Summary of Columbia Lake Stewardship Society's 2019 Water Quantity Monitoring Program

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February 2020

Executive Summary

The Columbia Lake Stewardship Society has been monitoring water levels on Columbia Lake and surrounding waters since 2014. The data collected to date have shown that the annual rise in lake level is due to water entering the lake from Dutch Creek during the spring runoff. That was a significant finding but it only provided an overview of lake behavior. Exchanges are taking place within the lake itself that need to be considered to fully understand behaviour. On the one hand, the lake gains water from precipitation, local streams and groundwater including subsurface transfer from the nearby Kootenay River. On the other, the lake loses water to evapotranspiration and consumptive use. Our current emphasis is on determining the relative contribution of these parameters to the overall lake water balance. Such information is required to efficiently manage the water resource. All these parameters are difficult to measure.

Work undertaken in 2019 focused on isolating the groundwater contribution. The approach taken assumed that losses due to evapotranspiration and consumptive use during winter are negligible. Thus, the outflow is balanced by the only source of inflow, namely groundwater, and by measuring outflow an upper limit on the groundwater contribution could be established. Accordingly, a gauging station was installed at the lake outlet in August. By late October the net outflow had dropped to 1.6 cubic metres per second, an unexpectedly low flow rate.

Such a low flow rate has two implications. One is that there is not an unlimited supply of water to meet future demands. Another involves the amount of water entering the lake from the Kootenay River via the aquifer beneath Canal Flats. The preliminary data presented here now suggests an upper limit for that inflow. The flow through the aquifer is part of the overall groundwater contribution. It cannot exceed the 1.6 cubic metres per second measurement. Since that rate is governed by the hydraulic head existing between the Kootenay River and the lake, and since that head remains nearly constant year-round (see Gillmor 2018) the rate will be the same year-round.

The 2018-19 water year was a bit different than previous years. February was unusually cold. March was drier than normal with the result that the high elevation snowpack was below normal. In the local area. The spring was one of the driest in the past six years. The situation reversed in late June when a series of rain events caused the remainder of the summer to be the wettest. The lake peaked June 3 at a level about 80 cm above its normal spring base level and about 10 cm below the long-term average.

1. Introduction

The Columbia Lake Stewardship Society (CLSS) started water quantity monitoring activities in the Columbia Lake Watershed in 2014. This is the sixth in a series of annual reports summarizing those activities.

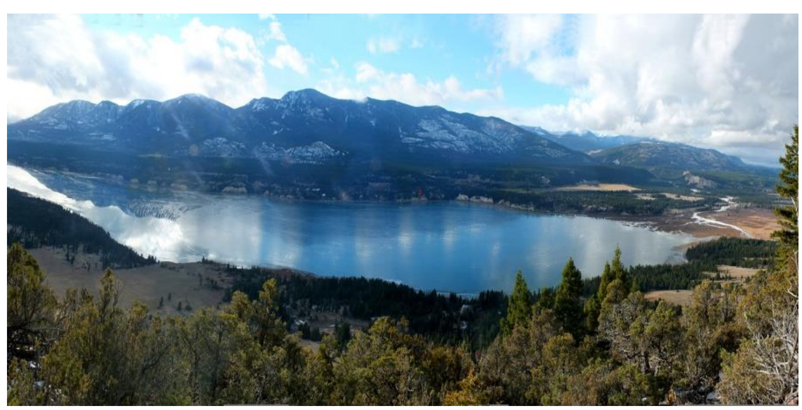
From the outset the purpose has been to examine the water balance by examining the quantity of water entering and leaving the lake. Long-term records reveal that the lake rises an average of 0.9 metres each year. Work undertaken in previous years has shown that most of that water comes from Dutch Creek during the spring runoff. That water is important. It maintains the water quality at a healthy level, it provides drinking water for local 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 these needs are growing and are in conflict. Water quantity monitoring plays a vital role in defining a strategy that will accommodate the demands of all users.

Measurement of the inflowing and outflowing water is complicated by the presence of the Dutch Creek delta to the north of the lake. Water is known to enter and leave the lake from the delta at several locations not all of which can be monitored. The approach to date has been to measure the inflow upstream and the outflow downstream of the delta. The difference is assumed to have entered the lake. While this accounts for an understanding of the rise and fall of lake level, there are other factors taking place within the lake that must be understood to gauge its health. Water also enters the lake from local streams, precipitation and groundwater including subsurface transport from the nearby Kootenay River. These gains are offset by losses due to evapotranspiration, consumptive use and outflow. The current emphasis is aimed at quantifying these gains and losses. All parameters are difficult to measure.

Data collection and management is an important aspect of monitoring and considerable effort has been expended to ensure that the collected data are accurate.

2. The Watershed

For convenience of measurement, the outflow point of the Columbia Lake Watershed has been and will continue to be on the Columbia River at the Highway 93/95 crossing near Fairmont Hot Springs. The area above that point is 881 square kilometres. The bulk, 696 square kilometres, is contained in the Dutch Creek sub-basin. The boundaries of the watershed are shown in the inset of Figure 1.



The actual outlet from the lake is not at the Highway crossing but a few hundred metres upstream. A series of small creeks enter the Columbia River between the two points and constitute about 9 square kilometres of the entire 881 square kilometre area. Also, the flow of Dutch Creek over its delta is subject to change. In the present channel configuration and when flow rates are low, water flows across the delta to directly enter Columbia River. That hasn't always been the case. The main channel is continually shifting and at times in the past directly entered the lake before reaching the river (see Jamieson, 2011).

The watershed contains no active glaciers and, except for a rudimentary weir made up of widely spaced boulders placed in the Columbia River upstream of the Fairmont Bridge, is uncontrolled.

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 watershed having continuous long-term records. The closest such station is the Cranbrook Weather Station (Cranbrook A) located at the Cranbrook - Kimberley Airport, some 60 km south of Canal Flats.

The mean monthly temperatures at that location for the 2018-19 water year (November 1, 2018 – October 31, 2019) are shown in Figure 2. The corresponding long-term normal values based on records accumulated over the 30-year period 1980-2010 are shown for comparison. A similar comparison is made for total precipitation in Figure 3.

The fall and early winter were warmer than normal but a very cold period set in during February and temperatures didn’t return to normal until late March. They then remained near normal until late in the season. Precipitation amounts fluctuated about normal values until February. Very little precipitation fell during March. April and May also tended to be dry but the rest of the season apart from August was abnormally wet.

The low precipitation amounts during March are reflected in the *Snow Survey and Water Supply Bulletin* compiled by the River Forecast Centre (2019). By April 1 when the snowpack is near peak, only 77 percent of the normal amount of snow in the East Kootenays had accumulated.

Snow depths measured at the Fairmont Hot Springs Resort Ltd Ski Hill weather station (see Figure 1 for location) are shown in Figure 4. The station is within range of snow making equipment so it may not accurately represent the actual accumulation. However, the period of melt is believed to be accurately represented. Melt began in mid-March and was complete by mid-April. At 1480 m above sea level, the station is nearly 680 m above lake level and indicates that much the area draining directly into the lake was snow free by mid-April.

The accumulated precipitation recorded during the April-October period at the Timber Springs location is shown in Figure 5 along with the corresponding amounts for each of the previous five years for comparison. The 2019 season started out dry and by June 21 the accumulated precipitation was the least recorded of the five years. A series of rainfall events over the following few days reversed the situation so that by July 9 the season had turned into one of the wettest of the five years.

In summary, the information from all sources is consistent in pointing to a low snowpack followed by a dry spring and then an abnormally heavy rainfall as summer commenced.

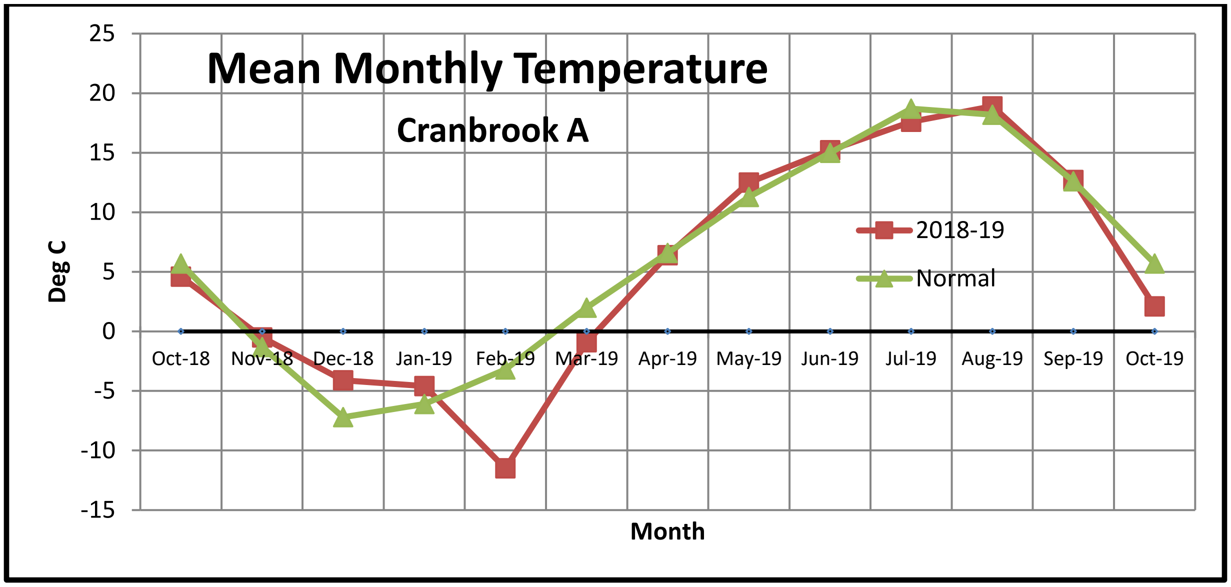


Figure 2 – Comparison of mean monthly temperatures at the Cranbrook- Kimberley Airport during the 2017-18 water year and the 1980-2010 long-term normal values.

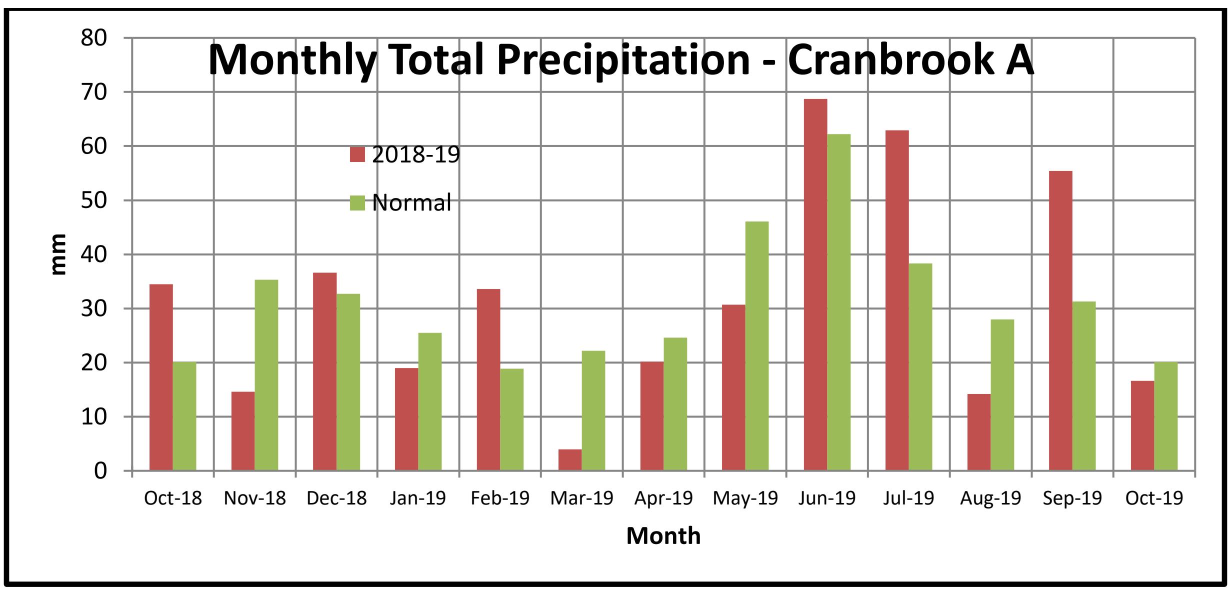


Figure 3 – As in Figure 2 except showing precipitation totals.

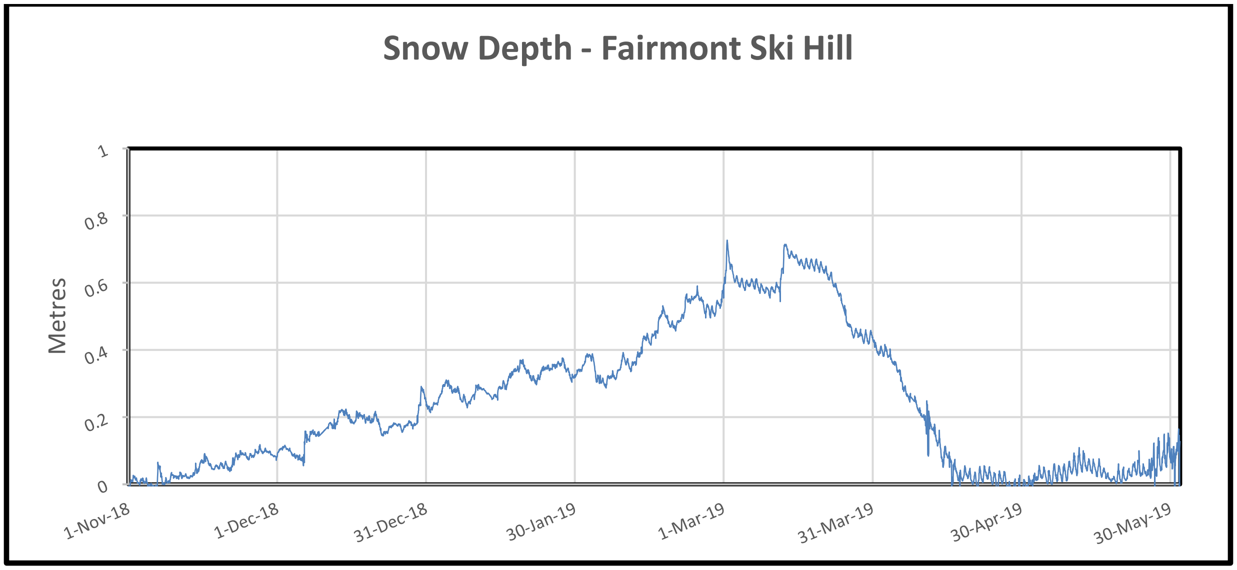


Figure 4 – Snow Depths recorded at the Fairmont Ski Hill weather station.

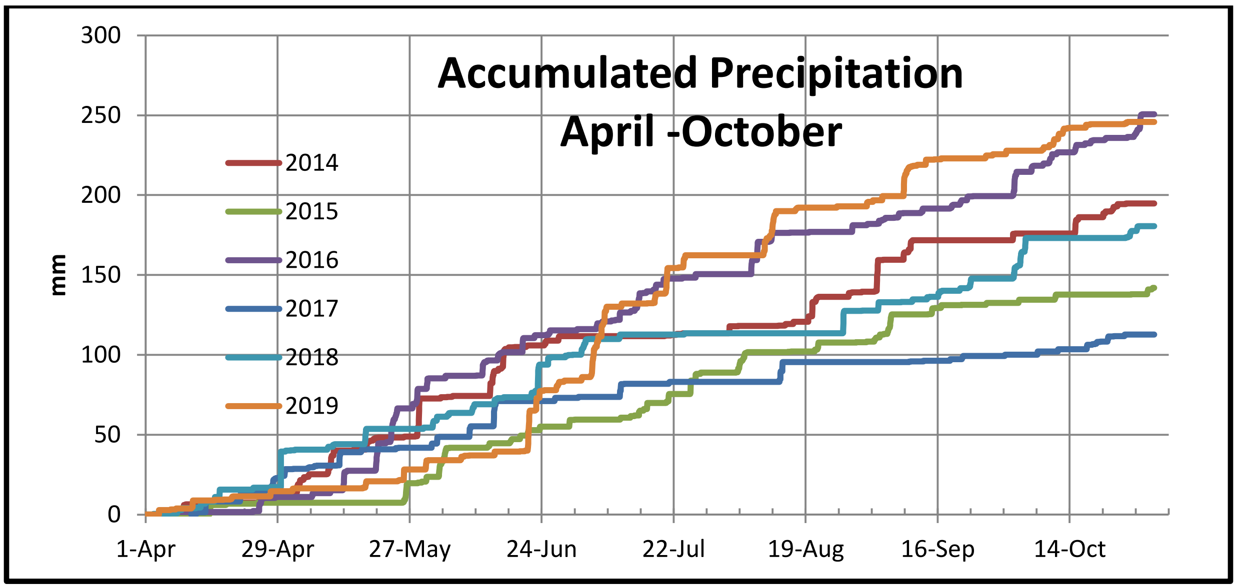


Figure 5 – Accumulated precipitation during the 2014 – 19 summer seasons at Timber Springs.

4. 2016 Activities

4.1. Stations

Four of the water level monitoring stations installed during 2014 and 15 remained in operation. Their locations are shown in Figure 1. One was situated in the Columere Marina (Columere) and measured lake level. The others were on the Headwaters Creek in the Columbia River Headwaters Park near Canal Flats (Canal Flats), on the Columbia River near Fairmont Hot Springs (WSC) and on Dutch Creek at the Highway 93/95 Bridge (DC). A fifth station, Lansdowne Creek installed in 2017 operates on Nature

Conservancy of Canada property. A new station (Outlet) was installed in August on the Columbia River just below the outlet from the lake.

All operated over the winter of 2018-19 except Outlet and the Dutch Creek Station where ice build up precludes the possibility of making any meaningful measurements

The recording rain gauge located in the Timber Springs community does not operate over winter. It was restarted April 3 and operated until December 1, 2019.

A weather station is operated on the Fairmont Hot Springs Airport (CYCZ) for aviation purposes. Recorded weather observations were obtained by telephone on a periodic basis and served to verify the performance of the data loggers.

4.2. Equipment Purchases

Two new data loggers were purchased during the 2018-19 water year. They were installed at the Water Survey of Canada and Dutch Creek sites to replace aging equipment.

4.3. Data Collection and Management Issues

The accumulation of silt and algae continued to be a problem at the Columere Marina site despite the logger having been raised in April 2018. Steps were taken to remove the silt on a periodic basis. A backup logger was also installed nearby as an additional step against loss of data.

Lack of familiarity with the downloading procedures for the newly acquired data loggers resulted in the loss of data at four locations during the period May 24 – June 5. Fortunately, backup loggers at all locations except the Water Survey of Canada site permitted reconstruction of the records.

The clock on the logger at Canal Flats timed out on July 29. The issue wasn't discovered until August 12 with the result that no data was collected during the intervening period.

The suspension cable holding the logger at the Lansdowne site broke sometime over winter with the result that the logger dropped to the bottom of the stilling well, a distance between 3 and 5 cm. No attempt has been made to correct the data. The logger was returned to its original position on April 12.

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 2018-19

The winter water temperature and level records for all stations are shown in Figures 6 and 7, respectively. Note that the Dutch Creek station only operated until November 28 due to ice buildup in the creek.

All stations recorded water temperature but the stilling well at the WSC site is recessed well into the riverbank so that the recorded temperatures do not represent those of the river and are therefore not shown.

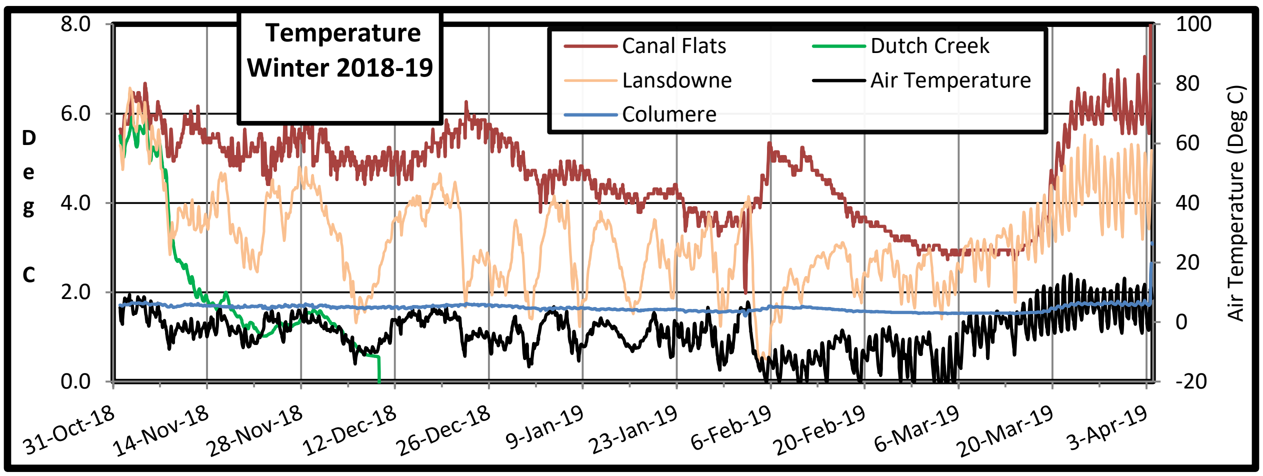


Figure 6 – Winter water temperatures. Air temperature superimposed at bottom of chart. Air temperatures below -20 were not recorded.

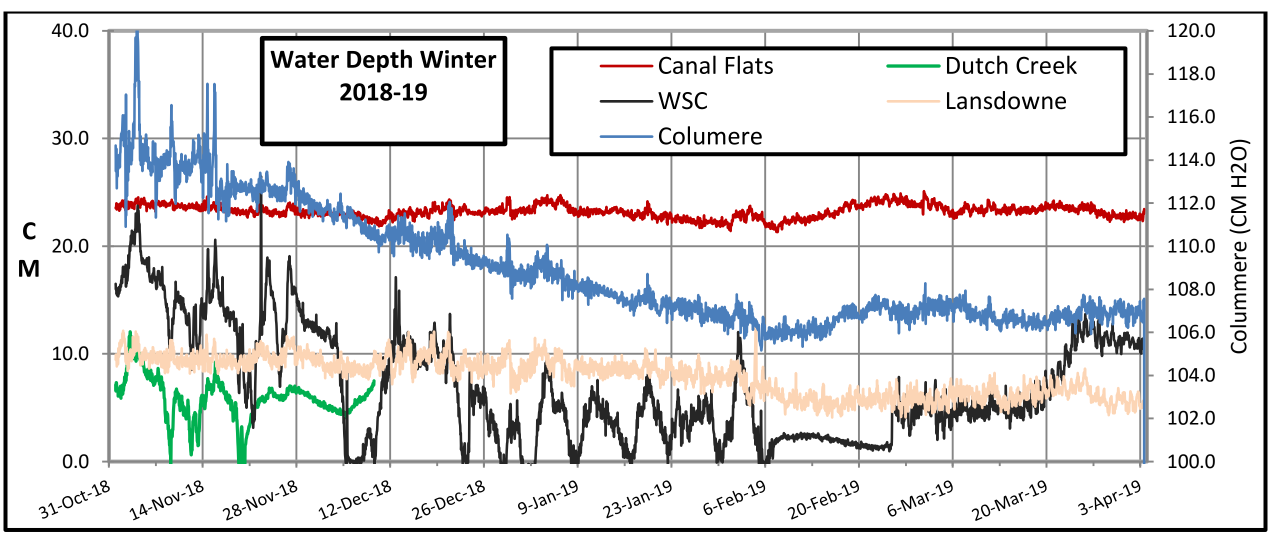


Figure 7 – Winter water depths. Datums are arbitrarily selected. The intakes at both the Dutch Creek and WSC sites are exposed at low water levels and therefore subject to freezing. Therefore, water levels below about 8 cm should be used with caution. Measurements ceased on Dutch Creek in late November due to the formation of ice jams.

The air temperature recorded at Timber Springs is overlain in Figure 6 for comparison. It is recorded using a data logger (BARO). It has a cutoff temperature of -20 Deg C and will not record below that level. Otherwise, it is considered as providing an accurate measure of air temperature. It was fitted with a shield to reduce radiative effects.

5.2 Open Water Season 2019

5.2.1 Water Temperature

The water temperatures recorded during the open water season at are shown in Figure 8. Again, temperatures recorded at the WSC site are non-representative and not shown. The temperature of the water recorded in the lake was well above that recorded at other locations for most of the season and is presumed to have been due to the absorption of solar radiation by suspended materials and the lakebed. The cooler temperatures recorded at Canal Flats are attributable to the Creek's groundwater source. Air temperatures recorded at Timber Springs are shown at the bottom of the chart for comparison

5.2.2 Water Level

The recorded water levels are shown in Figure 9. The reference levels were arbitrarily chosen and bear no relationship to any known elevation standard. Backwater from the lake engulfs the Canal Flats station during mid-summer so that the rise during that period does not represent a corresponding increase in flow. A disproportionate number of spikes appear in both the Columere and Canal Flats records and were caused by set up on the lake following periods of strong winds.

The lake peaked June 7 at a level about 80 cm above its normal spring base level and about 10 cm below the long-term average. Dutch Creek peaked 4 days earlier on June 3. The peak at the WSC cannot be established due to missing data but would likely have been in the same period.

The long-term average date for the peak to be reached at the WSC site is near June 20.

The daily rainfall amounts recorded at Timber Springs are shown in Figure 10 for comparison.

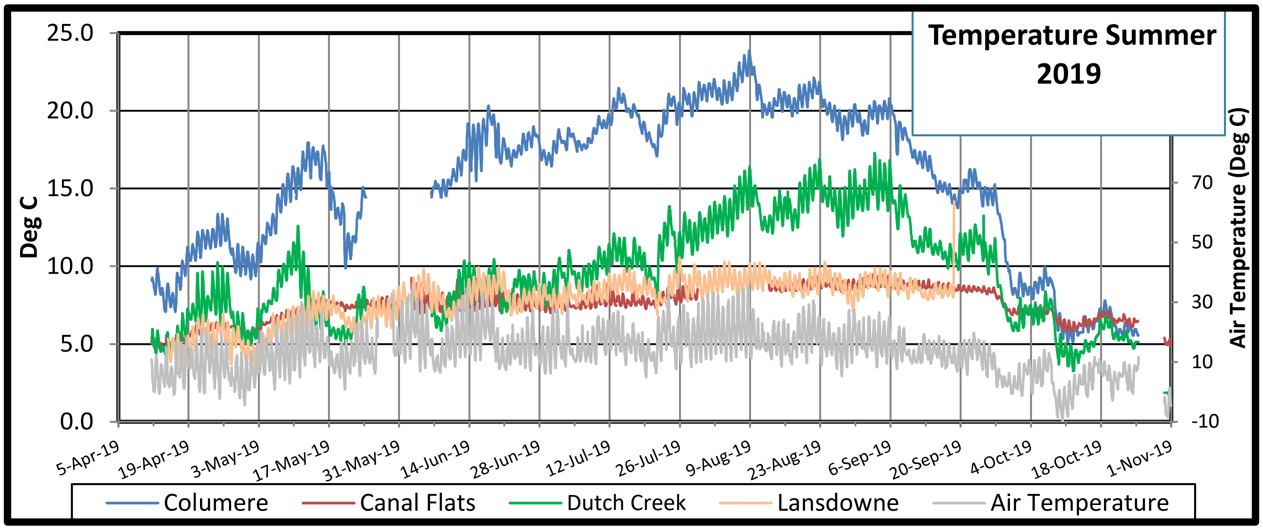


Figure 8 – Water temperatures recorded at the Columere, Canal Flats, Lansdowne and Dutch Creek sites. Air temperature was recorded at Timber Springs.

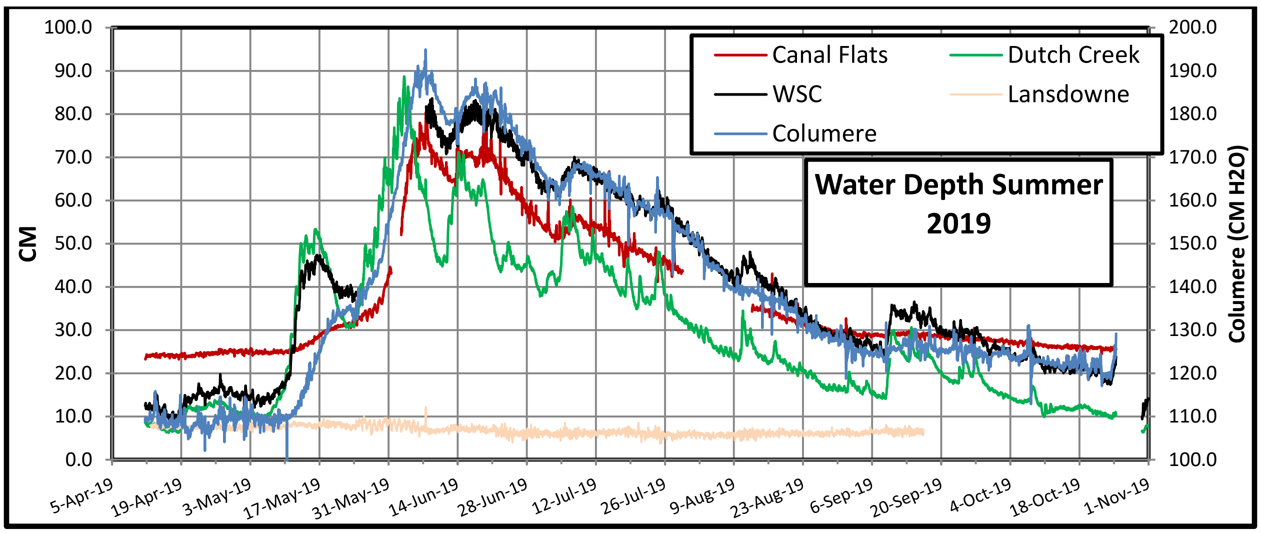


Figure 9 – Hourly water levels. Datums are arbitrarily selected.

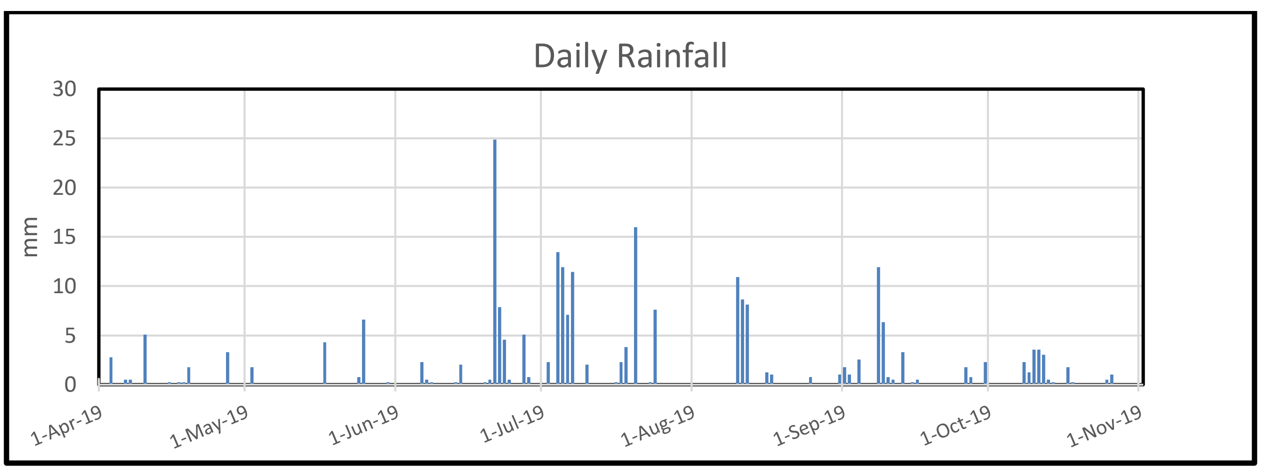


Figure 10 – Daily rainfall amounts recorded at Timber Springs.

5.2.3 Rating Curves

Only a small number of flow measurements were made during 2019 and they were made mainly to substantiate the accuracy of the rating curves established in 2018. Changes were found unnecessary and the curves described in the 2018 Summary were used compute the flows shown here.

5.2.4 Flow During the Open Water Season

Flows calculated for the open water period for the Columbia River and Dutch Creek are shown in Figure 11. The period begins on April 11 and continues until October 31, 2019 and encompasses the spring runoff and most of the subsequent recession. The level of Columbia Lake is also shown for comparison.

Warm temperatures prevailed during the periods: May 13-17, June 1-5, June 13-20 and July 5-7 (see Figure 8). The accelerated rate of snow melt during these periods resulted in corresponding rises in the flow in Dutch Creek that passed downstream into both the Columbia River and into Columbia Lake. The most significant of these was the June 3-7 peak period.

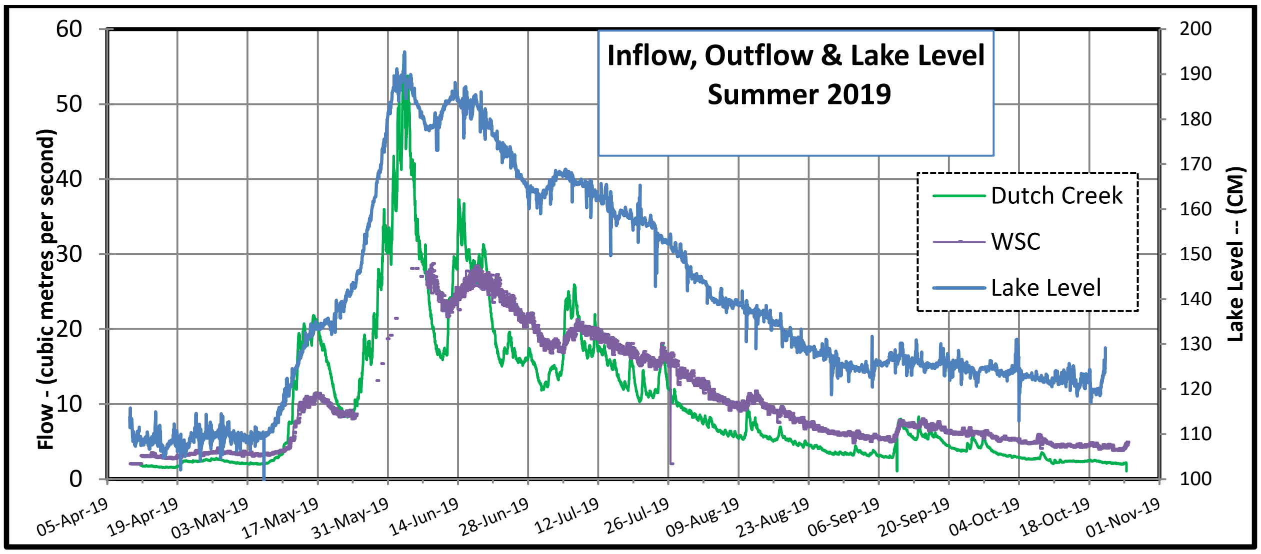


Figure 11 – Estimated hourly rates of flow on Dutch Creek and on the Columbia River at the WSC site. Lake level is also shown.

5.2.5 Recession of Dutch Creek Overflow

Dutch Creek overflows its banks during the spring runoff and water enters the lake. The overflow eventually peaks and then recedes as the season progresses. This water must be considered in any water balance calculation.

In order to gain an understanding of the rate of recession, two traverses were made over the delta near the south shore of Dutch Creek. One was made August 8 and the second October 24. A few side channels were found but only two emptied into the lake. They were labelled Streams A and B and are shown in Figure 12. The flow in Stream A was estimated to be about 0.36 cubic metre per second during the August traverse but had dropped to about .10 cubic metre per second by the October traverse. The flow in Stream B was significantly less on both occasions. Thus, it seems that by the end of the open water season much of the flow remains in the main channel and only a small amount enters the lake.

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Figure 12 – Image of Dutch Creek delta showing locations of Streams A and B. Date of image unknown.

5.2.6 Lake Outflow

A staff gauge was mounted on August 8 and a stilling well and logger on September 22 on the Columbia River just downstream of the outlet from Columbia Lake (Outlet Stn – see Figure 12). The purpose was to measure water level. Once enough flow measurements exist to establish a rating curve, it will serve to record the flow of water directly out of the lake.

The water levels recorded up to December 11 are shown in Figure 13. The water level declined steadily until about November 25 and then abruptly declined. By December 1 it had reached the bottom of the stilling well.

Two flow measurements were made, one on September 22 and the second on October 24. They are insufficient to establish a rating curve but do confirm that the flow rate decreased in relation to water level as expected.

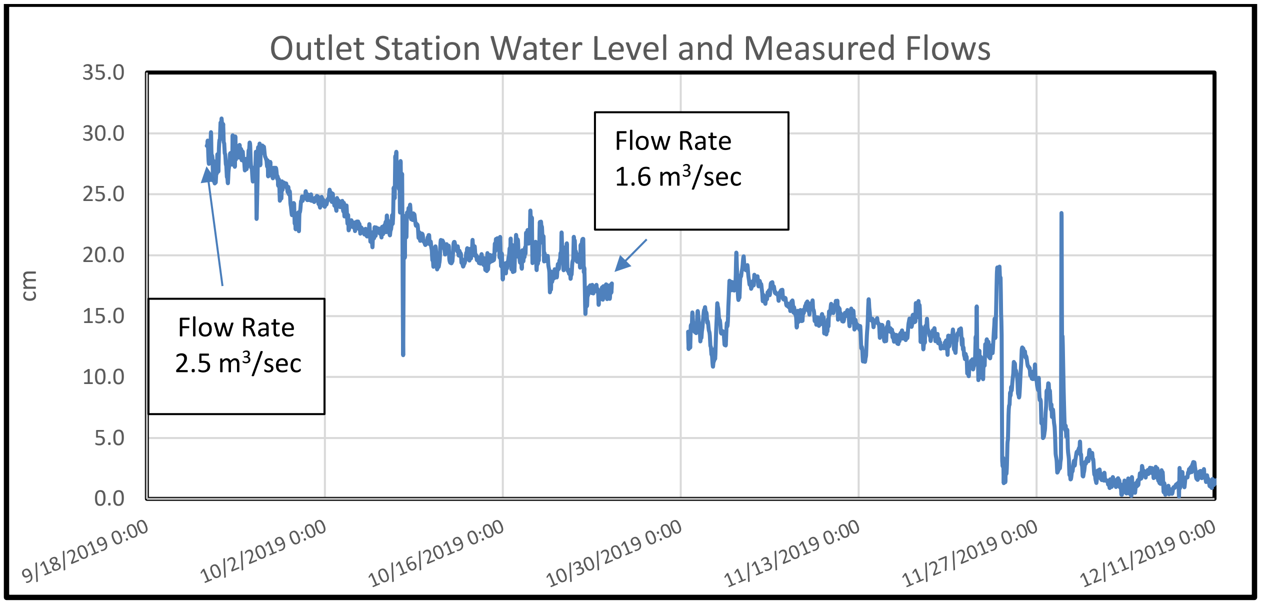

Figure 13 – Depth of water above logger at the Columbia Lake outlet.

6. Discussion

The period of record shown in Figure 13 is too short to draw firm conclusions. Nevertheless, the flow rates are lower than those suggested from work in previous years and, if real, have significant implications so should not be overlooked.

Figure 13 shows that the water depth was about 27 cm and outflow from the lake was 2.5 m^3/sec on September 22. By October 24 the water level had dropped to about 17 cm and the corresponding flow to 1.6 m^3/sec. After that the water level, and by inference the flow, continued to drop. It seems reasonable that the flow rate would have remained below 1.6 m^3/sec and will likely remain below that level until April 2020 when the lake starts to refill.

One implication is that little excess water is available during winter to meet demands for additional withdrawals. A second is that an upper limit on the amount of water entering the lake via the aquifer beneath Canal Flats is established. By assuming that losses due to evapotranspiration and consumptive are small, the inflow rate must balance the outflow rate. The inflow is predominantly groundwater and includes that flowing through the aquifer. Hence, the aquifer contribution is 1.6 m^3/sec or less. Gillmor (2018) has shown that the hydraulic head existing between the Kootenay River and the lake remains nearly constant year-round so that the flow through the aquifer also remains constant year-round.

Groundwater from other sources is not subject to same restriction and will likely be higher during summer than winter.

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8. Acknowledgements

Ellen Storey, a UBC Coop student, was of great assistance with the streamflow monitoring and data management activities.

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

Columbia Valley Local Conservation Fund
Regional District of East Kootenay
Lake Windermere Ambassadors
Columere Marina
Fairmont Hot Springs Resort Ltd. including the Riverside Golf Course and Fairmont Hot Springs Airport
Village of Canal Flats
Columbia Ridge Community Association
Timber Springs Community Association
Columere Park Community Association
Spirits Reach Community Association
BC Lake Stewardship Society
Nature Conservancy of Canada
Fairmont Creek Debris Flow Mitigation Project
Fellow members of the CLSS for reviews, helpful comments and suggestions

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 was collected using data loggers. The loggers measured pressure and temperature and record them in internal memory. The loggers were programmed to record every hour on the hour. Loggers from two different manufacturers were used. Prior to 2018 all were from Diver. In April 2018 two HOBO loggers were acquired. A further two HOBO loggers were purchased in March of 2019.

The 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.

A change in procedure was introduced at the beginning of this water year. In the past atmospheric pressure was measured at the Timber Springs location. Commencing November 1, 2018 measurements were made at the WSC site. The site is near lake level where most stations are located so that an elevation adjustment is no longer required. Exceptions are the Dutch Creek station which is 24 metres above lake level and the Lansdowne station at roughly 40 metres.

The calculation of water level is subject to errors from a variety of sources including improper measurement of atmospheric pressure, inaccurate calibration of pressure sensors, sensor drift, and changes in water density.

Atmospheric pressure was measured using HOBO logger 325 (H325). It also served as the standard against which the performance of all other loggers was evaluated. The accuracy of H325 in turn was periodically evaluated against the barometer at the Fairmont Hot Springs Airport (CYCZ) during the open water season. Comparison of the measurements is shown in Figure A1. H325 was consistently 0.7 cm H2O below the barometer even though both were at the same elevation. 0.7 cm H2O was added to the H2O readings to correct this offset.

Laboratory calibration was not undertaken due to cost. However, all the loggers were taken out of service at the beginning and the end of the open water season and operated near H325. The resulting pressure measurements are shown in Figures A2 and A3. For unknown reasons, the data from H325 could not be retrieved during the end of season trial. H326 was substituted as the reference. Also, Logger 1459, installed in Lansdowne Creek, is remotely located and is difficult to access so it was not included. However, spot readings were made during periodic summer visits and they confirmed that its bias had not changed from previous years.

The pressure sensors were not all in agreement thereby indicating a need for adjustment. The mean offsets from H325 at the beginning, middle and end of the water year are shown in Table A1. The offsets applied are also shown. The difference between offsets at the beginning and end of season for all pressure sensors, except H109 and H342) was less than 2.5 cm H2O indicating that drift, if it existed, was minimal. Accordingly, drift was ignored and a correction factor equivalent to the average of the beginning and end of season trials was applied to the respective sensor measurements. The correction factors applied H109 and H342 were arbitrarily selected and leaned toward the end of season bias.

No attempt was made to compensate for the effects of temperature on water density. Such compensation, had it been applied, would have resulted in a change of water depth by one centimetre at Columere at most and much less elsewhere.

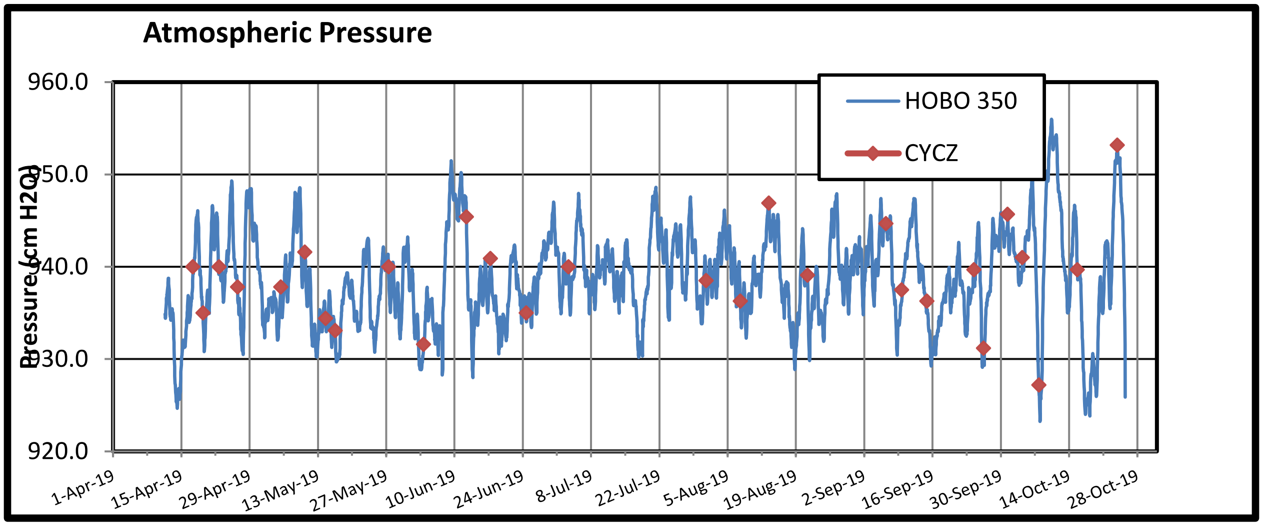


Figure A1 –BARO and CYCZ pressure records at beginning of open water season

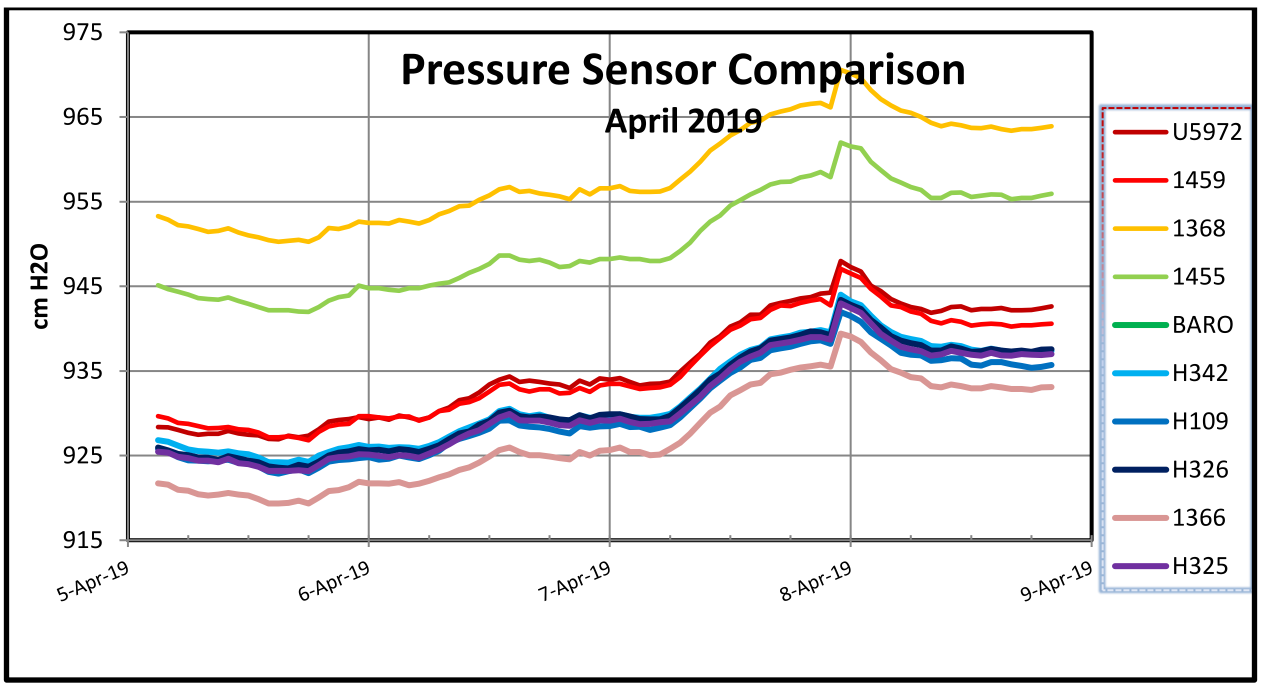
Table A 1 – Measured Offsets from H325 during Calibration trials

Logger ID	Oct-2018		Apr-2019		Oct-2019		
	Mean	Offset from H325	Mean	Offset from H325	Mean	Offset from H325	Correction Applied
U5972	940.5	3.9	935.5	4.6	954.2	5.2	*-4.6*
1459	940.1	3.5	935.0	4.1	953.2	4.2	*-4.1*
1368			958.3	27.4			*-27.4*
1455	954.3	17.7	950.1	19.2	970.4	21.4	*-19.2*
1366	933.1	-3.5	927.3	-3.6	945.0	-4.0	*3.6*
BARO	937.8	1.2	932.5	1.6	951.2	2.2	*-1.6*
H342			931.8	0.9	946.0	-3.0	*2.0*
H109			930.4	-0.5	945.5	-3.5	*2.0*
H326	936.8	.2	931.5	0.6	949.6	.6	*-.6*
H325	936.6	0.	930.9	0.0	949.0[1]	0	*0.*

[1]Pressure not recorded. Pressure assumed to have remained 0.6 cm H2O below H326 as per April 2019

Table A2 – Logger Deployment During 2018-19 Water Year

U5972	WSC – November 1 – April 3 DC – April 11 – July 29 (Back-up) July 29 – October 31 - Out of service due clock stop
1459	Canal Flats Nov 1- July 29 Out of service due clock stoppage July 29 – Aug 12 Canal Flats – Aug 12 – October 31
1368	Lansdowne
1455	WSC – June 5- July 7 (Back-up) Out of Service – July 7 – October 30 CF – October 30-31 (Back-up)
1366	DC - May 19 – August 16 (Back-up) August 16 – September 22 – Out of Service Col Lk Outlet - September 22 – October 31
BARO(1601)	Timber Springs – Atmospheric Pressure (Back-up)
H342	DC – April 11 – October 31
H109	WSC – April 11 – October 31
H326	Columere – Lake Level
H325	WSC – Atmospheric Pressure sensor



FigureA2 – Pressure readings from all other loggers in relation to H325 at the start of the season.

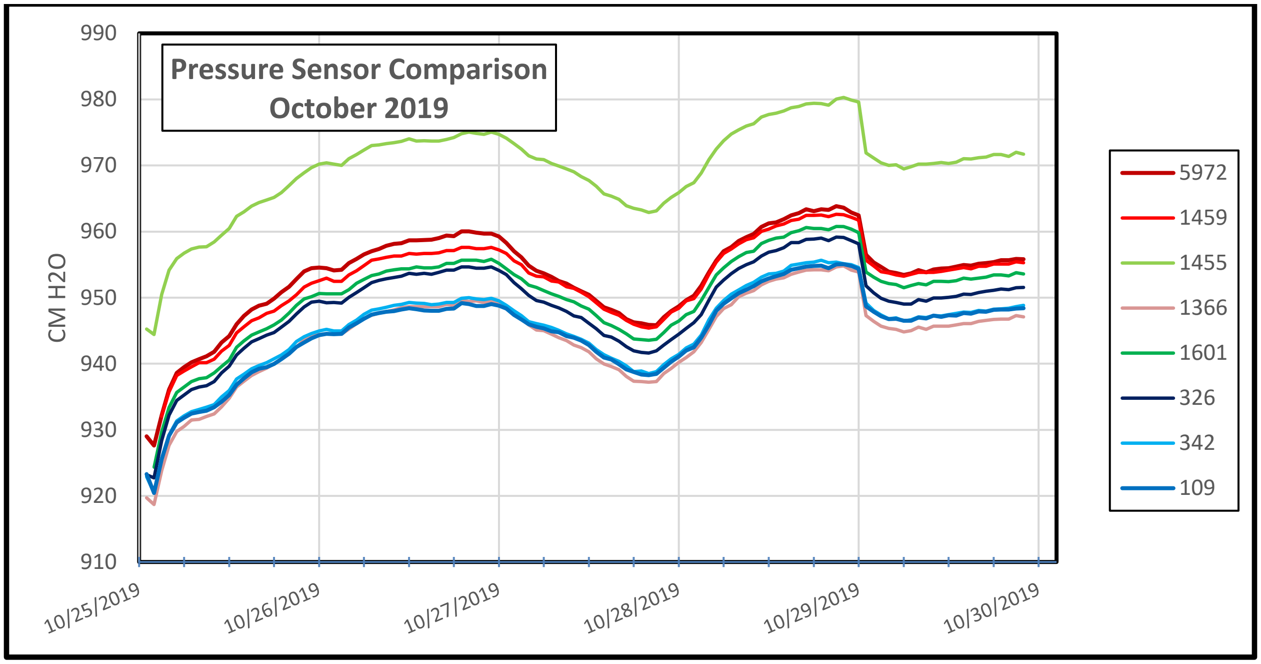


Figure A3 – Pressure readings from all loggers except 1459 in relation to H325 (reconstituted from H326) at the end of the season.

A2- Water Temperature

Beginning and end of season comparisons of the temperature sensors were made in similar fashion. The results are displayed in Figures A4 and A5, respectively. The loggers were exposed to the sun on April 8 and, although closely contained, some loggers received more radiation than others. That accounts for the variation on that date in Figure 8. Otherwise, the sensors were in good agreement.

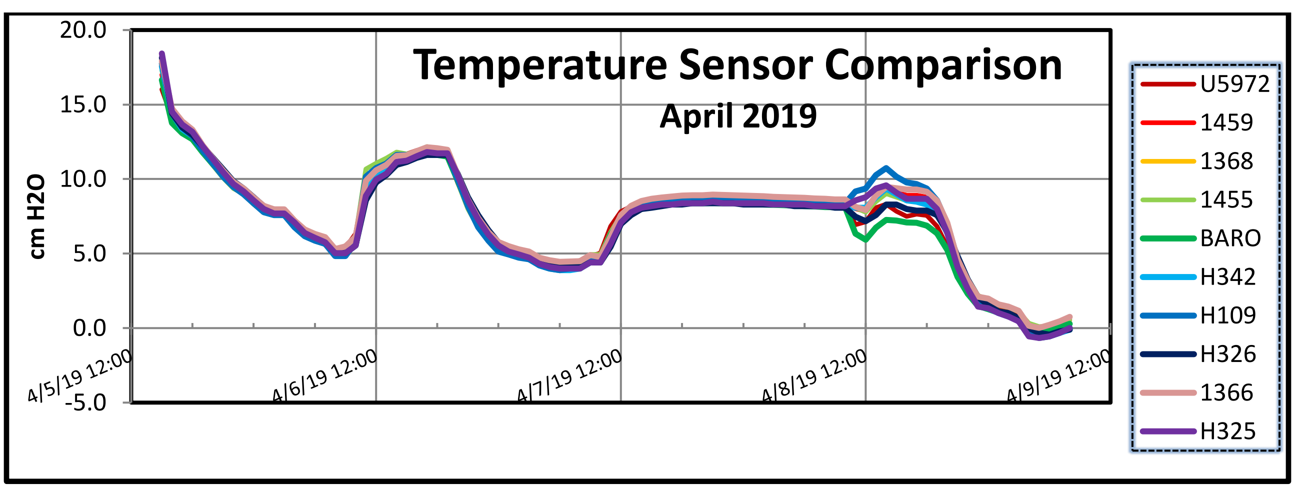


Figure A4 – Temperature readings in relation to H325 at the start of the season.

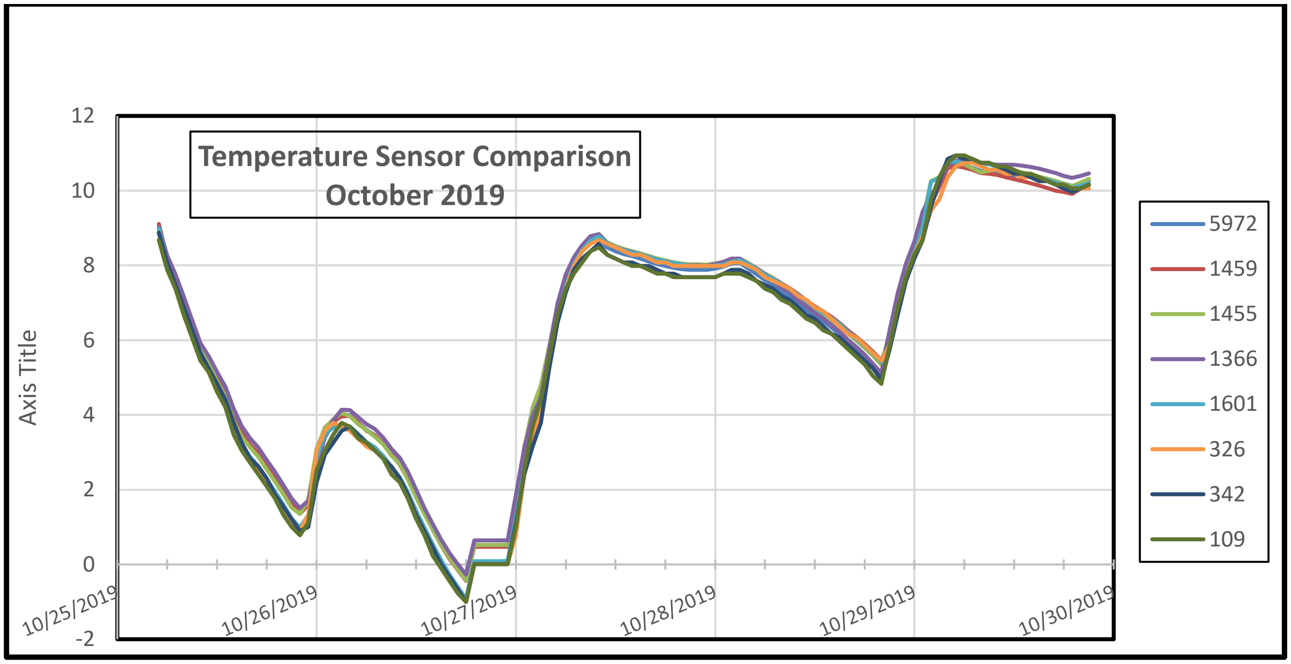


Figure A5 – Temperature readings in relation to H325 (reconstituted from H326) at the end of the season.

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 measurements. The stilling wells and intake pipes at each of the stream sites were back flushed periodically during the season.

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