Annual Report for “Field and Modelling Investigations for Alert – Hydrological Research and Drinking Water Supply Analysis for 2025-26”

(Final Report for 2025-26)

Due March 31, 2026

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Executive Summary

Upper Dumbell Lake is the primary freshwater-water source for Canadian Forces Station Alert. This multi-year project is designed to quantify watershed hydrology, lake storage, and withdrawal sustainability to support long-term water-management planning. This first year successfully established the monitoring infrastructure and mapping foundation required for a full hydrological assessment of Upper Dumbell Lake and supports evidence-based management of CFS Alert's water supply.

Major Accomplishments (2025 Field Season)

1. **High-Resolution Watershed Mapping**
   - Completed airborne LiDAR survey over ~15 km^2.
   - Generated the first fine-resolution Digital Elevation Model (DEM) for the Upper Dumbell Lake watershed.
   - Delineated watershed area as 9.05 km^2.
2. **Hydrological Monitoring Network Installed**
   - Stilling wells and pressure transducers installed in inlet and outlet streams.
   - Lakeside micrometeorological tower installed to support evapotranspiration estimation.
   - Lake temperature/oxygen sensor string deployed.
   - All equipment operating successfully since August 2025.
3. **Preliminary Water Budget Developed**
   - Lake area ~1.2 km^2; estimated volume ~1.4×10^7 m^3.
   - Net withdrawals by CFS Alert ~40,000 m^3/year.
   - Preliminary analysis indicates withdrawals represent a very small fraction of lake storage and annual inflow.
4. **Bathymetric Survey Prepared**
   - BathyLogger system tested successfully.
   - Full bathymetric survey delayed due to early freeze-up; scheduled for Aug/26.

Preliminary Conclusions

- Based on current withdrawal rates and preliminary hydrological estimates, **no hydrological risk to water supply reliability has been identified**.
- Estimated seasonal lake-level change from withdrawals is only a few centimeters; far smaller than intake depth (~6 m).
- Continued monitoring and completion of bathymetry and snowmelt measurements are required to confirm results.

Planned Work (2026)

- Snowpack and snowmelt hydrology campaign (May–June 2026).
- Streamflow measurements and rating-curve development.
- Completion of lake bathymetric survey.
- Updated water-budget analysis for inclusion in Nunavut Water Board reporting.

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Originally Proposed Scope of Work

The project aimed to provide a comprehensive quantification of hydrological inputs, outputs and major storage terms to/from Upper Dumbell Lake. A specific breakdown of proposed work included:

- Planning of work including any permitting
- Digitization of available maps for initial terrain analyses
- Unmanned vehicle (aerial drone and remote catamaran) training
- Hydrological field work
    - Drone flights with LiDAR (Light Detection And Ranging) sensor for collection of bare Earth topographic data
    - Georeferenced bathymetric survey of Upper Dumbell Lake
    - Stilling well, pressure transducer and barometer installation and well elevations survey in Upper Dumbell Lake, as well as inlet and outlet streams
    - Stream discharge measurements
    - Setup of lakeside micrometeorological tower
    - Water sampling for stable isotope analyses
- Data processing, GIS analyses and laboratory analyses (i.e., water isotopes)
- Project reporting to summarize field work, results and recommendations for following year

Summary of Accomplished 2025-2026 Work

Planning of work including any permitting.

All work was able to proceed safely and accurately. Permitting, including radio frequency disclosure for drone operations, hazardous materials transport for drone batteries, and permissions for drone operations, were all successfully obtained well ahead of field operations in August/September 2025.

Additionally, significant procurement was necessary to obtain certain equipment and cold weather gear. This, as well, was successful and all materials, gear and equipment needed for our work was obtained on schedule.

Digitization of available maps for initial terrain analyses.

Few resources exist for Alert in this regard, however DND was able to provide us with a NRCan 1:50,000 topographic map of the region including the Alert base and Upper Dumbell Lake. While not requiring digitization, this map (figure 1) was used to plan drone flight missions (figure 2) and to make an initial estimate of the watershed area feeding into Upper Dumbell Lake; approximately 10 km^2. A major component of this project is to improve mapping resources for the area, particularly for use in terrain analysis (points 4 and 5 below).

Additionally, the coarse bathymetric contour map from Apollonio and Saros (2014) was digitized, georeferenced and used to develop a GIS-based DEM for the lake. These data represent a preliminary means of assessing lake depth-volume-area relationships. Results are presented in the preliminary assessment of the Upper Dumbell Lake water budget in this report.

Figure 1: 1:50,000 topographic map of the Alert, NU region, including Upper Dumbell Lake. Dark outline is sketching of approximate watershed boundary based on topographic contours.

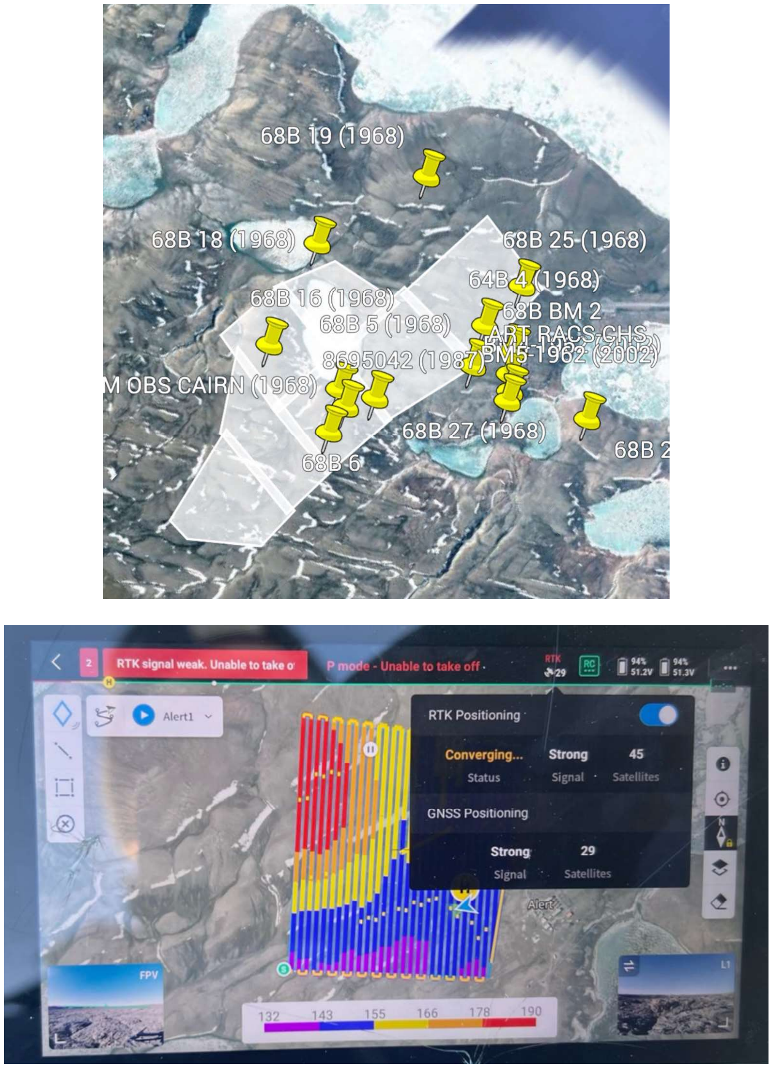

Figure 2: (a) Mission planning for drone flights across the Upper Dumbell Lake watershed; and (b) an example of a mission flight path for LiDAR data collection by drone.

Unmanned vehicle training.

During this year and ahead of August/September field work in Alert, both Dr. Carl Mitchell and MSc student Alice Hamam were trained and certified as drone pilots.

Hydrological field work, including:

Drone flights with LiDAR (Light Detection And Ranging) sensor for collection of bare Earth topographic data.

Several days of drone flights were completed in late August through early September at Alert. Figure 3 shows field operations using the DJI Matrice 300 drone with Zenmuse L1 LiDAR sensor. Drone work and data collection was fully successful for collection of bare Earth topographic data. Aerial photos are taken at set intervals during drone flights, though some flights later during field work did not retrieve photos due to a sensor malfunction that could not be resolved in the field (Figure 4). Further details are given at point 5 (data processing) and later in this report for construction of a preliminary water budget for Upper Dumbell Lake. All field operations in 2025 were conducted with zero safety incidents.

Figure 3: Drone deployment photos from summer 2025. Clockwise from left: drone operators Carl Mitchell and Alice Hamam set up the RTK system for accurate drone positioning; Matrice 300 drone pre-flight; Matrice 300 drone in-flight above tundra.

Figure 4: Example aerial photographs taken during drone deployments. Photography of station antennae was avoided.

Georeferenced bathymetric survey of Upper Dumbell Lake.

A BathyLogger system was procured this year. This consists of a remote-controlled, battery-powered catamaran equipped with RTK (real-time kinematic) positioning and downward sonar. Unfortunately, our travel to Alert was delayed by one week for reasons outside of our control. As a result, lake conditions were already climatically past our ability to conduct the survey in 2025 due to ice cover. Specifically, we were able to conduct preliminary testing of the system on Upper Dumbell Lake for one day (figure 5), but the lake had frozen over by the following day. This bathymetric survey was therefore not completed but will be a priority for planned August 2026 field work at Alert. For the purposes of an initial water balance, we are using coarse depth estimates from Apollonio and Saros (2014).

Figure 5: One-day testing of the BathyLogger system on Upper Dumbell Lake. Clockwise from left: Bathylogger system at shore (notice thin ice and surface bubble in above boat); Bathylogger system motoring toward a low-horizon Sun; Bathylogger system returning to shore. Upper Dumbell Lake froze over the following day, preventing us from completing the bathymetric survey in 2025.

Stilling well, pressure transducer and barometer installation and well elevation surveys in Upper Dumbell Lake, as well as inlet and outlet streams.

Stilling wells were installed at four stream inlets to Upper Dumbell Lake and in duplicate on the stream draining Upper Dumbell Lake (figure 6). Wells have been outfitted with datalogging pressure transducers for measuring water levels. An example of a stilling well installation, including steel bar support, is given in figure 7. A barometric pressure sensor was deployed with the micrometeorological tower to enable barometric compensation of water level data.

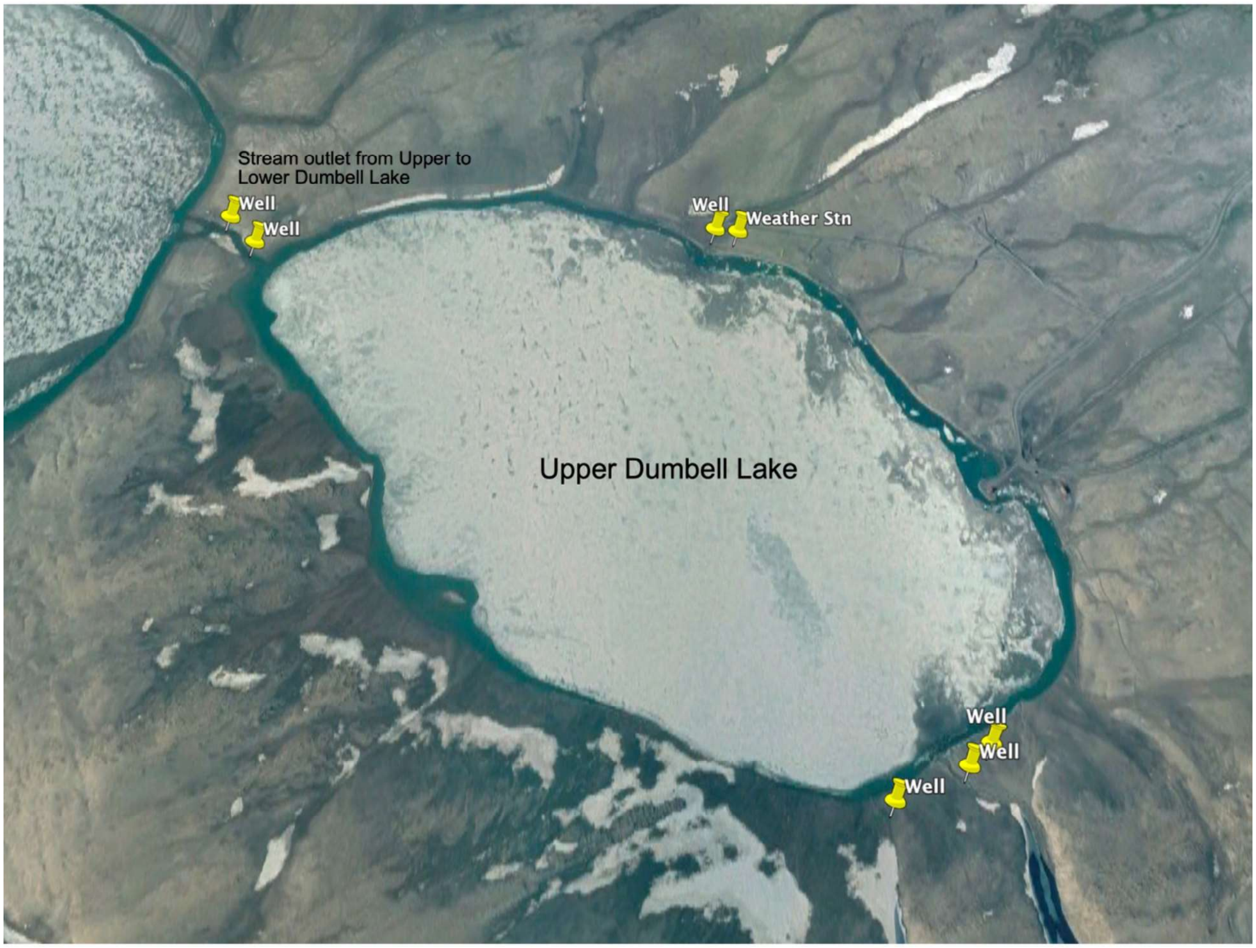

Figure 6: Map of Upper Dumbell Lake showing the deployment locations of stilling wells in streams ("Well") and the micrometeorological station ("Weather Stn").

Figure 7: Still well installation at outlet of Upper Dumbell Lake.

Stream discharge measurements.

Conditions during our field work in 2025 were entirely dry with no runoff to measure. Stream discharge measurements will therefore be the focus of a major field campaign scheduled for May through June 2026. Stream discharge measurements will be coupled with pressure transducer measurements in stilling wells to generate rating curves for each stream. Rating curve equations will then be used with hourly water level data from the pressure transducers to generate continuous streamflow records.

Setup of lakeside micrometeorological tower.

A micrometeorological tower was successfully established on the north shore of Upper Dumbell Lake (figure 6) and fully instrumented for measurements capable of applying the Penman-Monteith approach for estimation of evapotranspiration. This includes sensors to measure rainfall, net radiation, ground heat flux, air temperature, relative humidity, wind speed and direction, soil temperature and soil volumetric moisture content (figure 8).

With assistance from Environment and Climate Change Canada, the micrometeorological tower's power supply and data have been able to be managed continuously since August 2025 to present, outside of a 2-week period from October 8 to 22 when power was unexpectedly lost. An example of data from the tower, air temperature, is shown in figure 9.

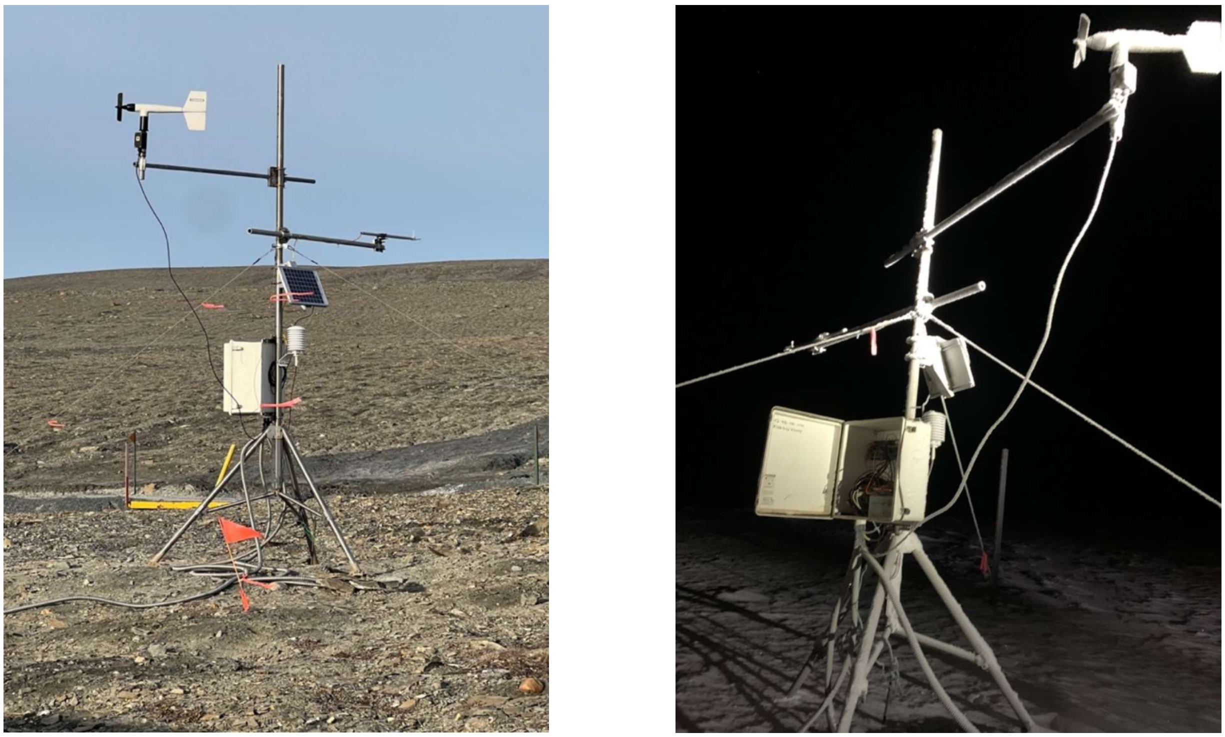

Figure 8: Micrometeorological tower deployed on the north shore of Upper Dumbell Lake. Left is original deployment. Right shows tower in late December 2025.

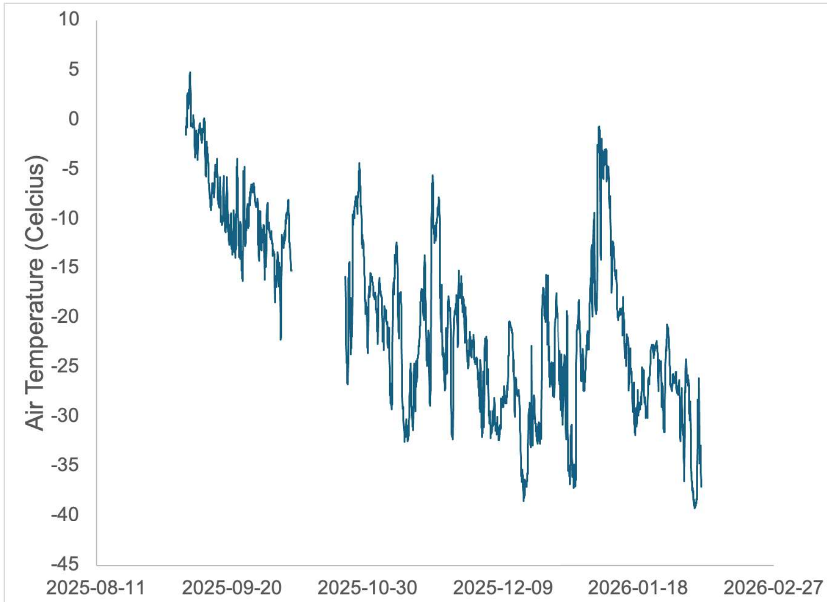

Figure 9: Example of continuous air temperature data from the micrometeorological tower from early September 2025 through mid-February 2026.

Water sampling for stable isotope analyses.

Due to a lack of runoff water in the basin, sampling for stable isotope analyses was delayed to 2026 when a comprehensive set of samples will be collected across snowmelt, stream runoff and lake water.

Data processing, GIS analyses and laboratory analyses.

Over 150 gigabytes of raw lidar data was collected during our August-September field trip to Alert and has been processed into nearly 3 terabytes of reconstructed lidar point cloud data and related digital products, such as maps.

The overall workflow included the following:

1. Field Data Acquisition

└─ Drone LiDAR flights (DJI Matrice 300 RTK + Zenmuse L1)

└─ GNSS/IMU trajectory recorded

└─ RTK corrections applied in flight

└─ Raw LiDAR point cloud + trajectory data collected

2. Initial LiDAR Processing (DJI Terra / Similar Software)

└ Import LiDAR raw data

└ Apply trajectory solution using PPK corrections from CFS Alert station

└ Time synchronization (LiDAR + IMU + GNSS)

└ Strip alignment / boresight correction

└ Generate georeferenced point cloud

3. Quality Control

└ Check flight overlap

└ Check vertical error

└ Verify ground control / check points

└ Remove obvious noise points

4. Multi-Mission Merge

└ Import point clouds from all missions

└ Align overlapping swaths

└ Remove duplicates

└ Merge into single unified point cloud

5. Point Classification

└ Ground points

└ Vegetation

└ Buildings / objects

└ Noise

8. GIS Integration (QGIS / ArcGIS)

└─ Import classified point clouds

└─ Fill sinks and generate Digital Elevation Model (DEM)

└─ Watershed delineation

└─ Stream network extraction

7. Raster Derivatives

└─ Hillshade

└─ Slope

└─ Curvature

└─ Flow direction

└─ Flow accumulation

Project reporting to summarize field work, results and recommendation for following year.

This report section has summarized all 2025 field work at Canadian Forces Station Alert. Results and recommendations for 2026 are in the following sections.

Additional work performed.

A 33 m long weighted rope with temperature sensors secured at every meter and additional dissolved oxygen sensors and a chlorophyll and light sensor, was deployed in the deepest basin of the lake in late August 2025. This also included a pressure transducer that will allow us to assess changes in lake level directly once the sensors are retrieved late summer 2026.

Preliminary Assessment of Upper Dumbell Lake Water Budget

Upper Dumbell Lake is the domestic water supply source for Canadian Forces Station Alert. A pumphouse at the northeast corner of the lake provides water to the base's treatment facility via a heat-traced pipe.

The water balance for Upper Dumbell Lake is assessed via the equation:

$$\Delta S = P + Q_{in} - ET - Q_{out} - W$$

Where ΔS is the change in storage of Upper Dumbell Lake, P is precipitation input directly to Upper Dumbell Lake, Q_{in} is the cumulative input to Upper Dumbell Lake via runoff, ET is evapotranspiration, Q_{out} is the discharge of water from Upper Dumbell Lake to Lower Dumbell Lake and W is net water withdrawal for usage by CFS Alert. Subsurface flows are expected to be small under continuous permafrost conditions.

Measurement and/or Estimation of Water Budget Variables

Storage

Due to the early freeze-up of Upper Dumbell Lake in 2025, the planned bathymetric survey of the lake was not possible and is instead planned for completion in summer 2026. Preliminarily, the only known, but relatively coarse, bathymetric map for Upper Dumbell Lake (Apollonio and Saros, 2014 – original field work performed in 1959) was digitized, georeferenced and applied in Geographic Information Systems to construct a preliminary lake-storage curve for the lake.

Upper Dumbell Lake has an area of 1.2 km^2, an average depth of 12.5 m and a maximum depth of 30+ m. Estimated lake volume based on digitized historical bathymetry is approximately 1.4×10^7 m^3, pending confirmation with modern survey. The depth-volume curve for Upper Dumbell Lake is shown in figure 10 and the depth-area curve is shown in figure 11.

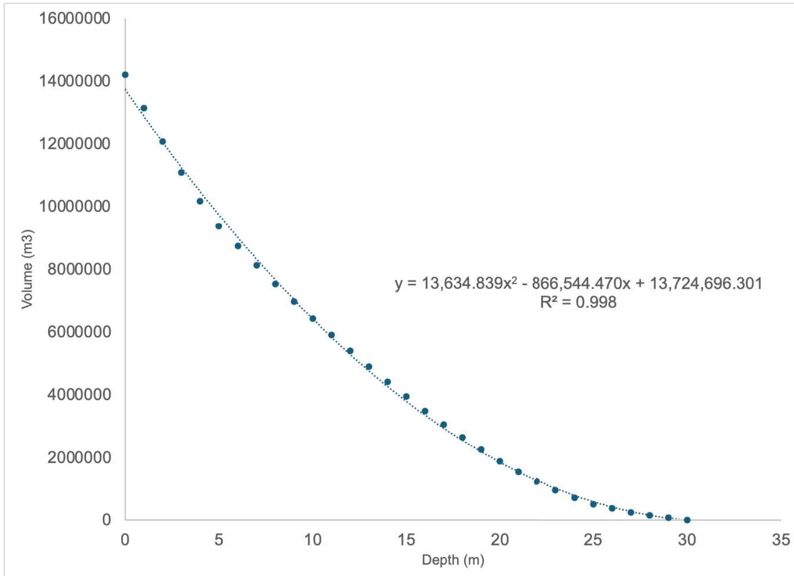

Figure 10: Preliminary depth-volume curve for Upper Dumbell Lake.

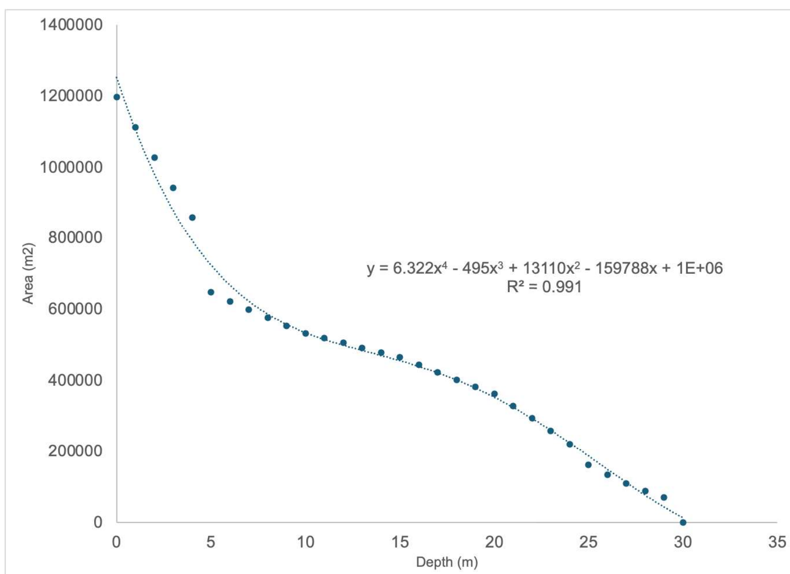

Figure 11: Preliminary depth-area curve for Upper Dumbell Lake.

Precipitation

Alert is situated in a polar desert, with low amounts of precipitation. Precipitation at Alert occurs predominantly as snowfall. Long-term records for snow and rain exist at Alert because of a long-time partnership with Environment and Climate Change Canada (ECCC). We measured no rain as precipitation during our field trip in August/September

2025. Long-term ECCC records reveal an average of 160 mm of precipitation per year, with only ~20 mm per year as rain. For inclusion in the water budget, long-term averages are used in this first report. The precipitation normals for Alert are shown in Table 1. Based on these climate normals, snow water equivalent is approximately 10% of snow depth.

Table 1: Precipitation averages for 1950-2025 at CFS Alert

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rain (mm)	0	0	0	0	0.1	2.4	10.3	5.4	0.2	0	0	0	18.2
Snowfall (cm)	10.6	8.0	10.3	10.8	15.7	11.8	12.9	17.6	31.3	22.3	13.6	10.8	176
Precip (mm)	8.5	6.6	8.6	9.2	10.7	12.9	22.8	22.3	23.0	14.6	9.9	8.7	157
Snow pack (cm)	27.0	28.9	30.3	33.3	35.0	19.3	0.7	1.0	10.2	18.6	22.4	24.7	

Runoff Input

Since the start of field work in 2025, conditions have been too cold to produce runoff. Almost all runoff in this area occurs during the spring freshet/snowmelt period from approximately late May through June. This project is well situated to measure 2026 runoff because of equipment installations in 2025, which would not have been possible to install *during* runoff in 2026.

For purposes of a preliminary water budget, runoff inputs are estimated as 65% of the overall snowpack water equivalent in late May. We do not have any means yet of estimating runoff ratios (i.e., how much of the snow water on the ground is translated into runoff vs. surface storage and infiltration), but there are some examples of relatively similar catchments in the high arctic to preliminarily draw from. Young et al. (2010), working on Bathurst Island, found that the study catchment with the closest surface characteristics to the Alert region (ice-rich, polygon terrain) had a runoff ratio of approximately 0.68 in relation to rainfall of varying quantities. In this preliminary water budget, we round this runoff ratio to 0.65 and multiply it by late May snow water equivalent (estimated as 10% of snow depth) to estimate spring runoff. Runoff for the other relatively warmer months (July and August) are estimated from overall precipitation inputs and multiplied by 0.65. Preliminary monthly estimates of runoff (in mm/month) are shown in figure 12.

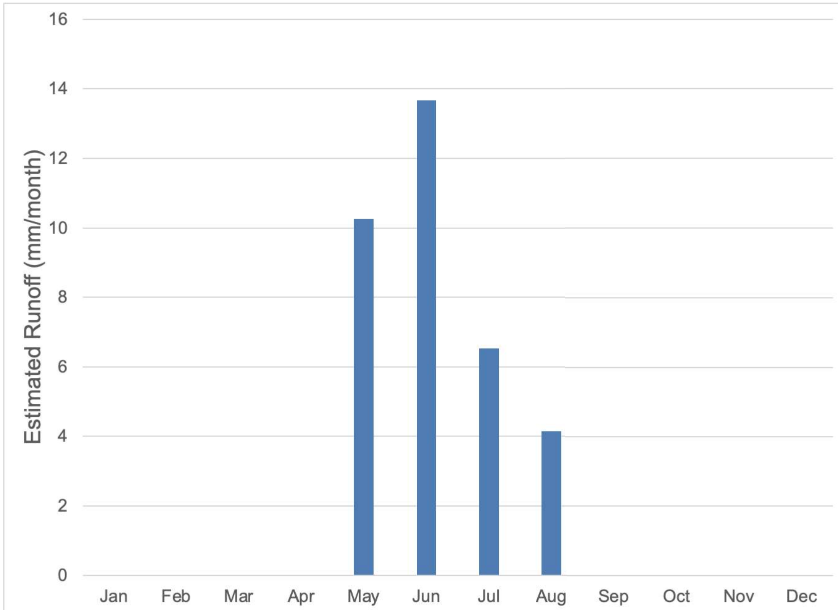

Figure 12: Preliminary estimates of monthly runoff at Alert.

Evapotranspiration

Measurements for estimating evapotranspiration began in September 2025 and are continuing. Our measurements up to present are included in figure 13. The short duration of measurements thus far limits our ability to estimate evapotranspiration for the region, but due to a low amount of energy in Alert, evapotranspiration is assumed to be low. These measurements current represent potential evapotranspiration and values are indeed low. The slightly elevated value for January coincides with an unusual warm spell at Alert in mid-January (see figure 9). Given that the lake is ice covered from early September through at least late June/early July, it is assumed that this forms a physical barrier to evaporation from the lake and that actual evaporation from Upper Dumbell Lake is therefore zero during these months and approximately 1 mm or less per day during July and August. This will be further verified in 2026.

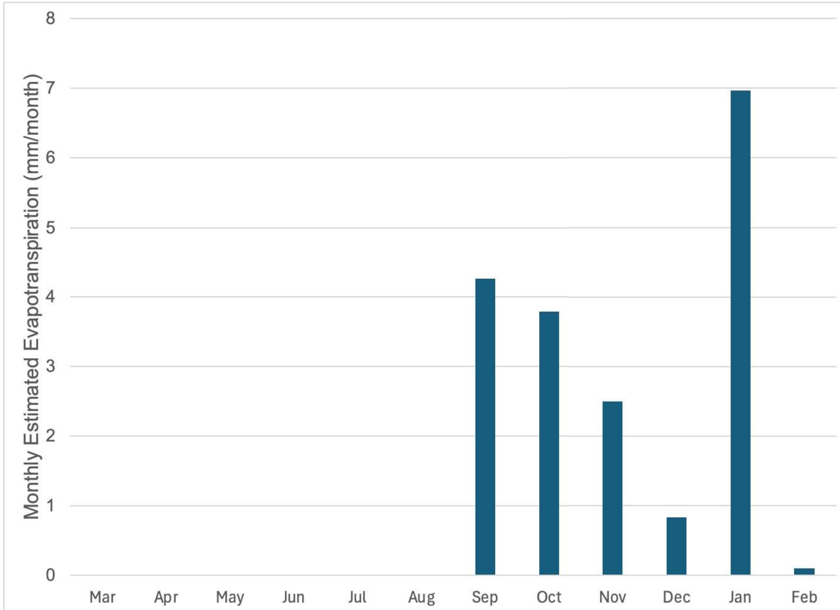

Figure 13: Preliminary estimates of *potential* evapotranspiration adjacent to Upper Dumbell Lake.

Runoff Output

Surface flow out of Upper Dumbell Lake happens solely through a short stream connecting it to Lower Dumbell Lake. This stream was setup with replicate stilling wells to enable generation and application of a rating curve, but the stream was not actively flowing during our first trip to Alert in late summer 2025. Flow is likely constrained to June through August and will be a focus of measurement efforts in 2026. At present, these flows are estimated from the lake hydrological surplus.

Withdrawals for Use by CFS Alert

CFS Alert keeps excellent records of net withdrawals from Upper Dumbell Lake for processing in their water treatment facility and distribution through the station. Net withdrawals range from approximately 2400 and 4400 m3 per month (figure 14), and total approximately 40,000 m^3 per year.

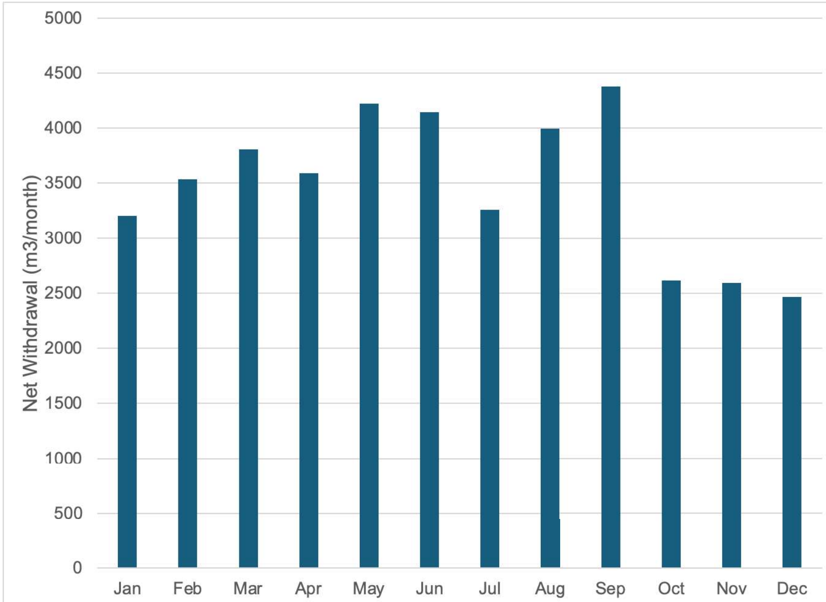

Figure 14: Net monthly withdrawals from Upper Dumbell Lake for use by CFS Alert.

Generation of a Fine-Resolution Digital Elevation Model for the Upper Dumbell Lake Catchment Area

The most significant accomplishment of the 2025 field season was the successful collection of LiDAR data across approximately 15 km2 of area encompassing the drainage basin for Upper Dumbell Lake. This has enabled the generation of a fine resolution digital elevation model (DEM), shown in figure 15. From this DEM, we have been able to delineate a highly accurate catchment area for Upper Dumbell Lake, with a final calculated area of 9.05 km^2.

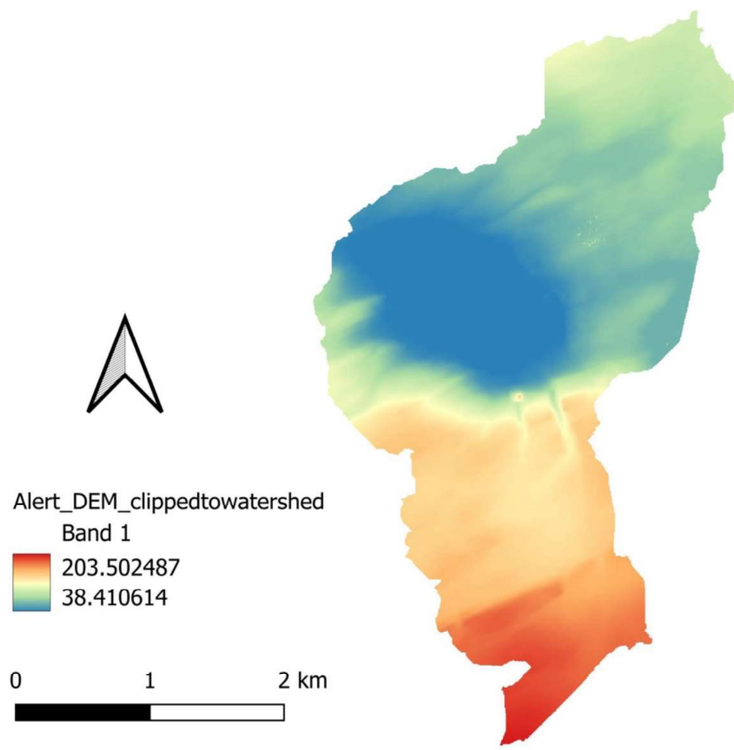

Figure 15: Digital Elevation Model (DEM) and watershed outline for Upper Dumbell Lake (in blue).

Bringing Together a Preliminary Water Budget for Upper Dumbell Lake

The entire watershed, delineated from the stream outlet from Upper Dumbell Lake and including Upper Dumbell Lake is 9.05 km^2. The lake itself has an area of 1.2 km^2, thus the contributing area to Upper Dumbell Lake is 7.85 km^2. We can use the catchment and/or lake area to scale hydrological measurements in mm into a volume measure that can be directly assessed against storage in the lake itself. At present, the outflow from Upper Dumbell Lake must be estimated based on assumptions of snowmelt runoff inputs being spread out across the June through August period. The outflow is now instrumented to aid our ongoing efforts to obtain true measurements at the outflow, which will first be conducted in late spring 2026. The preliminary water budget by month is shown in figure 16.

These findings are preliminary and will be updated following completion of a modern bathymetric survey, spring snow characterization and spring runoff measurements scheduled for 2026.

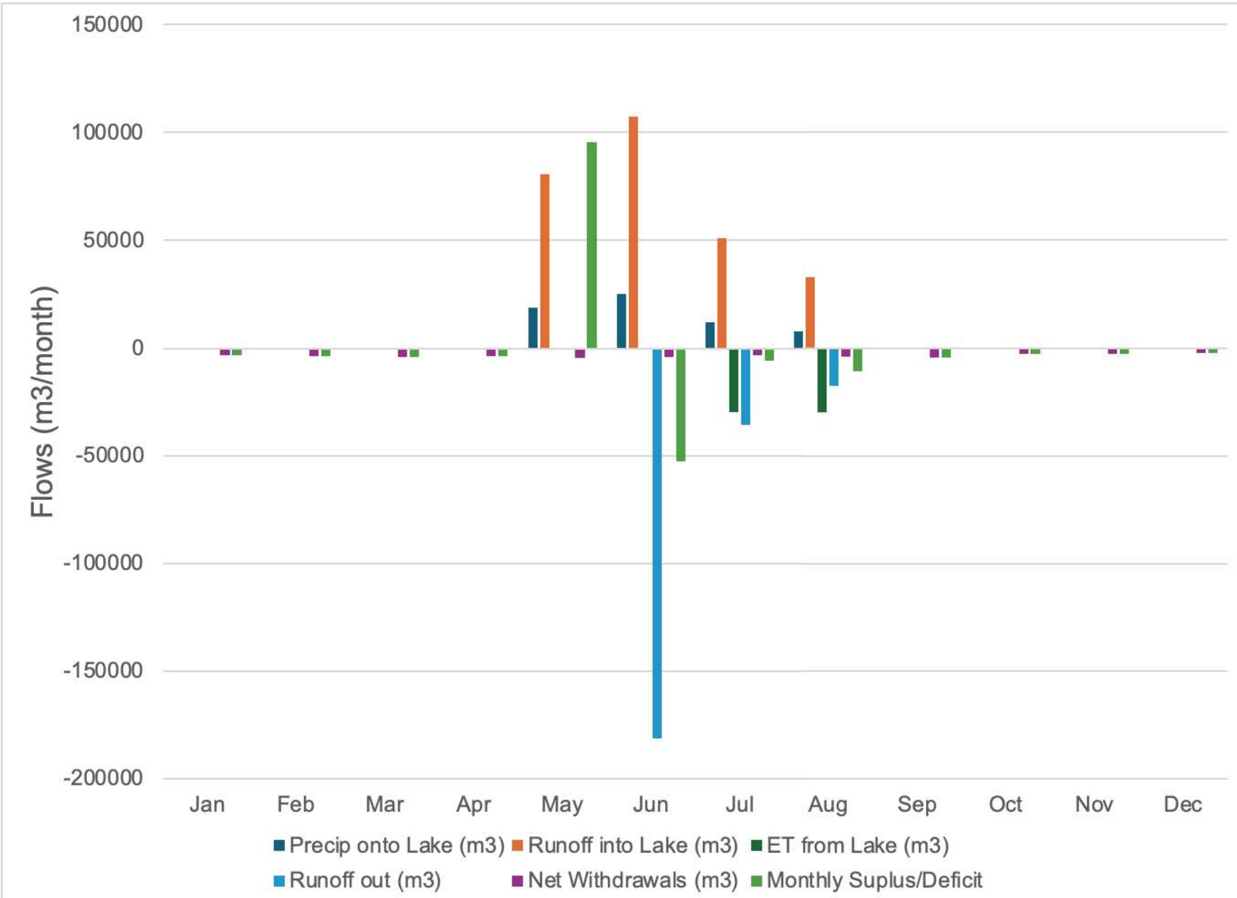

Figure 16: Preliminary water budget, by component and month for Upper Dumbell Lake.

Recommended Additional Inputs for Update to Nunavut Water Board

Professor Carl Mitchell (University of Toronto) was engaged in 2025 to begin a multi-year hydrological study for Upper Dumbell Lake, which constitutes CFS Alert's source of freshwater, as well as the surrounding watershed. First-year deliverables on this partnership include a completed fine-resolution digital elevation model of the watershed surrounding Upper Dumbell Lake (figure 15), hydrological infrastructure deployments in the lake's watershed (e.g., micrometeorological station), and a preliminary, but comprehensive examination of a water budget for Upper Dumbell Lake (figure 16) that can be used to inform adaptive additions to the CFS Alert Water Management Plan. An expected deliverable, a full bathymetric map for Upper Dumbell Lake, has been delayed to summer

2026 due to unexpectedly cold conditions in summer 2025, leading to only 5 days of open water in late August 2025 and freeze over of the lake before we were able to begin the remote operated vehicle, sonar-equipped survey of the lake.

Based on current withdrawal rates by CFS Alert, watershed inflow estimates, and intake depth, there is no evidence of hydrological risk. Water withdrawals from Upper Dumbell Lake are small relative to the lake's storage capacity and annual inflow from snowmelt runoff. Net winter water drawdown calculated for Upper Dumbell Lake (~2 cm) is minor compared to the water intake depth (~6 m below lake surface) and therefore current management does not present a risk to the reliability of the water supply under current operations. Even in unusually low-snowpack years (10–15 mm snow water equivalent), expected watershed runoff volumes to Upper Dumbell Lake substantially exceed annual withdrawals by CFS Alert. Any potential risk to intake operation would require unrealistically low snowpack conditions to be sustained over decades, and therefore hydrological risk is very low. Monitoring of annual snowpack and lake level, as well as completion of efforts begun to obtain accurate data about lake and watershed characteristics is recommended to enable long-term, accurate and adaptive management capabilities.

Estimated seasonal lake-level variation associated with water withdrawals at Upper Dumbell Lake is on the order of only a few centimetres (typically 2 cm), based on annual withdrawal volumes (~40,000 m^3) and the lake's surface area (~1.2 km^2). This magnitude of change is negligible relative to lake depth, shoreline slope and typical natural interannual variability in High Arctic lakes. No meaningful exposure of littoral habitat, alteration of overwintering depth or change in fish habitat is thus anticipated. Similarly, withdrawals represent a very small fraction of annual snowmelt inflow and therefore are not expected to measurably affect downstream flow to Lower Dumbell Lake.

These findings are preliminary and will be updated following completion of a modern bathymetric survey, spring snow characterization and spring runoff measurements scheduled for 2026. Lake level, snowpack and streamflow monitoring will continue for at least 3-4 additional years to assess interannual variability and climate-related trends.

A conceptual figure to demonstrate the primary drivers of seasonal hydrological variability is provided as figure 17. Note that this figure is not to scale.

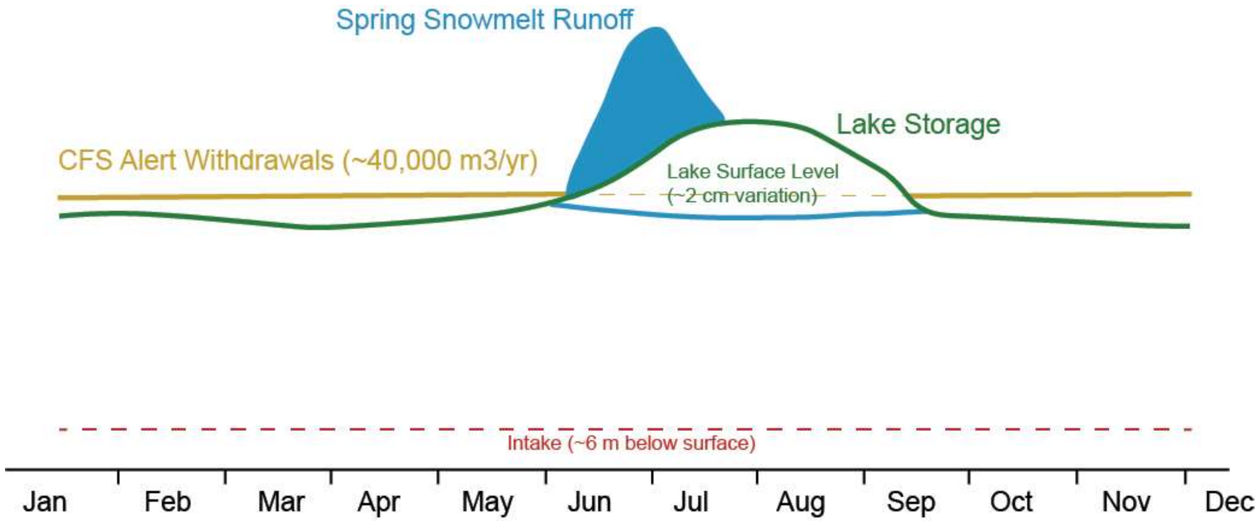

Figure 17: Conceptual rendering of major water inputs, withdrawals and variation of lake level in relation to intake depth. Diagram is not to scale.

Recommendations for Future Work at CFS Alert

Recommendations for work at and in support of CFS Alert for 2026-27 are now well-established. The primary purpose of work in the coming year is to complete all necessary measurements and obtain the data necessary to complete a full, measured water budget for Upper Dumbell Lake. This will avoid uncertainty through assumptions and application of data ranges from other areas of the high arctic. An additional purpose for 2026-27 is to plan, but possibly not yet carry out (time feasibility is limited for 2026) LiDAR-based mapping and characterization of possible contaminated sites at CFS Alert. We also plan to test aerial, drone-based fertilizer applications to contaminated sites at CFS Alert in support of efficient bioremediation at the station. Beyond 2026-27, replication of hydrological measurements is needed for at least an additional 3-4 years to understand effects from inter-annual climatic variability. Additionally, hydrological data will be used in a Climate Change Impact Assessment process to characterize the possible susceptibility of Upper Dumbell Lake's water supply to CFS Alert under future climate change projections for the region. Additional work related to contaminated sites compliance is also anticipated in future years. Overall, hydrological data will also support ongoing assessments of contaminant transport and permafrost-related infrastructure risks at CFS Alert.

Specific 2026-27 Plans

Travel to CFS Alert in mid-May through end of June for snow and snowmelt-specific field work, including:

- Repeat drone-based LiDAR survey of the Upper Dumbell Lake watershed during peak snow cover.
- Conduct large-scale snow density and depth survey across the watershed to enable validation of LiDAR-based snow water equivalent modelling.
- Monitor inlet streams to Upper Dumbell Lake and make multiple streamflow measurements at inlet streams for build-up of rating curves for continuous stream discharge estimation.
- Perform maintenance to other instruments and infrastructure as needed.

Travel to CFS Alert in mid-August through early-September for the primary purpose of completing the bathymetric characterization of Upper Dumbell Lake.

- Conduct bathymetric survey using remote operated vehicle/sonar measurements during ice-off period.
- Retrieve temperature/dissolved oxygen string from Upper Dumbell Lake, download data and re-deploy, if possible.

- Conduct drone flights using LiDAR sensor over known contaminated sites to “train” for spatial and topographic indices that may be used in year 3 for identification of unknown contaminated sites or waste dumps.
- Plan for additional microbial and biogeochemical work to assess function of bioremediation plots.
- Perform maintenance to other instruments and infrastructure as needed.

References

Apollonio, S.; Saros, J.E. 2014. Temporal and spatial dynamics of ice-covered Upper Dumbell Lake (Ellesmere Island, Arctic Canada) during the summer of 1959. *Arctic, Antarctic, and Alpine Research*, 46(2), 293-307.

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