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To:	Michael Osezua, Project Manager	From:	Andrew Sullivan P.Eng. Erica Bonhomme, Project Manager
	Colliers Project Leaders		Nunami Stantec Ltd.
File:	144930114	Date:	December 13, 2019

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**Reference:     Unnamed Lake Data Collection Summary Memorandum**

Nunami Stantec Limited (Nunami) is pleased to submit this technical memorandum to the City of Iqaluit (the City) which summarizes data collected at the Unnamed Lake in accordance with Nunami's proposal dated May 30, 2019. While the original scope of this work was to complete just two site visits to Unnamed Lake and its environs in 2019, Nunami staff completed numerous site visits owing to work completed under a separate scope (2019 Emergency Water Supply Project (the pumping program)) related to supplementation of the Lake Geraldine Reservoir.

This memo summarizes the data collected during all site visits completed in the summer and fall of 2019.

## **1        BACKGROUND**

The City currently obtains its potable water from the Lake Geraldine reservoir, located approximately 900m northeast of Iqaluit City Hall. In the summers of 2018 and 2019, reservoir volumes were found to be historically low and emergency water withdrawals from the Apex River were required to fill the reservoir prior to freeze-up. Additional potable water supply sources will be needed in future years to accommodate the City's growing population and drinking water demand. As an interim solution, the City has obtained approval from the Nunavut Water Board to obtain water from the Apex River until a permanent solution is implemented.

Nunami was retained by the City to identify alternative and/or additional long-term, sustainable potable water sources. As part of these investigations, an unnamed lake approximately 3 km northeast of the Lake Geraldine reservoir (coordinates: 63° 46' 46" N, 68° 26' 35" W; referred to as "Unnamed Lake") was identified as potential water source during the City's public engagements on water supply (Figure A-1, Attachment 1). At a meeting with the Amaruq Hunters and Trappers Association (HTA) in September 2018, the HTA expressed interest in the City's further investigation of Unnamed Lake as a supplemental drinking water supply source. Following the meeting, Nunami conducted a data gap analysis for Unnamed Lake and provided the results of this analysis in a memorandum to the City in December 2018. Data gaps identified at that time are listed below with some items addressed (Items 1,2, and 4) in this memo:

1. water level data and seasonal variability
2. bathymetry and volume
3. water balance
4. water quality
5. fish and fish habitat.

**Reference: Unnamed Lake Data Collection Summary Memorandum**

Under Service Contract SC805 change order 004, Nunami:

- downloaded data from pressure transducers and a barologger previously installed in Unnamed Lake to complete a data set of water levels in the lake throughout the year
- collected flow measurements in the outlet creek of Unnamed Lake
- collected and analyzed five surface water quality samples
- obtained a research permit for above studies

A bathymetric survey was completed by TetraTech Canada, and LiDAR imagery was obtained by Aethon Aerial Solutions, both under separate contracts to the City.

No water balance model was developed.

## **2 PERMITTING**

The described field studies required a Research Licence from the Nunavut Research Institute. On July 3, 2019, the City wrote to the Amaruq HTA describing the scope and purpose of studies at Unnamed Lake. The City did not receive reply comments. Nunami subsequently submitted a Project Proposal to the Nunavut Planning Commission (NPC) pursuant to the requirements of the Nunavut Planning and Project Assessment Act (NUPPAA). The NPC in a letter dated July 22, 2019, determined that the project would require screening by the Nunavut Impact Review Board (NIRB) before a licence could be issued.

Concurrent with the planned Unnamed Lake studies, the City was responding to an emergency situation declared by the Minister of Community and Government Services related to water supply shortage. The 2019 Iqaluit Emergency Water Supply Project was being designed to include withdrawing water from Unnamed Lake in addition to the Apex River. This pumping program would require additional monitoring of water levels, water quality and water outflow from Unnamed Lake. The previously installed loggers and planned data collection to support Unnamed Lake studies would contribute directly to the monitoring required to support the emergency pumping project. As an emergency, the provisions of NUPPAA section 152 were invoked, whereby screening of the emergency pumping project by the NIRB would not be required. As the scope of the Unnamed Lake studies was fully encompassed by the emergency pumping project, the Unnamed Lake studies project was withdrawn from the NPC-NIRB screening process by NIRB on September 10, 2019. Research Licence 01 028 19N-M was issued by the Nunavut Research Institute on August 1, 2019 and expires on December 31, 2019. The licence can be extended by request for up to one year.

A summary of research activities will be submitted by Nunami on behalf of the City by December 31, 2019.

**Reference: Unnamed Lake Data Collection Summary Memorandum**

### 3 FIELD DATA COLLECTION

Nunami staff completed field work at Unnamed Lake from July to October 2019. Field work tasks included collecting the following data; water quality, lake water levels, and lake outlet flows. Monitoring locations are shown on Figure A-1 (Attachment 1) and each of these field work tasks are discussed below.

#### 3.1 Water Quality

Field staff conducted surface water quality sampling in Unnamed Lake to assess its quality against Public Health Protection Northern Health water quality parameters. Sampling was done in accordance with Stantec Consulting Ltd. (Stantec)'s Standard Operating Procedures for surface water quality sampling. Sample locations and the analyses performed for each sample are shown in Table 3-1 below.

**Table 3-1 Laboratory Analysis – Water Quality Sample Location Summary**

Location ID	Parameters Sampled	Date Sampled	Latitude	Longitude
SW19-01	General Chemistry, benzene/ toluene/ ethylbenzene/ xylene (BTEX) and Petroleum Hydrocarbons (PHCs), Metals, and Microbiology	July 4, 2019 and September 12, 2019 (BTEX, PHC, and mercury)	63.781474	-68.45223
SW19-02	General Chemistry, BTEX and PHCs, Metals, and Microbiology	July 4, 2019 and September 12, 2019 (BTEX, PHC, and mercury)	63.77787	-68.44533
SW19-03	General Chemistry, BTEX and PHCs, Metals, and Microbiology	July 4, 2019 and September 12, 2019 (BTEX, PHC, and mercury)	63.77353	-68.43791
SW19-04	General Chemistry, BTEX and PHCs, Metals, and Microbiology	July 4, 2019 and September 12, 2019 (BTEX, PHC, and mercury)	63.77522	-68.44123
SW19-05	General Chemistry, BTEX and Petroleum Hydrocarbons, Metals, and Microbiology	July 4, 2019 and September 12, 2019 (BTEX, PHC, and mercury)	63.77502	-68.44905

Results and laboratory Certificates of Analysis were previously reported in Nunami's *Water Quality Sampling Unnamed Lake* memo, dated October 1, 2019 and provided in Attachment 2. The results of the water quality sampling program conducted at Unnamed Lake can be summarized by these brief points:

- Water quality in Unnamed lake is considered to be good based on the reported analytical results,
- BTEX and PHC were below laboratory detection limits,
- Total Coliforms and E.Coli were reported at 0 cfu/100ml.

**Reference: Unnamed Lake Data Collection Summary Memorandum**

## 3.2 Lake Water Levels

Water levels in Unnamed Lake were monitored from September 2018 through to October 2019. Recorded water levels are considered to reflect natural conditions between September 2018 and August 24, 2019. Water levels recorded after August 24, 2019 were influenced by the pumping program and should be interpreted as such.

### 3.2.1 Staff Gauge Readings

Water level data was collected from Unnamed Lake using a staff gauge located near the intake of a submerged pump (SNP UNL-01 on Figure A-1, attached) for the duration of the pumping program. Staff gauge readings were recorded daily during the pumping program by the contractor operating pumps and Nunami staff and used to monitor changes in water levels on a daily basis as a result of pumping. Water levels reported from staff gauge readings have not been surveyed and therefore provide only relative water level information (i.e. how water levels changed from day to day). Water levels recorded daily during the pumping program are summarized in the table below.

**Table 3-2 Staff Gauge Reading (Unnamed Lake) Summary**

Date	Unnamed Lake
	Water Level (m)
8/20/2019	0.750
8/21/2019	not measured*
8/22/2019	not measured*
8/23/2019	not measured*
8/24/2019	0.749
8/25/2019	0.740
8/26/2019	0.740
8/27/2019	0.700
8/28/2019	0.690
8/29/2019	0.670
8/30/2019	0.690
8/31/2019	0.680
9/1/2019	0.695
9/2/2019	0.720
9/3/2019	0.725
9/4/2019	0.720

Reference: Unnamed Lake Data Collection Summary Memorandum

**Table 3-2 Staff Gauge Reading (Unnamed Lake) Summary**

Date	Unnamed Lake
	Water Level (m)
9/5/2019	0.753
9/6/2019	0.750
9/7/2019	0.750
9/8/2019	0.740
9/9/2019	0.730
9/10/2019	0.725
9/11/2019	0.720
9/12/2019	0.720
9/13/2019	0.7150
9/14/2019	0.7110
9/15/2019	0.7000
9/16/2019	0.698
9/17/2019	0.695
9/18/2019	0.690
9/19/2019	0.696
9/20/2019	not measured*
9/21/2019	0.775
9/22/2019	0.772
9/23/2019	0.769
9/24/2019	0.765
9/25/2019	0.765
9/26/2019	0.755
9/27/2019	0.775
9/28/2019	0.775
9/29/2019	0.770
9/30/2019	0.770
10/1/2019	0.760
10/2/2019	0.755
* - Water levels not measured due to unsafe site access conditions or the presence of large waves making a staff gauge reading impractical.	

**Reference: Unnamed Lake Data Collection Summary Memorandum**

### **3.2.2 Pressure Transducers**

Three pressure transducer data loggers were deployed in Unnamed Lake in and near a shallow bay that connects to the lake's outlet channel. One data logger was deployed in approximately 3 m of water in the main portion of Unnamed Lake and required a boat to retrieve it (transducer 1). A second data logger was deployed in approximately 2.5 m of water in a small bay connecting Unnamed Lake to its outlet channel and also required a boat to retrieve it (transducer 2). These two transducers were deployed in September 2018 and recorded data through to October 2019. A third data logger was deployed in August 2019 in the small bay along the south shore of Unnamed Lake, in approximately 0.5 m of water. This logger was accessible from shore and was deployed to facilitate quick and safe access to water level information through the pumping program. Data were primarily corrected for atmospheric pressure using a barometric pressure transducer located on shore near the three data loggers. Barometric pressure data recorded at the site was validated using the Environment and Climate Change Canada (ECCC) Iqaluit Climate Station (Station ID 2402592). If discrepancies were found between the two data, the data provided by ECCC were used. Anomalous barometric pressure readings were observed with the onsite barologger and corrected based on the ECCC reported data between December 2018 and July 2019.

Local benchmarks were established during November 2018 field work near the data logger locations using real time kinematic (RTK) survey equipment. Establishing known elevation benchmarks allowed for water surface level data to be converted into water surface elevation data. A levelling survey of site benchmarks and water surface, using rod and level equipment, prior to and following each subsequent field visit and data logger download was completed. The levelling surveys allow for corrections to the data if the data logger has moved or the instrument has drifted overtime. This correction was necessary as transducer 1 and 2 were manually retrieved from the lake bottom for each download and replaced in approximately the same location following the download, the leveling survey accounted for any slight changes in placement of the unit.

Water surface elevation fluctuations correlated well between the three transducers. Figures 3-1, 3-2, and 3-3 provide the barometrically corrected water surface elevations for transducers 1, 2, and 3 for the duration of their respective deployments. Water elevations recorded by the three pressure transducers corresponds well with the manual staff gauge readings collected at UNL with the exception of the final ten days of the pumping program when manual staff gauge readings trended higher than those reported by the pressure transducers, as shown on Figure 3-3.

Reference: Unnamed Lake Data Collection Summary Memorandum

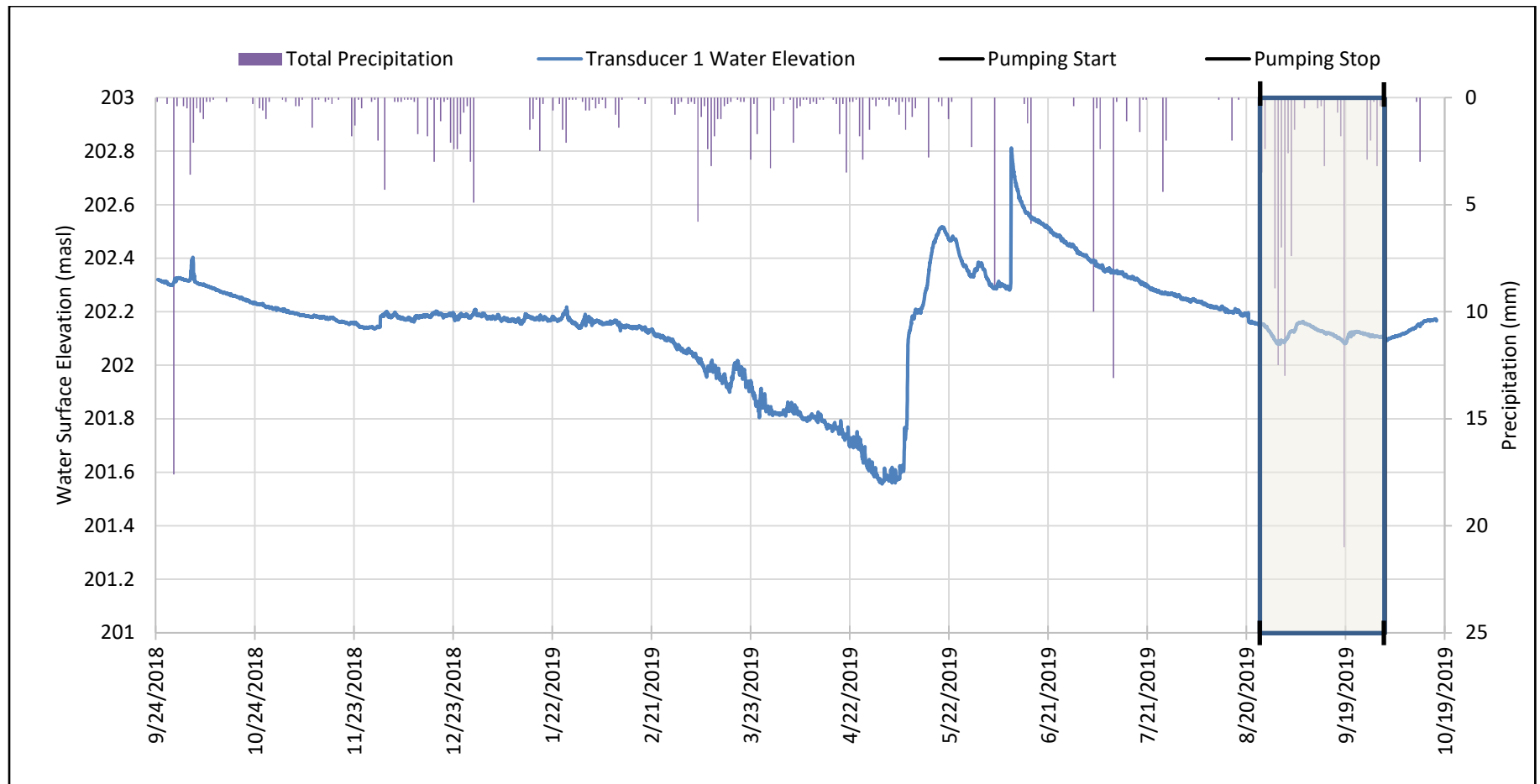


Figure 3-1 Unnamed Lake Transducer 1 Water Surface Elevations

Reference: Unnamed Lake Data Collection Summary Memorandum

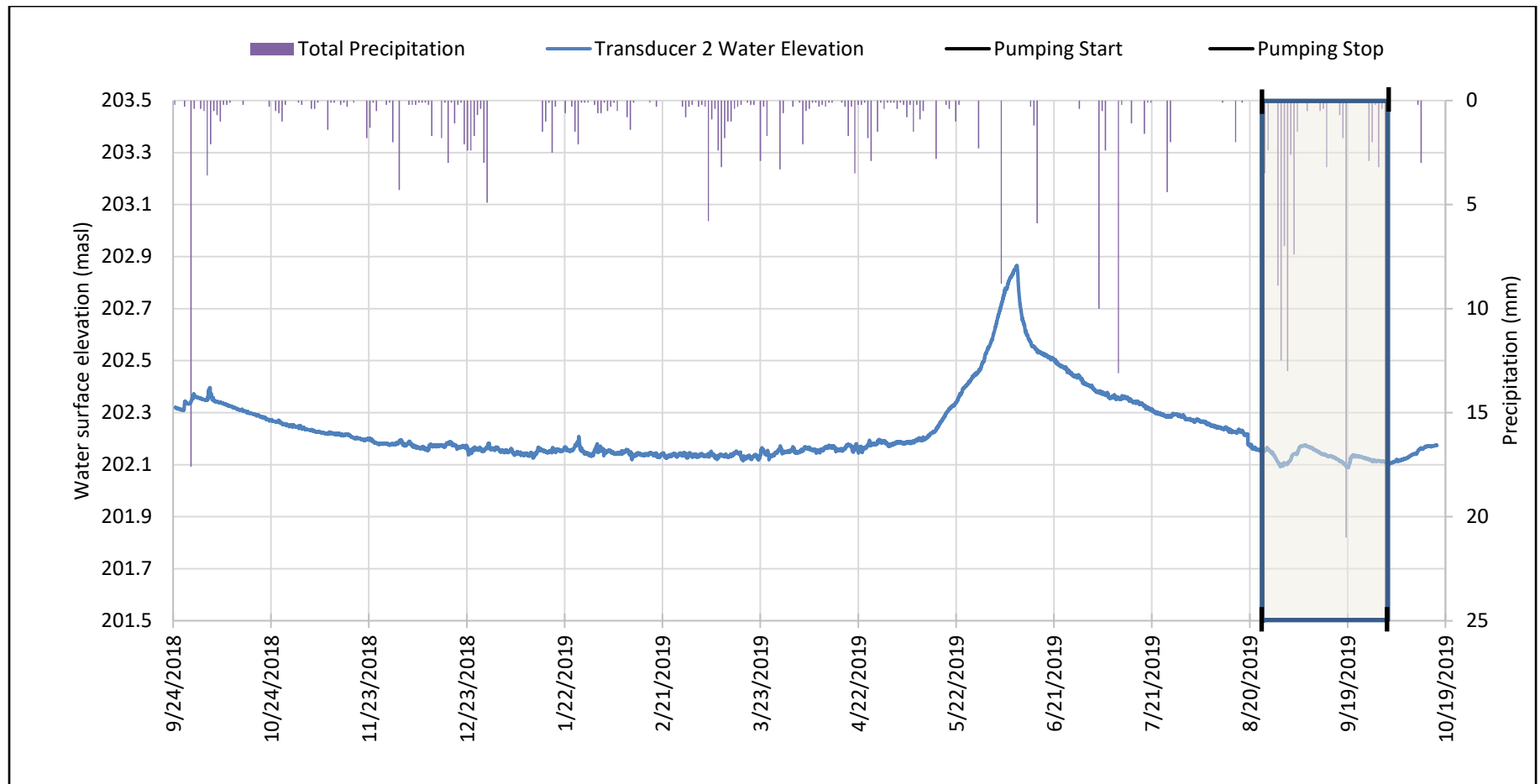


Figure 3-2 Unnamed Lake Transducer 2 Water Surface Elevations

Reference: Unnamed Lake Data Collection Summary Memorandum

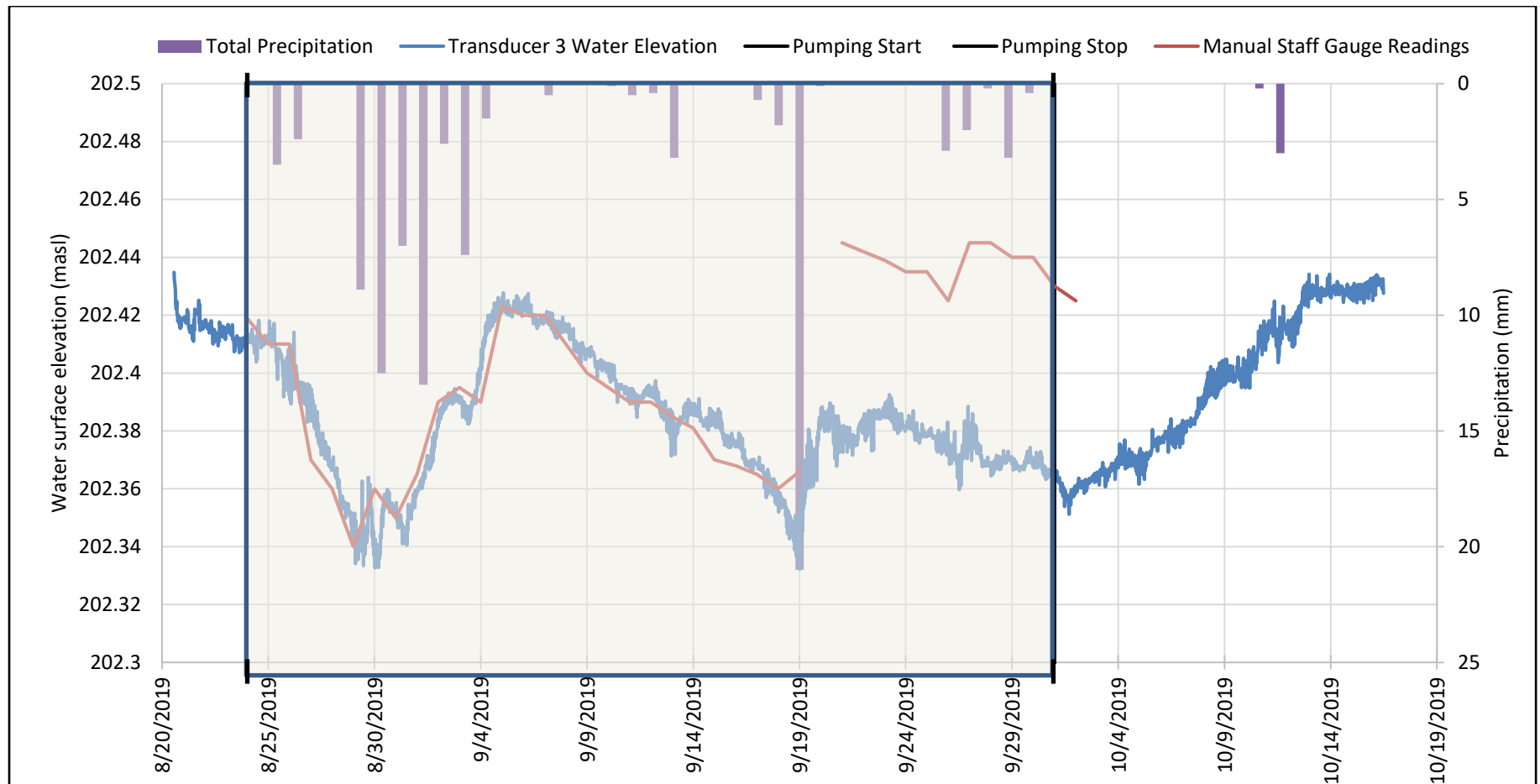


Figure 3-3 Unnamed Lake Transducer 3 Water Surface Elevations

**Reference: Unnamed Lake Data Collection Summary Memorandum**

### 3.3 Lake Outlet Flows

Spot flow measurements were completed daily at three locations under the monitoring requirements of the pumping program. One of these locations was on the outlet reach of Unnamed Lake:

- Unnamed Lake natural outflows (Apex N-1) – to determine the contribution of Unnamed Lake outflow to Apex River downstream of the Apex River pumping location and to establish potential impact on Apex River flows if the Unnamed Lake outflow is cut off during pumping activities.

Flow measurements were conducted by Nunami staff using Sontek Flowtracker equipment and following Environment Canada guidance (WSC, 2015).

Table 3-2 provides a summary of these data below. Data reported as 'not measured' was due to equipment malfunctions (replacement Flow Tracker shipped between Sept. 2<sup>nd</sup> and 9<sup>th</sup>, 2019) or unsafe weather/site conditions.

**Table 3-3 Field Flow Measurement Summary**

Date	Apex N-1 Flows (m <sup>3</sup> /s)
8/20/2019	not measured*
8/21/2019	0.0241
8/22/2019	0.0208
8/23/2019	not measured*
8/24/2019	0.0242
8/25/2019	not measured*
8/26/2019	0.0294
8/27/2019	0.0251
8/28/2019	0.0211
8/29/2019	0.0191
8/30/2019	0.0638
8/31/2019	0.0860
9/1/2019	0.1433
9/2/2019	not measured*
9/3/2019	not measured*
9/4/2019	not measured*
9/5/2019	not measured*
9/6/2019	not measured*

**Reference: Unnamed Lake Data Collection Summary Memorandum**

**Table 3-3 Field Flow Measurement Summary**

Date	Apex N-1 Flows (m <sup>3</sup> /s)
9/7/2019	not measured*
9/8/2019	not measured*
9/9/2019	not measured*
9/10/2019	0.0556
9/11/2019	not measured*
9/12/2019	0.0541
9/13/2019	0.0597
9/14/2019	0.0550
9/15/2019	0.0434
9/16/2019	0.0425
9/17/2019	0.0322
9/18/2019	0.0348
9/19/2019	not measured*
9/20/2019	not measured*
9/21/2019	0.1238
9/22/2019	0.0865
9/23/2019	0.0552
9/24/2019	0.0564
9/25/2019	0.0533
9/26/2019	0.0470
9/27/2019	0.0585
9/28/2019	0.0559
9/29/2019	not measured*
9/30/2019	not measured*
10/1/2019	0.0532
10/2/2019*	0.0408
* - not measured - field measurement not collected due to equipment issues or weather / safety concerns. Flowtracker was not working from Sept. 2 to Sept 10.	

**Reference: Unnamed Lake Data Collection Summary Memorandum**

## **4 DATA COLLECTED BY OTHERS**

In addition to field data collected by Nunami staff, the City also engaged with several other contractors to facilitate collection of bathymetric and topographic data related to Unnamed Lake and the surrounding area. These additional scopes of work are briefly discussed below.

### **4.1 Bathymetry**

Bathymetry data was collected by Tetra Tech Canada Inc. (Tetra Tech) between July 23 and 25, 2019. This work is summarized in Tetra Tech's *Iqaluit DFO Bathymetric Lake Surveys Report*, dated July 31, 2019 and attached to this memo (Attachment 3).

### **4.2 LiDAR**

An aerial survey was conducted by Aethon Aerial Solutions (AAS) to collect topographic data, specifically LiDAR data, between August 16 – 17, 2019. This work is summarized in AAS's City of Iqaluit Unnamed Lake Report attached to this memo (Attachment 4).

## **5 REFERENCES**

WSC. (2015). Measuring Discharge with FlowTracker Acoustic Doppler Velocimeters - Revision 4. Ottawa: Environment Canada.

## **6 CLOSURE**

Nunami Stantec Ltd. has prepared this memo for the sole benefit of the City of Iqaluit (the City) for the purpose of summarizing the Unnamed Lake Data Collection program completed in 2019. Any use of this report by a third party, or any reliance on decisions made based upon it, are the responsibility of such third parties.

Michael Osezua, Project Manager  
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**Reference: Unnamed Lake Data Collection Summary Memorandum**

The information provided in this memo was compiled from existing documents, data provided by the third-party consultants (hired by the City), and by field data compiled by Nunami Stantec Ltd. This memo represents the best professional judgement of our personnel available at the time of its preparation. Nunami Stantec Ltd. reserves the right to modify the contents of this memo, in whole or in part, to reflect any new information that becomes available. If any conditions become apparent that differ significantly from our understanding of conditions presented in this memo, we request that we be notified immediately.

Respectfully Submitted,

**NUNAMI STANTEC LIMITED**

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Attachment: Attachment 1 – Site Figure  
Attachment 2 – Water Quality Memo  
Attachment 3 – Bathymetry Report  
Attachment 4 – LiDAR Report

# **ATTACHMENT 1**

## **Site Figure**



# **ATTACHMENT 2**

## **Water Quality Memo**

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To:	Josip Deronja, Engineering Manager City of Iqaluit	From:	Erica Bonhomme, Project Manager Nunami Stantec
File:	144902884	Date:	October 1, 2019

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**Reference: City of Iqaluit 2019 Emergency Water Supplementation Program – Water Quality Sampling Unnamed Lake**

## **INTRODUCTION**

Nunami Stantec Limited (Nunami) is pleased to submit this Water Quality Sampling Memorandum (Memo) for the City of Iqaluit's Unnamed Lake to Apex River Water Withdrawal Program in 2019 (herein referred to as the "2019 Emergency Water Supplementation Program"). This Memo addresses the baseline water quality parameters of Table 1 of the Northern Health guidance for water source approval (Northern Health, 2012), provided to Nunami by A.Gill August 15, 2019, and additionally as required based on correspondence between A.Gill and E.Bonhomme of Nunami up to August 21, 2019. Water quality samples were collected on July 4 and September 12, 2019 at five locations within Unnamed Lake, as shown on Figure A-1 (attached). Water quality sampling was outside of the scope outlined in Nunami's Operational Monitoring Plan (Nunami Stantec 2019).

The objective of water quality monitoring activities was to establish confirm suitable water quality in Unnamed Lake as a source of drinking water for the City of Iqaluit, prior to transfer to Lake Geraldine reservoir. This memo presents the methodology, regulatory framework, results and conclusions.

## **REGULATORY FRAMEWORK**

Surface water chemical analytical results are compared to the following specific standards that are considered applicable to Unnamed Lake:

- Guidelines for Canadian Drinking Water Quality – Summary Table (Health Canada 2019),
- Northern Health Public Health Protection – Table 1. Required Water Quality Parameters (Northern Health 2019).

## **METHODS**

Field staff conducted surface water sampling in accordance with Stantec Consulting Ltd. (Stantec)'s Standard Operating Procedures. Special care was taken at the sampling locations to not disturb sediment to minimize the amount that entered sample containers. In-situ physical water quality parameters (temperature, pH, dissolved oxygen, and conductivity) were measured using a YSI 556 multi meter.

All surface water samples were collected in laboratory-supplied containers with appropriate preservative and placed in insulated coolers. Samples were uniquely labeled, and control was maintained using chain of custody forms. Sample locations and the analyses performed for each sample are shown in Table 1 below.

**Reference:** City of Iqaluit 2019 Emergency Water Supplementation Program – Water Quality Sampling Unnamed Lake

**Table 1 Sample location summary table**

Location ID	Parameters Sampled	Date Sampled	Latitude	Longitude
SW19-01	General Chemistry, benzene/ toluene/ ethylbenzene/ xylene (BTEX) and Petroleum Hydrocarbons (PHCs), Metals, and Microbiology	July 4, 2019 and September 12, 2019 (BTEX, PHC, and mercury)	63.781474	-68.45223
SW19-02	General Chemistry, BTEX and PHCs, Metals, and Microbiology	July 4, 2019 and September 12, 2019 (BTEX, PHC, and mercury)	63.77787	-68.44533
SW19-03	General Chemistry, BTEX and PHCs, Metals, and Microbiology	July 4, 2019 and September 12, 2019 (BTEX, PHC, and mercury)	63.77353	-68.43791
SW19-04	General Chemistry, BTEX and PHCs, Metals, and Microbiology	July 4, 2019 and September 12, 2019 (BTEX, PHC, and mercury)	63.77522	-68.44123
SW19-05	General Chemistry, BTEX and Petroleum Hydrocarbons, Metals, and Microbiology	July 4, 2019 and September 12, 2019 (BTEX, PHC, and mercury)	63.77502	-68.44905

## RESULTS

Analytical results for surface water are provided in Table A-1, attached. All water quality parameters were reported to be below the applicable standards with the exception of Total Alkalinity at all five locations and Lagelier Index (at 4°C) at four locations. Total alkalinity was below the lower threshold put forth in the Northern Health Public Health Protection Table 1, but it is noted that the lower limit of 30 identified in this standard is listed as approximate. Additionally, results for Langelier Index were slightly below the lower limit given by the Northern Health Public Health Protection Table 1, which is also listed as approximate.

Results for BTEX and PHC were all below the laboratory's detection limit. Total coliforms and Escherichia coli (E.Coli) were reported as zero colony-forming units (cfu) for all sample locations. Nutrient and metals analytical results were generally low, with many parameters reporting values below the laboratories detection limit.

Field parameters were measured using a YSI multi-parameter probe and are summarized in Table 2 below.

October 1, 2019

Josip Deronja, Engineering Manager

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**Reference:** City of Iqaluit 2019 Emergency Water Supplementation Program – Water Quality Sampling Unnamed Lake

**Table 2 Field parameters summary table**

Location ID	Temperature (°C)	pH	Conductivity (µs/cm)
SW19-01	9.03	7.03	30
SW19-02	9.04	7.05	30
SW19-03	9.00	6.96	29
SW19-04	8.62	7.06	29
SW19-05	12.22	7.8	34

## CONCLUSIONS

Based on the results of the water quality sampling program conducted at Unnamed Lake, the following conclusions can be made:

- Water quality in Unnamed lake is considered to be good based on the reported analytical results,
- BTEX and PHC were below laboratory detection limits,
- Total Coliforms and E.Coli were reported at 0 cfu/100ml.

## REFERENCES

Health Canada. 2019. Guidelines for Canadian Drinking Water Quality – Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

Northern Health. 2012. PHP Guideline of Required water quality parameters for Water Source Approval. Accessed September 21, 2019 at:

[https://www.northernhealth.ca/sites/northern\\_health/files/services/environmental-health/documents/guidelines-required-water-quality-parameters.pdf](https://www.northernhealth.ca/sites/northern_health/files/services/environmental-health/documents/guidelines-required-water-quality-parameters.pdf)

Nunami Stantec. 2019. "City of Iqaluit 2019 Emergency Water Supplementation Program - Operational Monitoring Plan." Iqaluit.

**Nunami Stantec Ltd.**

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Attachment: Figure A-1 – Sample locations  
Table A-1 – Analytical Water Quality Results



- Water Quality Sampling Location 2019
- Water Level Monitoring Location
- Flow Measurement July 2019
- SNP Location
- ▲ Water Survey of Canada Station
- 2019 Emergency Pumping Project Flow Monitoring Location

0 200 400 Metres

(At original document size of 8.5x11)

1:25,000



**Project Location**  
Iqaluit,  
Nunavut

Prepared by ACampigotto on 2019-09-23  
Reviewed by EBonhomme on 2019-09-23

Client/Project  
City of Iqaluit 2019 Emergency Water  
Supplementation Project

144902884

Figure No.  
1

**DRAFT**

Title  
**Apex River and Unnamed Lake Data  
Collection and Monitoring Locations**

### Notes

- Notes**
1. Coordinate System: NAD 1983 UTM Zone 19N
  2. Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Disclaimer: This document has been prepared based on information provided by others as cited in the Notes section. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

Table A-1  
Summary of Surface Water Analytical Results  
Lake Geraldine Water Supply  
Nunami Stantec Limited

Sample Location				SW19-01		SW19-02		SW19-03		SW19-04		SW19-05	
Sample Date				4-Jul-19	12-Sep-19	4-Jul-19	12-Sep-19	4-Jul-19	12-Sep-19	4-Jul-19	12-Sep-19	4-Jul-19	12-Sep-19
Sample ID				SW19-01	SW19-01	SW19-02	SW19-02	SW19-03	SW19-03	SW19-04	SW19-04	SW19-05	SW19-05
Sampling Company				STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC	STANTEC
Laboratory				BV	BV	BV	BV	BV	BV	BV	BV	BV	BV
Laboratory Work Order				B9I5722	B9P9085	B9I5722	B9P9085	B9I5722	B9P9085	B9I5722	B9P9085	B9I5722	B9P9085
Laboratory Sample ID	Units	Health Canada	Northern Health	KEV013	KUI442	KEV014	KUI443	KEV015	KUI444	KEV016	KUI445	KEV017	KUI446
General Chemistry													
Alkalinity, Carbonate (as CaCO3)	mg/L	n/v	n/v	<1.0	-	<1.0	-	<1.0	-	<1.0	-	<1.0	-
Alkalinity, Total (as CaCO3)	mg/L	n/v	30-500 <sup>D</sup>	16 <sup>D</sup>	-	16 <sup>D</sup>	-	16 <sup>D</sup>	-	16 <sup>D</sup>	-	17 <sup>D</sup>	-
Ammonia (as N)	mg/L	n/v	1.5 <sub>(3)</sub> <sup>D</sup>	0.15	-	0.25	-	0.072	-	<0.050	-	<0.050	-
Bicarbonate(as CaCO3, Calculated)	mg/L	n/v	n/v	16	-	16	-	16	-	16	-	17	-
Chloride	mg/L	≤250 <sup>A</sup>	250 <sup>D</sup>	1.6	-	1.3	-	1.5	-	1.2	-	1.4	-
Electrical Conductivity, Lab	µmhos/cm	n/v	800 <sup>D</sup>	46	-	45	-	45	-	45	-	47	-
Hardness (as CaCO3)	mg/L	n/v	250 <sup>D</sup>	20	-	19	-	19	-	19	-	20	-
Langelier Index (at 20 C)	none	n/v	-2 to +2 <sup>D</sup>	-1.77	-	-1.85	-	-1.78	-	-1.79	-	-1.67	-
Langelier Index (at 4 C)	none	n/v	-2 to +2 <sup>D</sup>	-2.02 <sup>D</sup>	-	-2.10 <sup>D</sup>	-	-2.03 <sup>D</sup>	-	-2.04 <sup>D</sup>	-	-1.92	-
Nitrate (as N)	mg/L	10 <sup>B</sup>	10 <sub>(3)</sub> <sup>D</sup>	<0.10	-	<0.10	-	<0.10	-	<0.10	-	<0.10	-
Nitrite (as N)	mg/L	1 <sup>B</sup>	1 <sub>(3)</sub> <sup>D</sup>	<0.010	-	<0.010	-	<0.010	-	<0.010	-	<0.010	-
Orthophosphate (as P)	mg/L	n/v	n/v	<0.010	-	<0.010	-	<0.010	-	<0.010	-	<0.010	-
pH, lab	S.U.	7.0-10.5 <sup>A</sup>	6.5-8.5 <sup>D</sup>	7.48	-	7.43	-	7.49	-	7.47	-	7.54	-
Phosphorus, Total	mg/L	n/v	0.1 <sub>(2)</sub> <sup>D</sup>	0.006	-	0.013	-	0.008	-	0.005	-	0.008	-
Saturation pH (at 20 C)	none	n/v	n/v	9.25	-	9.28	-	9.27	-	9.26	-	9.22	-
Saturation pH (at 4 C)	none	n/v	n/v	9.50	-	9.53	-	9.52	-	9.52	-	9.47	-
Sulfate	mg/L	≤500 <sup>A</sup>	500 <sup>D</sup>	2.7	-	2.5	-	2.4	-	2.4	-	2.8	-
Total Dissolved Solids (Calculated)	mg/L	≤500 <sup>A</sup>	500 <sup>D</sup>	23	-	22	-	22	-	22	-	24	-
Total Organic Carbon	mg/L	n/v	2.5 <sup>D</sup>	1.6	-	1.4	-	1.4	-	1.3	-	1.4	-
Turbidity, Lab	NTU	≤0.3/1.0/0.1 <sup>C</sup>	1 <sup>D</sup>	<0.1	-	<0.1	-	<0.1	-	<0.1	-	<0.1	-
BTEX and Petroleum Hydrocarbons													
Benzene	µg/L	5 <sup>B</sup>	5 <sub>(3)</sub> <sup>D</sup>	-	<0.20	-	<0.20	-	<0.20	-	<0.20	-	<0.20
Toluene	µg/L	24 <sup>A</sup> 60 <sup>B</sup>	24 <sub>(9)</sub> <sup>D</sup>	-	<0.20	-	<0.20	-	<0.20	-	<0.20	-	<0.20
Ethylbenzene	µg/L	1.6 <sup>A</sup> 140 <sup>B</sup>	2 <sub>(9)</sub> <sup>D</sup>	-	<0.20	-	<0.20	-	<0.20	-	<0.20	-	<0.20
Xylene, m & p-	µg/L	n/v	n/v	-	<0.40	-	<0.40	-	<0.40	-	<0.40	-	<0.40
Xylene, o-	µg/L	n/v	n/v	-	<0.20	-	<0.20	-	<0.20	-	<0.20	-	<0.20
Xylenes, Total	µg/L	20 <sup>A</sup> 90 <sup>B</sup>	300 <sub>(9)</sub> <sup>D</sup>	-	<0.40	-	<0.40	-	<0.40	-	<0.40	-	<0.40
PHC F2 (>C10-C16 range)	µg/L	n/v	n/v	-	<100	-	<100	-	<100	-	<100	-	<100
PHC F3 (>C16-C34 range)	µg/L	n/v	n/v	-	<200	-	<200	-	<200	-	<200	-	<200
PHC F4 (>C34-C50 range)	µg/L	n/v	n/v	-	<200	-	<200	-	<200	-	<200	-	<200
Chromatogram to baseline at C50	none	n/v	n/v	-	YES	-	YES	-	YES	-	YES	-	YES
Metals, Dissolved													
Calcium	mg/L	n/v	100 <sub>(2)</sub> <sup>D</sup>	6.6	-	6.4	-	6.5	-	6.5	-	6.7	-
Magnesium	mg/L	n/v	30 <sub>(2)</sub> <sup>D</sup>	0.80	-	0.77	-	0.74	-	0.76	-	0.81	-
Potassium	mg/L	n/v	400 <sub>(2)</sub> <sup>D</sup>	<1	-	<1	-	<1	-	<1	-	<1	-
Sodium	mg/L	≤200 <sup>A</sup>	1,000 <sub>(2)</sub> <sup>D</sup>	0.7	-	0.7	-	0.7	-	0.7	-	0.7	-
Metals, Total													
Aluminum	µg/L	<100/200 <sub>9</sub> <sup>A</sup>	n/v	5.5	-	5.5	-	5.1	-	5.1	-	8.0	-
Antimony	µg/L	6 <sup>B</sup>	6 <sub>(2)</sub> <sup>D</sup>	<0.50	-	<0.50	-	<0.50	-	<0.50	-	<0.50	-
Arsenic	µg/L	10 <sup>B</sup>	20 <sub>(2)</sub> <sup>D</sup>	<1.0	-	<1.0	-	<1.0	-	<1.0	-	<1.0	-
Barium	µg/L	1,000 <sup>B</sup>	1,000 <sub>(2)</sub> <sup>D</sup>	<2.0	-	<2.0	-	<2.0	-	<2.0	-	<2.0	-
Beryllium	µg/L	n/v	n/v	<0.50	-	<0.50	-	<0.50	-	<0.50	-	<0.50	-
Boron	µg/L	5,000 <sup>B</sup>	5,000 <sub>(2)</sub> <sup>D</sup>	<10	-	<10	-	<10	-	<10	-	<10	-
Cadmium	µg/L	5 <sup>B</sup>	5 <sub>(2)</sub> <sup>D</sup>	<0.10	-	<0.10	-	<0.10	-	<0.10	-	<0.10	-
Calcium	µg/L	n/v	100,000 <sub>(2)</sub> <sup>D</sup>	6,700	-	6,800	-	6,700	-	6,900	-	7,400	-
Chromium	µg/L	50 <sup>B</sup>	50 <sub>(2)</sub> <sup>D</sup>	<5.0	-	<5.0	-	<5.0	-	<5.0	-	<5.0	-
Cobalt	µg/L	n/v	n/v	<0.50	-	<0.50	-	<0.50	-	<0.50	-	<0.50	-
Copper	µg/L	≤1000 <sup>A</sup> 2,000 <sup>B</sup>	1,000 <sub>(2)</sub> <sup>D</sup>	<1.0	-	<1.0	-	<1.0	-	<1.0	-	<1.0	-
Iron	µg/L	≤300 <sup>A</sup>	300 <sub>(2)</sub> <sup>D</sup>	<100	-	<100	-	<100	-	<100	-	<100	-
Lead	µg/L	5 <sup>B</sup>	10 <sub>(2)</sub> <sup>D</sup>	<0.50	-	<0.50	-	<0.50	-	<0.50	-	<0.50	-
Magnesium	µg/L	n/v	30,000 <sub>(2)</sub> <sup>D</sup>	760	-	710	-	740	-	750	-	820	-
Manganese	µg/L	≤20 <sup>A</sup> 120 <sup>B</sup>	50 <sub>(2)</sub> <sup>D</sup>	3.1	-	2.6	-	2.9	-	3.5	-	2.8	-
Mercury	µg/L	1 <sup>B</sup>	1 <sub>(2)</sub> <sup>D</sup>	-	<0.01	-	<0.01	-	<0.01	-	<0.01	-	<0.01
Molybdenum	µg/L	n/v	n/v	<0.50	-	<0.50	-	<0.50	-	<0.50	-	<0.50	-
Nickel	µg/L	n/v	n/v	<1.0	-	<1.0	-	<1.0	-	<1.0	-	<1.0	-
Potassium	µg/L	n/v	400,000 <sub>(2)</sub> <sup>D</sup>	<200	-	<200	-	<200	-	<200	-	<200	-
Selenium	µg/L	50 <sup>B</sup>	10 <sub>(2)</sub> <sup>D</sup>	<2.0	-	<2.0	-	<2.0	-	<2.0	-	<2.0	-
Silicon	µg/L	n/v	n/v	480	-	460	-	460	-	450	-	540	-
Silver	µg/L	n/v	n/v	<0.10	-	<0.10	-	<0.10	-	<0.10	-	<0.10	-
Sodium	µg/L	≤200000 <sup>A</sup>	1,000,000 <sub>(2)</sub> <sup>D</sup>	660	-	670	-	660	-	650	-	730	-
Strontium	µg/L	n/v	n/v	10	-	9.7	-	9.9	-	9.9	-	10	-
Thallium	µg/L	n/v	n/v	<0.050	-	<0.050	-	<0.050	-	<0.050	-	<0.050	-
Titanium	µg/L	n/v	n/v	<5.0	-	<5.0	-	<5.0	-	<5.0	-	<5.0	-
Vanadium	µg/L	n/v	n/v	<0.50	-	<0.50	-	<0.50	-	<0.50	-	<0.50	-
Zinc	µg/L	≤5000 <sup>A</sup>	5,000 <sub>(2)</sub> <sup>D</sup>	<5.0	-	<5.0	-	<5.0	-	<5.0	-	<5.0	-
Microbiological Analysis													
Total Coliform Background	cfu/100mL	n/v	n/v	0	-	7	-	8	-	0	-	2	-
Total Coliforms	cfu/100mL	0 <sup>C</sup>	0 <sup>D</sup>	0	-	0	-	0	-	0	-	0	-
Escherichia coli (E.Coli)	cfu/100mL	0 <sup>C</sup>	0 <sup>D</sup>	0	-	0	-	0	-	0	-	0	-

See notes on last page.

Table A-1  
Summary of Surface Water Analytical Results  
Lake Geraldine Water Supply  
Nunami Stantec Limited

Notes:	
Health Canada	Health Canada (June 2019). Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.
A	Guidelines for Canadian Drinking Water Quality - Aesthetic Objectives/ Operational Guidelines
B	Guidelines for Canadian Drinking Water Quality - Maximum Acceptable Concentration
C	Guidelines for Canadian Drinking Water Quality - Microbiological Parameters
Northern Health	Public Health Protection, Environmental Health
D	Table 1. Required Water Quality Parameters
6.5 <sup>A</sup>	Concentration exceeds the indicated standard.
15.2	Measured concentration did not exceed the indicated standard.
<0.50	Laboratory reporting limit was greater than the applicable standard.
<0.03	Analyte was not detected at a concentration greater than the laboratory reporting limit.
n/v	No standard/guideline value.
-	Parameter not analyzed / not available.
(2)	Total metals required. Dissolved metals optional, but recommended if turbidity is elevated. Scan to include both high and low level metals.
(3)	Required for source water characterisation. If all are < 1 mg/L as N, later samples may be analysed for Total N only.
(9)	Required if hydrocarbon/gasoline type contamination is suspected. Contat laboratory for sampling procedure.
a	This is an operational guidance value, designed to apply only to drinking water treatment plants using aluminum-based coagulants; it does not apply to naturally occurring aluminum found in groundwater. The operational guidance values of 0.1 mg/L applies to conventional treatment plants, and 0.2 mg/L applies to other types of treatment systems.
i	High levels (above 500 mg/L) can cause physiological effects such as diarrhea or dehydration.

# **ATTACHMENT 3**

## **Bathymetry Report**

July 31, 2019

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

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

**Attention:** Matthew Hamp, Director of Public Works and Engineering

**Subject:** Iqaluit DFO Bathymetric Lake Surveys

*This 'Issued for Review' document is provided solely for the purpose of client review and presents our interim findings and recommendations to date. Our usable findings and recommendations are provided only through an 'Issued for Use' document, which will be issued subsequent to this review. Final design should not be undertaken based on the interim recommendations made herein. Once our report is issued for use, the 'Issued for Review' document should be either returned to Tetra Tech Canada Inc. (Tetra Tech) or destroyed.*

## 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  $\pm 4^\circ$  and a measurement accuracy of  $\pm 2.5$  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.

## 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.

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. 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 10% at Geraldine Lake at the time of the survey. Survey navigation was achieved using a navigation tracking software package that displayed the boat location and track lines in real time for the boat operator.

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

At each lake, ten GPS points were collected using the RTK rover unit along the shoreline to measure elevation of the water level at the time of the survey.

### 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). 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 (<0.5 m) 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 National Resources Canada (NRCAN) 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 available georeferenced satellite imagery 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.

### 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 measured CVD28 water elevation at the time of the survey. The absolute accuracy of this elevation measurement is approximately  $\pm 3$  cm. Water surface elevations have not yet been compared to LiDAR results, as at the time of this report the LiDAR data had not yet been collected. Once the LiDAR data is available, it is recommended that the Tetra Tech elevations be shifted to match the elevations obtained during the LiDAR program.

This can be achieved by comparing the elevation at a known location in both datasets. While on site, Tetra Tech recorded a 3D point on the eastern side of the dam in a location that can be easily found and surveyed during the LiDAR program. Similarly, points were collected on two distinctive rocks at either end of Unnamed Lake and flagged so that the LiDAR ground crew can find them and record their coordinates. Once collected, the LiDAR elevation at these locations can be compared to Tetra Tech's elevations at the same locations to determine the required elevation shift and thus accurately tie the two datasets together.

Once the water surface elevations have been shifted to match the LiDAR data, a comprehensive above- and below-water 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.

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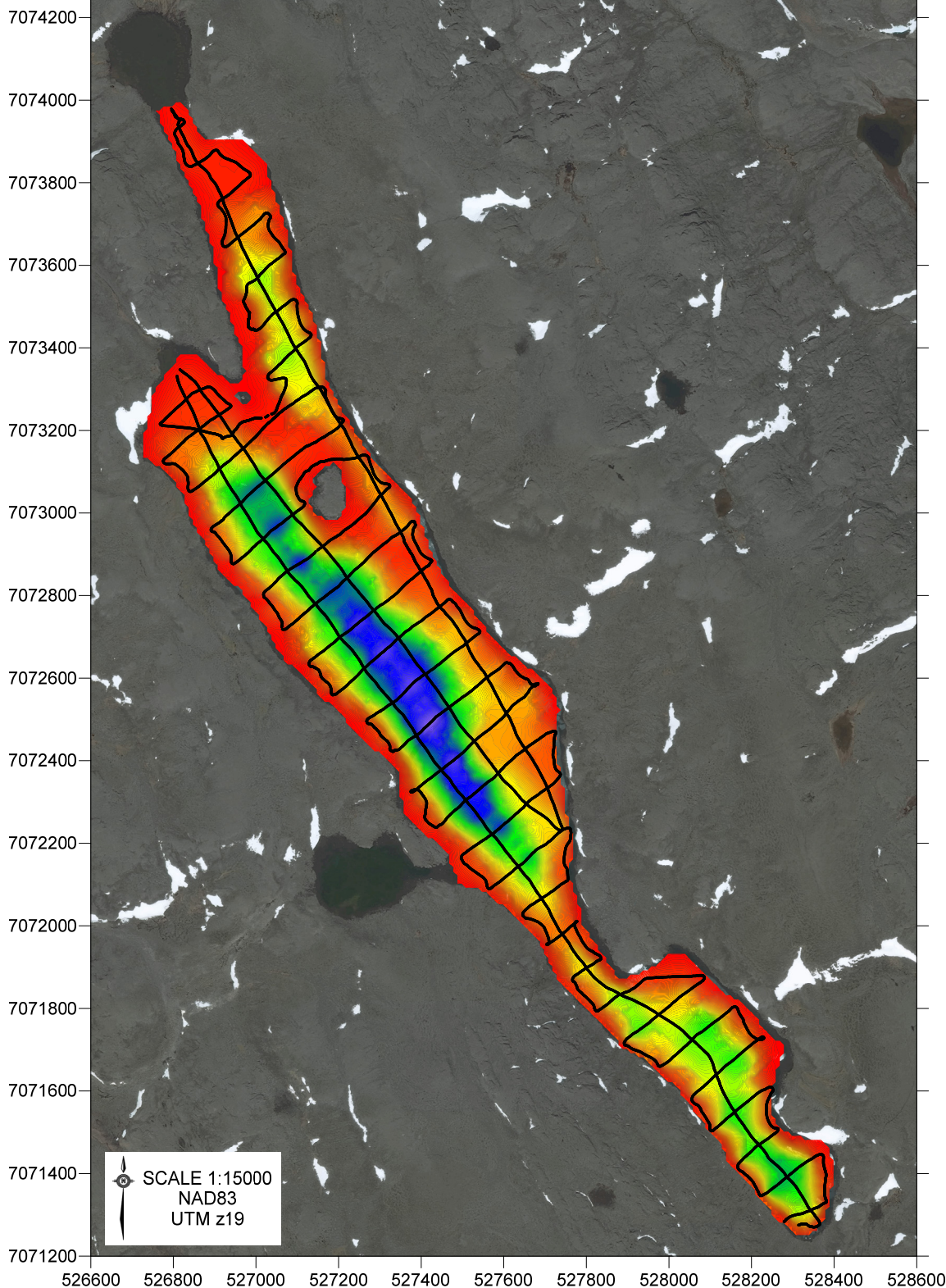
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/jf

## FIGURES

- Figure 1      Unnamed Lake Bathymetry Depth Results  
Figure 2      Lake Geraldine Bathymetry Depth Results

North (m)



Water Depth (m)

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<sup>2</sup>  
**Total Lake Volume:** 6,616,900 m<sup>3</sup>  
**Under Ice Volume:** 4,737,900 m<sup>3</sup>  
**Maximum Expected Ice Thickness Value Used:** 2.0 m  
**Calculated 5% Withdrawal Volume:** 236,895 m<sup>3</sup>

CLIENT

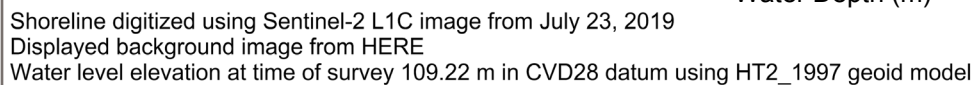


#### IQALUIT DFO BATHYMETRIC LAKE SURVEYS

**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**



### Figure 2

## APPENDIX A

### TETRA TECH'S LIMITATIONS ON USE OF THIS DOCUMENT

# **LIMITATIONS ON USE OF THIS DOCUMENT**

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### **1.3 STANDARD OF CARE**

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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.

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## 1.7 ENVIRONMENTAL AND REGULATORY ISSUES

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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

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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.

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## 1.9 LOGS OF TESTHOLES

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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

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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

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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.

# **ATTACHMENT 4**

## **LiDAR Report**

# **City of Iqaluit**

## **Unnamed Lake**



**August 16-17, 2019**

## Introduction

Aethon Aerial Solutions (AAS) conducted an aerial survey of the Unnamed Lake site in Iqaluit for the City of Iqaluit on August 16-17, 2019. The project site (see Figure 1) was located approximately 6 km [E] of CYFB (Iqaluit airport) and covered 28.9 square km. The project area was surveyed in 3 flights at 750' AGL.

### Survey Summary:

- Survey area: Unnamed Lake
- Collection dates: August 16-17, 2019
- Survey platform: B206
- Horizontal Datum: NAD83 CSRS, 2010 Epoch
- Vertical Datum: CGVD2013
- Geoid Model: CGG2013
- Projection: UTM Zone 19 [N]
- Deliverables:
  - Classified (unclassified, ground, water) LiDAR .las point cloud
  - 1 m ASCII (.xyz) grid
  - 7 cm RGB Orthomosaic in GeoTIFF and .ecw formats

## Survey Equipment

AAS partnered with Universal Helicopters to use their Bell 206 helicopter as the survey aircraft.

The sensor platforms included:

- Riegl VUX-1 laser scanner
- KVH1750 IMU
- Novatel GNSS 638/615
- Nikon D810 digital SLR

Ground Survey Equipment

- Leica iCON gps60 base station
- Leica iCON gps60 rover

## Survey Control

AAS surveyors utilized an NRCAN control monument named PALUG at the project site (see Figures 2 and 3). The monument is a HP3D brass cap embedded in the ground. Coordinates for the PALUG control monument were taken from NRCAN's published values and also checked using NRCAN's Precise Point Positioning service (see Table 1 and Figure 4). All AAS data has been referenced to the PALUG published coordinates from NRCAN. A second monument named 301 was utilized near the project site and is included in Table 1. Coordinates used for 301 were derived by a differential correction survey from PALUG.

Table 1 – PALUG control monument and permanent control spike 301 location.

NAME	SOURCE	LATITUDE	LONGITUDE	ELLIPSOIDAL HEIGHT (m)	CGG2013 GEOID ADJUSTMENT (m)
PALUG	NRCAN Published	63° 44' 39.413803"	-68° 28' 55.656848"	107.473	9.931
UTM Zone 19 [N]		EASTING (m)	NORTHING (m)	ORTHOMETRIC HEIGHT (m)	
		525561.320	7068622.867	117.404	

NAME	SOURCE	LATITUDE	LONGITUDE	ELLIPSOIDAL HEIGHT (m)	CGG2013 GEOID ADJUSTMENT (m)
PALUG	NRCAN PPP	63° 44' 39.41406"	-68° 28' 55.65713"	107.449	9.931
UTM Zone 19 [N]		EASTING (m)	NORTHING (m)	ORTHOMETRIC HEIGHT (m)	
		525561.316	7068622.875	117.380	

NAME	SOURCE	EASTING (m)	NORTHING (m)	ORTHOMETRIC HEIGHT (m)
301	Differential Correction	527151.2024	7070357.9979	171.8568

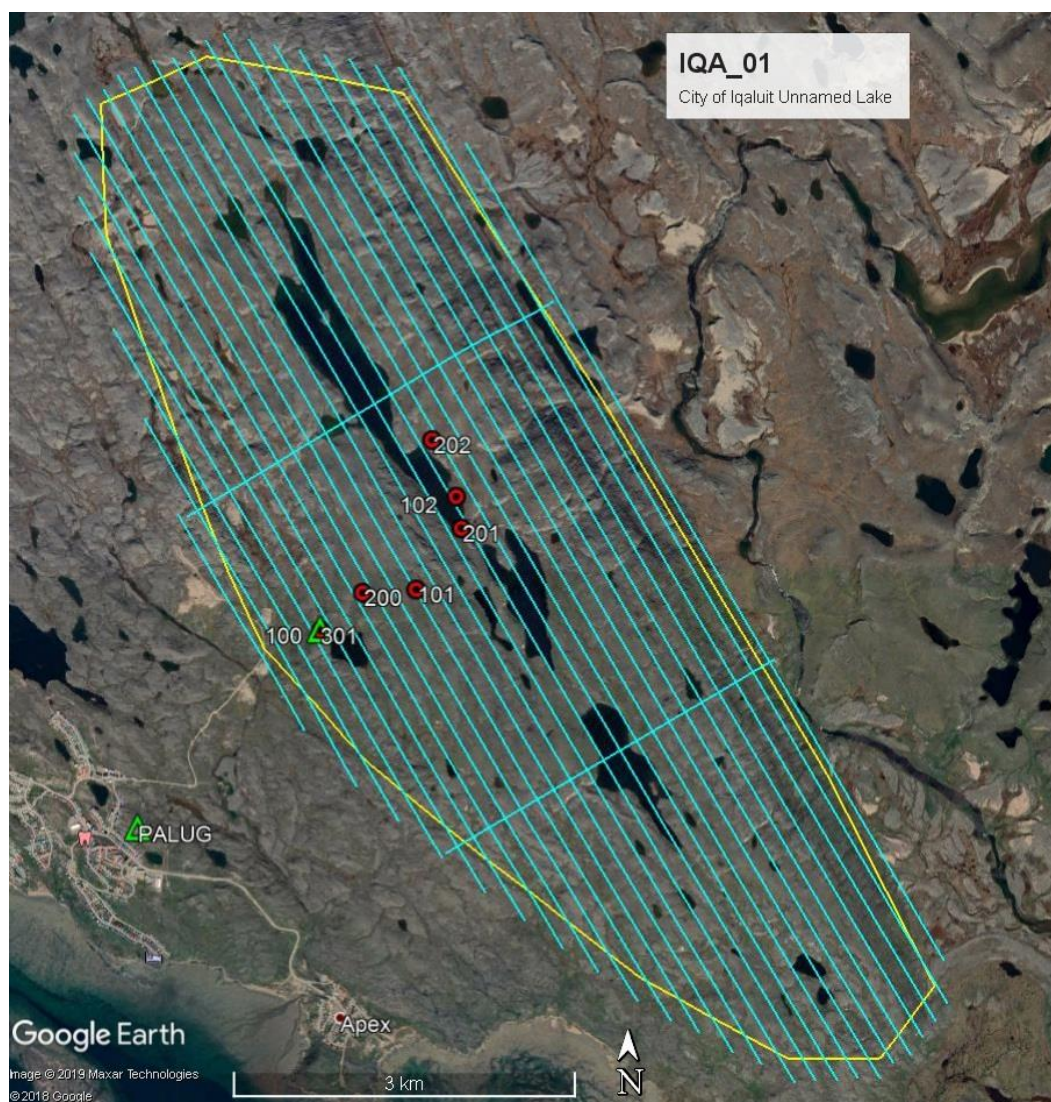


Figure 1 – Unnamed Lake survey area flight lines (blue), area of interest (yellow), GCPs (red markers) and control point locations (green triangle) overlain on Google Earth imagery.

## Check Point Data

AAS surveyors established 6 ground control targets (approximately 3ftx3ft) within the survey area from control point 301 for LiDAR and orthomosaic data analysis. 3 of the points were used for calibration and processing of the LiDAR data. The remaining 3 points have been compared vertically to the delivered LiDAR data in Table 3. 4 of the established ground control targets were painted to accurately georeference and assess the quality of the orthomosaic. (see Table 4).

*Table 3 – LiDAR ground targets and vertical accuracy measurements.*

SURVEYED GROUND CONTROL POINT					LiDAR
POINT NUMBER	COMMENT	EASTING (m)	NORTHING (m)	ORTHO. HEIGHT (m)	MEASURED Z DIFFERENCE (m)
1	200	527551.008	7070691.160	201.983	0.065
2	201	528391.550	7071253.310	205.802	0.018
3	202	528134.018	7072009.439	225.333	0.015
				MEAN	0.033
				RMSE	0.040
				STDEV	0.028

*Table 4 – Orthomosaic ground targets and horizontal accuracy measurements.*

SURVEYED GROUND CONTROL POINT					RGB IMAGERY
POINT NUMBER	COMMENT	EASTING (m)	NORTHING (m)	ORTHO. HEIGHT (m)	MEASURED X-Y DIFFERENCE (m)
1	100	527167.297	7070357.656	172.408	0.060
2	101	528021.931	7070723.655	244.707	0.000
3	102	528344.503	7071525.336	213.792	0.055
4	200	527551.008	7070691.160	201.982	0.110
				MEAN	0.056
				RMSE	0.068
				STDEV	0.045

## Data Acquisition

AAS surveyors flew the survey on August 16-17, 2019 to cover the project area of 28.9 km<sup>2</sup> in 3 flights of 26 flight lines at 750 ft AGL.

The flying speed was 40 knots (ground speed). AAS' GPS base station was set up on the PALUG control monument and operated continuously during data acquisition logging at a 1 second interval.

LiDAR data was collected using a Riegl VUX-1 scanner operating at 200 kHz at 750' AGL resulting in an overall point density of 17.3 points/m<sup>2</sup>.

## Data Processing

### LiDAR

#### *Calibration*

A calibration pattern is flown at the AAS test facility to compute the roll, pitch and heading offsets for the IMU and laser scanner. Sloped targets are set out in various orientations and a calibration flight pattern is flown over. New calibration values are computed every time the IMU is attached to the laser scanner.

Project specific calibration adjustments are made on a flightline-to-flightline basis and are unique to each flight.

#### *Classification*

ASPRS standard classified LiDAR point clouds version 1.2 are delivered in LAS format (see Table 5 below).

*Table 5 – LiDAR point classification scheme.*

CLASS NAME	CLASS NUMBER
Unclassified	1
Ground	2
Water	9

Automated classification algorithms determined the ground points from non-ground points. Skilled LiDAR technicians inspected the automated ground classification and adjusted any misclassified points where necessary. The next step is to classify the water from all remaining points which are left as unclassified.

### Orthomosaic

The completed aerial triangulation, LiDAR ground points and DEM are used to accurately georeference the orthophotos. Colour balancing and image touch ups are done to ensure a seamless orthomosaic is generated. The orthomosaic is exported in tiles in GeoTIFF and ECW formats at 7 cm pixel resolution.

## **Final Remarks**

AAS appreciates the opportunity to complete this survey for the City of Iqaluit and is available to answer any questions regarding the data collection and deliverables.

Please feel free to contact me at my coordinates below,

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## APPENDIX

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## RTK & BASE FIELD NOTES

Client: City of Igoumit Project Code: 1QA01  
Completed by: B Vallieres Date: Aug 13 / 19  
Job Name: Unnamed Lake Base Location: Palug  
Temperature: 15 Wind: 0 Cloud: 1/8  
Survey Equip: 1 CONGO UAV-☐ Marine-☐ Manned-☒ Airframe: B206  
Base File Name: \_\_\_\_\_ Base Stn ID: 300 Marker Type: Mon  
Coordinate System: N83 (2010) UTM Zone: 19  
Base Height: 1,200 Start Time: 0718 End Time: 1810 Raw Data Logging ☒  
Base Coords - N: \_\_\_\_\_ m E: \_\_\_\_\_ m Z: \_\_\_\_\_ m  
e base position: Known-☒ Unknown- ☐

[illegible]

\*enter  $\Delta$  horizontal and  $\Delta$  vertical values in description for check shots\*

Figure 2 – AAS base station setup sheet for PALUG control monument.



*Figure 3 – Image of PALUG control monument and base station near the Unnamed Lake survey site.*



## CSRS-PPP 2.26.1 (2019-05-31)



LEIC225n18-58000.19o  
300

<b>Data Start</b>	<b>Data End</b>	<b>Duration of Observations</b>
2019-08-13 13:18:59.00	2019-08-13 22:11:06.00	8:52:07
<b>Processing Time</b>		<b>Product Type</b>
13:10:06 UTC 2019/08/14		NRCan Rapid
<b>Observations</b>	<b>Frequency</b>	<b>Mode</b>
Phase and Code	Double	Static
<b>Elevation Cut-Off</b>	<b>Rejected Epochs</b>	<b>Estimation Steps</b>
7.5 degrees	0.00 %	1.00 sec
<b>Antenna Model</b>	<b>APC to ARP</b>	<b>ARP to Marker</b>
LEICG60 NONE	L1 = 0.130 m L2 = 0.134 m	H:1.560m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point)

### Estimated Position for LEIC225n18-58000.19o

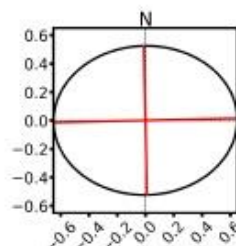
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2010)†	63° 44' 39.41406"	-68° 28' 55.65713"	107.449 m
Sigmas(95%)	0.004 m	0.005 m	0.013 m
A priori*	63° 44' 39.45627"	-68° 28' 55.73950"	106.774 m
Estimated – A priori	-1.307 m	1.130 m	0.675 m

Orthometric Height CGVD2013  
(CGG2013a)

117.380 m

(click for height reference  
information)

95% Error Ellipse (cm)  
semi-major: 0.650 cm  
semi-minor: 0.524 cm  
semi-major azimuth: 88° 44' 2.34"



UTM (North) Zone 19

7068622.875 m (N)  
525561.316 m (E)

Scale Factors  
0.999608 (point)  
0.999591 (combined)

\*(Coordinates from RINEX header used as a priori position)

†(Epoch transformation using velocity grid NAD83v70VG)

Figure 4 – NRCAN PPP report for the PALUG control monument near the Unnamed Lake survey site.