Government of Nunavut

Igloolik Water Reservoir Expansion

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Design Brief

Project Name
Igloolik Water Reservoir Expansion

Project Number
OTT-0000228428-A0

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Date Submitted
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PERMIT TO PRACTICE
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Date Feb 19, 2016
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NT/NU Association of Professional Engineers and Geoscientists

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1 Introduction

In June 2015, the Hamlet of Igloolik (Hamlet) experienced a water shortfall in their water reservoir. As a result an emergency response, which included utilizing an alternate water source lake was implemented. **Exp** Services Inc. (**exp**) were retained in the fall of 2015 to complete a risk assessment of the reservoir. This risk assessment concluded that the reservoir was at or near the end of its ability to provide over-winter storage for the Hamlet's population. As a result of the risk assessment the Department of Community and Government Services (CGS), Government of Nunavut (GN) retained the services of **exp** to provide engineering services for the design and construction of a reservoir expansion. The following report will set forth the design parameters for the reservoir expansion.

1.1 Background Information

The Hamlet is located on Igloolik Island in the northwest region of the Foxe Basin. Its water source is South Lake which is located in the southern region of the Island. Over-winter water storage is provided in an excavated reservoir located near the airport. The Igloolik water reservoir was constructed at the site of a small lake. Over-winter storage was increased through mass excavation to provide a total depth in parts of the lake of approximately 10 m. The reservoir was originally constructed in the late 1970's and was expanded in 1993 and in 1998. The Igloolik water reservoir is recharged on a yearly basis with water pumped from South Lake, see Figure 1, Appendix A.

In response to the shortfall of water experienced in the spring of 2015 a risk assessment was undertaken by **exp** to determine the water reservoir's ability to meet the over-winter requirements of the Hamlet. The drawdown analysis undertaken as part of this risk assessment for the winter of 2015 / 2016, based upon actual consumption rates from 2014 indicated that there would be minimal water available at the end of June 2016. The drawdown analysis did not account for any water consumption other than potable water. The report concluded, that the water reservoir would meet the Hamlet's water storage requirements for the 2015 / 2016 over-winter period, but with minimal reserve. The results were concluded to be outside the accuracy of the drawdown analysis for the reservoir, based on the precision of the information and assumptions. The Hamlet is therefore at risk of running out of water during the 2015 / 2016 overwinter period. The report concluded that the water reservoir was at the limits of its ability to meet the water consumption of the Hamlet. The risk assessment analyzed the reservoir's ability to meet the long term (20 year) requirements of the Hamlet based upon historical water consumption rates, 90 lpcd and the MACA (Municipal and Community Affairs, Northwest Territories) RWU (Residential Water Use) equations. The Risk Assessment Analysis estimates of shortfall of storage for all three consumptions rates for the year at 2035 / 2036 summarized in table below.

Table 1.1 – Summary of Drawdown Analysis Winter 2035 / 2036

Scenario	Estimated Shortfall In Storage
Actual Consumption Rates (75.3 lpcd)	13,000 m^3
RWU (90 lpcd)	23,000 m^3
MACA RWU (140.3 lpcd)	58,000 m^3

The findings of the risk analysis indicate that matter of available over-winter water storage in Igloolik requires immediate attention. On this basis CGS has directed that the following Design Brief for an expansion in stored water capacity be prepared.

2 Population

The Nunavut Bureau of Statistics publishes the Nunavut Population Projections which provide estimates of the population for all the communities within Nunavut to the year 2035. The Hamlet of Igloolik's published population projection (December 2014) for 2015 is an estimated population of 2039. The population projections as per the Nunavut Bureau of Statistics are shown in Table 2.1 below for the years 2014 through to 2036. A projection of population to 2036 has been developed based on an extrapolation of the estimates developed by the Nunavut Bureau of Statistics. The data provided by the Bureau indicates an annual rate of growth of population of 1.46%. This leads to an estimated population of 2,761 at a 20 year horizon.

Table 2.1 – Population Projections

Year	Population
2014	2007
2015	2039
2026	2409
2031	2580
2036	2761

3 Water Consumption and Storage

As per the direction of CGS, the MACA RWU equations were used to generate water consumption rates for planning for additional storage capacity, as is summarized in this report. A review of historic water consumption has been included for comparison purposes.

3.1 MACA RWU – The Equations

The General Terms of Reference for Community Water and Sanitation Services Study, as published by the Department of Municipal and Community Affairs (MACA), Government of Northwest Territories (GNWT) has a series of equations based on population, which estimate total water consumption including non-residential usage such as commercial, institutional and industrial activities. The MACA equations are all based on the RWU rates multiplied by a factor which are tied to the population of the Hamlet. The RWU for residents serviced by trucked water delivery and sewage pump out collection is specified as 90 lpcd.

The MACA RWU equations are as follows:

Total Community Population	Per Capita Water Usage
0 to 2,000	Residential Rate x (1.0 + 0.00023 x Population)
2,000 to 10,000	Residential Rate x (-1.0 + 0.323 x ln Population)
Over 10,000	Residential Rate x 2.0

Table 3.1 summarizes the consumption rates based on the MACA RWU Equations:

Table 3.1 - Actual Consumption Rates

Year	Population	Per Capita Daily Consumption (litres)
2015	2039	132
2026	2409	136
2031	2580	138
2036	2761	140

3.2 Water Consumption Rates Based on Actual Water Consumption Rates

The annual reports for the Hamlet's water licence were obtained through the Nunavut Water Board's public registry. Reported annual consumption, together with the populations from the Nunavut Bureau of Statistics, provides historical per capita daily consumption. Table 3.2 below summarizes the annual consumption and the per capita daily consumption rates for the years 2012 through 2014.

Table 3.2 – Historical Consumption Rates

Year	Population	Consumption (litres)	Per Capita Daily Consumption (litres)
2012	1906	51,227,919	73.6
2013	1952	53,096,725	74.5
2014	2007	55,085,387	75.2

The average historical water consumption rate for the period of 2012 to 2014 was 74.4 lpcd. This rate is considerably less than the consumption rate based on the MACA RWU equations which would imply that the use of the MACA RWU consumption rate will provide a conservative estimate.

3.3 Over-Winter Storage

The Hamlet's water reservoir is intended to provide over-winter storage to meet the Hamlet's water consumption requirements. The over-winter storage is typically defined by the period from the first day after recharge is completed to the end of winter. The existing reservoir has an over-winter capacity of approximately 46,500 m^3.

As per the Igloolik Water Reservoir Risk Assessment by **exp** (2015), it was reported by Hamlet staff that reservoir recharge from the source lake had been completed during the week of September 7th, 2015. As per the Risk Assessment Report, the date of September 7th will be used as the start of the over-winter storage period for the purpose of this report.

The last day of winter is difficult to quantify as it varies from year to year. One definition is, the first day that exhibits an average daily temperature of above 2^o C, followed by 3 consecutive days each one exhibiting a daily average air temperature of 0.5^o C. Defining the last day of winter by any such definition enables a historical description of the last day of winter, however it does not provide a prediction of the future dates for design or analysis purposes. In 2015, the water reservoir was reported as not recharged from spring runoff until late June. For the purpose of this report the date of June 30 will be used for the end of over-winter storage to capture such an extreme year.

Based on over-winter storage starting on September 7th and ending on June 30th, the water reservoir must be able to meet the Hamlet's water consumption requirements for 296 days

Based on the population projections summarized in Table 2.1 and water consumption rates as per the MACA RWU equations summarized in Table 3.1, the over-winter storage requirements for a 10 year, 15 year and 20 year design horizons are summarized in Table 3.3 below.

Table 3.3 – Over-Winter Storage Requirements

Year	Consumption Rate (lpcd)	Population	Over-winter (m^3)
2026	136	2409	96,977
2031	138	2580	105,388
2036	140	2761	114,416

4 Water Reservoir Storage Requirements

4.1 Fire Storage

The guidelines for Good Engineering Practices published by the GNWT, Public Works and Services – Section 12 - Water Storage, does not specify a fire storage requirement for seasonal storage facilities such as the Hamlet's water reservoir. However, for trucked systems there is a fire storage requirement for short term storage within or near the community of a minimum of 60,000 litres. It is **exp**'s interpretation that this storage requirement is for a refillable storage reservoir intended to service a single fire event.

As discussed in Section 3, the historical consumption rates are much lower than the design rates from the MACA RWU equations. For the purpose of this project, it is recommended that the fire flow storage requirement be assumed to be considered in these higher rates of consumption. As a minimum **exp** recommends that a 300,000 litre fire storage be reserved for fire storage which, in essence, would provide the equivalent of 5 fire events per year.

4.2 Freeboard

The Risk Assessment Report assumed a one metre freeboard when determining the storage requirements. Based on the topographic information available, the one metre freeboard provides a maximum water elevation of the reservoir of 50 m. The survey completed with the risk assessment showed the water level at the time of the survey to be approximately at 50 m. Hamlet staff indicated, at the time of the survey, that they typically fill the reservoir higher than the level in 2015 (50 m). They did not quantify how much higher the water elevation was when they considered it full. For the purpose of this project it is recommended that the maximum water elevation be considered to be 50 m.

4.3 Dead Zone

The OMM report for the water reservoir expansion from the late 1990's, reported that in 1993 an expansion of the facility was undertaken and this expansion was to include the extension of the intake pipe to reduce the dead zone. However, it was reported that the planned extension of the intake did not proceed. Based on the information provided in the OMM report, it is assumed that the existing intake elevation is at 43.10 m, with a potential extension to lower the intake to 42.45 m. For the purpose of this report the existing intake elevation of 43.10 m will be assumed.

5 3 - Dimensional Model of Reservoir

As part of the Risk Assessment project undertaken by **exp**, a 3 - dimensional computer model (3D model) of the reservoir was prepared. The 3 – dimensional model was used to develop an incremental volume model of the reservoir for use in the drawdown analysis. The 3D model of the reservoir was used to undertake a drawdown analysis of the 2014 / 2015 over-winter period. The results of the analysis is closely represented in the actual drawdown of the reservoir that occurred in the 2014 / 2015 winter, with the model showing a shortfall in storage at the end of May. This closely represents the historic events of early 2015. Therefore, it is concluded that the model is a good base for the evaluation of the reservoir expansion.

It should be noted that it was not possible to obtain an actual elevation of the intake to the truck-fill station. For the purpose of this report the intake elevation reported in the 1998 Oliver, Mangione, McCalla and Associates' (OMM) report was used. There may be some discrepancies between the reported elevation of the intake and the actual elevation relative to the survey completed in 2015. In addition, the critical elevation, when determining the storage capacity of the reservoir, is the elevation of the pump which may be different than the elevation of the intake. It is assumed that the reported 43.10 m elevation is actually the elevation of the pump.

It is understood that the Hamlet's Truck-fill Station will be upgraded in the near future. At the time of this report it was unknown if the upgrades included a change in the elevation of the intake pump. Therefore at this time the elevation is assumed to remain at 43.10 m. Actual information regarding the proposed upgrades should be made available and incorporated into the design of the reservoir expansion.

6 Drawdown Analysis Methodology

6.1 Static Drawdown Analysis

One method of calculating the volume of water available at the storage facility over the winter storage period is to determine the volume of water available under the design ice thickness. The design ice thickness is the maximum thickness of ice that has developed on the body of water over the winter period. This approach is considered a static method as the depth of ice is considered constant and is a conservative approach to calculating the volume of water available.

6.2 Dynamic Drawdown Analysis

The dynamic drawdown analysis approach recognizes the variability of ice and water consumption rates during the over-winter period. It recognizes that as water is withdrawn from storage on a continuous basis, the underside of the ice elevation would also drop as the water is being withdrawn beneath it. Additionally, the dynamic drawdown approach recognizes that the thickness of the ice cover grows during the winter, which also lowers the underside of ice elevation. The amount that the elevation of underside of ice would drop over a period of time is equal to the drop associated with consumption (the distance equivalent to the volume of water withdrawn divided by the area of the underside of the ice) and the growth in ice thickness combined.

For a dynamic drawdown analysis, the over-winter period is divided into segments, typically monthly. For each time segment the reduction in storage volume lost to ice growth and water consumption is removed from the overall volume. A dynamic drawdown analysis requires the estimation of monthly ice thickness over the course of the winter.

The process for calculating the dynamic drawdown analysis is as follows:

1. Establish the incremental time period, typically monthly.
2. Define the area to be used for the initial depth, typically the surface area of the reservoir at the start of the over-winter period.
3. Determine the volume of water withdrawn for an incremental time period (monthly consumption).
4. Determine the depth of water, due to consumption, by dividing the volume from Step 3 by the area in Step 2.
5. Define the ice growth for the incremental time period used in Step 3.
6. Calculate the new underside of ice elevation at the end of the period by subtracting the drop in elevation due to consumption as calculated in Step 4 and the incremental ice growth depth found in Step 5 from the initial depth in Step 1.
7. Repeat steps 2 through 6, substituting the area for the depth calculated in Step 6 for the initial area. Repeat this for each period in the season or until maximum permissible drawdown is reached.

6.3 Recommended Drawdown Analysis

The static approach is conservative as it assumes that the full depth of ice is generated prior to the start of water consumption and therefore it allocates the entire top section of the reservoir as an ice zone. As the upper region of a typical body of water has a much greater volume than the lower region per incremental depth this is deemed to be a conservative approach. The dynamic drawdown approach better represents the loss of water from storage both through the ice growth and consumption. The dynamic drawdown analysis will be utilized for this assessment.

7 Reservoir Expansion

7.1 General

As previously referenced the Risk Assessment Report determined that the existing reservoir could not meet the long term requirements of the Hamlet. To determine an initial estimate of the required excavation to meet the long term needs of the Hamlet for over-winter storage, dynamic drawdown analysis of the existing reservoir was undertaken for water consumption rates based upon the 10, 15 and 20 year design horizon. Based on the drawdown analysis included in Appendix B, the estimated shortfall for the reservoir for the three design horizons are summarized below.

Table 7.1 – Storage Shortfall Existing Reservoir

Design Horizon	Shortfall (m^3)
2026 (10 years)	42,400
2031 (15 years)	49,600
2036 (20 years)	57,200

As shown in Table 7.1 the estimate of the shortfall for the overwinter storage requirements for the Hamlet on a 20 year design horizon is approximately 57,200 m^3.

7.2 Reservoir Expansion Opportunities

7.2.1 Excavate to Limits of the Water Body

The alternative of excavating to the limits of the existing water body was examined to determine the increase in the over-winter storage capacity gained. It was determined that an area of approximately 7,100 m^2 is available for full depth excavation. This potential area for excavation is depicted on Figure 2. A 3D model of this option was prepared for the maximum limits of excavation, as shown on Figure 2 and dynamic drawdown analysis was completed. The dynamic drawdown analysis showed that the proposed expansion would not meet the over-winter storage capacity at any of the design horizons. The drawdown analyses are included in Appendix B and the summary of the storage shortfall of each are summarized in Table 7.2 below.

Table 7.2 – Storage Shortfall – Expanded Reservoir

Design Horizon	Shortfall (m^3)
2026 (10 years)	18,600
2031 (15 years)	26,200
2036 (20 years)	34,250

7.2.2 Lower the Water Intake and Reduce the Freeboard

As noted in Section 4.2, the Hamlet staff indicated that they have filled the reservoir above the 50 m elevation thereby reducing the freeboard. A drawdown analysis was completed for a reduction in the freeboard to 0.5 m, thereby increasing the storage depth. The drawdown analysis showed that decreasing the freeboard by 0.5 m would generate an additional 8,650 m^3 of over-winter storage capacity.

As referenced in Section 1 – Background Information, the OMM Report of 1998 indicated that there was an allowance in the original design of the reservoir to lower the water intake line from 43.10 m to 42.45 m, providing an additional depth of storage of 0.65 m. A drawdown analysis was undertaken for the 20 year design horizon based on the water intake line being lowered to 42.45 m. The drawdown analysis showed that reducing the intake elevation would create approximately 8,000 m^3 additional over-winter storage capacity.

The lowering of the intake and decreasing the freeboard as indicated above would not increase the storage sufficiently to meet the 20 year design horizon. Upon discussions with the GN it was confirmed the expansion of the water reservoir would set the water intake elevation and the Truck-fill Station design would be revised to match.

Reviewing the bathometric survey, it was determined that the elevation of the bottom of the reservoir was at an elevation between 40.0 and 41.0m. A 3D model was prepared using a water intake elevation of 42-0mmaintaining a minimum of 1.0m of dead zone. A drawdown analysis on an expanded reservoir with maximum elevation of 50.5 m and a bottom of active storage elevation of 42.0 m resulted in an over-winter storage capacity of 102,800 m^3. The drawdown analyses are included in Appendix B and the summary of the storage shortfall of each are summarized in Table 7.2 below.

Table 7.3 – Storage Shortfall/Surplus – Expanded Reservoir

Design Horizon	Shortfall/Surplus (m^3)
2026 (10 years)	5,500 Surplus
2031 (15 years)	3,000 Shortfall
2036 (20 years)	11,600 Shortfall

7.3 Review of Water Consumption Rate

The Hamlet's existing water reservoir successfully met the over-winter storage requirements until the 2014 / 2015 winter at which time the Hamlet experienced a shortfall in over-winter storage capacity. Discussions with the Hamlet staff indicated that it was felt that the shortfall was in part due to the incomplete filling of the reservoir during the recharge season in the summer of 2014, as well as a late spring melt. The proposed reservoir expansion to the limits of the existing water body as discussed in Section 7.2.2, does not meet the 15 or 20 year design horizons over-winter storage capacity based on the population projections and per capita water consumption utilizing the MACA RWU equations.

A series of drawdown analyses were undertaken to determine the maximum over-winter capacity that could be supported by the expanded water reservoir. It was determined that approximately 102,800 m^3 of over-winter storage would be available given the limits of excavation proposed and a lower water intake. Utilizing the MACA RWU equations it was determined that this over-winter storage capacity could support a population of approximately 2522 persons, which the population in 2029. For the design horizon (2036) population of 2761, the maximum over-winter storage capacity of 102,800 m^3 provides a daily consumption rate of 125 lpcd which is 168% of the historical consumption rate of the Hamlet.

8 Constructability of the New Water Reservoir

The expansion of the water reservoir is essentially a massive rock excavation or quarrying operation. The reservoir must be fully drained, the rocks drilled and blasted and then a mass excavation and removal process undertaken. The newly excavated reservoir must then be completely refilled prior to the onset of freezing weather. The existing reservoir has a ramp which allows access to the bottom of the reservoir and also is the location of the water intake line. This ramp will not be altered as part of the water reservoir expansion program.

The reservoir expansion referenced in Section 7, would result in an excavation of approximately 57,600 m^3 of material. The Hamlet currently has limited heavy equipment to undertake such a large mass rock excavation project. Much of the required equipment will need to be brought into the community by sealift. A review of sealift schedules for the Hamlet indicates that the first sealift typically does not arrive until early to mid-August. Beginning a mass excavation this late in the season would not allow for recharge of the reservoir before the onset of winter. Therefore, it is highly unlikely that mobilization and the expansion of the reservoir to its full capacity could be undertaken in a single construction season.

The two alternatives approaches for undertaking the work are:

1. In recognition that the Hamlet's water reservoir is at or near its capacity for overwinter storage a partial expansion of the reservoir be undertaken in the 2016 construction season with the equipment available within the community. A secondary and larger expansion could be undertaken in the 2017 construction season with the required equipment mobilized into the Hamlet in 2016. The draw back to this approach is the Hamlet would be required to operate the truck filling operations at a temporary facility located at South Lake for two summer. The operation of the temporary facility adds operational costs as the temporary facility is further from the Hamlet adding to the cycle time for the water trucks.

2. To reduce the operation cost for the Hamlet the project could be undertaken with mobilization in the first year (2016) and construction in the second (2017). The major drawback to this approach is expansion does not occur until 2017 requiring the Hamlet to be dependent on the existing reservoir for one more winter. This adds an additional year that the Hamlet is dependent on the current over-winter storage capacity which has been shown to be at or near its limits.

One of the key components of determining the level of effort required is to determine the disposal site for the material. A distant disposal site will greatly affect the cycle time for the trucks and would impact the construction schedule and cost.

Recognizing that other large earth moving projects may be required in the near future, there may be some benefit to considering the implications of multiple projects when tendering the water reservoir expansion.

9 Water Recharge of Water Reservoir

The recharging of the water reservoir is typically undertaken during the summer and typically spans from early July through to early or mid-September, weather permitting. As the construction season for the expansion of the water reservoir will encroach into the timeframe for the typical recharge of the water reservoir, the responsibility for ensuring that the reservoir is recharged prior to the first day of winter should be part of the expansion contract. The quantity of recharge should be sufficient to fill the dead zone, provide over-winter storage for the upcoming winter with a safety allowance, and an allowance for ice.

10 Temporary Truck-filling and Water Treatment

Expansion of the reservoir will temporarily render the truck-fill station unusable. Therefore, the provision of a temporary truck-fill station for the duration of construction will be required. The temporary truck-fill can withdraw water directly from the source (South Lake). This facility must meet the current level of treatment that is being achieved by the trucked delivery system for the Hamlet.

The temporary system must achieve (at a minimum) the following criteria:

- Easy fill connection for the existing delivery trucks
- 1000 litres per minute fill rate (for fire protection)
- A suitable free chlorine dosage following contact for disinfection (20 minute contact time)
- Supply water must be or a quality consistent with the current source

In order to achieve this there are two potential contract options:

1. The design of a temporary fill system could be undertaken and this would incorporate an automated system for chlorine addition, a scaffold design for support of the truck top fill mechanism, control for the flow rate and a separate power supply for control of automation. This could be considered to be a onetime use system and would have to be dismantled and mothballed in the Hamlet when the construction is complete. Parts of this system may be usable elsewhere, such as the generator, flow control valve and chlorination injection system. The system would need to be maintained by Hamlet staff while in operation. This would include checking the chlorine dosage and maintenance of all of the equipment. A prescribed wait time for each truck must then be established to achieve 20 minutes of contact time. The benefits of this system is level of disinfection can be monitored/controlled, with the drawback being additional equipment to be operated and maintained on a temporary basis. Another drawback could be the cost, as this would be a site specific design it would be purchased as part of the project and would be redundant after the project has been completed.
2. The use of a performance based contractor specification for the contractor to maintain a temporary truck-fill station is a common method of facilitating a temporary truck-fill station for this type of work. Historically a contractor will erect a scaffold for the truck top fill, provide a pump for filling and then facilitate a method for adding chlorine to the truck. This typically includes a pre-measured amount of J-12 Hypochlorite that must be added to each truckload every time it is filled. A prescribed wait time for each truck must then be established to achieve 20 minutes of contact time. The benefit to this is that any equipment (pumps, scaffold, valves, etc.) would be the responsibility of the contractor and would leave the site when the temporary filling is no longer required. The drawback is that the control of the disinfection addition is subjective and a method of checking that disinfection is being carried out is required.

Both contract options have some benefits and some drawbacks. Developing a method that will give the constancy for water quality and disinfection should be of utmost importance for the selection of the contract approach selection and planning for the temporary supply.

11 Summary and Recommendations

11.1 Summary

1. Based on the Risk Assessment undertaken by **exp** in the fall of 2015, it was concluded that the Hamlet's water reservoir is at, or near its ability to meet the Hamlet's over-winter water storage requirements.
2. For the design of the water reservoir expansion, the 20 year design horizon and water consumption rates based on the MACA RWU equations were selected.
3. The design population for the year 2036, based upon the Nunavut Bureau's statistics published for Nunavut population projections was 2761.
4. The water consumption rate, based on the MACA RWU equations for the population of 2761 is equal to 140 lpcd.
5. Review of historical water consumption rates for 2012 through to 2014 revealed an average consumption rate of 74.4 lpcd.
6. It is believed that the MACA RWU equations account for fire storage as part of the non-potable water usage. As an alternative it was recommended that a minimum storage of 300,000 litres be allocated based on five fire events, with a requirement of 60,000 litres per event.
7. A review of the existing water reservoir against the 20 year design horizon determined that the existing reservoir had a shortfall of approximately 57,200 m^3.
8. A drawdown analysis of an expansion of the reservoir to roughly the maximum limits within the existing waterbody was undertaken and this determined that the expanded water reservoir would still have a shortfall of approximately 34,250 m^3 at the design horizon of the year 2036.
9. The option of lowering the water intake line from 43.1, to 42.00 m, and the reduction of the freeboard from 1 m to ½ m in addition to the expansion of the reservoir footprint was examined. A series of drawdown analyses that were undertaken on the proposed expansion determined that a maximum over-winter storage capacity of approximately 102,800 m^3 would be available. This resulted in a shortfall of over-winter storage of 11,600m^3.
10. The 102,800 m^3 of storage could serve a population of 2,522 persons based on the demands estimated by the MACA RWU equation which corresponds to a population in the year 2029.
11. The 102,800 m^3 of storage corresponds to a consumption rate of 125 lpcd for the 2036 design horizon population of 2761. This is 11% less than the amount estimated by the MACA equations and is 168% of the Hamlet's historical consumption rate.
12. It was noted that the Hamlet has minimal heavy equipment to undertake such a large expansion of the water reservoir. As the sealift does not arrive into Igloolik until early to mid-August, there would be insufficient time for equipment to be mobilized and to undertake the full water reservoir expansion in a single season.
13. The expansion of the water reservoir would be required to occur during the recharge season which would impact the Hamlet's ability to recharge the reservoir.
14. The expansion of the water reservoir would temporarily put the Hamlet truck-fill station out of commission. Temporary truck-filling and water treatment facilities would be required to be operational during the expansion of the water reservoir. Any temporary truck-filling facility should meet the current standards of treatment which is chlorine disinfection.

15. There are two alternative approaches including the provision of temporary truck-filling and water treatment facilities in the contract for the expansion of the water reservoir. The first is provide a detail design which would be included in the contractor's responsibility. The second alternative would be to provide a performance specification, allowing the contractor to determine how best to meet the requirements set forth in the contract.

11.2 Recommendations

1. It is recommended that the existing water reservoir in Igloolik be expanded to the limits shown on Figure 2. It is further recommended that the intake be extended to elevation 42.0m and that freeboard be reduced to 0.5 m.
2. It is recommended that the responsibility to recharge the water reservoir prior to the winter season be included in the scope of services for the contractor undertaking the water reservoir expansion.
3. It is recommended that the water recharge capacity be sufficient to account for the dead zone, the projected overwinter water consumption of the Hamlet, a 300,000 litres fire protection allowance, plus a 20% contingency. The Hamlet currently operates a recharge pump, however, it is believed that the contractor should be responsible for providing their own equipment to complete the recharge and the Hamlet facility could be reserved for an emergency contingency.
4. It is recommended that the responsibility for the provision of temporary water truck-filling and water treatment facility be part of the contract for the water reservoir expansion. It is recommended that the contract included a performance specification allowing the contractor to best determine how to provide the required facility.
5. The proposed expansion of the water reservoir to the approximate limits of the existing waterbody and reducing the freeboard and lowering the water intake does not meet the 20 year design horizon requirements based on the population projection and per capita water consumption rates from the MACA RWU equations of 140 lpcd. As the proposed expansion would provide a daily consumption rate of 125 lpcd for the 20 year design horizon population, which is equal to 89% of the design consumption rate and is 168% of the historical demand, it is recommended that CGS reconsider the TOR for this expansion and undertake the expansion of the reservoir to the practical limits of the water body, reduce the freeboard to 0.5m and lower the water intake to 42.0 m.

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Appendix A – Figures

CLIENT

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SCALE NOT TO SCALE	PROJECT IGLOOLIK WATER RESERVOIR EXPANSION	PROJECT No. 228482
DATE December 15	TITLE LOCATION PLAN	DRAWING No. FIG.1
CAD SAB		

Filename: \\POTTFSG002\Data\Projects\Civil Engineering Services\228000\OTT-00228482-A0 - Igloolik Bathymetric Survey - GN\Design Phase\228482-FIG1.dwg
Last Saved: Oct 27, 2015 2:13 PM Last Plotted: Dec 24, 2015 10:24 AM Plotted by: butlers

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SCALE 1:750 DATE December 15 CAD JMc	PROJECT IGLOOLIK WATER RESERVOIR EXPANSION TITLE PROPOSED EXPANSION	PROJECT No. 228482 DRAWING No. FIG.2

Filename: P:\Projects\Civil Engineering Services\228000\OTT-00228482-A0 - Igloolik Bathymetric Survey - GN\60-Project Execution\2-Drawings\228482 OG.dwg
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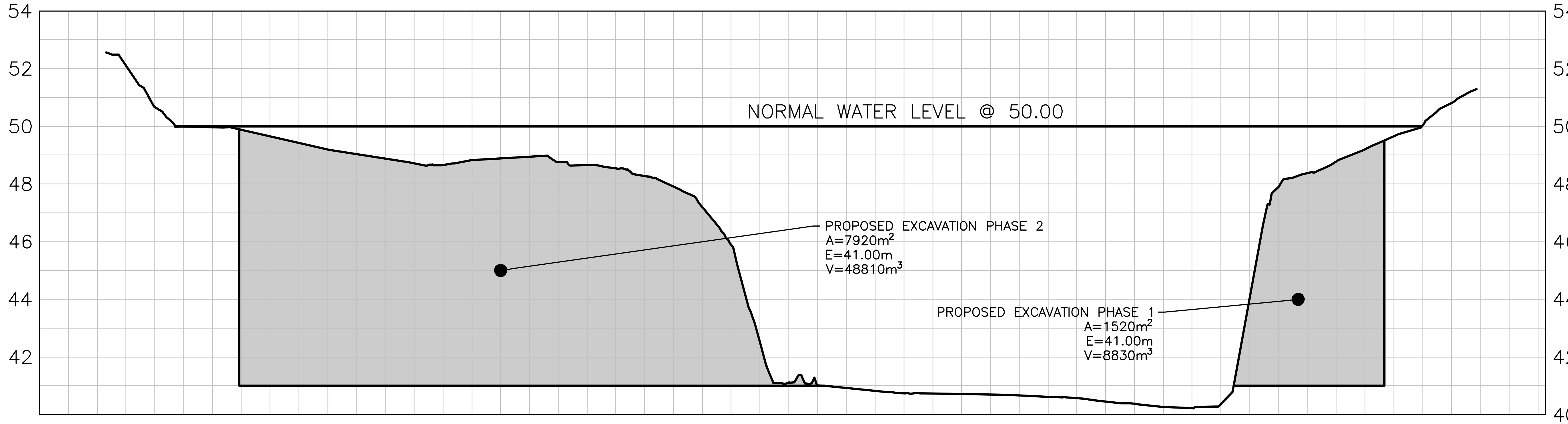
A–A



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SCALE H1:750, V1:150	PROJECT IGLOOLIK WATER RESERVOIR EXPANSION		PROJECT No. 228482
DATE Decemeber 15	TITLE RESERVOIR SECTIONS		DRAWING No. FIG.2
CAD JMc			

Filename: P:\Projects\Civil Engineering Services\228000\OTT-00228482-A0 – Igloolik Bathymetric Survey – GN\60-Project Execution\2-Drawings\228482 OG.dwg
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Appendix B – Drawdown Analysis

Drawdown Analysis
Existing Reservoir
Year 2026

Month	Underside of Ice (m)	Area (m^2)	Water Use (m^3)	Drop due to Use (m)	Ice Growth (m)
September	50.00	20102	7535	0.37	0.10
October	49.53	17949	10156	0.57	0.40
November	48.56	11043	9829	0.89	0.35
December	47.32	8738	10156	1.16	0.33
January	45.83	7712	10156	1.32	0.28
February	44.23	6910	9173	1.33	0.22
March	42.68		10156	#DIV/0!	0.16
April	#DIV/0!		9829	#DIV/0!	0.10
May	#DIV/0!		10156	#DIV/0!	0.06
June	#DIV/0!		9829		
	#DIV/0!				
Totals				#DIV/0!	2.00

Estimated Shortfall 42444

Drawdown Analysis
Existing Reservoir
Year 2031

Month	Underside of Ice (m)	Area (m^2)	Water Use (m^3)	Drop due to Use (m)	Ice Growth (m)
September	50.00	20102	8189	0.41	0.10
October	49.49	17785	11037	0.62	0.40
November	48.47	10671	10681	1.00	0.35
December	47.12	8567	11037	1.29	0.33
January	45.50	7543	11037	1.46	0.28
February	43.76	6663	9969	1.50	0.22
March	42.04		11037	#DIV/0!	0.16
April	#DIV/0!		10681	#DIV/0!	0.10
May	#DIV/0!		11037	#DIV/0!	0.06
June	#DIV/0!		10681	#DIV/0!	
	#DIV/0!				
Totals				#DIV/0!	2.00

Estimated Shortfall 49574

Drawdown Analysis
Existing Reservoir
Year 2036

Month	Underside of Ice (m)	Area (m^2)	Water Use (m^3)	Drop due to Use (m)	Ice Growth (m)
September	50.00	20102	8890	0.44	0.10
October	49.46	17660	11983	0.68	0.40
November	48.38	10323	11596	1.12	0.35
December	46.91	8389	11983	1.43	0.33
January	45.15	7372	11983	1.63	0.28
February	43.24	6376	10823	1.70	0.22
March	41.32		11983	#DIV/0!	0.16
April	#DIV/0!		11596	#DIV/0!	0.10
May	#DIV/0!		11983	#DIV/0!	0.06
June	#DIV/0!		11596	#DIV/0!	
	#DIV/0!				
					2.00

Estimated Shortfall 57179

Drawdown Analysis
Expanded Reservoir
Year 2026

Month	Underside of Ice (m)	Area (m^2)	Water Use (m^3)	Drop due to Use (m)	Ice Growth (m)
September	50.00	20102	7535	0.37	0.10
October	49.53	18702	10156	0.54	0.40
November	48.58	15828	9829	0.62	0.35
December	47.61	15462	10156	0.66	0.33
January	46.62	15162	10156	0.67	0.28
February	45.67	14891	9173	0.62	0.22
March	44.84	14668	10156	0.69	0.16
April	43.99	14479	9829	0.68	0.10
May	43.21	14200	10156	0.72	0.06
June	42.43		9829		
Totals				5.57	2.00

Estimated Shortfall 18580

Drawdown Analysis
Expanded Reservoir
Year 2031

Month	Underside of Ice (m)	Area (m^2)	Water Use (m^3)	Drop due to Use (m)	Ice Growth (m)
September	50.00	20102	8189	0.41	0.10
October	49.49	17933	11037	0.62	0.40
November	48.48	15851	10681	0.67	0.35
December	47.45	15408	11037	0.72	0.33
January	46.41	15202	11037	0.73	0.28
February	45.40	14817	9969	0.67	0.22
March	44.51	14577	11037	0.76	0.16
April	43.59	14314	10681	0.75	0.10
May	42.74		11037	#DIV/0!	0.06
June	#DIV/0!		10681	#DIV/0!	
	#DIV/0!				
Totals				#DIV/0!	2.00

Estimated Shortfall 26201

Drawdown Analysis
Expanded Reservoir
Year 2036

Month	Underside of Ice (m)	Area (m^2)	Water Use (m^3)	Drop due to Use (m)	Ice Growth (m)
September	50.00	20102	8890	0.44	0.10
October	49.46	17832	11983	0.67	0.40
November	48.39	15801	11596	0.73	0.35
December	47.30	15360	11983	0.78	0.33
January	46.19	15040	11983	0.80	0.28
February	45.11	14740	10823	0.73	0.22
March	44.16	14479	11983	0.83	0.16
April	43.17	14188	11596	0.82	0.10
May	42.26		11983	#DIV/0!	0.06
June	#DIV/0!		11596	#DIV/0!	
	#DIV/0!				
			114416		2.00

Estimated Shortfall 34251

Drawdown Analysis
Expanded Reservoir, Reduced Freeboard and Lowered Intake
Year 2026

Month	Underside of Ice (m)	Area (m^2)	Water Use (m^3)	Drop due to Use (m)	Ice Growth (m)
September	50.50	21567	7535	0.35	0.10
October	50.05	20212	10156	0.50	0.40
November	49.15	17090	9829	0.58	0.35
December	48.22	15712	10156	0.65	0.33
January	47.25	15344	10156	0.66	0.28
February	46.30	15071	9173	0.61	0.22
March	45.48	14839	10156	0.68	0.16
April	44.63	14610	9829	0.67	0.10
May	43.86	14393	10156	0.71	0.06
June	43.09	14116	9829	0.70	
	42.40				
Totals				6.10	2.00

Drawdown Analysis
Expanded Reservoir, Reduced Freeboard and Lowered Intake
Year 2031

Month	Underside of Ice (m)	Area (m^2)	Water Use (m^3)	Drop due to Use (m)	Ice Growth (m)
September	50.50	21567	8189	0.38	0.10
October	50.02	20321	11037	0.54	0.40
November	49.08	17002	10681	0.63	0.35
December	48.10	15564	11037	0.71	0.33
January	47.06	15288	11037	0.72	0.28
February	46.06	15002	9969	0.66	0.22
March	45.17	14756	11037	0.75	0.16
April	44.27	14510	10681	0.74	0.10
May	43.43	14266	11037	0.77	0.06
June	42.60	13997	10681	0.76	
	41.83				
Totals				6.67	2.00

Estimated Shortfall 3050

Drawdown Analysis
Expanded Reservoir, Reduced Freeboard and Lowered Intake
Year 2036

Month	Underside of Ice (m)	Area (m^2)	Water Use (m^3)	Drop due to Use (m)	Ice Growth (m)
September	50.50	21567	8890	0.41	0.10
October	49.99	20036	11983	0.60	0.40
November	48.99	16849	11596	0.69	0.35
December	47.95	15590	11983	0.77	0.33
January	46.85	14926	11983	0.80	0.28
February	45.77	14920	10823	0.73	0.22
March	44.82	14663	11983	0.82	0.16
April	43.85	14390	11596	0.81	0.10
May	42.94	14116	11983	0.85	0.06
June	42.03	13777	11596	0.84	
	41.19				
			114416	7.31	2.00

Estimated Shortfall 11146

Drawdown Analysis
Expanded Reservoir, Reduced Freeboard and Lowered Intake
Maximum Overwinter Storage

Month	Underside of Ice (m)	Area (m^2)	Water Use (m^3)	Drop due to Use (m)	Ice Growth (m)
September	50.50	21567	7987.1	0.37	0.10
October	50.03	20102	10765.36	0.54	0.40
November	49.09	17032	10418.74	0.61	0.35
December	48.13	15654	10765.36	0.69	0.33
January	47.11	15305	10765.36	0.70	0.28
February	46.13	15016	9723.38	0.65	0.22
March	45.26	14780	10765.36	0.73	0.16
April	44.38	14547	10418.74	0.72	0.10
May	43.56	14317	10765.36	0.75	0.06
June	42.75	14069	10418.74	0.74	
	42.01				
Totals				6.49	2.00