Summary of Columbia Lake Stewardship Society's 2014 Monitoring Program

Prepared by Bill Thompson

Introduction

The Columbia Lake Stewardship Society (CLSS) was formed in 2013. Its mission was defined as follows:

- "Act as a citizen-based, water stewardship group for Columbia Lake.
- Implement activities which monitor and help maintain the ecological health of Columbia Lake.
- Communicate and network with others, as required, to achieve the above."

The CLSS was not the first group to express interest in the health of Columbia Lake. Public concern was raised in the 1990's about water quality and hydrology due to increasing development. This prompted the Regional District of East Kootenay (RDEK) to undertake a study of the Lake's water quality, water levels, condition of the habitat, foreshore and recreational use. That Study resulted in the Columbia Lake Management Strategy prepared by Urban Systems (1997). One of its key recommendations was that a community based steering committee be formed. The rationale in part stated that "from this locally based citizen committee will flow the impetus for action and the desire to manage change effectively". Such a body was subsequently formed but disbanded after a few years due to lack of interest. The CLSS saw itself stepping forward to restart the process of establishing such a Committee.

The Strategy also recommended that water quality and water level monitoring programs be established. The CLSS saw both programs as necessary to provide baseline data on which future management decisions could be based. As a result, its first initiatives were to implement water quality and water quantity monitoring programs.

This document summarizes the results of the Society's first season's monitoring activities.

The Watershed

The watershed surrounding Columbia Lake has not been of constant size owing to meander of the channel within the delta of Dutch Creek. Aerial photos taken in 1975 showed that the Creek was flowing directly into the north end of Columbia Lake at a point not far from the Columere Marina. At some point in time after 1975 the channel changed so that the bulk of the flow was directly into Columbia River. Thus in theory the Dutch Creek drainage area is no longer part of the Lake watershed.

Another complicating factor is underground seepage. Urban Systems indicated that a large amount of water enters the Lake via sub-surface transport form the adjoining Kootenay River.

The combined Dutch Creek – Columbia Lake watershed is shown in Figure 1.

Water Quality Program

Planning for the water quality program started in late 2013. Field activities commenced following ice breakup in April 2014. To help get the program underway the Lake Windermere Ambassadors loaned sampling equipment and provided instruction on its operation. The first samples were taken on April 20. By June the CLSS had its own equipment. Field sampling continued until September 28 with various shoreline communities providing observers and boats. Nine sampling missions were conducted over the five month period. Sampling was conducted at four designated locations: N1, S1, S3 and S4 (see Figure 1). At each location onsite measurements were made of: dissolved oxygen, water temperature (Lake surface and bottom), conductivity (top and bottom), pH, turbidity, and water clarity (using a Secchi plate). Water samples were also taken and submitted to a Laboratory to be analyzed for phosphorous and nitrates. Basic weather and wave conditions as well as Lake Depth were recorded to provide background information.

Observed Data

The measurements recorded during the 2014 season are shown in Appendix 1.

Historical Data

Urban Systems emphasized the need to be on the lookout for trends that might signal deterioration in water quality. For this purpose it suggested that measurements, especially those of phosphorous and nitrogen, be compared with historical measurements. In an attempt to identify changes that might already have been taking place at the time of the preparation of the Management Strategy, Urban Systems conducted its own sampling program. Sampling was conducted on June 27 and June 28, 1996. The sampling was conducted at four sites that it identified as; S1, S2, S3 and S4. S1 and S3 correspond to those used in the 2014 program. Its site 4 was located about 1 km north of the south end of the Lake and did not coincide with the 2014 site 4.

One of the problems Urban Systems faced in attempting to quantify change was locating historical data for comparison. Only two data sets existed. One is described in Rocchini et al (1976). Inspection of that Report reveals that the sampling was conducted on September 23, 1973 at two sites. The first site was in the vicinity of the 2014 Site, S1. The second was near the south end of the Lake and close to the west shore. That location is shown in Figure 1.

The second study was conducted by RL&L Environmental Services Ltd. (1993). That Study could not be located to examine the original data. Urban Systems simply stated that the sampling was conducted in June 1983. The sampling locations were not identified and were lumped with other measurements into two site categories that Urban Systems identified as North End and South End. For purposes of this Report the day of observation is assumed to have been June 15.

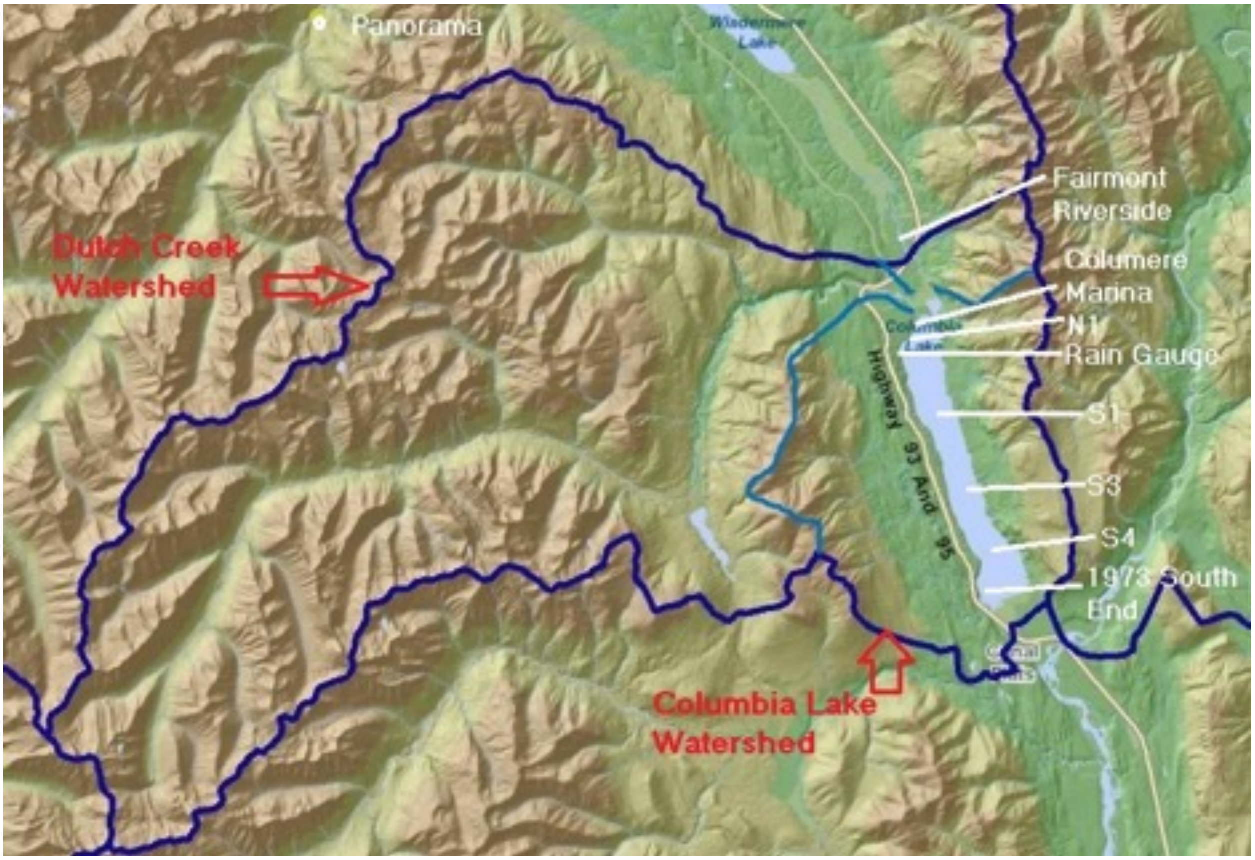

Figure 1 – Columbia Lake – Dutch Creek Drainage areas and sampling locations.

In an attempt to compare the 2014 data with earlier data the site categories used by Urban Systems have been adopted. All of the samples that it described as taken at North End, with the possible exception of the 1983 data, were taken near the 2014 Site, S1 and have been renamed S1 in the Figures that follow. There was no common location among the measurements falling in the South End category. Thus the South End description has been retained and observations from that area are identified in the Figures as S End Historical. Of those, the 1996 observations were taken near the 2014 site, S3, and is the only set that is known to be directly comparable.

The historical measurements including those made by Urban Systems in 1996 are shown in Appendix 2.

Examination of Water Quality Parameters

Water Temperature

Water temperature in combination with other parameters, most noticeably, dissolved oxygen and pH define the habitat that allows fish, other animals and plants to survive.

Figure 2 shows the surface water temperatures measured at each of the four locations over the course of the season. The water temperature peaked at about 25 Deg C in mid-July. Superimposed on the chart are the daily maximum and minimum air temperatures observed at Cranbrook Airport, the nearest weather station having a continuous record. July and August were unusually warm. The mean air temperature for July was 3.3 Deg C above the long term normal. August was 0.9 Deg C above the long term normal. Thus it seems likely that the water temperatures during July and August would also have been above normal.

The available historical data is shown in solid color in Figure 2. The values measured during June 2014 were above their historical counterparts. Those measured in September were only slightly warmer.

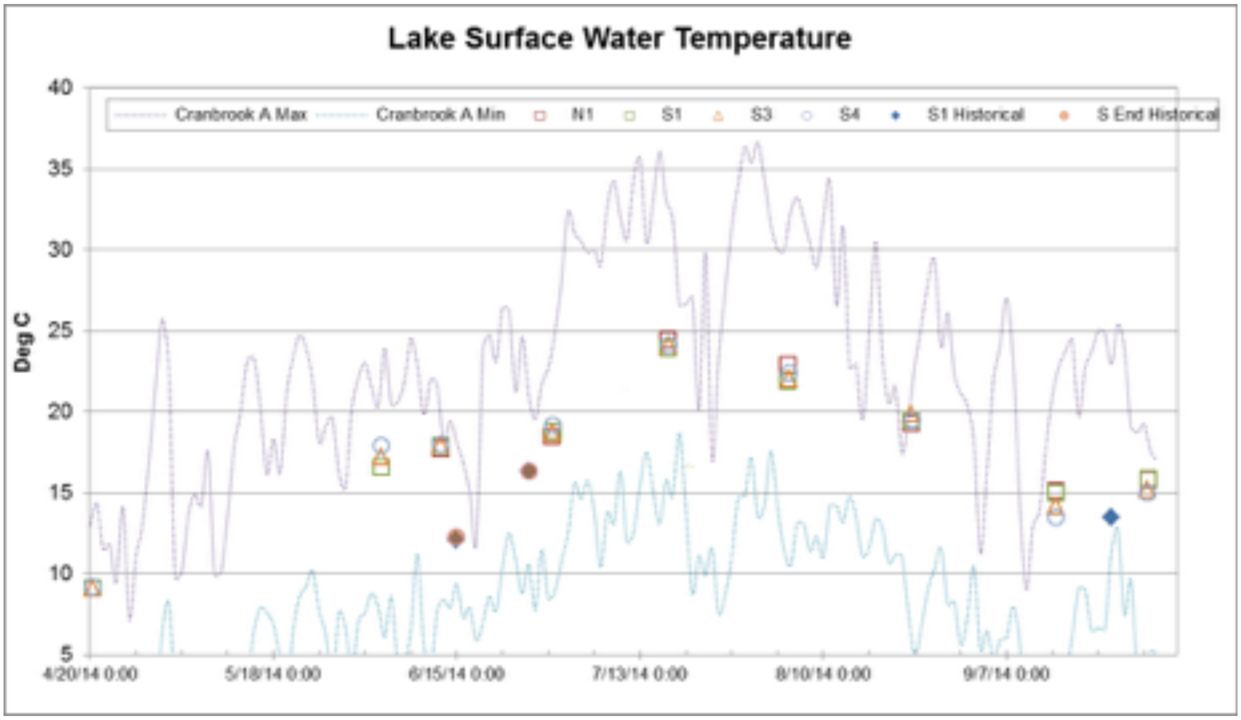

Figure 2 – Observed and historical surface water temperatures. Cranbrook Maximum and Minimum air temperatures are superimposed.

Dissolved Oxygen

The observed and available historical measures of dissolved oxygen are shown in Figure 3.

The mid-July and early September run counter to expectation. Normally the level of dissolved oxygen is higher in cool water and lower in warm water so that a decline would have been expected as spring progressed into summer with the opposite taking place in the fall. The July and September values clearly do not conform. It is unclear whether the values are real or in error. Harma (2014) also cites unusually values on Lake Windermere during the same period lending support to their credibility. On the other hand, a value of 14 mg/L is out of range.

The early season values compare favourably with the available historical values.

Low oxygen levels in combination with warm water can lead to fish kill. There were reports of dead fish during late July but in far fewer numbers than have been observed in the past.

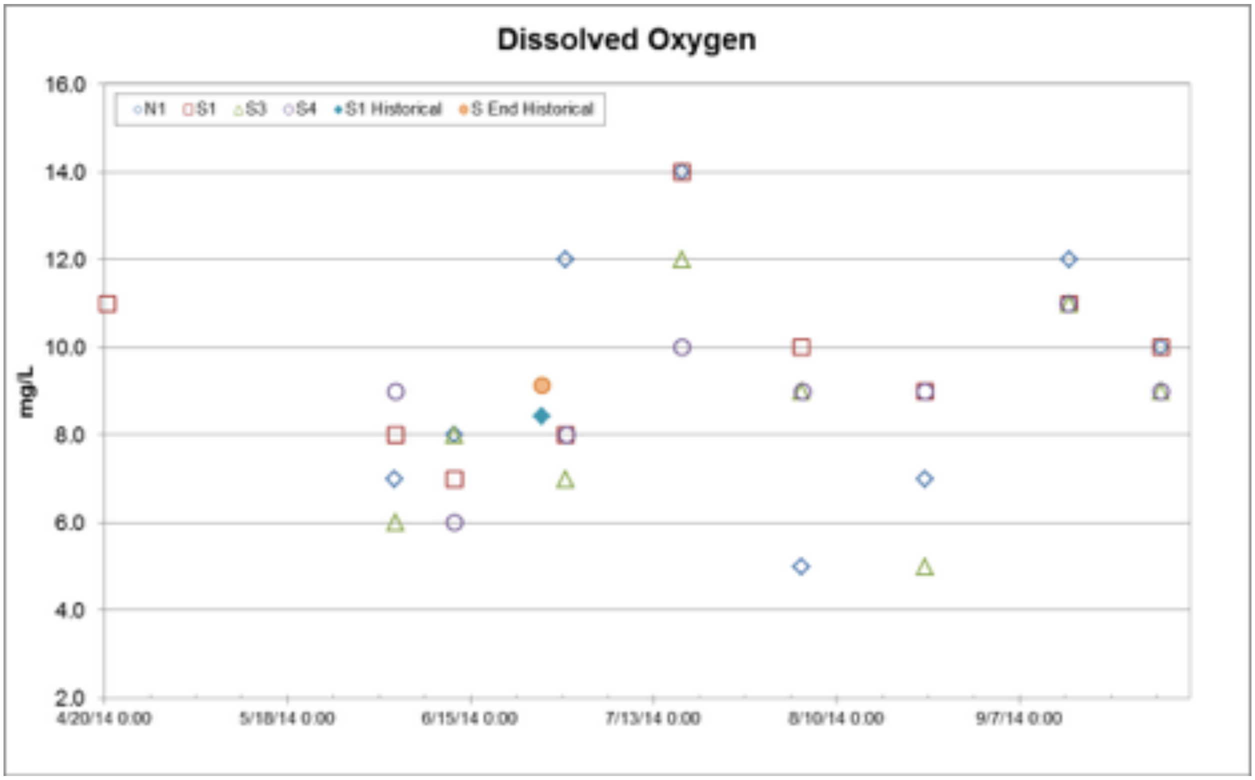

Figure 3 - Observed and measurements of dissolved oxygen made June 27 1996, the only set of historical data available for comparison

pH

The observed and available historical measures of pH are shown in Figure 4. Water is neutral at level 7 and alkaline at higher values. Thus Columbia Lake was alkaline throughout the season. This is characteristic of local lakes fed by water flowing over carbonaceous materials.

A seasonal trend was observed at all four locations. Values were lowest during the early spring and reached a peak by late August or early September before tapering off.

The early season values compare favourably with the historical values. The late season values are not in agreement but the sample size is too small to conclude that the difference is significant.

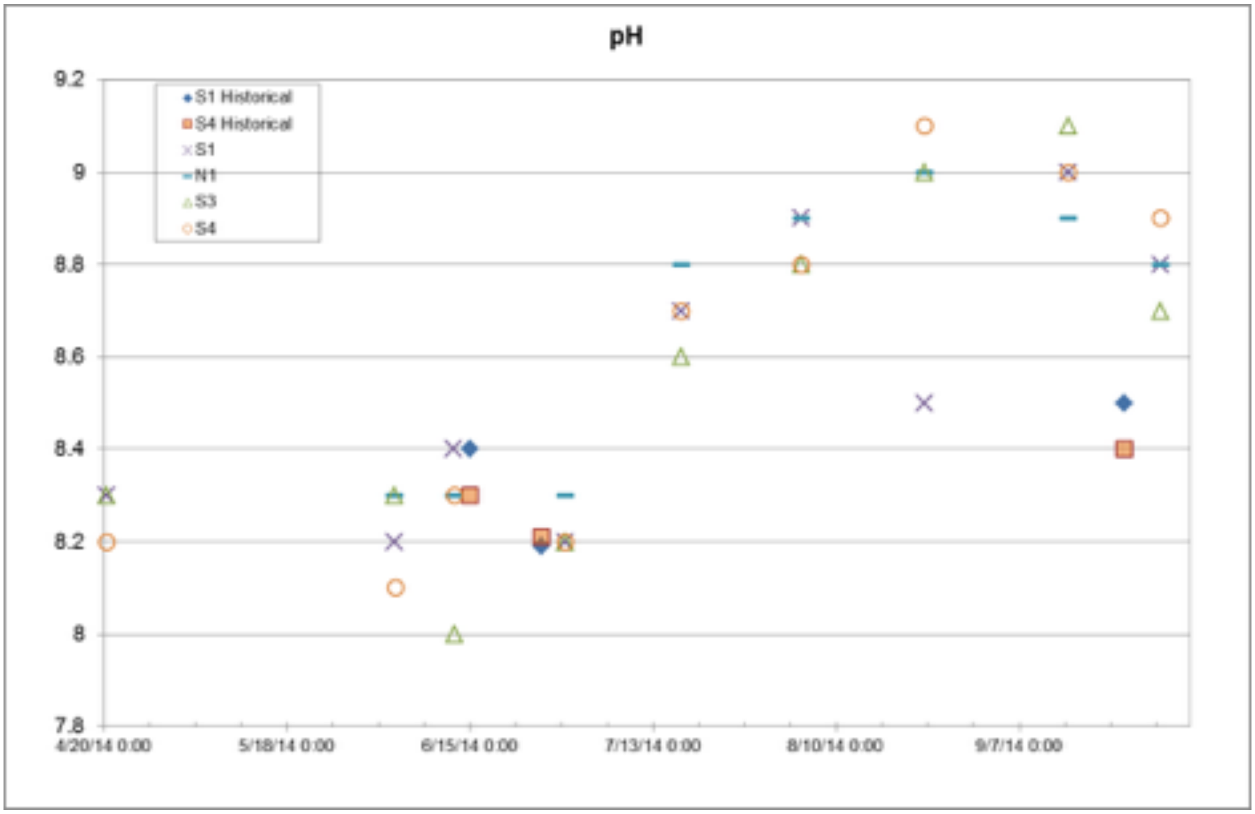

Figure 4 - Observed and historical measurements of pH.

Conductivity

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity is also affected by temperature: the warmer the water, the higher the conductivity.

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity. Streams that run through areas with clay soils tend to have higher conductivity.

Conductivity levels offer a clue to the nature of discharges entering the water system. A failing sewage system raises the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill lowers the conductivity.

The observed measures of surface conductivity are shown in Figure 5. Values of conductivity progressively increased from late spring until early July and then began to decrease reaching a minimum about mid-September. The mid-season peak is presumed to be due to warmer water temperatures and the influx of ions in runoff waters.

Elevated levels of conductivity were observed in the surface water on April 20. Since the ice had just disappeared from the Lake during the preceding few days it is assumed that materials present on or in the ice due to atmospheric transport had not yet completely dispersed.

There is some indication of geographic variation. On the whole conductivity levels werehigher over southern sections of the Lake than over northern sections. The trend is also evident in the 1996 observations. A reason for the variation, if real, cannot be advanced

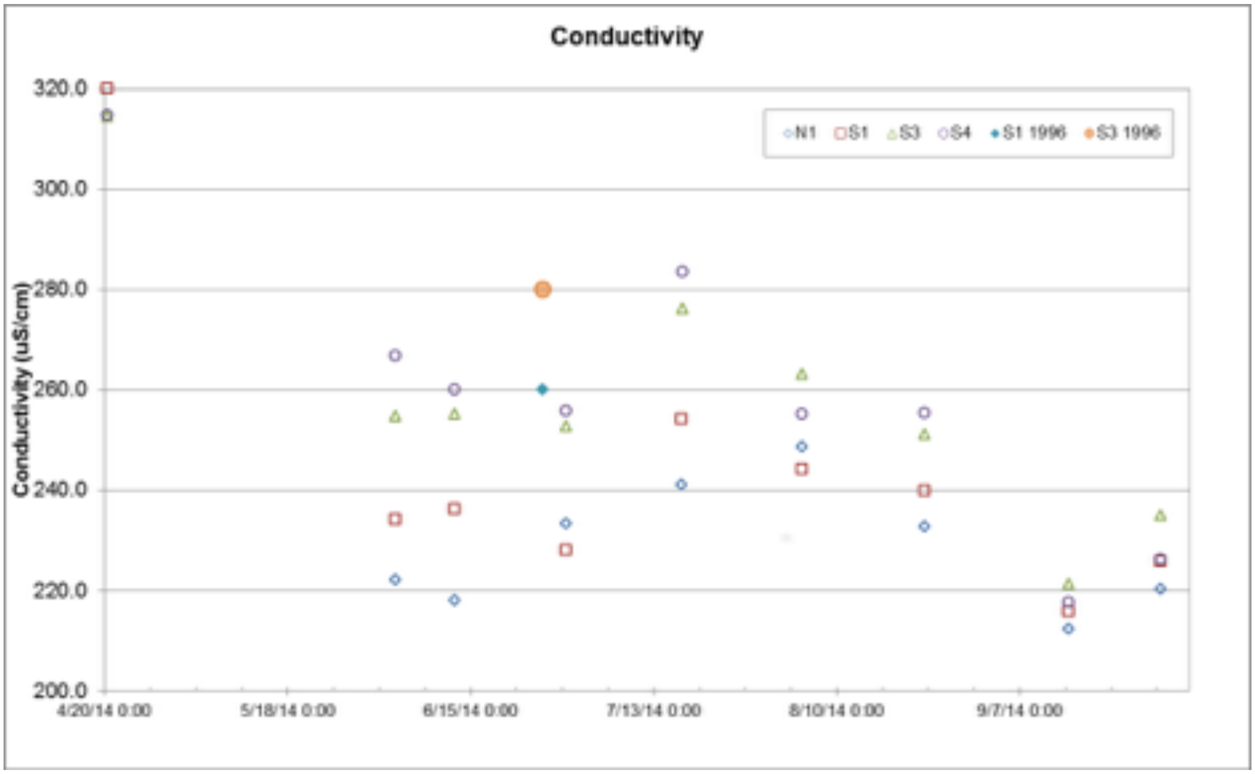

Figure 5 - Observed and historical measurements of Conductivity.

Turbidity

Turbidity is a measure of water clarity. Material suspended in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, and other substances. Turbidity can affect the color of the water.

Higher turbidity increases water temperatures because suspended particles absorb solar radiation more efficiently than pure water. This, in turn, reduces the concentration of dissolved oxygen (DO) because, as previously noted, warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water which in turn reduces photosynthesis and the production of DO.

Sources of turbidity include soil erosion, sediment carried by inflowing streams, mud stirred up from the Lake bottom by wave action and excessive algal growth.

The observed measures of turbidity are shown in Figure 6. Values of turbidity increased as the season progressed and reached a peak about mid-July and then began to decrease.

It should be noted that the values shown are biased to days having light winds. Measurements were not taken on windy days due to safety concerns. Wave action on windy days stirs up sediment to the extent that some sections of the Lake take on a distinct brown colour. Nevertheless, since observing programs are nearly always conducted in light wind conditions the values do provide an index for comparison.

Comparable values from earlier years are superimposed. The 2014 values generally fall within the range of the earlier values.

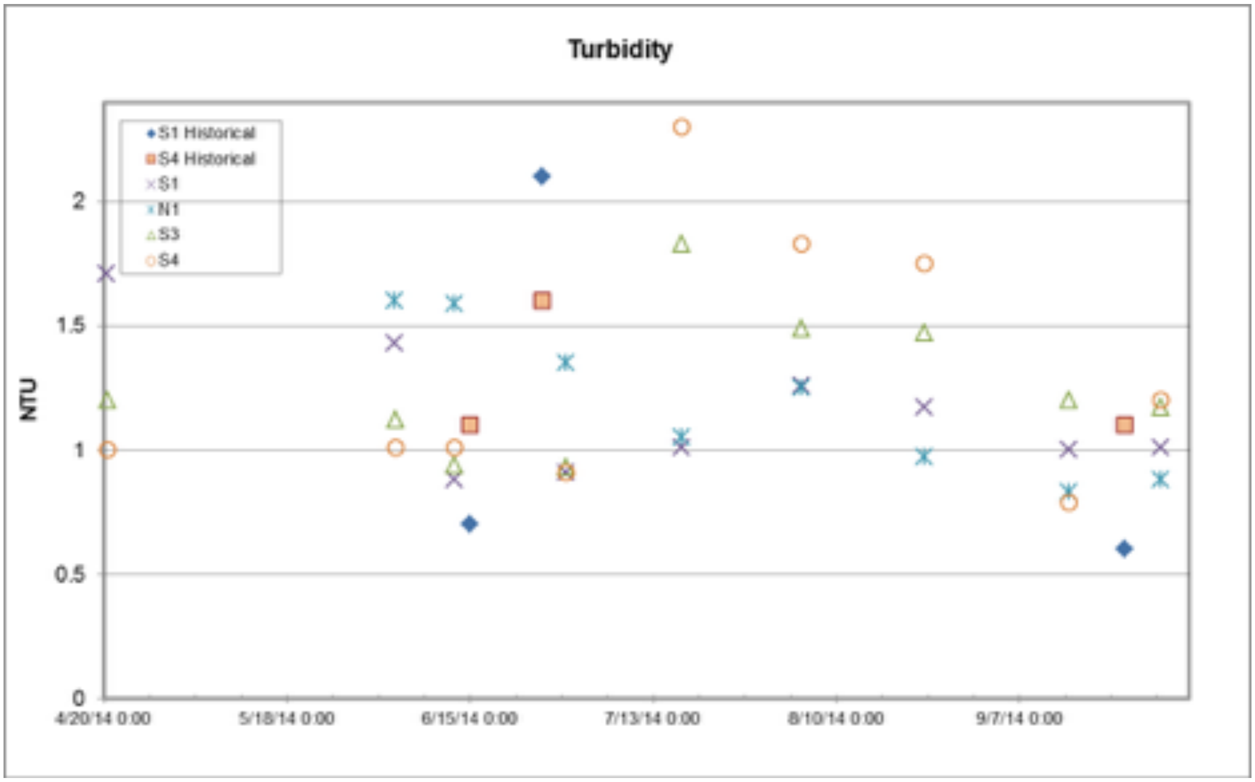

Figure 6 - Observed and historical measurements of Turbidity.

Secchi Depth

Water clarity can also be measured by observing the depth at which sight is lost of a submerged Secchi Disk (a black and white plate). The greater the depth to which the plate can be seen the greater the clarity. Secchi measurements are best suited for deep water lakes. In many BC lakes the disk is visible to four metres or more. Columbia Lake is shallow. The maximum Lake depth recorded at any of the sites was only 5.3 metres and was generally less. Thus in in water of normal clarity the disk would be visible on the Lake bottom.

The depths at which the Secchi disk disappeared from view are shown in Figure 7. Site N1 is not included because it was located in shallow water. Except for the July 17 and August 4 observations, the disk was still visible when lying on the Lake bottom.

Sight of the disk was lost before it reached the bottom during the July - early August missions signifying less clarity at those times. This is consistent with the trend for clarity displayed by the foregoing turbidity measurements. Thus, the amount of suspended material would have been a maximum at mid-summer.

The only available measurements available for comparison were those made by Urban Systems on June 28, 1996. They ranged from 3.5 to 4.0 metres and are consistent with those observed in 2014.

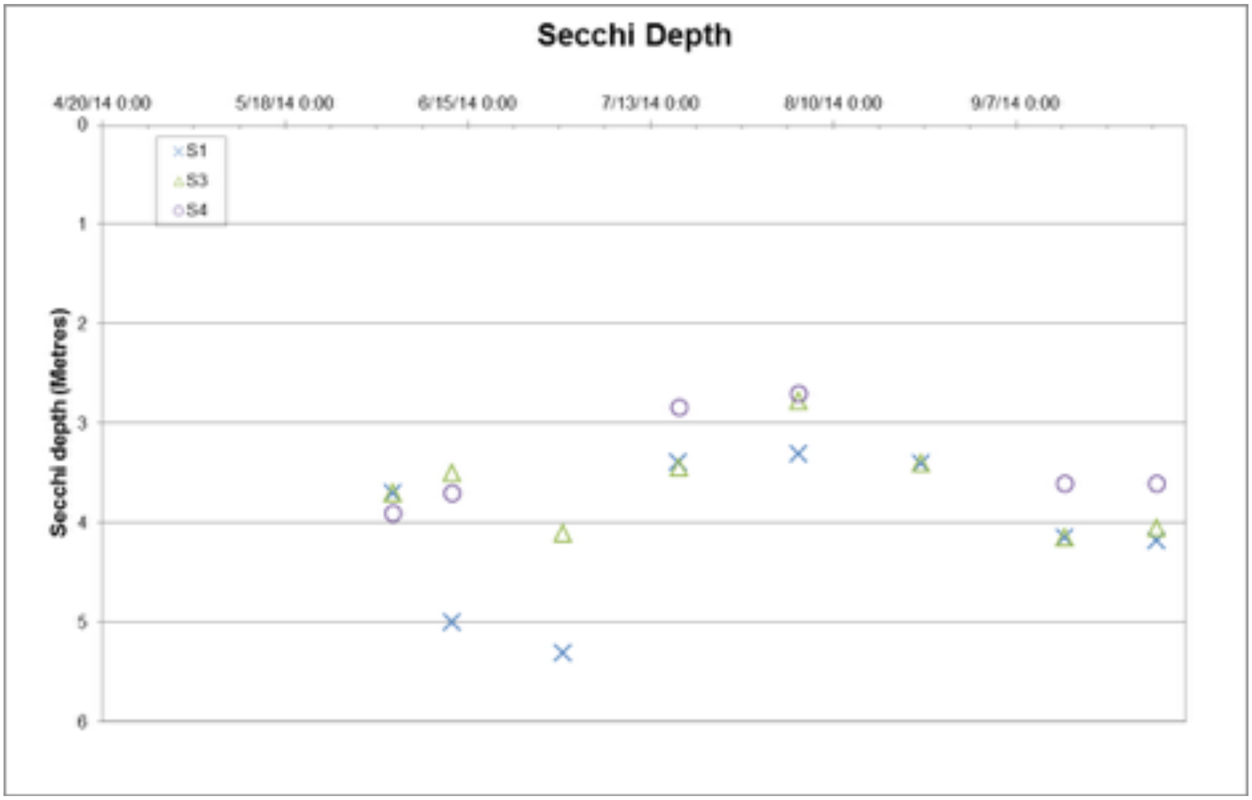

Figure 7 - Observed measurements of Secchi depth.

Phosphorous

Phosphorus is one of two essential nutrients necessary to sustain the food web specifically algae. In the absence of phosphorous algae cannot exist. An increase in phosphorus has the potential to set off a series of events that starts with rapid plant growth and algae blooms. These in turn lead to low levels of dissolved oxygen and ultimately to fish kill.

Sources of phosphorus include soil and rocks, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, and drained wetlands.

Phosphorous was sampled on only four occasions; April 20, June 3, June 29 and September 14. Of these, sampling was performed at Sites 3 and 4 on all four occasions. Site S1 was only sampled on April 20 and June 29th and N1 on June 3, June 29th and September 14. The number of samples is too small to conclude anything other than the values fall within or close to the range of those observed in the past.

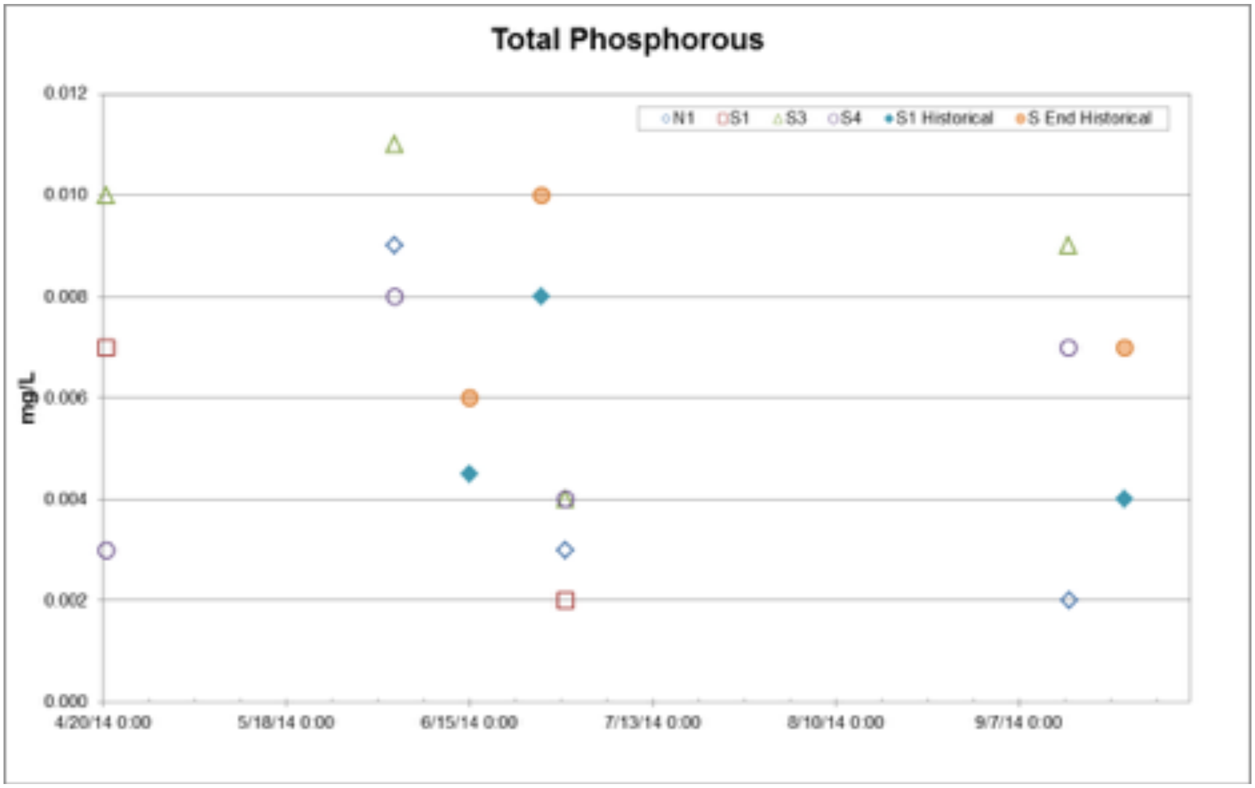

Figure 8 - Observed measurements of Total Phosphorous

Nitrogen

The second essential nutrient is nitrogen. Nitrogen is needed for plant growth. As was the case with phosphorous, elevated nitrogen levels cause more algae to grow which in turn blocks out sunlight and reduces the amount of oxygen available for fish. Nitrogen can be oxidized by microorganisms to produce nitrates and nitrites. Elevated levels of nitrates and nitrites in drinking water can produce undesirable health effects.

The most common sources of nitrogen and nitrogen compounds are agricultural activities, wastewater treatment, and discharges from industrial processes and motor vehicles.

Samples were taken on the same dates and following the same routine as those for phosphorous.

The samples were tested for Nitrate. All results were less than or equal to 0.010 mg/L, the Method Reporting Limit, except that for those taken on June 29 at sites N1 and S4. They tested 0.027 and 0.032 mg/L, respectively. The maximum acceptable concentration for nitrates according to the Canadian Drinking Water Guideline is 10 mg/L so that all samples fell well below that threshold.

It was not possible to compare the 2014 values with previous values because the compounds of nitrogen contained in the earlier values were not compatible.

Stratification

Cooler water entering lakes tends to settle to the bottom underlying the less dense, warmer water. In such cases the Lake is said to be stratified. In shallow lakes and especially those experiencing substantial inflow and fairly strong winds, mixing takes place so that most parameters are of similar magnitude throughout the water depth.

Urban Systems speculated that Columbia Lake was not stratified on the basis that its clarity allowed for heat absorption deep within the water. Also wind and wave activity further enhanced overturning. Figures 9 and 10 provide additional evidence that the Lake is not stratified, at least during the open water season. Figure 9 shows that the water temperatures near the bottom of the Lake were observed to be within a degree or two of those at the surface for each sample collected. Figure 10 shows that with the exception of one outlier a similar relationship was observed for conductivity. The outlier is suspected to be due a sampling issue but that cannot be confirmed.

These results tend to confirm Urban Systems assessment that the Lake is not stratified.

Summary

The 2014 sampling program provided the first insight into the temporal behavior of water quality parameters over the entire open water season. Prior to that, only snapshots of conditions in the months of June and September existed.

The summer of 2014 was unusually warm and water temperatures during July and August were probably warmer than normal. The water was slightly alkaline at the beginning of the season. Alkalinity increased as the season progressed reaching a maximum in late August-early September. Conductivity peaked in mid-July and was due to the warm water. Water clarity as measured both by Conductivity and the Secchi Disk was least during mid-summer. Some of the observed levels of dissolved oxygen did not fall within an expected range for the observed water temperatures but the discrepancy is felt to be due errors in sampling procedure and was not reflective of actual conditions

Phosphorous and Nitrates were sampled on four occasions,. The number of measurements was too few to identify seasonal trends.

Although the samples of phosphorous and nitrates were too few to judge directly whether or not changes were taking place in the nutrient load, the lack of substantial changes shown by the other parameters from historical values do not suggest a significant decline in the health of the Lake.

The main purpose of initiating this program is to detect future trends in lake water quality. Data collection needs to be sustained in order to detect such trends.

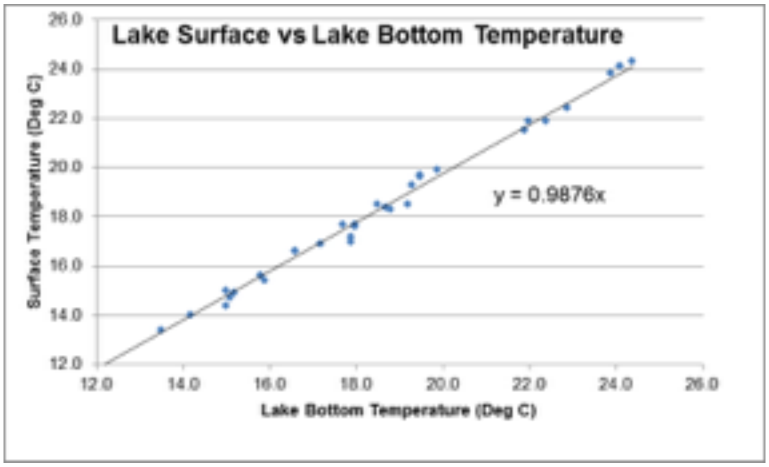

Figure 9 – Water temperatures measured at the surface compared with those measured at the bottom.

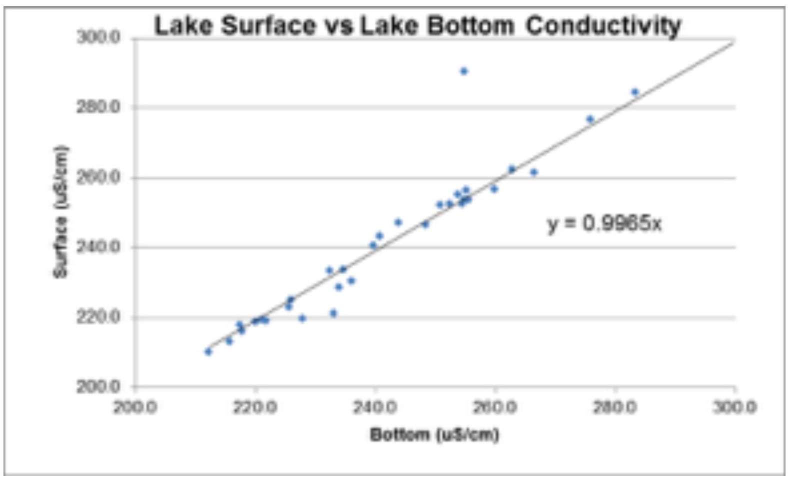

Figure 10 – Conductivity values measured at the Lake surface compared with those measured at the bottom.

Water Quantity

The goal of water quantity monitoring is to measure the inflow and outflow to Columbia Lake so as to better understand factors contributing to changes in water level.

One of the key decisions in designing the water quantity program was deciding on the area to be monitored. Although Dutch Creek no longer flows into Columbia Lake, there are a number of reasons favouring examination of the watersheds jointly. First, channels in the alluvial fan are not stable and flow could once again be routed directly back into the Lake. Secondly, the entry point of Dutch Creek is so close to the end of the Lake that it is not known what, if any, effect the flow out of Dutch Creek has on impeding the flow out of the Lake. Third, it is suspected that some water from Dutch Creek is being lost into the alluvial fan to reappear in the wetland area at the north end of the Lake. Fourth, increasing development in the lower reaches of Dutch Creek may have implications for water quality in the Lake should the channel return to its original location. Quite apart from the foregoing, and more significant, is that there is no practical means of monitoring the flow on the Columbia River above its confluence with Dutch Creek, a necessary step if the Lake is to be studied independently.

Water Survey of Canada operated a flow monitoring station on the Columbia River just upstream of the Bridge on Highway 93/95 near Fairmont Hot Springs (see Figure 1) from 1937 to 1998, a period of 56 years. Eight hundred ninety one square kilometres of drainage area exist above that point. Of that area only about 185 square kilometres reflects the contribution from the Lake and local inflow. The bulk, 696 square kilometres lies within the Dutch Creek watershed. Roughly 10 additional square kilometres lies within the Fairmont the Creek watershed. Even though the Fairmont Creek watershed is not part of the area of interest the old station site is the best location to conduct monitoring from a practical point of view.

Unfortunately the old station has been largely disassembled and the site reclaimed. In the longer term it is hoped to reopen the station but in the meantime a temporary station was installed to record outflow. It is located downstream on a bridge within the bounds of Fairmont Riverside Golf Course.

There are no known measurements of flow in Dutch Creek. There are also no known measurements of rainfall that might be used to estimate that flow. It is planned to install a water level station on Dutch Creek to compensate for that deficiency. It is also planned to install a water level monitoring station on the Source of the Columbia stream near Canal Flats. Its purpose will be to estimate the amount of sub-surface seepage entering the Basin from the Kootenay River.

Program Description

The water quantity program did not get underway until late in the season. By October data loggers had been installed at two locations, one in the Columere Marina and at the Fairmont Riverside site. Both locations are shown in Figure 1.

An hourly recording rain gauge had been in operation at a private residence on the west side of Columbia Lake. Arrangements were made to obtain data from that gauge. The rain gauge location is also shown in Figure 1.

The data loggers were equipped with sensors to measure pressure and temperature. The pressure sensors measured the combined weight of the overlying water and atmosphere. By removing the atmospheric component, the weight and thus the depth of the water above the sensor was calculated.

The data loggers were programmed to take an instantaneous measurement each hour on the hour. Data was downloaded via cable link to a computer.

The data loggers were removed for the winter on November 9.

The water levels recorded by the two recorders are shown in Figures 10 and 11. Hourly rainfall amounts recorded by the rain gauge are superimposed.

The water temperatures recorded at the two locations are shown in Figure 11.

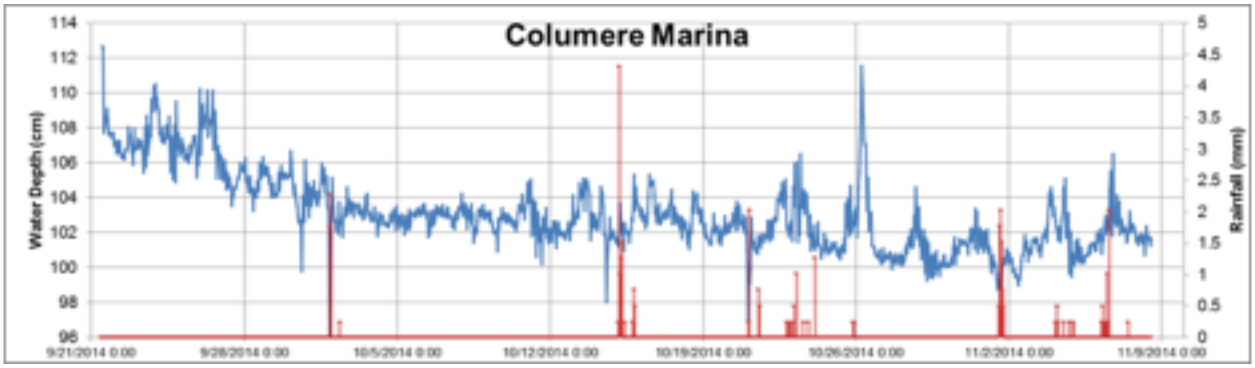

Figure 10– Hourly water levels recorded at the Columere Marina location with hourly rainfall amounts recorded at the 6058 Columbia Lake Road location superimposed.

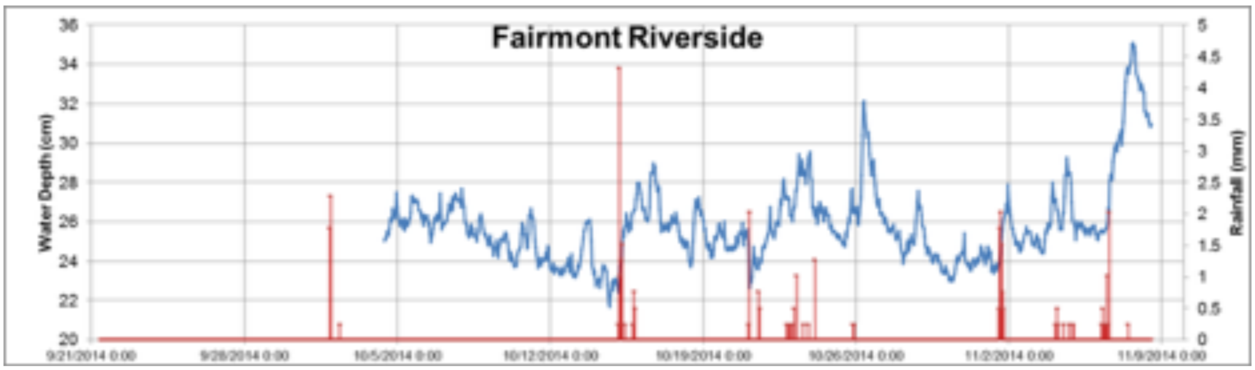

Figure 11– Hourly water levels recorded at Fairmont Riverside location with hourly rainfall amounts recorded at the 6058 Columbia Lake Road location superimposed.

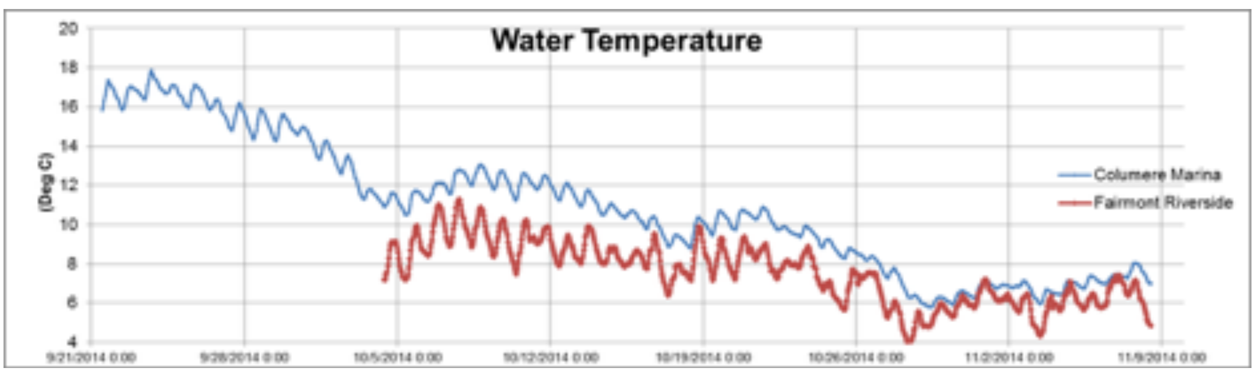

Figure 12– Hourly water temperatures recorded at the Columere Marina and Fairmont Riverside locations.

Interpretation

Columbia Lake usually peaks near the beginning of July and then begins to recede. On average the Lake level at peak is nearly one metre above its normal winter level.

Figure 10 indicates that the Lake level was well into recession by the time the data logger was installed on September 21. By October 5 the level began to taper off at a level about 103 cm above an arbitrarily selected datum. Superimposed on the downward trend are daily fluctuations. Some but not all follow rainfall events so that rainfall alone was not the cause of all of the fluctuations. Levels at the ends of long lakes are known to be affected by wind velocity. Wind velocity is not measured locally so that its impact could not be evaluated.

The second data logger was installed in the Columbia River the Lake on October 4. By that time spring runoff was finished and the River was heading toward its winter level. Again, significant fluctuations occurred, some lasting for two to three days and longer. The relationship with rainfall events is more apparent than it was on the Lake so that rainfall likely played a more significant role at this location.

Figure 12 shows the hourly water temperatures recorded at both the Columere Marina and Fairmont Riverside locations. As might be expected the water temperature decreased as the season progressed. Of some interest was a diurnal (day to night) variation in temperature at both locations. Water absorbs heat from the sun and some variation is to be expected. However, the magnitude of the variation especially at the Fairmont Riverside location seems excessive and needs to be investigated in the forthcoming season.

Summary and Conclusions

The Columbia Lake Stewardship Society successfully completed its first year of monitoring in the Columbia Lake watershed. It commenced water quality monitoring on Columbia Lake in April. By the end of September it had conducted nine sampling missions to four points on the Lake. Ten parameters were measured. The measurements provided for the first time an account of the temporal behavior of the water quality parameters over the season. They also added support to previously held views that the lake was not stratified. When compared with limited historical data, the recorded values did not suggest any significant downward trends in the health of the Lake. The intent is to continue annual monitoring to detect such trends.

The Society also commenced a water quantity monitoring program. The program did not get underway until late September. Two water level monitoring stations were installed and remained in place until November 9 when they were removed for the winter. The period of operation was too short to draw detailed conclusions about factors affecting Lake level and flow characteristics but was of sufficient duration to demonstrate the feasibility of using submerged data logger to measure water level and temperature. The program will resume in the spring and will be expanded to include two more locations.

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- Village of Canal Flats
- Columbia Lake CA
- Timber Springs CA
- Columere Park CA
- Observers
- Individuals that provided boats to conduct monitoring

APPENDIX 1

Observed Data 2014

Location	Date	Time (MDT)	Time Excel Format	Wave Conditions	Air Temp (Deg C)	Wind Direction	Wind Speed (km/hr)	Sky Cover (Percent)	Water Temp Surface (Deg/C)	Water Temp Bottom (Deg/C)	Lake Depth (m)	Secchi Depth (m)	Conductvity Sfc(uS/cm)	Conductivity Bottom (uS/cm)	ph	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Phosphorous (mg/L)	Nitrogen (mg/L)
Columbia N1	June 3/14	11:30	6/3/14 11:30 AM	Slightly wavy	18	S	5	80	16.6	16.6	2.35	2.35	222.0	218.6	8.3	7	1.60	0.009	<0.01
Columbia N1	June 12/14	12:30	6/12/2014 12:30	Wavy	17	S	10	30	17.7	17.7	2.44	2.44	218.0	215.6	8.3	8	1.59		
Columbia N1	June 29/14	13:58	6/29/2014 13:58	Slightly wavy	20	S	5	60	18.5	18.5	2.20	2.20	233.3	220.7	8.3	12	1.35	0.003	0.027
Columbia N1	July 17/14	7:10	7/17/2014 7:10	Calm	27.8	N	16	Overcast	24.4	24.3		2	241.0	242.9	8.8	14	1.05		
Columbia N1	Aug 4/14	15:41	8/4/2014 15:41	Calm	22	n/a	4.5	Cloudy, smoke	22.9	22.4	1.53	1.53	248.5	246.3	8.9	5	1.25		
Columbia N1	Aug 23/14	11:20	8/23/2014 11:20	Calm	15	SSW	5	Cloudy	19.3	19.3	2.5	2.5	232.6	232.9	9	7	0.97		
Columbia N1	Sep 14/14	12:52	9/14/2014 12:52	Calm	16.8	calm	0	Clear	15.1	14.7	1.83	1.83	212.4	209.8	8.9	12	0.83	0.002	<0.01
Columbia N1	Sep 28/14	14:21	9/28/2014 14:21	n/a	20.9	calm	0	Clear	15.8	15.6	1.80	1.80	220.3	218.3	8.8	10	0.88		
Columbia S1	April 20/14	10:45	4/20/14 10:45 AM	White caps	8				9.1		4.30		319.9		8.3	11	1.71	0.007	<0.01
Columbia S1	June 3/14	11:55	6/3/14 11:55 AM	Slightly wavy	18	S	5	80	16.6	16.6	5.20	3.70	234.1	228.3	8.2	8	1.43		
Columbia S1	June 12/14	13:05	6/12/2014 13:05	Slightly wavy	18	S	5	50	17.9	17.0	5.35	5.00	236.2	230.0	8.4	7	0.88		
Columbia S1	June 29/14	14:30	6/29/2014 14:30	Calm	20	C	0	60	18.8	18.3	5.30	5.30	228.0	219.3	8.2	8	0.91	0.002	<0.010
Columbia S1	July 17/14	7:40	7/17/2014 7:40	Sliight wind	28.8	N	16	Overcast	23.9	23.8		3.39	254.0	254.7	8.7	14	1.01		
Columbia S1	Aug 4/14	16:17	8/4/2014 16:17	n/a	24	WSW	21	Cloudy, thunder	21.9	21.5	4.88	3.3	244.1	246.9	8.9	10	1.26		
Columbia S1	Aug 23/14	11:45	8/23/2014 11:45	n/a	16	N	11	Cloudy	19.5	19.6	4.8	3.4	239.8	240.3	8.5	9	1.17		
Columbia S1	Sep 14/14	12:41	9/14/2014 12:41	Calm	17.9	calm	0	Clear	15.0	14.4	4.65	4.14	215.8	212.8	9.0	11	1.00		
Columbia S1	Sep 28/14	14:03	9/28/2014 14:03	n/a	17.8	S	5	Sunny	15.9	15.4	4.60	4.18	225.7	222.5	8.8	10	1.01		
Columbia S3	April 20/14	11:00	4/20/14 11:00 AM		7				9.1		4.30		314.5		8.3		1.20	0.010	<0.01
Columbia S3	June 3/14	12:15	6/3/2014 12:15	Slightly wavy	18	S	5	80	17.2	16.9	4.60	3.70	254.7	252.0	8.3	6	1.12	0.011	<0.01
Columbia S3	June 12/14	13:30	6/12/2014 13:30	Calm	18	S	0.5	100	18.0	17.6	4.20	3.50	255.1	253.4	8.0	8	0.94		
Columbia S3	June 29/14	14:45	6/29/2014 14:45	Slightly wavy	21	N	5	60	18.7	18.4	4.90	4.10	252.6	252.1	8.2	7	0.93	0.004	<0.010
Columbia S3	July 17/14	8:10	7/17/2014 8:10	Not recorded	26.3	N	16	Overcast	24.1	24.1		3.44	276.1	276.4	8.6	12	1.83		
Columbia S3	Aug 4/14	16:43	8/4/2014 16:43	n/a	26	NNW	10	Rain	22	21.9	4.27	2.77	263	262.1	8.8	9	1.49		
Columbia S3	Aug 23/14	12:04	8/23/2014 12:04	n/a	16	N	11	Cloudy	19.9	19.9	4.2	3.4	251	251.9	9	5	1.47		
Columbia S3	Sep 14/14	12:08	9/14/2014 12:08	Calm	13.9	calm	0	Clear	14.2	14.0	4.15	4.15	221.3	218.9	9.1	11	1.20	0.009	<0.01
Columbia S3	Sep 28/14	13:43	9/28/2014 13:43	n/a	19.8	S	10	Sunny	15.2	14.9	4.05	4.05	234.9	233.2	8.7	9	1.17		
Columbia S4	April 20/14	11:30	4/20/14 11:30 AM		8				9.2		3.70		314.6		8.2		1.00	0.003	<0.01
Columbia S4	June 3/14	12:40	6/3/2014 12:40	Slightly wavy		S	5	80	17.9	17.2	3.90	3.90	266.7	261.1	8.1	9	1.01	0.008	<0.01
Columbia S4	June 12/14	13:55	6/12/2014 13:55	Calm	18.4	C	C	100	18.0	17.7	4.25	3.70	260.0	256.4	8.3	6	1.01		
Columbia S4	June 29/14	15:10	6/29/2014 15:10	White caps	19	N	20	60	19.2	18.5			255.7	253.4	8.2	8	0.91	0.004	0.032
Columbia S4	July 17/14	8:25	7/17/2014 8:25	Not recorded	24.3	N	16	Overcast	24.1	24.1		2.84	283.5	284.2	8.7	10	2.3		
Columbia S4	Aug 4/14	17:06	8/4/2014 17:06	n/a	26	NNW	10	Sunny	22.4	21.9	3.76	2.7	255.1	290.1	8.8	9	1.83		
Columbia S4	Aug 23/14	12:15	8/23/2014 12:15	n/a	16	N	11	Cloudy	19.5	19.7	3.5		255.3	256	9.1	9	1.75		
Coumbia S4	Sep 14/14	11:45	9/14/2014 11:45	Calm	12	calm	0	Clear	13.5	13.4	3.60	3.60	217.6	217.4	9.0	11	0.79	0.007	<0.01
Coumbia S4	Sep 28/14	13:31	9/28/2014 13:31	n/a	18	S	10	Sunny	15.0	15.0	3.60	3.60	226.2	224.7	8.9	9	1.20		

APPENDIX 2

Historical Observations

PARAMETER	**1973-September 23**		**1983-June**		**1996-June 27/28**	
	SOUTH END	NORTH END	SOUTH END	NORTH END	SOUTH END	NORTH END
pH	8.4	8.5	8.3	8.4	8.47	8.77
TURBIDITY	1.1 (JTU)	0.6 (JTU)	1.1 (NTU)	0.7 (NTU)	1.6 (NTU)	2.1 (NTU)
TEMPERATURE Deg C°		13.5	12.3	12.1	16.7	16.3
Dissolved Oxygen mg/l					8.63	8.43
Conductivity MS (surface)					270	260
PHOSPHORUS Total mg/l PHOSPHORUS Total Dissolved mg/l	0.007 0.003	0.004 <0.003	0.006 <0.003	0.0045 <0.003	0.01 <0.003	0.008 0.003
NITROGEN Total mg/l NITROGEN, Nitrite/Nitrate mg/l	0.16 <.02	0.17 <.02	 <.02	 <.02	0.43 <.01	0.27 <.01