PARLBY CREEK - BUFFALO LAKE WATER MANAGEMENT PROJECT

WATER QUALITY UPDATE 1997-98

Prepared for:

Buffalo Lake Management Team

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EXECUTIVE SUMMARY

A diversion from the Red Deer River to raise the water level in Buffalo Lake began in spring 1996 and continued through 1997 and 1998. The purpose of this report is to update water quality data obtained from sites along the diversion route and in Buffalo Lake during the second and third summers of the diversion (1997 and 1998). Diversions are expected to continue each summer until the water level reaches the target elevation.

Pre-project water quality studies suggested that algal populations could increase in Buffalo Lake, because the lake's salinity would be reduced by dilution from diversion water. As well, the diversion represents an increased nutrient loading to the lake, which could also increase its algal growth. Thus, there is potential for recreational water quality to be degraded with the diversion in place.

As in 1996, water quality samples were collected in 1997 from the Red Deer River and at three sites along the diversion route to Buffalo Lake; in 1998, the intermediate sites (above and below Alix Lake) were not sampled. An additional Parlby Creek site was sampled in the spring in 1997 and 1998. Alix Lake and the three basins of Buffalo Lake were sampled both years.

In both 1997 and 1998, the pumps were run at full capacity most of the time. The total diversion inflow (June - October) was 13.93 million m^3 in 1997 and 10.46 million m^3 in 1998. The natural surface inflow (March - October) was about twice the diversion volume in 1997, but much less than the diversion volume in 1998 because spring runoff volumes were low. The water level of Buffalo Lake increased between 1995 and 1996 by 0.17 m from natural runoff and the diversion.

The total mass of nutrients, total dissolved solids and other substances increased along the diversion route as ponds, Alix Lake and Spotted Lake were flushed and the diversion water mixed with natural runoff water. The salinity of Alix Lake decreased over the summer, and water quality in the lake was better than in 1992.

Of the monitored sites in Buffalo Lake, Parlby Bay has shown the greatest change in water quality. Salinity, nutrient levels and chlorophyll *a* have declined since the diversion began. It is not known how macrophyte populations have been affected.

There was also a change in water quality in Secondary Bay. Levels of phosphorus and chlorophyll *a* were higher than in previous sampling programs. The source of much of the higher phosphorus levels is the lake bottom – the sediments or groundwater inputs. The larger algal population seems to have resulted primarily from the higher nutrient levels, rather than from decreased salinity. Nutrient levels in Secondary Bay were higher in 1997 than in 1998 because loading from all sources was higher.

There was no observable impact or change in water quality in Main Bay. Salinity and levels of nutrients and chlorophyll were similar to those in previous studies. There was no evidence of sewage contamination along the shoreline at Rochon Sands, nor in the pond at Rochon Sands.

For those water quality characteristics monitored in 1997 and 1998, the effect of the diversion has been positive on Alix Lake and Parlby Bay, negative on Secondary Bay and has had no measurable effect on Main Bay. Thus far, it seems unlikely that Main Bay will be affected by the diversion, because of the small volume of diversion water relative to the volume in the Bay. As well, Secondary Bay probably buffers the small additional quantity of nutrients contributed by the diversion. During high runoff years, nutrient inputs from the natural watershed have a much greater effect on Buffalo Lake than nutrients in the diversion water.

Bacteriological data collected at various sites along the diversion route and in Buffalo Lake indicated background levels except from the natural watershed of Parlby Creek (sampled at the Alix site). Fecal coliform counts at that site, particularly in summer, exceeded the guideline for resampling of 400 counts/100 mL on several occasions.

There were occasional exceedences of Canadian Water Quality Guidelines for metals in samples collected along the diversion route. The measured concentrations were generally only slightly higher than the guideline level and probably not a cause for concern.

ACKNOWLEDGMENTS

Staff of Monitoring Branch, including John Willis, Chris Rickard, Rick Pickering, and others collected samples from Buffalo Lake and Parlby Creek and measured flow along the diversion route. Morna Hussey analyzed phosphorus and chlorophyll samples. Chemical analyses were conducted by Maxxam Labs, Inc. and the Alberta Research Council. Microbiological samples were analyzed by the Provincial Laboratory of Public Health. Bridgette Halbig produced graphs and formatted the report. David Trew and Sean Douglas reviewed the report.

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1.0 INTRODUCTION

A water management project to stabilize Buffalo Lake by diverting water from the Red Deer River began in 1985. The objectives were to 1) provide a reliable water supply for the Village of Mirror, 2) improve agriculture through backflooding and 3) enhance fish and wildlife habitat (Carson-McCulloch/Golder 1997). The first year of the diversion from the Red Deer River to Buffalo Lake began in the spring of 1996. To monitor its impact, an intensive sampling program was conducted on the diversion and the two lakes affected by the diversion (Alix Lake and Buffalo Lake). The program continued in 1997 and 1998, although fewer sites were sampled in 1998.

The monitoring program's focus was mainly on temporal and spatial changes in levels of nutrients and salinity in the diversion water between the Red Deer River and Buffalo Lake, and in the lake itself. For Buffalo Lake, aquatic plant growth, especially algae, could increase as low-salinity Red Deer River water is added to the lake. Although the Environmental Impact Assessment (Environmental Management Associates 1990) determined that this was unlikely, two other studies on the lake indicated a potential for higher algal populations to occur (Noton 1984; Brassard and Trimbee 1989). Other concerns raised included changes in levels of nutrients, metals, bacteria, turbidity, suspended solids and winter dissolved oxygen concentrations.

The purpose of this report is to assess the impact of the second and third summers of diversion, and bring up to date the water quality information collected since the last update, which was completed in May 1997. The present report addresses the following questions, based on the 1997 and 1998 monitoring data:

- Has the 1997-98 diversion inflow decreased the salinity in Buffalo Lake?
- What is the contribution of phosphorus to the lake from the diversion?
- Has water quality in Alix Lake stabilized after three summers of diversion inflow?
- Is there any change in the amount of algae in Buffalo Lake in 1997-98 compared with other years?

As in the previous update report, this report is organized by water quality component such as salinity, nutrients, etc., and within these sections water quality is discussed at sites in the direction of flow, first along the diversion route, including Alix Lake, and then in Buffalo Lake.

2.0 METHODS

2.1 SAMPLING SITES AND FREQUENCY

In 1997, samples were collected from several locations along the diversion route to document how water quality is affected by mixing of diversion water and water present in the conveyance channel. Fewer sites were sampled in 1998. The sites are shown in Figure 1.

1. Red Deer River Pumphouse. Water was collected from the short channel leading to the pumphouse. In 1996, a comparison of data from samples collected simultaneously from the river and the channel indicated very little difference in water quality from the two areas. The pumphouse site was sampled every two weeks during the diversion period, June through October 1997 - 1998.
2. Alix Lake Inflow. The water at this point has passed along about eight kilometres of pipeline, channel and two small ponds. Samples were collected at a road-crossing culvert just before the diversion flow entered Alix Lake. The purpose of this site is to assess the quality of the water entering Alix Lake. It was sampled every two weeks during the diversion period in 1997, but was not sampled in 1998.
3. Alix Lake. A small lake (area 0.51 km^2, depth about 3 m) at the town of Alix, used for recreation. There were concerns about the diversion's impact on recreational water quality, since the diversion flushes through the lake. This site was sampled every four weeks, May through October both years.
4. Alix Lake Outflow. Samples were collected at the outlet of the lake, downstream of the control structure and gate used to trap debris. This site is above the point where the diversion water joins with Parlby Creek. The outflow was sampled every two weeks during the diversion period. It was sampled in 1997, but not in 1998.
5. Parlby Creek at Alix. Samples were collected at the federal flow gauge upstream of where Alix Lake outflow joins Parlby Creek. It was sampled twice per week during

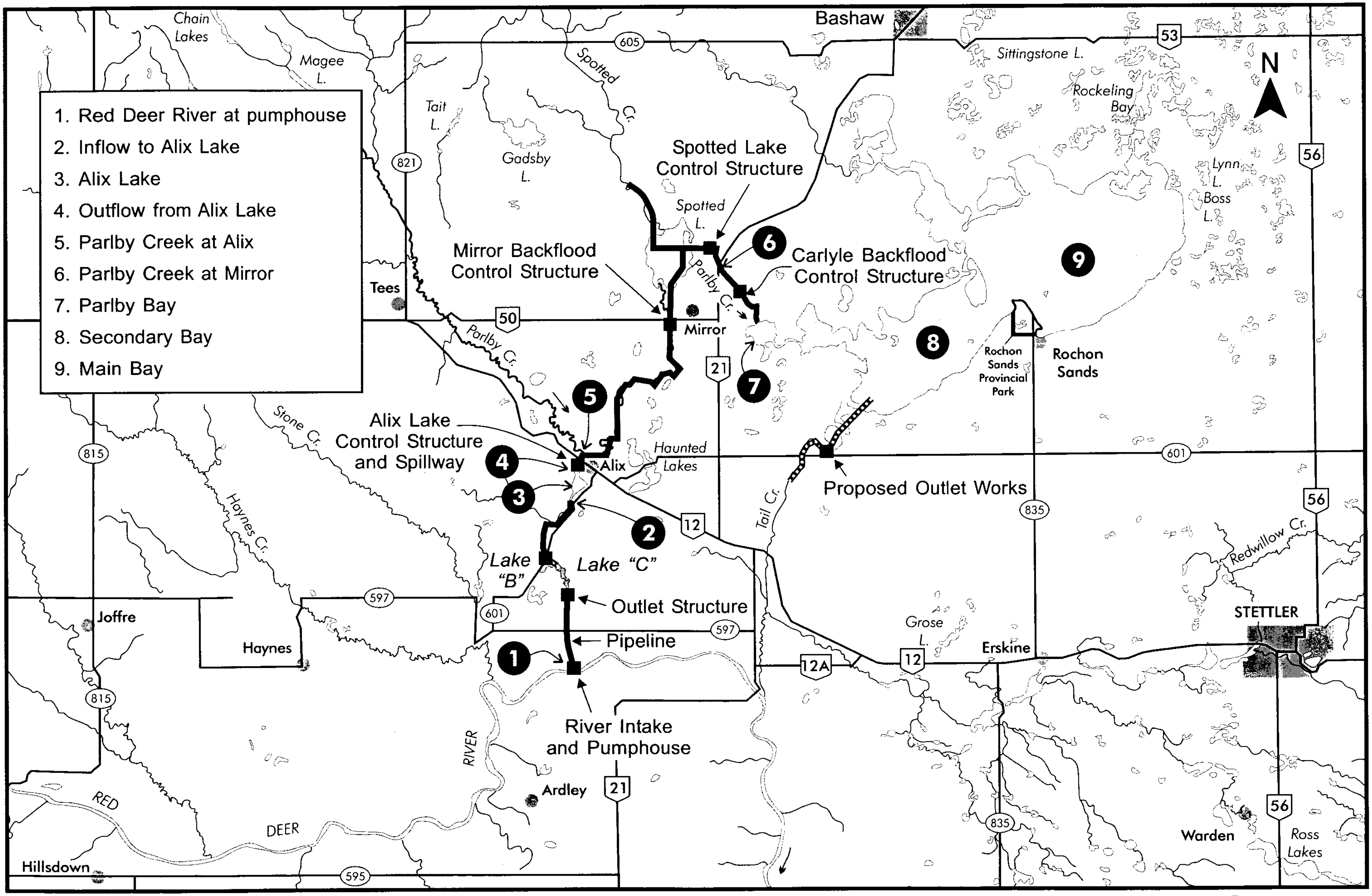

Figure 1. Sampling sites for 1997-98 water quality monitoring program, Parlby Creek - Buffalo Lake.

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spring runoff, and then sampling frequency was reduced as flows subsided. It was sampled in 1997 and 1998.

6. Parlby Creek at Mirror. This is the site of the provincial flow gauge on Parlby Creek, located near Highway 21 north of Mirror. The diversion here has passed through Spotted Lake, and includes natural flow in Parlby Creek. This site should be fairly representative of water entering Buffalo Lake (Parlby Bay), although backflooding between the sampling site and the lake in the spring may cause some alterations in water quality. This site was sampled twice per week during spring runoff both years, and then frequency was reduced to every two weeks, May through October.
7. Parlby Bay. This small bay receives the diversion flow first. It is connected to Buffalo Lake by a channel, called the Narrows, on which is located The Narrows Provincial Recreation Area. It was sampled every four weeks, May through October, both years.
8. Secondary Bay. The western, shallow portion of Buffalo Lake. Its major inflow comes through Parlby Bay; the bay was sampled every four weeks, both years.
9. Main Bay. The largest and deepest basin in Buffalo Lake; it was sampled every four weeks, both years.

In mid-summer 1997, bacteriological samples were collected from the shoreline of Buffalo Lake at Rochon Sands and Pelican Point to determine if septic systems along the shore were contributing bacteria, and to obtain background information before the lake water level increased. As well, a small pond at Rochon Sands was sampled on two occasions to address complaints that sewage was entering the pond from nearby cottages.

2.2 FIELD METHODS

The sites along the diversion route were sampled by filling bottles directly in the main portion of the flow, or by using a sampling bottle. For stream sites without continuous water level recorders, stream flow was gauged each time a sample was collected.

On each sampling day, Main Bay, Secondary Bay and Parlby Bay of Buffalo Lake and Alix Lake (Figure 1) were sampled by lowering a plastic tube from the surface down through the zone that light penetrates (termed the *euphotic zone*), as measured by an underwater light meter. These tube hauls of water were collected from several locations around each lake area and combined into one sample for the basin. Dissolved oxygen, temperature, conductivity and pH were measured at one-metre intervals from the surface to the bottom using Hydrolab equipment. Measurements were done in the deepest area of each basin. Transparency was measured with a Secchi disk, and light with an underwater photometer.

Bacteriological samples along the shoreline of Buffalo Lake at Rochon Sands and the small pond at Rochon Sands were collected by wading into the water and collecting a grab sample at mid-depth.

2.3 WATER QUALITY CHARACTERISTICS MEASURED

Variables measured at all sites included conductivity, pH, temperature, dissolved oxygen, major ions, alkalinity, hardness, total dissolved solids, total suspended solids, silica, phosphorus fractions, nitrogen fractions, and carbon.

In 1997, samples for heavy metals (copper, iron, lead, mercury, nickel and zinc) were collected at the Red Deer Pumphouse, Parlby Creek at Alix and Parlby Creek at Mirror. In 1997 and 1998, fecal coliform bacteria and *E. coli,* a specific intestinal fecal coliform bacterium, were monitored at the Red Deer Pumphouse, Alix Lake Inflow (1997 only), Parlby Creek at Alix, Parlby Creek at Mirror, Buffalo Lake Main Bay and Rochon Sands. Secchi transparency, light penetration and chlorophyll *a* were measured on all lake sites, and samples for phytoplankton and zooplankton were collected at the main sites in Buffalo Lake. Pesticide samples were collected occasionally at lake sites in 1997.

2.4 HYDROLOGY

Flow volume was measured at the pumphouse, and continuous discharge was recorded at the provincial gauging station on Parlby Creek near Mirror (Station 5CD902) and the federal gauging station on Parlby Creek at Alix (Station 5CD007). Instantaneous flow measurements were made approximately every two weeks during the diversion period at Alix Lake Inflow and Alix Lake Outflow in 1997 only.

A weekly water balance for Buffalo Lake was completed for 1997 (Douglas 1998). It was based on a detailed mass balance of the Buffalo Lake system, and was extended back to

1984 to ensure accurate calibration of the model used. Watershed runoff for the 1998 season was calculated by estimating the monthly basin yield for the Parlby Creek basin (excluding the flow volume from the diversion). This was extrapolated to the remainder of the Buffalo Lake watershed using the same proportion of Parlby basin runoff to total basin runoff as Douglas used for the 1997 data.

Water volumes for Main and Secondary bays were based on an area-capacity curve in W-E-R Engineering (1990) and water level–capacity relationships in Douglas (1998). The water volume for Parlby Bay was estimated from surface area and approximate depth, and the assumption that the volume increases proportionately to increases in water level.

2.5 DATA ANALYSIS

The total mass (*mass: the amount or weight of a substance)* of each constituent in the diversion water over the diversion period was calculated by multiplying the weekly volume of diversion water (D. Neis, pers. comm.) by the concentration of the substance for the appropriate time period. For the alternate weeks that weren't sampled, an average concentration was calculated using the concentration measured the week before and the week after the week in question. For Alix Lake Inflow and Outflow in 1997, mass was calculated from biweekly flow and concentration data.

Daily measured flows were available for Parlby Creek at Mirror and Parlby Creek at Alix. At these sites the data reduction program FLUX (Walker 1996) was used to calculate the total flow and total load for the monitoring period in 1997 and 1998 for each constituent. Although the program requires daily flows, daily concentrations are not necessary, as the program maps the flow/concentration relationship from the sample record onto the entire flow record and calculates load by this extrapolation technique.

To compare the mass of various substances in the lake for the three years sampled, the concentrations of each constituent measured in September were multiplied by the total water volumes in Parlby Bay, Secondary Bay and Main Bay.

The internal phosphorus loads for Secondary Bay and Main Bay were calculated from the mass increase of phosphorus in each bay over the summer, using a simple mass balance equation:

Internal Load = Change in mass in bay – Inputs to bay + Loss from bay

The change in mass is estimated from the amount of phosphorus in the lake when the concentration is lowest (July) and when the concentration is highest (September). The phosphorus that enters the bay over this period is subtracted. The contribution from Parlby Bay was estimated with the flow volume from Parlby Creek at Mirror and Parlby Bay total phosphorus concentrations during the time period. Similarly, the contribution to Main Bay from Secondary Bay was estimated with the same inflow volume and Secondary Bay phosphorus concentrations. The loss from Secondary Bay was included in the equation for that bay, but it was assumed there would be no loss from Main Bay. Any contribution from groundwater and sewage would also be included in the internal loading estimate.

3.0 RESULTS OF THE 1997 AND 1998 MONITORING PROGRAM

The primary focus of historical water quality monitoring programs on Buffalo and Alix lakes was the assessment of their fertility. Fertility is a measure of the potential for aquatic plant growth, both shoreline vegetation (technically called "macrophytes") and suspended algae ("phytoplankton"). An increase in the capacity of the lake to produce plants could lead to nuisance algal blooms, decreased levels of dissolved oxygen in winter (and the threat of fish kills), higher turbidity, and a general decline in recreational water quality. A lake characteristic related to this is salinity, because it has been shown that Buffalo Lake's high salinity depresses the growth of algae. Salinity is indicated by measurements of conductivity or total dissolved solids. Also included in the monitoring program was an assessment of the metals content of the diversion water, including mercury, and the dissolved oxygen condition in Buffalo Lake in winter.

3.1 DIVERSION

The 1997 diversion commenced June 2 and continued until October 31. Over this period, the total flow volume was 13.93 million m^3, at an average flow rate of approximately 1.06 m^3/s. This flow is about three times higher than in 1996, because the pumping capacity was increased with the operation of another pump for much of the summer. The full pumping capacity would result in a flow rate of about 1.4 m^3/s. In 1998, the flow volume was slightly lower, at 10.46 million m^3, and the pumping period extended from June 10 to October 1. The pumps were shut down for two weeks in July because the river carried a high silt load. The average flow rate was 1.21 m^3/s, but the maximum flow rate was achieved for a good part of the summer.

The volume of water that passed through Alix Lake during the diversion period would have flushed it about 18 times in 1997 and 13 times in 1998, as the lake volume is considerably smaller than the total amount of diversion water that entered it. Parlby Bay, with a somewhat smaller water volume, would have been flushed even more frequently during the diversion period. In Secondary Bay, however, the inflow volume during the diversion period was only one-third of the volume in the bay, which means that it would not be flushed completely in one diversion season. On an annual basis, flushing of Secondary Bay is fairly rapid compared with most lakes in central Alberta. For Main Bay, the volume of water assumed to have entered from the diversion and natural runoff in Parlby Creek between June and October 1997 was only 8% of the bay's volume. The residence time for Buffalo Lake, even with the additional water supplied by the diversion, is estimated to be approximately 11 years in 1997. Without the diversion, this would have been about 24 years. It should be understood that water leaves the lake only as evaporation, although during high inflow, water likely passes from Parlby Bay to Secondary Bay to Main Bay, since the greatest inflow is on the west end of the lake.

The water level of Buffalo Lake in 1997 and 1998 was slightly higher than in 1996 (Figure 2), but only part of this was due to the diversion. In 1997, there was a substantial spring runoff and there was also a heavy rainstorm in late June. Between March and October, local runoff contributed 41 million m^3 of water to the lake, whereas the diversion contributed only 14 million m^3 (Douglas 1998). In 1998, the quantity of local runoff was smaller (about 9 million m^3) whereas the diversion contributed 10.5 million m^3 to the lake. The maximum elevation achieved during 1996 - 1998 was 780.54 m, in June 1997. The target elevation is 780.85 m. If all of the 1997 diversion water were added to Buffalo Lake directly and at once, the increase in lake level would be about 0.135 m (5 inches), based on the area of the lake in the

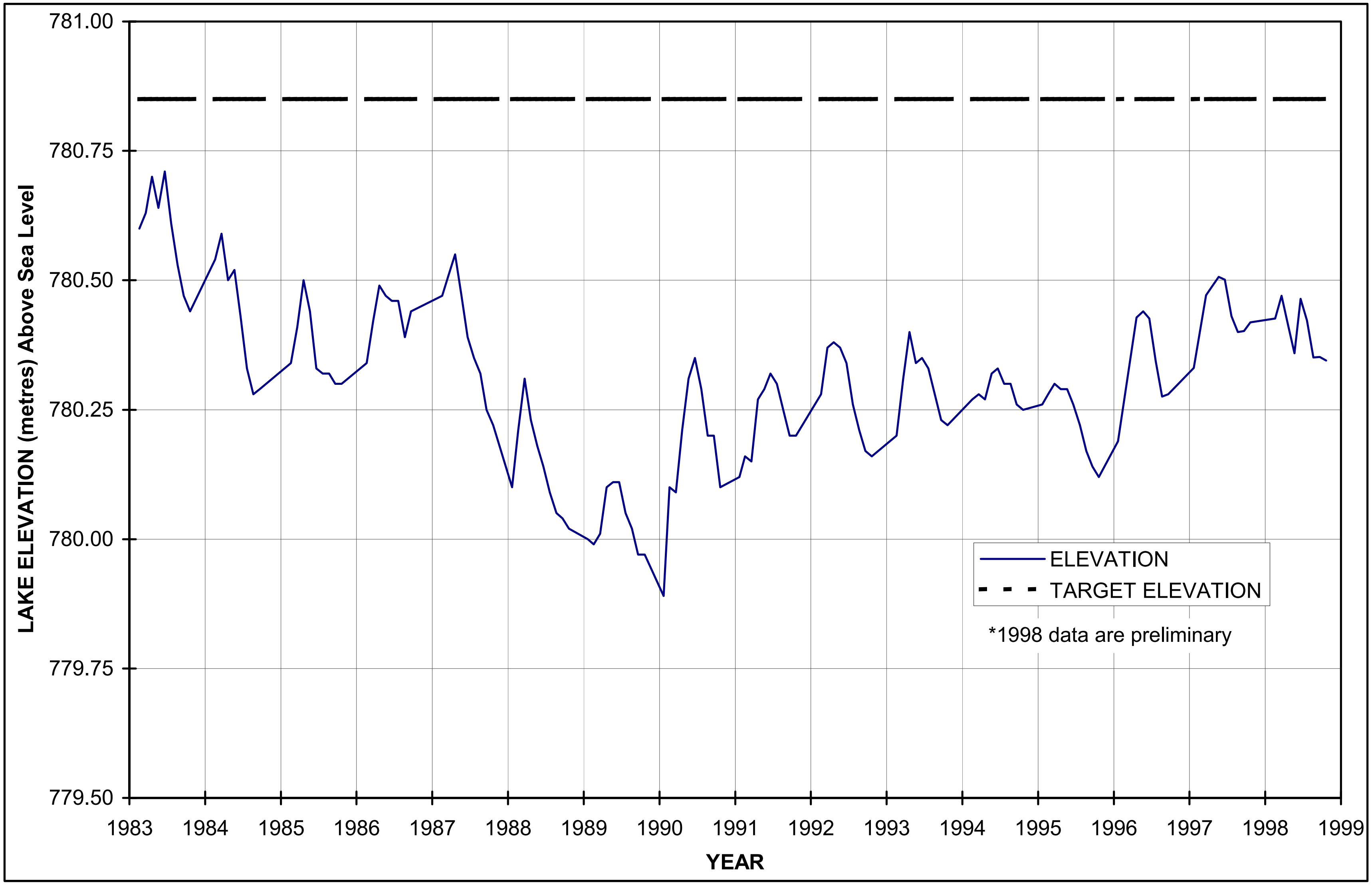


Figure 2. Monthly mean lake levels in Buffalo Lake near Erskine, 1983-1998

summer of 1997 (103 million m^2). Losses through the system and evaporation decrease this amount.

3.2 SALINITY

Salinity, or saltiness, of water is indicated by its level of total dissolved solids (TDS) or its electrical conductivity. Eight major ions collectively contribute to salinity in surface water in Alberta (calcium, magnesium, potassium, sodium, chloride, bicarbonate, carbonate and sulphate).

Diversion Route and Parlby Creek. Average 1996-98 values for routine water chemistry in the Red Deer River diversion and in Parlby Creek at Mirror are shown in Table 1.

Table 1. Average concentrations of major ions and related variables for the Red Deer River at the pumphouse and Parlby Creek at Mirror during diversion period (June through October) 1996-1998.

	Red Deer River at Pumphouse			Parlby Creek at Mirror		
	1996	***1997***	***1998***	***1996***	***1997***	***1998***
pH (range)	8.05-8.80	7.64-8.73	7.65-8.57	8.11-9.05	7.12-9.19	8.14-9.40
Conductivity, uS/cm	361	359	328	494	431	410
Total Suspended Solids, mg/L	5	8	54	4	5	2
Total Diss. Solids, mg/L	204	205	193	292	255	245
Calcium, mg/L	46.5	45.2	43.5	38.9	38.6	37.5
Magnesium, mg/L	14.8	15.1	14.9	26.0	20.6	20.5
Total Hardness, mg/L	177	174	171	204	181	179
Sodium, mg/L	10.5	10.7	8.9	36.0	27.8	29.0
Potassium, mg/L	1.7	1.7	2.2	4.4	3.1	3.8
Sulphate, mg/L	30.8	29.9	24.9	48.1	42.1	29.6
Chloride, mg/L	2.7	3.6	1.9	4.0	4.8	3.8
Silica, mg/L	2.2	1.9	4.0	2.0	2.7	3.0
Total Alkalinity, mg/L as $CaCO_3$	160	161	154	221	193	196
Bicarbonate, mg/L	189	183	182	250	217	224
Carbonate, mg/L	3	7	4	9.7	9.4	7.6
Number of Samples	12	11	7	12	11	7

Initially, water from the Red Deer River mixed with water in ponds, Alix Lake, Parlby Creek and Spotted Lake, and became more saline before it entered Buffalo Lake. Over time, water in Parlby Creek at the Mirror site is becoming more like Red Deer River water as lakes and ponds along the diversion route are flushed with diversion water. There has been a slight decline in hardness, conductivity, sulphate and other chemical attributes in Parlby Creek over the three years of sampling. Note, however, that concentrations of several constituents in the Red Deer River also declined over this period. The gradual decline in salinity in Parlby Creek likely has little effect on biota in the creek.

Another way to look at water quality at these sites is to determine the amount of each substance that passed through the site over the monitoring period, i.e., the total load (*load: mass or quantity of a substance over time).* The mass loads of various constituents in the diversion water and at sampling sites along the route in 1996, 1997 and 1998 are presented in Table 2. For comparison, the loads for entire open-water season (March – October) are presented along with the diversion loads calculated between June and October. Parlby Creek at Mirror is the last measurement site before Parlby Creek enters Buffalo Lake (Parlby Bay), so that the loads calculated at this site are assumed to enter the lake. During the diversion period, the mass of most of the major ions and TDS at the Mirror site is only slightly higher in 1997 and 1998 than in 1996. However, twice as much water passed this site over this period in 1997 than in 1996 and nearly twice as much passed in 1998 as in 1996. Substance contributions from along the diversion route and Spotted Lake have declined, especially from 1996 to 1997, even though mass loads from the Red Deer River increased with higher diversion flow volumes. The first year of flushing through the system with low-salinity water may have washed out these substances to some extent.

Note also that because 1997 was a fairly wet year, the total March – October TDS load in Parlby Creek at Mirror was about twice the load during the diversion period. In 1998, which was a fairly dry year, the total March – October TDS load was hardly greater than the load during the diversion period.

The "Balance" in the table represents the sum of the loads calculated for the outflow from Alix Lake and Parlby Creek at Alix in 1997, and Parlby Creek at Alix plus the Red

Table 2. Summary of mass loads of various constituents in the diversion to Buffalo Lake, June through October, 1996, 1997 and 1998. Data for Parlby Creek sites were calculated with FLUX.

1996

Site	Total Flow million m^3	Na kg	SO_4 kg	Cl kg	K kg	TDS kg	Total HCO_3* kg	Mg kg	Ca kg	TP kg	TDP kg	TKN kg	NO_2+NO_3 kg	NH_3-N kg
		Major Ions and Related Variables								*Nutrients*				
Red Deer Diversion	4.56	48,031	140,289	12,163	7,700	931,969	436,799	67,351	212,126	149	58	1,520	n.d.	89
Parlby Creek at Mirror	**7.24**	**350,697**	**399,091**	**33,621**	**34,948**	**2,504,348**	**1,175,369**	**209,702**	**317,522**	**730**	**500**	**6,992**	**n.d.**	**790**

1997

Site	Total Flow million m^3	Na kg	SO_4 kg	Cl kg	K kg	TDS kg	Total HCO_3* kg	Mg kg	Ca kg	TP kg	TDP kg	TKN kg	NO_2+NO_3 kg	NH_3-N kg
		Major Ions and Related Variables								*Nutrients*				
Red Deer Diversion	13.93	149,555	429,343	41,906	23,688	2,850,164	2,726,128	213,301	626,786	410	108	4,794	971	210
Inflow to Alix Lake	12.78	157,715	453,347	46,426	24,504	2,689,022	2,481,635	217,595	541,964	120	54	11,335	81	208
Outflow from Alix Lake	14.19	168,948	440,575	43,377	27,988	2,520,318	2,344,008	236,373	432,552	198	69	6,059	66	219
Parlby Creek at Alix	1.99	172,182	88,430	12,586	12,348	961,420	995,427	62,223	114,508	526	430	2,505	23	61
Parlby Creek at Mirror	**16.25**	**289,600**	**558,600**	**78,400**	**38,400**	**3,380,500**	**2,861,800**	**292,300**	**564,900**	**523**	**213**	**6,812**	**95**	**259**
*BALANCE***	*16.18*	*341,130*	*529,005*	*55,963*	*40,336*	*3,481,738*	*3,339,435*	*298,596*	*547,060*	*724*	*499*	*8,564*	*89*	*280*
Parlby Cr. at Mirror, Total Flow Mar. - Oct.	29.55	883,000	1,337,300	167,800	244,400	7,553,900	6,211,500	557,700	1,077,600	4,843	3,177	44,258	1,775	1,290
Parlby Cr. At Alix, total flow Mar - Oct.	12.02	579,211	389,056	79,016	124,383	3,645,211	3,456,540	231,101	450,088	4,481	3,544	20,286	4,850	1,614

*Carbonate + bicarbonate

**Parlby Cr at Alix + Alix Lake Outflow. These values should be similar to Parlby Cr. at Mirror if the substance behaves conservatively.

1998

Site	Total Flow million m^3	Na kg	SO_4 kg	Cl kg	K kg	TDS kg	Total HCO_3* kg	Mg kg	Ca kg	TP kg	TDP kg	TKN kg	NO_2 +NO_3 kg	NH_3-N kg
		Major Ions and Related Variables								*Nutrients*				
Red Deer Diversion	10.46	101,071	294,978	19,164	22,928	2,071,710	2,010,391	163,087	451,894	514	100	4,484	398	592
Inflow to Alix Lake	not measured													
Outflow from Alix Lake	not measured													
Parlby Creek at Alix	1.65	144,903	61,059	9,920	7,461	739,809	761,232	46,202	79,025	548	510	2,678	5.1	93
Parlby Creek at Mirror	**12.58**	**299,773**	**342,592**	**43,054**	**42,411**	**2,736,227**	**2,665,686**	**238,114**	**428,179**	**590**	**399**	**8,554**	**28.8**	**191**
*BALANCE***	*12.11*	*245,974*	*356,037*	*29,084*	*30,389*	*2,811,519*	*2,771,623*	*209,289*	*530,919*	*1,062*	*610*	*7,162*	*403*	*685*
Parlby Cr. at Mirror, Total Flow Mar. - Oct.	13.73	387,438	413,940	55,607	51,790	3,308,662	3,204,168	276,013	504,149	736	485	10,692	33.8	252
Parlby Cr. At Alix, Total Flow Mar. - Oct.	3.25	268,974	104,255	18,944	16,159	1,361,170	1,411,502	88,098	149,008	828	733	4,965	11.8	135

*Carbonate + bicarbonate

**Parlby Cr at Alix + Red Deer Diversion. These values should be similar to those for Parlby Cr. at Mirror if the substance behaves conservatively.

Deer diversion in 1998. This was done to determine if there were major additions or losses through the system that were unaccounted for. If there were no changes in concentration and no loss/gain of water between Alix Lake and the Mirror site on Parlby Creek, the "Balance" value should equal the value measured at the Mirror site. Note that the amount of water measured at the Mirror site is very similar to the "Balance" total flow value (less than 5% difference). This suggests that there are no major additions or losses of water through the system. The mass loads of most of the major ions and TDS also match fairly well. The small discrepancies noted could be due to timing of sample collection or averaging imprecision.

In 1997, the water flowing out of Alix Lake was generally similar to the water flowing in, whereas in 1996, concentrations in the outflow were higher than in the inflow. This probably indicates that the lake has been thoroughly flushed, and its water is basically Red Deer River water. The inflow and outflow were not measured in 1998.

Buffalo Lake. Water chemistry data for sites in Buffalo Lake for 1995, 1997 and 1998 are listed in Table 3. Concentrations of TDS and other attributes have decreased in Parlby

Table 3. Average concentrations of major ions and related variables for Buffalo Lake, May-October 1995 (pre-diversion), 1997 and 1998. Number of samples = 6 for each area per year. Units are mg/L except where indicated otherwise.

	Parlby Bay			Secondary Bay			Main Bay		
	95	**97**	**98**	**95**	**97**	**98**	**95**	**97**	**98**
pH (range), pH units	8.49 - 9.84	8.31- 9.58	8.21 – 9.25	9.16 - 9.30	8.96 – 9.13	9.00 – 9.11	9.29 - 9.32	9.13 – 9.31	9.08 – 9.22
Conductivity, uS/cm	721	491	550	2428	1982	2317	2825	2817	2767
Total Diss. Solids	447	292	310	1673	1300	1460	1980	1900	1826
Calcium	30	38	28	9	15	9.4	5	7	6.5
Magnesium	36	24	24	77	60	63	80	80	77
Total Hardness	223	193	170	336	284	282	363	349	336
Sodium	92	41	56	502	363	421	607	572	529
Potassium	9	5.4	5.7	37	31.5	33.6	43.0	44.3	41.8
Sulphate	73	47	47	414	315	369	508	463	469
Chloride	8	4.3	4.9	15.1	13.9	14.9	16.3	17.8	16.8
Silica	5.4	3.28	2.67	2.1	4.34	1.95	1.2	1.63	0.94
Total Alkalinity as $CaCO_3$	333	217	235	1033	823	914	1194	1179	1142
Bicarbonate	315	232	233	950	791	862	1051	1046	1001
Carbonate	45	16	26	152	104	124	199	190	192

Bay since 1995, although calcium concentrations in 1997 were higher than in 1995, before the diversion began. In 1998, concentrations of these routine chemical variables were still somewhat higher in Parlby Bay than in Parlby Creek at Mirror. The bottom sediments and evaporative losses of water in Parlby Bay may be maintaining these higher levels.

Although conductivity in Secondary Bay declined to the lowest recorded average in 1996 (1971 µS/cm), it increased in 1997 and again in 1998. The conductivity in both latter years is within the historical range.

In Main Bay, annual differences in concentrations of major ions were less than in the other basins, as would be expected with a small inflow volume relative to the volume in the Bay. Note that in spite of lower runoff volumes in 1998 compared with the other years, concentrations continued to decline slightly. It is possible that the movement of more dilute water from Secondary Bay has affected the salinity of Main Bay. Unfortunately, there is no information on water movement between bays.

A long-term picture of salinity in Main and Secondary bays is presented in Figure 3, which shows median conductivity for all the years for which there are data. The conductivity in Main Bay varies less from year to year compared with that in Secondary Bay. This is probably because in any given year, the amount of inflow to Secondary Bay has a greater influence on its water quality than in the larger Main Bay. For the historical data set, there is a strong inverse statistical relationship between water level and salinity in Buffalo Lake (Mitchell 1996), but the relatively high water level observed in the lake in 1997 and 1998 reduced the conductivity in Main Bay only marginally. The salinity of the lake is increasing over the long term, because until the water level gets high enough to spill out of the lake at its outlet, all substances entering the lake remain there. Loss to groundwater is unlikely, because the static head of aquifers is higher than the lake elevation (Crompton 1984). The enhanced inflow due to the diversion and high runoff has suppressed the increasing salinity to some extent in the last few years. Although more years of data are needed to draw conclusions, the diversion may not reduce salinity in Buffalo Lake. It may, however, decrease the rate at which salinity increases (Crompton 1984).

Substance mass in each basin of Buffalo Lake for the three diversion years is presented in Table 4. These mass loads are based on September data for each year, after the bulk of the diversion water had entered the lake. Concentrations of some substances have declined,

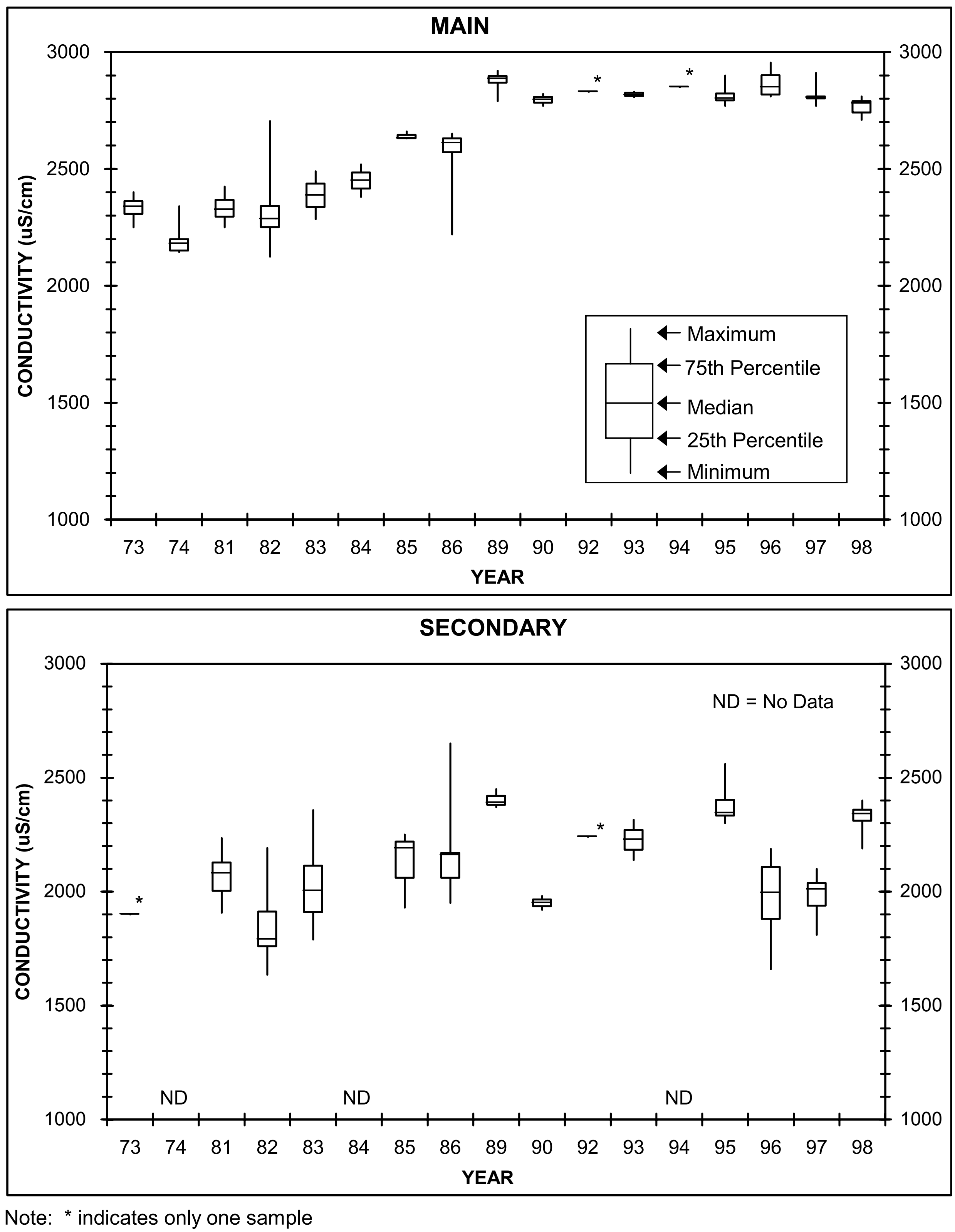


Figure 3. Conductivity in Buffalo Lake, April to September, 1973 to 1998.

Table 4. Substance mass in Buffalo Lake, September, 1996 - 1998. Mass in kg, volume in m^3.

	Parlby Bay			Secondary Bay			Main Bay		
Site	**1996**	**1997**	**1998**	**1996**	**1997**	**1998**	**1996**	**1997**	**1998**
Volume	400,000	563,000	555,000	39,000,000	42,000,000	41,480,000	220,258,000	239,800,000	235,300,000
Major Ions and Related Variables									
Na	13,000	7,150	9,213	15,171,000	16,380,000	18,292,680	125,547,060	139,563,600	130,356,200
SO_4	16,320	16,496	12,488	12,870,000	14,280,000	15,098,720	103,521,260	113,185,600	111,061,600
Cl	1,400	1,182	1,110	542,100	609,000	597,312	3,788,438	4,460,280	3,929,510
K	2,052	951	2,664	1,318,200	1,335,600	1,522,316	9,889,584	10,934,880	10,541,440
TDS	91,600	78,257	91,575	53,547,000	58,380,000	61,805,200	421,133,296	466,411,000	440,011,000
Total HCO_3*	40,800	68,686	91,020	20,241,000	45,108,000	47,038,320	158,145,244	353,465,200	333,184,800
Mg	11,160	8,952	9,047	2,476,500	2,478,000	2,745,976	17,092,021	19,543,700	19,129,890
Ca	6,160	9,290	11,655	639,600	508,200	365,024	1,321,548	1,738,550	1,129,440
Nutrients									
TP	14	17	30	5,733	5,628	4,546	17,180	21,342	13,530
TDP	7	7	10	1,482	1,302	1,493	7,489	8,393	8,188
TKN	304	484	438	96,720	80,430	72,175	533,024	520,366	381,186
NO_2+NO_3	9	1	2	1,014	315	124	4,625	1,918	706
NH_3-N	12	23	11	3,120	1,470	1,659	19,823	9,592	14,118

* carbonate plus bicarbonate

but the actual mass of most substances in the basins is not declining as might be expected. A likely reason for this is the increased loading of these substances via the diversion. Although the inflow water is more dilute, the diversion represents a net increase in mass loading to Buffalo Lake. In Parlby Bay, however, the mass of total dissolved solids (TDS) dropped by half the first year of the diversion, largely because Parlby Bay flushes so rapidly. In 1997 and 1998 the mass of TDS in the bay did not decline further. Parlby Bay received 8.7 million kg of total dissolved solids from Parlby Creek in 1996, 7.5 million kg in 1997 and 3.3 million kg in 1998 (based on data from Parlby Creek at Mirror). Yet, the mass of TDS in the bay remained at 0.08 – 0.09 million kg. Thus, up to 8.7 million kg of TDS must have passed to Secondary Bay each year, although certain substances such as calcium may have precipitated out to the bottom sediments, reducing the TDS mass.

In 1996, the amount of TDS that increased in Secondary Bay over the summer was approximately the same as that lost from Parlby Bay. From May 1997 to October 1997, TDS mass in the bay increased by about 8.7 million kg. The contribution from Parlby Bay amounted to about 3.5 million kg during the diversion period, with an additional 2.5 million kg added in spring 1997. Other sources could be groundwater, natural runoff and movement of water from Main Bay. Between May and September 1998, TDS in Secondary Bay increased by about

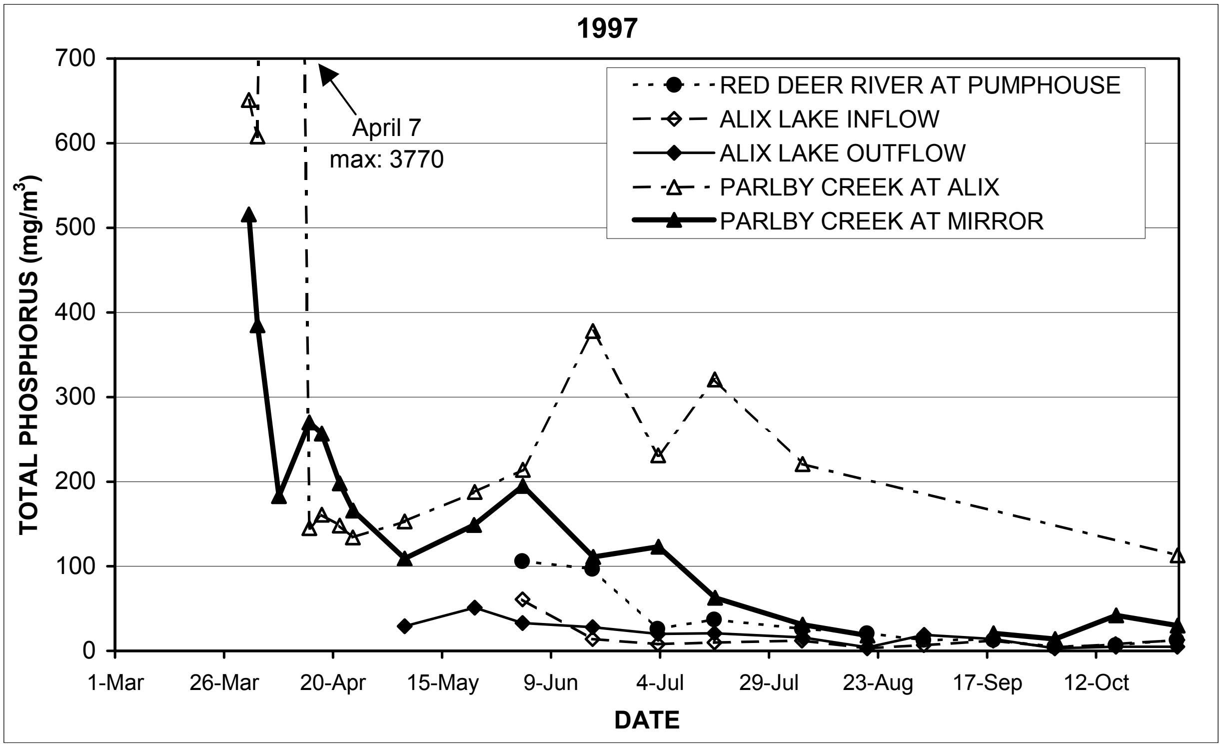
4 million kg, and the contribution from Parlby Bay was 2.9 million kg. These estimates are very rough at best, and it is not known how long it would take water from Parlby Bay to enter the main part of Secondary Bay and become mixed. However, it does seem that the salinity measured in Secondary Bay can be accounted for largely by loading from Parlby Bay.

Water probably also moves from Secondary Bay to Main Bay, or the reverse, but this relationship is much less clear than with the other two areas of the lake. For example, it appears there was a loss of TDS from Main Bay over the summer in 1997, which may account for some of the increase in Secondary Bay in 1997. In 1996 and 1998, the differences in mass between the spring and fall are probably within measurement error. Historically, the TDS concentration has always been lower in Secondary Bay than in Main Bay, suggesting that mixing is limited.

3.3 NUTRIENTS

Phosphorus and nitrogen are primary nutrients governing recreational water quality in most lakes. They were measured in all samples collected during the Parlby Creek-Buffalo Lake water quality studies in 1997-98 (and in previous studies). In most lakes, phosphorus levels provide the best indicator of water quality, because phosphorus is usually the nutrient in shortest supply relative to the needs of growing algae. If algae living in the lake have an abundant phosphorus supply, the result may be a large growth of algae, and therefore reduced recreational water quality. Nuisance algal growth has not occurred in Buffalo Lake in the past, in spite of relatively high phosphorus concentrations, because its salinity depresses the growth of phytoplankton (Goudey et al., 1990; Bierhuizen and Prepas 1985). Nitrogen (as nitrate- or ammonia-nitrogen) is also an essential nutrient, but in typical Alberta lakes nitrogen does not control the size of the algal population.

Diversion Route and Parlby Creek. Table 5 presents average nutrient data for various sites along the diversion route in 1997, and Figure 4 shows concentrations of total phosphorus at diversion route sites over time for 1997 and 1998. Concentrations of phosphorus in the Red Deer River diversion were lower than in Buffalo Lake, and these concentrations declined even further in the diversion channel between the river and Alix Lake inflow. As in 1996, phosphorus was removed from the water in the early part of the season while nitrogen, primarily organic nitrogen, was added. This can be explained by the growth of aquatic plants along this section, which



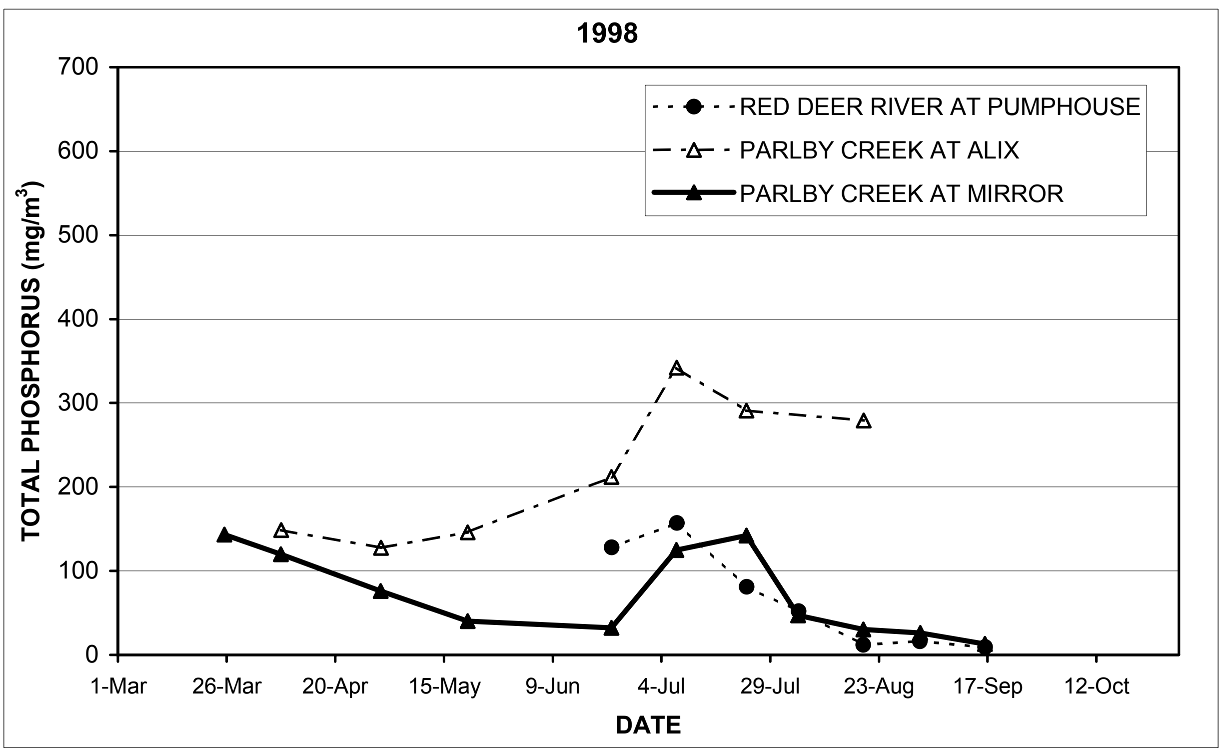


Figure 4. Concentrations of total phosphorus along the diversion route, 1997 and 1998. (Sites are listed in direction of flow.)

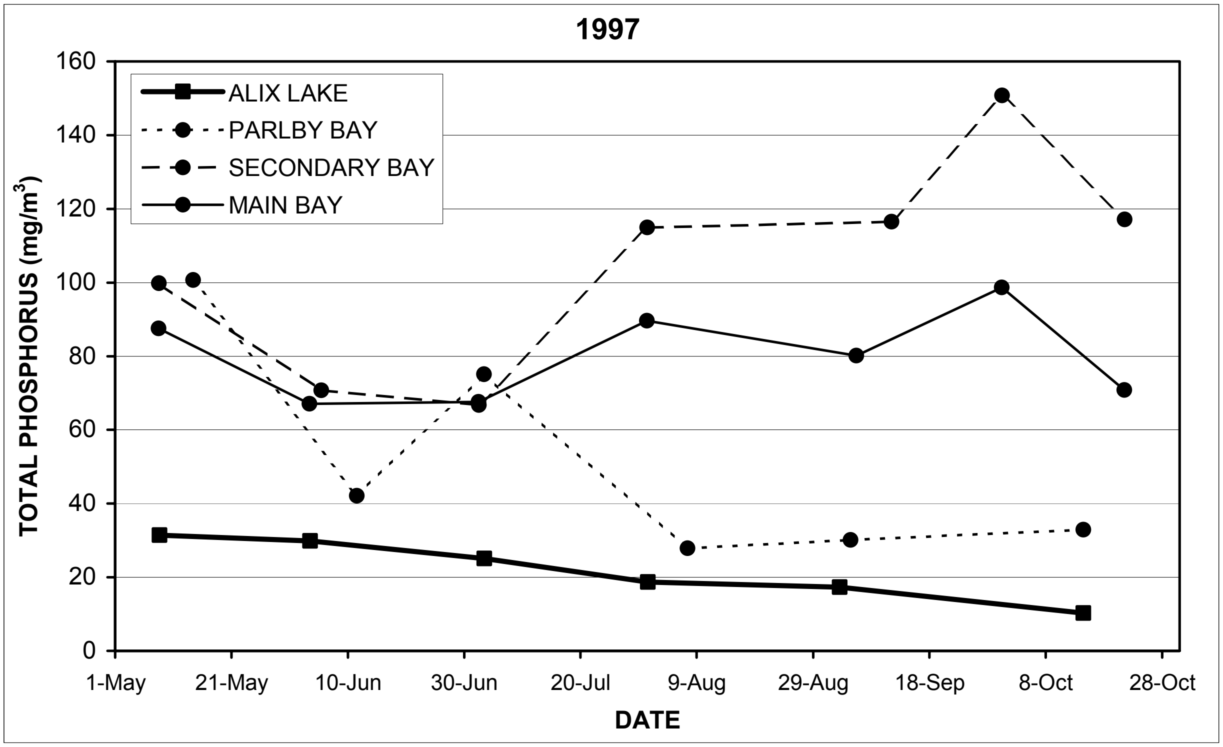
Table 5. Average concentrations of nutrients and bacteria for the Red Deer River at the pumphouse, Alix Lake inflow and outflow, Alix Lake, Parlby Creek at Alix, and Parlby Creek at Mirror, June to October 1997. Bacteria data are as geometric means. Units are mg/m^3 unless indicated otherwise.

	Red Deer River	Alix Lake Inflow	Alix Lake	Alix Lake Outflow	Parlby Creek at Alix	Parlby Creek at Mirror
Total Phosphorus	33.1	13.8	20.2	15.3	246	64.8
Total Diss. Phosphorus	8.5	7.0	7.5	4.9	183	39.4
Total Kjeldahl Nitrogen	340	1040	430	430	1160	560
Nitrite + Nitrate - Nitrogen	78	5	3	5	11	6
Total Ammonia Nitrogen	10	15	13	12	30	20
Silica, mg/L	1.9	1.9	1.2	1.0	8.5	2.7
Fecal Colif. Bacteria, Cts/100 mL	15	15			294	25
E. coli, cts/100 mL	9	9			254	19
Number of Samples	11	11	5	11	6	11

convert the high concentrations of inorganic nitrogen and phosphorus to organic compounds. By the end of the pumping season, nutrient concentrations in river water and at Alix Lake Inflow were similar.

The average 1997 TP concentration in Alix Lake was about a third of the average value recorded for 1992 (60 mg/m^3), and the average DP concentration in 1997 was nearly one-fourth of that for 1992 (27 mg/m^3). Concentrations were slightly higher in 1998, likely because phosphorus levels in the diverted water were higher. Total phosphorus levels declined gradually over the summer of 1997 in Alix Lake as concentrations in the diversion water declined (Figure 5, top graph); this was not as obvious in 1998. Total kjeldahl nitrogen concentrations followed this pattern as well in Alix Lake in 1997, but were higher than concentrations in the diversion water in 1998, for unknown reasons. In general, it appears that the water quality of Alix Lake is very similar to that in the Red Deer River and has improved considerably since the diversion began.

In 1997, phosphorus concentrations in the Alix Lake inflow and outflow were fairly similar during the diversion period, as would be expected with such a high flushing rate. The Alix Lake outflow joins Parlby Creek, which has very high levels of phosphorus even during the summer period. The flow rate in this creek is very low, however, so that concentrations further



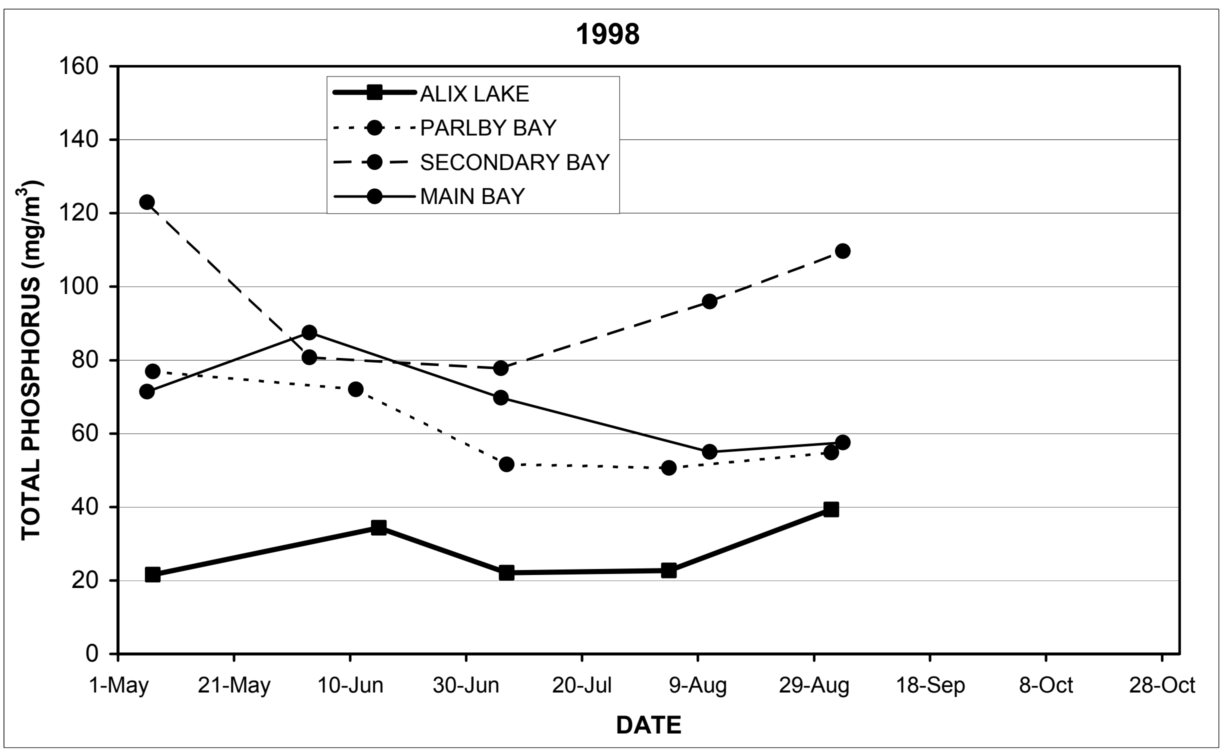


Figure 5. Concentrations of total phosphorus in Buffalo and Alix lakes, 1997 and 1998. (Sites are listed in direction of flow.)

downstream at the Mirror site were not greatly increased. Although phosphorus concentrations were higher at the Mirror site than in the other diversion route sites, levels declined over summer (Figure 4). By August, phosphorus concentrations were lower than in Buffalo Lake, although not as low as in the diversion water at that time.

Table 2 presents mass loads of nutrients for 1996 - 1998. The mass load data for 1997 reflect a loss of total and dissolved phosphorus between the Red Deer diversion and the inflow to Alix Lake. As well, more phosphorus left Alix Lake than entered it via Alix Lake Inflow (the difference was 78 kg TP, 15 kg DP). However, this apparent loss would be reduced by the amount of phosphorus contributed by other inputs to Alix Lake over the summer, from such sources as atmospheric deposition, diffuse runoff, groundwater and the bottom sediments. The estimated decrease in mass in the lake, based on measured lake data, was only about 23 kg (assuming that the lake volume estimate of 1.2 million m^3, cited in Shaw 1994, is accurate). There was also a calculated net loss of phosphorus from Alix Lake in 1996, but again, inputs other than the diversion were not accounted for. In 1998, the inflow and outflow were not sampled.

In both 1997 and 1998, the amount of phosphorus passing the Mirror site on Parlby Creek was lower than in 1996, although the amount of water diverted in 1997 and 1998 was higher. This suggests that the diversion water, which is relatively low in phosphorus, is scouring this nutrient (and others) from the system. Most of the phosphorus entering Buffalo Lake via the diversion route appears to come from natural flow in Parlby Creek upstream of where it joins the diversion. Between Parlby Creek at Alix and Parlby Creek at Mirror, there is a loss of phosphorus, probably in Spotted Lake. This is evident by comparing the measured total phosphorus load at the Mirror site with the sum of loads from Alix Lake Outflow and Parlby Creek at Alix ("Balance" in Table 2), which suggests that 200 kg was lost between Parlby Creek at Alix and Parlby Creek at Mirror in 1997 and nearly 500 kg in 1998. There appears to be little loss of total kjeldahl nitrogen in this area, but there was a large decrease in inorganic nitrogen, of which the Red Deer River contributes large amounts.

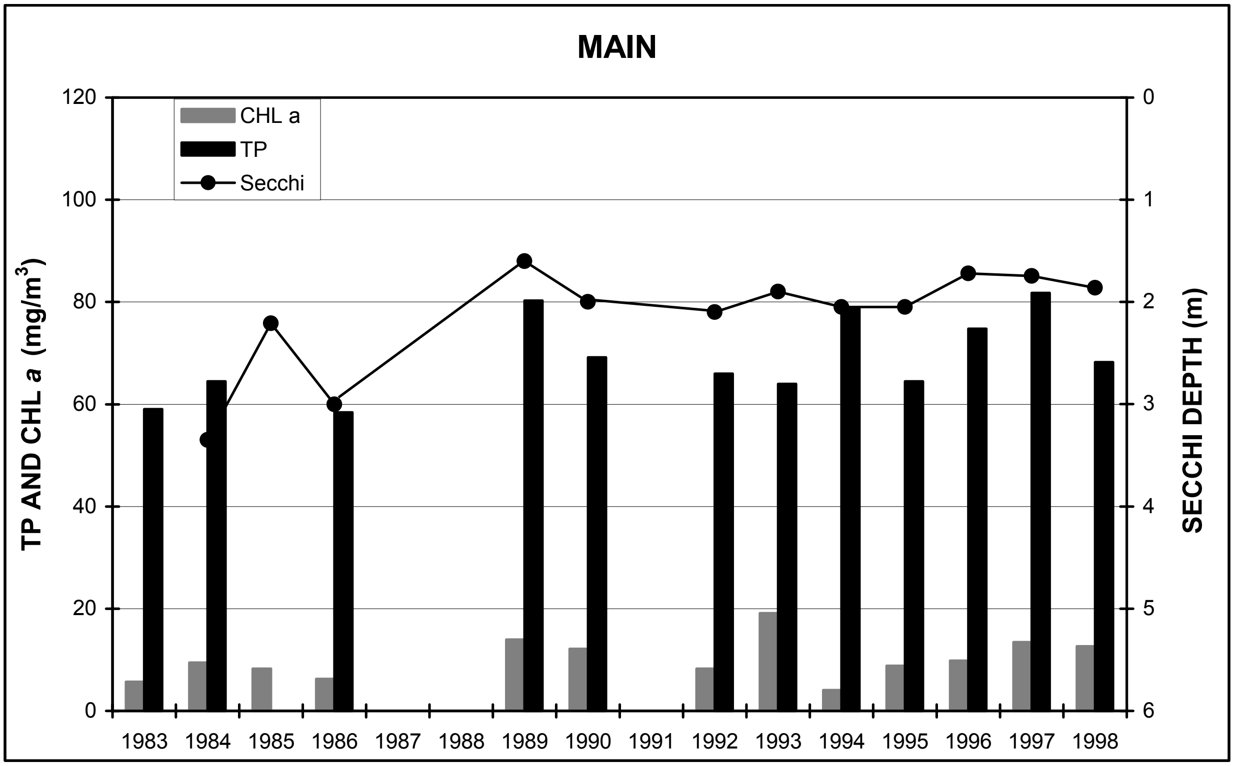
<u>Buffalo Lake.</u> Average concentrations of nutrients for Buffalo Lake in 1995, 1997 and 1998 are listed in Table 6. Although average nutrient concentrations in Buffalo Lake have not changed appreciably over the past four years, there are slight differences in Parlby and

Table 6. Average concentrations of nutrients and chlorophyll *a* (mg/m^3) and Secchi depth (m) for Buffalo Lake, May-October 1995 (pre-diversion), 1997 and 1998. Number of samples = 6 for each area in 1995 and 1997, 5 for 1998.

	Parlby Bay			Secondary Bay			Main Bay		
	95	**97**	**98**	**95**	**97**	**98**	**95**	**97**	**98**
Total Phosphorus	73	52	61	80	105	97	67	80	68
Total Dissolved Phosphorus	30	26	25	30	34	38	36	38	36
Total Nitrogen	1732	1100	1136	3026	3492	2106	2798	2747	2213
Total Kjeldahl Nitrogen	1729	919	1130	3024	3476	2088	2789	2727	2200
Nitrite + Nitrate - N	3	2	6	2	16	18	9	20	13
Ammonia - N	29	30	28	25	73	66	32	51	55
Chlorophyll *a*	9.1	3.9	5.9	8.1	19.4	14.9	9.4	12.9	12.7
Secchi Depth	Bot	0.7	bot	1.2	0.7	0.7	1.9	1.7	1.9

Secondary bays that suggest trends. The average open-water total phosphorus concentration in Parlby Bay dropped after the diversion began, as would be expected with the increased flushing rate resulting from the diversion. As well, total phosphorus levels declined over the summer in 1997 (Figure 5) and to a lesser extent in 1998. Average total nitrogen concentrations also dropped after the diversion began, but inorganic nitrogen levels have changed little over this period. All ammonia-nitrogen values measured in Parlby Bay in 1997 and 1998 were well below the Canadian Water Quality Guideline for the protection of aquatic life (Environment Canada 1999).

Average total and dissolved phosphorus concentrations observed in Secondary Bay have increased somewhat since the diversion began (Table 6). Although the concentration of total phosphorus was lower in 1998 compared with that in 1997, the average dissolved phosphorus level was slightly higher. The average total phosphorus concentration in Secondary Bay is higher all three diversion years than was observed in previous years sampled (Figure 6, bottom graph). During the summer in Secondary Bay, the concentration of total phosphorus increased rather than declined as it did in Parlby Bay (Figure 5). This increase in concentration suggests that the bottom sediments may be a source of phosphorus for Secondary Bay. Approximately 2800 kg of the 3500-kg increase in the phosphorus mass in the bay between July



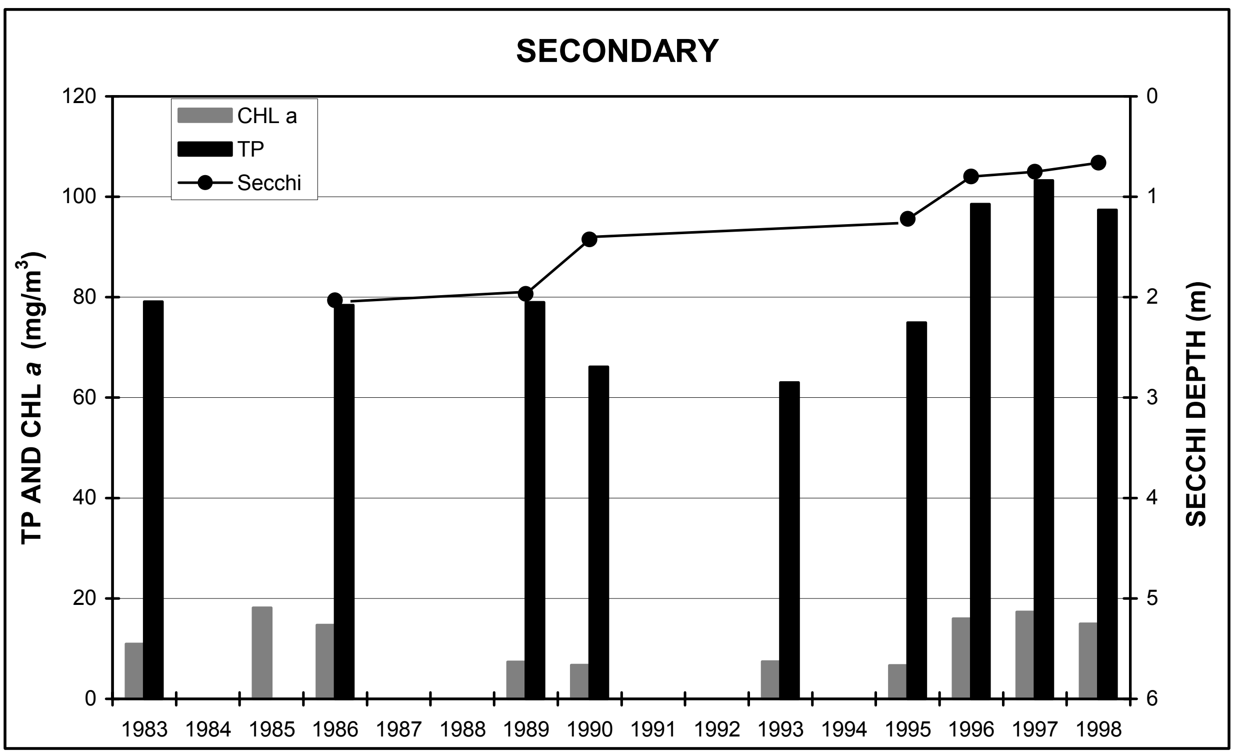


Figure 6. Average open-water Secchi depth and concentrations of chlorophyll *a* and total phosphorus in Buffalo Lake, May-September.

and September 1997 were unaccounted for by watershed, Parlby Bay and atmospheric inputs during the summer. This quantity would have been larger, because some portion of the phosphorus mass in Secondary Bay moved into Main Bay. A rough estimate for this is on the order of 1200 kg for this time period, but it is not known how water (and phosphorus mass) moves between these basins over the summer. In 1998, the net internal load was considerably smaller (about 1000 kg including the amount estimated to move into Main Bay). This may explain why phosphorus concentrations were somewhat lower in Secondary Bay in 1998, compared with those in 1997. Additional years of sampling will be needed to determine whether the higher phosphorus concentrations in Secondary Bay represent a new balance with inputs, or is a temporary instability resulting from higher inflows and flushing of nutrients from Parlby Bay.

The average total nitrogen concentration in Secondary Bay was lower in 1998 than in previous years, although levels of inorganic nitrogen seem to have increased. All ammonia-nitrogen values measured in the Bay in 1997 and 1998 were below the Canadian Water Quality Guideline for the protection of aquatic life, although several values both years approached the guideline level.

So far, there has been no change in nutrient levels in Main Bay. The year to year differences in average concentrations of phosphorus and nitrogen in Table 6 are most likely natural variation. Figure 6, which compares average phosphorus concentrations for the three diversion years with those from other years sampled, also suggests no overall change. Concentrations of total phosphorus increased over the summer of 1997 (Figure 5), but declined over the summer of 1998. The increase in phosphorus concentration in 1997 cannot be explained solely by inputs from the watershed, Secondary Bay and atmospheric deposition. The amount of phosphorus mass in the bay increased by 7500 kg between July and the end of September. External inputs amounted to about 2500 kg, of which about 1200 kg was estimated to come from Secondary Bay (assuming that water moved into Main Bay from Secondary Bay at the same rate as in Parlby Creek at Mirror). This leaves about 5000 kg unaccounted for, which likely came from the lake bottom. This source would include phosphorus contributed by groundwater and sewage, although the latter is probably negligible. There was no evidence of internal loading in 1998, however, so this mechanism probably plays only a minor role in governing water quality in this part of Buffalo Lake.

Mass loads of phosphorus and nitrogen for each of the study years are presented in Table 4. In general, the differences in phosphorus mass in each basin from year to year are fairly minor, even though the concentration data suggest trends. Although it appears that the total mass of phosphorus has increased in Parlby Bay, this may just be a function of sample timing or frequency. More likely, it may relate to the lower flushing through the bay into Secondary Bay, due to lower spring and summer runoff volumes. This might also explain the lower phosphorus mass in Secondary Bay in 1998.

In all three basins, the mass of nitrite+nitrate-nitrogen declined dramatically, and that of total kjeldahl nitrogen declined to a lesser extent in Secondary and Main Bays. Trends were not apparent for ammonia-nitrogen.

A theoretical phosphorus "budget" for Buffalo Lake in 1997 and 1998 is presented in Table 7. Although the estimates for the net internal load are rough at best, the data provide an indication of the potential difference in phosphorus loading that can occur from year to year, even though the quantity contributed by the diversion is similar. Note that the contribution from the diversion is a minor portion of the total phosphorus load. The difference in the amount contributed by the watershed during the two years was dramatic, and overshadows the diversion contribution. As well, internal loading was much greater in 1997 than in 1998, for unknown reasons.

Table 7. Total phosphorus loading to Buffalo Lake in 1997 and 1998. Loads in kilograms per year.

Source	1997	% of Total	1998	% of Total
Watershed	9000	44	1891	35
Diversion	410	2	514	9
Atmospheric Deposition*	2000	10	2000	37
Internal Load**	~9,000	44	~1,000	19
Total	~20,000	100	~5,400	100
Total inflow for year	56 million m^3		19 million m^3	

* From Shaw, et al. 1989.
** Includes bottom sediments, groundwater and sewage inputs, but does not account for phosphorus that returns to the bottom sediments during this period (therefore, it is a "net" load).

3.4 CHLOROPHYLL *a*

Chlorophyll *a*, the photosynthetic pigment in algal cells, is easily measured in a water sample; it provides an estimate of the amount (biomass) of suspended algae in the lake on the sampling day. Along with phosphorus levels, chlorophyll *a* concentrations indicate the fertility or trophic status of the lake and are therefore an excellent indicator of recreational water quality.

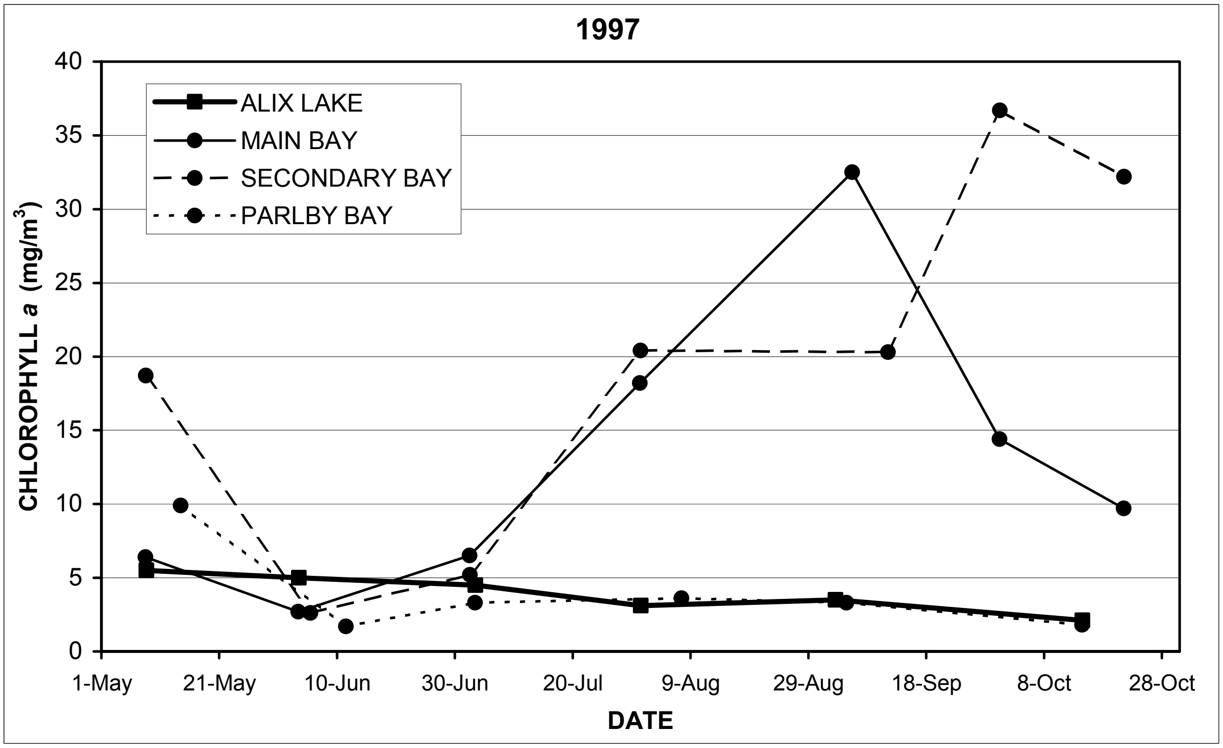
Through the summers of 1997 and 1998, Alix Lake was completely flushed by diversion water that was relatively low in nutrients. It is not surprising, therefore, that the average amount of chlorophyll *a* in the lake water has declined since the diversion began (see text box below). As well, concentrations of chlorophyll *a* remained low throughout the summer (Figure 7). The diversion has had a positive effect on recreational water quality of Alix Lake, at least in terms of the amount of suspended algae in the water.

Average Concentrations of Chlorophyll *a* in Alix Lake, May-October, 1992-1996

1992	16.1 mg/m^3	eutrophic
1996	7.8 mg/m^3	meso-eutrophic
1997	4.0 mg/m^3	mesotrophic
1998	5.8 mg/m^3	mesotrophic

As in Alix Lake, Parlby Bay was flushed with water containing relatively low levels of nutrients. Consequently, average chlorophyll *a* concentrations in Parlby Bay have also declined (Table 6). Levels also declined over the summer (Figure 7) as phosphorus concentrations decreased. The average chlorophyll *a* concentration over the last three years puts Parlby Bay in the mesotrophic category, although this rating is based on phytoplanktonic chlorophyll *a*, which does not consider the bay's dense macrophyte population.

Secondary Bay had higher average concentrations of chlorophyll *a* in 1996, 1997 and 1998 than in 1995. Although the average chlorophyll concentrations in summer 1996 and 1997 were more than double that of the previous summer, they fall into the historical range for the bay (Figure 6). However, measurements in September and October were higher all three diversion years than had been recorded at any time in sampling programs conducted before the diversion began. This is likely a result of increased internal loading of phosphorus in the bay, or is perhaps



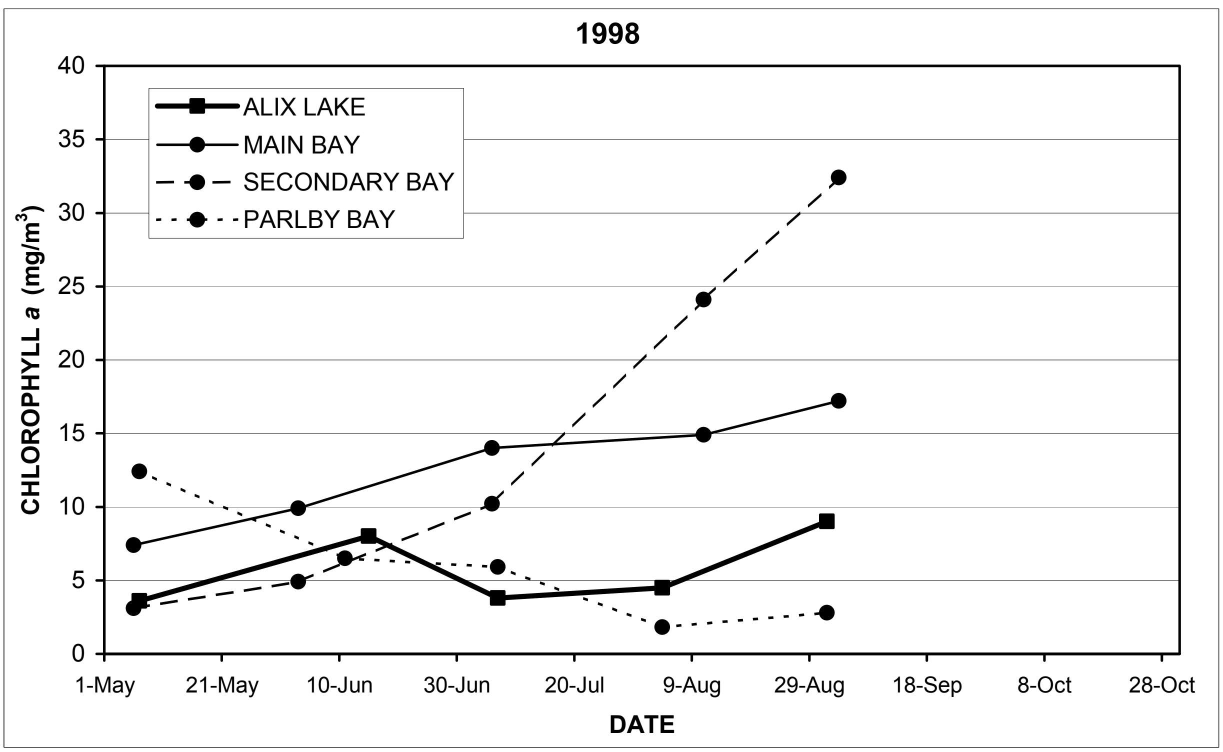


Figure 7. Concentrations of chlorophyll *a* in Alix Lake and Buffalo Lake Main, Secondary and Parlby bays, 1997 and 1998.

related to the slight decline in salinity that occurred in 1996 and 1997, but to a lesser extent in 1998.

Average chlorophyll *a* concentrations in Main Bay in 1997 and 1998 were very similar to those from 1995 (Table 6) and previous sampling programs. Chlorophyll *a* concentrations were highest in September each year sampled (Figure 7). Historically, peak chlorophyll *a* concentrations occurred in August most years. Phosphorus concentrations seem to have peaked somewhat later in the summer during the diversion years as well. The diversion inflow may have moved phosphorus from Secondary Bay into Main Bay, whereas formerly there would have been very little inflow to Main Bay during the latter part of the summer. This may have allowed algal populations to persist longer in the summer.

3.5 DISSOLVED OXYGEN

Buffalo Lake is well-mixed during the summer, and therefore concentrations of dissolved oxygen remain high. In winter, however, dissolved oxygen can become very low, especially in shallow areas. For example, in March 1997, dissolved oxygen concentrations measured in Alix Lake, Parlby Bay and Secondary Bay were very nearly zero. Historically, complete oxygen depletion occurred some winters in Secondary Bay, but in others, levels were unusually high. There are insufficient historical data for Alix Lake and Parlby Bay to assess past conditions, but it is likely that these shallow water bodies typically became anoxic in winter. In Main Bay, levels were sufficient to allow fish survival in the top three or four metres (2 to 6 mg/L). Levels measured in 1997 were similar to those measured other winters in Main Bay.

3.6 BACTERIA

Fecal coliform bacteria and *E. coli*, a species of intestinal bacteria in warm-blooded animals, were monitored in the diversion water both years at the Red Deer pumphouse, Parlby Creek at Alix, Parlby Creek at Mirror and the Main Bay of Buffalo Lake. As well, bacteria were sampled in the Alix Lake Inflow in 1997. Average numbers of fecal coliform and *E. coli* bacteria (expressed as geometric means) for 1997 are presented in Table 5. There were too few samples collected over a 30-day period to use Canadian Water Quality Guidelines to compare with the data. However, several values from Parlby Creek at Alix exceeded the guideline for resampling of 400 *E.coli* per 100 mL. The highest counts at this site in 1997 were 2500 *E.coli* and 3600 fecal coliform bacteria per 100 mL in mid-July. There were also a few high values in Parlby Creek at Alix in 1998. The source of these high counts is unknown, but should probably be investigated since nutrient concentrations were also high at this time. All data from the other sites in both 1997 and 1998 were at levels considered background for surface waters, including those from Main Bay of Buffalo Lake.

A bacteriological survey was conducted in July 1997 along the shoreline at Rochon Sands in Buffalo Lake. The results of the survey indicate no apparent contamination of the nearshore lake water with sewage from cottages. As in 1996, bacteriological samples were collected from a small pond in the Summer Village of Rochon Sands in July and August 1997. The data revealed no evidence of sewage contamination from nearby cottages, although counts were slightly above background at one location during the sampling in August. It was determined that cattle had access to the pond in this area, and they are the likely source of the bacteria.

3.7 METALS

Selected metals were analyzed in samples collected from the Red Deer pumphouse, Parlby Creek at Alix and Parlby Creek at Mirror in 1997 (Table 8). Compliance with Canadian Water Quality Guidelines (Environment Canada 1999) for the protection of aquatic life was 100% for mercury and nickel, and nearly so for lead, but other metals exceeded guidelines occasionally. Although most of the exceedences for the Red Deer River at the Pumphouse occurred when suspended solids levels were high, this was not always the case. Suspended solids levels were relatively low at the other sites, yet exceedences also occurred. Most of the values exceeding guidelines are only slightly higher and probably not a cause for concern. Exceedences of the guidelines for copper, lead, and zinc occur occasionally in the Red Deer River and other rivers in the province. For the Red Deer, Anderson (1996) suggested that the most likely source of these metals is sediment in runoff from the drainage basin or re-suspended from the river bottom during periods of high flow. Sources for the slightly elevated levels of these metals along the diversion route are unknown, and would have to be investigated further.

Table 8. Average concentrations of metals at three sites along the diversion from the Red Deer River to Buffalo Lake and compliance with Canadian Water Quality Guidelines for the protection of aquatic life, 1997. "Compliance" = number of samples meeting guideline/ total number of samples. "Avg" = average concentration for all samples, in milligrams per cubic metre. Range indicated for certain metals guidelines depends on hardness of water.

	Guideline	Red Deer River at Pumphouse		Parlby Creek at Alix		Parlby Creek at Mirror	
		Avg	Compliance	Avg	Compliance	Avg	Compliance
Aluminum	100	144	4/7	106	3/5	52	8/8
Chromium	8.9	4.5	5/6	5.6	4/5	11	4/6
Copper	3 – 4	6	2/6	3.4	3/5	4.8	3/7
Iron	300	550	7/11	290	8/12	360	12/17
Lead	4 – 7	2	5/6	1.4	5/5	0.8	7/7
Mercury	0.1	0.005	6/6	0.010	3/3	0.006	6/6
Nickel	110-150	5.5	6/6	11.4	5/5	14.6	7/7
Zinc	30	32	2/6	27	4/5	46	5/7

4.0 DISCUSSION

The water quality of the Red Deer River diversion at the pumphouse was very good during the study years, especially after mid-summer when levels of suspended solids (TSS) declined. In 1998, TSS levels were slightly higher in the diversion in June and July compared with those of 1996 and 1997. The pumps were shut down for about two weeks in early July 1998 when the silt load in the river was high. Compared with the water quality of Buffalo Lake, river levels of dissolved materials such as major ions, nutrients and organic carbon were very low. Certain metals exceeded guideline concentrations occasionally, but are likely not a cause for concern. Indicator bacteria in the diversion water were measured at levels considered natural or background.

The measured mass (amount) of total phosphorus in the diversion water at the pumphouse over the summers of 1997 and 1998 was less than 3% of the total phosphorus mass in the Main Bay of Buffalo Lake. The measured diversion phosphorus mass is very similar to the 475 kg used by Goudey et al. (1990) for pre-project impact predictions. The mass of total phosphorus at the Mirror site on Parlby Creek was only slightly higher than the mass in the diversion, even though natural runoff in the Parlby Creek watershed contributed phosphorus mass equivalent to the amount in the diversion. Goudey et al. (1990) predicted that there would be uptake of phosphorus along the diversion route, especially in Spotted Lake, and therefore the mass load entering Buffalo Lake would be reduced. This seems to be occurring, although the diversion still represents an increased phosphorus load to Buffalo Lake compared with the pre-diversion natural load. For years with high natural inflow, however, phosphorus loading from the diversion is a very minor portion of the total phosphorus load to Buffalo Lake.

Mass loads of other substances increased slightly along the diversion route toward Buffalo Lake in 1997 and 1998, but not to the extent that occurred in 1996. It appears that these substances are gradually being washed out along the diversion route. The water chemistry at various sampling sites was very similar to that of the Red Deer River.

Although comparative pre-diversion data are limited, it appears that the water quality in Alix Lake has improved. Over the past three years, the lake has become mesotrophic, whereas data collected in 1992 suggested it was eutrophic. As long as water quality in the Red Deer River is maintained, the diversion is a benefit to Alix Lake. However, if nutrient levels should gradually increase in the Red Deer River, users of Alix Lake might perceive deterioration in its water quality, especially with the rapid flushing that the lake would receive under a full pumping program.

In Buffalo Lake, Parlby Bay has also shown an improvement in water quality. The enhanced flushing from the diversion has reduced salinity in the bay, and its water quality resembles that of Parlby Creek, especially by the end of summer. The average total phosphorus concentration has declined by about 25% and the chlorophyll concentration by about 40% over 1995 levels. These changes in water quality could result in increased aquatic macrophyte growth or species change in the bay due to reduced salinity, but generally the effect of the diversion is positive.

In Secondary Bay, the effect of the diversion is not as clear-cut. Although conductivity declined in Secondary Bay between 1995 and 1996, it did not continue to decline the following two years. It would seem that the decrease in conductivity from 1995 to 1996 bears out the prediction by Goudey et al. (1990). They suggested that conductivity would decrease by 15 to 20% during the initial years of the project, although the lake would continue to become more saline over the long term. However, they were referring to the whole lake, not just Secondary Bay, and even with the higher inflows in 1997, conductivity did not continue to decline in Secondary Bay, as the prediction would suggest.

Although salinity remained within its historical range, levels of phosphorus measured in the bay during the summer since the diversion began are higher than recorded in previous sampling programs. As well, the average concentration of chlorophyll *a* for 1996-1998 is twice the 1995 level, and at the upper end of the historical range. This supports the prediction in early studies that Secondary Bay would have higher algal biomass under project conditions (Alberta Environment 1984), but the large increase in chlorophyll *a* cannot be explained by changes in salinity. Goudey et al. (1990) predicted the increase in chlorophyll *a* would be in the range of 1 mg/m^3, or from about 8 mg/m^3 to 9 mg/m^3. The average concentration for the three post-diversion years is 17.8 mg/m^3. Salinity increased in Secondary Bay in 1997 and again in 1998, but there was not a concomitant decrease in chlorophyll *a* levels. There was no relationship between conductivity (a measure of salinity) and levels of chlorophyll *a* in the bay over the historical record, in spite of historical data that suggests that there is a relationship between salinity and algal biomass. The algal population appears to respond more to levels of phosphorus rather than salinity, as Noton (1984) suggested.

Over the next few years, it is unlikely that water quality in Secondary Bay will improve. Eventually, if water is diverted most years, low-nutrient water may replace the enriched water now in the bay, leading to an improvement in conditions in the bay. This would depend on how the bottom sediments respond to reduced phosphorus concentrations in the overlying water. Nevertheless, internal loading should decline eventually, reaching a new steady-state, as occurred in sediment experiments conducted on Eagle Lake near Calgary (Environmental Management Associates 1991).

The diversion did not seem to affect the water quality of Main Bay, because the volume of flow was very small compared with the volume in the basin. Water from the diversion (mixed with natural runoff) first had to pass through Parlby and Secondary bays. In 1997, the estimated phosphorus loading from Secondary Bay to Main Bay (assuming the same flow rate as the diversion) was about 1700 kg during June - October. This contribution would increase the total phosphorus concentration in Main Bay by about 7 mg/m^3, an amount that is within measurement error and natural variation in the bay.

So far, there is no evidence that there is contamination from sewage systems at Rochon Sands in Buffalo Lake nor in the small pond at Rochon Sands. The shoreline at Pelican

Point could not be sampled because gulls and other birds use the shoreline for resting. Fecal coliform bacteria in their droppings cannot be distinguished from those in sewage.

For those water quality characteristics monitored in 1997 and 1998, the effect of the diversion has been positive on Alix Lake and Parlby Bay, negative on Secondary Bay and has had no measurable effect on Main Bay. Water quality along the diversion route appears to have reached equilibrium with the diversion water, but it is not clear whether this is true for Buffalo Lake. The theoretical phosphorus loads to Buffalo Lake were so different (and imprecise) that it additional years of data will be needed to sort out how diversion impacts fit in with natural variation due to climatic differences from year to year. Thus far, it seems unlikely that Main Bay will be affected positively or negatively, because Secondary Bay seems to buffer inputs from the diversion, as it did under pre-project conditions. Although it may not be necessary to do a complete sampling program every year, it would be prudent to conduct minimal lake sampling annually, and then a more intensive one-year monitoring program in perhaps two to three years.

5.0 CONCLUSIONS

1. The water quality of the Red Deer River diversion water was better than in Buffalo Lake, in terms of total dissolved solids and nutrients.

2. The volume of natural runoff in Parlby Creek during March - October 1997 was greater than the volume of the diversion water, and therefore natural conditions most influenced water quality in Buffalo Lake that year. In 1998, the diversion had a greater influence, because there was very little runoff that year.

3. The concentration of nutrients, total dissolved solids and other substances increased along the diversion route toward Buffalo Lake, but not to the extent that occurred in 1996. The diversion water may be washing out these substances.

4. The water quality of Alix Lake has improved since the diversion began, and closely resembles Red Deer River water.

5. In Buffalo Lake, small Parlby Bay showed the greatest change in water quality as a result of the diversion and natural runoff. Salinity and phosphorus concentrations have declined since the diversion began, but now appear to be stabilized.

6. The greatest negative change in water quality occurred in Secondary Bay, where phosphorus and chlorophyll *a* concentrations were higher during the diversion years than in 1995 and most other years for which there are records.

7. There was no observable impact or effect of the diversion on water quality in Main Bay.

8. Phosphorus loading in the diversion is a small percentage of the annual total phosphorus load to Buffalo Lake.

9. There is no evidence of sewage contamination along the shoreline of Buffalo Lake at Rochon Sands, nor in the pond at Rochon Sands.

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Appendix I. Buffalo Lake, Alix Lake and diversion data, 1997-1998.

Parlby Creek - Buffalo Lake Water Management Project - 1997 LAKES DATA.

MAIN BAY - AB05CD1040

Sampling Date	Chlorophyll *a* mg/m3	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	DOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L
08-May-97	6.4	87.5	35.8	2.661	0.011	0.03	2.65	39.1		2770	9.24	1940	*0.2*
03-Jun-97	2.7	67.1	44.6	2.424	0.024	0.07	2.4	35.8		2810	9.19	1910	*0.2*
02-Jul-97	6.5	67.6	40.9	3.1015	*0.0015*	0.07	3.1	36.2		2810	9.22	1840	*0.2*
31-Jul-97	18.2	89.6	36.5	3.658	0.058	0.05	3.6	40		2800	9.13	1830	4
05-Sep-97	32.5	80.1	31.4	3.01	0.01	0.02	3	40.6		2910	9.26	1940	10
30-Sep-97	14.4	98.7	39.2	1.347	0.007	0.06	1.34	39.2			9.31	1950	4
21-Oct-97	9.7	70.8	41.1	3.026	0.026	0.06	3	39.9		2800	9.23	1890	3
average	**12.9**	**80.2**	**38.5**	**2.747**	**0.020**	**0.051**	**2.727**	**38.7**		**2816.7**		**1900.0**	**3.1**
June-Oct.	14.0	79.0	39.0	2.76	0.0211	0.06	2.74	38.6		2826		1893	3.6
May-Sept.	13.5	81.8	38.1	2.70	0.0186	0.05	2.68	38.5		2820		1902	3.1

SECONDARY BAY - AB05CD0860

Sampling Date	Chlorophyll *a* mg/m3	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	DOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L
08-May-97	18.7	99.8	34.2	10.806	0.006	0.02	10.8	30.4		1810	9.06	1170	15
05-Jun-97	2.6	70.7	39.5	2.123	0.023	0.11	2.1	30.6		2030	8.96	1300	3
02-Jul-97	5.2	66.7	42.5	2.129	0.029	0.11	2.1	29.7		2040	9.08	1310	1
31-Jul-97	20.4	114.9	30.4	2.728	0.028	0.05	2.7	34.1		1990	9.01	1270	16
11-Sep-97	20.3	116.5	26.3	1.926	0.006	0.03	1.92	31.6		2100	9.08	1390	20
30-Sep-97	36.7	150.8	35.5	1.917	0.007	0.04	1.91	31.6			9.13	1390	32
21-Oct-97	32.2	117.1	31.4	2.813	0.013	0.15	2.8	30.9		1920	9.04	1270	22
average	**19.4**	**105.2**	**34.3**	**3.492**	**0.016**	**0.073**	**3.476**	**31.3**		**1982**		**1300**	**16**
June-Oct.	19.6	106.1	34.3	2.27	0.0177	0.08	2.255	31.4		2016		1322	16
May-Sept.	17.3	103.2	34.7	3.60	0.0165	0.06	3.588	31.3		1994		1305	15

PARLBY BAY - AB05CD0840

Sampling Date	Chlorophyll *a* mg/m3	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	DOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L
14-May-97	9.9	100.7	42.2	1.9015	*0.0015*	0.04	1.9		21.4	681	8.31	418	*0.2*
11-Jun-97	1.7	42.1	27.3	1.3215	*0.0015*	0.03	1.32	19.3		775	8.59	480	*0.2*
03-Jul-97	3.3	75.1	52.4	0.9415	*0.0015*	0.03	0.94	17.2		598	8.55	346	*0.2*
07-Aug-97	3.6	27.8	14.6			0.01	*0.025*	9.3		259	9.25	144	*0.2*
04-Sep-97	3.3	30.1	12.9	0.8615	*0.0015*	0.04	0.86	7.3		247	9.58	139	7
14-Oct-97	1.8	32.9	9.5	0.474	0.004	0.03	0.47	6.7		387	8.33	223	4
average	**3.9**	**51.5**	**26.5**	**1.100**	**0.002**	**0.030**	**0.919**	**12.0**	**21.4**	**491.2**		**291.7**	**2.0**
June-Oct.	2.7	41.6	23.3	0.90	0.0021	0.03	0.72	12.0		453		266	2
May-Sept.	4.4	55.2	29.9	1.26	0.0015	0.03	1.01	13.3		512		305	2

PARLBY CREEK NW OF ALIX - AB05CD0430

Sampling Date	FLOW m3/sec	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	DOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L
27-Mar-97	0.251		189	18.134	0.334	0.27	17.8	15	15	486	7.51	281	12
31-Mar-97	4.7	651	524	3.24	0.64	0.37	2.6	16.9		333	7.44	190	23
02-Apr-97	7.13	608	456	1.797	0.977	0.23	0.82	20.6		335	7.37	202	62
07-Apr-97	4.7	3770	3150	2.515	0.775	0.14	1.74		20.1		7.67	245	9
14-Apr-97	1.64	145	110	1.112	0.012	0.03	1.1		15.4		7.78	278	1
17-Apr-97	2.54	161	117	1.499	0.049	0.02	1.45		15.2		7.65	244	6
21-Apr-97	3.06	148	111	0.5815	*0.0015*	0.02	0.58	17.1		415	7.77	237	10
24-Apr-97	1.81	134	112	1.075	*0.015*	0.03	1.06		17		7.76	340	3
06-May-97	0.286	153	102	1.0715	*0.0015*	0.03	1.07	15.9		729	8.09	435	1
22-May-97	0.32	188	160	1.201	0.021	0.03	1.18	16.9		853	8.18	522	5
02-Jun-97	0.27	214	169	1.164	0.014		1.15	18.2		892	8.2	544	3
18-Jun-97	0.445	378	321	1.43	0.01	0.02	1.42	21.5	25.5	806	8.06	496	2
03-Jul-97	0.377	231	185	1.313	0.013	0.06	1.3	23.4		716	8.22	427	*0.2*
16-Jul-97	0.021	321	221	0.776	0.016	0.03	0.76	23.9	24.3	828	8.38	505	20
05-Aug-97	0.025	221	116	1.3715	*0.0015*	0.02	1.37	17.5		822	8.43	500	5
30-Oct-97	0.133	113	87	0.95	0.01	0.01	0.94	17.6	15.7	812	8.14	478	*0.2*
average		**496**	**383**	**2.452**	**0.181**	**0.09**	**2.27**	**18.7**	**18.5**	**669**		**370**	**10**
June-Oct.		246.3	183.2	1.167	0.011	0.03	1.16	20.4	21.8	813		492	5
May-Sept.		243.7	182.0	1.190	0.011	0.03	1.18	19.6	24.9	807		490	5

ALIX LAKE - AB05CD1070

Sampling Date	Chlorophyll *a* mg/m3	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	DOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L
08-May-97	5.5	31.4	8.5	0.553	0.003	0.03	0.55	7		427	8.08	247	1
03-Jun-97	5	29.8	10.4	0.5015	*0.0015*	*0.005*	0.5	6.7		413	8.25	236	*0.2*
03-Jul-97	4.5	25.1	8.8	0.4215	*0.0015*	0.02	0.42	8.4		340	8.42	186	*0.2*
31-Jul-97	3.1	18.7	7.2	0.488	0.008	0.03	0.48	7.5		288	8.43	171	*0.2*
02-Sep-97	3.5	17.3	6.5	0.4815	*0.0015*	*0.005*	0.48	6.6		306	8.05	178	*0.2*
14-Oct-97	2.1	10.3	4.8	0.273	0.003	*0.005*	0.27	6.4		352	8.22	202	*0.2*
average	**4.0**	**22.1**	**7.7**	**0.453**	**0.0031**	**0.02**	**0.45**	**7.1**		**354**		**203**	**0.3**
June-Oct.	3.6	20.2	7.5	0.433	0.0031	0.013	0.43	7.1		340		195	0.2
May-Sept.	4.3	24.5	8.3	0.489	0.0031	0.018	0.49	7.2		355		204	0.4

Less than values = 0.5 of Detection Limit (in italics)

Parlby Creek-Buffalo Lake Water Management Project - 1997 DIVERSION DATA.

RED DEER RIVER AT PUMPHOUSE - AB05CD1570

Sampling Date	FLOW m3/S	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	DOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L
02-Jun-97	0.776	106	23	0.381	0.101		0.28	8.4		350	8.03	195	13
18-Jun-97	1.117	97	26	0.475	0.095	0.02	0.38	7.3		328	7.64	181	49
03-Jul-97	0.356	26	11	0.283	0.003	0.01	0.28	7.4	7.7	352	8.73	203	*0.2*
16-Jul-97	0.827	37	9	1.06	0.63	0.01	0.43	7.3		348	8.38	194	8
05-Aug-97	1.177	26	5	0.385	0.005	0.03	0.38	5.1		333	8.64	192	6
20-Aug-97	1.199	21	*1.5*	0.424	0.014	0.01	0.41	5.3	5	377	8.43	214	5
02-Sep-97	0.764	13	4	0.3415	*0.0015*	*0.005*	0.34	4.1		332	8.64	201	*0.2*
18-Sep-97	1.015	13	*1.5*	0.3515	*0.0015*	*0.005*	0.35	5.7		342	8.44	193	*0.2*
02-Oct-97	1.386	5	*1.5*	0.3115	*0.0015*	0.02	0.31	4.7		374	8.51	216	*0.2*
16-Oct-97	1.270	7	4	0.309	0.009	0.01	0.3	4.2		407	8.31	228	*0.2*
30-Oct-97	0.801	13	7	0.2725	*0.0025*	*0.005*	0.27	4.4	3.8	406	8.53	233	2
average		**33.1**	**8.5**	**0.418**	**0.0785**	**0.01**	**0.34**	**5.8**	**5.5**	**359**		**205**	**7.6**

ALIX LAKE INFLOW - AB05CD1580

Sampling Date	FLOW m3/s	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	DOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L
02-Jun-97	0.009	61	47	2.0015	*0.0015*		2	34		1430	8.35	989	*0.2*
18-Jun-97	1.14	14	*1.5*	6.2515	*0.0015*	0.02	6.25	6.6		346	7.88	200	*0.2*
03-Jul-97	0.381	8	4	0.3215	*0.0015*	0.02	0.32	9.3	8.8	320	8.37	181	*0.2*
16-Jul-97	1.2	10	4	0.365	0.005	0.01	0.36	6		331	8.16	182	*0.2*
05-Aug-97	1.12	12	5	0.3815	*0.0015*	0.02	0.38	6	6.3	333	8.09	191	*0.2*
20-Aug-97	1.14	3	*1.5*	0.361	0.011	*0.005*	0.35	4.4		344	8.12	188	*0.2*
02-Sep-97	0.825	7	3	0.393	0.003	0.02	0.39	5.6		347	8.04	200	*0.2*
18-Sep-97	1.12	12	*1.5*	0.349	0.009	0.01	0.34	6.7		352	8.14	196	*0.2*
02-Oct-97	1.4	4	*1.5*	0.466	0.006	0.03	0.46	5.2		367	8.2	213	*0.2*
16-Oct-97	1.29	8	4	0.291	0.011	*0.005*	0.28	4.3		391	8.23	225	*0.2*
30-Oct-97		13	4	0.32	0.01	*0.005*	0.31	4		408	8.31	233	*0.2*
average		**13.8**	**7.0**	**1.046**	**0.0055**	**0.015**	**1.04**	**8.4**	**7.6**	**452**		**273**	**0.2**

ALIX LAKE OUTFLOW - AB05CD1590

Sampling Date	FLOW m3/S	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	DOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L
06-May-97	0.007	29	6	0.4515	*0.0015*	0.01	0.45	6.6		419	8	232	3
22-May-97	*0.005*	51	23	0.864	0.044	0.09	0.82	8.1		578	7.64	296	4
02-Jun-97	0.002	33	13	0.596	0.016		0.58	7.8		427	8	236	2
18-Jun-97	1.56	28	14	0.4515	*0.0015*	0.02	0.45	8.6		360	8.09	202	*0.2*
03-Jul-97	0.26	20	5	0.4015	*0.0015*	0.01	0.4	8.5		325	8.43	184	*0.2*
16-Jul-97	1.07	21	5	0.674	0.004	0.01	0.67	8.8	8.7	301	8.65	167	*0.2*
05-Aug-97	1.29	16	4	0.4715	*0.0015*	0.02	0.47	7.1		274	8.67	153	1
20-Aug-97	0.692	4	*1.5*	0.399	0.009	0.01	0.39	6		295	8.37	164	*0.2*
02-Sep-97	1.46	19	*1.5*	0.5015	*0.0015*	*0.005*	0.5	6		296	8.49	167	*0.2*
18-Sep-97	1.23	14	*1.5*	0.404	0.004	0.01	0.4	6.2		308	8.1	171	*0.2*
02-Oct-97	1.83	3	*1.5*	0.3515	*0.0015*	0.03	0.35	5.3	4	310	8.4	178	*0.2*
16-Oct-97	1.55	5	4	0.229	0.009	*0.005*	0.22	5		341	8.33	189	*0.2*
30-Oct-97	0	5	3	0.306	0.006	*0.005*	0.3	3.8		382	8.37	220	*0.2*
average	**0.8**	**19.1**	**6.4**	**0.469**	**0.008**	**0.019**	**0.46**	**6.8**	**6.4**	**355**		**197**	**0.9**
June-Oct.		15.3	4.9	0.435	0.005	0.013	0.43	6.6	6.4	329		185	0.4

PARLBY CREEK AT MIRROR (gauging site) - AB05CD0440

Sampling Date	FLOW m3/S	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	DOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L
27-Mar-97	0.06		1550	10.53	0.03	4.3	10.5	30.3	28.1	516	7.12	290	12
31-Mar-97	2	516	398	3.33	0.68	0.24	2.65	20.9		377	7.25	229	3
02-Apr-97	2.06	385	292	1.149	0.459	0.12	0.69	22.7		457	7.35	276	3
07-Apr-97	0.831	183	123	1.84	0.07	0.04	1.77		24.2		7.67	319	7
14-Apr-97	2.54	270	193	1.464	0.014	0.05	1.45		20.5		7.72	243	9
17-Apr-97	5.45	257	147	1.853	0.003	0.03	1.85		20.1		7.55	243	12
21-Apr-97	4.27	198	106	4.5515	*0.0015*	0.03	4.55	20		457	7.76	267	20
24-Apr-97	1.14	166	113	1.625	*0.015*	0.03	1.61		20.2		7.69	320	5
06-May-97	0.869	109	106	1.3215	*0.0015*	0.02	1.32	20		646	7.93	371	4
22-May-97	0.465	149	132	2.104	0.024	0.18	2.08	25		840	8.07	521	5
02-Jun-97	0.428	195	141	1.196	0.016		1.18	21.7		981	8.14	614	3
18-Jun-97	1.09	111	85	0.7815	*0.0015*	0.04	0.78	11.5	12.9	525	8.18	311	3
03-Jul-97	0.724	123	97	1.1215	*0.0015*	0.05	1.12	17.6		600	8.46	358	*0.2*
16-Jul-97	1.06	63	37	0.324	0.004	0.02	0.32	11.4		353	8.81	203	2
05-Aug-97	0.927	31	19	0.4915	*0.0015*	0.02	0.49	7.8	7.8	275	9.19	159	2
20-Aug-97	1.2	18	*1.5*	0.426	0.016	0.02	0.41	6.6		293	9.15	170	1
02-Sep-97	1.05			0.6015	*0.0015*	*0.005*	0.6	6.6		292	9.15	177	*0.2*
18-Sep-97	1.42	21	4	0.4215	*0.0015*	*0.005*	0.42	5.8		313	8.4	175	2
02-Oct-97	1.3	14	*1.5*	0.393	0.003	0.01	0.39	5.5		315	8.44	184	*0.2*
16-Oct-97	0.854	42	3	0.209	0.009	0.01	0.2	6.7		367	8.26	206	27
30-Oct-97	1.38	30	5	0.257	0.007	*0.005*	0.25	5	4.5	424	8.16	245	16
average		**151.6**	**177.7**	**1.71**	**0.065**	**0.26**	**1.65**	**14.4**	**17.3**	**472**		**280**	**7**
June-Oct.		**64.8**	**39.4**	**0.57**	**0.006**	**0.02**	**0.56**	**9.7**	**8.4**	**431**		**255**	**5**

Parlby Creek - Buffalo Lake Water Management Project - 1997 LAKES DATA.

MAIN BAY - AB05CD1040

Sampling Date	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	SO4 mg/L	Cl mg/L	HCO3 mg/L	CO3 mg/L	T. Alk. mg/L CaCO3	Hardness mg/L	Silica mg/L	Secchi m	F. COLI cts/100 mL	E. COLI cts/100 mL
08-May-97	6	81.2	44	618	478	16.9	1020	183	1140	349	2.5	1.25	2	2
03-Jun-97	6.49	84.2	46.1	599	465	15.4	1040	177	1150	363	1.7	3.9	11	4
02-Jul-97	6.97	75.3	41.8	534	482	16.8	965	199	1120	327	1.7	1.6	3	3
31-Jul-97	8.1	78.6	42.1	540	418	17.3	1050	199	1200	344	1.8	1.25	20	20
05-Sep-97	7.66	83.2	45.9	587	451	18.1	1050	218	1230	362	1.3	1.2	2	2
30-Sep-97	6.84	80	45.4	577	493	19.2	1030	216	1210		1.06	1.27	9	9
21-Oct-97	6.62	80.1	44.7	551	456	21.1	1170	140	1200	346	1.35	1.6	2	2
average	**7.0**	**80.4**	**44.3**	**572.3**	**463.3**	**17.8**	**1046.4**	**190.3**	**1178.6**	**348.5**	**1.6**	**1.7**	**5**	**4**
June-Oct.	7.1	80.2	44.3	565	461	18.0	1051	192	1185	348	1.49	1.80	5	5
May-Sept.	7.0	80.4	44.2	576	465	17.3	1026	199	1175	349	1.68	1.75	5	5
													geo mean	geo mean

SECONDARY BAY - AB05CD0860

Sampling Date	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	SO4 mg/L	Cl mg/L	HCO3 mg/L	CO3 mg/L	T. Alk. mg/L CaCO3	Hardness mg/L	Silica mg/L	Secchi m	F. COLI cts/100 mL	E. COLI cts/100 mL
08-May-97	17.3	57	29.5	338	276	12.2	709	85.5	724	278	7.1	0.5		
05-Jun-97	17	64.7	34.8	342	337	13	774	102	805	309	6.3	1.8		
02-Jul-97	16.6	58.9	31.2	359	335	13.4	769	106	808	284	3.9	1.25		
31-Jul-97	16.4	59	30.5	364	278	13.4	807	109	843	284	4.4	0.4		
11-Sep-97	11.9	58.1	31.1	384	342	13.9	848	121	898	269	3	0.3		
30-Sep-97	12.3	60.1	32.6	397	339	15	841	109	871		2.95	0.25		
21-Oct-97	13.7	59	30.7	359	295	16.2	792	95.4	809	277	2.7	0.4		
average	**15.0**	**59.5**	**31.5**	**363.3**	**314.6**	**13.9**	**791.4**	**104.0**	**822.6**	**283.5**	**4.3**	**0.7**		
June-Oct.	14.7	60.0	31.8	368	321	14.2	805	107	839	285	3.88	0.73		
May-Sept.	15.3	59.6	31.6	364	318	13.5	791	105	825	285	4.61	0.75		

PARLBY BAY - AB05CD0840

Sampling Date	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	SO4 mg/L	Cl mg/L	HCO3 mg/L	CO3 mg/L	T. Alk. mg/L CaCO3	Hardness mg/L	Silica mg/L	Secchi m	F. COLI cts/100 mL	E. COLI cts/100 mL
14-May-97	61.7	28.9	11.5	59.7	62.6	6.9	359	6.71	306	273	11.4	0.7		
11-Jun-97	46.1	36	9.51	86.1	92	7.9	371	17	333	263	0.8			
03-Jul-97	47.2	27.2	5.24	53.8	37.7	4.1	312	14.5	280	230	4.2	0.8		
07-Aug-97	18.5	16	1.99	14.9	26	1.6	83.4	23.2	107	112	1	0.8		
04-Sep-97	16.5	15.9	1.69	12.7	29.3	2.1	60.2	31	101	107	1.3	0.75		
14-Oct-97	38.8	17.8	2.55	19.8	33.2	3.3	206	4.18	176	170	1	0.6		
average	**38.1**	**23.6**	**5.4**	**41.2**	**46.8**	**4.3**	**231.9**	**16.1**	**217.2**	**192.5**	**3.3**	**0.7**		
June-Oct.	33.4	22.6	4.2	37	44	3.8	207	18	199	176	1.66	0.74		
May-Sept.	38.0	24.8	6.0	45	50	4.5	237	18	225	197	3.74	0.76		

PARLBY CREEK NW OF ALIX - AB05CD0430

Sampling Date	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	SO4 mg/L	Cl mg/L	HCO3 mg/L	CO3 mg/L	T. Alk. mg/L CaCO3	Hardness mg/L	Silica mg/L	Secchi m	F. COLI cts/100 mL	E. COLI cts/100 mL
27-Mar-97	30.3	18.3	9.04	51.8	32.2	4	266	0.25	218	151	10.2		700	700
31-Mar-97	20.3	11.6	12.9	28.4	24.8	6.3	162	0.25	133	98.5	7.51		8	8
02-Apr-97	25.9	13.2	14.2	25.6	24.9	7.4	169	0.25	139	119	9.2		16	2
07-Apr-97	28.8	14.9	13.2	34	21.9	6	226	0.25	185	133	11.2		4	4
14-Apr-97	34.1	17.7	8.87	46.3	25.3	4.9	280	0.25	230	158	11.3		4	4
17-Apr-97	34.5	16.1	8.24	36.6	25.9	5.3	234	0.25	192	153	10.9		8	8
21-Apr-97	34.9	16.1	9.09	32.8	27.5	5.1	223	0.25	183	154	8.9		6	4
24-Apr-97	43.7	20.3	9.19	46.4		8.5	279	0.25	229	193	9.86		3	2
06-May-97	59.9	26.4	7.36	67.7	51.6	12.1	419	0.25	344	258	6.9		12	12
22-May-97	62.6	30.8	7.44	100	61.9	9.1	499	0.25	409	283	5.3		180	170
02-Jun-97	66.3	32.4	6.57	103	72.9	7.7	510	0.25	418	299	6		240	220
18-Jun-97	56.3	32	5.89	91.6	49.1	6.2	507	0.25	416	272	11.2		220	210
03-Jul-97	55.8	28.5	5.9	69.4	30.4	4.9	462	0.25	379		13.8		280	260
16-Jul-97	51.9	29.9	7.01	98.9	45.4	6	507	11.4	435	253	4.25		3600	2500
05-Aug-97	59.5	32.1	7.06	87.1	67.7	11	442	14.1	386	281	6.8		1000	750
30-Oct-97	53.4	32.9	6.87	85.4	25.1	7.2	533	0.25	437	269	8.8		12	12
average	**44.9**	**23.3**	**8.68**	**62.8**	**39.1**	**7.0**	**357**	**1.8**	**296**	**205**	**8.9**		**45**	**35**
June-Oct.	57.2	31.3	6.55	89.2	48.4	7.2	494	4.4	412	275	8.5		293	254
May-Sept.	58.9	30.3	6.75	88.2	54.1	8.1	478	3.8	398	274	7.8		274	240
													geo mean	geo mean

ALIX LAKE - AB05CD1070

Sampling Date	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	SO4 mg/L	Cl mg/L	HCO3 mg/L	CO3 mg/L	T. Alk. mg/L CaCO3	Hardness mg/L	Silica mg/L	Secchi m	F. COLI cts/100 mL	E. COLI cts/100 mL
08-May-97	42.3	22.8	4.16	19.8	41.3	10	213	0.25	175	200	2.3	2.5		
03-Jun-97	35	24	4	22	44.2	3.4	207	0.25	170	186	1.1	2.7		
03-Jul-97	33.3	17.4	2.34	14	31	2.3	160	5.92	141	155	2.6	2.6		
31-Jul-97	33	16	1.91	11.6	25.2	3.9	150	4.84	131	148	1.05	2.7		
02-Sep-97	33	16.6	1.63	12.8	28.4	2.7	166	0.25	136		0.7	2.7		
14-Oct-97	42.7	16.5	1.67	11.2	33.3	2.8	188	0.25	154	175	0.5	2.75		
average	**36.6**	**18.9**	**2.62**	**15.2**	**33.9**	**4.18**	**181**	**1.96**	**151**	**173**	**1.4**	**2.7**		
June-Oct.	35.4	18.1	2.31	14.3	32.4	3.02	174	2.3	146	166	1.2	2.7		
May-Sept.	35.3	19.4	2.81	16.0	34.0	4.46	179	2.3	151	172	1.6	2.6		

Parlby Creek-Buffalo Lake Water Management Project - 1997 DIVERSION DATA.

RED DEER RIVER AT PUMPHOUSE - AB05CD1570

Sampling Date	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	SO4 mg/L	Cl mg/L	HCO3 mg/L	CO3 mg/L	T. Alk. mg/L CaCO3	Hardness mg/L	Silica mg/L	Secchi m	F. COLI cts/100 mL	E. COLI cts/100 mL
02-Jun-97	48.2	13.6	2.08	8.09	26.4	2.2	188	*0.25*	154	176	5.98		96	92
18-Jun-97	43.7	13	1.93	8.58	25.4	2.2	171	*0.25*	140	163	6.05		150	120
03-Jul-97	44.8	14.2	1.71	11.4	26.6	2.9	177	12.6	166	170	1.3		6	*2*
16-Jul-97	40.8	13.5	1.77	10.3	25.3	2.1	184	5.29	160	158	2.87		14	14
05-Aug-97	41	14.8	1.62	10.6	30.9	2.2	158	12.2	150	163	0.7		6	*2*
20-Aug-97	46.8	16	1.96	12.2	29.2	3.4	194	7.25	171	183	2.2		20	20
02-Sep-97	46	16.3	1.24	9.81	31.9	4.2	160	11.1	150		1.1		6	4
18-Sep-97	39.7	14.1	1.56	9.75	31.8	3.1	174	6.37	153	157	*0.025*		40	40
02-Oct-97	50.2	17.5	1.6	10	31.5	2.7	192	6.84	169	198	*0.025*		8	3
16-Oct-97	46.9	16.6	1.5	11.6	39	5.5	208	3.46	176	186	*0.025*		4	4
30-Oct-97	49.1	16.1	1.8	15.3	31	8.8	210	8	185	189	0.2		6	*2*
average	**45.2**	**15.1**	**1.71**	**10.69**	**29.9**	**3.6**	**183**	**6.69**	**161**	**174**	**1.86**		**15**	**9**
													geo mean	geo mean

ALIX LAKE INFLOW - AB05CD1580

Sampling Date	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	SO4 mg/L	Cl mg/L	HCO3 mg/L	CO3 mg/L	T. Alk. mg/L CaCO3	Hardness mg/L	Silica mg/L	Secchi m	F. COLI cts/100 mL	E. COLI cts/100 mL
02-Jun-97	61.4	89.8	15.2	158	374	4.4	554	8.86	469	523	8.25		69	54
18-Jun-97	44.8	15.4	2.3	10.5	26.3	2.9	196	*0.25*	161	175	4.4		25	17
03-Jul-97	35.4	15.3	2.16	11.6	24	2.6	168	5.52	147	147	0.7		40	34
16-Jul-97	36.7	14.6	1.59	8.94	28.4	2	179	*0.25*	147	152	1.6		23	23
05-Aug-97	39.1	15.2	1.71	10.6	29.5	5	179	*0.25*	147	160	1.13		58	14
20-Aug-97	36.9	14.9	1.51	9.18	28.9	5.1	183	*0.25*	150	154	1.54		6	6
02-Sep-97	44.1	16.8	1.55	10.6	31	2.9	185	*0.25*	152		1.3		17	*2*
18-Sep-97	39.4	15.1	1.77	10.4	34.1	3.4	184	*0.25*	151	161	0.5		12	4
02-Oct-97	47.6	18.4	2.1	10.7	32.2	3	199	*0.25*	163	195	0.6		17	17
16-Oct-97	49.9	17.3	1.31	10.6	35.6	4.6	211	*0.25*	173	196	1.05		3	*2*
30-Oct-97	43.5	18.2	2.18	16.1	35.5	4.3	219	3.04	185	184	*0.025*		*2*	*2*
average	**43.5**	**22.8**	**3.03**	**24.3**	**61.8**	**3.7**	**223**	**1.77**	**186**	**205**	**1.92**		**15**	**9**
													geo mean	geo mean

ALIX LAKE OUTFLOW - AB05CD1590

Sampling Date	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	SO4 mg/L	Cl mg/L	HCO3 mg/L	CO3 mg/L	T. Alk. mg/L CaCO3	Hardness mg/L	Silica mg/L	Secchi m	F. COLI cts/100 mL	E. COLI cts/100 mL
06-May-97	37.9	20.5	3.62	17.4	39.7	5.7	215	*0.25*	176	179	1.95			
22-May-97	40.6	26.9	4.51	32.9	44.2	5	284	*0.25*	233	212	2.8			
02-Jun-97	34.2	21.6	3.78	20.5	42.8	3.5	218	*0.25*	179	174	1.65			
18-Jun-97	30.3	19.2	2.86	15.8	36	3	189	*0.25*	155	155	2.3			
03-Jul-97	29.5	16.8	2.27	13.5	32.1	2.5	163	5.71	143		2.75			
16-Jul-97	22.5	16.5	2.35	14.1	31.1	2.2	139	8.89	129	124	1.2			
05-Aug-97	26.2	14.9	1.77	10.8	25.4	1.9	126	9.41	119	127	0.85			
20-Aug-97	27.7	15.4	1.56	10.1	26.9	5.6	146	3.67	126	133	0.8			
02-Sep-97	28.9	16.4	1.57	12.8	28.4	2.7	139	7.07	126		0.7			
18-Sep-97	30.6	15.4	1.87	10.5	30.3	2.6	160	*0.25*	131	140	0.64			
02-Oct-97	34	17.6	2.01	10.5	30.7	3.7	153	3.19	131	157	*0.025*			
16-Oct-97	36.3	15.9	1.21	7.02	35.2	3.1	175	2.44	148	156	*0.025*			
30-Oct-97	43.9	18.2	2.09	15.2	36	4.4	191	4.2	164	185	*0.025*			
average	**32.5**	**18.1**	**2.42**	**14.7**	**33.8**	**3.5**	**177**	**3.53**	**151**	**158**	**1.21**			
June-Oct.	31.3	17.1	2.12	12.8	32.3	3.2	164	4.12	141	150	0.997			

PARLBY CREEK AT MIRROR (gauging site) - AB05CD0440

Sampling Date	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	SO4 mg/L	Cl mg/L	HCO3 mg/L	CO3 mg/L	T. Alk. mg/L CaCO3	Hardness mg/L	Silica mg/L	Secchi m	F. COLI cts/100 mL	E. COLI cts/100 mL
27-Mar-97	31.3	16.7	28	35.6	55.9	7.7	221	*0.25*	181	147	8.7		11	4
31-Mar-97	30.8	15.4	17.6	19.3	72.6	6.8	124	*0.25*	102	140	7.51		92	92
02-Apr-97	40.5	19.9	16.3	26.8	63.6	5.4	201	*0.25*	165	183	10.9		66	66
07-Apr-97	48.2	23.5	15.3	33.7	62.3	6.3	257	*0.25*	211	217	13.5		8	8
14-Apr-97	30.1	15.9	12.1	31.5	45.6	6.7	201	*0.25*	165	141	10.2		4	3
17-Apr-97	32.8	16.1	11.6	32.6	41.4	6	204	*0.25*	167	148	11.1		4	4
21-Apr-97	36.1	18	12	36.8	47.2	5.9	221	*0.25*	181	164	11		84	84
24-Apr-97	35.2	19.4	11.6	44.2		9.1	239	*0.25*	196	168	12.8		*2*	*2*
06-May-97	50.4	24.4	9.75	52.5	54.1	6.5	346	*0.25*	284	226	11.5		*2*	*2*
22-May-97	66.3	35.4	12.6	84.8	87.7	9	449	*0.25*	368	311	12.2		170	96
02-Jun-97	80	40.1	8.59	97.8	119	7.3	522	*0.25*	428	365	9.8		210	130
18-Jun-97	41.6	24.2	4.02	38.1	55.3	4	286	*0.25*	235	204	5		120	66
03-Jul-97	49.1	25.5	4.88	51.4	36.2	5.1	346	12.3	304		8.7		180	120
16-Jul-97	26.5	18.8	3	21.5	32.5	2.6	165	15.3	161	144	1.6		180	140
05-Aug-97	24.8	15.6	1.74	12.7	26.2	3.5	104	22.8	123	126	1.5		14	9
20-Aug-97	27.3	15.5	1.59	11.8	27.8	7.4	114	21.5	129	132	0.6		23	16
02-Sep-97	29	17.3	1.82	15	30	6.1	112	22.4	129		0.43		4	4
18-Sep-97	29.9	15.5	1.91	11.6	32.6	2.7	154	3.37	132	139	0.6		25	17
02-Oct-97	33.9	17.9	2.31	11.8	31.8	5.1	154	4.19	133	158	0.5		26	26
16-Oct-97	38.4	17	1.66	11.3	34.8	3.9	197	*0.25*	162	166	0.5		*2*	*2*
30-Oct-97	44.4	19.6	2.65	22.9	36.4	5	228	*0.25*	187	192	0.94		*2*	*2*
average	**39.4**	**20.6**	**8.62**	**33.5**	**49.7**	**5.8**	**231**	**5.02**	**197**	**183**	**6.65**		**20**	**16**
June-Oct.	**38.6**	**20.6**	**3.11**	**27.8**	**42.1**	**4.8**	**217**	**9.35**	**193**	**181**	**2.74**		**25**	**19**
													geo mean	geo mean

Parlby Creek - Buffalo Lake Water Management Project - 1997 LAKES DATA.

MAIN BAY - AB05CD1040

Sampling Date	Al mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Hg ng/L	Hg ug/L	Ni mg/L	Zn mg/L
08-May-97				0.1					
03-Jun-97				0.02					
02-Jul-97	0.07			0.07					
31-Jul-97				0.19					
05-Sep-97	0.11			0.14					
30-Sep-97				0.21					
21-Oct-97				0.24					
average	**0.09**			**0.14**					
June-Oct.				0.15					
May-Sept.				0.12					

SECONDARY BAY - AB05CD0860

Sampling Date	Al mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Hg ng/L	Hg ug/L	Ni mg/L	Zn mg/L
08-May-97				0.17					
05-Jun-97				0.13					
02-Jul-97	0.06			0.09					
31-Jul-97				0.35					
11-Sep-97	0.22			0.32					
30-Sep-97				0.61					
21-Oct-97				0.41					
average	**0.14**			**0.30**					
June-Oct.				0.32					
May-Sept.				0.28					

PARLBY BAY - AB05CD0840

Sampling Date	Al mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Hg ng/L	Hg ug/L	Ni mg/L	Zn mg/L
14-May-97				0.29					
11-Jun-97	0.01			0.1					
03-Jul-97	*0.005*			*0.005*					
07-Aug-97				0.02					
04-Sep-97	0.02			0.03					
14-Oct-97				0.18					
average	**0.01**			**0.10**					
June-Oct.				0.07					
May-Sept.				0.09					

PARLBY CREEK NW OF ALIX - AB05CD0430

Sampling Date	Al mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Hg ng/L	Hg ug/L	Ni mg/L	Zn mg/L
27-Mar-97									
31-Mar-97									
02-Apr-97									
07-Apr-97				0.24					
14-Apr-97				0.19					
17-Apr-97				0.13					
21-Apr-97									
24-Apr-97				0.16					
06-May-97		*0.001*	0.0023	0.49	0.0005			0.0192	0.075
22-May-97				0.19					
02-Jun-97	0.14	0.015	0.0049	0.51	0.0041		*0.0025*	0.021	0.014
18-Jun-97	0.04			0.24					
03-Jul-97	0.01	*0.001*	0.0017	0.21	0.0013		0.021	0.006	0.007
16-Jul-97	0.27			0.63					
05-Aug-97	0.07	0.008	0.0052	0.18	*0.00015*			*0.00025*	0.019
30-Oct-97		0.001	0.0027	0.32	0.001	7		0.0105	0.0207
average	**0.1060**	**0.0052**	**0.0034**	**0.29**	**0.0014**	**7**	**0.012**	**0.0114**	**0.027**
June-Oct.	0.1060	0.0063	0.0036	0.35	0.0016		0.012	0.0094	0.015
May-Sept.	0.1060	0.0063	0.0035	0.35	0.0015		0.012	0.0116	0.029

ALIX LAKE - AB05CD1070

Sampling Date	Al mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Hg ng/L	Hg ug/L	Ni mg/L	Zn mg/L
08-May-97				0.09					
03-Jun-97				*0.005*					
03-Jul-97	0.02			*0.005*					
31-Jul-97				0.03					
02-Sep-97	0.02			0.11					
14-Oct-97				*0.005*					
average	**0.020**			**0.041**					
June-Oct.	0.02			0.031					
May-Sept.				0.048					

Parlby Creek-Buffalo Lake Water Management Project - 1997 DIVERSION DATA.

RED DEER RIVER AT PUMPHOUSE - AB05CD1570

Sampling Date	Al mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Hg ng/L	Hg ug/L	Ni mg/L	Zn mg/L
02-Jun-97		0.016	0.0039	1.54	0.0013		*0.0025*	0.0153	0.041
18-Jun-97	0.47			0.83					
03-Jul-97	0.05	*0.001*	0.0027	0.06	0.0024	1.6	0.007	0.005	0.058
16-Jul-97	0.17			0.2					
05-Aug-97	0.1	*0.001*	0.011	0.02	0.0041		0.018	*0.00025*	0.046
20-Aug-97	0.17			0.43					
02-Sep-97	*0.005*	*0.001*	0.0077	2.89	0.0016	*0.3*		0.0072	0.033
18-Sep-97	0.04			*0.005*					
02-Oct-97		*0.001*	0.0105	0.04	0.0027	*0.3*		0.005	0.015
16-Oct-97				0.01					
30-Oct-97		0.0034	0.004	0.07	0.002	1.8		0.0121	0.0257
average	**0.1436**	**0.0039**	**0.0066**	**0.55**	**0.0024**	**1.0**	**0.009**	**0.0075**	**0.0365**

ALIX LAKE INFLOW - AB05CD1580

Sampling Date	Al mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Hg ng/L	Hg ug/L	Ni mg/L	Zn mg/L
02-Jun-97				0.06					
18-Jun-97	0.05			0.02					
03-Jul-97	*0.005*			*0.005*					
16-Jul-97	0.02			*0.005*					
05-Aug-97	0.05			*0.005*					
20-Aug-97	0.1			0.01					
02-Sep-97	0.05			*0.005*					
18-Sep-97	*0.005*			*0.005*					
02-Oct-97				0.04					
16-Oct-97				0.01					
30-Oct-97				0.08					
average	**0.040**			**0.022**					

ALIX LAKE OUTFLOW - AB05CD1590

Sampling Date	Al mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Hg ng/L	Hg ug/L	Ni mg/L	Zn mg/L
06-May-97				*0.005*					
22-May-97				0.13					
02-Jun-97	0.05			0.06					
18-Jun-97	0.01			*0.005*					
03-Jul-97	*0.005*			*0.005*					
16-Jul-97	*0.005*			*0.005*					
05-Aug-97	0.05			*0.005*					
20-Aug-97	0.01			*0.005*					
02-Sep-97	*0.005*			*0.005*					
18-Sep-97	*0.005*			*0.005*					
02-Oct-97				0.02					
16-Oct-97				*0.005*					
30-Oct-97				0.04					
average	**0.018**			**0.023**					
June-Oct.				0.01					

PARLBY CREEK AT MIRROR (gauging site) - AB05CD0440

Sampling Date	Al mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Hg ng/L	Hg ug/L	Ni mg/L	Zn mg/L
27-Mar-97									
31-Mar-97									
02-Apr-97									
07-Apr-97				0.31					
14-Apr-97				0.2					
17-Apr-97				0.14					
21-Apr-97									
24-Apr-97				0.13					
06-May-97		0.01	0.0028	0.21	0.0009			0.0162	0.056
22-May-97				0.3					
02-Jun-97	0.08	0.036	0.0038	0.66	0.0008		0.007	0.0229	0.027
18-Jun-97	0.05			0.14					
03-Jul-97	0.03	*0.001*	0.002	0.21	0.0005		0.005	0.0064	0.01
16-Jul-97	0.07			0.1					
05-Aug-97	0.07	0.008	0.0078	0.02	*0.00015*		0.011	*0.00025*	0.01
20-Aug-97	0.03			0.03					
02-Sep-97	0.04	*0.001*	0.005	2.29	0.0006		0.009	0.0043	0.012
18-Sep-97	0.08			0.19					
02-Oct-97		0.007	0.0056	0.18	0.001	0.6		0.03	0.017
16-Oct-97				0.58					
30-Oct-97		0.0042	0.0063	0.5	0.0013	5.6		0.0222	0.193
average	**0.0563**	**0.0096**	**0.0048**	**0.36**	**0.0008**	**3.1**	**0.008**	**0.0146**	**0.046**
June-Oct.		**0.0095**	**0.0051**	**0.45**	**0.0007**			**0.0143**	**0.045**

Parlby Creek - Buffalo Lake Water Management Project - 1998 LAKES DATA.

MAIN BAY - AB05CD1040 field 10301

Sampling Date	Chlorophyll *a* mg/m3	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L	HCO3+CO3 mg/L	Fe mg/L
06-May-98	7.4	71.4	38.5	1.683	0.033	*0.005*	1.65	39.2	2710	9.16	1820	1	1378	0.18
03-Jun-98	9.9	87.5	36.6	2.411	0.011	0.06	2.4	39.8	2780	9.13	1820	*0.2*	1378	0.18
06-Jul-98	14	69.7	32.3	2.0815	*0.0015*	0.05	2.08	38.3	2740	9.19	1800	6	1360	0.24
11-Aug-98	14.9	55	36.3	3.263	0.013	0.05	3.25	38.9	2810	9.08	1820	2	1397	0.13
03-Sep-98	17.2	57.5	34.8	1.6215	*0.0015*	0.06	1.62	41	2790	9.22	1870	*0.2*	1416	0.14
average	**12.68**	**68.22**	**35.700**	**2.212**	**0.012**	**0.045**	**2.200**	**39.4**	**2766**		**1826**	**2**	**1386**	**0.174**

SECONDARY BAY - AB05CD0860 field 10301

Sampling Date	Chlorophyll *a* mg/m3	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L	HCO3+CO3 mg/L	Fe mg/L
06-May-98	3.1	123	33.9	1.774	0.044	0.04	1.73	32.5	2190	9.04	1390	8	1054	0.33
03-Jun-98	4.9	80.7	59.1	2.227	0.027	0.16	2.2	34.8	2360	9.05	1490	*0.2*	1138	0.28
06-Jul-98	10.2	77.8	26.7	1.7215	*0.0015*	0.05	1.72	32	2310	9.09	1390	10	1040	0.36
11-Aug-98	24.1	95.9	34.7	3.061	0.011	0.04	3.05	35.6	2400	9	1540	8	1186	0.39
03-Sep-98	32.4	109.6	36.2	1.7415	*0.0015*	0.04	1.74	37.4	2340	9.11	1490	19.5	1134	*0.005*
average	**14.94**	**97.4**	**38.120**	**2.105**	**0.017**	**0.066**	**2.088**	**34.5**	**2320**		**1460**	**9**	**1110**	**0.273**

PARLBY BAY - AB05CD0840 field 10301

Sampling Date	Chlorophyll *a* mg/m3	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L	HCO3+CO3 mg/L	Fe mg/L
07-May-98	12.4	76.9	23.7	0.9415	*0.0015*	0.03	0.94	14.7	652	8.21	388	2	366.5	0.08
11-Jun-98	6.5	72	29.7	1.568	0.008	0.05	1.56	23.4	781	9.25	468	19	417.4	0.19
07-Jul-98	5.9	51.6	26.2	1.291	0.011	0.03	1.28	16.1	616	8.97	332	9	300.6	0.64
04-Aug-98	1.8	50.6	26.4	1.0815	*0.0015*	0.01	1.08	11	321	8.83	195	3	183.6	0.04
01-Sep-98	2.8	54.8	18.6	0.7915	*0.0015*	0.02	0.79	10.4	257	9	165	2	163.6	*0.005*
average	**5.88**	**61.2**	**24.920**	**1.135**	**0.005**	**0.028**	**1.130**	**15.1**	**525**		**310**	**7**	**286**	**0.191**

ALIX LAKE - AB05CD1070 field 10301

Sampling Date	Chlorophyll *a* mg/m3	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L	HCO3+CO3 mg/L	Fe mg/L
07-May-98	3.6	21.6	6.7	0.813	0.003	*0.005*	0.81	5.8	283	8.35	153	*0.2*	132	0.02
15-Jun-98	8	34.3	9.8	0.453	0.003	0.02	0.45	8.5	262	9.19	150	3	121.4	0.05
07-Jul-98	3.8	22.1	8	1.204	0.004	0.01	1.2	5.6	308	8.21	169	*0.2*	154.5	0.04
04-Aug-98	4.5	22.7	7.9	0.5015	*0.0015*	*0.005*	0.5	8.1	315	7.81	178	*0.2*	173.5	0.03
01-Sep-98	9	39.3	8.3	0.7215	*0.0015*	0.03	0.72	8	317	7.97	185	9	179.5	*0.005*
average	**5.78**	**28.0**	**8.140**	**0.739**	**0.003**	**0.014**	**0.736**	**7.200**	**297.000**		**167.000**	**2.520**	**152**	**0.029**

Less than values = 0.5 of Detection Limit (in italics)

Parlby Creek-Buffalo Lake Water Management Project - 1998 DIVERSION DATA.

RED DEER RIVER AT PUMPHOUSE - AB05CD1570 lab 100923

Sampling Date	Avg. Flow m3/sec	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L	HCO3+CO3 mg/L	Fe mg/L
22-Jun-98	1.3414	128	7	0.689	0.089	0.06	0.6	5.4	316	7.65	177	137	168.5	
07-Jul-98	0	157	17	0.835	0.085	0.04	0.75	8.9	295	7.88	175	156	170.5	
23-Jul-98	1.1921	81	7	0.583	0.003	0.01	0.58	7.8	331	8.55	203	11	194.8	
04-Aug-98	1.3414	52	17	0.523	0.003	0.01	0.52	8.9	334	8.27	193	15	198.5	
19-Aug-98	1.1979	12	*1.5*	0.379	0.079	0.01	0.3	6.1	334	8.5	200		200.4	
01-Sep-98	1.4838	16	6	0.343	0.003	0.01	0.34	5.1	333	8.57	201	1	197.4	
16-Sep-98	1.4815	9	9	0.308	0.018	0.13	0.29	4.4	353	8.46	202	2	189.8	
average		**65.0**	**9.21**	**0.523**	**0.040**	**0.039**	**0.483**	**6.7**	**328**		**193**	**54**	**189**	

PARLBY CREEK AT MIRROR (gauging site) - AB05CD0440 lab 100923

Sampling Date	Avg. Flow m3/sec	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L	HCO3+CO3 mg/L	Fe mg/L
25-Mar-98	0.049	143.1	38.3	1.947	0.017	0.45	1.93	17.7			470	3	478.5	0.52
07-Apr-98	0.156	119.9	41.8	1.0815	*0.0015*	0.03	1.08	8.9	338	7.81	207	3	222.5	0.6
30-Apr-98	0.333	76	37.8	1.6415	*0.0015*	0.02	1.64	17.8			430	3	384.5	0.34
20-May-98	0.023	40	33	1.193	0.003	*0.005*	1.19	19.4	796	8.47	494	2	495.4	
22-Jun-98	1.36	32	4	0.7315	*0.0015*	*0.005*	0.73	8.1	305	9.4	175	4	151.6	
07-Jul-98	0.783	125	107	1.487	0.007	0.03	1.48	19.5	689	8.27	415	*0.2*	414.2	
23-Jul-98	0.974	142	120	1.18		0.02	1.18	16.2	504	8.69	316	*0.2*	306	
04-Aug-98	1.4	47	29	0.6315	*0.0015*	0.01	0.63	9.4	335	8.32	190	2	189.5	
19-Aug-98	1.39	30	20	0.6015	*0.0015*	0.02	0.6	11	399	8.14	236		243.5	
01-Sep-98	1.27	26	14	0.5415	*0.0015*	0.02	0.54	9	311	8.59	187	*0.2*	185	
16-Sep-98	1.29	13	10	0.3315	*0.0015*	*0.005*	0.33	6.2	328	8.43	195	2	181.5	
average		**72.2**	**41.4**	**1.033**	**0.004**	**0.056**	**1.030**	**13.018**	**445**		**301**	**2**	**296**	**0.49**
June - Oct.		**59.3**	**43.4**	**0.8**	**0.002**	**0.016**	**0.784**	**11.343**	**410.1**		**244.9**	**1.4**	**238.8**	

PARLBY CREEK AT ALIX (gauging site) - AB05CD0430 lab 100923

Sampling Date	Avg. Flow m3/sec	Total P mg/m3	TDP mg/m3	TN mg/L	NO2+NO3 mg/L	NH3 mg/L	TKN mg/L	TOC mg/L	COND uS/cm	pH units	TDS mg/L	TSS mg/L	HCO3+CO3 mg/L	Fe mg/L
07-Apr-98	0.393	148.4	73.3	1.5815	*0.0015*	0.04	1.58	10.5	371	8.01	235	11	248.5	0.64
30-Apr-98	0.193	127.6	93.7	1.1315	*0.0015*	0.02	1.13	14.3			407	2	401.5	0.28
20-May-98	0.309	146	134	1.0215	*0.0015*	*0.005*	1.02	17.7	741	8.16	445	6	482.5	
22-Jun-98	0.039	212	155	1.657	0.007	0.04	1.65	22	828	8.62	511	4	497	
07-Jul-98	0.714	342	318	1.623	0.003	0.06	1.62	22.4	736	7.86	443	3	455.5	
23-Jul-98	0.132	291	291	1.853	0.003	0.03	1.85	25.7	802	8.24	498	*0.2*	511.5	
19-Aug-98	0.066	279	241	1.3015	*0.0015*	0.05	1.3	22.3	755	8.18	465		504.5	
average		**221**	**187**	**1.453**	**0.003**	**0.035**	**1.45**	**19.3**	**706**		**429**	**4**	**443**	**0.46**
June - Oct.		**281**	**251**	**1.609**	**0.004**	**0.045**	**1.605**	**23.1**	**780**		**479**	**2**	**492.1**	