Lake Sawyer Water Quality

A Report on Water Quality Monitoring Results
for Water Year 2010 at Lake Sawyer

Lake Sawyer

Prepared for the City of Black Diamond
by the King County Lake Stewardship Program

February 15, 2011

King County

Overview

The King County Lake Stewardship Program (KCLSP) collaborated with citizen volunteers to monitor Lake Sawyer between 1993 and 2004. In 2006, the City of Black Diamond contracted with KCLSP to continue monitoring Lake Sawyer. Water quality monitoring is done on a schedule of once per month, versus the typical every other week for other lakes in the program. The water quality data indicate that currently the lake has moderate productivity (low mesotrophic) with good water quality.

There is a public boat launch and a large regional park adjacent to the lake that allow members of the public to access for recreation and to launch boats. Lake users should track aquatic plants growing near shore to monitor Eurasian watermilfoil and to catch early infestations of Brazilian elodea or other noxious weeds.

This report refers to two common measures used to predict water quality in lakes. The Trophic State Index or TSI (Carlson 1977) is a method of calculating indicators from collected data that allows comparison between different parameters and predicts the volume of algae that could be produced in the lake. A second measure is the nitrogen to phosphorus ratio (N:P), which is used to predict what groups of algae may become dominant in the lake during certain periods. Both the TSI and N:P ratios have been calculated using the available data collected through the volunteer monitoring program.

The discussion in this report focuses on the 2010 water year. Specific lake data used to generate the charts in this report can be downloaded from the King County Lake Stewardship data website at:

http://www.metrokc.gov/dnrp/wlr/water-resources/small-lakes/data/default.aspx.

Or can be provided in the form of excel files upon request.

Physical Parameters

Secchi clarity and water temperatures were gathered by the volunteer from May through October 2010. Physical parameters were recorded each time water samples were collected through the sampling season.

Secchi transparency is a common method used to assess and compare water clarity. It is a measure of the water depth at which a black and white disk disappears from view when lowered from the water surface.

For Lake Sawyer, Secchi transparency values ranged from 2.1 m to 4.8m, averaging 3.3 m (Figure 1). While somewhat less clear than the last several years, the Secchi transparency values were comparable to those of 2001–2004 and are above the values from the mid to late 1990s after diversion of the experimental sewage plant.

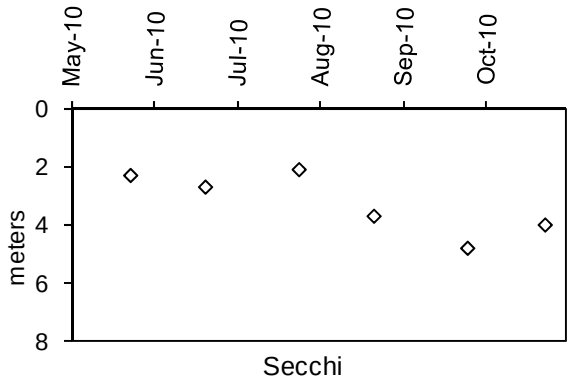

Figure 1. Lake Sawyer Secchi Transparency

Water temperatures during the sample period followed a pattern similar to other lakes in the region, with temperatures warming to summer maximum temperatures occurring between mid-July and mid-August, and temperatures cooling in the fall. The temperatures through the sampling season ranged from 13.0 degrees Celsius to 23.0 degrees Celsius with an average of 17.5 (Figure 2). The maximum temperature was in late July, reflecting the hot weather experienced in the region during that period.

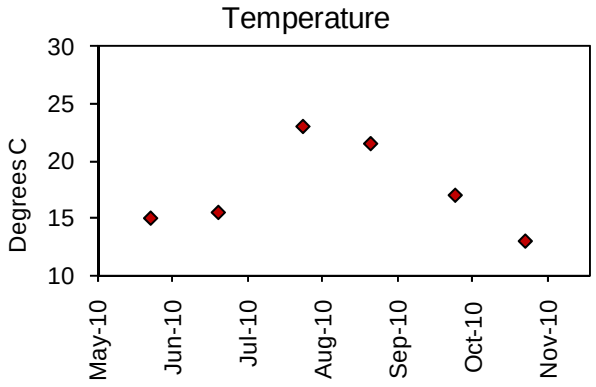

Figure 2. Lake Sawyer Water Temperatures

Nutrient and Chlorophyll Analysis

Phosphorus and nitrogen are naturally occurring elements necessary in small amounts for both plants and animals. However, many activities associated with residential development can increase concentrations of these nutrients beyond natural levels. In lakes of the Puget Sound lowlands, phosphorus is often the nutrient in least supply, meaning that biological productivity is often limited by the amount of available phosphorus. Increases in phosphorus concentrations can lead to more frequent and dense algae blooms–a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by species that can produce toxins. Samples collected by volunteers are analyzed for total phosphorus (TP) and total nitrogen (TN) concentrations at one meter depth.

Total phosphorus (TP) and total nitrogen (TN) concentrations followed a pattern throughout the May–October sampling period similar to previous years (Figure 3). In 2010, the TN started higher and decreased slowly until fall overturn began, when it raised slightly by late October. TP values followed a similar pattern, but varied less throughout the season, with the lowest values in mid summer.

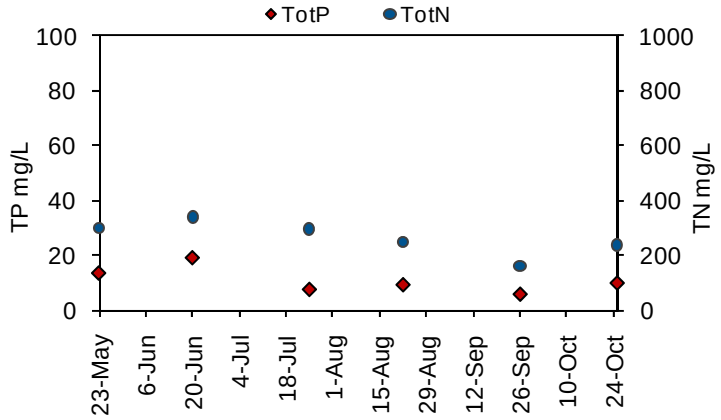

Figure 3. Lake Sawyer Nutrients

The ratio of nitrogen (N) to phosphorus (P) can be used to determine if conditions are favorable for the growth of cyanobacteria (bluegreen algae) that can impact beneficial uses of the lake. When N:P ratios are below 20, cyanobacteria often dominate the algal community due to their ability to take nitrogen from the air. Total phosphorus and total nitrogen remained in relatively constant proportion to each other through the sampling period, ranging from 17.8 to 37.1 with an average of 25.3, which suggests that conditions were generally less favorable for nuisance bluegreen growth, but some populations could have been sustained, particularly in spring when the ratio was at a minimum.

Chlorophyll *a* values were relatively low throughout the monitoring season in Lake Sawyer (Figure 4), with the maximum value occurring in late June. The low levels reflect phytoplankton volumes in the surface water mid-lake, but do not preclude the possibility of accumulations of buoyant algae colonies along shores that are downwind. Pheophytin (degraded chlorophyll) remained near the level of detection throughout the majority of the season.

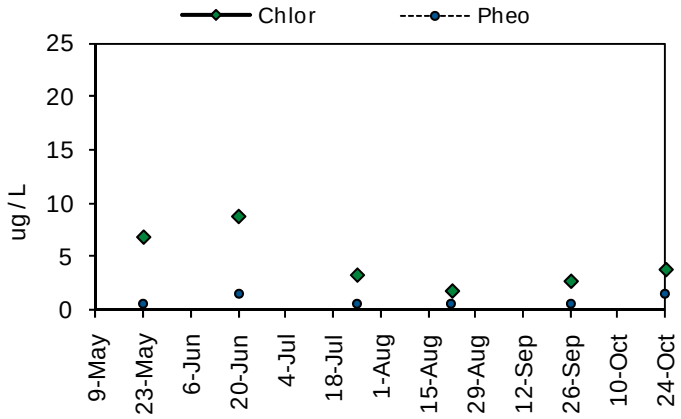

Figure 4. Lake Sawyer Chlorophyll *a* and Pheophytin Concentrations

Profile temperature data indicate that thermal stratification was present early in the season (by May) and persisted through the summer (Table 1). In the bottom samples in both May and August there were elevated levels of TP, as well as ammonia present, indicating that the hypolimnion (bottom water) of Lake Sawyer is low in oxygen early in the summer season and progresses towards anoxia, causing release of phosphorus from the sediments. This internal loading was quite apparent in the August bottom sample, in which TP was nearly 3-fold higher than it was in May.

Table 1. Lake Sawyer Profile Sample Analysis

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Sawyer	5/23/10	2.3	1	15.0	6.8	<MDL	0.300	<MDL	0.0139	<MDL	0.087	65.8
			8	8.0	5.2	<MDL	0.446		0.0140			
			16	7.0			0.582	0.129	0.0660	0.0280		
Sawyer	8/22/10	3.7	1	21.5	1.8	<MDL	0.251	0.005	0.0097	<MDL	0.084	53.4
			8	9.0	10.2	3.2	0.282		0.0187			
			15	7.5			0.764	0.588	0.1710	0.0374		

TSI Ratings

A common method of tracking water quality trends in lakes is by calculating the "Trophic State Index" (TSI), developed by Robert Carlson in 1977. TSI values predict the biological primary productivity of the lake based on measurements of water clarity (Secchi) and concentrations of TP and chlorophyll *a*. There are 3 categories of productivity: oligotrophic (low productivity, below 40 on the TSI scale); mesotrophic (moderate productivity, between 40 and 50); and eutrophic (high productivity, above 50).

TSI-indicators are created by averaging all 1m data collected for May through October. The TSI for Total P was lower than the other two indicators, placing in the mid oligotrophic range, similar to a number of previous years (Figure 5), although it showed a small increase from 2009. The average TSI for Secchi decreased slightly, though the TSI for chlorophyll increased to a mesotrophic level similar to 2006-2007. The average of the indicators in 2010 placed the lake just above the mesotrophic threshold, very similar to where it has been since 1998.

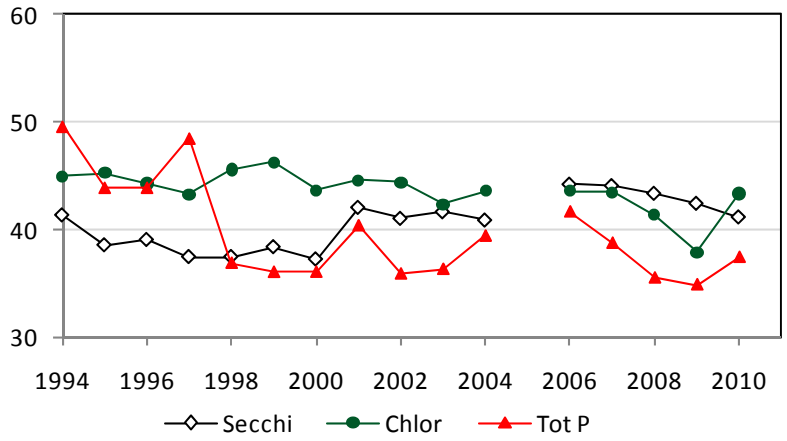

Figure 5. TSI Values at Lake Sawyer

TMDL

The Total Maximum Daily Load for Lake Sawyer set by the Washington Department of Ecology in 1993 defined a goal of an average of 16 ug/L total phosphorus concentration for the lake, but did not include the time period or water volume for which this was to be calculated. A wasteload allocation of zero was set in accordance with the removal of the Black Diamond wastewater treatment plant discharge to Rock Creek. A total annual influx of 715 kg phosphorus was estimated to meet the 16 ug/L average concentration target. Load allocations for tributary input was set at 511 kg/yr and internal loading input at 124 kg/yr, with 80 kg/yr allowed for other sources such as direct runoff and dust fall.

Onwumere (WDOE publication 02-02-054 December 2002) found that Lake Sawyer appeared to be meeting the TMDL target as a long term average, but noted that it might not be meeting a maximum in-lake mean summer target. The Lake Sawyer Water Quality Implementation Plan (June 2009) noted that significant urban growth was scheduled for the area and that such development had the potential for impacting water quality in the lake.

The long term data set collected by King County and trained volunteer monitors begins in 1985 and continues to the present, with a one year gap in 2005. Average June–September 1m values (Figure 6) show that there was a number of years around the time of the decommissioning of the sewage treatment plant when summer average phosphorus concentrations were higher than previously measured and were generally above the TMDL goal. However, since 1998 the values have been similar to the late 1980s and have shown no cause to believe that the lake is not meeting the standard set in the TMDL or that it is trending upward over the long term.

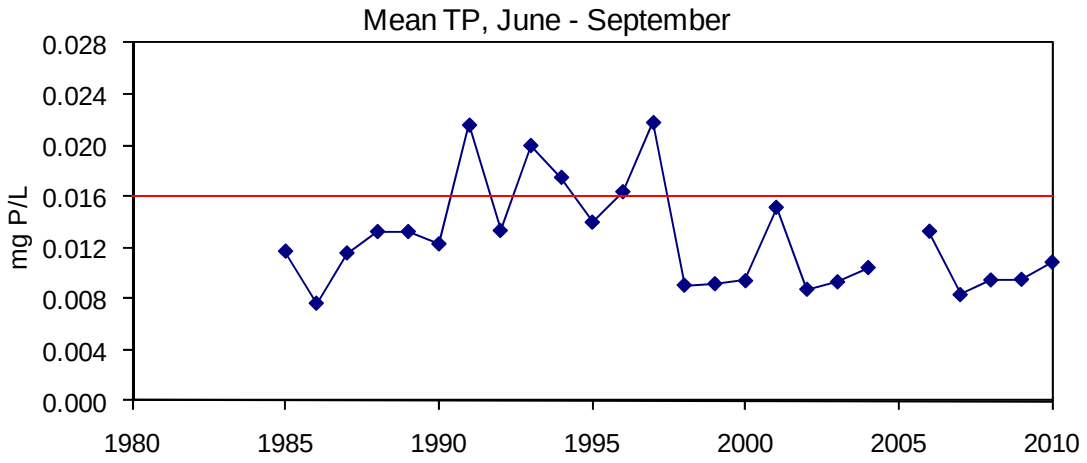

Figure 6. Summer average total phosphorus at 1m depth at Lake Sawyer

The data continue to be encouraging in that it suggests that currently Lake Sawyer is meeting the TMDL and has been doing so for over 10 years. However, because significant land development in the watershed is expected to occur in the near future, it is important to continue monitoring to look for changes as it proceeds, as well as for some time afterwards, in order to be sure that the permit controls are consistent with meeting water quality goals and targets.

Inlet Water quality

A second monitoring effort beginning in 2006 has focused on the water quality of the major streams flowing into Lake Sawyer: Rock Creek (station LSIN1) and Ravensdale Creek (station LSIN9). The program consists of sampling once a month by volunteers at the creek mouths during the wet season (generally November through May) when both creeks are flowing heavily. At the same time, water flowing from the lake at the outlet weir is also sampled (LSIN10). An additional goal was set of sampling one storm a year if possible, but this has not been accomplished in all years.

Volunteers were trained to take the routine samples and were provided with prepared sample bottles and equipment. Samples were submitted to the King County Environmental Laboratory for analysis. Parameters measured included specific conductivity and total alkalinity as indicators of development, total phosphorus and orthophosphate for TMDL monitoring, total suspended solids, temperature and water stage for flow calculations. For storms, oil and grease are measured for 3 stations of the 8 stations.

Total alkalinity and Specific Conductivity

Specific conductivity measures the amount of dissolved salts in water that can carry an electrical current at 25 degrees Celsius. Total alkalinity, also known as acid neutralizing capacity, measures the amount of calcium carbonate equivalents in the water that act as a buffer, thus moderating pH changes. It is closely related to the "hardness" of the water.

In general, both specific conductivity and total alkalinity are tied to the soil types and rocks found in the drainage basin. Both parameters generally increase as a basin is developed because of soil disturbance, as well as concrete emplacement. Because of this, they can be used as indicators of development over time.

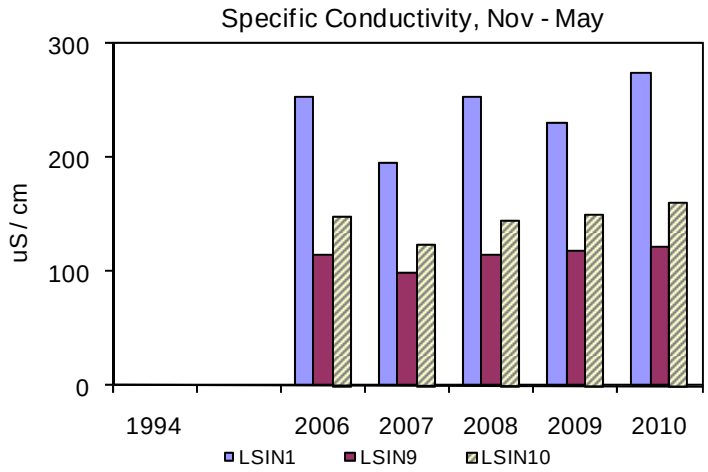

Figure 7. Wet season average of specific conductivity for Lake Sawyer and inlets

Rock Creek (LSIN1) is higher in specific conductivity than Ravensdale each year (Figure 7), while water from Lake Sawyer at the outlet appears to be a mixture of the two, but is closer to Ravensdale in value. The hydrological model constructed in the 1990s for the Lake Management Plan assigned more inflow from Ravensdale than Rock

Creek, based on the measurements taken in 1993-1994. Therefore, the water from Ravensdale that has lower specific conductivity would have a greater effect on the lake than the smaller inflow from Rock Creek, and this is reflected by the water from the lake being closer to Ravensdale in value, though still between the two inlets. This is also consistent with present land use in the two basins; in particular it should be noted that Rock Creek drains a currently inactive coal mining site that includes bare soils and rock outcroppings. Unfortunately, specific conductivity and total alkalinity were not measured in 1993-94, so a long-term comparison cannot be made.

Total alkalinity follows the same pattern as specific conductivity (Figure 8). Alkalinity in the lake is higher than in Ravensdale Creek, but significantly lower than Rock Creek.

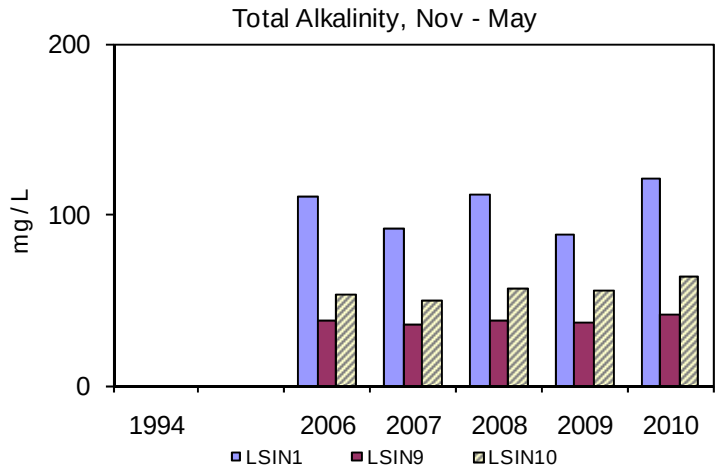

Figure 8. Wet season average of total alkalinity for Lake Sawyer and inlets

Phosphorus

Inputs of both total phosphorus and orthophosphate were also measured on a monthly basis from November through May. Total phosphorus is a measure of all phosphorus in a sample, in both dissolved and particulate form, while orthophosphate is comprised of dissolved, inorganic phosphate that is readily available for immediate uptake as a nutrient for algae and aquatic plants. While theoretically all phosphorus could be available for biological growth over time, in practice a certain amount entering the lake is likely to be buried in the sediments and never reach the water column in an available form or flow away from the lake in the outflow, particularly in winter when the lake water is mixed thermally and the lake has a low water residence time.

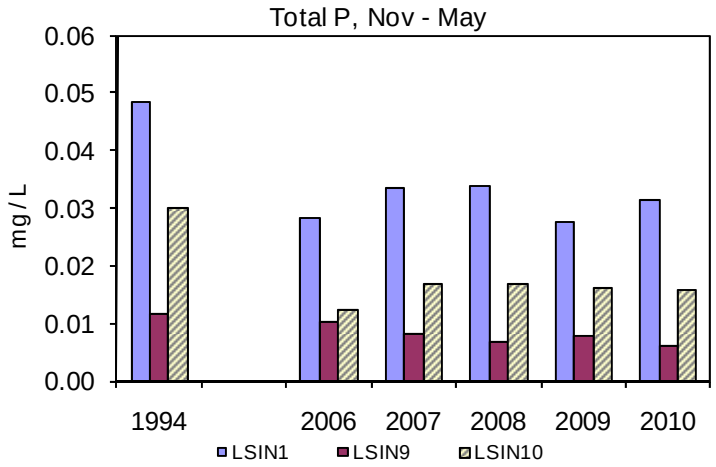

Figure 9. Wet season average of total phosphorus for Lake Sawyer and inlets

Total phosphorus has clearly declined at all three sampling sites when compared to the 1994 water year (Figure 9), with the most dramatic decline occurring in Rock Creek, consistent with the diversion of sewage effluent from the wetland as called for in the TMDL for phosphorus reduction. A significant decline has occurred in the Lake Sawyer outlet as well, and this could reflect a decrease in the pool of sedimentary phosphorus recycled internally with the fall overturn. However, this data represents winter flows and lake concentrations, while the adopted TMDL is does not detail the time period to be used.

There is a well-documented relationship between winter phosphorus concentrations in temperate lakes and spring/summer algae production, so that lower winter P values may be used to predict algae production the next growing season. There is a lag time for most Pacific Northwest lakes between when the most phosphorus enters lakes (winter) and when it is utilized (summer). This is due to the seasonal variation in climate, which delivers most inflow to water bodies during the winter, while summer tends to produce very low base flows with little water delivery to lakes, as well as little outflow. The result is that summer nutrient inputs may actually be very small though the concentrations in the inlet waters may be high. Thus, the decrease in winter phosphorus concentrations is a good indicator for Lake Sawyer that algae may also be reduced, and the data are encouraging in terms of the future prognosis for the lake.

A similar pattern was found for orthophosphate (OPO4, Figure 10). The apparent increase over the 3 years 2006-2008 should not cause alarm, as some variation between years can be expected based on flows and the randomized nature of sampling dates, and since 2008 the value has dropped. Trends generally cannot be reliably calculated until a minimum of 8 consecutive years of data have been collected. In 2010, the OPO4 average was a little lower than in 2009 for both Rock and Ravensdale Creeks, as was the value at the outlet.

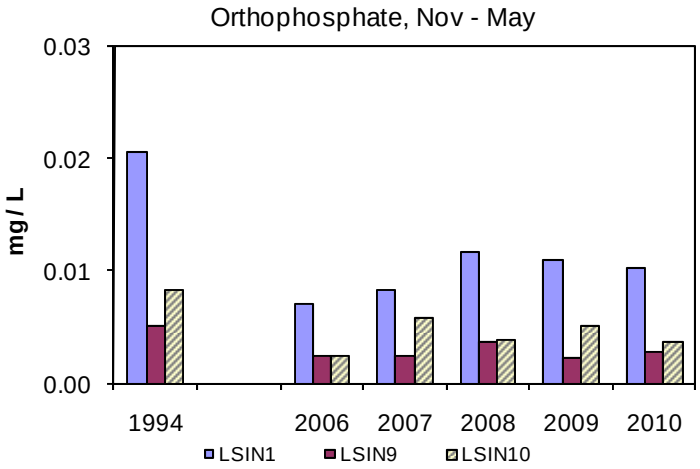

Figure 10. Wet season average of orthophosphate for Lake Sawyer and inlets

Storm water samples

The technical services contract between Black Diamond and King County called for sampling 1–2 storm events each year during November–May, but in the past it has been difficult to match up the meeting of storm criteria with volunteer availability and the operational hours of the King County Environmental Laboratory.

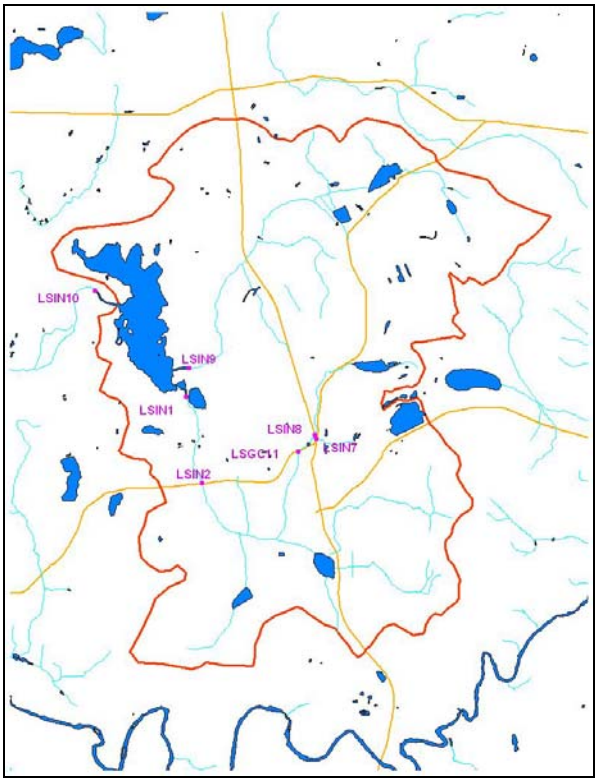

Figure 11. Location of storm sample sites on Ginder Creek, Rock Creek, Ravensdale Creek and the Lake Sawyer outlet

In 2010, staff from the city of Black Diamond agreed to sample stream sites during business hours if a precipitation event met the storm criteria, and this resulted in a storm event sampled on May 28, 2010 at seven sites (Figure 11). Storm samples were taken by collecting a single grab sample from each site as soon as possible after the criterion of 1' of rain in 24 hours had been met.

The measured parameters were the same as for the routine sampling, with the addition of "Hem:oil and grease" measurements (Hem stands for hexane extractable materials) at 3 stations: LSIN1 (mouth of Rock Creek), LSIN9 (mouth of Ravensdale Creek), and LSIN10 (outlet of Lake Sawyer). The sample from LSIN10 was below the detection limit of 2.0 mg/L, while the samples from LSIN1 and LSIN9 were just above at 2.3 and 2.4 mg/L respectfully. This shows that small amounts of oil and grease are present in storm runoff, but one sample set is not enough to characterize storm water flow. At present, there are no state water quality standards for oil and grease concentrations.

The following discussion includes data from 2 previous storm events, dated November 5, 2006 and March 24, 2007, which were sampled by volunteer monitors.

Total alkalinity and Specific Conductivity

Comparing values for these parameters among stations can point to a particular stretch of waterway where inputs from increased development or soil disturbance are entering the stream. A jump in value for either of these parameters can occur in stormwater running over impervious surfaces or exposed soils and subsoils.

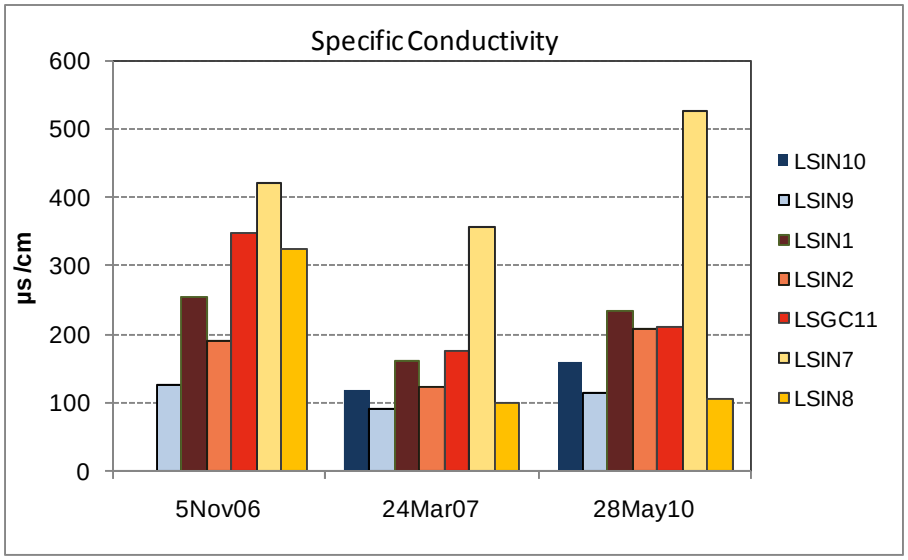

Figure 12. Specific Conductivity at 7 sites for 3 specific storm events in the lake Sawyer watershed.

In Figure 12, the dark blue bar represents the outlet from Lake Sawyer, while light blue is the lower station on Ravensdale Creek. The yellow, orange, and brown bars represent tributaries and stations along Rock Creek's path, from Ginder Creek's crossing under Highway 169 (site LSIN8 and tributary LSIN7 before it enters Ginder) downstream to a

crossing under Roberts Drive (LSCG11) heading south. The first Rock Creek site (LSIN2) is where Rock Creek crosses under Roberts Drive heading north, while LSIN1 is the routine monitoring site just before Rock Creek enters Lake Sawyer. There is a distinct pattern reflected in all 3 events, even though storm sampling by taking single grab samples is notoriously variable in results. LSIN7 consistently has the highest value of all the samples, which may relate to the nature of the mine site property that it drains. When it is combined with water in Ginder Creek, the resulting water is between the two upper stations in value, but generally still higher than LSIN2, which includes water from three other tributaries. There is an increase in conductivity between LSIN2 and LSIN1 where the water flows through a large gravel operations site.

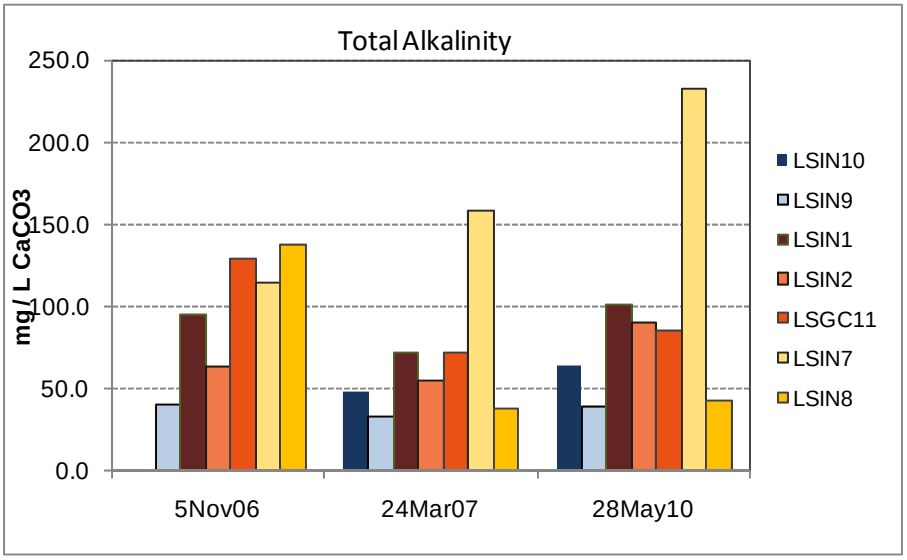

Figure 13. Total Alkalinity at 7 sites for 3 specific storm events in the lake Sawyer watershed.

Total alkalinity (acid neutralizing capacity) tells an essentially similar story, with the difference that in the 2006 event, higher alkalinity was measured in the upper Ginder Creek sample than the mine site tributary, but in subsequent storms the water was very low in alkalinity. There may be some record of activities near Ginder Lake or along the stream at that time that could be pertinent.

Total Suspended Solids

Total suspended solids is a measure of the amount of material being carried in water . It can be especially high during storm events through erosion of side channels by increased flows and through excess runoff flowing over land instead of infiltrating soils, picking up dust and other particles as it moves. Increases in nutrients carried by streams during storms are often attributable to the constituents of suspended solids in the water. Wetlands and stormwater facilities are often designed to retain water long enough to allow the suspended solid load to settle out of the water before it proceeds downstream, thus removing a portion of the nutrient load.

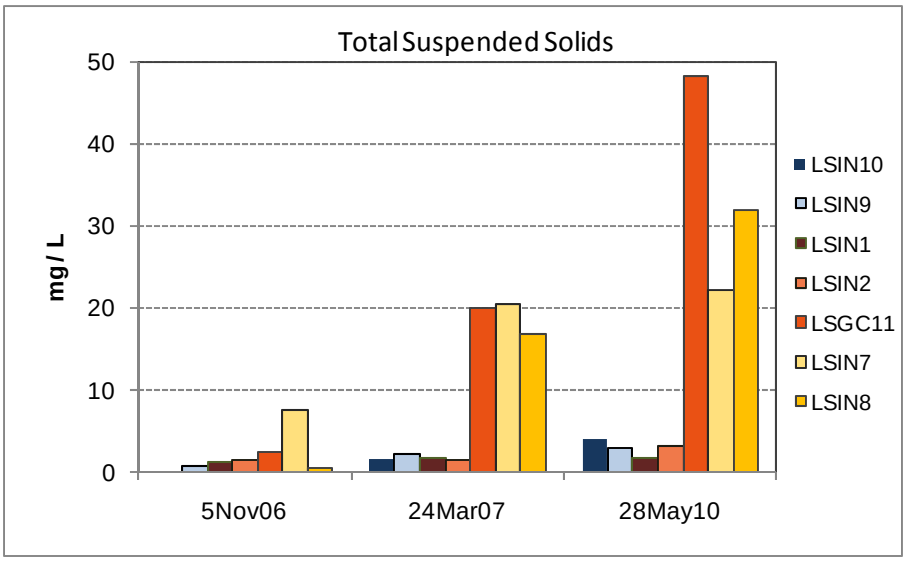

Figure 14. Total suspended solids at 7 sites for 3 specific storm events in the lake Sawyer watershed.

Data from storm events in the Lake Sawyer watershed (Figure 14) are consistent with these ideas. Stations along Ginder Creek in the upper watershed carry a much higher sediment load than the Rock Creek stations that are located in the flat, wetland dominated lower portion of the channel just before entering the lake. Either the other inlets are diluting the heavily laden waters of Ginder Creek before reaching the LSIN2 station or the wetlands are serving the function of detaining water long enough for sediment to fall out of suspension, thus reducing the input to Lake Sawyer. An interesting result from the May 28,2010 storm is that total phosphorus in the lake water is actually higher than in either Ravensdale or Rock Creeks, probably due to algae populations in water laving the lake.

Phosphorus

Both total phosphorus and orthophosphate were measured for storm events. In general, for storm samples the amount of total phosphorus varies in relationship with the amount of total suspended solids in the water, while orthophosphate is more independent of suspended materials and should vary less with the degree of storm erosion.

While all of the Ginder and Rock Creek samples are higher in phosphorus than the Ravensdale Creek samples(Figure 15), the pattern between stations is not as consistent as it was for total suspended solids. It is possible that there may be a change in make-up of the sediments between the stations, with some upper stations carrying more large, inorganic particles than the lower stations in the watershed, due to differential rates of settling. Fine organic particles are often lighter and do not settle as quickly as mineral or rock fragments when water velocities decrease. However, this cannot be determined without measuring total organic carbon for each sample, which was not done.

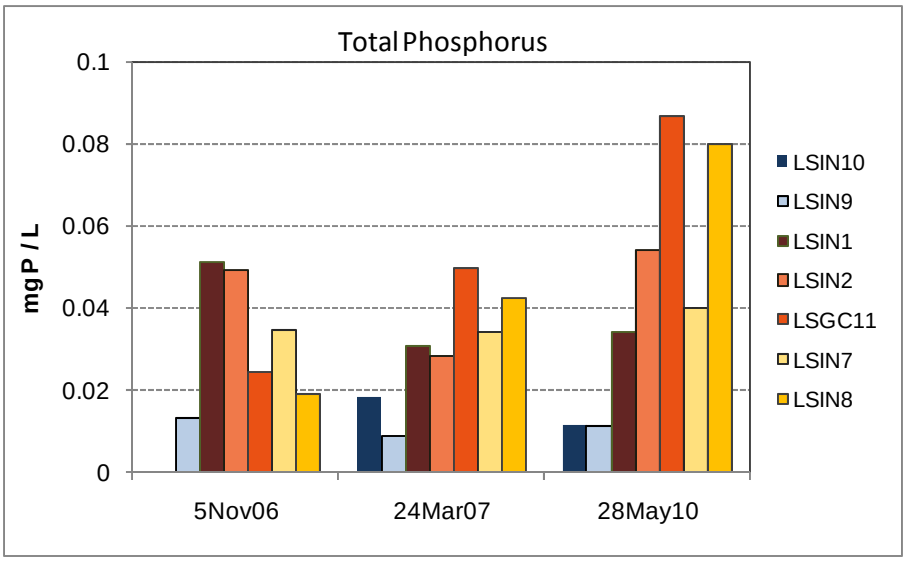

Figure 15. Total phosphorus at 7 sites for 3 specific storm events in the lake Sawyer watershed.

While the 2007 and 2010 storms had essentially the same pattern for total phosphorus concentrations, the 2006 storm was quite different, showing a steady increase in phosphorus content downstream. It is possible that this is evidence of a pulse of material going through the inlet channel, but this is a speculation that cannot be checked.

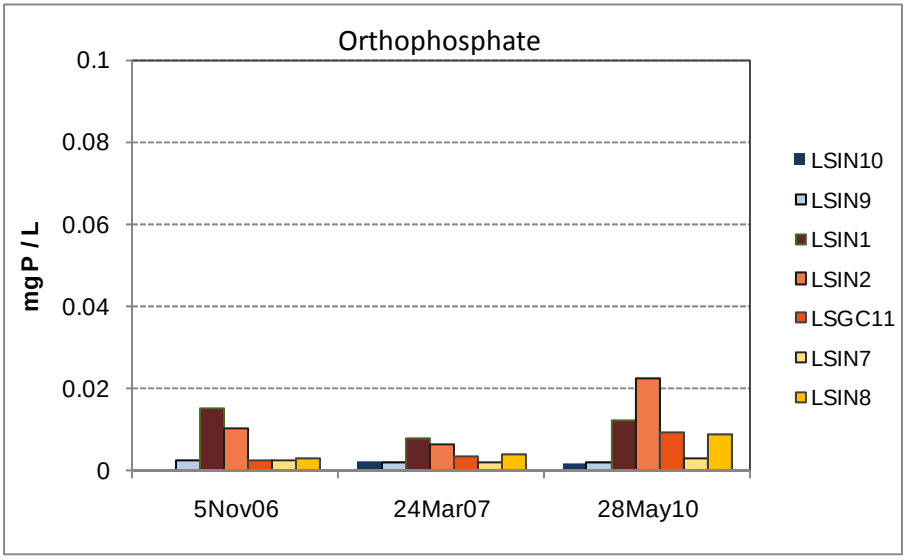

Figure 16. Orthophosphate at 7 sites for 3 specific storm events in the lake Sawyer watershed

In contrast, orthophosphate, which is found dissolved in water and is readily available for algal uptake as a nutrient, was nearly always found at lower concentrations in the water from the Ginder Creek stations than in the downstream Rock Creek stations. However, it is important to note that the maximum concentrations are still much lower than for total phosphorus for all of the samples.

Conclusions and Recommendations

Based on May–October monitoring data, water quality in Lake Sawyer has appeared to be relatively stable over the last decade. The nutrients in the lake varied a small amount during the sampling season and the N:P ratios were generally greater than 20 in 2010, which indicated that conditions in the lake are often unfavorable for bluegreen algae blooms, but there might be times of the year when they can be found in the lake, particularly if concentrated against a shoreline by wind.

The inlets have showed a decline in phosphorus since the 1990s, but insufficient data has been collected as yet to calculate long term annual trends for routine monitoring. Baseline values of total alkalinity and specific conductivity have been set to use as references when development in the watershed occurs. Continued monitoring should be carried out to assess conditions and to ensure that water quality remains consistent in Lake Sawyer as the area continues to be developed.

Storm sampling carried out to date suggests that more erosion is taking place during storms in the upper watershed of Ginder Creek than in the lower portion of Rock Creek, particularly from the tributary coming from the mine site. However, the flat topography of the downstream portion of Rock Creek may be catching some of the sediments before they enter the lake. It appears from one initial sample set that hexane-extractable oil and grease may not be a concern at this time.