Summary of Columbia Lake Stewardship Society's 2018 Water Quantity Monitoring Program

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January 2019

Executive Summary

The Columbia Lake Stewardship Society started monitoring water levels in 2014 with the expectation that in time the data would help explain how water moves through Columbia Lake. Of interest was an explanation for the annual rise and fall in the level of the lake. That rise is important. It helps maintain the quality of the water, it ensures that an adequate supply of water exists for consumptive use during mid-summer and it provides the medium for water based recreational activities that attract tourists and second home owners. In short, it underpins the local economy. It is also important from an environmental perspective. The annual incursion of new water revitalizes the habitat upon which wildlife and aquatic species depend. Downstream impacts may also exist.

Data collected in 2017 (see Thompson, 2017) suggested that the rise was due to water entering the Lake from Dutch Creek during the spring runoff but confirmation was not possible owing to the lack of measurements during conditions of high water. Steps were taken in 2018 to acquire the necessary high-water measurements and they confirmed that the rise is due to inflow from Dutch Creek.

In the present channel configuration on the Dutch Creek delta, water from Dutch Creek flows across the delta directly into the Columbia River when water levels are low. Once the spring melt is underway the situation changes. Water from Dutch Creek enters the Columbia River faster than it can be carried away. The excess backs up into Columbia Lake causing it to rise. Once the inflow peaks, the lake level begins to recede and the stored water gradually drains out through the Columbia River.

This analysis differs from that presented in the 1997 Columbia Lake Management Strategy (see RDEK, 1997) on two points. First the newly acquired data shows that the actual inflow from Dutch Creek is less than was estimated. Secondly, because of the overestimate, it appeared that more water entered the delta than flowed out. It was reasoned that the excess water was lost to the delta and groundwater. The present data shows that all the water entering the delta can be accounted for without having to consider losses through infiltration.

With the new-found ability to measure inflow from Dutch Creek the Columbia Lake contribution to downstream flow can be determined. About 60,000,000 cubic metres left the Lake during the 2017-18 water year. When averaged over the year this equates to a flow rate of about 2 cubic metres per second.

The Columbia Lake Stewardship Society plans to maintain the existing monitoring program but will now shift attention to measuring the parameters that together make up the outflow, namely: groundwater, surface runoff, precipitation, evaporation and consumptive use.

1. Introduction

This is the fifth in a series of annual reports on water quantity monitoring activities conducted by the Columbia Lake Stewardship Society (CLSS) in the Columbia Lake Watershed.

From the outset the purpose has been to account for the inputs and outputs of water to the lake, in short, examining the water balance. Of significant interest is the component that causes the lake to rise an average of 0.9 metres each year. That rise is important. It cannot be stated with certainty what would happen if the lake did not rise but the following are possible. The quality of the water may degrade, there may more extensive weed growth, there may be insufficient inflow to meet consumptive demand at mid-summer, and the quality of water based recreational activities may be diminished threatening the viability of the local tourism industry. There may also be environmental impacts. The quality of the habitat that sustains wildlife and aquatic species may be diminished. Finally, there may be downstream impacts such as, for example, changes in water quality and sediment deposition.

Analysis of the 2017 data (see Thompson, 2017) pointed to a connection between the rise in lake level and the runoff flowing from Dutch Creek. Much of the 2018 program was geared toward exploring that connection.

From the beginning, data collection and management has been an important aspect and considerable effort is expended to ensure that the collected data are accurate. 2017-18 was no different. Back up manual water level measurements were taken to verify automated measurements, sensors were compared with known standards and rating tables were updated.

Other, independent studies of water exchanges are ongoing. Gillmor (2018) examined the structure of the aquifer beneath the Canal Flats area and determined that the hydraulic gradient favors the movement of water northward toward the Lake. Of great relevance to this report was the finding that the hydraulic gradient which drives water movement remains nearly uniform throughout the year meaning that there is little variation in the seasonal rate of groundwater inflow.

2. The Watershed

For convenience of measurement the outflow point of the Columbia Lake Watershed is 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. Warm Creek enters the Columbia River between the two points and constitutes about 9 square kilometres of the entire 881 square kilometre area. Also, in the area is the delta of Dutch Creek. In its present configuration and when flow rates are low , water from Dutch Creek flows across the delta to directly enter Columbia River. That hasn't always been the case. The channels are continually shifting and at times in the past have 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 2017-18 water year (November 1, 2017 – October 31, 2018) 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 winter were cold and wet resulting in a heavy accumulation of snow. The trend was reversed by May 1 when that month turned out to be exceptionally warm triggering an unusually early spring melt. By June temperatures returned to near normal but July and August were again above normal and dry.

Regional snow conditions are compiled by the River Forecast Centre (2018). By May 1 the water equivalent of the snowpack in the East Kootenays was 150 percent of normal. The melt rate was rapid during May due the warm temperatures but slowed sufficiently during June to avoid major flooding.

Local measurements of snow depth are also made at the recently installed weather station on the Fairmont Hot Springs Resort Ltd Ski Hill as part of the Fairmont Creek Debris Flow Mitigation Project (see Figure 1 for location). Snow depths during the 2017-18 water year are shown in Figure 4. Melt began in early April and was complete by the end of April. This contrasts with the River Forecast Centre assessment but since the station is at lower elevation (1480 m) than most of the stations in the River Forecast Centre network it is felt to be representative of melt rates in the vicinity of the Lake.

A recording rain gauge has been in operation in the Timber Springs Community on a seasonal basis since 2013. The accumulated precipitation recorded during the last five summers is shown in Figure 5. The 2018 record falls within the midst of earlier years with the exception that a dry period extended from late June until late August. Again, as during 2017, that mid-season dry period resulted in an unusually high incidence of forest fires.

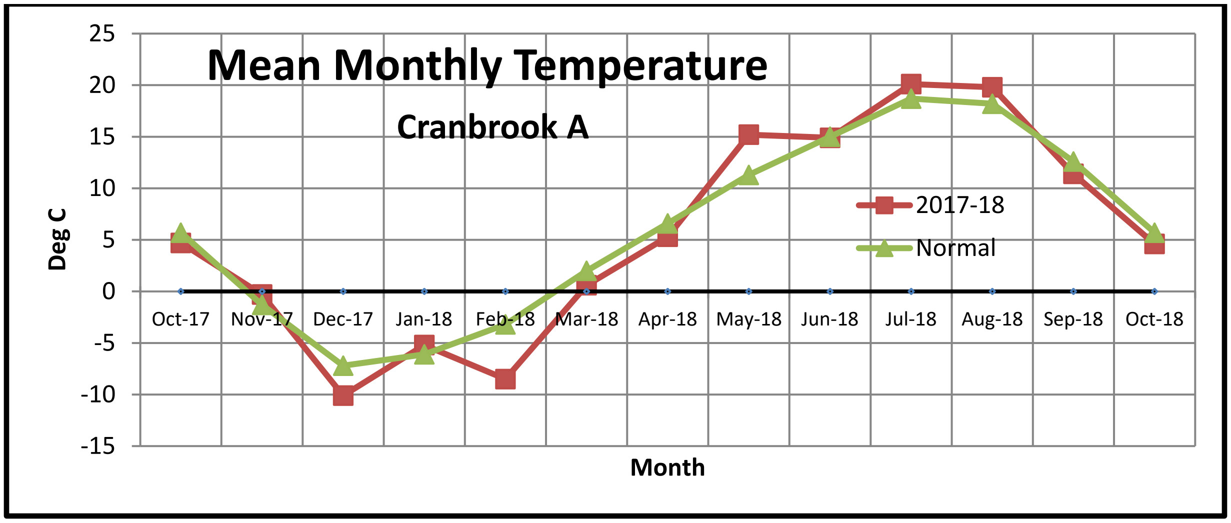


Figure 2 – Comparison of mean monthly temperatures at the Cranbrook- Kimberley Airport during the 2017-18 water year and the 1980-2010 long-term normal values.

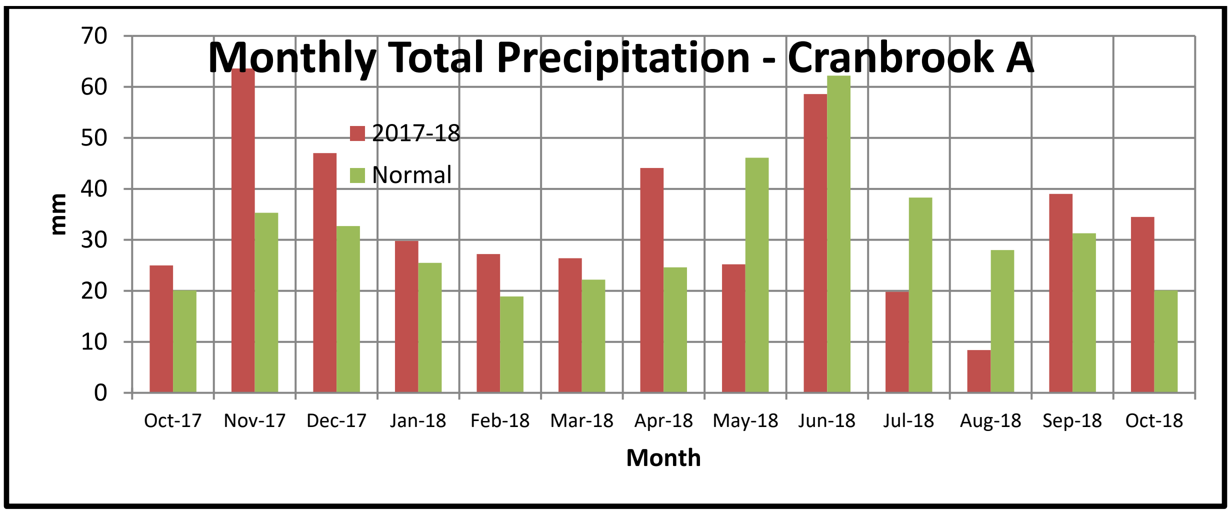


Figure 3 – As in Figure 2 except showing precipitation totals.

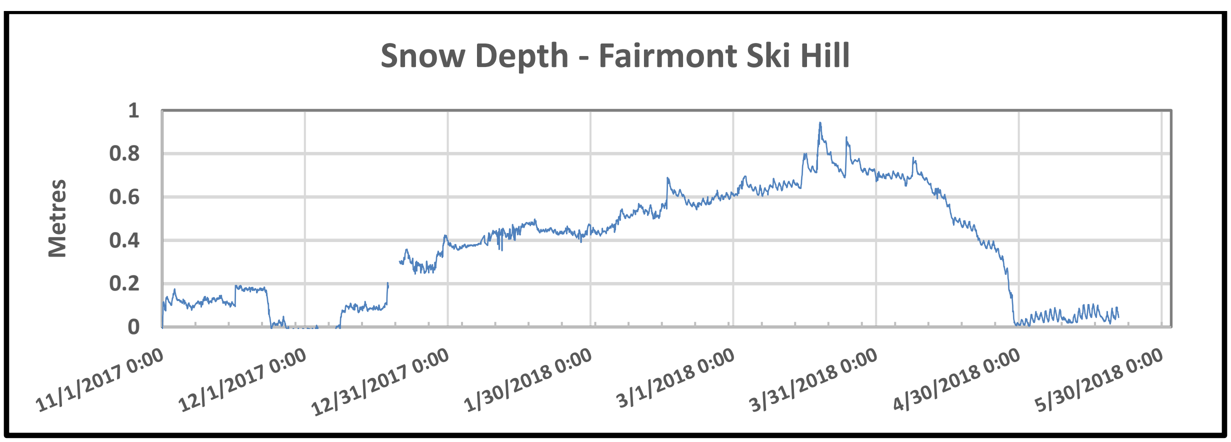


Figure 4 – Snow Depths recorded on the Fairmont Ski Hill

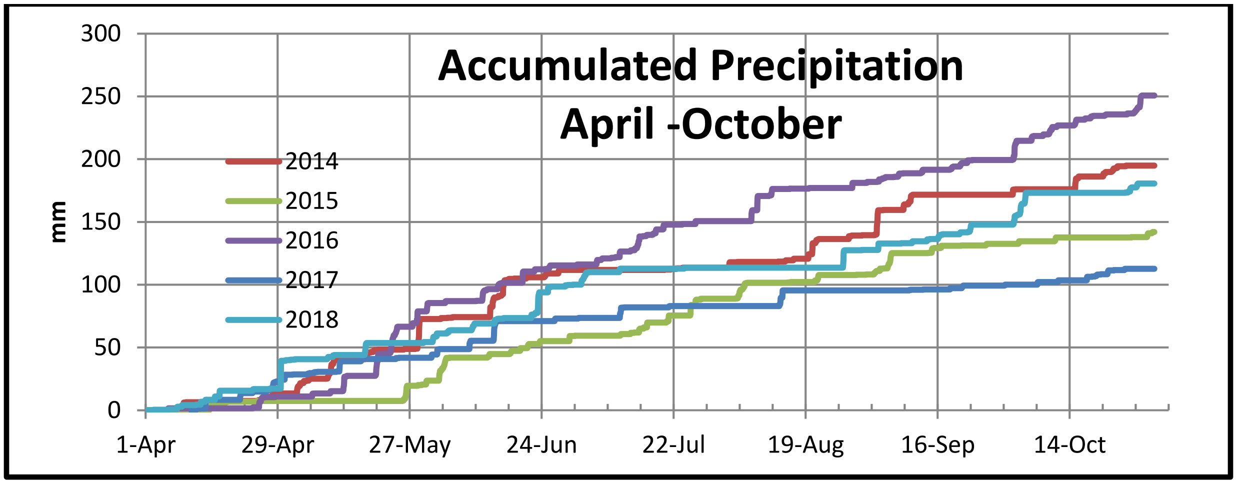


Figure 5 – Accumulated precipitation during the 2014, 2015, 2016, 2017 and 2018 summer seasons at Timber Springs. In 2018, the rain gauge was not put into operation until April 16. The values for early April are from the Fairmont Hot Springs Airport (CYCZ).

4. 2016 Activities

4.1. Stations

Four of the water level monitoring stations installed in 2015 remained in operation during 2018. Their locations are shown in Figure 1. One was situated in the Columere Marina 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). In cooperation with the Nature Conservancy of Canada a new station was installed on Lansdowne Creek (see Figure 1) in the fall of 2017. That creek flows from the slopes on the east side of Columbia Lake and the purpose of the installation was to examine the behaviour of streams contributing local inflow.

All were kept in operation over the winter of 2017-18 except for the Dutch Creek Station where the logger was pulled November 28 as a safeguard against damage due to ice buildup.

The recording rain gauge located in the Timber Springs community does not operate over winter. It was restarted April 16 and operated until December 6, 2018.

A weather station is operated on the Fairmont Hot Springs Airport (CYCZ) for aviation purposes. A digital copy of a portion of the recorded weather observations was obtained and served mainly to verify the performance of the data loggers.

4.2. Equipment Purchases

Two new data loggers were purchased during the 2017-18 water year. One was installed in the stilling well at the Water survey of Canada site to measure atmospheric pressure at Lake level with a view to replacing the existing BARO logger as a reference. The second was installed at the Columere site to replace logger U5972 which had exhibited erratic behaviour during the previous season.

4.3. Data Collection and Management Issues

Several issues observed during the 2016-17 season were addressed.

Algae growing upward from the lake bed were beginning to interfere with the operation of the logger at the Columere Marina site. The issue was remedied by moving the logger upwards by 13.1 cm. on April 18.

The erratic behavior of Logger U5972 was investigated. Testing revealed that it was influenced by the ambient temperature. Comparison tests (See Appendix A for details) showed it to be accurate within the range 4 to 15 Deg C but exhibited a bias at higher and lower temperatures. The logger was taken out of service during the 2017-18 season and used only in a backup capacity. The impact of temperature on the behaviour of the other loggers was also investigated. Most were found to be generally stable over the 0 to 25 Deg C range. Many do not measure correctly but are stable and the size of the offsets is known. Offsets are removed via software prior to analysis.

Logger measurements of water level at the Dutch Creek and WSC sites were observed to deviate from manual measurements made on the shoreline during 2017 especially when water levels were high. It was suspected that debris captured by trees and other shoreline fixtures retarded flow causing water levels near the shoreline to be slightly higher. The issue was examined by affixing a second logger to the end of the intake pipe at the Dutch Creek site. Comparison confirmed the accuracy of the logger and the suspicion.

4.4. Sensor Accuracy

As noted, 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. Overwinter 2017-18

Three of the original stations were kept in operation over the winter of 2017-18. The fourth, Dutch Creek only operated until November 28. The new Lansdowne Station also remained in operation over winter. The water temperature and water level records for those stations are shown in Figures 6 and 7, respectively.

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

The air temperature is also shown in Figure 6 for comparison. In the absence of a proper local thermometer air temperature is recorded using the reference data logger (BARO) mounted at Timber Springs. It has a cutoff temperature of -20 Deg C and will not record below that level. It is otherwise felt to provide an accurate measure of air temperature. It was fitted with a shield to reduce radiative effects.

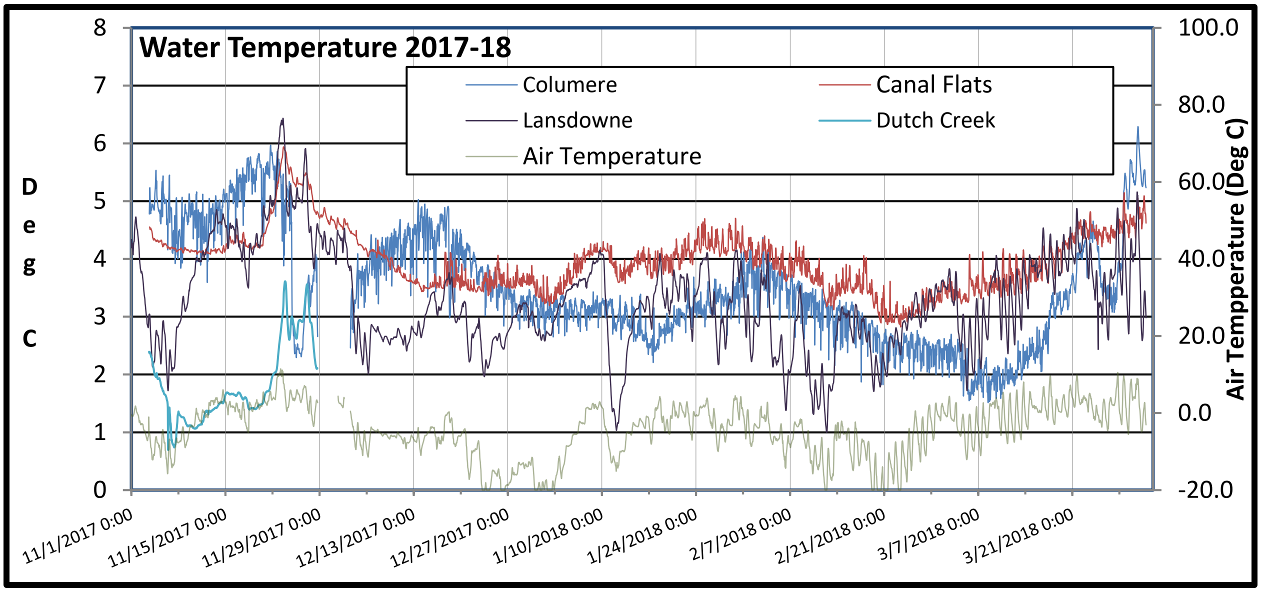


Figure 6 – Overwinter water temperatures. Air temperature superimposed at bottom of chart. Air temperatures below -20 were not recorded.

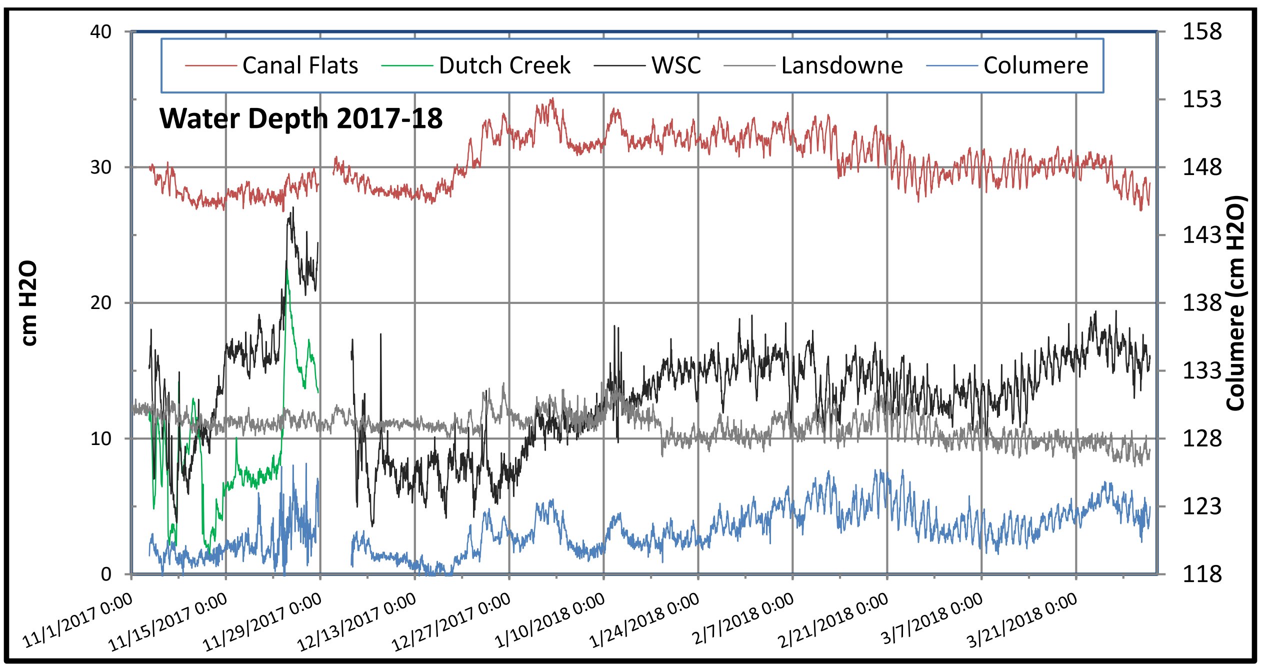


Figure 7 – Overwinter water depths. Lake level (Columere) shown at bottom.

5.2 Open Water Season 2018

5.2.1 Water Temperature

The water temperatures recorded during the open water season at three of the four stations 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 both the inflow and outflow points for most of the season and is presumed to have been caused by the absorption of solar radiation by suspended materials and the lake bed. 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 water levels recorded at all four stations 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.

Water level peaks were recorded almost simultaneously at the WSC and the Columere sites on May 29. A peak was also recorded at the Dutch Creek site on May 29 but was not the highest. Higher values were recorded on both May 26 and 27.

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. Of note was a significant rain event on June 23 that produced a secondary peak on all water levels except Lansdowne over the ensuing days.

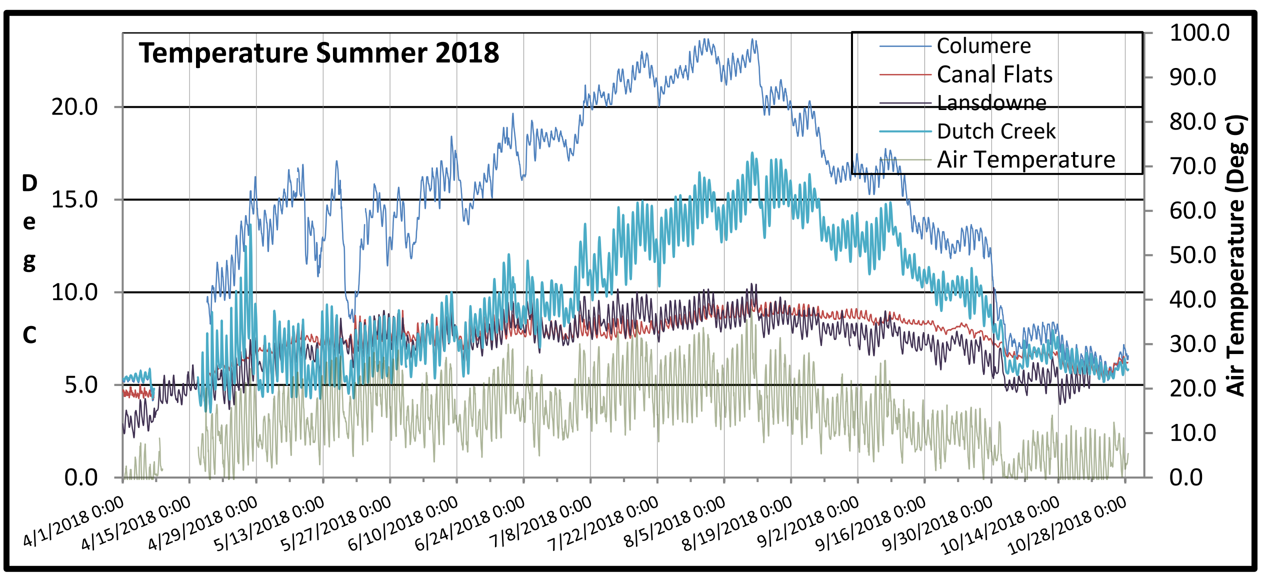


Figure 8 – Water temperatures recorded at the Columere, Canal Flats, Lansdowne and Dutch Creek sites. Air temperature was recorded at Timber Springs.

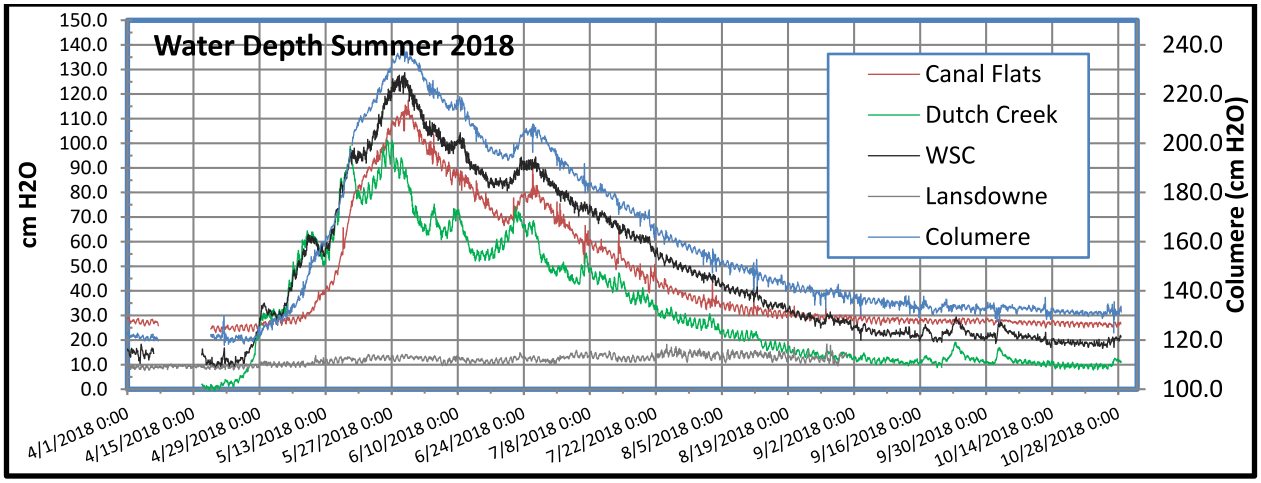


Figure 9 – Hourly water levels.

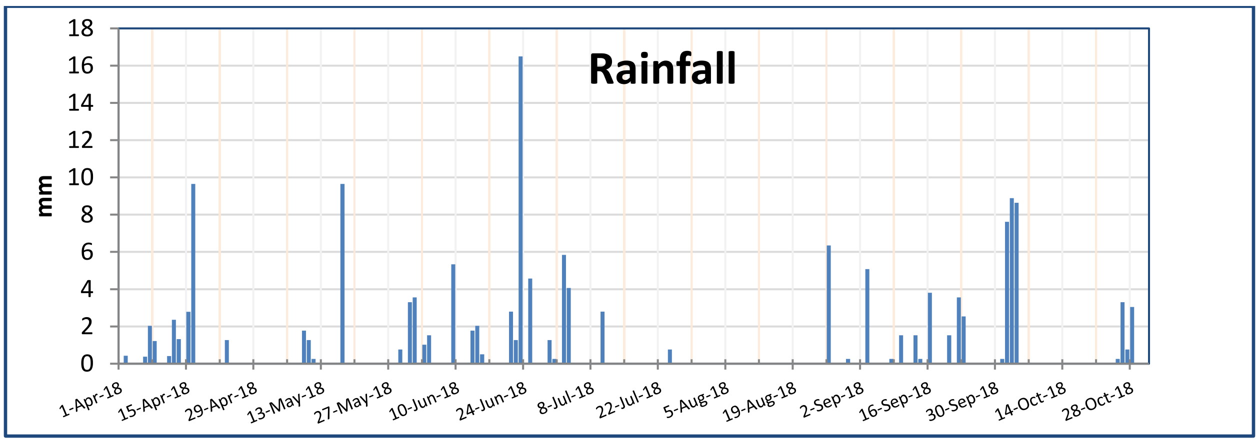


Figure 10 – Daily rainfall amounts recorded at Timber Springs.

5.2.3 Rating Curves

A common measure of a water body is its level. It is used to assess floods, compute drafts for navigation, and for making day to day and seasonal comparisons in general. it is not a useful measure for water balance studies. Volume is required for that purpose. Volume is determined from the flow in rivers or in the case of lakes, from changes in water level. Flow is calculated by measuring the cross-sectional area of a stream and water velocity. Velocity is measured using a current meter. The flow increases with water depth. By taking a series of velocity measurements at different water depths (stage) a relationship between stage and flow (discharge) can be established. This stage-discharge relationship (better known in practice as a rating curve) can then be used to obtain a continuous record of the volume of water being discharged from a time sequence of water levels such as those provided by the data loggers.

5.2.3.1 Columbia River

A series of flow measurements were made at the WSC site during the 2016-17 season. Five additional flow measurements were made during 2018. Adding these to the existing base of measurements resulted in a minor adjustment to the rating curve used in the 2017 Report. The data set and rating curve used in the 2017 Report (2016-17) are shown in Figure 11. Superimposed are the five new measurements taken in 2018 and the corresponding updated rating curve, based on all the original data plus the five new flow measurements (2016-18).

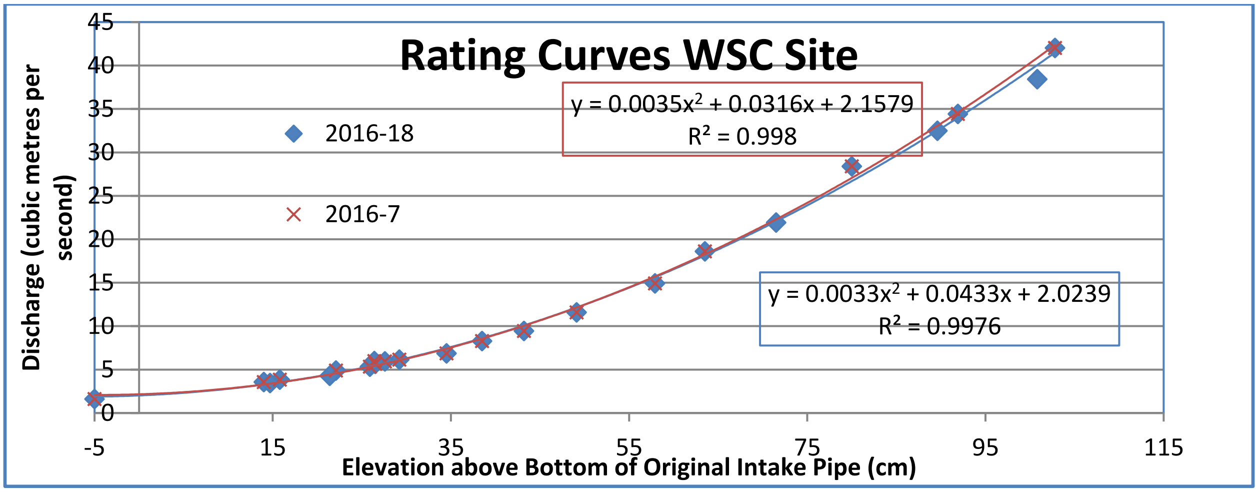


Figure 11 – Rating curves based on water level and flow data collected at the WSC during the 2016-17 season and over the entire 2016-18 period including the five additional measurements made in 2018.

5.2.3.2 Dutch Creek

Flow measurements were also made on Dutch Creek during 2016-17 season but all were made when water levels were low. Two measurements made in high water were contributed by a private firm. A major objective in 2018 was to obtain additional measurements in conditions of high water. Dutch Creek is fast flowing and requires the use of a platform located above the water from which to suspend a current meter. In late 2017 a request was made to the BC Ministry of Transportation and Infrastructure to operate from the highway bridge overlying Dutch Creek. A permit was granted on condition that a flagging company be contracted to control traffic. This allowed for three high water flow measurements to be made. A fourth measurement had been made earlier in the season when the water level was low. The 2016-17 data points and corresponding rating curve is shown in Figure 12. The four new points acquired in 2018 are superimposed. Also superimposed is the updated rating curve based on all data points (2016-18).

The contribution of the three high water points is significant. The projected flow rates during high water are much lower using the updated curve than those provided by the earlier curve.

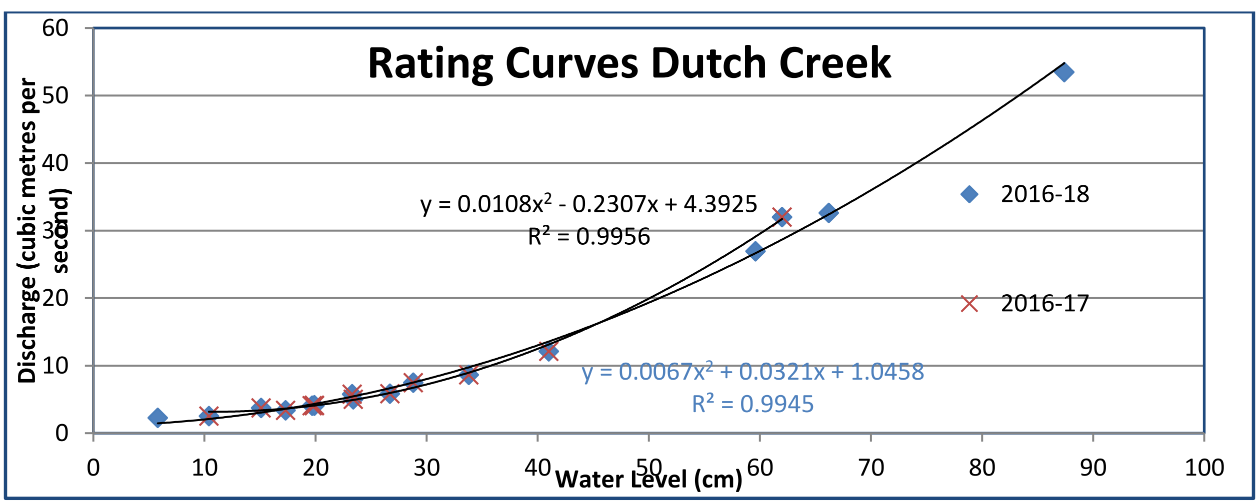


Figure 12 –Rating curves for Dutch Creek. One is based on flow measurements available up to 2017.

The second is derived from the same data set plus four new measurements made during 2018. The upgraded curve yields lower flow rates when water levels are high.

5.2.4 Flow

Flows for the Columbia River and Dutch Creek constructed from the respective upgraded rating curves and water levels in Figure 9 are shown in Figure 13. The period begins on April 24, the date on which the water level in Dutch Creek first responded to the spring runoff, and continues until October 28., 2018 and encompasses the spring runoff and most of the subsequent recession. The level of Columbia Lake is also shown for comparison.

Once the runoff was underway, the rate of flow at the Dutch Creek site consistently exceeded that at the WSC Site until May 27. During that period water was being stored and since the lake was rising simultaneously the excess water was almost certainly being stored in the lake. Shortly after the inflow reached a peak, the lake level also crested and thereafter, with one or two exceptions, outflow predominated. Water was gradually lost from storage during the extended period of recession that followed.

The maximum recorded hourly rate of flow at the WSC Site was estimated to be 65 cubic metres per second (cms) and occurred on May 29. The corresponding value in 2017 was 70 cms. Detailed statistics for the original station operated at that site are available for further comparison online at [https://wateroffice.ec.gc.ca/report/statistics_e.html?stn=08NA045&mode=Table&type=stat&results_type=statistics&dataType=Daily&parameterType=Flow&y1Max=1&y1Min=1.](https://wateroffice.ec.gc.ca/report/statistics_e.html?stn=08NA045&mode=Table&type=stat&results_type=statistics&dataType=Daily&parameterType=Flow&y1Max=1&y1Min=1)

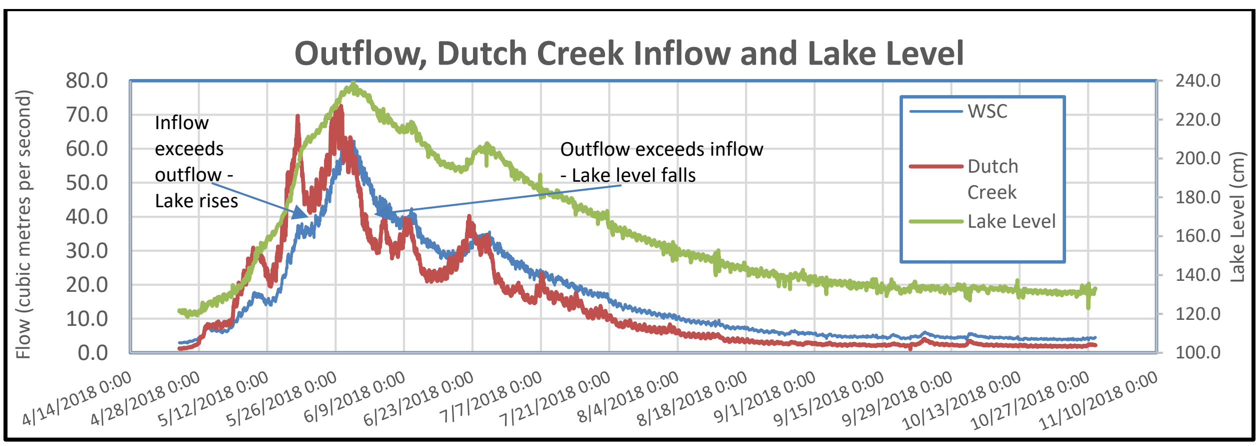
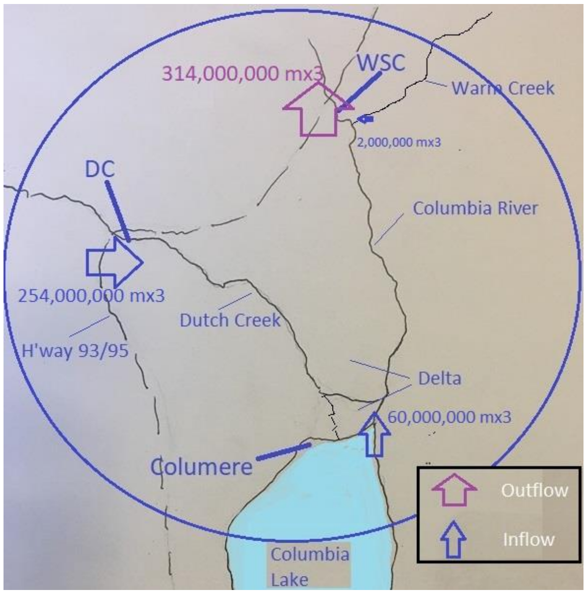


Figure 13 – Estimated hourly rates of flow on Dutch Creek and on the Columbia River at the WSC site. Lake level is also shown.

5.2.5 Seasonal Inflow and Outflow Volumes

Flows calculated from the updated rating curves, especially that from Dutch Creek, makes it possible to estimate the volumes of water being transferred over the delta area. The schematic map (left) shows the points where water enters and leaves the wetlands area surrounding the Dutch Creek delta. Water enters from three locations: Dutch Creek, Columbia Lake, and Warm Creek and associated smaller tributaries. It exits via the Columbia River. The volume flowing from the area over the 2017-18 year is estimated to have been 314,000,000 cubic metres based on the WSC flow data. The inflow from Dutch Creek is estimated to have been 254,000,000 3^3 based on the DC flow data. The inflow from Warm Creek is estimated to have been 2,000,000 cubic metres or less and since that amount is within the error margin in the foregoing estimations has not been considered. Simple subtraction permits the heretofore unknown flow out of Columbia Lake to be estimated. It was about 60,000,000 cubic metres for the 2017-18 water year and made up about 19 percent of the total outflow. The proportion will change from year to year.



5.2.6 Proportion of Dutch Creek Water Entering Columbia Lake

The difference between the WSC outflow and the Dutch Creek inflow also offers some insight into exchanges taking place in Columbia Lake.

The rise in Columbia Lake represents stored water. The rate at which that water is being stored can be calculated from the surface area of the lake and the hourly change in lake level measured at the Columere site. Figure 14 shows the accumulation of the hourly changes over the April 14 – Oct 28, 2018 period. The hourly rate at which excess runoff was being accumulated can also be calculated from the Dutch Creek and WSC records. The accumulation of those hourly amounts is also shown in Figure 14.

Not unexpectedly the amount of stored water reached a maximum when the lake peaked. The stored water is from two sources. One is the excess runoff from Dutch Creek shown in green. The other, shown in purple, is the net local inflow into the lake and is the result of the integration of gains to the Lake from groundwater, surface runoff and precipitation and the losses from evaporation and consumptive use.

By July 11 all of the excess Dutch Creek runoff held in storage had been depleted. After that only accumulated local inflow remained and the lake will continue to draw down until later in the year when it reaches its normal winter level.

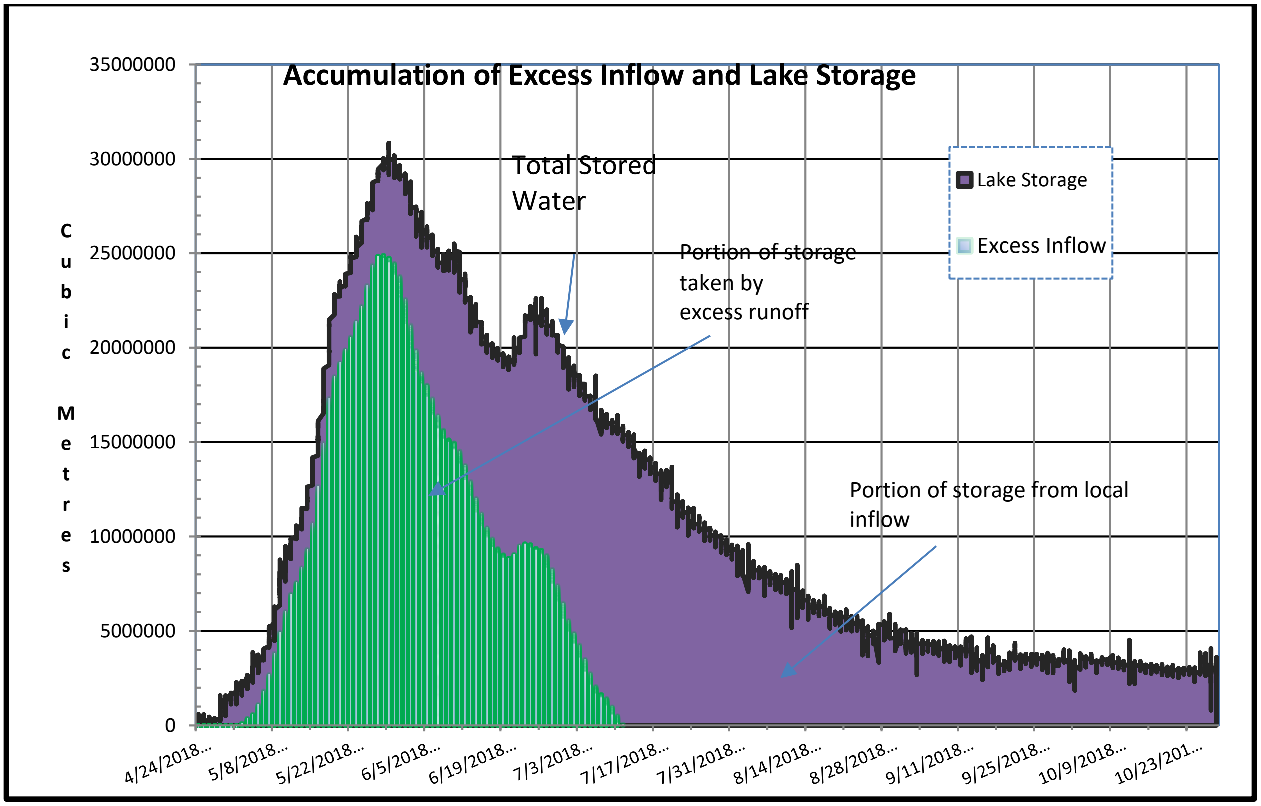


Figure 14 – Comparison of contribution of water from Dutch Creek to total change in lake volume.

6. Discussion

The findings here contrast with the perspective presented in the Lake Management Strategy (see RDEK, 1997) on two points.

First, the Strategy estimated the average annual flow from Dutch Creek to be 397 million cubic metres at a point above the alluvial fan. The measured flow at the Dutch Creek bridge during the 2017-18 water year, a year of near normal runoff, to have been only 254,000,000 cubic metres, a substantially smaller volume. In fairness, the estimate was derived by transposing the flow from Toby Creek, an accepted procedure in situations where there are no actual measurements.

Secondly, because of the overestimate the inflow from Dutch Creek alone exceeded the outflow at the WSC site. The excess was judged to have been lost to the alluvial fan and ground water. The revised flow estimates show that the inflow from Dutch Creek does not exceed the outflow when examined on an annual basis but there is a period a few weeks following the onset of the spring runoff when the reverse is true. This results in an excess of water that backs up into the lake causing it to rise. In effect, the lake becomes a reservoir. Eventually the inflow drops off and the Columbia River regains the ability to carry off the stored water. Thus, all the surface water entering the delta is accounted for and there are no significant losses to infiltration.

The foregoing shows that water Dutch Creek enters the lake and, as a result, upstream activities may have an impact on the health of the lake. Development that alters the natural flow during the runoff period will have an impact on lake level. There are also implications for water quality.

7. Network Adequacy, Design and Future Activities

The CLSS's monitoring program has reached a point where it is working well and has been successful in determining the interaction between Dutch Creek and Columbia Lake waters. The network will be maintained to extend the database so that the effects of variations in climate might be examined. Apart from replacing some aging data loggers and damaged equipment no major changes are anticipated in equipment in the forthcoming year.

Now that a means of calculating the outflow from the lake has been established attention can be shifted toward calculating the water balance of the lake. As noted, water enters the lake from groundwater, surface runoff and precipitation and is lost from the lake through evaporation and consumptive use. A new initiative will be initiated estimate their respective contributions to the balance.

8. Conclusion

Hydrometric data collected over the past four years and especially over the past season has brought a fresh insight to the way water flows into and out of Columbia Lake.

The annual rise and fall of Columbia Lake is attributable to waters entering the lake from Dutch Creek during the spring runoff. Water flows from Dutch Creek faster than it can be carried away by the Columbia River. This excess water spills out over Dutch Creek delta and enters the Lake. The lake serves as a reservoir until the Columbia River regains the ability to carry off the excess.

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10. Acknowledgements

Salena Dewar-Ghazal, a summer student, assisted with streamflow monitoring activities and data management. Nancy Wilson and Pat Silver also assisted with monitoring.

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 the 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
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 data was collected using data loggers. The loggers measured pressure and temperature and recorded 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.

The pressure sensors are non-vented. This means that the sensor measures the pressure exerted by the column of water above the pressure sensor 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. One of the Diver loggers, referred to here as the BARO, is designed to measure atmospheric pressure

Errors may arise due to improper measurement of atmospheric pressure, inaccurate calibration of pressure sensors, sensor drift, and changes in water density.

The BARO logger also served as a standard against which the performance of the remaining loggers was evaluated. The accuracy of the BARO in turn was evaluated by comparison with the barometer in the weather station at the Fairmont Hot Springs Airport (CYCZ). Simultaneous measurements were made at both locations at the beginning and the end of the open water season. The results are shown in Figures A1 and A2.

The records at the beginning and the end of the season displayed an average difference of 2.3 and 3.6 cm H2O, respectively. For reasons of convenience and security, the BARO is in the community of Timber Springs at an elevation of about 40 metres above that of the Airport. The pressure must be reduced to Airport level to be comparable. The mean of beginning and end of season values was assumed to be applicable to the entire open water season and hence a correction of 3.0 cm H2O was applied. The elevations of all monitoring stations except Dutch Creek are within 5 metres of Airport level so that no further elevation correction is required. The Dutch Creek station is 24 metres higher than the Airport. 1.0 cm H2O was added to the BARO readings to obtain the atmospheric pressure at that location.

All the remaining loggers except logger 1459 were taken out of service and operated in close proximity to the BARO for a few days at the beginning and the end of the open water season. The resulting pressure measurements are shown in Figures A3 and A4. Logger 1459, installed in Lansdowne Creek, was difficult to access and only spot readings made during periodic visits were available for comparison. They showed that its bias had not changed from previous years.

The newly acquired HOBO loggers were not yet available for the beginning of the season test and were compared with the BARO separately. The results are shown in Figure A5.

The pressure sensors were not all in agreement thereby indicating a need for adjustment. The mean offsets from the BARO at the beginning and the end of the season are shown in Table A1. The difference between offsets at the beginning and end of season readings for each of the pressure sensors was less than 2 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 that were applied from April 17, 2018 onward and are also shown in Table A1.

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.

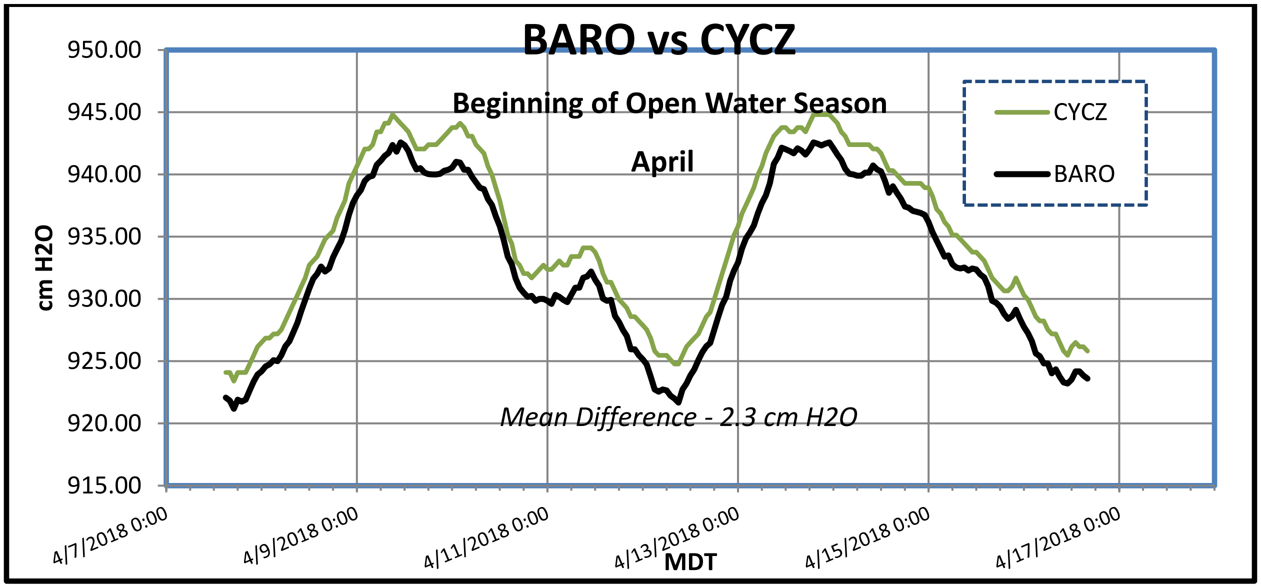


Figure A1 –BARO and CYCZ pressure records at beginning of open water season.

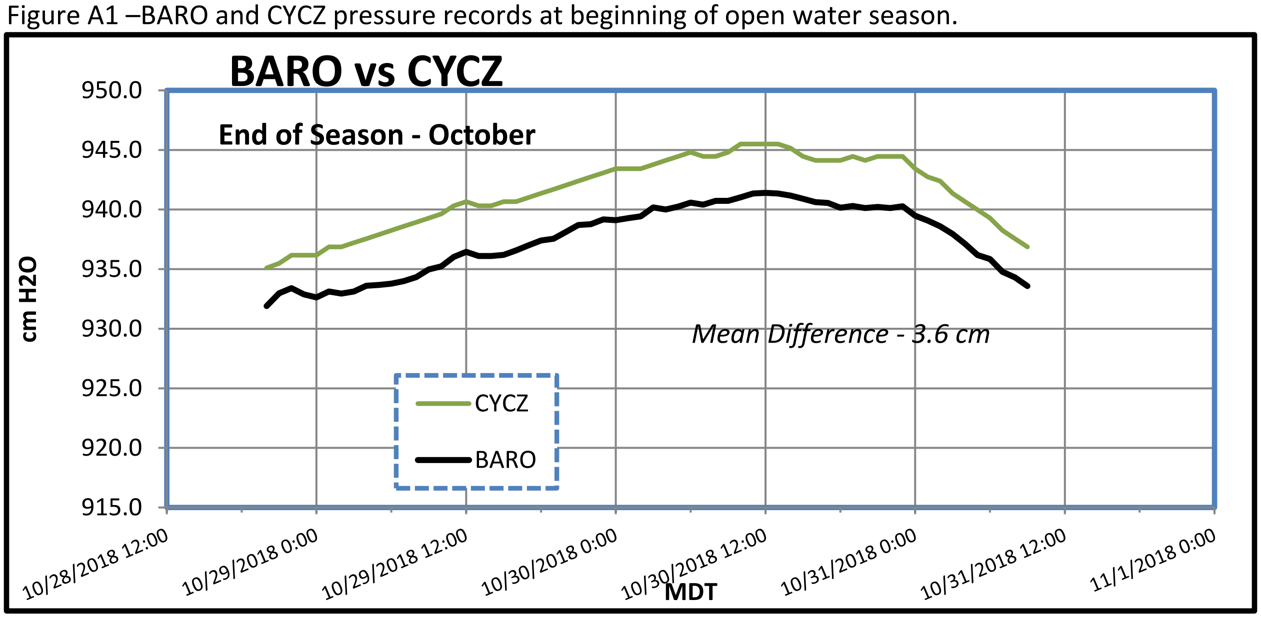


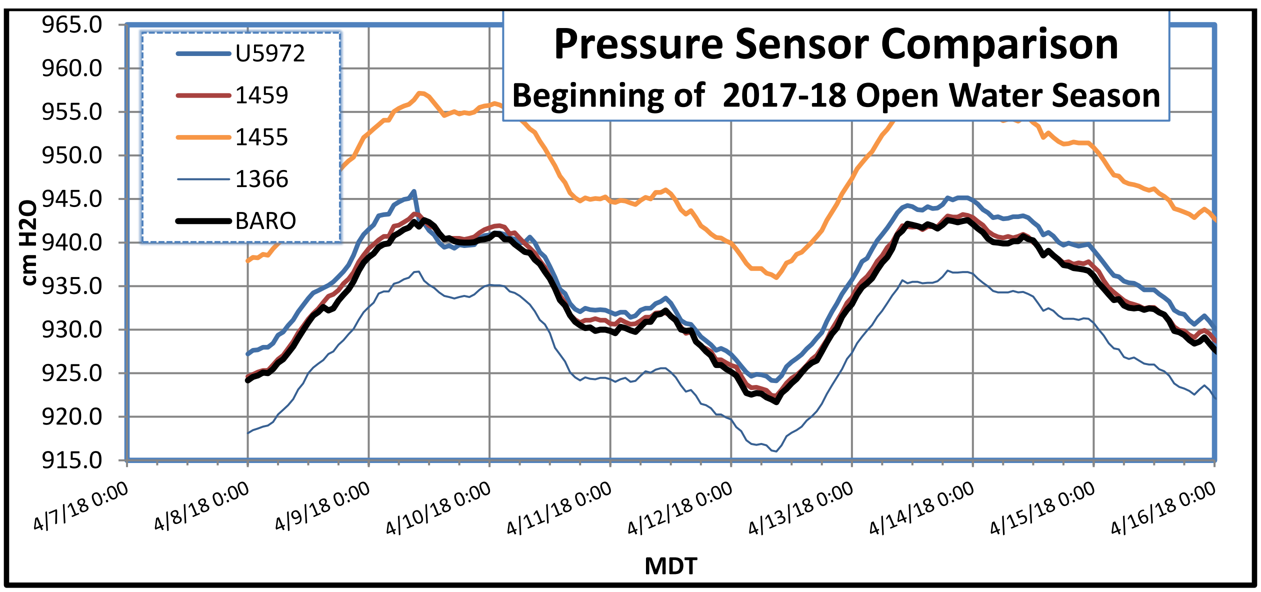
Figure A2 –CYCZ and BARO pressure records at end of open water season.

Table A 1 – Measured Offsets from BARO during Calibration trials

2018

		Beginning of Season		End of Season		Correction
Logger ID	Location	Mean	Offset from BARO (cm H2O)	Mean	Offset from BARO (cm H2O)	Applied (cm H2O)
U5972[1]	Columere/DC	933.2	0.0	940.5	2.7	1.4
H326[2]	Columere		-2.5	936.8	-1.0	-1.8
1459	Canal Flats	933.2	0.0	940.1	2.3	1.2
H325[3]	WSC		-2.7	936.6	-1.2	-2.0
1455	Dutch Creek	947.6	14.4	954.3	16.5	15.5
1366	WSC	927.3	-5.9	933.1	--4.7	-5.3
BARO	Timber Springs	933.2	0.0	937.8	0.0	0.0

1. U5972 at Columere Nov 3 until Apl 7. Backed up by 1455 from Dec 3 until April 7. Back up at Dutch Creek Apr 23 until Sep 30
2. Tested independently at beginning of season. H326 replaced U5972 at Columere April 18
3. Tested independently at beginning of season H325 installed at WSC May 10 to measure atmospheric pressure.



FigureA3 – Pressure readings from all other loggers in relation to the BARO at the start of the season.

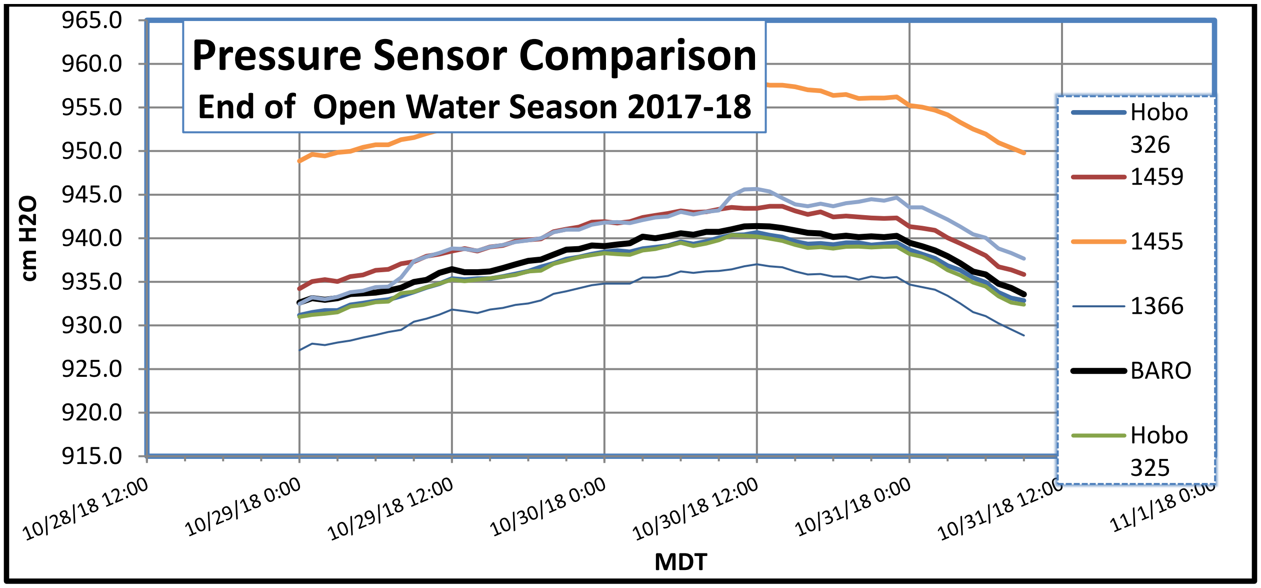


Figure A4 – Pressure readings from all loggers except 1459 in relation to the BARO at the end of the season.

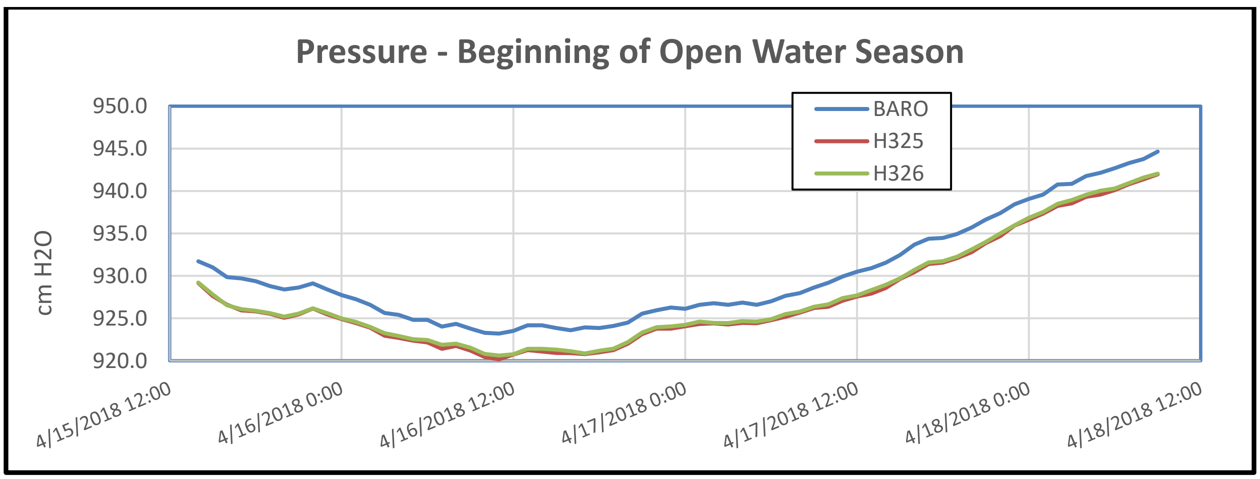


Figure A5 – Pressure readings from loggers H325 and H326 in relation to the BARO at the beginning of the open water season.

A2- Water Temperature

Beginning and end of season comparisons of the temperature sensors were made in similar fashion. The results are displayed in Figures A6 and A7, respectively. The test bed was not an ideal one. The BARO was better exposed to the open atmosphere than the other loggers with the result that its temperatures varied a bit more especially during the spring trials. The other loggers consistently provided values of similar magnitude and hence those loggers are judged to have provided data of acceptable accuracy.

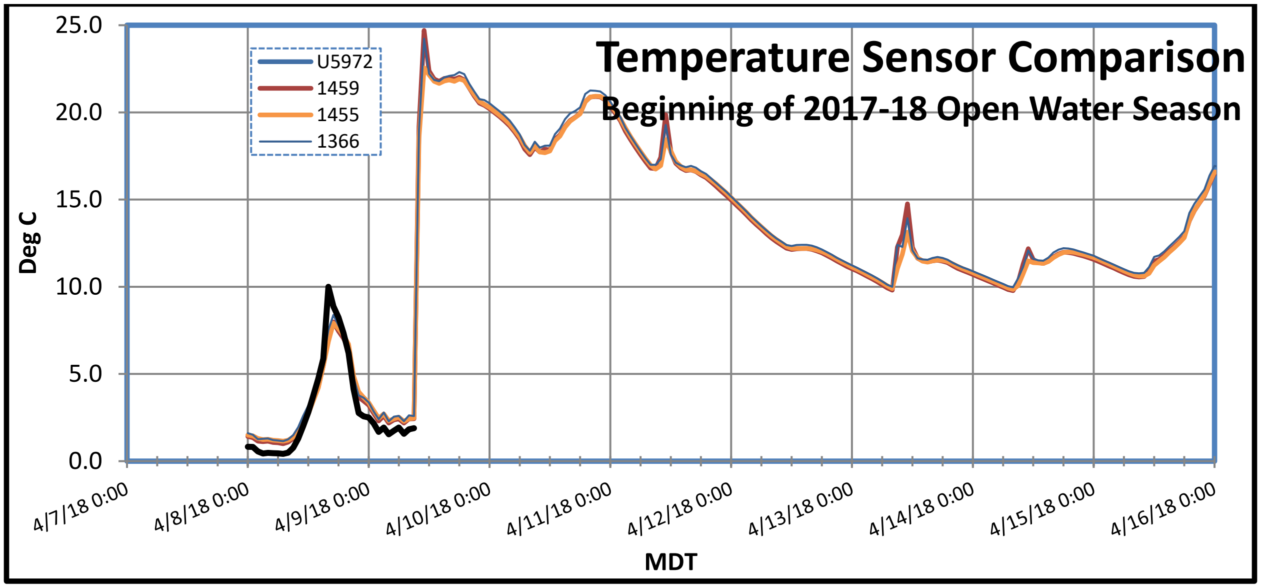


Figure A6 – Temperature readings from all loggers in relation to the BARO at the start of the season.

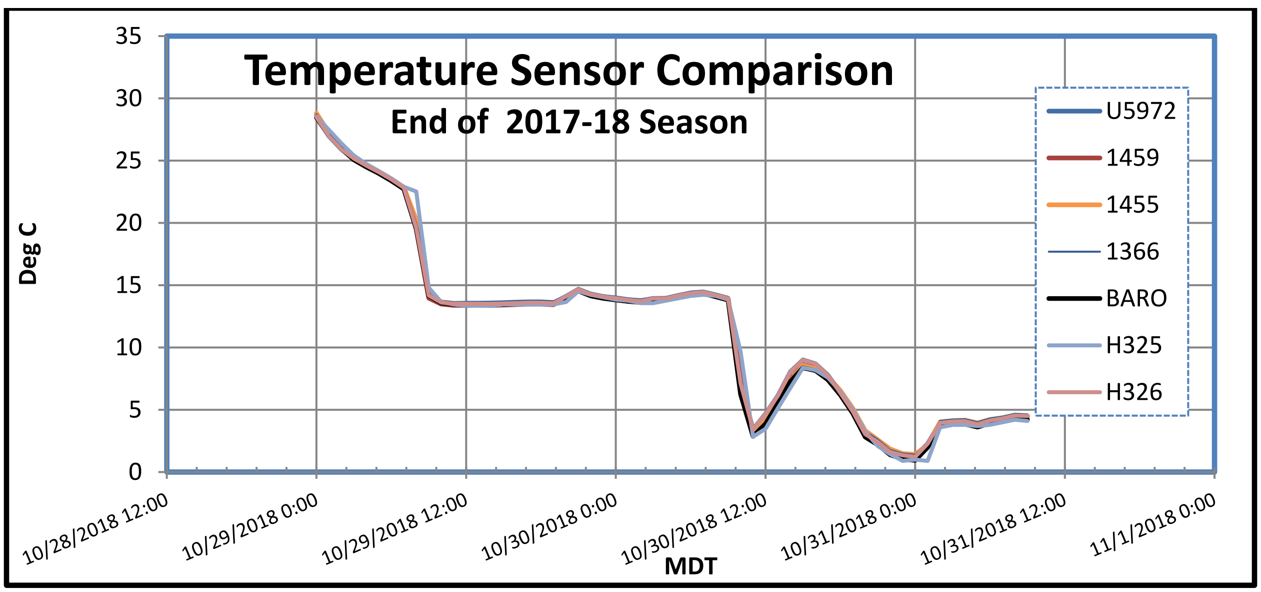


Figure A7 – Temperature readings from all loggers in relation to the BARO at the end of the season.

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 was not further calibrated.