# Summary of Columbia Lake Stewardship Society's 2022 Water Quantity Monitoring Program

Prepared by W. Thompson, M.Sc.

January 2023

## Executive Summary

2022 was the eighth year of operation for the CLSS Water Quantity Monitoring Program.

The year was marked by an above normal snowpack, a cool spring and a hot dry summer. Together they contributed to a runoff pattern that deviated from those experienced in earlier years, resulting in the lake cresting later and at a higher level.

A long-standing problem in examining the local hydrology is the lack of weather information. The source of such information in the past has been the Cranbrook Airport which is 60 km distant and not representative of local conditions, especially precipitation. Over the past few years weather information has been recorded at locations in the Panorama area and the records are now of sufficient duration that a picture of the local climate is beginning to emerge, particularly of snow depth. Using that information, the emphasis this year was on examining the snow cover – runoff relationship.

The snowpack depth at the 2250 metre elevation did not begin to decrease until about May 1, about one month later than usual. By that time, the depth of the snowpack was well above the depths of previous years. Further, owing to the cool spring, it was slow to melt and it was late June before the ground was snow free. Less snow existed at lower levels and melted earlier but did not trigger a significant response in Dutch Creek. The greatest response occurred when the high-level melt began in earnest, suggesting that most of the runoff that fuels lake rise originates from snow stored at elevations of 2250 metres and higher.

Usually, Dutch Creek overflows its banks during the spring runoff with some of the overflow entering the lake causing it to rise. One of the consequences of the unusually large volume of runoff this year was an overflow so large it covered the Dutch Creek delta to the extent that it became an extension of the lake. Such circumstances complicate water balance calculations because incoming and outflowing water volumes cannot be calculated from the available information. Either the volume of water passing beneath the Dutch Creek bridge or a lake surface area – elevation relationship, and preferably both, are required.

Not all the hydrological issues were confined to the runoff period. A cold outbreak during December created an ice jam that blocked the Columbia River, backing water up into the lake and causing it to rise by 20 cm or more.

Due to the effort expended in examining the newfound snow data little progress was made on computing evapotranspiration losses and groundwater gains in the lake that was underway in previous years.

# 1. Introduction

The Columbia Lake Stewardship Society (CLSS) started water quantity monitoring activities in the Columbia Lake Watershed in 2014. This is the eighth in a series of annual reports and summarizes activities conducted during the 2021-22 water year, from November 1, 2021, to October 31, 2022.

The CLSS mission is “to preserve the ecological health and water supply of Columbia Lake for present and future generations …”. Preserving the water supply is a significant task. It requires an understanding of how water enters and leaves the lake. Long-term records reveal that the lake rises an average of about 0.9 metres each year. That rise is important. It maintains the water quality at a healthy level, provides drinking water for residents, irrigates crops, and supports the local tourism industry. It also provides the habitat that sustains wildlife and aquatic species. The demands for water to meet such a variety of needs are growing and are in conflict.

Most of the rise is attributable to overflow from Dutch Creek as the snowpack melts and runs off each spring, but it is not the only factor affecting lake level. Water is also gained from surface runoff, precipitation, and groundwater. These gains are offset by losses to evapotranspiration, consumptive use and outflow. The monitoring program is aimed at determining how these gains and losses influence the water supply and help define a management strategy to accommodate the needs of those placing demands on the local water supply.

# 2. The Watershed

For the convenience of measurement, the outflow point of the Columbia Lake Watershed is often regarded as a point on the Columbia River at the Highway 93/95 crossing near Fairmont Hot Springs. This is a bit of an oversimplification. The area of the drainage area above that point is 881 square kilometres. The bulk, 696 square kilometres, is contained in the Dutch Creek sub-basin.

A delta has formed near the mouth of Dutch Creek. The flow of Dutch Creek over its delta is braided and subject to change. In the present channel configuration, when flow rates are low and unimpeded, the main channel flows directly across the delta to enter the Columbia River, a few tens of metres below the lake outlet. When Dutch Creek is high, the main channel overflows its banks and water spills into Columbia Lake. During this period, the flow in the outlet channel is reversed so that a substantial portion of the overflow enters the lake by this means. The main channel is continually shifting, and at times in the past flowed directly into the lake before reaching the river (see Jamieson, 2011).

Thus, the actual outlet from the lake is not at the Highway crossing but just over three kilometres upstream, except as will be noted during periods of very high water. A series of small creeks enter the Columbia River downstream of the Dutch Creek junction and constitute about nine square kilometres of the entire 881 square kilometre area. The area above the lake outlet is 176 square kilometres. The boundaries of the watershed are shown in the inset of Figure 1.

The overall watershed contains one active glacier[1]. There are no significant control structures though minor structures impound or divert water on inflowing creeks on the west side of the lake.


Figure 1 – Map showing station locations. Entire watershed boundary is shown in inset. Site abbreviations are provided in Section 4.1.

# 3. Antecedent and Concurrent Conditions

There are no weather stations within the entire watershed having a continuous long-term climatological record. The closest station is the Cranbrook Weather Station (Cranbrook A) located at the Cranbrook - Kimberley Airport, some 60 km south of Canal Flats.

[1] This contradicts earlier reports in this series in which it was stated that no glaciers exist. Mapping conducted during the past year revealed a glacier straddling the western boundary of the Dutch Creek watershed.

The mean monthly temperatures at that location for the 2021-22 water year (November 1, 2021 – October 31, 2022) are shown in Figure 2. The corresponding long-term normal values based on records accumulated over the 30-year period 1980-2010 are superimposed for comparison. Three departures from normal stand out – a warm fall, a cool spring, and a warm summer. Of these the cool spring was the most significant because, as will be shown, it delayed snow melt, runoff, and lake rise.

In previous reports, Cranbrook A was used as the precipitation reference. A base of good quality local precipitation data, some from elevated locations, is gradually being accumulated from stations in the Panorama area. This report will mark a shift away from using the Cranbrook A data toward the local data. During the ski season, snow depth is recorded at three elevations on the ski hill at Panorama Mountain Resort (Summit at elevation 2350 m asl, Mid Mountain at 2018 m, and Village at 1185 m). Snow depth is also measured year-round at the nearby Little Dragon avalanche monitoring station (2250 m) and at Toby Creek (1180 m), both operated under the BC Ministry of Transport and Infrastructure's Avalanche and Weather Program. All are just outside the watershed (see Appendix B) but are deemed sufficiently close to represent the amount of water held in the local mountain snowpack. Snow depth continues to be measured at the weather station on the Fairmont Hot Springs Resort Limited's ski hill (1485 m) installed in 2016 under the Cold Spring Creek Debris Flow Mitigation program.

The Little Dragon station was installed in the fall of 2017 so that four seasons of measurements exist with which to compare the 2021-22 snow season. The comparison is displayed in Figure 3. In general, snow accumulated during the 2021-22 season at or slightly above the rates of previous years, but the significant departure is from April 1 onward. April 1 is usually the date when melt overcomes accumulation and runoff gets underway. While the snow depths during the earlier years generally conformed with this tendency, those of 2022 did not. Melt did not get underway until early May and not in earnest until May 20, much later than in the earlier years. It was not until June 20 before the ground was snow free, about three weeks later than the norm of the previous years. The delay is attributed to the cold spring.

Figure 4 provides insight into the distribution of snow by elevation. As might be expected, snow depths were greater, and the snowpack remained for a longer period at higher elevations than at lower elevations. At the lowest level stations, melt had finished by the end of April, almost two months before the snow had left the Little Dragon site.

The base of local summer precipitation is also expanding. The Timber Springs weather station continued to operate during 2022, bringing the number of years of operation to nine. Rainfall amounts recorded during the 2022 April-October period are compared in Figure 5 with the corresponding average over the period, 2013 to 2021, inclusive. 2022 was dry, with only about seventy percent of the seven-year average recorded. There were only two significant rainfall events, one on June 13 and the second on August 27. Rainfall amounts at the Fairmont Ski Hill and at the newly installed Spur Lake location are also shown. The amounts at both locations were greater than those recorded at the Timber Springs location.

# 4. 2022 Activities

## 4.1. Stations

All water level monitoring stations in operation during the 2021 season remained in operation. The stations were: Columere Marina (Col), Headwaters Park near Canal Flats (CF), Columbia River near Fairmont Hot Springs (WSC), Dutch Creek at the Highway 93/95 Bridge (DC), Lansdowne Creek, Columbia Lake south (ColLkS), and (Outlet) located near the lake outlet. The locations are shown in Figure 1. DC, Outlet and ColLkS only operated during the open water season. Lake level is recorded at both the Col and ColLkS stations.

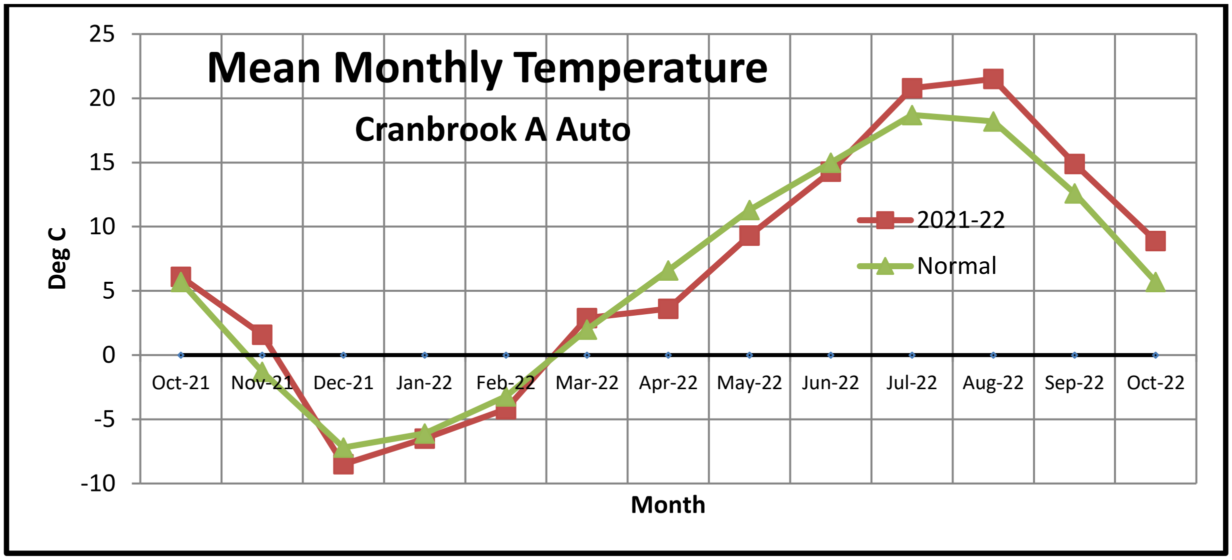


Figure 2 – Mean monthly temperatures at the Cranbrook- Kimberley Airport during the 2021-22 water year and the corresponding 1980-2010 long-term normal values.

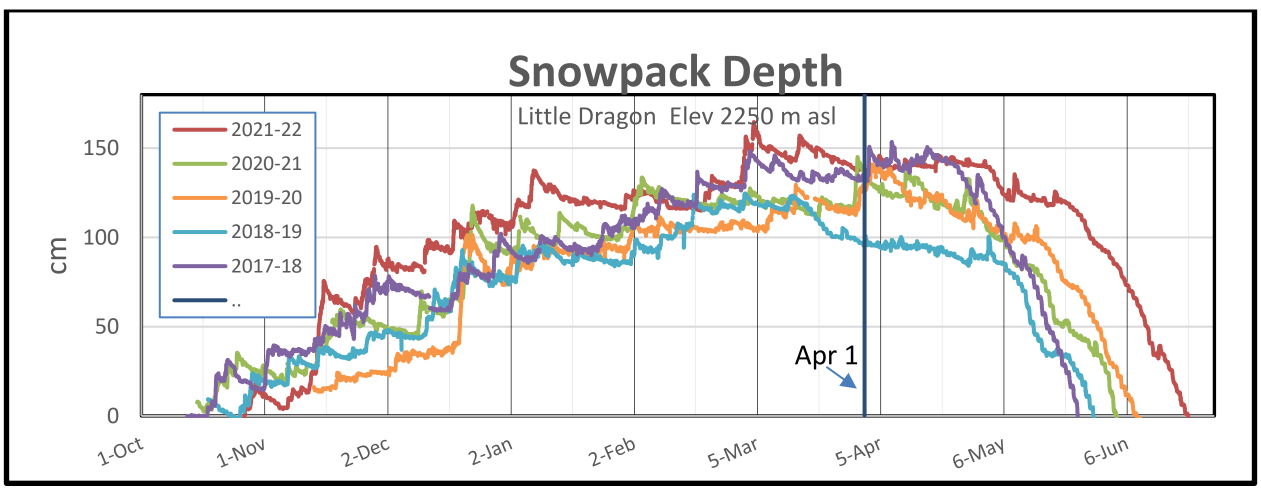


Figure 3 – Snow Depths recorded at the Ministry of Transportation and Infrastructure's Little Dragon Snow weather station located near Panorama at an elevation of 2250 metres asl.

The Timber Springs weather station also remained in operation and recorded wind speed and direction, temperature, relative humidity and precipitation at hourly intervals.

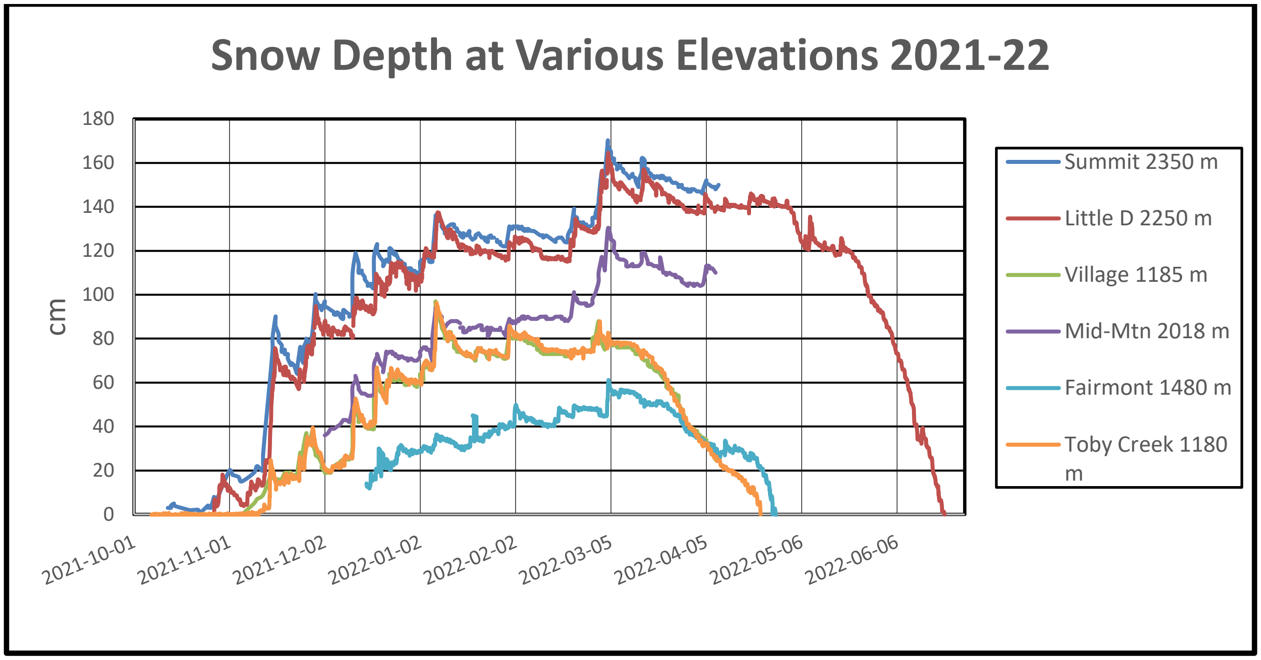


Figure 4 – Snow Depths recorded at stations of varying elevations near Panorama and the Fairmont Ski Hill.

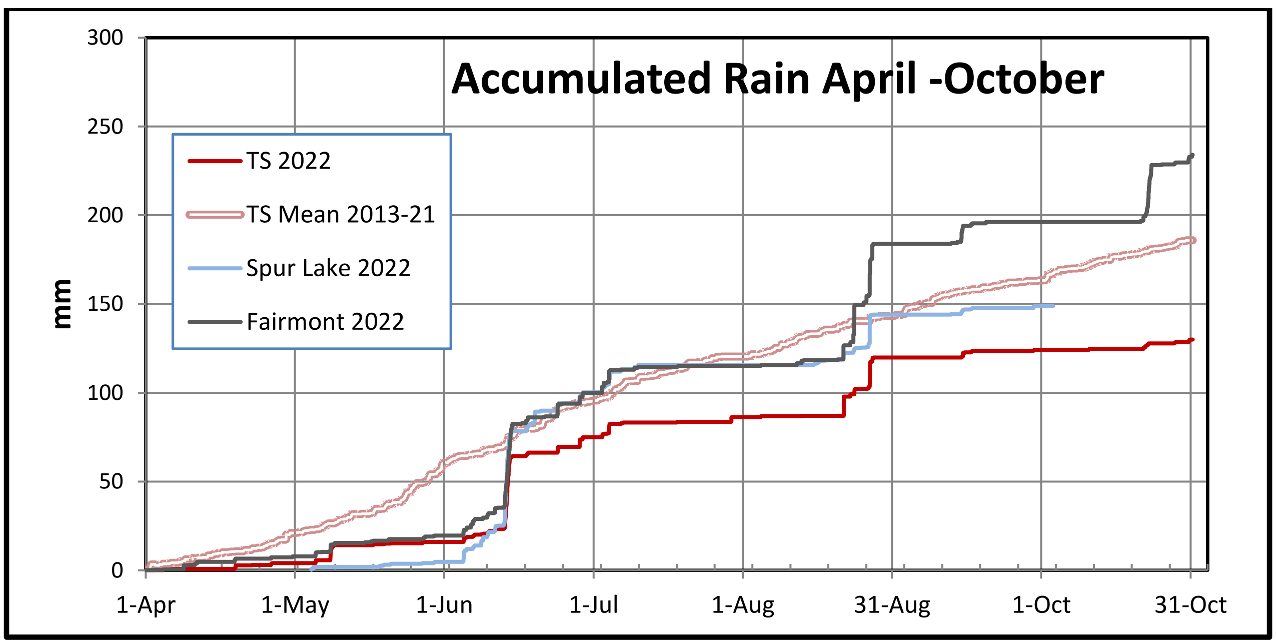


Figure 5 – Accumulated precipitation measured at the Timber Springs and Fairmont Ski Hill weather stations and at Spur Lake during 2022. The 2013 – 2021 period average at Timber Springs is superimposed. The Spur Lake rain gauge was not activated until May 5.

## 4.2. Equipment Purchases

Two HOBO tipping bucket rain gauges were purchased during the season.

As the season neared an end, discussions were underway with Living Lakes Canada to share the cost of an upgrade to the lake level monitoring station (Col). The proposed upgrade would entail installing a stilling well and intake pipe to provide a more permanent reference for establishing water depths. Under the present arrangement, the reference is subject to movement and considerable time and effort is required to correct for that movement. The means of data collection and management will also change. Data will be distributed via a cellular network to the internet, where it will be available to anyone with an internet connection. A substantial decrease in data management activities is expected.

## 4.3. Data Collection and Management Issues

Both tipping bucket rain gauges were deployed. One was installed near the Canal Flats water level monitoring station on April 5 and the second near Spur Lake on May 5.

The funnel on the Canal Flats gauge was found detached on two occasions so that its record was incomplete. The Spur Lake site is at an elevation of 1175 metres above sea level and is intended to examine rainfall on mountain slopes. The access road to this site is not well maintained and access will likely be limited to the May to October period.

Additional flow measurements were conducted on the Columbia River during high water to help improve the accuracy of the WSC rating curve.

The weather station at the Fairmont Hot Springs Airport was closed early in the season, resulting in the loss of a local barometer required to evaluate logger performance. As an interim measure, one of the loggers was designated as a reference and taken to Calgary, where its performance was evaluated against a barometer in an Environment and Climate Change Canada office. The remaining loggers were evaluated against that logger. A search is underway to find an alternate local precision barometer.

One logger failed during the season but the rest performed adequately though some continued to exhibit drift. Corrections for drift are made via software during the processing of the data.

Each summer, the Columbia Basin Watershed Network (now part of Living Lakes Canada) works in partnership with Selkirk Geospatial Research Centre at Selkirk College to support watershed groups. The CLSS was fortunate to obtain the services of intern Chenoa McLean from the College to map various physical characteristics in the combined Columbia Lake/Dutch Creek watershed. In time, the information contained therein will be used in attempts to simulate flow from mountain streams.

## 4.4. Sensor Accuracy

The performance of the loggers is routinely checked. The steps involved and corrective measures that were applied are outlined in Appendix A.

# 5. Water Temperature and Level

## 5.1. Winter 2021-22

The winter water temperature and water level recorded at the primary stations (Col, DC and WSC) are shown in Figures 6 and 7, respectively. The logger at the Dutch Creek station only operates during part of the winter season due to ice build-up on the river. It was removed on December 5, 2021, when ice began to appear and was re-installed on March 8, 2022.

The mean daily air temperature recorded at Timber Springs is superimposed in Figure 6 for reference. The significant event was a rapid drop in temperature during the first week of December. A blockage in flow, likely due to an ice jam, on the Columbia River followed. Water backed up to flood parts of the Dutch Creek delta and ultimately the lake where water levels rose over 20 cm during the following three weeks. At the outset, Dutch Creek remained largely open, and the water temperature was near zero. Those, combined with the fast flow, provide the ingredients for the creation of frazil ice, a precursor for the formation of ice jams. More intense cold periods followed later in the winter, but by then, most streams were ice covered.

The flow at WSC abruptly dropped to zero at the start of the blockage and remained low until January 4. It is likely that the intake pipe froze following the drop and recorded values during that period do not reflect actual conditions.

## 5.2 Open Water Season 2022

### 5.2.1 Water Temperature

The water temperatures recorded during the open water season at the primary stations are shown in Figure 8. Outlet temperatures are superimposed and, as has been observed in previous years, are an indicator of the direction of water movement at the lake outlet. Cool water temperatures persisted until mid-June indicating the passage of cold water from Dutch Creek into the lake. Over the following five weeks, a transition took place during which the water temperature increased to near that of the lake, indicating flow reversal and warm water flowing out of the lake. The transition period was later this year than in previous years.

Mean daily air temperatures recorded at Timber Springs are superimposed for reference.

### 5.2.2 Water Level

The recorded water levels are shown in Figure 9. The levels represent the depth of water above a local reference and bear no relationship to any known elevation standard.

The lake reached its highest level on July 4 when it reached an elevation of nearly 120 cm above its mid-April low. Dutch Creek peaked June 23, eleven days earlier. A delay of this length is a bit unusual considering that Dutch Creek is the main source of inflow. However, intermittent rain events during this period likely made up for the decreased water supply from Dutch Creek.

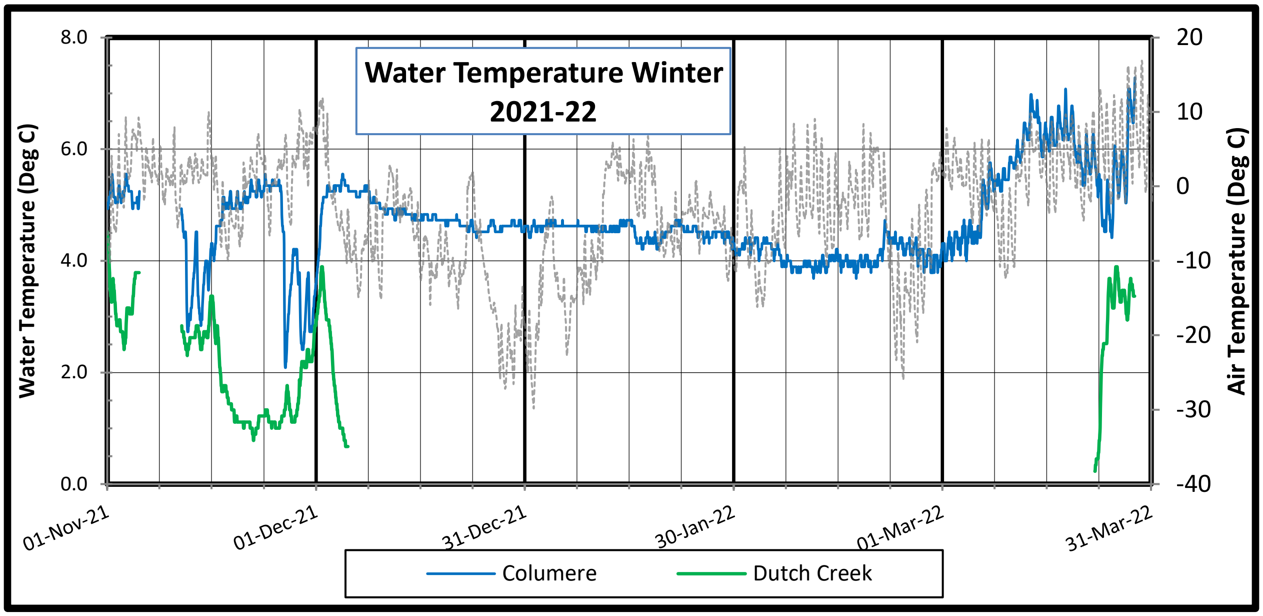

Figure 6 – Winter water temperatures. The logger at Dutch Creek is removed during the winter to prevent ice damage. Air temperatures recorded at Timber Springs are superimposed.

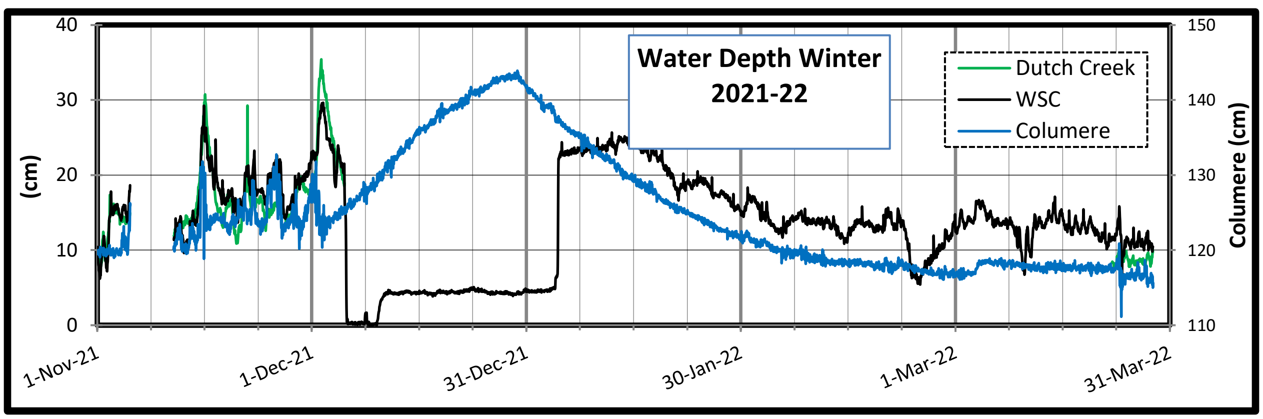

Figure 7 – Winter water depths recorded by loggers. A blockage on the Columbia River is believed to have formed on December 5, backing water up into the lake. The intake at the WSC site is exposed at low water levels and is likely to have frozen following a drop in water level at that time and remained frozen until January 4. The record during that period does not reflect the actual conditions. The logger on Dutch Creek was removed on December 5 and not returned to service until March 22.

There were also other factors that will complicate attempts to establish lake water balance. The 2022 water levels recorded on Columbia Lake are compared with the corresponding average levels over the seven-year period 2014 to 2020 and to the water levels of 2021 in Figure 10. Three issues standout. One is that the rise of the water level trailed its counterparts by nearly two weeks. A second is that the crest level was well above that of previous years, including 2021, a high-water year. The third is that the period of high water extended over a longer period than in previous years. These had on-the-ground consequences. Visual observations during this period indicated that much of the Dutch Creek delta was under water and that the elevation of the floodwater reached the elevation of the lake. In effect, the flood water became a northward extension of the lake.

### 5.2.3 Rating Curves

Three new flow measurements were made on the Columbia River at the WSC site in an attempt to refine the accuracy of the WSC rating curve. While helpful, improvement is still required. Part of the problem is errors in depth measurements caused by the drift of the current meter in fast flowing, high water. Discussion with Jonathan Jeffrey of BC MOE led to the suggestion that attaching markers to the suspension line might help improve the accuracy of the depth measurements. That will be tried next season.

# 6. Local Water Exchanges

Owing to the focus on snowmelt, no progress was made in attempting to refine the lake water balance.

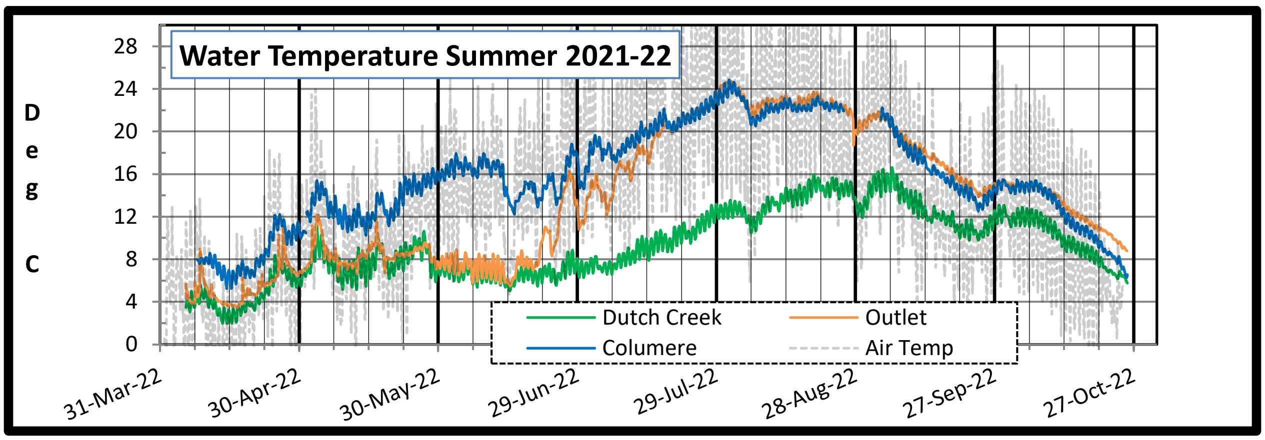


Figure 8 – Water temperatures. Air temperature at Timber Springs superimposed.

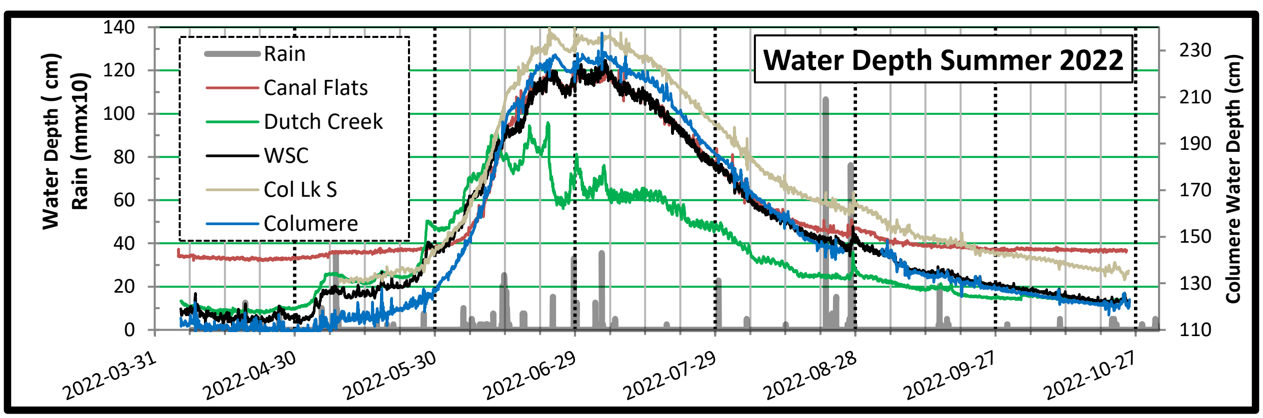


Figure 9 – Hourly water depths in cm. Depths are as recorded by loggers and do not relate to a common reference level. Rainfall amounts are in tenths of millimetres.

# 7.0 Discussion

The examination of the snow data conducted here indicates that snow depth, especially at high elevations, has the potential to be a useful predictor of the timing and volume of runoff and ultimately lake level. More work will be required to develop useful relationships. The work should first focus on relating the rise in water level in Dutch Creek to the decline of the mountain snowpack, and following that, linking the lake water level to the level of Dutch Creek.

The second task is complicated due to the accumulation of water on the Dutch Creek delta. The volume of that water must be known, and it cannot be calculated from existing information. A lake surface elevation – surface area relationship or an improved rating curve for Dutch Creek is required, preferably both

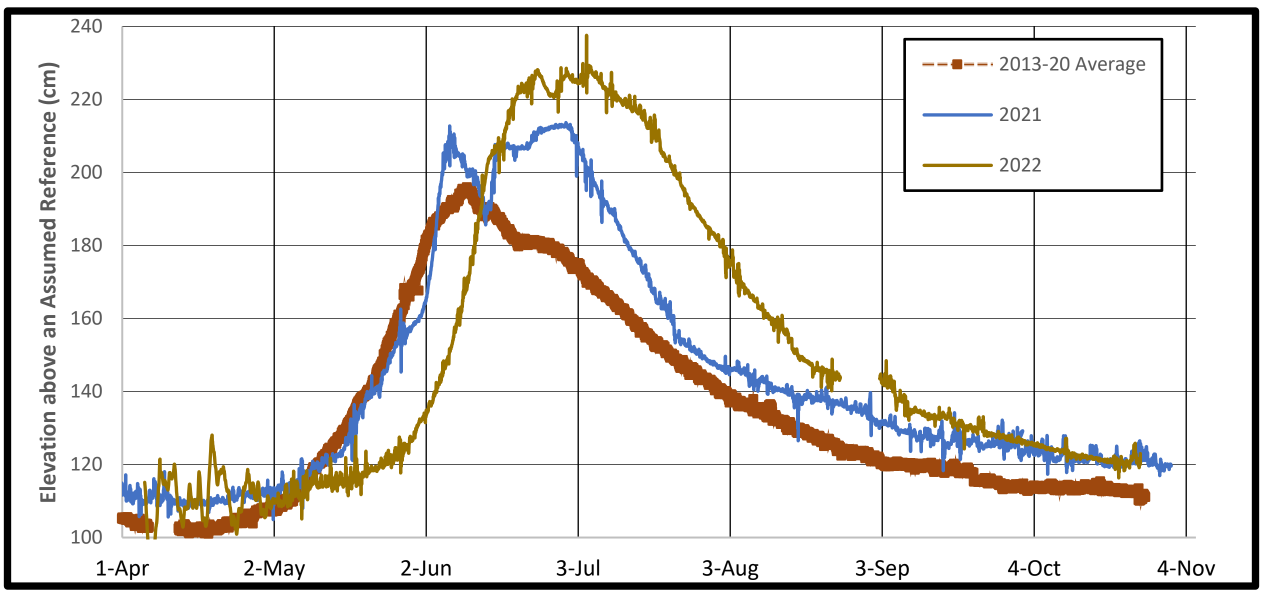


Figure 10 – 2022 water levels compared to the 2014 to 2021 average and 2021 water levels. Levels are above an arbitrarily selected reference.

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# 8. Acknowledgements

Lucas Fuertes, a UBC student, played a key role in collecting and tabulating field data. Leah Downey, CLSS Program Coordinator, continued to find time from her administrative activities to assist with flow measurements. Special thanks to Andrew Nelson of Panorama Mountain Resort for describing the monitoring procedures conducted in the vicinity of Panorama and for the backlog of data collected at the Resort. Thanks also to Jonathan Jeffrey from the BC Ministry of Environment for helpful information on measuring stream velocity and data archival. Tom Symington and Caily Craig are thanked for reviewing this document.

The support of the following organizations, communities, and individuals is gratefully acknowledged:

BC Ministry of Transport and Infrastructure
BC Hydro
Environment and Climate Change Canada
Columbia Valley Local Conservation Fund
Regional District of East Kootenay
Lake Windermere Ambassadors
Living Lakes Canada
Columere Marina
Fairmont Hot Springs Resort Ltd.
Village of Canal Flats
Columbia Ridge Community Association
Columere Park Community Association

Spirits Reach Strata
BC Lake Stewardship Society
Nature Conservancy of Canada
Fairmont Creek Debris Flow Mitigation Project
All donors whose contribution made the purchase of monitoring equipment possible.

# Appendix A

## Accuracy of Measurements

The integrity of an analysis depends on accurate measurements. The following describes the steps taken to evaluate equipment performance and to minimize error.

## A1 -Water Level

Water information is collected using data loggers. The loggers measure pressure and temperature and record them in internal memory. The loggers are programmed to record every hour on the hour. Loggers from two different manufacturers, Van Essen (Diver) and Onset (HOBO), are in use.

All loggers are non-vented. This means that the sensor measures the pressure exerted by the column of water above the logger plus that of the atmosphere. The atmospheric pressure must be removed to obtain the pressure exerted by the water alone. Once removed, water depth can be calculated from the water pressure. Atmospheric pressure is measured using a separate logger (HOBO logger 325) mounted at the WSC site at an elevation of 809 metres asl. Most stations are located at lake level (808.5 metres asl), therefore an elevation adjustment is not required. Exceptions are the Dutch Creek station, which is twenty-four metres above lake level, and the Lansdowne station, roughly forty metres above lake level.

Logger H325 also served as the standard for evaluating the performance of all other loggers. In the past, its accuracy was evaluated against the barometer mounted at the Fairmont Hot Springs Airport (CYCZ). The Airport's management changed hands during the year, and the new managers elected to discontinue its operation. As an interim measure, H325 was taken to Calgary in August and evaluated against an Environment Climate and Change barometer (see Figure A1).

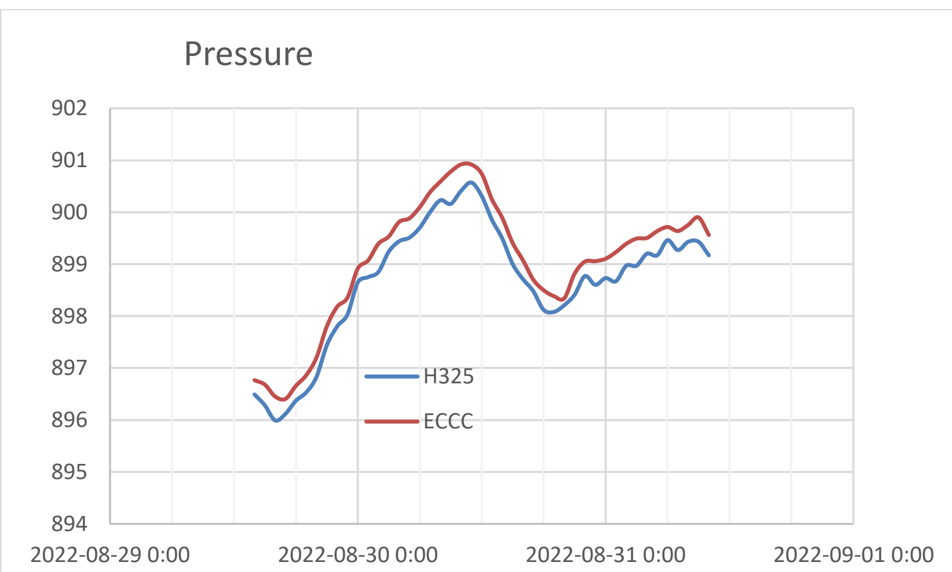


Figure A1 – Deviation of atmospheric pressure measured by logger H325 from Environment Canada Climate Change barometer. Deviation was 0.4 hPa (ECCC-H325)

All loggers are taken out of service twice during the year, at the beginning and at the end of the open water season and collocated with H325 for a period of a few days. The pressures recorded during those periods are shown in Figures A2 and A3. The pressure sensors were not all in agreement thereby indicating a need for an offset adjustment. The mean offsets from H325 were calculated and are shown in Table A1. The offsets were applied to the six-month period following the comparison tests.

No correction was made for the effects of temperature on water density.

The locations at which the loggers were deployed are shown in Table A2.

## A2- Water Temperature

Beginning and end-of-season comparisons of the temperature sensors were made in a similar fashion. The records are displayed in Figures A3 and A4, respectively. The exposure of the loggers to sunlight was uneven during both trials causing some to record slightly warmer temperatures than others. Otherwise, good agreement is shown.

## A3- Other

Other steps were taken to ensure the integrity of the data. Manual measurements of water level were taken at each location periodically during the season to verify the accuracy of the recorded pressure measurements. The stilling wells and intake pipes at each of the stream sites were periodically back flushed.

The current meter was calibrated by the manufacturer prior to purchase and has not been further calibrated.

Table A1 – Measured Offsets from H325 during Comparison trials

| Nov-21 | | | Mar-22 | | | Oct-221 | | |
|---|---|---|---|---|---|---|---|---|
| **Logger** | **cm H2O** | **Diff fm H325** | **Logger** | **cm H2O** | **Diff fm H325** | **Logger** | **cm H2O** | **Diff fm H325** |
| *H325* | *934.4* | *0* | H325 | 932.2 | 0 | H325 | 932.8 | 0 |
| 1459 | 940.9 | 6.5 | 1459 | 938.9 | 6.7 | 1459 | 941.7 | 8.9 |
| 1366 | 930.7 | -3.7 | 1366 | 928.8 | -3.4 | 1366 | 928.9 | -3.9 |
| BARO | 933.3 | -1.1 | BARO | 30.7 | -1.5 | BARO | 928.7 | -4.1 |
| U5972[1] | | | 5972 | U/S | | 5972 | U/S | |
| AV083 | 934.8 | 0.4 | AV083 | 932.6 | 0.4 | AV083 | 933.3 | 0.5 |
| H012 | 935.4 | 1.0 | H012 | 932.8 | 0.6 | H012 | 933.5 | 0.7 |
| H013 | 935.8 | 1.4 | H013 | 933.6 | 1.4 | H013 | 934.7 | 1.9 |
| H326 | 934.4 | 0.0 | H326 | 932.6 | 0.4 | H326 | 932 | -0.8 |
| H109 | 930.4 | -4.0 | H109 | 927.1 | -5.1 | H109 | 925.5 | -4.4 |
| H691 | 934.9 | 0.5 | H691 | 933 | 0.8 | H691 | 935.8 | 3 |

[1] U5972 not removed due to ice

Table A2 – Logger Deployment During 2021-2022 Water Year

| | |
|---|---|
| U5972 | Outlet – Backup – Nov to Dec 13, 2021, and then failed |
| 1459 | WSC – backup Nov 2, 2021, to Oct 25, 2022 |
| 1366 | Outlet Nov to Dec 13, Jan 15 to Oct 25 |
| BARO (1601) | Jan 15 to Mar 28 – Outlet backup<br>Col – backup – Apr 5 to May 7, Oct 2 to 25<br>May 7 to Oct 2 – clock stopped, no record |
| H109 | Lansdowne -Nov to Oct |
| H326 | Columere – Lake Level – Nov 2021 to Oct 25, 2022 |
| H325 | WSC – Atmospheric Pressure sensor – Nov, 2021 to Oct 25, 2022 |
| H012 | WSC – Nov 2021 to Oct 25, 2022, |
| H013 | DC – Nov 2 – Nov 9<br>Out of service – Nov 9 – Mar 29<br>DC – Mar 29 – Oct 31 |
| H691 | CF – Atmospheric Pressure – Nov 13 to Mar 28<br>Columbia Lake South – Apr 5 to Oct 25 |
| AV083 | CF – Nov 2, 2021, to Oct 25, 2022 |

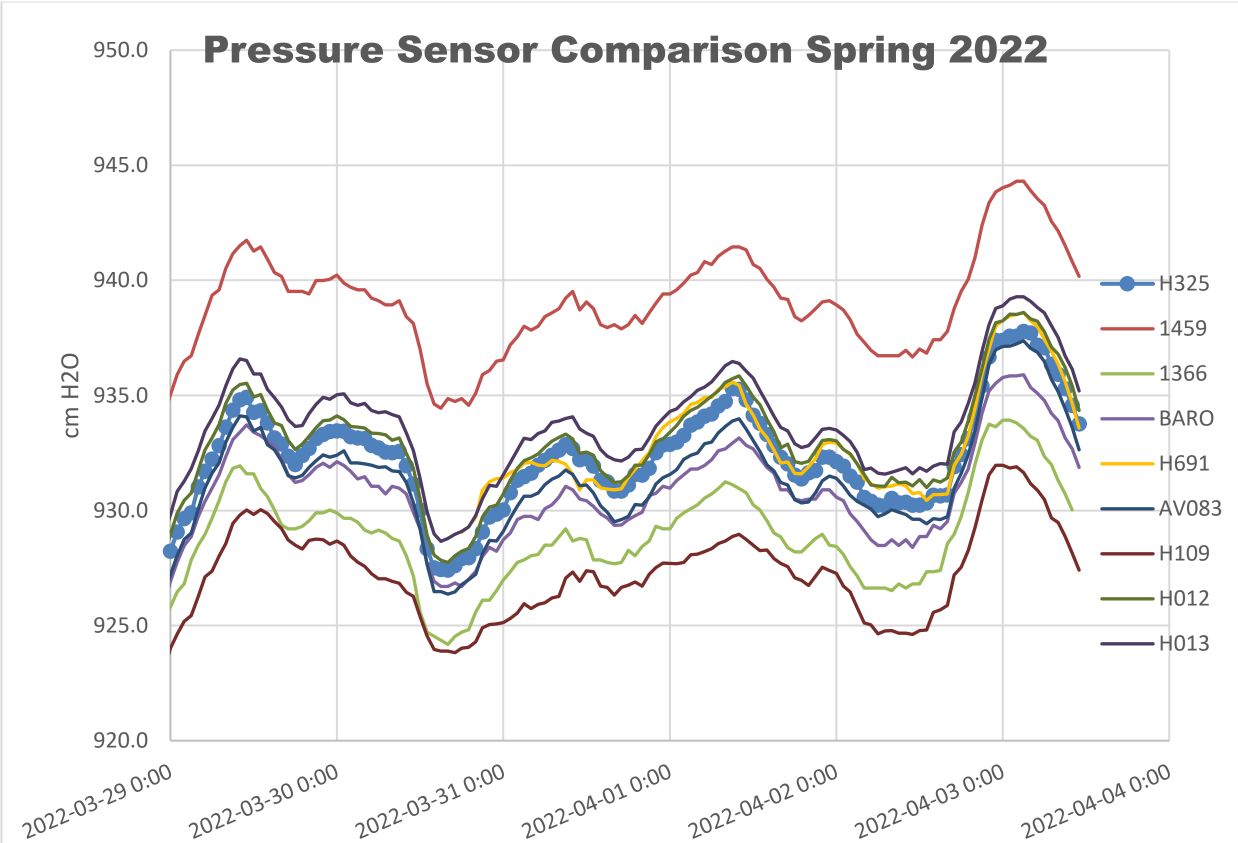


Figure A2 – Pressure readings from all loggers in relation to H325 at mid-water year.

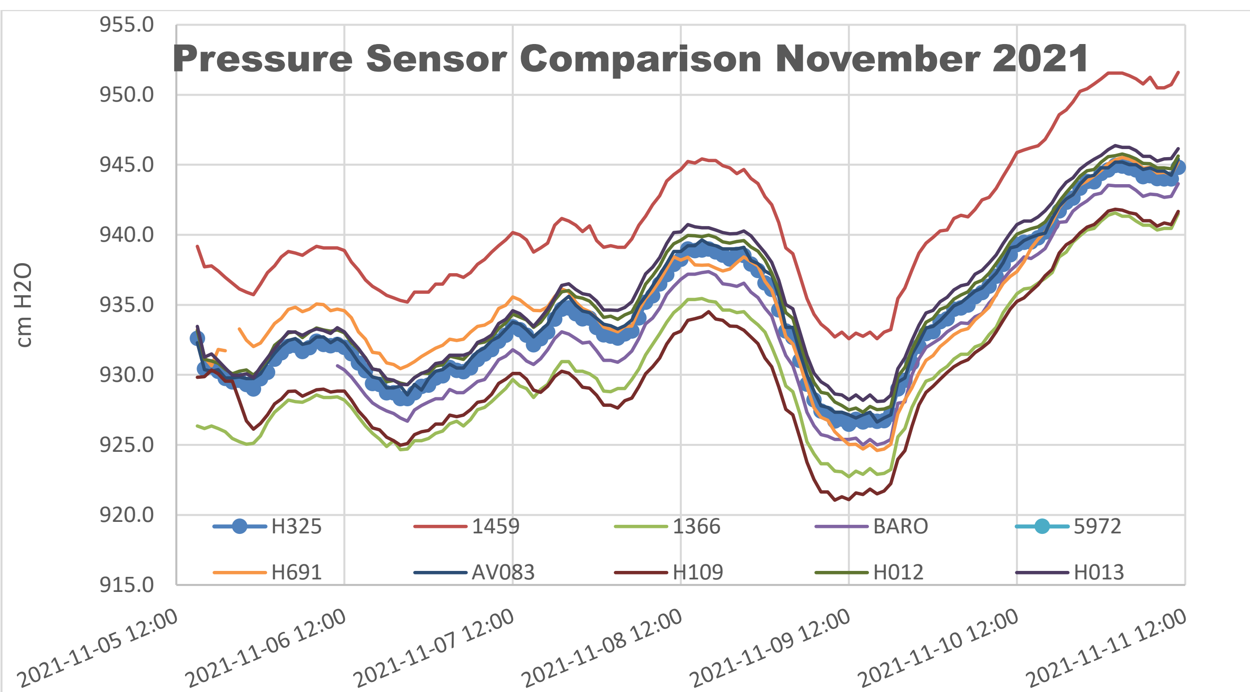


Figure A3 – Pressure readings from all loggers in relation to H325 at end of water year.

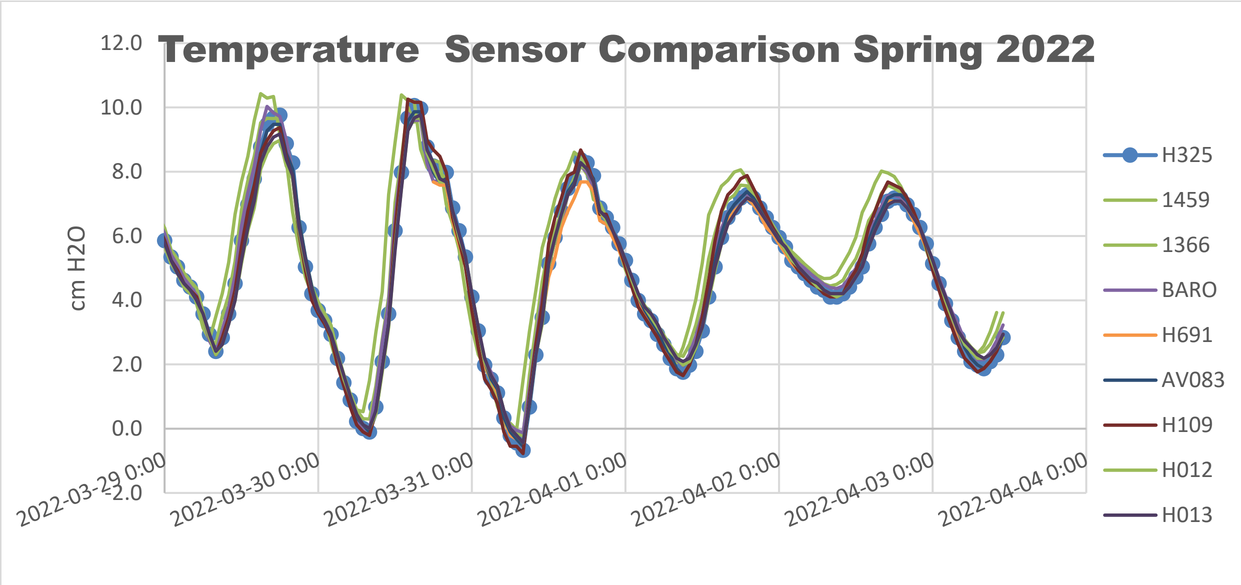


Figure A4 – Temperature readings in relation to H325 at mid water year.

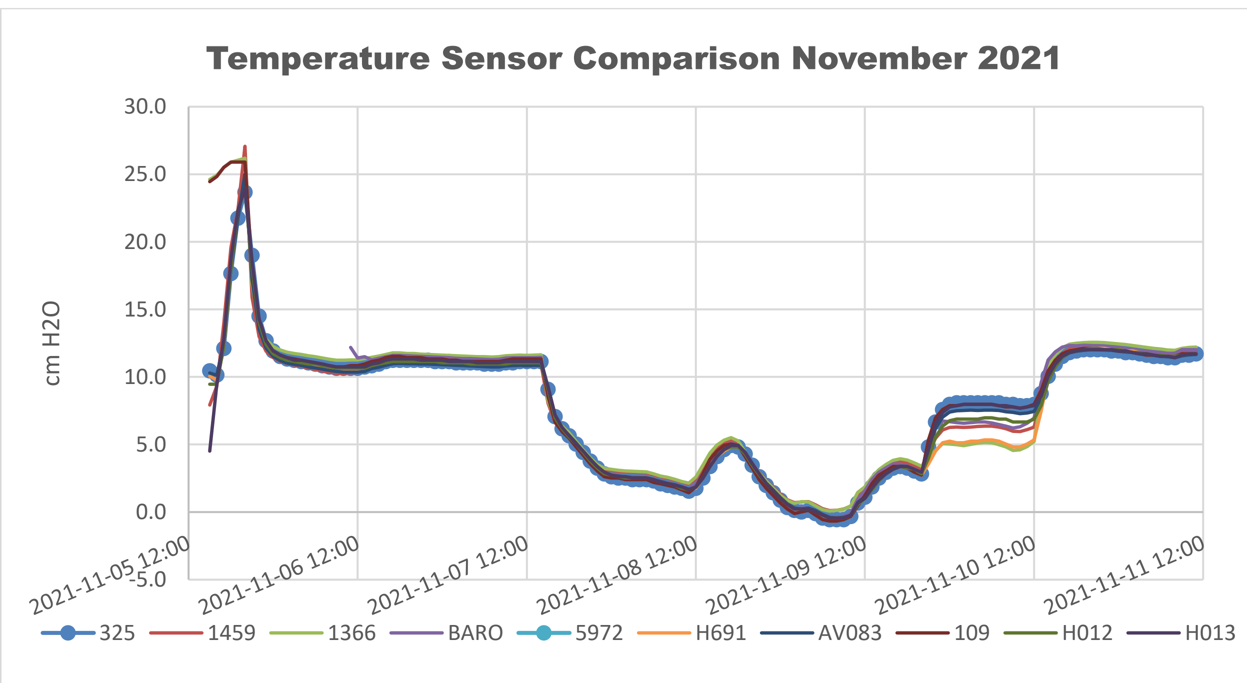


Figure A5 – Temperature readings in relation to H325 at the end of the water year.

# APPENDIX B