# Hydrology Assessment
# Grise Fiord, Nunavut
# - DRAFT -

*November 17, 2014*


Submitted to: **GOVERNMENT OF NUNAVUT – COMMUNITY AND GOVERNMENT SERVICES**

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November 17, 2014

**Government of Nunavut – Community and Government Services**
2nd Floor, GNO 1045
P.O. Box 379
Pond Inlet, NU, X0A 0S0

**ATTENTION: Joni Kyak**

**RE: HYDROLOGY ASSESSMENT, GRISE FIORD, NUNAVUT**

ARKTIS Solutions Inc. is pleased to provide the Government of Nunavut – Community and Government Services with the above-mentioned draft report.

We trust that the information presented in this report satisfies the requirements of the project. Please do not hesitate to contact the undersigned if there are any questions or comments regarding this report.

Sincerely,

ARKTIS SOLUTIONS INC.

Matthew Hamp, P.Eng
VP Nunavut Affairs & Operations
ARKTIS SOLUTIONS INC.
Phone:867.446.4129

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# 1.0 INTRODUCTION

The Government of Nunavut - Department of Community and Government Services (GN-CGS) contracted ARKTIS Piusitippaa Inc. (ARKTIS) to complete a hydrology assessment of the potable water source (glacier-fed stream) for the hamlet of Grise Fiord, Nunavut. This report fulfills the contract requirements of this project.

This report is presented as follows:

**Section 2.0 – Background**

**Section 3.0 – Delineation of the Grise Fiord Watershed**

**Section 4.0 – Water Supply Modelling**

**Section 5.0 – Conclusions**

**Section 5.0 – Recommendations**

**Section 6.0 – Limitations of Liability**

**Section 7.0 – Closing**

# 2.0 BACKGROUND

## 2.1 Community

The municipality of Grise Fiord, Nunavut is located 76°25′ N latitude and 82°54′ W longitude in the southern region of the High Arctic on Ellesmere Island within the Qikiqtani Region of Nunavut. The population of Grise Fiord in 2014 was estimated to be 158 according to the Government of Nunavut[1].

## 2.2 Grise Fiord Glacier and the Existing Community Water Supply System

Grise Fiord Glacier is located southwest of the Grise Fiord community on Ellesmere Island, Nunavut, the melt water from which currently provides the sole potable water for the hamlet. Melt water from the glacier flows towards the community via stream in the summer months and is collected and pumped into a 5,000,000 L reservoir tank. The stored water is then treated with chlorine and trucked as needed throughout the community. The current watershed is naturally recharged by precipitation, as well as glacial runoff (**Figure 1**).

[1] Nunavut Bureau of Statistics, Population Estimates and Projections (http://www.eia.gov.nu.ca/stats/population.html).

# 3.0 DELINEATION OF GRISE FIORD WATERSHED

## 3.1 Watershed Delineation

A delineation of the area that contributes to the recharge of the current Grise Fiord watershed is a necessary component in assessing the regional hydrology, and the sustainability of the water supply. A topographical survey of the general area has been collected by LiDAR, a form of remote sensing, and will be used as the primary source of data in this evaluation. Additionally, a survey of the probable watershed area[2] is available and will be used in conjunction with the topographical data to produce AutoCad Civil 3D surface maps.

Watershed delineation modelling was undertaken using AutoCad Civil 3D. The runoff coefficient selected for this exercise was 0.700, which has been found in studies to be representative of runoff conditions in arctic locations underlain by continuous permafrost[3].

From the initial data, the entire area of the watershed running through Grise Fiord was suggested to be 1,390,000 $m^2$. However, due to the single mountain gully that hosts the Grise Fiord glacier, the watershed that plays a role in supplying the community with water is likely much more localized, and is outlined in **Figure 2.** This is supported in the Grise Fiord Community Plan[4], which has acted as additional reference in the overall definition of the watershed area that hosts the Grise Fiord glacier fed stream. After creating this modified watershed overlay, it was possible to estimate that the area of the current watershed is 220,000 $m^2$.

Although the existing watershed in Grise Fiord possesses several advantages such as its distance to possible sources of contamination, it is important to note that the relative area is small and relies heavily on recharge from precipitation and glacial melt water. This presents a risk to the quantity of water that can be supplied to the community. For example, if annual precipitation and melt water volumes are not reached during the summer months to supply the community in a given year, Grise Fiord could be in dire need of an alternative water supply. The community has identified a potential second water source in the event that the Hamlet requires an additional or replacement source. However, the alternative source also poses some risk due to the distance required to access and pump water, and the brief period of time that water will flow in this arctic climate. As Grise Fiord glacier and the existing watershed are the current sources of potable water for the community, the lack of development for the alternative water source presents a potentially serious issue for the long term supply of fresh water for this municipality.

## 3.2 Limitations of Watershed Area Delineation

The accuracy of the topographical map, and the lack of field data concerning the hydrological regime in Grise Fiord are the major limiting factors in the delineation of the watershed area. While surveying has been completed, it is somewhat limited, and was not taken over a wide enough geographical area to capture the entire topography of the watershed.

Additionally, the physical attributes of the Grise Fiord glacier melt water streams and other hydrological features that would affect the delineation of the watershed area, could not be measured or accounted for. Actual elevations may vary from the topographical data used, which may also affect the watershed area calculation. A detailed survey and field hydrological study would be needed to account for these features.

[2] Government of Nunavut, Lands Division.
[3] Lewkowicz, A.G and French, H.M, The hydrology of small runoff pots in an area of continuous permafrost, Banks Island, N.W.T. 4th Canadian Permafrost Conference. 1982. Pg. 151-162
[4] Grise Fiord Community Plan 2008 - 2028. Fotenn Planning and Urban Design. February 2009

As such, there may be differences between the predicted watershed area, and actual physical conditions. Further steps needed to rectify this uncertainty are discussed in **Section 0**.

# 4.0 WATER SUPPLY MODELLING

## 4.1 Parameters

The precipitation data used in calculating the recharge into the Grise Fiord water balance is displayed in **Table 1**. Environment Canada has maintained one weather station for Gise Fiord, which contains significant gaps in the weather data collected. In some years, up to two months of precipitation data is missing in these records. To ensure better accuracy, as well as a contiguous weather data record, precipitation volumes collected from the closest weather station in Resolute, Nunavut will be used in place of the Grise Fiord results with two or more months of missing data. How the dataset was assembled has been detailed in the footnotes of **Table 1.**

A representative evapotranspiration data set obtained from a study performed in Nanisivik[5] by Aboriginal Affairs and Northern Development Canada (AANDC) measured an evapotranspiration rate of 192 mm/year. Due to the effort needed to measure actual evapotranspiration rates, little data is available in Nunavut. As such, the data from Nanisivik is the most accurate available, and was considered to be adequately representative of the weather conditions in Grise Fiord for the purposes of this evaluation.

The surface area for the watershed in Grise Fiord used in the water balance calculations in this report is 220,000 $m^2$, which was delineated using an AutoCAD file from the GN-CGS Lands Division. A summary of the estimated characteristics of the Grise Fiord watershed are provided in **Table 2**, and a summary of the estimated characteristics of the Grise Fiord Glacier is outlined in **Table 3**.

A prediction of water use in Grise Fiord over the 30 year design life period was performed by ARKTIS in order to fully understand future municipal water use as population increases. A summary of the water use information employed in the water balance calculations is provided in **Table 4**.

## 4.2 Methodology

An entire water balance method was used to calculate the outputs and inputs from Grise Fiord watershed and glacier. Water is removed from the watershed from evaporation and municipal use, and is recharged back into the watershed from direct precipitation and glacial runoff.

At the time of writing this report, the maximum amount of fresh water that can be stored and released in regional glaciers in Grise Fiord has not been quantified by any study. As such, the average annual net balance of the glacier contributing to the water shed was assumed to be equal to that of the Meighen Ice Cap[6]. Due to the relative small size of this ice cap, it was assumed to provide the best conservative estimate for this evaluation, as it has been studied since 1960. From this data, the Grise Fiord glacial melt water contributing to the runoff volume of the watershed was estimated to be 145 mm water equivalent (w.e.), using the equation:

$$B_n = P - R - E \qquad [7]$$

[5] Bob Reid. Evaporation Modelling at Mine Sites in the Northwest Territories and Nunavut, Canada. Arctic Science 2000. Whitehorse, Yukon, Canada. Sept 21-24, 2000.
[6] D.O. Burgess. Mass balance of the Devon (NW), Meighen, and South Melville ice caps, Queen Elizabeth Islands for the 2012-2013 balance year. Geological Survey of Canada. 2014.
[7] W.S.B. Paterson. The Physics of Glaciers. 3rd ed. Elsevier Science Ltd., 1994.

Where:
$B_n$ =Average net balance per year
P = Annual precipitation
R = Total annual runoff
E = Average annual evaporation

This equation assumes that average annual net balance, and the average annual evapotranspiration remain constant, while annual precipitation fluctuates. After finding the average annual runoff from glacial melt, the following equation was used:

$$\Delta S = (R_{GLACIER} + P_{WATERSHED}) - E - U$$

Where:
$\Delta S$ = change in storage and the remaining water supply volume
$R_{GLACIER}$ = annual runoff from Grise Fiord Glacier
$P_{WATERSHED}$ = annual precipitation entering the watershed area
E = annual evapotranspiration
U = annual municipal water use

This change in storage equation assumes that the entirety of the precipitation and glacial melt water entering the watershed undergoes evapotranspiration, and drains into the municipal reservoir. This assumption was made based upon the examination of topographical and remote sensing imagery, and is limited by the lack of information available concerning the hydrological regime of the watershed, and the glacial characteristics in Grise Fiord. For the case in warm season, where the evapotranspiration (E) exceeds the precipitation into the watershed area ($P_{WATERSHED}$), additional recharge into the watershed is assumed to be contributed by glacial runoff. This assumption is supported as it is likely that during the warm season where E > $P_{WATERSHED}$, water flow caused by snow melt and glacial melt is substantial enough to produce a flowing stream. Conversely, during the cold season, precipitation storage is in the form of snow and ice, and likely undergoes negligible evapotranspiration. As part of the detailed hydrological assessment and model, it is important to accurately quantify each variable.

The evapotranspiration, and municipal water use (outputs) are known quantities in this equation, while the annual precipitation and glacial runoff (inputs) amounts fluctuate. Multiple water balance models were run with varying annual precipitation and glacial runoff volumes to assess the sensitivity of the water volume in Grise Fiord to climatic fluctuations. Additionally, a water balance model for the existing 5,000,000 L water reservoir was run to evaluate if this storage volume is supportive of a growing population. The water balance was completed for a 30 year period for each of the modeled cases, and is detailed in **Table 5**.

## 4.3 Results

The results of the water balance modelling are presented in **Table 6**. If the annual precipitation amount is greater than, or equal to the average annual precipitation amount, the model shows that the current Grise Fiord watershed and glacial melt will be sufficient to recharge the reservoir tank every year. The instances where the model shows that the water supply needs are not met from precipitation and glacial melt, is if the community experiences the 3 year lowest annual precipitation average as the annual precipitation, and with the lowest recorded annual precipitation. However, most importantly, the results also reveal that Grise Fiord's 5,000,000 L water reservoir tank runs dry by the end of year 0.

## 4.4 Limitations of Water Balance Results

Due to limitations in the data available, as well as the data quality, the results of this modelling exercise should be considered preliminary. In addition to the limitations in the delineation of Grise Fiord's watershed area and hydrological data (as detailed in **Section 3.2**), the glacial, and climatic data used in the modelling exercise is of uncertain quality, and infers significant gaps in the data set. At the time of writing this report, known characteristics of the Grise Fiord glacier are very limited and had to be estimated from a study completed on a different ice cap. As such, the glacial runoff estimation brings significant uncertainty in contributions to the annual Grise Fiord water supply. Because both precipitation and glacial melt are the driving factors in recharge, any error in the source data and subsequent calculations would significantly change the results of the Grise Fiord water balance. It is also important to note that both climate and annual precipitation display significant fluctuations, which are illustrated in **Figure 3**.

The lack of calculated evapotranspiration data for Grise Fiord also limits the accuracy of any attempt at modelling the water supply. Aside from municipal water use, evapotranspiration is the main source of water removal from the Grise Fiord water shed and glacier. A different evapotranspiration rate in Grise Fiord could significantly change the recharge rate of watershed and glacier. Ideally, this would be quantified through additional field work.

Due to the uncertainty in the limited topographical data, and the lack of field studies detailing the hydrological regime, significant discharge or recharge hydrological features (such as streams, or additional glaciers) could potentially be missed by this water balance evaluation. This missing data could alter the predictions for the Grise Fiord water supply contained in this report.

# 5.0 CONCLUSIONS

Based on the preliminary water balance modelling, the Grise Fiord glacier and existing watershed provides an adequate water supply in Grise Fiord over the 30 year lifespan, providing that prolonged severe drought conditions do not occur. However, the volume of the current 5,000,000 L potable water storage tank is not adequate to sustain the community. If this small storage container is coupled with the occurrence of severe drought conditions, the water supply for Grise Fiord could run dry before year 0. Drought conditions could potentially be a result due to a lack recharge from precipitation and glacial melt. Given the small size of the current watershed and glacier and the lack of inflow from other rivers or lakes, Grise Fiord is uniquely vulnerable to changing precipitation conditions.

It should be noted that the assessment performed for this report was strictly for water quantity, not water quality. In terms of water quality, however, the distance of the glacier and watershed from direct sources of contamination would likely allow the water supply to be of good standard, and permanently unusable under the currently employed method of water extraction and treatment.

# 6.0 RECOMMENDATIONS

To address the limitations in this evaluation described in **Section 3.2** and **Section 4.4**, it is firstly recommended that a minimum additional 2,000,000 L potable water reservoir is brought to the community to sustain the growing population's water supply needs. Furthermore, the new storage tank should meet the compulsory requirements to effectively store water in an arctic climate.

It is also recommended that a full hydrological field study is completed for the currently used and surrounding Grise Fiord watersheds to obtain better quality information regarding the Grise Fiord water supply. This study should include the following:

- Surveying the water supply watershed area of Grise Fiord at an enhanced resolution;
- A field review, which would delineate and quantify hydrological features that would impact the currently used and surrounding Grise Fiord watersheds. The field review should include:
    - Measurement of flow rates and water levels for major streams and channels; and,
    - An evaluation of the modeled watershed area.
- An assessment of the evapotranspiration rate of Grise Fiord.

Because glacial runoff plays a key role in Grise Fiord's water supply, it is also recommended that details regarding the size, and annual net balance of the Grise Fiord Glacier are made known. As additional glaciers in the area contribute to other watersheds, it would be advantageous to quantify their details to provide a comparison analysis, in the event that alternative measures are required.

## 7.0 LIMITATIONS OF LIABILITY

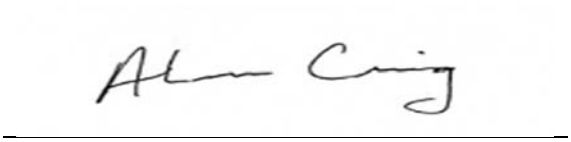
This report has been prepared for the exclusive use of the Government of Nunavut, Community and Government Services for the specific application described in **Section 1.0** of this report. It has been prepared for information purposes only. No other warranty is made, either expressed or implied. For further limitations, please refer to the General Conditions provided in **Appendix B**.

## 8.0 CLOSING

We trust that this report meets your present requirements. Please contact the undersigned should there be any questions.

ARKTIS Piusitippaa Inc.

ORIGINAL SIGNED BY



Andrew Craig, B.Sc., Geoscientist In-Training
Environmental Specialist

REVIEWED BY

Matthew Hamp, P.Eng
VP Nunavut Affairs & Operations

# APPENDIX A – MAPS, TABLES AND PHOTOGRAPHS


**Figure 1 – Site location and layout of Grise Fiord, Nunavut. Image provided by Google Earth**

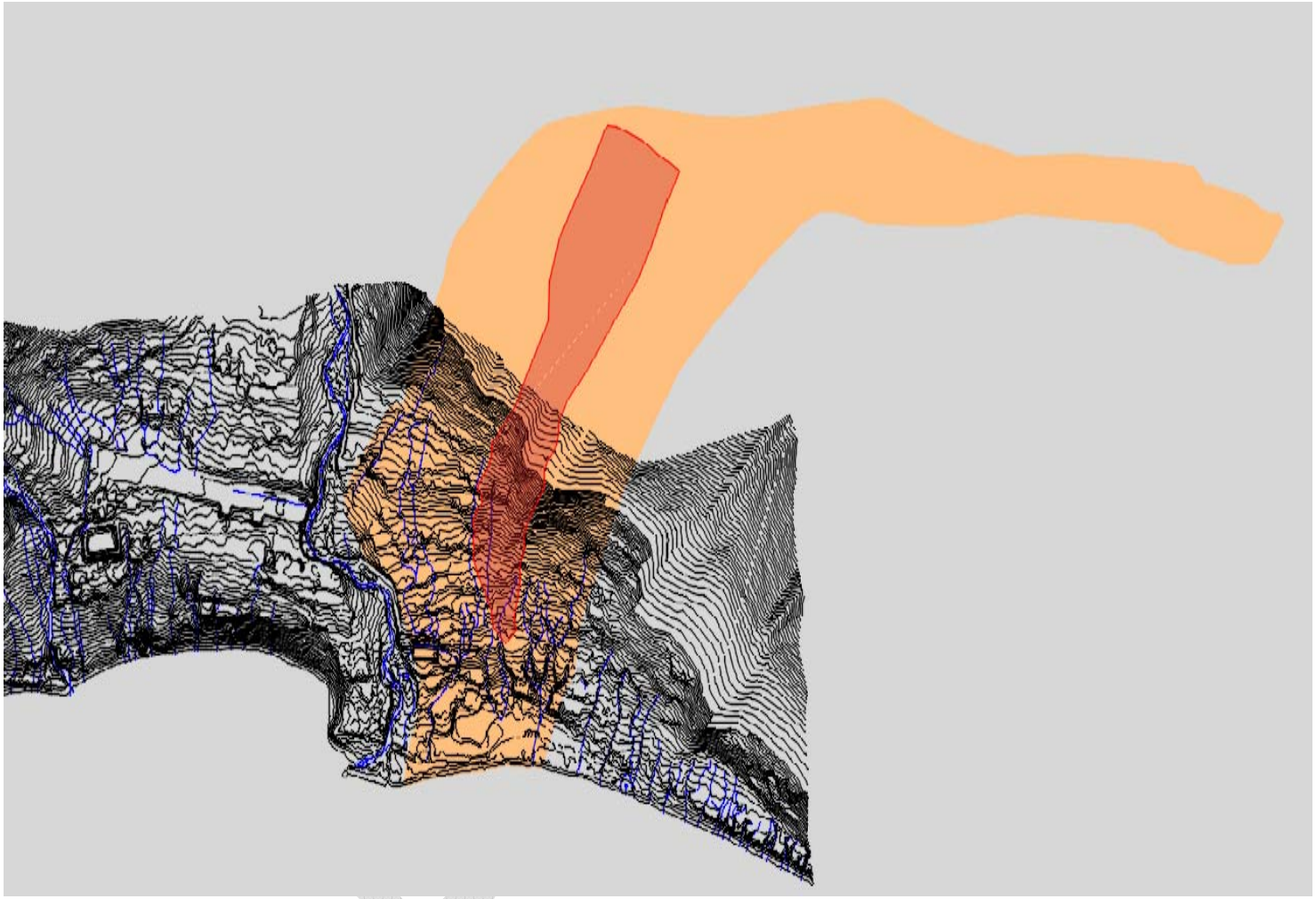


**Figure 2 – The delineated watershed area for the Grise Fiord water supply, as shown in the red area. One meter contours are displayed in black. The area of the entire watershed is shown as the orange area. Additional hydrological features are shown in blue.**

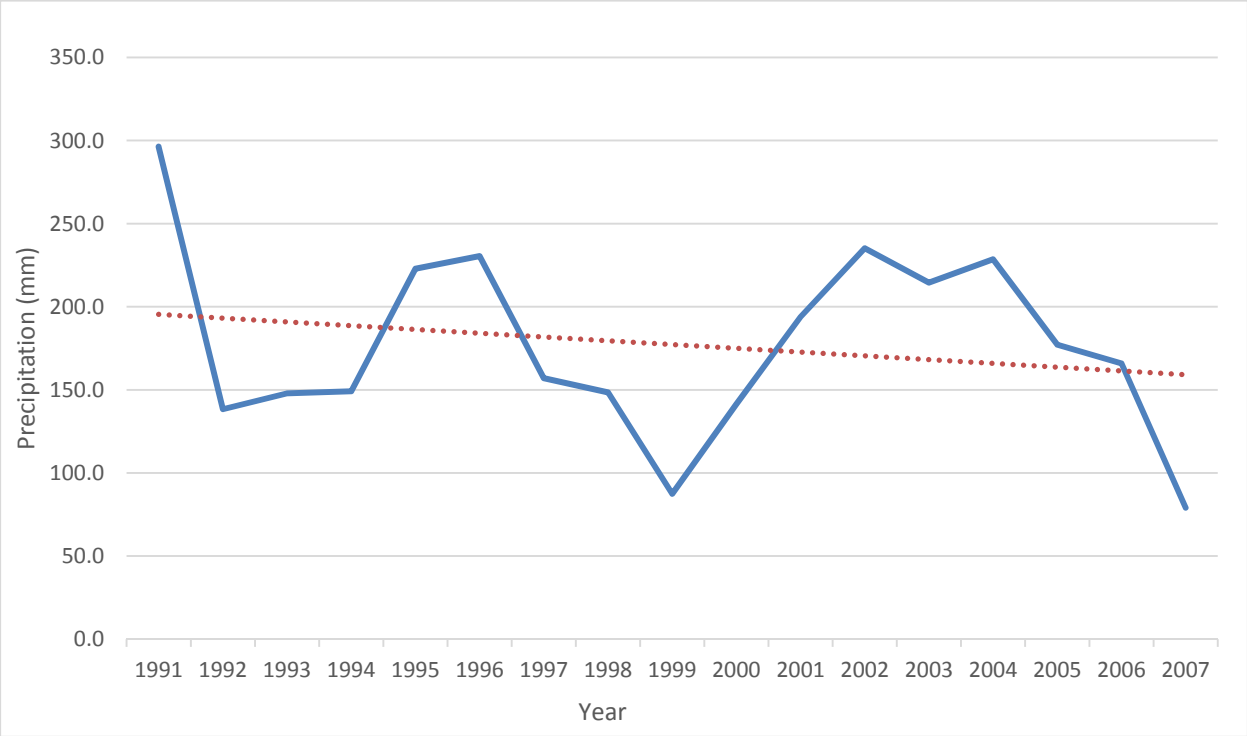



**Figure 3 – A chart of the modified annual precipitation of Grise Fiord from 1991 to 2007, shown in blue, with the trend line shown in red.**

**Table 1 – Modified Annual Precipitation in Grise Fiord, NU.**

| Year | Annual Precipitation (mm) |
|---|---|
| 1991 | 296.3[A] |
| 1992 | 138.4[A] |
| 1993 | 147.9[B] |
| 1994 | 149.1[A] |
| 1995 | 222.9[A] |
| 1996 | 230.5[B] |
| 1997 | 157.0[A] |
| 1998 | 148.5[A] |
| 1999 | 87.4[A] |
| 2000 | 141.4[A] |
| 2001 | 193.9[A] |
| 2002 | 235.2[A] |
| 2003 | 214.5[B] |
| 2004 | 228.6[A] |
| 2005 | 177.2[A] |
| 2006 | 165.9[A] |
| 2007 | 79.1[B] |
| **Average** | **177.3** |

[A] Precipitation data obtained from the Grise Fiord Weather Station (Latitude: 76°25'12.000" N Longitude: 82°54'00.000" W)
[B] Precipitation data obtained from the Resolute Weather Station (Latitude: 74°43'12.000" N Longitude: 94°58'12.000" W)

**Table 2 – Estimated characteristics of the Grise Fiord Watershed**

| Parameter | Watershed |
|---|---|
| Surface Area | 220,000 $m^2$ |
| Average annual evapotranspiration | 192 mm |

**Table 3 – Estimated characteristics of Grise Fiord Glacier, based on Meighen Ice Cap**

| Parameter | Glacier |
|---|---|
| Surface Area | 92,000 $m^2$ |
| Average Annual Total Runoff | 145.3 mm w.e. |
| Average Annual Net Balance | -160 mm w.e. |

**Table 4 – Prediction of water use for the municipality of Grise Fiord, Nunavut**

| Facility Year | Calendar Year | Estimated Population[A] | Water Use | Total Water Use[B] | Total Annual Water Use[C] |
|---|---|---|---|---|---|
| | | | (lpcd) | (L/day) | ($m^3$) |
| 0 | 2014 | 158 | 93 | 14,717 | 5,372 |
| 1 | 2015 | 158 | 93 | 14,755 | 5,385 |
| 2 | 2016 | 159 | 93 | 14,791 | 5,399 |
| 3 | 2017 | 159 | 93 | 14,852 | 5,421 |
| 4 | 2018 | 160 | 93 | 14,927 | 5,449 |
| 5 | 2019 | 162 | 93 | 15,123 | 5,520 |
| 6 | 2020 | 163 | 93 | 15,227 | 5,558 |
| 7 | 2021 | 164 | 93 | 15,352 | 5,603 |
| 8 | 2022 | 166 | 93 | 15,464 | 5,644 |
| 9 | 2023 | 167 | 93 | 15,562 | 5,680 |
| 10 | 2024 | 168 | 93 | 15,671 | 5,720 |
| 11 | 2025 | 169 | 93 | 15,778 | 5,759 |
| 12 | 2026 | 170 | 94 | 15,867 | 5,792 |
| 13 | 2027 | 171 | 94 | 16,021 | 5,848 |
| 14 | 2028 | 171 | 94 | 15,966 | 5,828 |
| 15 | 2029 | 170 | 94 | 15,919 | 5,810 |
| 16 | 2030 | 169 | 94 | 15,845 | 5,783 |
| 17 | 2031 | 169 | 93 | 15,782 | 5,761 |
| 18 | 2032 | 168 | 93 | 15,722 | 5,738 |
| 19 | 2033 | 168 | 93 | 15,666 | 5,718 |
| 20 | 2034 | 167 | 93 | 15,598 | 5,693 |
| 21 | 2035 | 169 | 93 | 15,776 | 5,758 |
| 22 | 2036 | 171 | 94 | 15,956 | 5,824 |
| 23 | 2037 | 172 | 94 | 16,139 | 5,891 |
| 24 | 2038 | 174 | 94 | 16,323 | 5,958 |
| 25 | 2039 | 176 | 94 | 16,510 | 6,026 |
| 26 | 2040 | 178 | 94 | 16,698 | 6,095 |
| 27 | 2041 | 180 | 94 | 16,889 | 6,165 |
| 28 | 2042 | 182 | 94 | 17,083 | 6,235 |
| 29 | 2043 | 184 | 94 | 17,278 | 6,306 |
| 30 | 2044 | 186 | 94 | 17,476 | 6,379 |

**Notes:**
[A] Population data projections and growth rate were provided by Nunavut Bureau of Statistics
[B] Total Water Use = Residential Water Use × (1.0 + (0.00023 × Population)) for populations under 2,000 people as recommended in GNWT Water and Sewage Facilities Capital Program: Standards and Criteria, July 1993. Residential Water Use is assumed to be 90 lpcd.

**Table 5 – The modeled precipitation, glacial melt, and storage cases for the Grise Fiord water balance**

| Recharge | Precipitation | Grise Fiord Glacial Melt (GM) | Description |
|---|---|---|---|
| Average annual precipitation | 177.3 mm | 145.3 mm w.e. | The average annual precipitation of the modified Grise Fiord climate data set. |
| 3 year low precipitation average | 101.6 mm | 69.6 mm w.e. | The average of the lowest 3 years of annual precipitation in the modified Grise Fiord climate data set. |
| 3 year high precipitation average | 254.0 mm | 222 mm w.e. | The average of the highest 3 years of annual precipitation in the modified Grise Fiord climate data set. |
| Lowest recorded annual precipitation | 79.1 mm | 47.1 mm w.e. | The lowest recorded annual precipitation in the modified Grise Fiord data set (recorded in 2007). |
| Ideal total annual precipitation and glacial melt | 5,000,000 L | | The full volume of the municipal potable water reservoir tank. |

**Table 6 – The results of water balance modeled for the watershed in Grise Fiord, Nunavut**

| Facility Year | Calendar Year | Precipitation per annum | | | | |
|---|---|---|---|---|---|---|
| | | 177.3 mm + GM | 101.6 mm + GM | 254.0 mm + GM | 79.1 mm + GM | 5,000,000 L Reservoir |
| | | Grise Fiord Water Volume ($m^3$) | | | | |
| 0 | 2014 | 71,091 | 37,727 | 104,896 | 27,811 | 5,000 |
| 1 | 2015 | 23,395 | 0 | 57,200 | 0 | 0 |
| 2 | 2016 | 23,381 | 0 | 57,186 | 0 | 0 |
| 3 | 2017 | 23,359 | 0 | 57,164 | 0 | 0 |
| 4 | 2018 | 23,332 | 0 | 57,137 | 0 | 0 |
| 5 | 2019 | 23,260 | 0 | 57,065 | 0 | 0 |
| 6 | 2020 | 23,222 | 0 | 57,027 | 0 | 0 |
| 7 | 2021 | 23,177 | 0 | 56,982 | 0 | 0 |
| 8 | 2022 | 23,136 | 0 | 56,941 | 0 | 0 |
| 9 | 2023 | 23,100 | 0 | 56,905 | 0 | 0 |
| 10 | 2024 | 23,060 | 0 | 56,865 | 0 | 0 |
| 11 | 2025 | 23,021 | 0 | 56,826 | 0 | 0 |
| 12 | 2026 | 22,989 | 0 | 56,794 | 0 | 0 |
| 13 | 2027 | 22,933 | 0 | 56,737 | 0 | 0 |
| 14 | 2028 | 22,953 | 0 | 56,757 | 0 | 0 |
| 15 | 2029 | 22,970 | 0 | 56,775 | 0 | 0 |
| 16 | 2030 | 22,997 | 0 | 56,802 | 0 | 0 |
| 17 | 2031 | 23,020 | 0 | 56,824 | 0 | 0 |
| 18 | 2032 | 23,042 | 0 | 56,847 | 0 | 0 |
| 19 | 2033 | 23,062 | 0 | 56,867 | 0 | 0 |
| 20 | 2034 | 23,087 | 0 | 56,892 | 0 | 0 |
| 21 | 2035 | 23,022 | 0 | 56,827 | 0 | 0 |
| 22 | 2036 | 22,956 | 0 | 56,761 | 0 | 0 |
| 23 | 2037 | 22,890 | 0 | 56,694 | 0 | 0 |
| 24 | 2038 | 22,822 | 0 | 56,627 | 0 | 0 |
| 25 | 2039 | 22,754 | 0 | 56,559 | 0 | 0 |
| 26 | 2040 | 22,685 | 0 | 56,490 | 0 | 0 |
| 27 | 2041 | 22,616 | 0 | 56,420 | 0 | 0 |
| 28 | 2042 | 22,545 | 0 | 56,350 | 0 | 0 |
| 29 | 2043 | 22,474 | 0 | 56,279 | 0 | 0 |
| 30 | 2044 | 22,402 | 0 | 56,206 | 0 | 0 |

# APPENDIX B – GENERAL TERMS AND CONDITIONS

## USE OF REPORT

This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

This report and the assessments and recommendations contained within are intended for the sole use of the Government of Nunavut – Department of Community Government and Services (herein after referred to as the "Client"). Arktis Piusitippaa Inc. (herein after referred to as "API") does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any third party unless otherwise authorized in writing by API. Any unauthorized use of the report is at the sole risk of the user.

The Contract states under Terms and Conditions for Consulting Services that "All copyright in the Material belongs exclusively to the Government of Nunavut, Department of Community and Government Services and on request the Contractor shall deliver document satisfactory to the Government of Nunavut, Department of Community and Government Services, waiving moral or other legal rights the Contractor or his employees or subcontractors may have in the Material and confirming and vesting such copyright in the Government of Nunavut, Department of Community and Government Services."

## LIMITATIONS OF REPORT

This report is based solely on the conditions which existed on site at the time of API's investigation. The client, and any other parties using this report with the express written consent of the clients and API, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive.

The client, and any other party using this report with the express written consent of the client and API, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made.

The client acknowledges that API is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

During the performance of the work and the preparation of this report, API may have relied on the information provided by third parties. While API endeavors to verify the accuracy of such information when instructed to do so by the client, API accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

## LIMITATIONS OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of API providing the services requested, the client agrees that API's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

a. With respect to any claims brought against API by the client arising out of the provisions or failure to provide services hereunder shall be limited to the amount of fees paid by the client to API under this Agreement, whether the action is based on breach of contract or tort;
b. With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold

harmless API from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by API, whether the claim be brought against API for breach of contract or tort.

**STANDARD OF CARE**

Services performed by API for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

**ALTERNATE REPORT FORMAT**

Where API submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed API's instruments of professional service), the Client agrees that only the signed and sealed (if applicable) hard copy versions shall be considered final and legally binding. The hard copy versions submitted by API shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by API shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions (or scanned electronic versions thereof) of API's instruments of professional services shall not, under any circumstances, no matter who owns or uses them, be altered by any party except API. The Client warrants that API's instruments of professional services will be used only and exactly as submitted by API.