Iqaluit Water Storage Pre-Feasibility Study

Type of Document:
Report

Project Name:
Iqaluit Water Storage Pre-Feasibility Study

Project Number:
FRE-00257710-A0

Prepared By:

EXP
2650 Queensview Drive
Ottawa, Ontario, K2B 8H8
t: +1.613.688.1899
f: +1.613.225.7337

REGISTERED PROFESSIONAL ENGINEER
S.D. PLOURDE
LICENSEE
10/23/2020
NT/NU

Date Submitted:
2020-07-03 Draft
2020-10-16 Final

Marc Lafleur, P.Eng.
Project Engineer
Infrastructure Services

Simon Plourde, P.Eng.
Project Engineer
Infrastructure Services

Table of Contents

List of Tables

List of Figures

List of Appendices

List of Appendix Figures

Executive Summary

The present storage capacity of the Lake Geraldine Reservoir is not adequate to satisfy future water demand by the City. Thus, additional water storage alternatives is required to ensure the City can meet demands of its growing population. The objective of this study is to evaluate options to provide additional water storage, in addition to the available storage volume within the Lake Geraldine Water Reservoir. This report is intended to define alternatives for additional raw water storage, evaluate viable alternatives, provide recommendations on the preferred alternative and implementation measures for project execution.

The following summarizes the design basis for the Pre-Feasibility Study:

- Iqaluit's General Plan High Growth Rate (3.38 %) population projection to 2050 design horizon
- Per Capita Water Demand of 400 L/day
- 1.9m ice depth used in estimating water storage loss during the over-winter period
- The over-winter period is considered to be 244 days long, where there is assumed to be no replenishment of the reservoir during this period

The total storage required, in excess of the available existing storage within Lake Geraldine, to satisfy the projected population growth and raw water demand to 2050 was estimated to be 1,247,500 m3 during the over-winter period and 1,824,500 m3 annually.

Following the alternatives definition, the three viable alternatives to satisfy storage capacity requirements for the City of Iqaluit were determined to be:

- Alternatives that are hydraulically connected to Lake Geraldine:
    - Excavation of additional storage volume within Lake Geraldine
    - Excavation of additional storage volume in close proximity to Lake Geraldine
- Alternatives that are hydraulically independent to Lake Geraldine:
    - Combination of excavated and bermed reservoir in close proximity to Lake Geraldine

The evaluation scheme developed to determine the preferred alternative examined; technical performance, economic efficiency and community impact as the three broad based areas for evaluation. The alternatives evaluation determined the preferred alternative to be the excavation and berming of a hydraulically independent reservoir. Considerations for the existing topography surrounding Lake Geraldine and the location of rock escarpments is essential when selecting a potential site location. Utilizing these features will aid in minimizing the capital costs associated with excavation and berming works A conceptual representation of the preferred option was prepared, see Figure 7-1 within the body of the report. It is estimated that the total capital cost of this alternative would be approximately $64M.

A preliminary schedule in Gantt chart format was prepared, suggesting some of the next activities and actions required by the City to advance the project execution. It is essential that at this point forward, the advancement of this project incorporates decisions related to water storage as well as water supply as they are both mutually dependent.

1 Introduction

1.1 Overview

The City of Iqaluit (City) currently uses Lake Geraldine as a water storage reservoir to supply raw drinking water to the community. The reservoir has experienced low water levels in the past few years leading to a deficit in available drinking water volumes in the summer of 2018 and 2019. The City is looking to explore options for additional water storage to sustain its long-term water supply requirements. Additional water storage alternatives will be needed to ensure the City can meet both supply and demand requirements for the growing population for years to come.

EXP was retained by the City to review the current estimates of available water storage in the Lake Geraldine Reservoir, and evaluate options to provide for additional raw water supply storage. This report is intended to establish the Design Basis and assumptions for completing the Water Storage Pre-Feasibility Study, define alternatives for additional raw water storage, evaluate viable alternatives, provide recommendations on the preferred alternative and implementation measures for project execution.

1.2 Purpose

The objective of this study is to evaluate options for additional water storage, in addition to the available storage volume in the Lake Geraldine Water Reservoir. The specific tasks of this study include:

- Perform a desktop review of previous reports, studies and investigations regarding current water storage and water demand requirements for the City of Iqaluit.
- Establish a design basis for long-term water storage requirements that will satisfy the anticipated population growth and water demand for the City of Iqaluit.
- Investigate options for additional water storage which will meet the requirements of the design basis.
- Complete a technical assessment and preliminary calculations in order to assist with the validation of proposed alternatives.
- Evaluate the viable alternatives for supplementary storage.
- Provide recommendations on the preferred alternative and outline implementation measures required for project execution.

2 Previous Investigations

2.1 Lake Geraldine Reservoir Storage – Desktop Review and Assessment (Nunami Stantec, 2019)

This Desktop Study provides a high-level analysis of winter storage volumes available within the Lake Geraldine reservoir as well as the inaccessible portions of the reservoir. Bathymetry data from the Geological Survey of Canada's 2008 survey of Lake Geraldine was analyzed to determine the current volume of available water and present options for additional water withdrawal. The study determined the following:

- Total Volume within Reservoir at Capacity – 1,793,000 m^3
  - Inaccessible Volume due to geometry (year-round) – 112,500 m^3
  - Inaccessible Volume due to Ice (winter months) – 585,000 m^3
  - Total Volume of accessible Water (winter months) – 1,095,500 m^3

2.2 Iqaluit Water Audit (EXP, 2018)

This report provided annual raw water consumption for the City of Iqaluit from 2009 to 2016 and determined that growth in raw water consumption appears to be largely independent of growth in population.

2.3 Lake Geraldine Water Balance Assessment (Golder, 2013)

Golder determined that Lake Ice Depths of 1.9m are appropriate representations of ice thicknesses in a year of median winter weather. generated stage-storage relationship using ERSI 3-D Analyst and bathymetric data collected in the summer of 2008. Golder estimated 1,890,000 m^3 of available water supply in Lake Geraldine Reservoir.

2.4 City of Iqaluit Raw Water Supply and Storage Review (Trow, 2004)

The total accessible storage volume of the Lake Geraldine reservoir is approximately 1,076,000 m^3. This estimate accounts for a maximum ice depth in Lake Geraldine was determined to be 1.9 m.

3 Project Design Basis

3.1 Design Horizon

The year 2050 will be used as the design horizon for this analysis to project water storage requirements for the growing population of Iqaluit. Mid-term projections to 2030 and 2040 will also be presented in order to provide greater context.

3.2 Population Projection

Population data is available from the Nunavut Bureau of Statistics and from the City of Iqaluit General Plan. The Bureau provides a population estimate of 8,242 in Iqaluit for 2018 (NBS 2018).

The City of Iqaluit General Plan provides three population projection scenarios for Low, Medium and High growth estimates. The High projection is based on an annual growth rate of 3.38%, which was the average rate of growth observed between the 2001 and 2006 Census data. The Medium population projection includes an average annual growth rate of 2.87% which was estimated as part of the GN Bureau of Statistics community level population projections in 2000. The annual growth rate of 2.04% was used for the Low population projection. The Low population projection scenario will be omitted in this analysis in order to provide a conservative estimate for future planning of water storage requirements. The High projected population estimate is recommended for estimating long-term water storage requirements. The Medium projected population estimate will also be presented and will provide some additional context to future water storage requirements.

The range of projected population growth from 2018 to 2050 is summarized in Table 1 below.

Table 3-1: Population Projection

Year	Medium Growth (2.87%)	High Growth (3.38%)
2018	8,242	8,242
2020	8,744	8,839
2025	10,075	10,440
2030	11,608	12,332
2035	13,375	14,566
2040	15,411	17,204

Year	Medium Growth (2.87%)	High Growth (3.38%)
2045	17,757	20,321
2050	20,460	24,002

Observed population growth between from 2008 to 2018 and the Medium and High projected growth scenarios are illustrated in Figure 1 below.

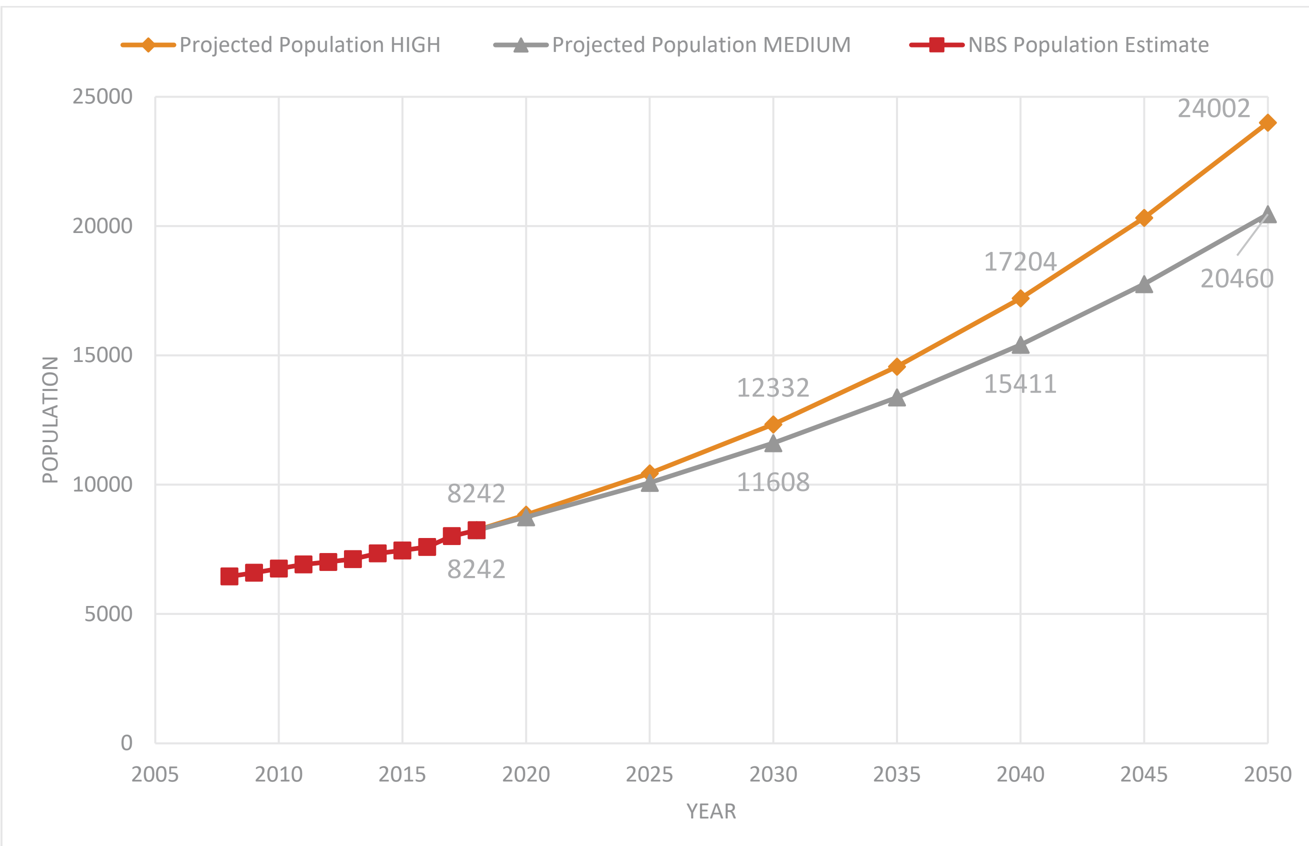

Figure 3-1: Population Projections

3.3 Per Capita Water Demand

The City of Iqaluit Municipal Design Guidelines recommends using an average domestic water usage rate of 400 L/capita/day (Lpcd) for design purposes. The City has provided data for raw water consumption from Lake Geraldine for the period 2009 to 2019. This data, together with the annual population as provided by the Nunavut Bureau of Statistics (NBS), yield average raw water demand per capita as presented in Table 2 below. The NBS provides population estimates up to 2018, so the average raw water demand per capita has been calculated based on population estimates up to 2018.

Table 3-2: Average Raw Water Demand Per Capita

Year	Raw Water Consumption (m^3)	Population (NBS)	Raw Water Demand per Capita (L/day)
2009	901,550	6,593	375
2010	877,090	6,755	356
2011	839,610	6,916	333
2012	871,670	7,013	341
2013	930,360	7,123	358
2014	990,140	7,343	369
2015	1,088,690	7,456	400
2016	1,249,150	7,590	451
2017	1,208,200	8,011	413
2018	1,190,700	8,242	396
		AVERAGE:	**381**

From the data presented in Table 2 above, it is observed that the average raw water demand from 2009 to 2018 is 381 Lpcd. Therefore, the design rate of 400Lpcd adopted by the City of Iqaluit is deemed reasonable and conservative. Therefore, 400 Lpcd will be used to project future water storage requirements.

The following observations are drawn from the above data:

- Water consumption on the order of 930,000 m^3 annually was essentially stable for the 6-year period between 2008 and 2013.
- Water consumption rose over the period from 2014 to 2017, with the most dramatic increase occurring in 2016.
- Water Consumption for the most recent years of record (2017 and 2018) decreased to a demand closer to 400 Lpcd.
- The average Raw water Demand per capita from 2009 to 2018 was of 381 L/day.
- Growth in water consumption appears to be largely independent of growth in population.

3.4 Water Demand Projection

The following Tables, 3-3 and 3-4 summarize the daily water demand and annual water demand projections, based on the assumptions described previously.

Table 3-3: Daily Water Demand Projection (m^3/day)

Year	Medium Growth (2.87%) (m^3/day)	High Growth (3.38%) (m^3/day)
2018	3,297	3,297
2030	4,643	4,933
2040	6,165	6,882
2050	8,184	9,601

A raw water consumption rate of 400 Lpcd will be applied to calculations regarding forecasting of future population growth and associated consumption for the City of Iqaluit. This represents a conservative estimate for future water infrastructure planning. Management of water losses, such as bleeds and leaks, will have a bearing upon total water consumption. This will, in turn, impact the service life of raw water storage improvements. Table 3-4 and Figure 3-2 below present the projected annual water demands at an average rate of 400 Lpcd in comparison with 300 Lpcd. A significant reduction in the total required storage is observed with an average consumption of 300 Lpcd. This represents an opportunity providing incentive for the City of Iqaluit to implement water conservation strategies, manage watermain bleeds and watermain leaks/breaks.

Table 3-4: Annual Water Demand Projections for Low and High Consumption rates

Year	Low Consumption (300 Lpcd) High Growth (3.38%) (m^3/year)	High Consumption (400 Lpcd) High Growth (3.38%) (m^3/year)
2018	903,000	1,204,000
2030	1,351,000	1,801,000
2040	1,884,000	2,512,000
2050	2,629,000	3,505,000

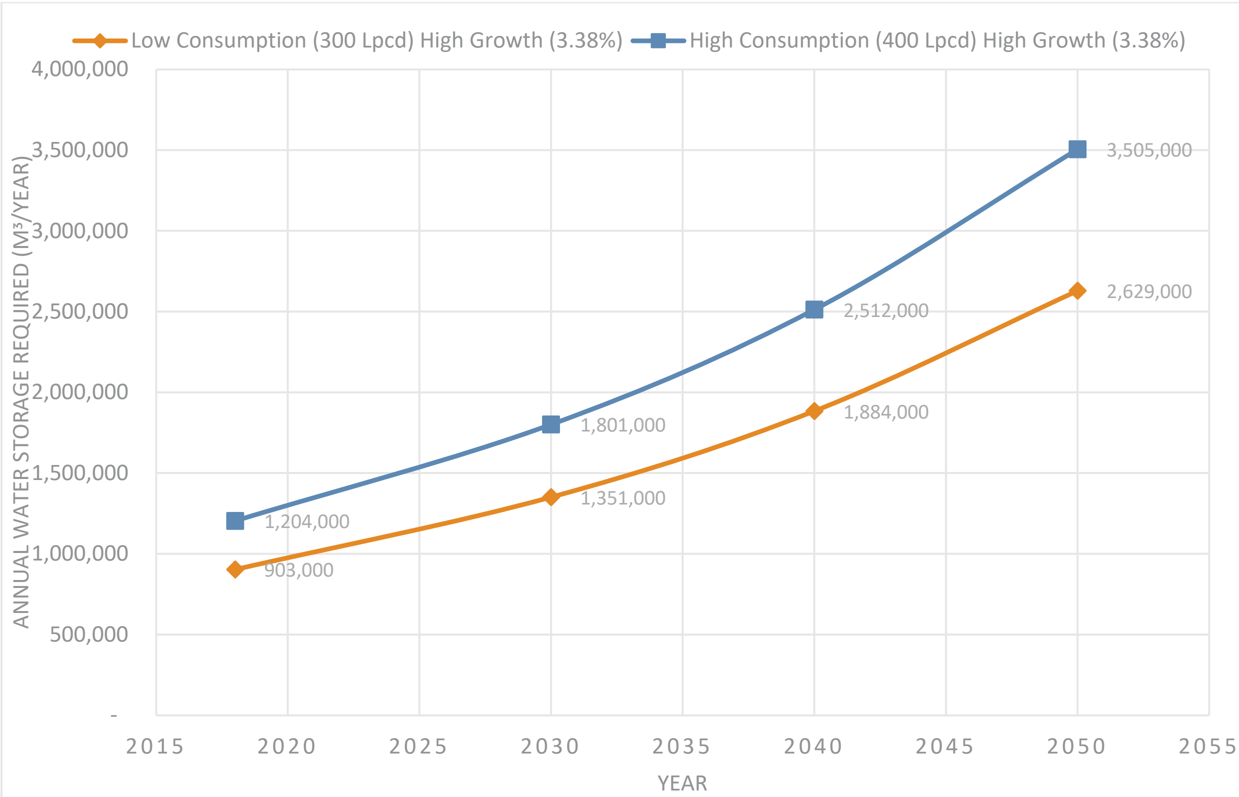

Figure 3-2: *Projected Annual Water Storage Required for Low and High Consumption rates*

3.5 Water Storage Related Issues

There is assumed to be no replenishment of the reservoir while the Lake Geraldine watershed is frozen. This frozen over-winter period varies from year to year. For the purpose of this analysis, the over-winter period is defined as September 31 through May 31. This 244-day over-winter period is considered a conservative estimate.

A critical aspect of ensuring that the City of Iqaluit maintains its capability to meet water demands throughout the year is ensuring adequate storage to meet the demand through the over-winter period. In addition to the lack of water input to the reservoir during the over-winter months, there is a loss of lake storage availability due to freezing and ice formation. The maximum ice depth in Lake Geraldine is estimated to be 1.9m (Trow, 2004). This maximum ice depth of 1.9m will be used in the evaluation of water storage alternatives.

The projected over-winter raw water demand for the City of Iqaluit is summarized in Table 5 based on the Medium and High Population projection scenarios and an average raw water consumption rate of 400

Lpcd. These estimates do not include the stored water loss due to ice formation. The loss due to ice cover will vary based on the geometry of the storage. The matter of loss of storage will be evaluated during the identification of water storage alternatives.

Table 3-5: Over-Winter Raw Water Demand Projection

Year	Medium Growth (2.87%) (m^3)	High Growth (3.38%) (m^3)
2018	805,000	805,000
2030	1,133,000	1,204,000
2040	1,505,000	1,680,000
2050	1,997,000	2,343,000

3.6 Existing Lake Geraldine Water Storage

Nunami Stantec completed a Desktop Study in 2019 providing a high-level analysis of winter storage volumes available within the Lake Geraldine reservoir as well as the inaccessible portions of the reservoir. Bathymetry data from the Geological Survey of Canada's 2008 survey of Lake Geraldine was analyzed to determine the following:

- Total Volume within Reservoir at Capacity – 1,793,000 m^3
  - Inaccessible Volume due to geometry (year-round) – 112,500 m^3
  - Inaccessible Volume due to Ice (winter months) – 585,000 m^3
  - Total Volume of accessible Water (winter months) – 1,095,500 m^3

The existing water storage findings from the recent Nunami Stantec study will be used in the evaluation of additional water storage required to meet the long-term needs of Iqaluit's growing population.

3.7 Potential Water Sources

The two likely candidate sources for this supplemental water are Unnamed Lake and the Sylvia Grinnell River. Both of these sources for replenishment are situated between 3 km and 4 km from Lake Geraldine.

3.8 Design Basis Summary

The following summarizes key findings from the desktop review and assumptions that will form the design basis for the Pre-Feasibility Study Report:

- Analysis is based on High Population Growth Rate (3.38 %) out to 2050, with Medium Population Growth Rate (2.87 %) to provide additional context. Mid-term projections to 2030 and 2040 are presented in this analysis for greater context.
- Per Capita Water Demand of 400 Lcpd will be used in analysis.
- The maximum ice depth used in estimating water storage loss during the over-winter period is 1.9m.
- The over-winter period is considered to be 244 days long, where there is assumed to be no replenishment of the reservoir.
- Existing accessible water in the Lake Geraldine Reservoir (over-winter period) = 1,095,500 m^3.

4 Constraints

4.1 Constraints Mapping

A preliminary Constraints Map has been developed to identify locations in the community and the surrounding area where it would not be suitable to develop a new water storage facility. The Constraints Map is enclosed in Appendix A.

As per the Constraints Map, the proposed site should not be located:

- On known/abandoned dump sites
- On known historical/cemeteries areas
- On known hunting/trapping areas
- On planned development areas
- On designated park areas

5 Alternatives Definition Process

The following broad categories of storage alternatives have been considered:

- Alternatives remote from Lake Geraldine and the existing water treatment plant
- Alternatives in proximity to Lake Geraldine which can be connected to the existing water treatment plant

These broad categories of storage alternatives have been further defined in the following sections and will be screened to establish their technical feasibility. The remaining alternatives following the screening process will be evaluated in greater detail prior to the selection of the recommended alternative.

5.1 Storage Requirement Targets

From the design basis presented previously, the projected raw water required to satisfy the anticipated population growth and water demand for the City of Iqaluit is summarized in Table 5-1 below. The summary presents the additional raw water storage required, in excess of the following existing storage capacity of Lake Geraldine (Nunami Stantec, 2019):

- Total Volume of accessible Water Storage during Over-Winter Period – 1,095,500 m^3
- Total Volume of accessible Water during Summer months – 1,680,500 m^3

As indicated previously, the over-winter 244-day period is the critical storage where there is assumed to be no replenishment of the reservoir and the upper 1.9m of storage is inaccessible due to ice formation. The following Table 5-1 summarizes the total storage required, in excess of the available storage available within Lake Geraldine, to satisfy the projected population growth and water demand.

Table 5-1: Summary of Raw Water Demand Projections

Year	Additional Over-Winter Storage Required (m^3)	Additional Annual Storage Required (m^3)
2030	108,500	120,500
2040	584,500	831,500
2050	1,247,500	1,824,500

6 Alternatives Remote from Lake Geraldine

6.1 General

Water storage alternatives that are remote from Lake Geraldine and the existing water treatment plant which have been considered can be categorized in the following broad groups:

- Over-winter reservoir refill
- Over-winter impoundment
- Desalination of water stored in the sea

The greatest technical challenges associated with these potential alternatives relate to the conveyance of raw water to the existing water treatment plant or the treatment of raw water near the over-winter storage location. The technical feasibility of these alternatives as well as the challenges and risk associated with them will be further defined and evaluated in the following sections.

6.2 Over-Winter Reservoir Refill

There is the potential for the incorporation of refill of the City's water reservoir, Lake Geraldine, during the winter. This would entail pumping water from some other source following depletion of the Lake Geraldine reservoir. The two likely candidate sources for this water are Unnamed Lake and the Sylvia Grinnell River. Both of these sources for potential replenishment are situated between 3 km and 4 km from Lake Geraldine. Replenishment of Lake Geraldine would occur following depletion of a portion of the water stored in Lake Geraldine. Thus, this strategy would require the operation of a resupply pipeline during winter conditions.

The scope of the works required to implement this strategy would include a pumphouse at the water source, facilities to pre-heat the water prior to conveyance through the pipeline, and an insulated pipeline that terminates at Lake Geraldine. The need for locally generated electrical power is anticipated, as such is required for the operation of boilers, controls and communications. An all-weather road that provides access to the pumphouse would be required to permit fuel delivery and ongoing operational supervision.

One of the greatest technical challenges is associated with freeze risk for the pipeline connecting the pumphouse to Lake Geraldine. It is likely that the need for replenishment would arise later in the winter. It is also likely that the pipeline will be installed at or near the ground surface. Freeze prevention during pipeline operation will require insulated piping. The presence of the insulation system will damp variations of the water pipeline temperature from the daily variations. In a similar fashion, when out of service the piping within the insulation system will take on a temperature that approximates the average of the environment around the pipe. Canadian Normals indicate mean temperatures for March and April as -23.2 ^{o}C and -14.2 ^{o}C respectively. On this basis it can be assumed that means must be available to place the system into service when the internal temperature of the pipeline is -20 ^{o}C. In view of the length of the pipeline, combined with the internal temperature, it is virtually inevitable that the water will freeze if pumped directly into the pipeline. Heating of the water at the pumphouse cannot provide sufficient heat energy to assure that freeze does not occur during start-up. An additional challenge with this alternative is the existing terrain considerations, where any low points within the piping would hold water after pumping and would certainly freeze. A means to drain these locations along the piping would be required, along with roads for access.

It has been concluded that some method of preheating must be in place. Such a system would raise the pipeline temperature above 0 ^{o}C prior to the initiation of pumping. Such an approach has been used in Cape Dorset for a pipeline that is slightly longer than 1 km. For the case of Cape Dorset stainless steel piping with electrical heat tracing has been used. The supply pipeline in Cape Dorset has frozen on more than two occasions. Substantial mid-winter effort was required to restore water service for the community. A more robust and reliable arrangement than that provided in Cape Dorset would be required, as the inability to replenish the water reservoir could render the City uninhabitable, leaving much of the water distribution system with freeze damage. It is likely that a new approach to pre-heating the pipeline would require development. This is viewed to be a large technical risk for a system that would be essential for ongoing occupancy of the City.

The technical risks relating to vulnerability to freeze, combined with the dependence on a new and untested approach to pre-heating of the pipeline are viewed to be sufficiently high that incorporation of over-winter refill into the proposed alternatives is not appropriate unless no other feasible alternatives are available. This is independent of other issues including the challenges of operating an essential facility, remote from the community, during winter conditions.

6.3 Over-Winter Impoundment

Water storage alternatives incorporating over-winter impoundment which have been considered are:

- Impoundment of existing water courses, such as the Apex River
- Constructed storage facilities remote from Lake Geraldine

A first aspect to consider with impoundment of an existing water course is that it will be very challenging from a regulatory perspective.

Over-winter impoundment storage alternatives remote from Lake Geraldine could be achieved with independent water treatment, treated water storage and a high lift pumping station connected to the existing distribution system. An important consideration with this approach is that the system would be required to operate on a continuous basis over the winter months to avoid freeze. Such alternatives would have very high capital costs as well as operations costs. The current operating costs of water treatment plant operation in Iqaluit would roughly double if independent water treatment was required.

Without independent water treatment, this alternative which incorporates over-winter impoundment would require over-winter pumping to the existing Lake Geraldine reservoir. The technical issues associated with occasional over-winter operations of pipelines have been considered in the previous section of this report. This approach is not considered feasible and will not be advanced for further detailed consideration.

6.4 Desalination

Alternatives that include desalination could supplement over-winter storage at Lake Geraldine using water taken from Frobisher Bay. The scope of the required works would include an intake, a salinity removal process, a method to introduce the treated water into the City distribution system, together with supporting systems such as electrical power and a building. The greatest need for additional water will arise during late winter and this will extend into the spring. Thus, there must be the capability to put this system into service during winter conditions.

Desalinated water could potentially be discharged into Lake Geraldine, or directly into the City distribution system. Directing this treated water to Lake Geraldine would require an insulated pipeline, approximately 2 km in length. The greatest challenge with this pipeline is related to freeze risk if an attempt is made at placing this pipe into service during winter conditions. There are also challenges related to discharge directly into the City distribution system. Water quality issues can arise from the mixing of water from 2 treatment processes. There are also issues with disruption of circulation patterns and increased freeze risk due the change in the location where water is introduced into the distribution system. This strategy also requires that water continue to be drawn from Lake Geraldine, so as to avoid freeze of portions of the existing distribution network.

Reverse osmosis is the most likely process that could be used to remove salinity from water taken from Frobisher Bay. This process has seen good success in several locations around the world. The process entails the pumping of water, under high pressure, through a membrane. One specific issue is energy consumption due to the high-pressure pumping requirements. Energy requirements are of the order of

4 kw-hr per cubic metre of water produced. Current average day water consumption is approximately 3,400 m^3/day. This leads to an energy cost for solely process pumping of approximately $3,000 daily.

The greatest technical challenges are likely associated with the intake. The tidal difference at Iqaluit can exceed 11 metres. Additionally, Frobisher Bay is ice covered during the winter. The combination of tide and ice cover would require that the intake draw water at a depth of 15 m, or more, below the high water level. This would place the intake almost 1 km off the beach if continuous operation, independent of tides is required. Substantial protection from ice damage would be required over the intake pipeline. Complicated freeze protection measures would also be required for the intake.

A desalination facility would include various systems in support of the water treatment process. These would include a building, electrical power supply, a storage tank, high pressure pumping into the distribution system and mechanical systems. The mechanical systems would include boilers and heat exchangers, which are required to heat incoming water, prior to the desalination process. Heating of this incoming water is required for two reasons. Firstly, water taken from Frobisher Bay will likely be colder than 0^oC, as this water would be drawn from an ice covered sea water environment. Secondly this water must be pre-heated to approximately 5^oC prior to introduction into the distribution system to reduce the risk of distribution system freeze. For a daily production of 3,400 m3 it is estimated that 2,300 L/day of heating fuel would be required. An initial estimate of energy costs for electrical energy for the reverse osmosis process, and raw water heating places these daily operating costs in excess of $5,000 daily.

It is concluded that desalination of water taken from Frobisher Bay is not a desirable alternative to advance, unless no other feasible alternative is identified. This is based on projections of high operating costs, combined with substantial technical challenges, especially with the provision of a reliable raw water intake. On this basis desalination will not be incorporated into the alternatives proposed for further consideration.

6.5 Summary

Water storage alternatives that are remote from Lake Geraldine and the existing water treatment plant are not considered financially and technically practical and will not be carried forward, unless other more feasible alternatives cannot be identified.

7 Alternatives in Proximity to Lake Geraldine

7.1 General

Water storage alternatives in proximity to the existing Lake Geraldine reservoir have the benefit of making use of existing raw water intake to the water treatment plant. These potential alternatives could be hydraulically connected to Lake Geraldine and operate at the same water level, or hydraulically independent of lake Geraldine.

7.2 Hydraulically Connected to Lake Geraldine

Water storage alternatives that would be hydraulically connected to Lake Geraldine which have been considered are:

- Raising the high-water level of Lake Geraldine
- Excavation of additional storage volume within Lake Geraldine
- Excavation of additional storage volume in close proximity to Lake Geraldine

The technical feasibility of these alternatives as well as the challenges and risk associated with them with be further defined and evaluated in the following sections.

7.2.1 Raising High Water Level of Lake Geraldine

Since the Lake Geraldine dam was originally constructed in the 1950's, the dam has been upgraded several times to increase the total storage capacity. The most recent upgrade in 2006 raised the dam spillway elevation to 111.3m masl. Further raising the high-water level of the existing Lake Geraldine will be considered as a potential alternative to increasing total storage capacity and meeting over winter raw water storage demand for the City of Iqaluit. This alternative would require a higher dam elevation as well as berming works to contain the higher water level within Lake Geraldine. Important considerations associated with this alternative include:

- Technical attainability and feasibility
- Structural and geotechnical analysis required to determine the feasibility of raising the dam
- Alterations required to raise the existing dam such as rock anchoring to preserve stability
- Construction Costs
- Environmental and water quality implications
- Increased accessible storage volume vs inaccessible storage volume over winter months

Raising the dam spillway elevation would require enhanced stability of the hydraulic structure. Raising the dam elevation is a challenging undertaking. The natural topography above the existing high-water level raises issues regarding efficiency of this alternative. This relates to the fact that the upper 1.9 m of impounded water stored is not available for over-winter use due to ice formation at shallow depths. Berming surrounding the Lake Geraldine will be required to contain the water storage volume at a higher elevation.

Computations have been carried out based on bathymetry data and topographic information to establish the additional water storage volume that would be gained at incremental increases in reservoir storage elevation. It has been determined that the high-water level of Lake Geraldine must be raised by 5m from 111.3m to 116.25m in order to meet the storage requirements of the design horizon. Refer to Figure 2 included in Appendix A, which illustrates the location and length of berms that would be required to contain the water at the higher storage elevation of 116.25m. The level of construction effort required to raise the existing dam elevation to 116.25m and maintain the structural integrity of the existing reservoir is considered very high. Since the dams was originally constructed in the 1950's, the dam spillway has been raised several times to increase the storage capacity whereby additional rock anchors were required. A further increase in the dam height is not considered technically feasible. Advancement of this alternative would require the replacement of the dam with a new structure.

The greatest risk associated with this alternative is the unlikelihood of successful completion at a date that would permit refill of the lake prior to onset of winter. There is also possibility of harm to the community as a result of construction due to the release of water required prior to the construction of a new dam. Continuity of water supply to the community during construction would be very challenging.

In view of the formidable technical challenges and the scale of the risks, this alternative will not be retained for further evaluation and consideration.

7.2.2 Excavation of Additional Storage Volume within Lake Geraldine

Excavation of Additional Storage Volume within Lake Geraldine will be considered as a potential alternative to increasing total storage capacity to meet over winter raw water storage demand for the City of Iqaluit. This alternative would require excavation of sufficient rock volume below the existing high-water level to provide an additional 1,824,500 m^3 of supplementary storage to meet the 2050 design horizon. A consideration for water storage lost due to ice would be required to ensure an additional 1,247,500 m^3 of additional storage is accessible over the winter months.

The greatest risk associated with construction activities is the risk of damage to the existing dam structure due to blasting. This risk would be controlled with appropriate construction supervision. The risk of impact on water quality due to construction activities is considered moderate. There is potential for construction equipment fuels and lubricants contaminating the water within Lake Geraldine, which can be largely mitigated. The risk to the public is reduced by the treatment of the raw water within Lake Geraldine prior to consumption by consumers.

The construction capital works associated with this alternative include drilling, blasting and excavation within Lake Geraldine, as well as loading, transporting and disposing of excavated material. This alternative will require some rock excavation that is above the water level, which is necessary, but will not provide additional storage capacity. An important consideration for the City of Iqaluit is that the capital works associated with this alternative could be strategically coordinated with quarrying operations. This would offset, to some degree, the high capital cost associated with the excavation activities required for this alternative. A phased approach could be considered to gradually meet the water storage needs of the growing population of Iqaluit. An important consideration is that following construction, there would be no additional operation or maintenance costs associated with this alternative.

An important consideration with the alternative of excavating within Lake Geraldine to create additional storage capacity is the portion of the water volume within the lake that is currently inaccessible due to the geometry of the lake. As part of the desktop review and assessment of Lake Geraldine Reservoir Storage completed by Nunami Stantec in 2019, it was determined that a total volume of 112,500 m^3 is inaccessible year-round due to the Lake Geometry. It was estimated that by excavating or trenching a channel from the water intake through the rock sills down to an elevation of 101m masl would allow withdrawal of an additional 83, 400 m^3 of water. This will increase the total accessible storage volume by approximately 8%. The additional volume of 83,400 m^3 is far from the 1,824,500 m^3 storage required to meet the needs of the population projected to 2050. However, it could be strategically incorporated as part of the alternative if excavation of additional storage volume within Lake Geraldine is selected.

A preliminary analysis has been completed to determine the additional storage volume that could be provided by excavating within Lake Geraldine. Excavating 100% of the existing footprint of Lake Geraldine down to the water intake level of 101m would provide approximately 1 857 000 m^3 of total additional water storage. An additional 1 116 000 m^3 would be provided during the over-winter period, accounting for the storage lost due to ice formation. This is slightly less than the required additional 1, 247, 500 m^3 of over-winter storage required to meet the needs of the design horizon. Refer to Figure 3 included in Appendix A.

This Alternative will be retained for further evaluation and consideration as a viable option.

7.2.3 Excavation of Additional Storage Volume in Close Proximity to Lake Geraldine

Excavation of Additional Storage Volume within close proximity to Lake Geraldine will be considered as a potential alternative to increasing total storage capacity and meeting raw water storage required. This alternative incorporates the construction of another independent storage cell that is hydraulically linked to the reservoir. A phased approach comprised of a series of independent storage cells which are hydraulically connected to Lake Geraldine will also be considered. A channel interconnecting the new storage with Lake Geraldine will be required.

There is the opportunity to consider the following alternative additional reservoir arrangements.

- Construction of a single reservoir cell, providing sufficient added storage volume to meet the design horizon of 2050.
- Construction of a cell to meet the mid-term (2030) requirements of the community, followed by the construction of an additional cell at such date that demands dictate (ie- phased approach).

The feasibility of this alternative is largely impacted by the existing topography within close proximity to Lake Geraldine, as most of the lake shoreline rises steeply. The footprint of new water storage cell(s) will cover a large area and any rock excavation above the existing reservoir's high-water level will not provide any additional available water storage because the reservoirs will be hydraulically connected. An analysis of the surrounding topography was completed. The rapid rise in ground elevation adjacent to the lake leads to large amount of rock excavation above the existing lake water level. The relative proportions of rock excavation, compared to the resulting storage, are disproportionate to the point where viability is at jeopardy. However, this approach could be used in combination with the alternative of excavating additional volume within Lake Geraldine to meet the storage requirements of the design horizon.

As with the alternative of excavation within Lake Geraldine to obtain additional storage volume, there is marginal risk of unsuccessful construction completion. The risk associated with construction activities impacting the dam structure due to blasting will depend on the proximity to the dam and would be controlled with appropriate blast design and construction supervision. The risk of impact on water quality due to construction activities is considered moderate. There is potential for construction equipment fuels and lubricants contaminating the new water storage reservoir. The benefit of having the new excavated storage independent from Lake Geraldine means that any risk or contamination will be isolated from Lake Geraldine.

The construction capital works associated with this alternative include drilling, blasting and excavation, as well as loading, transporting and disposing of excavated material. An important consideration for the City of Iqaluit is that the capital works associated with this alternative could be strategically coordinated with quarrying operations. This would mitigate some of the capital cost associated with the excavation activities required for this alternative. A phased approach could be considered to gradually meet the water storage needs of the growing population of Iqaluit. An important consideration is that following construction, there would be negligible additional operation or maintenance costs associated with this alternative.

This Alternative will be retained for further evaluation and consideration as a viable option.

7.3 Hydraulically Independent from Lake Geraldine

Water storage alternatives that would be hydraulically independent from Lake Geraldine, but that would be in close proximity to the lake which have been considered are:

- Construction of an above grade reservoir in close proximity to Lake Geraldine
- Excavation of an additional reservoir in close proximity to Lake Geraldine
- Combination of excavated and bermed reservoir in close proximity to Lake Geraldine

There are multiple criteria which must be considered in order to determine if a location is a viable option for additional storage, including:

- Distance from Lake Geraldine
- Elevation difference relative to Lake Geraldine
- Topography and terrain considerations between reservoirs
- Potential for contamination

The distance from Lake Geraldine, the existing topography, and underlying soil conditions are the main limiting factors in identifying a suitable storage location for either an above grade or excavated reservoir. These alternatives will require a means to transfer the water into Lake Geraldine which will be functional during winter conditions. The new storage location will need to be within close proximity to Lake Geraldine to assure reliable transfer of water during harsh mid winter conditions.

The largest risk associated with having alternative water storage hydraulically independent of lake Geraldine relates to the transfer of water between reservoirs during the winter months and the risk of having the water transfer mechanism fail. Another risk associated with this alternative is leakage from the bermed/lined reservoir. This risk can be mitigated through proper design and construction supervision.

The risk of impact on water quality due to construction activities is considered moderate. There is potential for construction equipment fuels and lubricants contaminating the new water storage reservoir.

7.3.1 Construction of an Above Grade Reservoir in Close Proximity to Lake Geraldine

Bermed and lined water reservoirs have been successfully utilized in other communities in Nunavut including Arviat. The feasibility of the development of an above grade reservoir within close proximity to Lake Geraldine is strongly impacted by site topography. Site gradients should be less than 5%, and the maximum feasible site gradient is 10%. Some additional basic design criteria for this alternative are as follows:

- Containment berms must have a minimum top width of 4 m
- Internal and exterior berm slopes will be a maximum of 3:1
- Access roads will have a maximum road slope of 8%
- Maximum recommended water depth of 7m

Based upon the above, a footprint of approximately 550 m x 550 m square (approximately 30 hectares) would be required to meet the design horizon of 2050. As noted above, the preferred site gradients should be less than 5%, with a maximum feasible gradient of 10%. Following a review of the existing site topography within close proximity to Lake Geraldine, it was determined that there is not a large enough area that is within the tolerable gradient required to accommodate this size a reservoir above existing grade. Refer to Figure 4 included in Appendix A. Therefore, an above grade reservoir will not be carried forward for further evaluation.

7.3.2 Excavation of an Additional Reservoir in Close Proximity to Lake Geraldine

Rock excavations have been successfully used for water storage reservoirs communities within Nunavut. Examples include Igloolik and Coral Harbour. This method of storage is feasible at sites with outcropped rock.

As with the alternative of excavating a storage reservoir that is hydraulically connected to Lake Geraldine, there is the opportunity to consider the following alternative additional reservoir arrangements.

- Construction of a single reservoir cell, providing sufficient added storage volume to meet the design horizon of 2050.
- Construction of a cell to meet the mid-term (2030) requirements of the community, followed by the construction of an additional cell in 10 years.

A benefit of the alternatives that are hydraulically independent of Lake Geraldine relate to the flexibility of the proposed water storage elevation. Based on the existing topography surrounding Lake Geraldine, the potential site location can be selected to minimize capital costs associated with drilling, blasting and excavation works. Furthermore, this alternative does not have a constraint on the maximum depth of water that can be stored within the reservoir. An important consideration in design will be the maximum construction access road slope of 8% into the excavation area.

The challenges and risk associated with this alternative are similar to those presented in the previous section on excavating additional storage volume that is hydraulically linked to Lake Geraldine. The largest risk associated with having alternative water storage hydraulically independent of Lake Geraldine relates to the transfer of water between reservoirs during the winter months and the risk of having the water transfer mechanism fail.

This alternative will be retained for further evaluation and consideration as a viable option.

7.3.3 Combination of excavated and Bermed & lined reservoir in close proximity to Lake Geraldine

An above grade reservoir constructed within close proximity to Lake Geraldine has been determined to be infeasible due to insufficient land area that is within the tolerable gradient required to accommodate this size of above grade reservoir. However, a combination of an excavated and bermed reservoir in close proximity to Lake Geraldine will be considered as a potential alternative. Rock escarpments can form a natural impervious barrier and can be used in combination with constructed Berms with a liner to form a water containment facility. Excavated materials can be evaluated during construction and may meet specifications to be used for the construction of the perimeter berms.

As described in the previous section, a benefit of the alternatives that are hydraulically independent of Lake Geraldine relate to the flexibility of the proposed water storage elevation. Based on the existing topography surrounding Lake Geraldine and the location of rock escarpments, the potential site location can be selected to minimize capital costs associated with excavation and berming works, while facilitating mid-winter transfer of water. This alternative could serve as both an efficient and cost-effective means of achieving the required storage volume to meet the design horizon.

An important consideration for the City of Iqaluit is that the capital works associated with this alternative could be strategically coordinated with quarrying operations. This would mitigate the high capital cost associated with the excavation activities required for this alternative. A phased approach could be considered to gradually meet the water storage needs of the growing population of Iqaluit. This would entail phasing the construction of multiple cells to meet the needs of the City as the population grows. Phasing would however create some redundant work which would increase the total capital costs to meet the ultimate design needs. The operation and maintenance costs associated with this alternative relate mainly to the mid-winter water transfer, maintenance of the access road, annual berm inspections.

The largest risk associated with having alternative water storage hydraulically independent of Lake Geraldine relates to the transfer of water between reservoirs during the winter months and the risk of having the water transfer mechanism fail.

A preliminary analysis has been completed to determine a potential location for this alternative. Refer to Figure 5, included in Appendix A. The conceptual location selected for further analysis is the higher ground to the northeast of Lake Geraldine. This alternative incorporates excavation to an elevation of 113m and berming along the perimeter of the new reservoir to contain the water storage at a high-water elevation of 127m. This alternative has the potential of providing the required supplementary storage to meet the requirements of the design horizon. Figure 7-1 below is a three-dimensional representation of the potential excavated and bermed reservoir. This Alternative will be retained for further evaluation and consideration as a viable option.

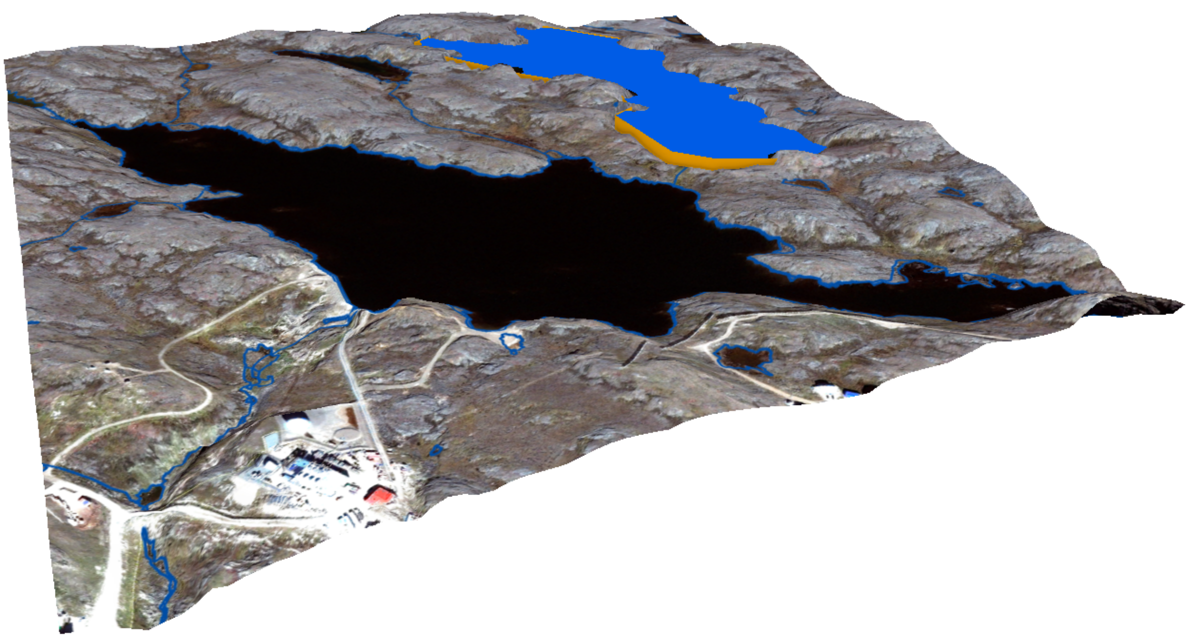

Figure 7-1: Three-Dimensional Representation of an Excavated & Bermed Reservoir

7.4 Summary

The following alternatives have been retained for detailed evaluation:

- Alternatives that are hydraulically connected to Lake Geraldine:
    - Excavation of additional storage volume within Lake Geraldine
    - Excavation of additional storage volume in close proximity to Lake Geraldine
- Alternatives that are hydraulically independent to Lake Geraldine:
    - Combination of excavated and bermed reservoir in close proximity to Lake Geraldine

8 Evaluation Scheme

Prior to undertaking the evaluation of the water storage alternatives that have been carried forward from the alternative definition, a scoring and weighting scheme has been developed.

The evaluation scheme examines the following three broad based areas:

- Technical Performance
- Economic Efficiency
- Community Impact

Several key issues were considered within each of these categories. Each of the alternatives which have been carried forward for further consideration will be evaluated on a score from 0 to 10 for each parameter presented in the following sections. A weighting factor will be applied to the score received for each parameter in order to reflect the importance each criterion. Comment is sought both on the proposed evaluation criteria and the weight applied to each criterion.

8.1 Technical Performance

8.1.1 Storage Requirement

The design basis for the long-term water storage pre-feasibility study has determined the additional water storage volume that will satisfy the anticipated population growth to the end of the design period (2050). On this basis, the ability to store sufficient water is considered to be a pass-fail requirement. Alternatives will not receive further consideration if this water storage criterion is not met.

8.1.2 Ease of Expansion Via Project Phasing

This parameter will consider the ease of phasing of each potential alternative. Due to the quantities of water projected for a 30-year design horizon, the scale of this project is large in terms of construction durations and capital requirements. It is anticipated that a phased approach would be attractive to the City for several reasons. This would provide the time needed to secure the capital required to fund the construction activities. Smaller construction packages would also ensure that a broader group of qualified contractors are able to bid on the project, thus they are not unable to bid due to financial bonding limitations. A phased construction approach would also ensure that the storage requirements being constructed are reflective of the shorter-term demand projections. Alternatives will be scored progressively lower as the challenges with phasing increase. A weighting of 10 has been applied to this parameter in recognition of the value of this requirement.

8.1.3 Risk of Technical Successful Completion

This parameter has been used to evaluate the likelihood of successful completion of the alternative. Risks that will be considered against successful completion include:

- Potential impact on water quality arising during the construction period
- Risk to the existing water supply and water storage structures
- Risk of jeopardizing the availability of the required over-winter storage during the winter following construction.

Alternatives will be awarded progressively lower scores as the risk associated with the probability of successful completion increases. A weighting factor of 7 has been assigned to this criterion.

8.1.4 Constructability Technical Effort

The success of any potential alternative requires the appropriate construction operations and quality control. The level of effort required to achieve suitable level of performance has been considered. This assessment accounts for the technical difficulty of all construction activities, as well as the necessary performance requirements of both the equipment as well as the operators. Alternatives which necessitate unique equipment and technically skilled operators will receive lower scores for this criterion. The anticipated length of the construction period required for a potential alternative will also be considered. A weighting of 7 has been applied to this parameter.

8.2 Economic Efficiency

8.2.1 Capital Cost

Provision of additional water storage which will meet the needs of the City of Iqaluit till the design horizon of 2050 will represent a substantial capital investment as well as a need for ongoing operating expenditures. Capital cost is an important consideration as the City of Iqaluit must fund the project out of their short-term budget, in an environment of many competing obligations. A weight of 10 has been applied to capital cost in recognition of this significant financial constraint.

8.2.2 Life Cycle Cost

This parameter, which is a measure of financial efficiency, is based upon the value of the estimated capital plus present value cost of operating expenditures required over the design life of the alternatives. This criterion is included in the evaluation scheme as a tool to avoid the selection of an alternative with modest capital costs, but onerous ongoing operating costs.

As an example, alternatives that entail mid-winter transfer of water, operating costs to consider are associated with; the site access during the period of water transfer, utilities, fuel delivery and required maintenance. A high weight of 10 has been applied to this parameter in recognition of the merits of alternatives that are economically efficient over the long term.

8.2.3 Risk of Unexpected Expenditures

This parameter evaluates the risks of unanticipated expenditures throughout the life of the alternatives. An example of such an expenditure is the response to an unanticipated operational failure such as pipe failure due to freeze. The evaluation of the risk of unanticipated spending considers both the likelihood of such need and the resulting costs associated with repair. A low weight of 4 has been applied to this parameter as a reflection of the unreliability of this estimate.

8.3 Community Impact

8.3.1 Maintenance Burden due to Access

This parameter evaluates the added maintenance burden for municipal staff as a result of the potential alternative. The alternatives that entail mid-winter access require the provision of vehicle access, which will require road maintenance and snow removal. The added level of effort required by the City to maintain access to the water storage facility has been considered. These concerns have been incorporated into the evaluation scheme from the perspective of the acceptance from the community of the additional maintenance burden. A weight of 7 has been applied to this parameter.

8.3.2 Worker Safety

Worker safety concerns have been considered in the evaluation of alternatives. Issues that were considered include those associated with working at a remote facility and safety concerns due to the necessity to access to the site during harsh mid-winter conditions. The highest weight of 10 has been applied to the concern over worker safety.

8.3.3 Disruption to the Community

This parameter will evaluate the nuisance to the community arising from the construction as well as the operation of the new storage facility. One consideration is the disruption of transportation routes throughout the City. Potential alternatives may also have an impact on foot paths and snowmobile trails in the community. A weight of 7 has been applied to this parameter.

8.3.4 Environmental Consideration

The Environmental Considerations parameter will evaluate the general risk to the environment arising from disruption of the landscape due to earthworks associated with the supplementary storage. Potential Environmental Considerations may relate to items such as runoff, dust, noise, wetlands, etc. A weight of 8 has been applied to this parameter.

8.4 Evaluation Scheme Summary

The parameters, scoring scale and weights for each parameter are presented in the following table:

Table 8-1: Evaluation Scheme Summary

Parameter	Scoring Scale	Score	Weight	Weighted Score
Technical Performance				
Storage Requirement	Pass/Fail	Pass	N/A	
Ease of Expansion Via Project Phasing	1-10		10	
Risk of Technical Successful Completion	1-10		7	
Constructability Technical Effort	1-10		7	
Economic Efficiency				
Capital Cost	1-10		10	
Life Cycle Cost	1-10		10	
Risk of Unexpected Expenditures	1-10		4	
Community Impact				
Maintenance Burden due to Access	1-10		7	
Worker safety	1-10		10	
Disruption to the Community	1-10		7	
Environmental Consideration	1-10		8	
Total				

9 Alternatives Evaluation

9.1 Excavation within Lake Geraldine

9.1.1 Technical Performance

Although the alternative of excavation within Lake Geraldine is a simplistic solution to the shortfall of holding capacities, the execution strategies carry considerable amounts of technical challenges and risk with the anticipated methodology of the work. A project that requires underwater excavation is not entirely uncommon; however, a project that necessitates large quantities of underwater excavation within a municipal water reservoir is quite unique. This brute force approach provides a 1:1 ratio for material displaced to water storage equivalency, thus 1m^3 of material removed equates to an increase in storage capacity of 1m^3.

Dredging is the operation of excavating material from a water environment. It is believed that there are two potential dredging techniques which could be successful in removing material from within Lake Geraldine to increase water storage capacities: mechanical dredging and hydraulic suction dredging. Both techniques would require detailed geological information, environmental studies, contingency plans, specialized equipment, strict controls, constant monitoring, and significant time to complete. Currently, the geological composition surrounding Lake Geraldine is not well known, and it is assumed that the excavation of solid bed rock will be required. The use of mechanical dredging techniques would therefore necessitate the blasting of the bedrock to fracture the rock to appropriate size for extraction. It is envisioned that drills and long reach excavation equipment would need to be mounted on barges. The excavated material would then be loaded on barges and brought to shore where the material would then again be loaded into trucks and brought to a dump site. Hydraulic dredging is another technique of excavating material underwater. It uses suction to remove material from within a body of water. There are dredges referred to as cutter and suction dredges which are equipped with large drill heads which are capable of cutting through hard surfaces, even bedrock depending on a variety of variables such as the rock quality designation (RQD) and the class of dredge. If this technique would be deemed adequate, rock blasting would not be required and therefore dramatically mitigates risks associated with this alternative. From experience, bedrock in Iqaluit typically is considered to be quite “hard”, and the portability requirements needed to access the Lake may not allow for an appropriately sized dredge to cut through the bedrock. Due to the lack of confidence that hydraulic dredging can adequately perform, the analysis will continue assuming mechanical dredging techniques will be utilized.

A preliminary analysis has determined that excavating within Lake Geraldine could provide the supplementary storage to meet the 2050 design horizon. From a phasing perspective, this approach is very attractive as there is no redundant work or lost effort associated with completing the excavation. As material is removed, equivalent storage is gained. Due to the nature of this approach, work must be conducted whilst the Lake is generally ice free. This restriction would only allow for work throughout the summer and fall months and there are concerns that the potential quantity of material removed within a season would be significantly less then desired quantities. As a rough estimate, it is believed that mechanical dredging methodology would be at a minimum 50% slower than typical non-submerged rock excavation and this would be evident in the unit price of excavation removal. As a rough estimate, dependent of resources applied, it is estimated that only 150,000m^3 to 200,000m^3 could be removed within a year.

There is abundant risk associated with this methodology, and mitigation measures are challenging. There are two immediate concerns related to undesirable outcomes associated with blasting, that is unintended fracturing and the negative effects of vibration. The outcome of a blasting error or rock inconsistency could jeopardize the Lake Geraldine's and the dam's ability to contain water. Additional environmental risks associated are related to turbidity and the potential contamination of Lake Geraldine during construction. The overall risks to the water supply and storage structures are considered to be extremely high.

The level of technical effort required to achieve suitable performance has been reviewed. This assessment contemplates the equipment needed amount of operator attention and the required skill levels of the operators. Excavation activities within Lake Geraldine will require higher operating effort and specialized expertise that is not readily available in Iqaluit. The contractor will be required to import equipment and the appropriate personnel to operate. It is assumed that the work on land could utilize local resources and personnel, but it is likely the contractor would benefit from using mining equipment such as haul truck as opposed to triaxles. Even with the import of mining trucks, the contractor could train and utilize the local work force to execute. The level of effort to achieve suitable performance is concluded to be significantly high.

9.1.2 Economic Efficiency

9.1.2.1 Capital Costs

Provision of additional water storage which will meet the needs of the City of Iqaluit till the design horizon of 2050 will represent a substantial investment. As with any excavation or mining assignment, the double handling of material adds considerable costs. In contrast, this material may present an opportunity for the City, as any suitable material removed may be utilized to fabricate aggregate for future use by or for the City. There could therefore be return value in the contractor processing the material further. For this to be possible, sufficient space and access become critical when evaluating dump locations for this magnitude of material. Additionally, the consideration of hauling costs has a significant effect on the feasibility of this assignment should a nearby dumping and processing location not be possible.

A class D cost estimate has been prepared for this alternative and the results are presented in Table 9-1 below. The capital cost for the excavation of 1.3M m^3 assuming mass rock excavation costs of approximately $150 per cubic meter is estimated at $195,000,000. It is further assumed that improvements to access Lake Geraldine as well as a dump site will be required and an estimate of $250,000 has been allocated for these activities.

Table 9-1: Cost Estimate for Excavation within Lake Geraldine

Description	Quantity	Units	Unit Rate	Total Cost
Access Improvements	1	LS	$ 250,000.00	$ 250,000.00
Excavation	1,300,000	m^3	$ 150.00	$ 195,000,000.00
Total				$ 195,250,000.00

9.1.2.2 Operating Costs

While the capital cost of excavating within Lake Geraldine are considered to be very high, an important consideration is that following construction, there would be no additional ongoing operation or maintenance costs associated with this alternative. Inspections and monitoring would likely be required but these costs are considered to be negligible. With the lack of operational and maintenance activities, this simplistic approach has minimal risk of future unexpected expenditures post construction.

9.1.3 Community Impact

The alternative of excavating additional storage capacity within Lake Geraldine would not impose an added level of effort required by the City to operate or maintain access to the water storage facility. Nor would there be added concerns over worker safety or disruption of routes out of the community post construction. There would be disruptions to traffic routes and the community during the construction, mobilization, and demobilization as a significant amount of large equipment would be required at the site which will require access through municipal roads. Assuming the selected dump site is near Lake Geraldine, the trucking routes could be designed to minimize interference with local traffic. The footprint of this dump site would require a significant area of land, as 1.3M m^3 of excavated material swollen at 30% would require an area of roughly 169,000m^2 assuming the dump pile is 10m high. The 1.3M m^3 being the additional over-winter storage target to meet the 2050 design horizon. Dependent on the location of the dump location, which is assumed to be in proximity to the Plateau development may impact snowmobile trails, walking trails, berry picking grounds, or other uses of the tundra. Furthermore, there would be ongoing disturbance to the nearby community affected by the dust, noise and vibrations caused by construction activities spanning several years.

The execution strategies of this alternative carry large amounts of environmental risk associated with the methodology of the construction work. Environmental risks include increased turbidity within the reservoir, the potential for water contamination, and damage to the containment ability of Lake Geraldine during construction. At the dump location, erosion and sediment control measures will be permanently required. Once the construction is complete and Lake Geraldine's storage capacity has been expanded, these risks related to water storage and quality throughout daily operations are drastically minimized.

9.1.4 Evaluation Summary

The following Table 9-2 summarizes the evaluation of excavating additional storage volume within Lake Geraldine.

Table 9-2: Evaluation Summary for Excavation within Lake Geraldine

Parameter	Weight	Excavation Within Lake Geraldine		Comments
		Score	Weighted Score	
Technical Performance				
Storage Requirement	N/A	Pass		• Based on existing elevations, the Lake could be depended to achieve the additional storage needed
Ease of Expansion Via Project Phasing	10	8	80	• Favorable as there is no redundant effort/work associated with phasing, except for mobilization efforts • Volumes of additional storage require solely excavation, therefore excavate as needed in each phase • 1:1 ratio for material displaced versus storage gained

Parameter	Weight	Excavation Within Lake Geraldine		Comments
		Score	Weighted Score	
Risk of Technical Successful Completion	7	4	28	• Challenging to ensure negative impacts throughout construction are not encountered • Significant risks to the existing containment within Lake Geraldine and the Dam due to blasting
Constructability Technical Effort	7	4	28	• Requires specialized equipment and operators • Significant mobilization efforts for barges and excavation equipment • Significant monitoring required
Economic Efficiency				
Capital Cost	10	2	20	• Very capital intensive
Life Cycle Cost	10	4	40	• Due to high capital requirements • No additional operation and maintenance, all cost is capital based
Risk of Unexpected Expenditures	4	8	32	• Due to lack of maintenance and operational requirements, minimal risks
Community Impact				
Maintenance Burden due to Access	7	10	70	• The use of existing facilities, no additional access needed
Worker safety	10	7	70	• Modest safety concerns throughout construction, post construction has minimal risks
Disruption to the Community	7	8	56	• Minor disruptions throughout mobilization and construction, once operational there is no additional impact to community
Environmental Consideration	8	4	32	• Several considerable risks associated with water quality & existing impoundment throughout construction
Total			**456**	

9.2 Excavation in close Proximity to Lake Geraldine

9.2.1 Technical Performance

The nature and estimated quantities of excavation lead to the conclusion that this would be considered a mining project requiring specialized resources. Due to the topography adjacent to Lake Geraldine and the estimated footprint of a storage cell, this approach provides an estimated 1.4:1 ratio for material displaced to water storage equivalency. Thus 1.4m^3 of material removed equates to an increase in storage capacity of 1m^3. This is due to the existing material within the footprint of the reservoir that is above the dam's existing spillway elevation. As this reservoir is hydraulically connected to Lake Geraldine, water storage is not achieved until the excavation is below the spillway elevation. Further, as noted in previous sections, overwinter storage capacity is not increased until approximately 2m below the dam's spillway due to ice. Under this condition, the design objective must be able to provide storage for 1.8M m^3 of water.

The successful completion of this project will require detailed geological information, environmental studies, contingency plans, specialized equipment, strict controls, constant monitoring, and significant time to complete. Currently, the geological composition surrounding Lake Geraldine is not well known, and it is assumed that the excavation of bedrock will be required. The use of blasting equipment would be necessary to fracture the rock to appropriate size for extraction. The excavated material would be loaded into trucks and brought to a designated dump site. For this to be possible, sufficient space and access become critical when evaluating dump locations for an estimated 2.5M m^3 (bank) of material. Hauling costs have a significant effect on the feasibility of this assignment should a nearby dumping location not be possible. Further, it should be noted that the estimated excavation quantities are considered as in-situ or bank, therefore, allowing a bulking factor would be appropriate. At this point, accounting for a 30% bulking factor would equate to the generation of 3.25M m^3 of material would need to be hauled away. A small portion of this material could be utilized to construct the permanent access roads to the cell, and the remainder would be sent to a dump site. In contrast, this material may present an opportunity for the City, as any suitable material removed may be utilized to fabricate aggregate for future use by or for the City. There could therefore be return value in the contractor processing the material further.

This alternative is attractive from a phasing perspective, as the City may wish to proceed with a phased approach to reduce capital investments. This would be completed by strategically constructing multiple cells at different points in time. This approach would create a trivial amount of redundant work due to shared containment berms or the removal of shared berms.

There are significant risks associated with this alternative, relating to undesirable outcomes associated with blasting, unintended fracturing of rock, and the negative effects of vibration. Due to the assumed locations for the reservoir (North of Lake Geraldine), it is believed these risks can be adequately mitigated throughout the construction of the reservoir. One of the greatest technical challenges with the construction will be completion of the hydraulic connections between the new reservoir cell and Lake Geraldine. It is envisioned that a channel connecting the new cell and Lake Geraldine would be necessary. Due to the lower volume of work associated with this task specifically, it can likely be managed appropriately.

The level of effort required to achieve suitable performance has been reviewed. This assessment contemplates the equipment needed and the required skill levels of the operators. Excavation activities adjacent to Lake Geraldine would benefit from equipment that is suited for mining works. Although there is some equipment currently in Iqaluit, the existing quantities are viewed as insufficient and would require mobilization of a dedicated mining fleet. In conjunction with the anticipated quantities, it is believed that increases from the local equipment class would be economical. This machinery would require experienced operators of modest skills, and it is believed the local work force could be adequately trained to operate. One of the more challenging activities is the hydraulic connection linking the new cell to the Lake Geraldine reservoir. This task will require a higher level of specialized equipment and operating skills which will have to be imported. One of the attractive aspects of this project would be that the majority of the construction activities could continue throughout the winter months, thus shortening the schedule and reducing a contractor’s indirect costs. The level of effort to achieve suitable performance is concluded to be moderately high.

9.2.2 Economic Efficiency

9.2.2.1 Capital Costs

As noted above the City may wish to construct multiple cells which could be strategically constructed at different points in time. This would lead to marginal increased costs associated with the construction. The estimate below will assume the project will be built in one single cell. Another attractive consideration of this alternative is the ability of the contractor working throughout the winter months as there are advantages to mass excavation throughout sub-zero temperatures. Assuming the project were to be operational year-round and dependent on resources applied it estimated that the construction works alone would require approximately 4 years to complete

A class D cost estimate has been provided below in table 9-3. The largest capital cost for this alternative is the excavation and hauling of excavated material. The 2.5M m^3 of excavation required is estimated at a unit price of approximately $50 per cubic meter which equates to an estimated $125M in excavation. This assumes a dump site could be located in close proximity to the excavation. The total cost of this alternative is estimated to be $132,375,000.

Table 9-3: Cost Estimate for Excavation in close Proximity to Lake Geraldine

Description	Quantity	Units	Unit Rate	Total Cost
Build New Access Road	2,500	Lm	$ 950.00	$ 2,375,000.00
Excavation and Hauling of material	2,500,000	m^3	$ 50.00	$ 125,000,000.00
Hydraulic channel to Lake Geraldine	1	LS	$ 2,000,000.00	$ 2,000,000.00
Supply and Install Liner	100,000	m^2	$ 30.00	$ 3,000,000.00
Net Total				$ 132,375,000.00

9.2.2.2 Operating Costs

While the capital cost of construction will represent the largest financial investment for the City, there are additional operating and maintenance costs which are important to take into consideration. For example, the operation and maintenance of roads for year-round access to the new reservoir cell should the City desire. The City could also choose to not maintain the construction road as there is no need for routine access to the cell if it is functioning correctly. This is due to the absence mechanical devices which require operation, service, fuel or have the potential for failure. Inspection of the storage cell(s) should occur on an annual basis to monitor for leaks and containment issues. Provision for liner repairs should be made on a 10-year occurrence. Other required maintenance activities include the hydraulic channel connecting the new storage to Lake Geraldine is also expected and scaling of the reservoir's rock walls. Most of the new reservoir's rock walls will have never experienced freeze thaw cycles and it is expected that scaling may be required on a 10-year occurrence. The following Table 9-4 summarizes an opinion of the operating and maintenance costs which have be taken into consideration for this alternative. Note, all costs are assumed in present value.

Table 9-4: Operation & Maintenance Cost Estimate for Excavation in close proximity to Lake Geraldine

Description	Occurrence	Unit Rate	Operating Costs Over 30 Years
Containment inspection	Per year	$ 10,000	$ 300,000
Road maintenance	Per Year	$ 20,000	$ 600,000

Liner repairs	Per 10 years	$ 100,000	$ 300,000
Maintenance of Hydraulic channel to Lake Geraldine	Per 10 years	$ 200,000	$ 600,000
Scaling of reservoir rock walls due to freeze thaw	Per 5 years	$ 20,000	$ 120,000
Operating & Maintenance Cost Over 30 Years Total			$ 1,920,000

9.2.3 Community Impact

The alternative of excavating a new reservoir that is hydraulically connected in close proximity to Lake Geraldine will impose minimal additional effort required by the City to operate or maintain. As noted above, the City may elect to not regularly maintain year-round access to the new reservoir once it is operational as periodic inspection visits would likely suffice. Dependent on the City's decision, there would be some added safety concerns due to location and access should mid-winter visits be necessary. This risk is considered to be moderate as the frequency of visits is likely low. A minimum of two to three visits spread over the winter period would be required to ensure that there are no issues with the water transfer operation.

There would be disruptions to traffic routes and the community during the construction mobilization and demobilization as a significant amount of large equipment would be required at the site which will require access through municipal roads. There would be some disturbance to the nearby community (dependent on access and dump location) affected by the dust, noise and vibrations caused by mobilization activities. Assuming the selected dump site is near the new reservoir, the trucking routes could be designed to not interfere with local traffic. The footprint of this dump site would require a significant area of land, as 2.5M m^3 of excavated material swollen at 30% would require an area of roughly 325,000m^2 assuming the pile is 10m high. Dependent on the location, this may impact snowmobile trails, walking trails, berry picking grounds, or other uses of the tundra. The dump site would also require permanent sediment and erosion control measures to be installed.

The potential execution strategies of this alternative carries moderate amounts of environmental risk associated with the methodology of the work. As the majority of this work is conducted on land while constructing the reservoir, the environmental risks include disruption of the tundra landscape due to earthworks and the potential contamination of the water supply due to fuel leaks and construction activities. The risks of contamination can be mitigated and contained with proper practices and procedures as water would not be introduced into the reservoir until the construction is complete and any spills that may occur are thoroughly cleaned. There is also the necessity for some in water work as the hydraulic connections between the new cell and Lake Geraldine are completed. This work would require using machinery in Lake Geraldine which introduces the potential for contamination, increased turbidity, and negative effects on the Lake's containment ability. It is assumed that the excavation quantities are significantly reduced to complete the connections which increases the feasibility of smaller, more controlled, and environmentally friendly execution strategies that would aid in mitigating these risks.

9.2.4 Evaluation Summary

The following Table 9-4 summarizes the evaluation of excavation in close proximity to Lake Geraldine.

Table 9-5: Evaluation Summary for Excavation in Close Proximity to Lake Geraldine

Parameter	Weight	Excavation in Close Proximity to Lake Geraldine		Comments
		Score	Weighted Score	
Technical Performance				
Storage Requirement	N/A	Pass		• Based on surrounding topography, the additional storage needed can be achieved
Ease of Expansion Via Project Phasing	10	7	70	• Phasing is challenging due to mobilization issues for mining equipment. • 1.4:1 ratio for material displaced versus storage gained
Risk of Technical Successful Completion	7	6	42	• Moderate risks to the existing containment within Lake Geraldine and the Dam due to blasting
Constructability Technical Effort	7	6	42	• Requires some specialized mining equipment and operators • Significant mobilization effort • Moderate monitoring required
Economic Efficiency				
Capital Cost	10	5	50	• Capital intensive

Parameter	Weight	Excavation in Close Proximity to Lake Geraldine		Comments
		Score	Weighted Score	
Life Cycle Cost	10	5	50	• Capital Intensive • Moderate operation and maintenance
Risk of Unexpected Expenditures	4	8	32	• Due to lack of maintenance and operational requirements, minimal risks
Community Impact				
Maintenance Burden due to Access	7	7	49	• Access road required
Worker safety	10	7	70	• Minimal safety concerns throughout construction and during operation
Disruption to the Community	7	7	49	• Minor disruptions throughout mobilization and construction • During construction there will likely be disturbance due to noise, vibration and dust possibly
Environmental Consideration	8	6	48	• Considerable risk associated with water quality throughout construction
Total			**502**	

9.3 Excavation & Berming of Hydraulically Independent Reservoir

9.3.1 Technical Performance

One key advantage of having a hydraulically independent reservoir in comparison to hydraulically connected reservoirs is that the system is not constrained by pre-existing elevations. Dependent on the selected site topography and the estimated footprint of the reservoir, this approach provides an estimated 0.7:1 ratio for material displaced to water storage equivalency. Thus 0.7m^3 of material excavated could provide water storage capacity of 1m^3. The material that is removed through excavation is valued as it becomes utilized to construct and increase the elevation of the containment berms, thus increasing storage capacities. This approach will increase the footprint of the City's water storage system and therefore capacities must consider the storage that is lost due to ice formation at the surface. Under this condition, the design object must be able to provide the over winter storage of 1.247M m^3 of water.

The successful completion of this project will require detailed geological information, environmental studies, contingency plans, specialized equipment, strict controls, constant monitoring, and significant time to complete. Currently, the geological composition surrounding Lake Geraldine is not well known, and it is assumed that the excavation of bedrock will be required. The use of blasting equipment would be necessary to fracture the rock to appropriate size for extraction. The contractor will need to implement earthworks management protocols to sort and select material that is suitable for berm construction. It is believed that the blasting process will produce material that is suitable as is, and some material that would require further processing to be deemed suitable. The appropriately sized material would be loaded into trucks and brought to a berm placement site. The unsuitable material would either be brought to a dump site for further processing. For this to be possible, sufficient space and access becomes critical when evaluating berm as well as waste dump locations. This is to stress the impact of hauling costs on the feasibility of this assignment. Further, it should be noted that the estimated excavation quantities are considered as in-situ or bank, therefore, allowing a bulking factor would be appropriate. At this point, accounting for a 30% bulking factor, therefore the excavation of 1.0M m^3 would equate to the generation of 1.3M m3 of material would need to be handled. In addition to the material utilized to construct the berm, another small portion of this material could be utilized to construct the permanent access road to the cell, and the remainder would be sent to a dump site. In contrast, this waste material may present an opportunity for the City, as the excess material could be utilized to fabricate aggregate for future use by or for the City. This could create return value in having the contractor processing the material further.

This alternative is moderately appealing from a phasing perspective, as the City may wish to construct multiple cells which could be strategically constructed at different points in time. This would lead to increased costs associated with the construction due to redundant work such as additional containment berms needed for phasing. The cost estimate below will assume the project will be built in one single cell. Another attractive component of this alternative is the possibility of the contractor working throughout the winter months as there are advantages to excavation in sub-zero temperatures.

There are certainly risks associated with this alternative, they relate to undesirable outcomes associated with blasting, that is unintended fracturing and the negative effects of vibration. Due to the assumed locations for the reservoir and the proximity to Lake Geraldine, it is believed these risks can be adequately mitigated throughout the construction. One of the greatest technical challenges with the construction will be completion of the hydraulic connections between the new reservoir cell and Lake Geraldine. It is envisioned that buried piping connecting the new cell and Lake Geraldine would be necessary. This conveyance piping is exposed to functionality risks associated with pipe freeze, especially during mid-winter water transfer. Careful consideration of these challenges during design will aid in mitigating these risks. This piping system will require operational access and some level of appropriate maintenance throughout the course of its life.

The level of effort required to achieve suitable performance has been reviewed. This assessment contemplates the equipment needed and the required skill levels of the operators. Excavation activities adjacent to Lake Geraldine would benefit from equipment that is suited for mining works. Although there is some suitable equipment currently in Iqaluit, the existing quantities are viewed as insufficient and would require mobilization of additional equipment. This machinery would require experienced operators of modest skills, and it is believed the local work force could be adequately trained to operate. The most challenging activity is likely the hydraulic connection linking the new cell to the Lake Geraldine reservoir, but the local contractors are capable of completing this task. One of the attractive aspects of this project would be that the majority of the construction activities could continue throughout the winter months, thus shortening the schedule and reducing a contractor's indirect costs. The level of effort to achieve suitable performance is concluded to be moderately high.

9.3.2 Economic Efficiency

9.3.2.1 Operating Costs

As noted above the City may wish to construct multiple cells which could be strategically constructed at different points in time. This would lead to marginal increased costs associated with the construction. The cost estimate will assume the project will be built in one single cell. Another attractive consideration of this alternative is the ability for the contractor to work throughout the winter months as there are advantages to mass excavation throughout sub-zero temperatures. Assuming the construction were to be operational year-round and dependent on resources applied it estimated that the construction works alone would require approximately 3 years to complete.

The largest capital cost for this alternative is the excavation and hauling of excavated material. The 0.9M m^3 of excavation required is estimated at a unit price of approximately $50 per cubic meter which equates to an estimated $45 million in excavation. This assumes a dump site could be located in close proximity to the excavation. The total capital cost of this alternative is estimated in Table 9-6 to be $64,325,000.

Table 9-6: Cost Estimate for Excavation & Berming of a Hydraulically Independent Reservoir

Description	Quantity	Units	Unit Rate	Total Cost
Build New Access Road	3,500	Lm	$ 950.00	$ 3,325,000.00
Excavation and Hauling of material	900,000	m^3	$ 50.00	$ 45,000,000.00
Berm Construction	400,000	m^3	$ 30.00	$ 12,000,000.00
Hydraulic Connections & Water Transfer facility	1	LS	$ 1,000,000.00	$ 1,000,000.00
Supply and Install Liner	100,000	m^2	$ 30.00	$ 3,000,000.00
Net Total				$ 64,325,000.00

9.3.2.2 Operating Costs

While the capital cost of construction will represent the largest financial investment for the City, there are additional operating and maintenance costs which are important to take into consideration. These costs include operation of roads for year-round access to the new reservoir cell, operation of the conveyance infrastructure, and periodic berm and liner inspections. The City would need to maintain the access roads due to the presence of mechanical devices which require operation, service, fuel and have the potential for failure. Provision should be made for rehabilitation of the water transfer facility in the event of operation failure, as well as repair of the water transfer pipeline due to freeze damage. Provision for liner repairs should be made on a 10-year occurrence. Most of the new reservoir's rock walls will have never experienced freeze thaw cycles and it is expected that scaling may be required on a 10-year occurrence. The following Table 9-7 summarizes an opinion on the operating and maintenance costs which have been taken into consideration for this alternative. Note, all costs are presumed as present value.

Table 9-7: Operation & Maintenance Cost Estimate for Excavated and Bermed Reservoir

Description	Occurrence	Unit Rate	Operating Costs Over 30 Years
Berm and liner inspection	Per year	$ 10,000	$ 300,000
Access road maintenance	Per year	$ 20,000	$ 600,000
Liner repairs	Per 10 years	$ 100,000	$ 300,000
Water transfer facility operation	Per year	$ 50,000	$ 1,500,00
Water transfer facility repairs	Per 15 years	$ 125,000	$ 250,000
Scaling of reservoir rock walls due to freeze thaw	Per 5 years	$ 10,000	$ 60,000

Operating & Maintenance Cost Over 30 Years Total			$ 3,010,000

9.3.3 Community Impact

The alternative of excavating a new reservoir that is hydraulically independent to Lake Geraldine will impose modest additional effort required by the City to operate or maintain. As noted above, the City will need to regularly maintain a year-round access to the new reservoir along with the operation of appropriate conveyance infrastructure. This would add safety concerns due to location and access for mid-winter visits. This risk is considered to be moderate as the frequency of visits is likely low. There would be disruptions to traffic routes and the community during the construction mobilization and demobilization as a significant amount of large equipment would be required at the site which will require access through municipal roads. There would be some disturbance to the nearby community affected by the dust, noise and vibrations caused by mobilization activities. Assuming the selected dump site is near the new reservoir, the trucking routes would not interfere with local traffic. The location of the reservoir along with the dump site will require a significant area of land which may impact snowmobile trails, walking trails, berry picking grounds, or other uses of the tundra.

The potential execution strategies of this alternative carry minor amounts of environmental risk associated with the methodology of the work. As the majority of this work is conducted on land while constructing the reservoir, the environmental risks include localized disruption of the tundra landscape due to earthworks. There is the potential for contamination of the water supply due to fuel leaks and construction activities. These risks can be mitigated and contained with proper practices and procedures as water would not be introduced into the reservoir until the construction is complete and any spills that may occur are thoroughly cleaned. There is also the necessity for minor in water works at the outlet of the conveyance infrastructure. This work would likely require using machinery in Lake Geraldine which introduces the potential for contamination, increased turbidity, and negative effects on the Lake's containment ability. It is assumed that the work quantities are small and therefore the feasibility of smaller, more controlled, and environmentally friendly execution strategies would aid in mitigating these risks.

9.3.4 Evaluation Summary

The following Table 9-8 summarizes the evaluation of excavation in close proximity to Lake Geraldine.

Table 9-8: Evaluation Summary for Excavation and Berming of Hydraulically Independent Reservoir

Parameter	Weight	Excavation & Berming of Hydraulically Independent Reservoir		Comments
		Score	Weighted Score	
Technical Performance				
Storage Requirement	N/A	Pass		• Based on surrounding topography, the additional storage needed can be achieved
Ease of Expansion Via Project Phasing	10	5	50	• Large volume of excavation required for further storage • 0.7:1 ratio for material displaced versus storage gained • Additional effort required for berming works to accommodate phasing
Risk of Technical Successful Completion	7	7	49	• Moderate risks to the existing containment within Lake Geraldine and the Dam due to blasting • Minimal risk of leakage through containment berms
Constructability Technical Effort	7	8	56	• Requires some specialized mining equipment and operators • Moderate monitoring required
Economic Efficiency				
Capital Cost	10	9	90	• Moderate capital intensive
Life Cycle Cost	10	5	50	• High operation and maintenance costs
Risk of Unexpected Expenditures	4	8	32	• Due to lack of maintenance and operational requirements, minimal risks
Community Impact				
Maintenance Burden due to Access	7	7	49	• Access road required
Worker safety	10	7	70	• Minimal safety concerns throughout construction and post construction

Parameter	**Weight**	**Excavation & Berming of Hydraulically Independent Reservoir**		**Comments**
		Score	**Weighted Score**	
Disruption to the Community	7	7	49	• Minor disruptions throughout mobilization and construction, once operational there is minimal additional impact to community • There will likely be disturbance due to noise, vibration and dust possibly during construction
Environmental Consideration	8	6	48	• Considerable risk associated with water quality throughout construction
Total			**543**	

10 Alternatives Selection

The following Table 10-1 compares the evaluation of the alternatives. Based on the preceding evaluation, the preferred alternative is the excavation and berming of a hydraulically independent reservoir.

Table 10-1: Comparison of Alternatives Evaluation

Parameter	Weight	Excavation Within Lake Geraldine	Excavation in Proximity to Lake Geraldine (Hydraulically Connected)	Excavated & Bermed Hydraulically Independent Reservoir
		Weighted Score	Weighted Score	Weighted Score
Technical Performance				
Storage Requirement	N/A			
Ease of Future Expansion	10	80	70	50
Risk of Technical Successful Completion	7	28	42	49
Operating Technical Effort	7	28	42	56
Economic Efficiency				
Capital Cost	10	20	50	90
Life Cycle Cost	10	40	50	50
Risk of Unexpected Expenditures	4	32	32	32
Community Impact				
Maintenance Burden due to Access	7	70	49	49
Worker safety	10	70	70	70
Disruption to the Community	7	56	49	49
Environmental Consideration	8	32	48	48
Total		**456**	**502**	**543**

11 Implementation Issues

11.1 Outline Schedule of Remaining Steps for Project Execution

A preliminary schedule in Gantt chart format has been prepared, suggesting some of the next activities and actions required by the City to advance the project execution. The schedule presents a suggested sequence of design tasks, including investigations, further studies, regulatory approvals, and estimated construction timeframe to complete the development of the selected alternative. It is important to note that all activities have been estimated assuming an ultimate design criterion is desired, and no phasing will occur. Should phasing be desired, the schedule could be marginally accelerated. Further the schedule assumes imminent advancement of the subsequent activities.

As indicated in the schedule, the next steps would commence after the completion of the Iqaluit Water Storage Pre-Feasibility study. It is essential that at this point forward, the advancement of this project incorporates decisions related to water storage as well as water supply as they are both mutually dependent. To answer the question of how or where the City will store sufficient water for the projected population of 2050, the desirable answer must be influenced by how and where the water will be supplied. Once this has been determined, identifying appropriate potential site locations will be heavily influenced by the geotechnical, environmental, and regulatory constraints associated with the potential site. For this reason, it has been proposed to conduct a preliminary geotechnical and environmental investigation to confirm the suitability of potential sites, soon followed by seeking regulatory approvals to ensure there are no "show stopping" constraints.

In general terms, there are various potential studies which may be required before the project proceeds to construction, these include:

- Geotechnical Investigations
- Environmental Investigations
- Archeological Investigations
- Wildlife (fish/ birds/ mammals) Impact Assessments
- Community Consultations
- Public Safety
- Socio Economic

There are various potential regulatory requirements that may need to be coordinated for permitting and regulatory approvals from the following Acts and regulatory agencies:

- Nunavut Land Claims Agreement
- Nunavut Waters and Nunavut Surface Rights Tribunal Act
- Nunavut Waters Regulations
- Public Health Act
- Nunavut Planning and Project Assessment Act
- Iqaluit General Plan and Zoning Bylaw
- Iqaluit Airport Zoning Regulations
- Nunavut Wildlife Act
- Fisheries Act

12 Recommendations & Conclusions

The present storage capacity of lake the Lake Geraldine Reservoir is not adequate to satisfy future water demand by the City. The total storage required, in excess of the available existing storage within Lake Geraldine, to satisfy the projected population growth and raw water demand to 2050 was estimated to be 1,247,500 m^3 during the over-winter period and 1,824,500 m^3 annually.

Potential alternatives were originally categorized under two generic options; alternatives in close proximity to Lake Geraldine and alternatives remote from Lake Geraldine. Upon detailed review of the risks and feasibility associated with both generic classifications, it was concluded that the preferred classifications were alternatives in close proximity to Lake Geraldine. Several options under this category were then analyzed, and three alternatives were carried forward to detailed evaluation. Those are:

- Alternatives that are hydraulically connected to Lake Geraldine:
    - Excavation of additional storage volume within Lake Geraldine
    - Excavation of additional storage volume in close proximity to Lake Geraldine
- Alternatives that are hydraulically independent to Lake Geraldine:
    - Combination of excavated and bermed reservoir in close proximity to Lake Geraldine

The alternatives evaluation determined the preferred alternative to provide supplementary storage to be the excavation and berming of a hydraulically independent reservoir.

The potential site location and shape of the reservoir should be greatly influenced by the existing topography surrounding Lake Geraldine as well as geological conditions. Optimizing the design to incorporate existing features such as rock escarpments will aid in minimizing the capital costs associated with excavation and berming works. Additionally, site selection will be affected by the suitability of excavated material for reuse as part of the berm construction. The total capital cost of this alternative is estimated to be $64,325,000.

As indicated in the schedule, the next steps would commence after the completion of the Iqaluit Water Storage Pre-Feasibility study. It is essential that at this point forward, the advancement of this project incorporates decisions related to water storage as well as water supply as they are both mutually dependent. To answer the question of how or where the City will store sufficient water for the projected population of 2050, the desirable answer must be governed by how and where the water will be supplied. Once this has been determined, identifying appropriate potential site locations will be heavily swayed by the geotechnical, environmental, and regulatory constraints associated with the potential site. Preliminary site investigations will help expedite the site selection process.

The preliminary schedule provides a suggested critical path of activities and actions required by the City to advance the project execution. An estimated time frame required for permitting and regulatory approvals required has been provided. Approvals from the agencies listed previously are required to validate the site selection. The risk of delays during the regulatory approval process will have a direct impact on the remaining project execution schedule. For this reason, it has been proposed to conduct a preliminary geotechnical and environmental investigation to confirm the suitability of potential sites, soon followed by seeking regulatory approvals to ensure there are no “show stopping” constraints.

Due to the large capital expenditure along with a lengthy construction period, a phased approach to implementing the objectives of this project will likely be desired. The preferred alternative does present the opportunity to implement a phased approach as the City may wish to construct multiple cells which could be strategically built at different points in time. This would lead to increased costs associated with the construction due to redundant work such as additional containment berms needed for phasing and mobilization costs. Additionally, phasing the work would allow the City to monitor population growth as the design values in this report are based on long term projections. Further, it provides the opportunity for the City to continue increasing the efficiency of their water distribution network with the intention of reducing the average daily consumption of raw water per capita. Lastly, should phasing be preferred, the schedule could be marginally accelerated.

A final recommendation is for the City to promote public awareness of the importance of water conservation to reduce growth in demand. In parallel with actively working on a water loss control strategy emphasizing the reduction of unintended water losses that is not the result of end-user consumption. Examples of unintended losses include leaks and breaks within the treated water distribution system. Reducing the end user consumption and the unintended treated water losses will have a direct impact on reducing the supplementary raw water storage needed to meet the needs of Iqaluit’s growing population.

13 Legal Notification

This report was prepared by EXP Services Inc. for the account of the City of Iqaluit.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. EXP Services Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this project.

Appendix A - Figures

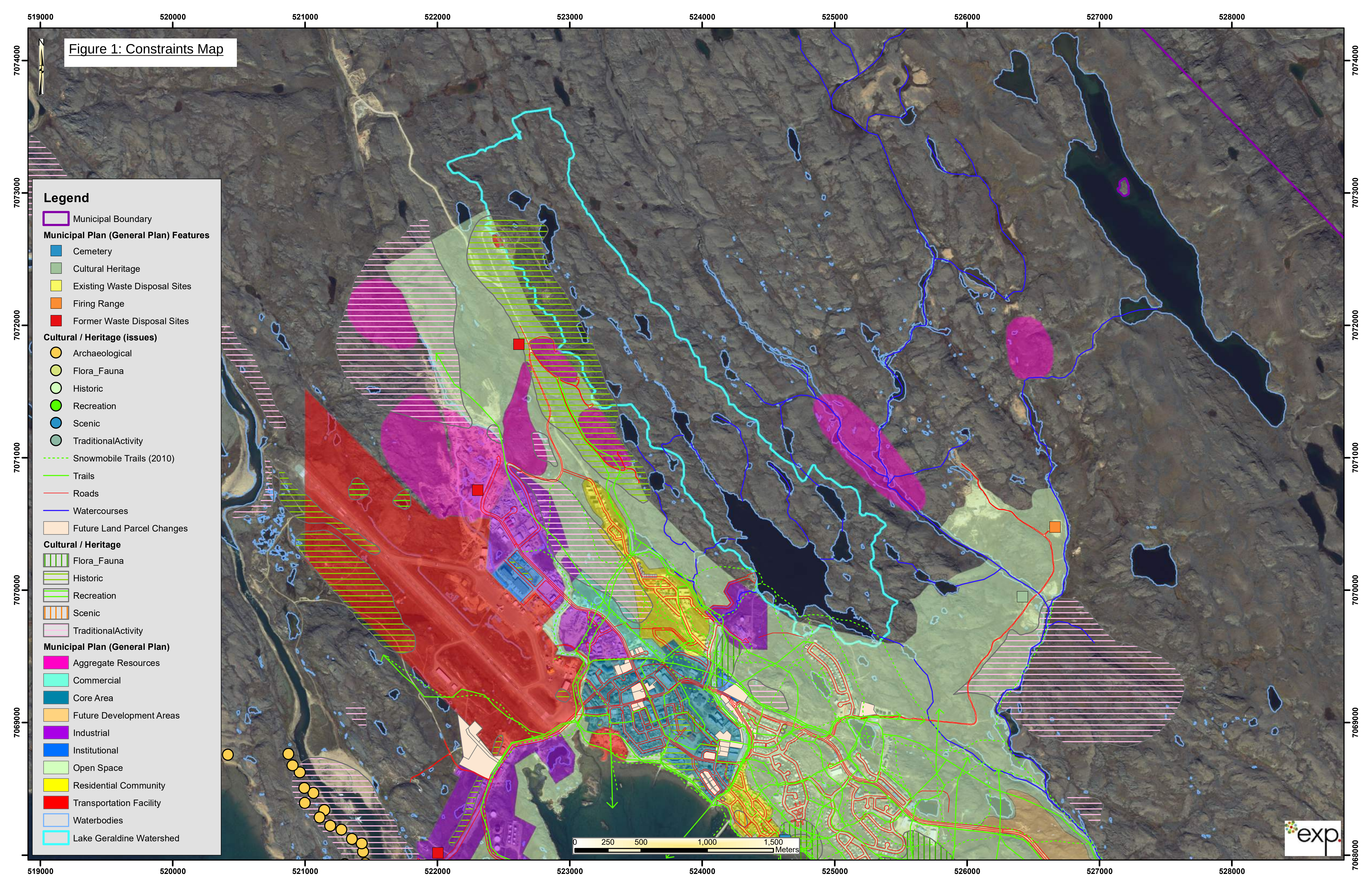

Figure 1: Constraints Map

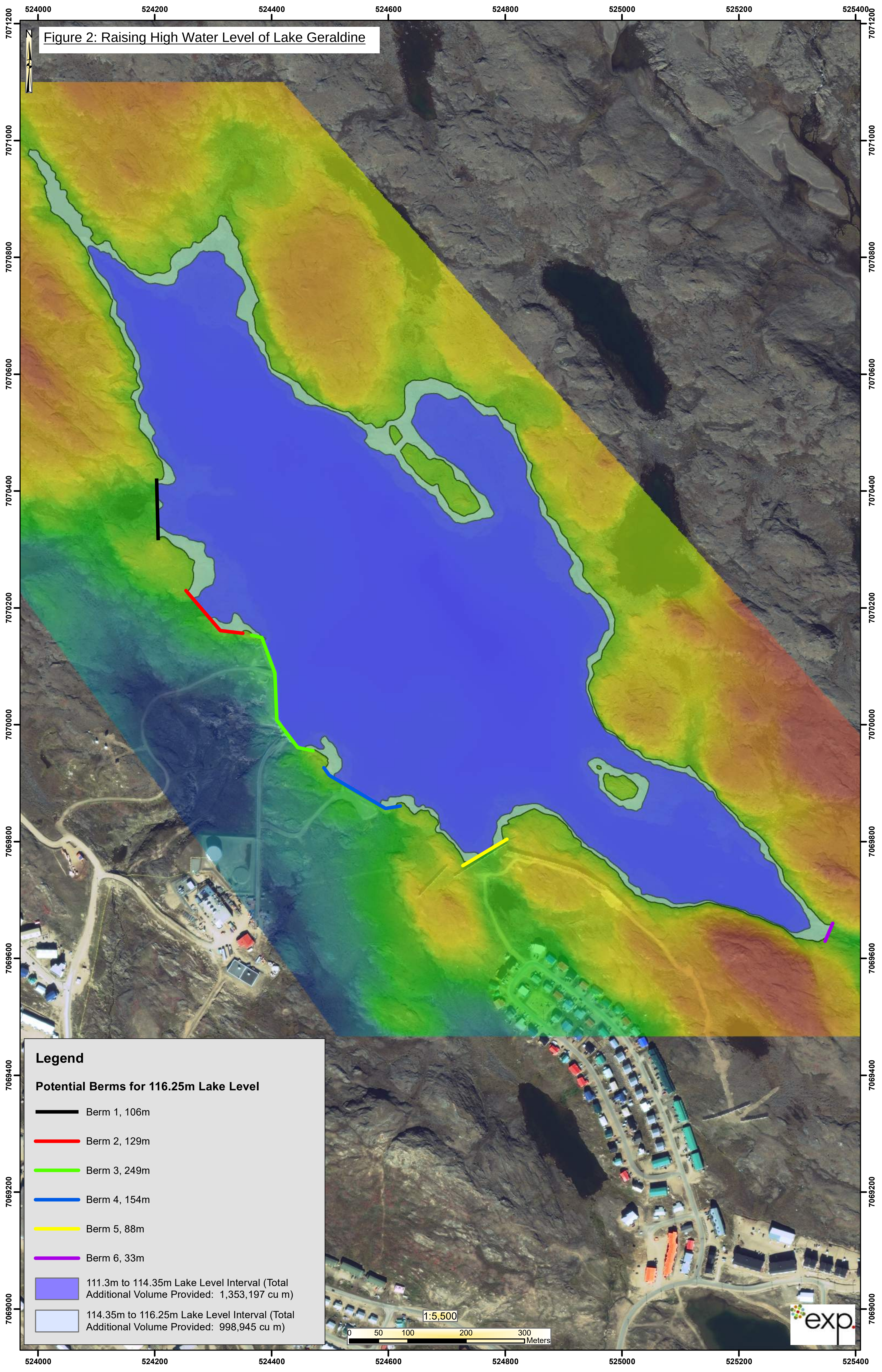
Figure 2: Raising High Water Level of Lake Geraldine
N
Legend
Potential Berms for 116.25m Lake Level
Berm 1, 106m
Berm 2, 129m
Berm 3, 249m
Berm 4, 154m
Berm 5, 88m
Berm 6, 33m
111.3m to 114.35m Lake Level Interval (Total Additional Volume Provided: 1,353,197 cu m)
114.35m to 116.25m Lake Level Interval (Total Additional Volume Provided: 998,945 cu m)
1:5,500
0 50 100 200 300
Meters
exp.
524000
524200
524400
524600
524800
525000
525200
525400
7071200
7071000
7070800
7070600
7070400
7070200
7070000
7069800
7069600
7069400
7069200
7069000

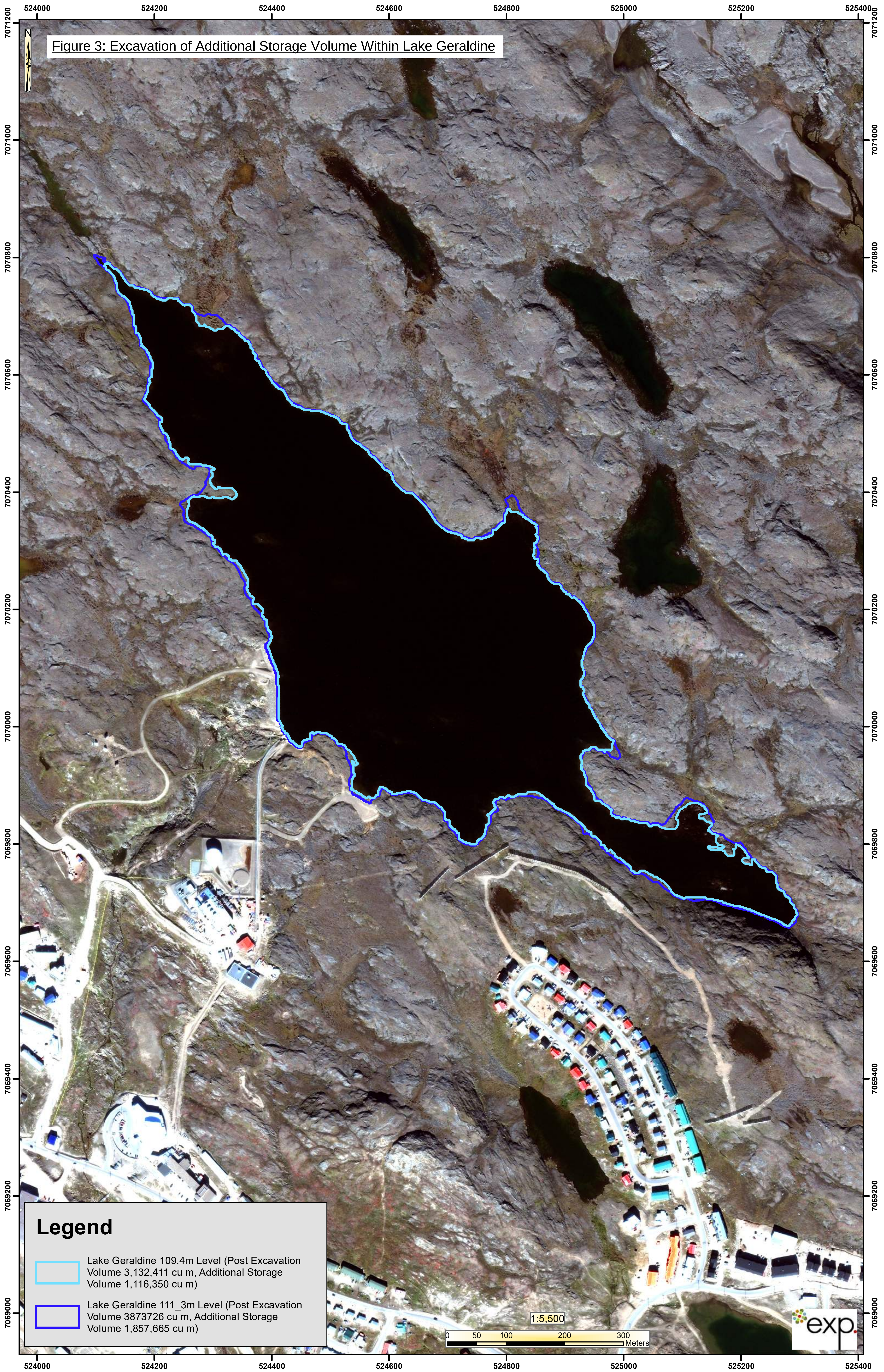

Figure 3: Excavation of Additional Storage Volume Within Lake Geraldine

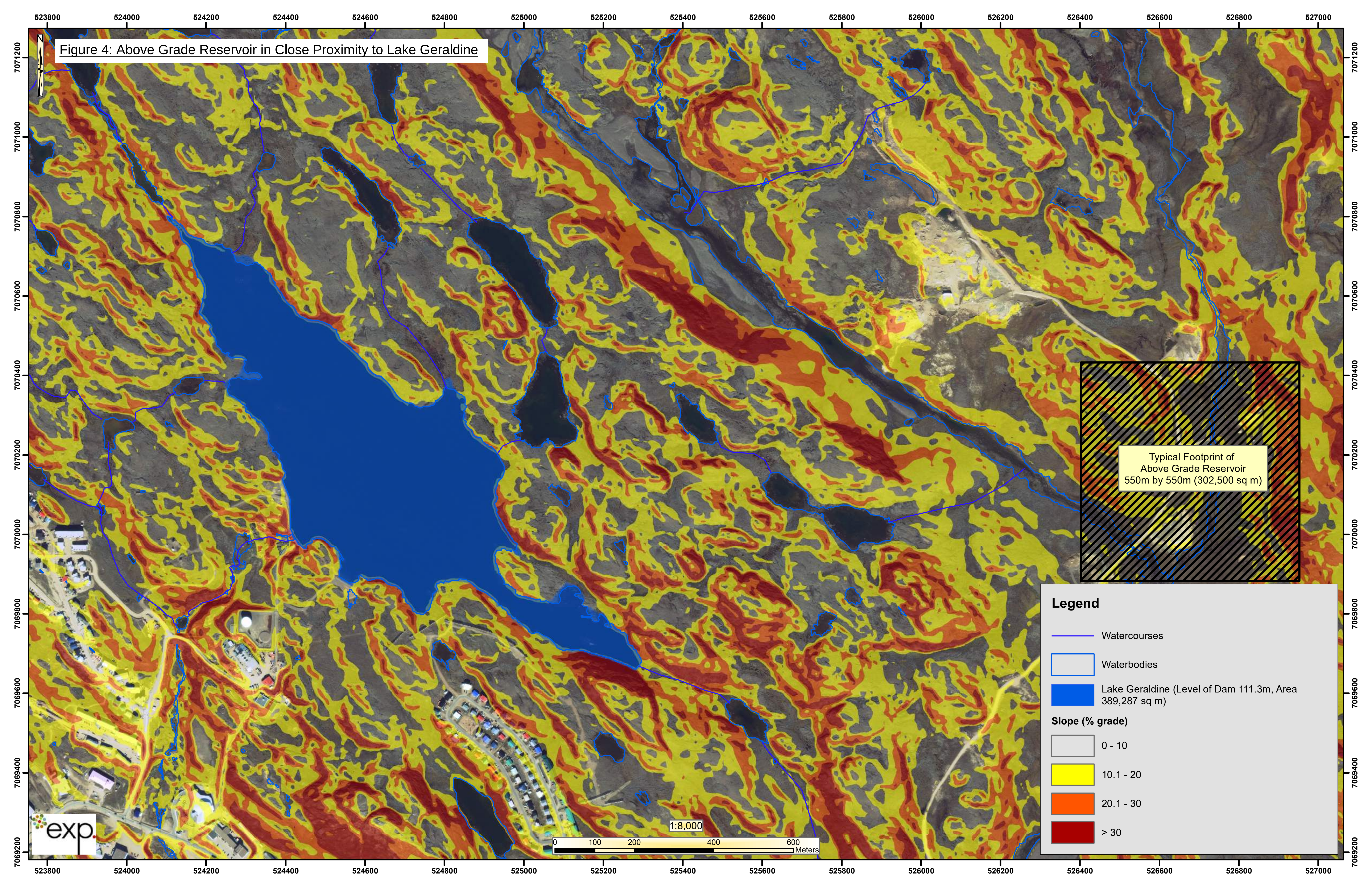

Figure 4: Above Grade Reservoir in Close Proximity to Lake Geraldine

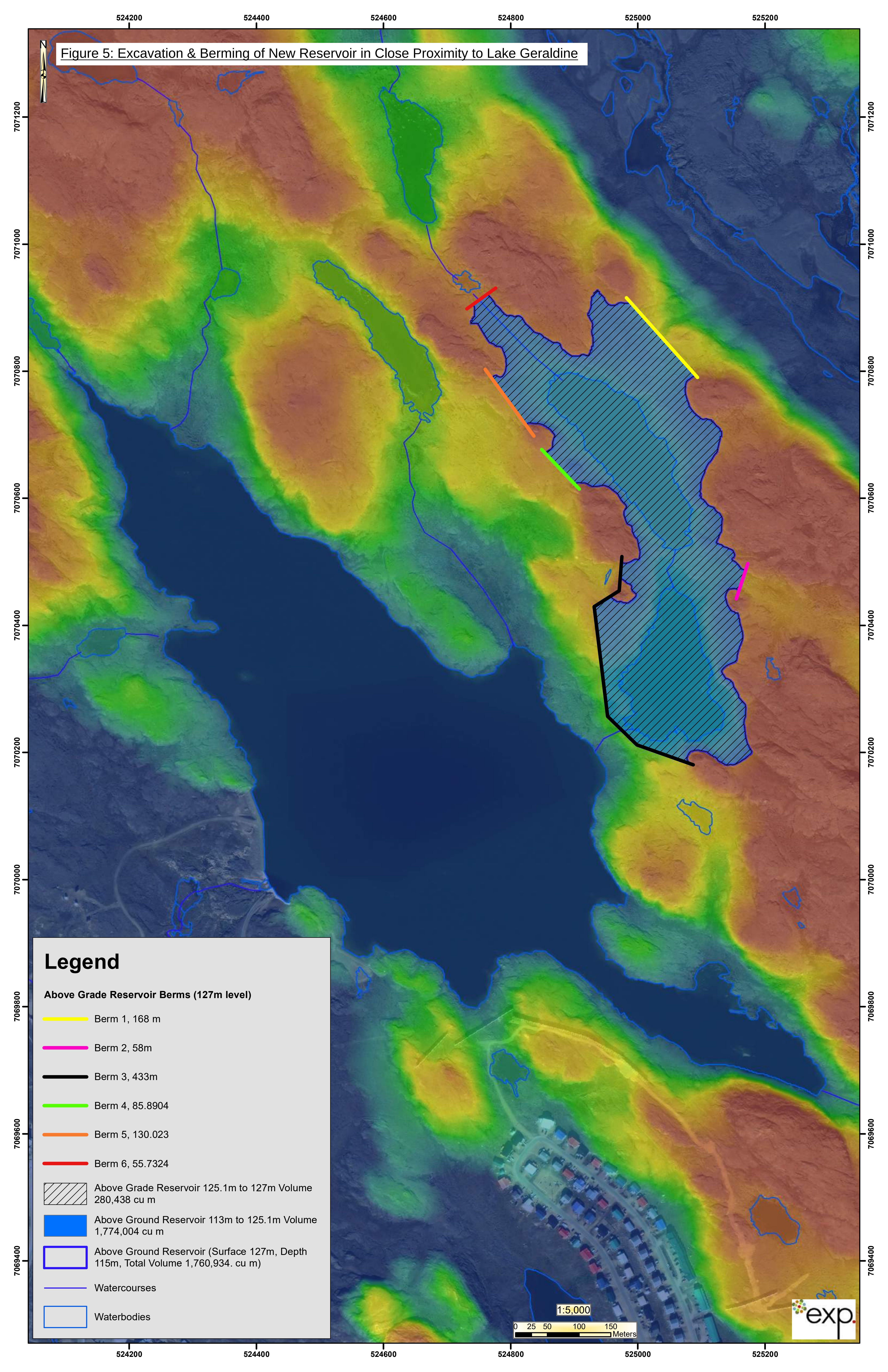
Figure 5: Excavation & Berming of New Reservoir in Close Proximity to Lake Geraldine
Legend
Above Grade Reservoir Berms (127m level)
Berm 1, 168 m
Berm 2, 58m
Berm 3, 433m
Berm 4, 85.8904
Berm 5, 130.023
Berm 6, 55.7324
Above Grade Reservoir 125.1m to 127m Volume 280,438 cu m
Above Ground Reservoir 113m to 125.1m Volume 1,774,004 cu m
Above Ground Reservoir (Surface 127m, Depth 115m, Total Volume 1,760,934. cu m)
Watercourses
Waterbodies
1:5,000
0 25 50 100 150 Meters
524200
524400
524600
524800
525000
525200
7071200
7071000
7070800
7070600
7070400
7070200
7070000
7069800
7069600
7069400
exp.

Figure 6
Estimated Project Implementation Schedule

ID	Task Name
1	
2	**Potential Storage Site Selections**
3	City to Review all Water Storage Work
4	City to Review all Water Supply Work
5	City to Select Potential Water Storage Locations
6	Presentation and Request for Approval to Council
7	
8	**Further Preliminary Design Advancement**
9	**Geotechnical Investigations**
10	City to Prepare Preliminary Geotechnical Scope of Work
11	Engagement of Geotechnical Consultant
12	Field Program
13	Preparation of Preliminary Finding Report
14	**Environmental**
15	City to Prepare Preliminary Environmental Scope of Work
16	Engagement of Environmental Consultant
17	Field Program
18	Ppreparation of Preliminary Finding Report
19	**Land Transfers & Regulatory Agencies**
20	Preparation and Submission of Application Form to Planning & Lands Administrator
21	Application Presented to Council
22	Application Submitted to NPC, NIRB & NWB
23	**Potential Further Studies Required**
24	Archeological Study
25	Wildlife Impact
26	Community Consultations & Public Safety
27	Socio Economic Impacts
28	Approvals Received
29	
30	Presentation and Request for Approval to Council
31	Site Selection Validated
32	
33	**Preliminary Site Design Work**
34	City to Prepare Preliminary Storage Design Scope of Work
35	Engagement of Prime Design Consultant
36	Field Investigation and Survey Program
37	Preparation of Preliminary Design Package
38	Feasibility Study Including Cost Estimates
39	
40	City Evaluation and Council Approval to Advance to Detailed Design
41	
42	**Detailed Site Design Work**
43	City to Prepare Detailed Scope of Work Package
44	Engagement of Prime Detailed Design Consultant
45	Detailed Geotechnical Investigations
46	Geotechnical Reporting
47	Preparation of Detailed Site Designs
48	Preparation of Tender Documents & Specifications
49	Tendering Period
50	Contractor Award
51	
52	**Construction Start**
53	Mobilization
54	Start of Construction Operations
55	Anticipated Completion