TETRA TECH

September 3, 2019

ISSUED FOR USE
FILE: ENG.GEOP03157-01
Via Email: m.hamp@city.iqaluit.nu.ca

City of Iqaluit
City Hall, P.O. Box 460
Iqaluit, NU X0A 0H0

Attention: Matthew Hamp, Director of Public Works and Engineering

Subject: Iqaluit DFO Bathymetric Lake Surveys

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was retained by the City of Iqaluit (the City) to conduct bathymetric surveys on two lakes. The two lakes surveyed were Unnamed Lake and Lake Geraldine, approximately 5 km and 1.5 km northeast of Iqaluit, NU, respectively.

The City has historically obtained its fresh water supply from the Lake Geraldine water reservoir. In 2018 a shortage of water in the reservoir was experienced following the spring freshet, requiring the City to supplement the drinking water supply from an additional source. The City's objective is to develop a sustainable long-term water supply. Unnamed Lake has been identified as a possible alternative water supply source. A bathymetric survey is required for the lake to provide an accurate map of lake morphometry and a calculation of potential available water volume. Additionally, a bathymetric survey was requested for Lake Geraldine to assess its current conditions.

The City required the bathymetric surveys to be completed in accordance with Scenario E of Application of the NWT Winter Water Withdrawal Protocol with Bathymetric Profiles of Select Small Lakes in the Mackenzie Delta Region (DFO 2005). Data was collected between July 23 and July 25, 2019.

2.0 EQUIPMENT

Tetra Tech utilized an Ohmex SonarMite single beam acoustic echosounder to complete the bathymetric survey. The SonarMite has a 235 kHz active transducer, a beam width of ± 4° and a measurement accuracy of ± 2.5 cm. The SonarMite unit employs digital signal conditioning and analysis circuitry to digitally output water depths at a rate of 2 Hz. The water depth measurements are recorded to a field laptop computer.

A Topcon HiperXT real-time kinematic (RTK) GPS system was used to provide positioning information. The GPS base station was positioned on shore for each lake and broadcast positioning correction information. The GPS rover was setup on the boat to receive positioning corrections from the base and integrate corrected positions with the echosounder data as the data was recorded. Given appropriate satellite constellations at the time of data collection, the RTK system typically provides 2 cm horizontal accuracy and 2 cm to 3 cm vertical accuracy.

The bathymetric survey for Unnamed Lake was conducted from a 9.5-foot zodiac with a Yamaha 4 HP outboard motor. The bathymetric survey on Lake Geraldine was conducted from a 12-foot Princecraft aluminum boat with a Yamaha 4 HP outboard motor.

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3.0 DATA COLLECTION

The bathymetric survey was carried out by James Mickle, P.Geoph. (AB) of Tetra Tech's Calgary office. Data was collected between July 23 and 25, 2019. Survey support was provided by Qairrulik Outfitting, based in Iqaluit. Lake Geraldine was accessible by truck, while Unnamed Lake was only accessible by ATV. Surveys were carried out using the equipment listed in Section 2.0.

Survey navigation was achieved using a navigation tracking software package that displayed the boat location and pre-programmed track lines in real time for the boat operator. Data was collected with three longitudinal profiles and transverse profiles spaced every 100 m on Unnamed Lake with the location of the profiles optimised to account for the shape of the lake. For Lake Geraldine, a single longitudinal profile and transverse lines every 100 m were collected. In addition to the bathymetric lines, circumferential data representing the complete shoreline outline (0 metre water depth) of both lakes was obtained by digitising a Sentinel-2 L1C satellite image acquired on July 23, 2019. To fix the lake surface elevations at the time of the survey, 10 RTK GNSS locations distributed around each lake were collected, the average value of which was used; at both lakes. The maximum and minimum water level elevations for each lake were within +/- 1 cm of the average value. The averaged value for both lakes was further corrected using a temporary field control point that was measured during both the bathymetric survey and the August 2019 LiDAR program

Based on the shape of both lakes and the paper "Application of the NWT Winter Water Withdrawal Protocol with Bathymetric Profiles of Select Small Lakes in the Mackenzie Delta Region, 2005", it is estimated that the volumes calculated potentially underestimate total volumes by 5% in the case of Unnamed Lake and between 5% and 10% at Geraldine Lake at the time of the survey. The larger potential error for Geraldine Lake is due to the presence of an inaccessible lobe at the south end due to very shallow water conditions at the time of the bathymetric survey.

Three sonar depth calibrations were completed for each lake as part of Tetra Tech's standard Quality Control/Quality Assurance (QA/QC) procedures.

3.1 Unnamed Lake

The bathymetric survey on Unnamed Lake was completed between July 24 and 25, 2019. Data collection tracks for the survey are plotted on Figure 1.

Two small bays can be seen in Figure 1 at the north end and west side of the lake. Tetra Tech was able to access a small portion of the north bay, but the water level was so shallow that the sonar system could not provide depth readings. The west bay was inaccessible due to shallow water depths (<0.5 m) and numerous rocks. Based on field observations, it is assumed that both bays will be isolated from the main water body during winter (frozen) conditions. Therefore, the two bays would not affect the under ice water volume.

3.2 Lake Geraldine

The bathymetric survey on Lake Geraldine was completed on July 23, 2019. Data collection tracks for the survey are plotted on Figure 2.

The southeast arm of Lake Geraldine was inaccessible due to a section of dry land approximately 50 m in length preventing the boat from passing. Extremely rough and rocky terrain was noted on the land around the southeast arm, preventing movement of the boat to that area. Small rocks were also noted protruding from the water in the middle of the southeast arm, so it is assumed that the water depth was minimal. This portion of Lake Geraldine was

essentially cut off from the main lake at the time of the survey and thus would not contribute to the immediate water withdrawal capacity of the lake.

Two small islands were present at the time of the survey. These are seen as small gaps in the bathymetry data in Figure 2. Water was extremely shallow (<0.3 m) with numerous rocks in the channel between the larger island and the western shore, preventing a data collection track in this channel. Due to the low water level, this channel is expected to freeze to ground in the winter and therefore not affect the under ice water volume.

4.0 DATA PROCESSING

Data processing consisted of the following steps:

- Submitting static GPS base station observation files to the Natural Resources Canada (NRCAN) online precise point positioning (PPP) correction system;
- Applying PPP horizontal and vertical corrections to all positioning information;
- Applying depth corrections to bathymetry data based on sonar depth calibrations;
- Averaging the ten water level elevations recorded for each lake to establish an elevation for each lake surface at the time of the survey (see Section 5.1);
- Digitizing the shoreline from georeferenced satellite imagery taken within a couple of days of the bathymetric survey to assign the water surface outline (i.e., 0 m depth contour) at the time of the bathymetric survey;
- Contouring the water depth data using a Kriging algorithm;
- Plotting depth contour results on georeferenced air photos;
- Calculating the lake surface areas using the digitized shoreline; and
- Calculating the required lake volumes using the trapezoidal method of calculation and subtracting the required estimated ice thickness (2.0 metres) as per the DFO Protocol (2015) for calculating water withdrawal volumes above the tree line.

4.1 QA/QC

Tetra Tech's QA/QC procedures included conducting sonar depth calibrations in multiple locations on each lake. This was done by manually measuring the lake depth using a weighted tape measure and comparing that number to the depth displayed by the sonar at the same location. Depth calibrations are typically conducted in three locations per lake. Differences between the manually measured depths and the sonar readings are plotted and used to determine what depth corrections are required to be applied to the bathymetric results.

Additionally, crossline consistency is checked as part of the QA/QC procedures. At locations where transverse survey lines intersect longitudinal survey lines, depth values are compared between the two survey passes over the same location. Discrepancies in depth values between the two passes could be indicative of positioning errors. For these surveys, no significant discrepancies between crosslines were noted.

5.0 RESULTS

Survey results for Unnamed Lake and Lake Geraldine are presented in Figures 1 and 2, respectively. Each figure shows a bathymetric colour contour map. A table has been included on each figure summarizing the required information from DFO Protocol for Winter Water Withdrawal in the Northwest Territories. This includes:

- Lake ID;
- Coordinates;
- Surface area;
- Total lake volume;
- Under ice volume;
- Max expected ice thickness value used; and
- Calculated 5% withdrawal volume.

5.1 Vertical Data Positioning

A lake surface elevation has been provided on each figure for the corrected CVD28 water elevation at the time of the survey. The absolute accuracy of this elevation measurement is approximately ± 3 cm. The water surface elevation of both lakes been further corrected using a common survey point measured during both the bathymetry and LiDAR programs, and a vertical shift of -1.78 cm was applied to the GNSS position data collected to align the lake bottom elevations with the LiDAR program results.

An x,y,z DEM based on a 2 metre grid size has been generated for the bathymetric data so that an elevation contour model can be generated for the region by combining the sonar and LiDAR datasets.

6.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of City of Iqaluit and their agents. Tetra Tech Canada Inc. (operating as Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than City of Iqaluit, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on Use of this Document attached in the Appendix or Contractual Terms and Conditions executed by both parties.

7.0 CLOSURE

We trust this document meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully Submitted,
Tetra Tech Canada Inc.

PROFESSIONAL GEOSCIENTIST ALBERTA
JAMES MICKLE

SEP 4, 2019

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Signature
Date September 4, 2019
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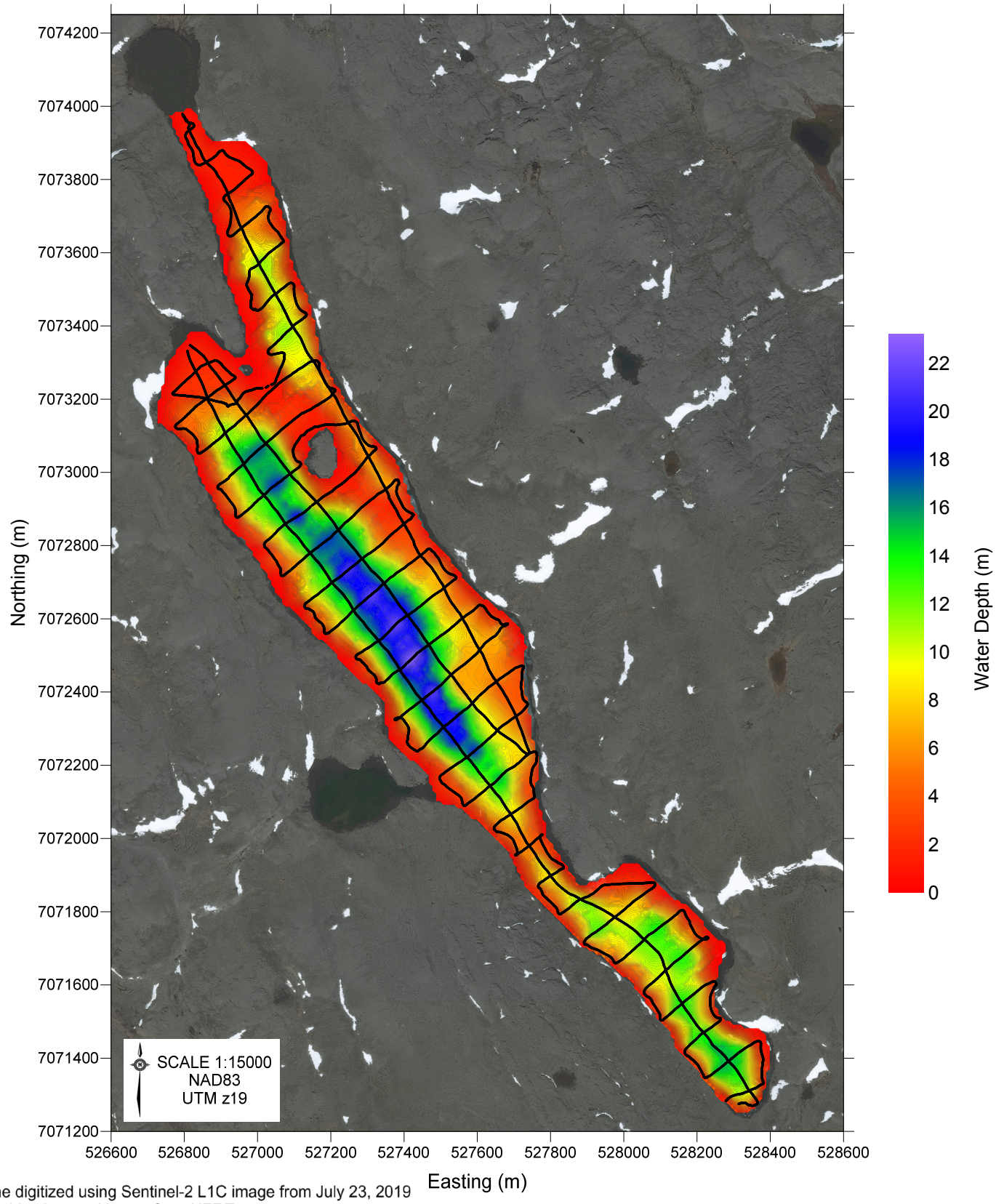
NT/NU Association of Professional Engineers and Geoscientists

FIGURES



Shoreline digitized using Sentinel-2 L1C image from July 23, 2019
Displayed background image from HERE
Water level elevation at time of survey 203.32 m in CVD28 datum using HT2_1997 geoid model

LEGEND

Data collection tracks

DFO Lake Summary

Lake ID: Unnamed Lake
Centre Coordinates: 527,432 m E 7,072,564 m N
Surface Area: 911,300 m^2
Total Lake Volume: 6,616,900 m^3
Under Ice Volume: 4,737,900 m^3
Maximum Expected Ice Thickness Value Used: 2.0 m
Calculated 5% Withdrawal Volume: 236,895 m^3

CLIENT: Iqaluit

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IQALUIT DFO BATHYMETRIC LAKE SURVEYS

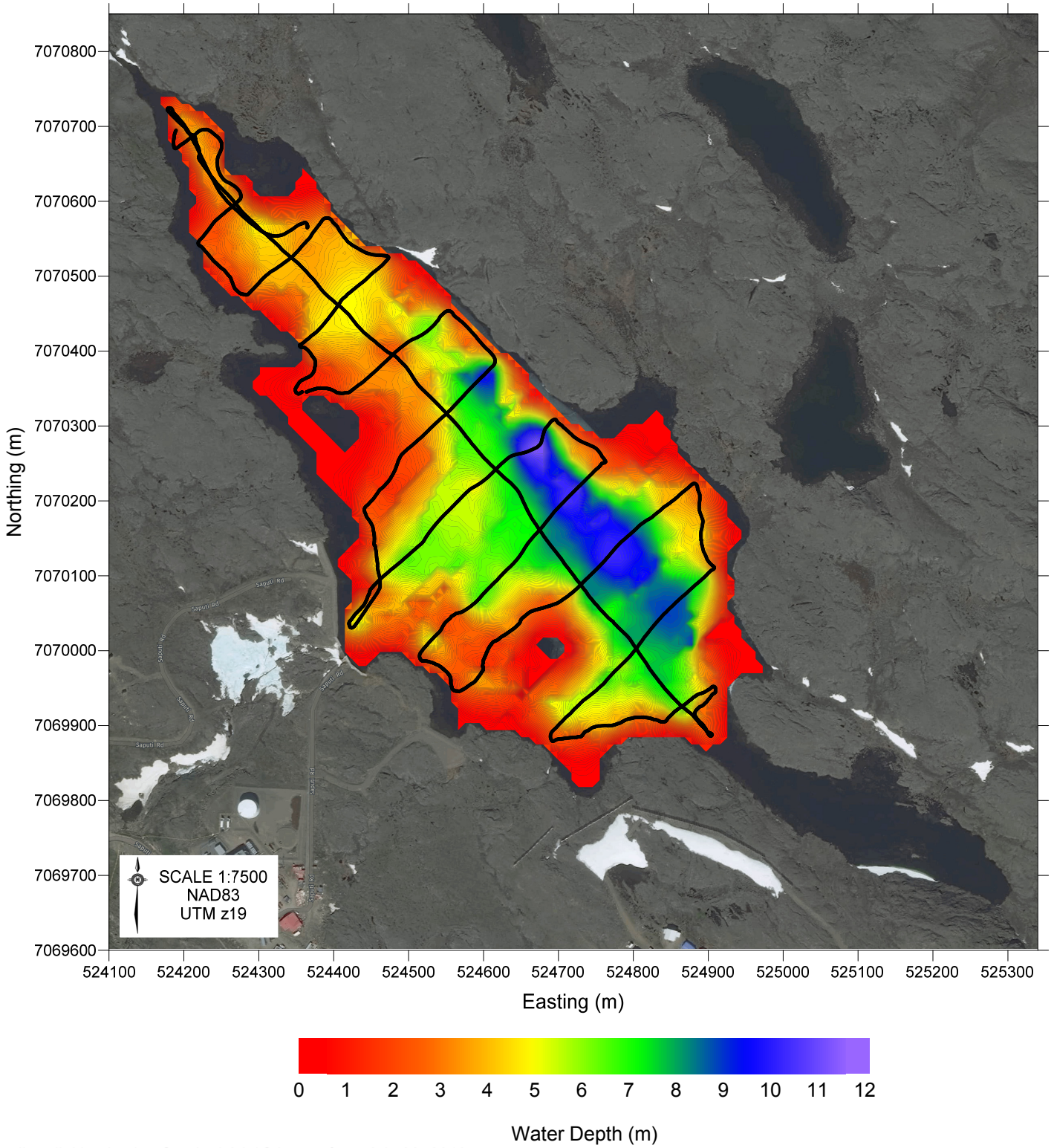
Unnamed Lake Bathymetry Depth Results

Data Collected July 24-25, 2019

PROJECT NO.	DWN	CKD	APVD	REV
ENG.GEOP03157-01	CB	RJM	PIF	0

OFFICE	DATE
EBA-EDM	July 31, 2019

Figure 1



Shoreline digitized using Sentinel-2 L1C image from July 23, 2019
Displayed background image from HERE
Water level elevation at time of survey 109.22 m in CVD28 datum using HT2_1997 geoid model

LEGEND

Data collection tracks

DFO Lake Summary

Lake ID: Lake Geraldine
Centre Coordinates: 524,638 m E 7,070,159 m N
Surface Area: 293,800 m^2
Total Lake Volume: 1,205,600 m^3
Under Ice Volume: 589,800 m^3
Maximum Expected Ice Thickness Value Used: 2.0 m
Calculated 5% Withdrawal Volume: 29,490 m^3

CLIENT: Iqaluit

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IQALUIT DFO BATHYMETRIC LAKE SURVEYS

Lake Geraldine
Bathymetry Depth Results
Data Collected July 23, 2019

PROJECT NO.	DWN	CKD	APVD	REV
ENG.GEOP03157-01	CB	RJM	PIF	0

OFFICE	DATE
EBA-EDM	July 31, 2019

Figure 2

APPENDIX A

TETRA TECH'S LIMITATIONS ON USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOPHYSICAL

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

The Professional Document is intended for the sole use of TETRA TECH's Client (the "Client") as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the "Contract" herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

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Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

1.3 STANDARD OF CARE

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

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by third parties other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this report, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to explore, address, or consider and has not explored, addressed, or considered any environmental or regulatory issues associated with the development of the site.

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgemental in nature as to both type and condition. TETRA TECH does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

1.9 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

1.10 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. TETRA TECH does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

1.11 SURFACE WATER AND GROUNDWATER CONDITIONS

Surface and groundwater conditions mentioned in this report are those observed at the times recorded in the report. These conditions vary with geological detail between observation sites; annual, seasonal and special meteorological conditions; and with development activity. Interpretation of water conditions from observations and records is judgmental and constitutes an evaluation of circumstances as influenced by geology, meteorology and development activity. Deviations from these observations may occur during the course of development activities.