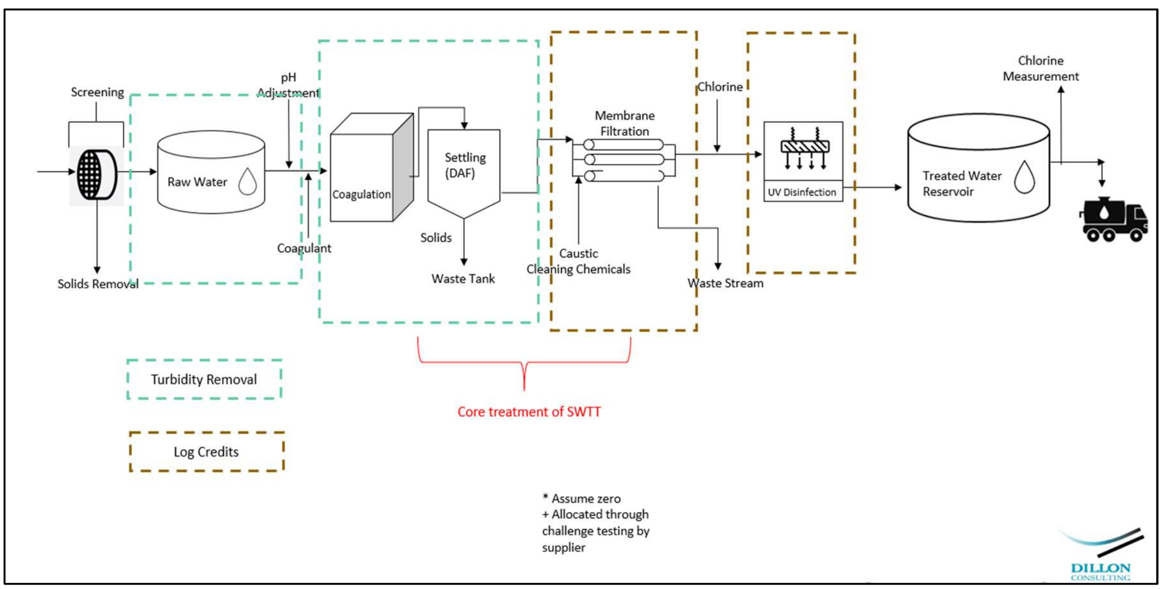

Figure 4-1: SWTT Treatment Process

This treatment process includes provision for the flocculation and removal of dissolved organic compounds, to allow the DAF and membrane filtration processes to remove these elements and improve the treated water quality, reducing the DBP formation potential to acceptable levels. This treatment process is robust in all elements of removal and disinfection, providing confidence in its capabilities to treatment of surface water sources from most communities evaluated as part of the SWTT project. Effectively, SWTT would need to treat the worst case water source from all of the study communities, which included dissolved organics that were DBP precursors.

Grise Fiord was included in the SWTT project, as it was scheduled as a priority for a water infrastructure upgrade. During this time, water sampling results from the historical water source (the Basin) was analyzed as part of the larger analysis of results from 9 communities for its treatability using the SWTT process. This project was intended to determine a common treatment system for all applicable communities within NU, and did not consider specific community characteristics such as community resources, remoteness beyond what is normally experienced within NU communities.

Table 4-2 list each SWTT treatment step, and log-removal credits allocated to each step.

Table 4-2: SWTT Log-removal Credits by Treatment Step

Process	Log Credit Crypto	Log Credit Giardia	Log Credit Virus
Coagulation/DAF	**NA**	**NA**	**NA**
Membrane Filters	3.0 +	3.0 +	0*
UV Disinfection	3.0	3.0	0
Chlorination	0.0	0*	4.0
Total	**6.0 +**	**6.0 +**	**4.0**
Minimum GCDWQ	**3.0**	**3.0**	**4.0**

**Giardia* credits from chlorination is possible, dependant upon downstream contact time.

4.2 Grise Fiord Simplified Treatment Approach

Based on the unique source water quality characteristics for the new Grise Fiord WTP, Dillon has developed a simplified treatment approach that is both more suitable to the specific water quality in Grise Fiord, and that addresses operational and resource constraints within this community, while maintaining GCDWQ treatment objectives.

The treatment process proposed is as follows, and is shown in **Figure 4-2**:

- Raw water settling/clarification in the storage tanks;
- Floating intake within the raw water storage tanks to feed the most clarified water to the WTP;

- Filtration step 1: Coarse micron cartridge filtration: 10 – 20-micron sizing, with selection based on particle size distribution analysis;
- Filtration step 2: Medium micron cartridge filtration: 1-5-micron nominal particle sizing to protect fine filters;
- Filtration step 3: 1-Micron absolute fine filter cartridges: These cartridges would be certified for LT2 (*Long-Term Enhanced Surface Water Treatment Rule, US Environmental Protection Agency*), and would be placed in series to maximize log-removal credits for *Cryptosporidium* and *Giardia.* Online turbidity monitoring is required following the filters when the WTP is producing water. GCDWQ require 0.3 NTU turbidity following the filter 95% of the time to receive log removal credit;
- UV disinfection;
- Primary Chlorination; and
- Secondary Chlorination (using treated water tank recirculation).

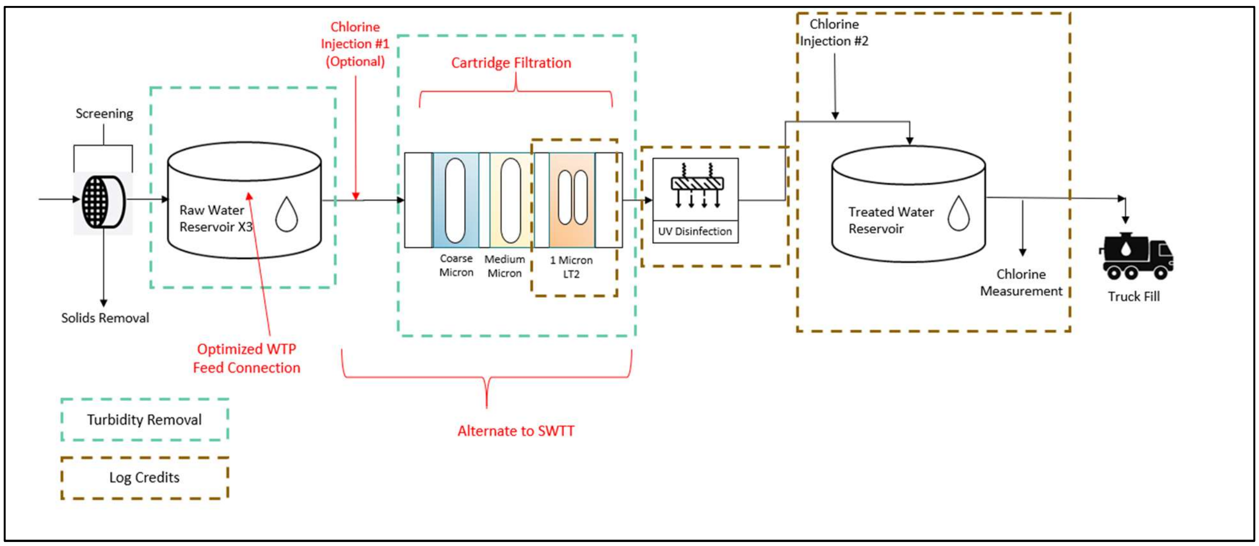

Figure 4-2: Cartridge Filtration Treatment Process

This proposed treatment process has been optimized based on the unique characteristics and operations of the Grise Fiord water system, in that the raw water is stored for prolonged periods within the tanks allowing for natural sediment settling, as well as the very low level of dissolved organics within the source water. Operations of this treatment process is significantly simplified, with chlorine being the only chemical, and no backwashing required for the filters. Filters are manually changed when pressure differential indicates it is required, which will be outlined in the operations and maintenance manual. Overall, we feel this is the most simplistic treatment approach for Grise Fiord WTP while still achieving GCDWQ requirements.

There are existing WTPs in Nunavut that use cartridge filtration, including Naujaat, Coral Harbour, Sanikiluaq, Igloolik, Pangnirtung, and others. These communities have had varying levels of success due to rapid/frequent clogging of the cartridges. However, the raw water turbidity in Grise Fiord will not cause rapid plugging, and the cartridge sizing will be optimized based on PSD analyses, allowing protection of the LT2 filters, prolonging their life as much as possible.

Table 4-3 outlines the treatment steps for the proposed simplified approach, and allocated log-removal credits associated with each step. In this case, with the LT2 cartridge filters in series, the simplified treatment process will exceed the minimum treatment objectives required by GCDWQ, and will meet the recommended treatment of 5.5-log removal credits for *Cryptosporidium* and *Giardia*. This treatment process capitalizes on the low level of DBP precursor organic compounds in the source water and natural clarification occurring in the raw water tanks.

Table 4-3: Cartridge Treatment Process Log-removal Credits by Treatment Step

Process	Log Credit Crypto	Log Credit Giardia	Log Credit Virus
Clarification in Raw Water Tanks	**NA**	**NA**	**NA**
Coarse/Medium Cartridge Filters	0	0	0
LT2 Cartridge filters, in series	2.5	2.5	0
UV Disinfection	3.0	3.0	0
Chlorine/Tank	0.0	0*	4.0
Total	**5.5**	**5.5**	**4.0**
Minimum GCDWQ	**3.0**	**3.0**	**4.0**

5.0 SWTT vs Cartridge Treatment Comparison

The SWTT process and the recommended simplified cartridge filtration process are both capable of exceeding GCDWQ treatment requirements for the Grise Fiord WTP. **Table 5-1** provides an overview of the log removal credits for each.

Table 5-1: SWTT vs Cartridge Process Log-Removal Credits

Treatment Process	Log Credit Crypto	Log Credit Giardia	Log Credit Virus
SWTT	**6.0 +**	**6.0 +**	**4.0**
Cartridge Process	**5.5**	**5.5**	**4.0**
Minimum GCDWQ	**3.0**	**3.0**	**4.0**

Operationally, the SWTT process is much more complex, requiring chemical dosing of coagulant in addition to the chlorine, as well as backwashing and chemical cleaning of the membrane filters. Based on the Nunavut WTP Classification system, SWTT at Grise Fiord would classify as a Class 2 system. The simplified cartridge filtration process only requires manual replacement of the filter elements at specified pressure differentials for maintenance of the filtration system. Chlorination would be identical to the existing system at Grise Fiord. Based on the Nunavut WTP Classification system, this simplified cartridge filtration process would classify as a 'low' class 1. Details for the classification assessment are included in **Appendix B**.

Table 5-2 outlines the advantages and disadvantages for the two treatment systems, including qualitative discussion on capital and operational costing.

Table 5-2: Treatment Process Advantages and Disadvantages

Treatment Method	Advantages	Disadvantages
SWTT (DAF + UF)	• Follows standardized GN strategy. • No solid waste streams. • Highly redundant treatment system. • Very reliable high-quality treated water. • Can respond to variations in water quality.	• Sophisticated systems and operations that are not necessary based on Grise Fiord source water quality. • Operator training critical for success (Class 2). • Larger footprint. • Capital and operational cost is higher. • Wastewater stream from membrane filtration backwash to manage • Higher risk to maintain reliable water supply due to operational complexity. • Use of additional chemicals onsite. Will require storage for chemicals.
Simplified LT2 Cartridge Filtration Approach	• Simplified operations (class 1). • Smaller system footprint. • Operators can be more easily trained. • No backwash wastewater. • No new chemicals used onsite compared to current operations • Operational similarities to existing system.	• Less redundancy in treatment credits (can be mitigated by installation of redundant cartridge filter trains). • Produces a solid waste stream for disposal (used cartridges will go to landfill). • Unable to remove dissolved organics (precursors to DBPs), however, these are below threshold levels at Grise Fiord.

	• Ideal candidate for water community production volumes and source water quality.	

6.0 Treatment Process Recommendation

Based on the Airport River source water sampling results from 2023 (low turbidity and DBPs), Dillon established that an optimized treatment process for Grise Fiord WTP is a cartridge filtration system, with UV disinfection and chlorination. This process will be a significant reduction in operational complexity, in comparison with the SWTT process, and will provide the lowest level of risk for water treatment operations and reliable water service within the community, while still exceeding minimum requirements for GCDWQ.

Based on the above rationale, Dillon is recommending that the treatment process for the new Grise Fiord WTP be modified to a more simplified cartridge filtration approach that limits operational complexity, while still meeting GCDWQ treatment objectives.

Appendix A
General Water Chemistry

Grise Fiord Water Chemistry Summary				2022[1]			2023							2022/2023		
		Guidelines for Canadian Drinking Water		August		June	July							Min	Max	Average*
				2022-08-04	2022-08-04	2022-06-29	2023-07-18	2023-07-18	2023-07-18	2023-07-18	2023-07-19	2023-07-19	2023-07-19			
Parameters	Units	MAC (mg/L)	AO (mg/L)	2022 Airport Creek	2022 Airport Creek 2	Raw Airport Creek	0 Hour Settled River	Raw River 2	River 3	Raw River 1	Treated Truck	24 hour Settled River	48 hour Settled River			
							23-018506-2	23-018495-1	23-018495-2	23-018506-1	23-018493-1	23-018496-1	23-018496-2			
Colour, True	CU		≤ 15 TCU	2.000	2.000	2.000	2.000	2.000	3.0	2.000	3.0	2.000	2.000	2.00	3.00	2.29
Conductivity	umhos/cm			132	132	96	113	112.0	116	113	102	114	114	102.00	116.00	112.00
Hardness	mg/L			69	68	48	56.8	57.1	58.6	57.4	42.1	56.7	55.3	42.10	58.60	54.86
Langelier Index (25C)	No Unit													0.00	0.00	NA
Langelier Index (60C)	No Unit													0.00	0.00	NA
pH	pH units		7.0-10.5	7.5	7.56	7.32	7.16	6.64	6.76	7.17	6.84	7.16	7.18	6.64	7.18	6.99
TDS	mg/L		≤500	67.0	67.0	48.0	57.0	57.0	58.0	57.0	52.0	58.0	58.0	52.00	58.00	56.71
Transmittance, UV	%T			99.3	99.3	97.3	99.3	99.1	99.1	98.9	97.1	99.3	99.1	97.10	99.30	98.84
Turbidity	NTU	≤ 0.3		1.4	1.1	6.5	1.3	2.7	1.4	1.4	1.1	1.2	1.2	1.10	2.70	1.47
TSS	mg/L			3	3	13	3	3	3	3	3	3	3	3.00	3.00	3.00
Alkalinity (CaCO3)	mg/L			65.0	75.0	43.0	68.0	54.0	55.0	70.0	44.0	63.0	62.0	44.00	70.00	59.43
Ammonia (N)	mg/L							0.05	0.05					0.05	0.05	0.05
Bicarbonate (HCO3)	mg/L	3												0.00	0.00	NA
Bromide (Br)	mg/L													0.00	0.00	NA
Carbonate (CO3)	mg/L													0.00	0.00	NA
Chloride (Cl)	mg/L		≤250	1.6	1.7	4.4	1.4	1.3	1.3	1.4	5.5	1.4	1.4	1.30	5.50	1.96
Fluoride (F)	mg/L	1.5		0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.10	0.10	0.10
Hydroxide (OH)	mg/L													0.00	0.00	NA
Nitrate (N)	mg/L	10		0.10	0.10	0.10	0.05	0.06	0.06	0.05	0.08	0.09	0.05	0.05	0.09	0.06
Nitrite (N)	mg/L	3	3											0.00	0.00	NA
Sulfate (SO4)	mg/L		≤500	4.00	4.00	1.00	2.00	1.00	1.00	2.00	3.00	2.00	2.00	1.00	3.00	1.86
Dissolved Inorganic Carbon	mg/L													0.00	0.00	NA
Dissolved Organic Carbon	mg/L			0.2	0.2	1.1	0.2	0.2	0.2	0.2	2.0	0.8	0.2	0.20	2.00	0.54
Total Carbon	mg/L													0.00	0.00	NA
Total Inorganic Carbon	mg/L													0.00	0.00	NA
Total Organic Carbon	mg/L			0.2	0.2	1.1	0.2	0.2	0.2	0.2	2.0	0.8	0.2	0.20	2.00	0.54
E. coli	MPN/100mL	0		0.0000	0.0000	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	0.00	0.00	NA
Total Coliforms	MPN/100mL	0		Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	0.00	0.00	NA
Aluminum (Al)*	mg/L	2.9	<0.1	0.0400	0.0300	0.04	0.05	0.05	0.05	0.04	0.02	0.03	0.04	0.02	0.05	0.04
Aluminum (Total)	mg/L			Not tested	Not tested	0.14 Ar-	0.05	0.05	0.04	0.04	0.02	0.03	0.04	0.02	0.05	0.04
Antimony (Sb)	mg/L	0.006												0.00	0.00	NA
Arsenic (total)	mg/L			Not Tested	Not Tested	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00	0.00	0.00
Arsenic (As)	mg/L	0.010 ALARA		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00	0.00	0.00
Barium (Total)	mg/L			Not tested	Not tested	0.008	0.010	0.010	0.010	0.009	0.145	0.009	0.009	0.01	0.15	0.03
Barium (Ba)	mg/L	2.0		0.0110	0.0100	0.013	0.009	0.009	0.010	0.009	0.148	0.009	0.009	0.01	0.15	0.03
Beryllium (Be)	mg/L													0.00	0.00	NA
Bismuth (Bi)	mg/L													0.00	0.00	NA
Boron (Total)	mg/L			Not tested	Not tested	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.01	0.01	0.01
Boron (B)	mg/L	5		0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.005000	0.01	0.01	0.01
Cadmium (total)	mg/L			Not Tested	Not Tested	0.000015	0.000015	0.000015	0.000015	0.000015	0.000015	0.000015	0.000015	0.00	0.00	0.00
Cadmium (Cd)	mg/L	0.007		0.000015	0.000015	0.000015	0.000015	0.000015	0.000015	0.000015	0.000015	0.000015	0.000015	0.00	0.00	0.00
Calcium (total)	mg/L			Not tested	Not tested	13.70	18.50	18.10	18.70	18.40	12.90	17.70	17.80	12.90	18.70	17.44
Calcium (Ca)	mg/L			21.40	21.00	13.80	17.80	17.80	18.30	18.00	12.60	17.90	17.40	12.60	18.30	17.11
Cesium (Cs)	mg/L	10	0.05											0.00	0.00	NA
Chromium (total)	mg/L			Not Tested	Not Tested	0.001000	0.001000	0.001000	0.001000	0.001000	0.002	0.001000	0.001000	0.00	0.00	0.00
Chromium (Cr)	mg/L	0.05		0.002000	0.002000	0.001000	0.001000	0.001000	0.001000	0.001000	0.0018	0.001000	0.001000	0.00	0.00	0.00
Cobalt (Co)	mg/L													0.00	0.00	NA
Copper (total)	mg/L			Not tested	Not tested	0.0004	0.002000	0.002000	0.002000	0.002000	0.049	0.002000	0.002000	0.00	0.05	0.01
Copper (Cu)	mg/L	2	1	0.002000	0.002000	0.0005	0.002000	0.002000	0.002000	0.002000	0.042	0.002000	0.002000	0.00	0.04	0.01
Cyanide	mg/L	0.2		0.005000	0.005000	0.005000	0.005000			0.005000	0.005000	0.005000	0.005000	0.01	0.01	0.01
Iron (total)	mg/L			Not tested	Not tested	0.199000	0.04	0.047	0.033	0.037	0.061	0.023	0.025	0.02	0.06	0.04
Iron (Fe)	mg/L		≤0.3	0.017	0.015	0.017	0.034	0.039	0.026	0.031	0.043	0.024	0.019	0.02	0.04	0.03
Lead (total)	mg/L			Not Tested	Not Tested	0.00007	0.00002	0.00002	0.00002	0.00002	0.00015	0.00008	0.00006	0.00	0.00	0.00
Lead (Pb)	mg/L	0.005		0.000020	0.000020	0.000070	0.00002	0.00002	0.00002	0.00002	0.00011	0.00008	0.00004	0.00	0.00	0.00
Lithium (Li)	mg/L													0.00	0.00	NA
Mangesium (Mg)	mg/L			Not tested	Not tested	3.22	3.00	3.06	3.13	3.02	2.57	2.90	2.87	2.57	3.13	2.94
Manganese (total)	mg/L			Not tested	Not tested	0.006	0.009	0.013	0.019	0.005	0.010	0.001	0.001	0.00	0.02	0.01
Manganese (Mn)	mg/L	0.12	≤ 0.02	0.001000	0.001000	0.002	0.001	0.001	<0.001	0.001	0.009	<0.001	<0.002	0.00	0.01	0.00
Mercury	mg/L	0.001		0.000020	0.000020	0.000020	0.000020	0.000020	0.000020	0.000020	0.000020	0.000020	0.00002	0.00	0.00	0.00
Molybdenum (Mo)	mg/L													0.00	0.00	NA
Nickel (Ni)	mg/L													0.00	0.00	NA
Phosphorous (P)	mg/L													0.00	0.00	NA
Potassium (total)	mg/L			Not tested	Not tested	0.200000	0.100000	0.10	0.100000	0.100000	0.100000	0.100000	0.100000	0.10	0.10	0.10

Grise Fiord Water Chemistry Summary				2022¹			2023							2022/2023		
		Guidelines for Canadian Drinking Water		August		June	July									
				2022-08-04	2022-08-04	2022-06-29	2023-07-18	2023-07-18	2023-07-18	2023-07-18	2023-07-19	2023-07-19	2023-07-19	Min	Max	Average*
Parameters	Units	MAC (mg/L)	AO (mg/L)	2022 Airport Creek	2022 Airport Creek 2	Raw Airport Creek	0 Hour Settled River	Raw River 2	River 3	Raw River 1	Treated Truck	24 hour Settled River	48 hour Settled River			
Potassium (K)	mg/L			0.100000	0.100000	0.2	0.100000	0.100000	0.100000	0.100000	0.100000	0.1	0.100000	0.10	0.10	0.10
Rubidium (Rb)	mg/L													0.00	0.00	NA
Selenium (total)	mg/L			Not Tested	Not Tested	0.001000	0.001000	0.001000	0.001000	0.001000	0.001000	0.001000	0.001000	0.00	0.00	0.00
Selenium (Se)	mg/L	0.05		0.001000	0.001000	0.001000	0.001000	0.001000	0.001000	0.001000	0.001000	0.001000	0.001000	0.00	0.00	0.00
Silicon (Si)	mg/L													0.00	0.00	NA
Silver (Ag)	mg/L		N/A											0.00	0.00	NA
Sodium (total)	mg/L			Not tested	Not tested	1.80	0.90	0.90	0.90	0.90	3.20	0.90	0.80	0.80	3.20	1.21
Sodium (Na)	mg/L		≤200	0.90	0.90	1.80	0.70	0.90	0.80	0.70	3.10	0.70	0.70	0.70	3.10	1.09
Strontium (Sr)	mg/L	7												0.00	0.00	NA
Tellurium (Te)	mg/L													0.00	0.00	NA
Thallium (Tl)	mg/L													0.00	0.00	NA
Thorium (Th)	mg/L													0.00	0.00	NA
Tin (Sn)	mg/L													0.00	0.00	NA
Titanium (Ti)	mg/L													0.00	0.00	NA
Tungsten (W)	mg/L													0.00	0.00	NA
Uranium (total)	mg/L			Not Tested	Not Tested	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Uranium (U)	mg/L	0.02		0.00006	0.00006	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Vanadium (V)	mg/L													0.00	0.00	NA
Zinc (total)	mg/L			Not tested	Not tested	0.005	0.011	0.016	0.024	0.009	0.018	0.005	0.005	0.01	0.02	0.01
Zinc (Zn)	mg/L		≤5.0	0.005	0.005	0.0070	0.005	0.005	0.005	0.005	0.014	0.005	0.005	0.01	0.01	0.01
Zirconium (Zr)	mg/L													0.00	0.00	NA
Total Dissolved Carbon	mg/L													0.00	0.00	NA
Bromochloroacetic Acid	mg/L													0.00	0.00	NA
Dibromoacetic Acid	mg/L			Not tested	Not tested	Not tested	0.002000	0.002000	0.002000	0.002000	0.002000	Blank	0.002000	0.00	0.00	0.00
Dichloroacetic Acid	mg/L			Not tested	Not tested	Not tested	0.002600	0.00670	0.0029	0.00600	0.00370	Blank	0.00300	0.00	0.01	0.00
Total Haloacetic Acid	mg/L	0.00008		Not tested	Not tested	Not tested	0.005300	0.00670	0.005300	0.0060	0.01410	Blank	0.005300	0.01	0.01	0.01
Monobromoacetic Acid	mg/L			Not tested	Not tested	Not tested	0.002900	0.002900	0.002900	0.002900	0.002900	Blank	0.002900	0.00	0.00	0.00
Monochloroacetic Acid	mg/L			Not tested	Not tested	Not tested	0.004700	0.004700	0.004700	0.004700	0.004700	Blank	0.004700	0.00	0.00	0.00
Trichloroacetic Acid	mg/L			Not tested	Not tested	Not tested	0.005300	0.005300	0.005300	0.005300	10.40	Blank	0.005300	0.01	10.40	1.74
2,3-Dibromopropionic Acid (SS)	%													0.00	0.00	NA
Benzene	mg/L	0.005		Not Tested	Not Tested	Not Tested	0.000500	0.000600	0.000700	0.000500	0.000500	Blank	0.000500	0.00	0.00	0.00
Bromodichloromethane	mg/L			Not Tested	Not Tested	Not Tested	0.002000	0.002000	0.002000	0.002000	0.0	Blank	0.002000	0.00	0.01	0.00
Bromoform	mg/L			Not Tested	Not Tested	Not Tested	0.005000	0.005000	0.005000	0.005000	0.005000	Blank	0.005000	0.01	0.01	0.01
Chloroform	mg/L			Not Tested	Not Tested	Not Tested	0.0	0.0	0.0	0.0	0.0	Blank	0.0	0.00	0.04	0.01
Dibromochloromethane	mg/L			Not Tested	Not Tested	Not Tested	0.002000	0.003000	0.004000	0.002000	0.002000	Blank	0.002000	0.00	0.00	0.00
Ethylbenzene	mg/L	0.00014	0.0000016	Not Tested	Not Tested	Not Tested	0.000500	0.000600	0.000700	0.000500	0.000500	Blank	0.000500	0.00	0.00	0.00
Total Trihalomethanes	mg/L	0.1		Not Tested	Not Tested	Not Tested	0.0	0.0	0.0	0.0	0.1	Blank	0.006000	0.01	0.05	0.02
Toluene	mg/L	0.00006	0.000024	Not Tested	Not Tested	Not Tested	0.000500	0.000600	0.000700	0.000500	0.000500	Blank	0.0	0.00	0.00	0.00
Xylene, m,p-	mg/L	0.00009		Not Tested	Not Tested	Not Tested	0.001000	0.002000	0.003000	0.001000	0.001000	Blank	0.001000	0.00	0.00	0.00
Xylene, m,p,o-	mg/L	0.00009		Not Tested	Not Tested	Not Tested	0.001100	0.001200	0.001300	0.001100	0.001100	Blank	0.001100	0.00	0.00	0.00
Xylene, o-	mg/L	0.00009		Not Tested	Not Tested	Not Tested	0.000500	0.000600	0.000700	0.000500	0.000500	Blank	0.000500	0.00	0.00	0.00
PHC F1 (C6-C10)	mg/L			0.025000	0.025000	0.025000	0.025000	0.025000	0.025000	0.025000	0.025000	Blank	0.025000	0.03	0.03	0.03
PHC F2 (>C10-C16)	mg/L			0.050000	0.050000	0.050000	0.050000	0.050000	0.050000	0.050000	0.050000	0.050000	0.050000	0.05	0.05	0.05
PHC F3 (>C16-C34)	mg/L			0.400000	0.400000	0.400000	0.400000	0.400000	0.400000	0.400000	0.400000	0.400000	0.400000	0.40	0.40	0.40
PHC F4 (>C34-C50)	mg/L			0.400000	0.400000	0.400000	0.400000	0.400000	0.400000	0.400000	0.400000	0.400000	0.400000	0.40	0.40	0.40
Acenaphthene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Acenaphthylene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Anthracene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Benzo(a)anthracene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Benzo(a)pyrene	mg/L			0.000010	0.000010	0.000010	0.000010	0.000010	0.000010	0.000010	0.000010	0.000010	0.000010	0.00	0.00	0.00
Benzo(b)fluoranthene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Benzo(b+k)fluoranthene	mg/L			0.000100	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100	0.000100	0.00	0.00	0.00
Benzo(g, h, i)perylene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Benzo(k)fluoranthene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Chrysene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Dibenzo(a,h)anthracene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Fluoranthene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00

Grise Fiord Water Chemistry Summary				2022[1]			2023							2022/2023		
		Guidelines for Canadian Drinking Water		August		June	July							Min	Max	Average*
				2022-08-04	2022-08-04	2022-06-29	2023-07-18	2023-07-18	2023-07-18	2023-07-18	2023-07-19	2023-07-19	2023-07-19			
Parameters	Units	MAC (mg/L)	AO (mg/L)	2022 Airport Creek	2022 Airport Creek 2	Raw Airport Creek	0 Hour Settled River	Raw River 2	River 3	Raw River 1	Treated Truck	24 hour Settled River	48 hour Settled River			
Fluorene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Indeno(1,2,3, -cd)Pyrene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Methylnaphthalene, 1-	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Methylnaphthalene, 2-(1-)	mg/L			0.001000	0.001000	0.001000	0.001000	0.002000	0.003000	0.001000	0.001000	0.001000	0.001000	0.00	0.00	0.00
Methylnaphthalene, 2-	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Naphthalene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Phenanthene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Pyrene	mg/L			0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.00	0.00	0.00
Total PAH	mg/L			Not tested	Not tested	Not tested	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00	0.00	0.00

[1] Mix of Basin and River Water

[2]Treated water from delivery truck - mix of basin and river water

*Note that any value in red font is less than that value

*Note that the average includes only 2023 samples directly from the River to exclude any water samples that include basin water

Appendix B
WTP Classification by Nunavut Water Treatment Plant Classification System

Item		Points	Grise Fiord SWTT	Grise Fiord Cartridge WTP	Grise Fiord Comments
Size					
Design flow average day, or peak month's average day, whichever is larger (1 point per 1.892 million litres. Round up.) Design flow: Consider this to be the design capacity of the plant. Examples 40 MLD = 19 points 18.9 MLD = 10 points (20 points maximum allowed)		1-20	1	1	31,500 people required for 2 pts, anything less, 1 pt. 178 persons
Water Supply Sources					
Seawater/saltwater		10	5	5	Surface water source
Groundwater (non - GUDI)		0			
Groundwater under the direct influence of surface water (GUDI)		5			
Surface water		5			
Average Raw Water Quality Variation: Applies to all sources (surface and groundwater). Key is the effect on treatment process changes that would be necessary to achieve optimized performance.					
Groundwater (non - GUDI, no variability in water quality)		0			
Groundwater (GUDI, no variability in water quality)		0			
High quality surface water consistently less than 0.3 NTU		1			
Surface water - natural lake or constructed reservoir (subject to minor water quality variation, < 10 NTU)		2	2	2	
Surface water - river or lake source (> 10 NTU and < 100 NTU)		3			
Surface water - river or lake source (seasonally exceeds 100 NTU during spring runoff, minor variability the rest of the year)		4			
Water quality variations significant enough to require pronounced and/or very frequent chemical dose changes		5			
Severe variations - source subject to high risk non-point discharges, agricultural/urban storm runoff, watershed flooding severely impacting water quality risk		7			
Raw water quality subject to agricultural or municipal waste point source discharges		8			
Raw water quality subject to industrial waste pollution		10			
Water quality is subject to:					
Taste and/or odour for which treatment process adjustments are routinely made		2			
Source water dissolved organic carbon (where filtration other than reverse osmosis or nanofiltration is used and coagulation is not the primary control method for DBPs) - 3 points where minimal data is available and can be updated to a lower score once comprehensive water quality data is available	<5.0 mg/L DOC with no DBP exceedance	0	0	0	2023 Data shows low to non-detectable DOC and DPBs. No exceedances.
	<5.0 mg/L DOC with DBP exceedance	2			
	>5.0 mg/L DOC	3			
Iron and/or manganese - treated water total Fe < 0.3 mg/L and total Mn < MAC		0	0	0	
Iron - treated water total Fe concentration > 0.3 mg/L (points apply only if UV disinfection is used)		2			
Manganese - treated water total Mn concentrations above MAC		3			
Algal growths for which treatment process adjustments are routinely made		3			
Chemical Treatment / Addition Processes					
Fluoridation - acid-based systems		4			
Fluoridation - salt-based systems		2			
Prechlorination		2		2	Possible pre-chlorination to prevent fouling of cartridges.
pH adjustment for process control (e.g., pH adjustment aids coagulation)		4			
Stability or Corrosion Control (If the same chemical is used for both Corrosion Control and pH adjustment, count points only once) or re-alkalisation		2			
Disinfection/Oxidation (Note: Points are additive to a maximum of 15 points allowed for this category.) Check all that apply:					
Chlorination:	Sodium hypochlorite or calcium hypochlorite delivered to site	4	4	4	Hypochlorites not generated on site
	On-site hypochlorite generation	6			
	Chlorine gas	8			
	Chloramination	10			
	Chlorine dioxide	10			
Ozonation		10			
UV Irradiation		3	3	3	
Iodine, Peroxide, or similar		5			
Potassium permanganate (not used for greensand filtration)		4			
Coagulation / Flocculation and Filter Aid					
Coagulation and flocculation with media filtration (not membrane filtration)		6			
Coagulation and flocculation with membrane filtration (for organics removal)		3	3		
Coagulant aid / Flocculant chemical addition (in addition to primary coagulant use)		2			
Flocculation for media filtration		2			
Flocculation for membrane filtration		0			
Filter aid addition (non-ionic / anionic polymers)		2			
Clarification / Sedimentation					
Sedimentation (plain, tube, plate)		4			
Contact adsorption		6			
Other Clarification processes (air flotation - DAF, ballasted clarification, etc)		6	6		
Upflow clarification ("sludge blanket clarifier")[2]		8			
Filtration					
Granular media filtration (Surface water / GUDI) - pre-treatment, including inline pressure media filtration	with coagulation	10			
	without coagulation	5			
Granular media filtration (Surface water / GUDI) - primary filtration, including inline pressure media filtration	with coagulation	20			
	without coagulation	10			
Groundwater filtration		6			
Membrane filtration (primary filtration)		15	15		
Nanofiltration and reverse osmosis		15			
Membrane filtration (NF or RO pre-treatment)		10			
Diatomaceous earth (pre-coat filtration)		10			
Cartridge Filter Arrays / bag filters		3		3	
Pre-filtration (strainers, staged filtration, etc.): add one point per stage to a maximum of 3 points		1 - 3	1	1	SWTT has strainers, Cartridge filters will be staged.
Slow sand		5			
Other Treatment Processes					
Aeration		3			
Air stripping (including diffused air, packed tower aeration)		5			
Ion-exchange / softening		5			
Greensand filtration		10			
Lime-soda ash softening (includes: chemical addition, mixing/flocculation/clarification/filtration - do not add points for		20			
Granular activated carbon filter (do not assign points when included as a bed layer in another filter)		5			
Powdered activated carbon		2			
Reservoir management employing chemical addition		2			
Blending sources with significantly different water quality	To achieve MAC compliance	4			
	To achieve AO compliance	2			
Electrodialysis		15			
Other: Certification authority may assign 2 to 15 additional points for processes not listed elsewhere in this document.		2-15	3	3	Added 3 points to each year to account for maintenance of raw water tanks and boiler systems.
Residual Disposal					
Discharge to land, sewer, lagoon, or equivalent		0			
Discharge to land, sewer, lagoon, or equivalent (with high salinity)		0			

On-site disposal, land application	0			
Discharge lagoon / drying bed, with no recovery / recycling - e.g., downstream outfall	0			
Backwash recovery/recycling: discharge to basin or lagoon and then to source	2			
Backwash recovery/recycling: discharge to basin or lagoon and then to plant intake	3			
Facility Characteristics - instrumentation - use of SCADA or similar instrumentation systems to provide data with:				
Monitoring / alarm only, no process operation - plant has no automated shutdown capability	0	0	0	Limited process operation - e.g., remote shutdown capability
Limited process operation - e.g., remote shutdown capability	0			
Moderate process operation - alarms and shutdowns, plus partial remote operation of plant	1			
Extensive or total process operation - alarms and shutdowns,full remote operation of plant possible	2			

Base score	**43**	**24**	
Class	**Class 2**	**Class 1**	

Appendix C

Supplemental Geotechnical Assessment – Foundation Review for New WTP and Storage Tanks, Grise Fiord, NU

September 1, 2023

Concentric Associates International Inc.
c/o Steven Versteegen
700 Richmond Street, Suite 307
London, ON N6A 5C7
via E-mail: stevenv@concentriceng.com

Re: GRI-G2302 Supplemental Geotechnical Assessment - Foundation Review for New Water Treatment Plant (WTP) & Water Storage Tanks, Grise Fiord, NU

Dear Mr. Versteegen:

The purpose of this letter is to provide a review of the geotechnical report prepared for the above-referenced project and further recommendations regarding suitable foundation types based on Adaptive Baseline Geotechnical Ltd.'s (ABG's) geotechnical perspective. Included below is a summary of previous findings followed by our own interpretation of the available information, current permafrost conditions, climate change considerations and foundation recommendations to support design and construction of the project. The information presented herein has been determined in accordance with the most recent editions of the National Standard of Canada CAN/BNQ 2501-500/2017 *Geotechnical Site Investigations for Building Foundations in Permafrost* and Canada Standards Association (CSA) PLUS 4011:19 *TECHNICAL GUIDE Infrastructure in permafrost: A guide for climate change adaptation*.

1.0 Background Information

The new WTP is currently proposed to be founded atop a thickened perimeter concrete slab-on-grade, with two smaller exterior water storage tanks (treated water and wastewater) adjacent the building. In addition, the new WTP project will include the construction of two larger diameter tanks for raw water storage, constructed adjacent the new WTP building. A geotechnical investigation for this project was completed by Exp Services Inc. (exp) in 2022. Included within the geotechnical report is a Geothermal Analysis for the WTP and all exterior water storage tanks. The applicable report is:

- Feasibility Study Geotechnical Investigation, Water Treatment Plant, Grise Fiord, Exp, Project #FRN-21016638-A0 dated 22 March 2022.

During the exp investigation, three sites (Sites 2, 3 and 8) were investigated for feasibility purposes and it was determined that both Sites 2 and 3 are equally suitable for construction of the new WTP from a geotechnical perspective. Sites 2 and 3 are both underlain by frost susceptible, potentially thaw unstable granular soils and bedrock was not encountered within 10 meter below grade (mbg). Ground temperature data from the investigation suggested a current mean annual ground temperature (MAGT) of -12°C at the sites.

Exp proposed that the new WTP be founded on spread and strip footings on an engineered fill pad with insulation and thermosyphons. The smaller water storage tanks were proposed to be founded on the same engineered fill pad as the WTP and the larger raw water storage tanks were proposed to be founded on a separate engineered fill pad with underlying horizontal insulation (no thermosyphons required based on their thermal modelling). According to exp, adfreeze piles were not considered as a foundation option because they cannot be relied upon to perform satisfactorily during the life of the structure given the unknown future effects of climate change and due to an apparently interpreted required for the WTP building to be founded on grade.

2.0 Historical Climate and Permafrost Conditions

Grise Fiord is located at approximately 76° 25' N and 82° 54' W on the southern coast of Ellesmere Island in the Qikiqtaaluk Region of Nunavut. Based on current permafrost mapping, the community is located within the zone of continuous permafrost.

Mean Annual Air Temperature (MAAT) and Indices: A review of Environment Canada climate records for the community revealed a relatively complete set of historical monthly air temperatures spanning the period from 1993 to 2022. The data indicates the MAAT over this time-period was -13.8°C and the average thawing and freezing indices were about 254°C-days and 5301°C-days respectively.

Active Layer Thickness: Based on the above-noted historical air temperature data, simplified empirical methods and active layer thickness measurements, it is estimated that the active layer currently varies between approximately 0.8 and 1.3 m, depending on site-specific variables (such as surficial cover, site drainage, sun exposure and in-situ moisture content). Based on ABG's review of available ground temperature data for the community (including the exp site-specific thermistor data), the current maximum active layer thickness is estimated as 1.3 m at the site.

Mean Annual Ground Temperature (MAGT): Based on a review of the available ground temperature data for the community (including the exp thermistor data), the current MAGT is estimated as -12°C at the site.

3.0 Climate Change in Foundation Design

ABG anticipates that the current maximum active layer thickness throughout the site is approximately 1.3 m and the current MAGT is approximately -12°C. Changes to the active layer thickness and MAGT throughout the life of the structure will depend on many variables, possibly including but not limited to actual current values, changes to MAAT, snow cover, precipitation, surface/groundwater flow, material gradation and in-situ ice content.

CSA PLUS 4011:19 provides that under a high greenhouse gas scenario the MAAT in Grise Fiord is estimated to increase by approximately 2.4°C over the next 30 years (by 2053) compared to the historic temperature trends which were available up to 2022. It is noted however, that recent research infers that greenhouse gas emissions over the next 30 years and beyond may be even higher than previously anticipated and new scenarios continue to be produced by global experts. Therefore, accurately estimating what the active layer thickness and MAGT will be 30 years from now is well beyond the scope of this assessment.

To support the current project, we have adjusted the historical temperature data to incorporate the above-noted changes to the MAAT and utilized the same simplified empirical methods from Section 2.0

to generate an estimated maximum active layer thickness 30 years from now. We have also assumed (conservatively) that the MAGT will change in step with the MAAT over this period. The process results in future estimated values for the maximum active layer thickness and MAGT of 1.8 m and -9.6°C respectively.

Given the inherent uncertainties surrounding the effects that climate change and site development will have on active layer thickness and MAGT at the site, we recommend introducing some additional conservatism by the way of engineering judgement. For this reason, we have used a design active layer thickness of 2.1 m and a design MAGT of -9.3°C for pile design at the site.

It is further recommended that a series of thermistors be installed along with select pile installations such that ground temperature monitoring can be carried out to establish the actual site-specific ground temperature profile over time. In this way, the assumptions made to support design can be confirmed based on the real-world conditions during the pile installations and any issues that may occur can be better understood and dealt with accordingly.

It is noted that CSA PLUS 4011:19 states *"The requirement for monitoring, reporting, and reacting to any changes that are noted must be recognized early in the project. The responsibilities need to be defined at the project outset and budgets allocated to collect and summarize the data. An annual review by the geotechnical engineer is recommended with more frequent reviews if undesirable trends appear. Monitoring is pointless unless the data collected are evaluated".* This speaks to the importance of implementing a proper and consistent ground temperature monitoring program that includes review and input from qualified geotechnical personnel as part of responsibly addressing climate change in relation to foundation design and maintenance.

4.0 Discussion and Recommendations

Based on ABG's review of the existing information, our experience in the community and with similar projects throughout the territory, the sub-surface soils and MAGT reported by exp for Site 2 is consistent with our previous findings nearby. It is our opinion that that adfreeze piles should be considered as a suitable foundation for the proposed WTP building, provided that the building can be elevated up off the ground per our recommendations below.

Furthermore, it is our opinion that the thermal modelling carried out by exp regarding the larger raw water storage tanks agrees well with previous thermal models we have carried out for similar projects in more southern communities throughout Nunavut; therefore, the recommendations included within their report are suitable for use as is and can be used to support design and construction of the larger and smaller water storage tank foundations. It is noted that the thermal modelling showed a requirement for 100 mm of rigid horizontal insulation directly beneath each tank and this layer of insulation must extend out beyond the perimeter of each tank for some specified distance. If the design team wishes to add additional buffer against the potential effects of climate change or other similar unknowns, it is our opinion that the most cost effective way to approach this would be doubling the proposed insulation layer thickness and increasing the projection by 25 to 33%. Thicker insulation will effectively maintain the underlying permafrost in a colder condition (further limiting the impact a heated water tank will have on the underlying soils) and extending the projection of that insulation will effectively provide increased buffer against any increased seasonal thaw depth over time.

Recommendations to support design and construction of adfreeze piles are provided below.

8.1 Adfreeze Steel Pipe Piles

Adfreeze steel pipe piles carry the applied loads through an adfreeze bond between the steel pipe and the sand slurry backfill/overburden. The adfreeze bond is used to resist both compression and uplift loads. The following table provides unfactored Ultimate Limit States (ULS) and Serviceability Limit States (SLS) adfreeze bond capacities for anticipated pile diameter, as well as the required minimum embedment from a geotechnical perspective.

It must also be noted that local equipment dictates the size and length of piles that can be safely installed in each community. In general, the heavy equipment available in smaller communities such as this can safely lift and install a 141 mm outside diameter (OD) steel pipe pile measuring up to 15 m in total length (including stickup above grade). For this reason, it may be necessary to utilize groups of two or more piles at a given location depending on the building design and loading.

The adfreeze pile design parameters include an adjustment for the anticipated effects that a porewater salinity of 10 ppt would have on freezing through the adfreeze pile bond zone. The minimum embedment presented above is intended to provide enough resistance to avoid frost jacking of piles based on the design active layer thickness.

TABLE 1 - Adfreeze Pile Design Parameters

Pile Outside Diameter (mm)	Unfactored ULS Adfreeze Bond Capacity (kPa)	SLS Adfreeze Bond Capacity (kPa)	Minimum Embedment Below Finish Grade (m)
114 or 141 (unslotted)	280	65	10.0

Notes: 1) ULS geotechnical resistance factor of 0.4 should be applied for compression loads.
2) ULS geotechnical resistance factor of 0.3 should be applied for tension loads.
3) SLS bond capacity based on 30 mm of creep over 30 years.
4) Minimum embedment is based on engineering judgement taking into consideration the requirement to resist a design frost jacking force of 150 kPa through the design active layer thickness and incorporating some additional embedment to help counter the possible unknown effects of climate change.

Given the difficulties in accurately estimating the active layer thickness (due to its dependence on many site-specific variables), it is also recommended that a suitable bond breaker be provided through the design active layer thickness of each pile as a secondary measure.

The frost jacking force of 150 kPa is a recommended design force based on anticipated soil conditions and the use of steel pipe piles. Therefore, the design frost jacking force does not require the application of a load factor during pile design and shall be considered together with other uplift forces acting on the structure (i.e. wind) to determine the actual pile embedment/socket length required for final design.

For lateral design, we have estimated values of horizontal subgrade modulus based on the anticipated stratigraphy and our installation methods, as shown in the following table. If additional lateral capacity is required, ABG can work with the structural designer to determine more specific lateral load capacity of the piles given the anticipated design loads and potentially less conservative assumptions (i.e. L-Pile analyses).

TABLE 2 - Estimated Horizontal Subgrade Modulus Values

Assumed Soil Profile	Depth (mbg)	Coefficient of Subgrade Reaction (k_s, kN/m^3)
Sand (thawed, active layer, above groundwater)	0.0	0
Sand (thawed, active layer, above groundwater)	0.1	1,000
Sand (thawed, active layer, above groundwater)	0.5	7,000
Sand (thawed, active layer, below groundwater)	1.0	9,000
Sand (thawed, active layer, below groundwater)	1.5	25,000
Sand (thawed, active layer, below groundwater)	2.0	48,000
Sand (thawed, active layer, below groundwater)	2.1	65,000
Sand (frozen, permafrost)	2.2	71,000
Sand (frozen, permafrost)	2.5	83,000
Sand (frozen, permafrost)	3.0	95,000
Sand (frozen, permafrost)	3.5	106,000
Sand (frozen, permafrost)	4.0	118,000
Sand (frozen, permafrost)	4.5	142,000
Sand (frozen, permafrost)	5.0	166,000
Sand (frozen, permafrost)	5.5	166,000
Sand (frozen, permafrost)	6.0	166,000
Sand (frozen, permafrost)	6.5	180,000
Sand (frozen, permafrost)	7.0	180,000
Sand (frozen, permafrost)	7.5	180,000
Sand (frozen, permafrost)	8.0	180,000
Sand (frozen, permafrost)	8.5	190,000
Sand (frozen, permafrost)	9.0	190,000
Sand (frozen, permafrost)	9.5	190,000
Sand (frozen, permafrost)	10.0	190,000

Notes: 1) Coefficient of subgrade reaction calculated for a 141 mm steel pipe pile.

It is essential that a good bond is developed between the pile and the frozen sand slurry; therefore, the steel piles below the design active layer thickness must be free of paint, lacquer, oil, grease and dirt.

To avoid group effect considerations, individual piles should be at least 3 pile diameters apart center-to-center. Further recommendations pertaining to consideration of group effect can be provided upon request if closer pile spacing is required.

The piles should be installed in pre-drilled oversize holes at least 50 mm larger than the pile diameter. The piles should be installed open ended in the hole and vibrated down to the design depth while adding low saline sand (less than 5 ppt) and fresh water around the pile diameter. The interior of the piles should be filled with low saline sand to the final ground elevation to prevent air circulation inside the pile.

It is noted that freeze back around the piles may take several weeks before full pile capacity can develop. The piles should not be fully loaded until the ground temperature readings indicate stabilized frozen conditions around the piles equal to those assumed for design. For a building supported on adfreeze piles, we would recommend a multi-bead thermistor be installed to the bottom of one adfreeze pile with individual thermistor beads spaced at 0.5 m increments from surface to 5 m depth and 1.0 m increments below 5 m depth. This thermistor string can also allow for long-term monitoring of the active layer thickness and MAGT through the bond zone as recommended in Section 5.0. This information could prove valuable in the future if piles experience issues (heave or settlement) as understanding the issue is key to successfully remediating it. Most ideally, a proper and consistent ground temperature monitoring program will be established and any warming of the MAGT or deepening of the active layer can be detected and remediated before issues with the structure are realized. Potential mitigation strategies may include the placement of rigid insulation or installation of adjustable pile caps.

As noted above, seasonal groundwater flow through the active layer may be moderate dependant on actual site topography; therefore, the use of casings may be required unless the pile installations can take place while the ground is completely frozen (November to May). Groundwater flow into adfreeze pile holes should be avoided as such water may delay freeze-back substantially.

The base of the heated structures should be at least 1.0 m above final grade to permit good air circulation under the building. It is necessary to maintain this air space to ensure that heat from the structure will not degrade the permafrost and reduce the pile capacity. In our experience, the following site activities represent some common examples of site usage that can result in performance issues (heave or settlement) of adfreeze piles following successful design and installation:

- Hoarding/skirting the air space or using it for storage restricting air flow and allowing heat transfer;
- Snow clearing activities resulting in the stockpiling/mounding of snow against one or more sides of the air space restricting airflow during winter and introducing vast amounts of melt water during the spring freshet deepening the active layer and contributing to permafrost degradation; and
- Poor site grading around the piles causing surface water to flow towards/past or pond around the piles deepening the active layer thickness and potentially degrading the permafrost permanently.

5.0 Closure

We trust the information contained herein is adequate for your present purposes. Should you have any questions about the contents of the report, or if we can be of any further assistance, please do not hesitate to contact the undersigned at your convenience.

PERMIT TO PRACTICE
ADAPTIVE BASELINE GEOTECHNICAL LTD.
Signature
Date 01-SEP-2023
PERMIT NUMBER: P 1501
NT/NU Association of Professional Engineers and Geoscientists

Sincerely,

Adaptive Baseline Geotechnical Ltd.

REGISTERED PROFESSIONAL ENGINEER
J.A. SMITH
LICENSEE
NWT/NU

Sean Dillon, P.Eng. (NT/NU)
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Attachments: ABG's Site-Specific Thermistor Report (based on exp reported data)

Thermistor Report

** Ground temperature data from Feasability Study Geotechnical Investigation by exp**

PROJECT No.:	GRI-G2302			THERMISTOR No.:		T1	
PROJECT NAME:	WTP Site 2			DATE INSTALLED:		October 6, 2021	
PROJECT LOCATION:	Grise Fiord, NU			LOCATION:		BH5	
	Date of Reading :	2021-10-07	2021-10-10	2021-10-14			

Thermistor Bulb	Depth (m)	Temp (°C)	Temp (°C)	Temp (°C)	Temp (°C)	Temp (°C)	Temp (°C)	Temp (°C)
AIR	1.5							
1	-0.5	-1.1	-1.8	-3.6				
2	-1.0	-1.5	-1.7	-2.4				
3	-1.5	-1.5	-1.7	-2.4				
4	-2.0	-2.0	-2.1	-2.4				
5	-3.0	-3.2	-3.3	-3.4				
6	-4.0	-4.8	-4.8	-4.9				
7	-6.0	-7.6	-7.6	-7.5				
8	-8.0	-9.3	-9.3	-9.2				
9	-10.0	-10.1	-10.1	-10.1				
10								
11								
12