PARLBY CREEK - BUFFALO LAKE WATER MANAGEMENT PROJECT

WATER QUALITY UPDATE 1996

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. The purpose of this report is to present water quality data obtained from sites along the diversion route and in Buffalo Lake during the first summer of the diversion, which is 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.

Water quality samples were collected from the Red Deer River and at three sites along the diversion route to Buffalo Lake; in Alix Lake, which receives diversion water; in Parlby, Secondary, Main and Bashaw bays of Buffalo Lake; and in a small pond downstream of the Buffalo Lake outlet. Additionally, bacteriological samples were collected from the shoreline of Buffalo Lake and from the Red Deer River and Parlby Creek.

The full pumping capacity of the diversion was not used during the summer of 1996. The total diversion inflow (June - October) was 4.56 million m^3, and the natural surface inflow (March - October) would have amounted to about 22 million m^3, for an estimated total surface inflow of about 27 million m^3 for 1996. 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 showed the greatest change in water quality over the summer. Salinity was reduced, and concentrations of nutrients and chlorophyll *a* were lower in 1996 than in 1995.

There was also a change in water quality in Secondary Bay. Levels of phosphorus and chlorophyll *a* were higher than in previous sampling programs, and the magnitude of phosphorus release from the bottom sediments was greater. The larger algal population seems to have resulted from reduced salinity and increased phosphorus concentration. The main cause of this effect was the large spring runoff rather than the diversion.

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 1995 and in previous studies. There was no evidence of sewage contamination along the shoreline at Rochon Sands, nor in the pond at Rochon Sands. Data collected from Pelican Point could not be used, because of contamination by gulls.

Although water quality changes occurred along the diversion route and in Buffalo Lake in 1996, it is unlikely that what was observed in 1996 is the final state of any of these water bodies. It will take several years for the diversion channel and the lakes to reach equilibrium with the chemistry of the diversion inflow. The fast-flushing Alix Lake and Parlby Bay will reach equilibrium first, then Secondary Bay. Water quality in Secondary Bay may eventually improve. It is not possible to predict whether or not there will be an effect on the Main Bay of Buffalo Lake.

ACKNOWLEDGMENTS

Staff of Monitoring Branch, including Mike Bilyk, Monica Polutranko, Randy Sweeney, 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 Chemex Labs, Inc. and the Alberta Environmental Centre. Microbiological samples were analyzed by the Provincial Laboratory of Public Health. Bridgette Halbig produced graphs and formatted the report. David Trew, Kenn Looten and Leigh Noton provided review comments.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

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, four areas of Buffalo Lake, a pond at the outlet of the lake, and Alix Lake, through which the diversion water flows. The 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 this to occur. Other concerns raised include 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 first summer of diversion, and bring up to date the water quality information collected since the last update, which was completed in July 1996. The report addresses the following questions, based on the 1996 monitoring data: 1) How does the chemistry of the diversion water change as it travels along the conveyance route to Buffalo Lake? 2) Has the 1996 diversion inflow decreased the salinity in Buffalo Lake? 3) What is the contribution of phosphorus to the lake from the diversion? 4) Has Alix Lake been affected by the diversion? 5) Is there any change in the amount of algae in Buffalo Lake in 1996 compared with other years? 6) Is there sewage contamination of Buffalo Lake, either from cottage septic systems or from the diversion?

The 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

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. The sites are shown in Figure 1.

1. Red Deer River Pumphouse. Water was collected from the short channel leading to the pumphouse. Extra samples collected directly from the river to compare with channel samples indicated very little difference in water quality from the two areas. The pumphouse site was sampled every two weeks during the diversion period, June 3 to October 31, 1996.

2. Alix Lake Inflow. The water at this point has passed along about 8 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. Sampled every two weeks during the diversion period.

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 water quality impacts of the diversion, which flushes through the lake, on recreational use. This site was sampled every four weeks, May through October.

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 four weeks, alternating with lake sampling dates, during the diversion period. By alternating lake and outlet sampling dates, samples collected every two weeks can be assigned to the outlet, since lake and outflow water quality were expected to be the same.

5. 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 every two weeks, May through October.

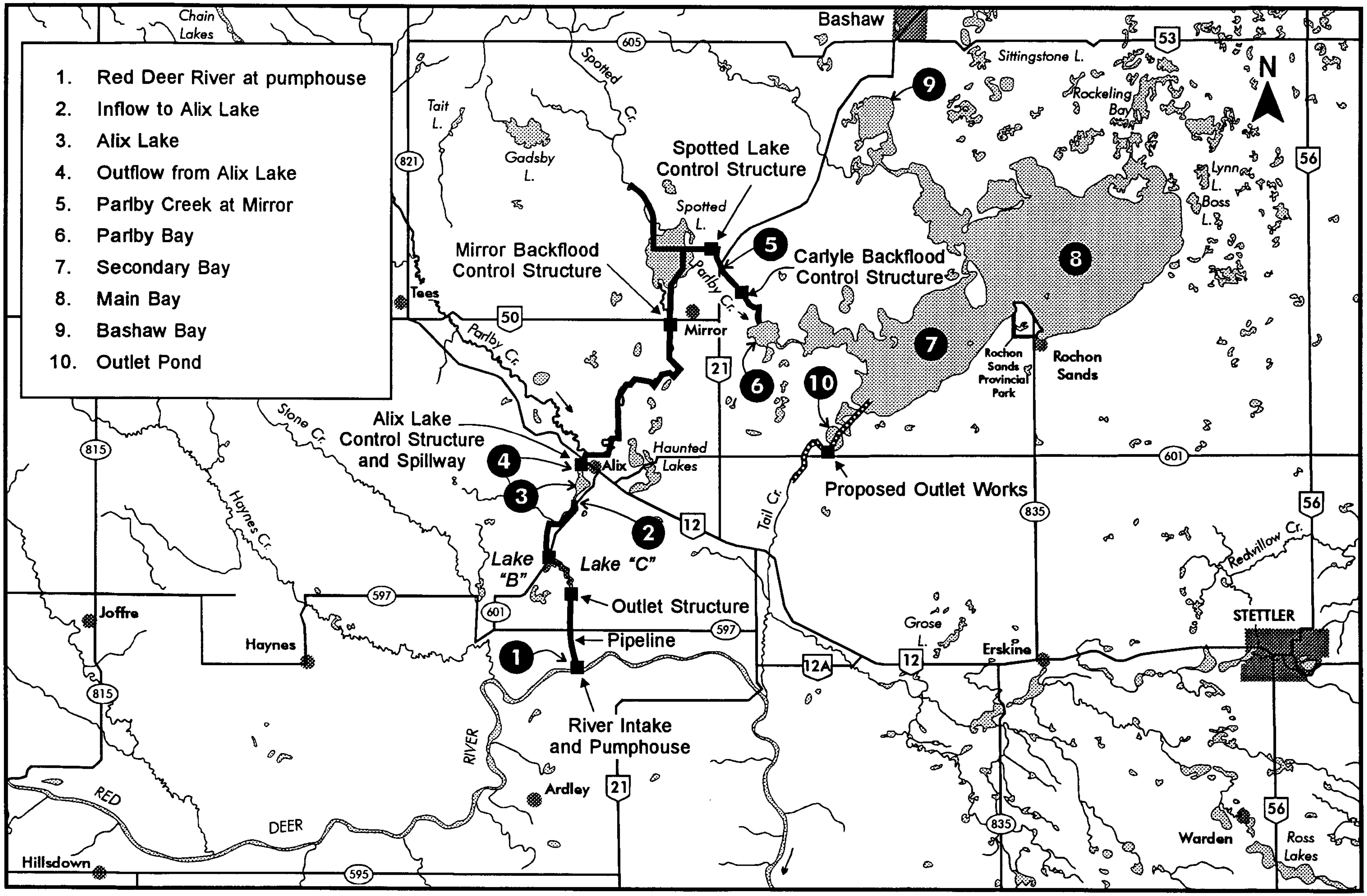

Figure 1. Sampling sites for 1996 water quality monitoring program, Parlby Creek - Buffalo Lake.

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6. 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.

7. Secondary Bay. The western, shallow portion of Buffalo Lake. Its major inflow comes through Parlby Bay; the bay was sampled every four weeks.

8. Main Bay. The largest and deepest basin in Buffalo Lake; it was sampled every four weeks.

9. Bashaw Bay. A large shallow water body to the northwest of Buffalo Lake. It is presently not connected to Buffalo Lake, but would be if the water level increased. Local residents were concerned about water quality in the bay, and the effect of the diversion. Bashaw Bay was sampled every four weeks.

10. Outlet Pond. A small water body in or near the historic outlet channel from Buffalo Lake (Secondary Bay). Outflow from Buffalo Lake has not occurred in decades, and therefore there is no connection between Outlet Pond and Buffalo Lake. The purpose of sampling the pond was to obtain background information on water quality before the area is channelized during development of the outlet works. The pond was sampled every four weeks.

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.

On each sampling day, Main Bay, Secondary Bay, Bashaw 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. Outlet Pond was also sampled six times; samples were collected by wading into the pond.

In mid-summer, 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 periodically to address complaints that sewage was entering the pond from nearby cottages.

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.

Samples for heavy metals (cadmium, iron, lead, manganese, mercury, nickel, zinc) were collected at the Red Deer Pumphouse and Parlby Creek at Mirror. Fecal coliform bacteria and *E. coli,* a specific intestinal fecal coliform bacteria, were monitored at Red Deer at Pumphouse, Alix Lake Inflow, Parlby Creek at Mirror and Buffalo Lake Main Bay. 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.

2.4 WATER VOLUME

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

The total amount of water leaving Alix Lake calculated from these measurements appears to be higher than would be expected (the average flow rate measured at Alix Lake Outflow was 0.582 m^3/second, whereas the diversion flow rate was 0.349 m^3/second). It appears that the outlet elevation on Alix Lake varied over the summer because plant material clogged the screens at the control structure. The screens were cleaned off periodically, which would release more water from the lake for a period of time. It is not known how this relates to days when flow measurements were made. Therefore, a conservative approach was taken by assuming that the amount of water leaving Alix Lake was the same as that entering it via the diversion. Natural effects such as watershed inflows, direct precipitation and evaporation are insignificant compared with the total diversion volume.

Water volumes for Secondary and Main Bays of Buffalo Lake were estimated from information in W-E-R Engineering (1990) and the elevation of the lake in May and October. The water volume for Parlby Bay was estimated from surface area and approximate depth.

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 concentration of the substance by the volume of water. A constant flow rate was assumed for the diversion from the Red Deer River at the pumphouse, based on the pumping rate of the smaller of the two pumps, which was used for nearly all of the summer. Total mass loads at Alix Lake Inflow were calculated by multiplying the flow volume for each sampling day (two-week intervals) by the concentration on that day, and then taking a mean daily load for the total number of days sampled. This was extrapolated to the 151-day pumping period. To check this method of calculating total mass, two other methods were used: 1) a daily flow for each pumping day was extrapolated from the measured data, and average concentrations were interpolated between sampling dates for each measured concentration, and the total summed; 2) since flow was measured at approximately two-week intervals, the measured concentration was applied to the total flow for this period, and the two-week substance masses summed for the summer. All three methods produced similar results.

Daily measured flows were available for Parlby Creek at Mirror. At this site the data reduction program FLUX (Walker 1987) was used to calculate the total flow and total load for the monitoring period in 1995 and 1996 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.

To calculate the mass of various substances in the lake in spring and fall, the concentrations of each constituent measured in May and October were applied to the total water volumes in Parlby Bay, Secondary Bay and Main Bay for the sampling dates.

3.0 RESULTS OF THE 1996 MONITORING PROGRAM

The focus of historical water quality monitoring programs on Buffalo and Alix lakes has been primarily on their fertility. Fertility is a measure of the potential for aquatic plant growth, both shoreline vegetation (technically called "macrophytes") and suspended algae ("phytoplankton"). A change 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.

3.1 DIVERSION

The diversion commenced June 3, 1996 and continued until October 31, 1996. Over this time period, the total flow volume was 4.561 million m^3, at a flow rate of approximately 0.35 m^3/s. Only one of two available pumps was used continuously during the diversion period, because of mechanical problems with the other pump. The full pumping capacity would result in a flow rate of about 1.4 m^3/s. The time required for water to move the 34 km from the pumphouse to Buffalo Lake in 1996 was about a week, but may have been less once the system flushed through (D. Neis, pers. comm., Dec. 1996).

The volume of water that passed through Alix Lake would have flushed it several times, as the lake volume is about one-third of the total amount of diversion water that entered it. Similarly, several flushes of Parlby Bay occurred over the summer, whereas the volume that entered Secondary Bay from Parlby Bay during the diversion period was considerably smaller than the volume in Secondary Bay. For Main Bay, the volume of water assumed to have entered from the diversion and natural runoff in Parlby Creek between June and October was only about 3% of the bay's volume.

The water level of Buffalo Lake increased in 1996 (Figure 2), but only part of this was due to the diversion. In July 1995 the monthly mean water elevation was 780.26 m and in

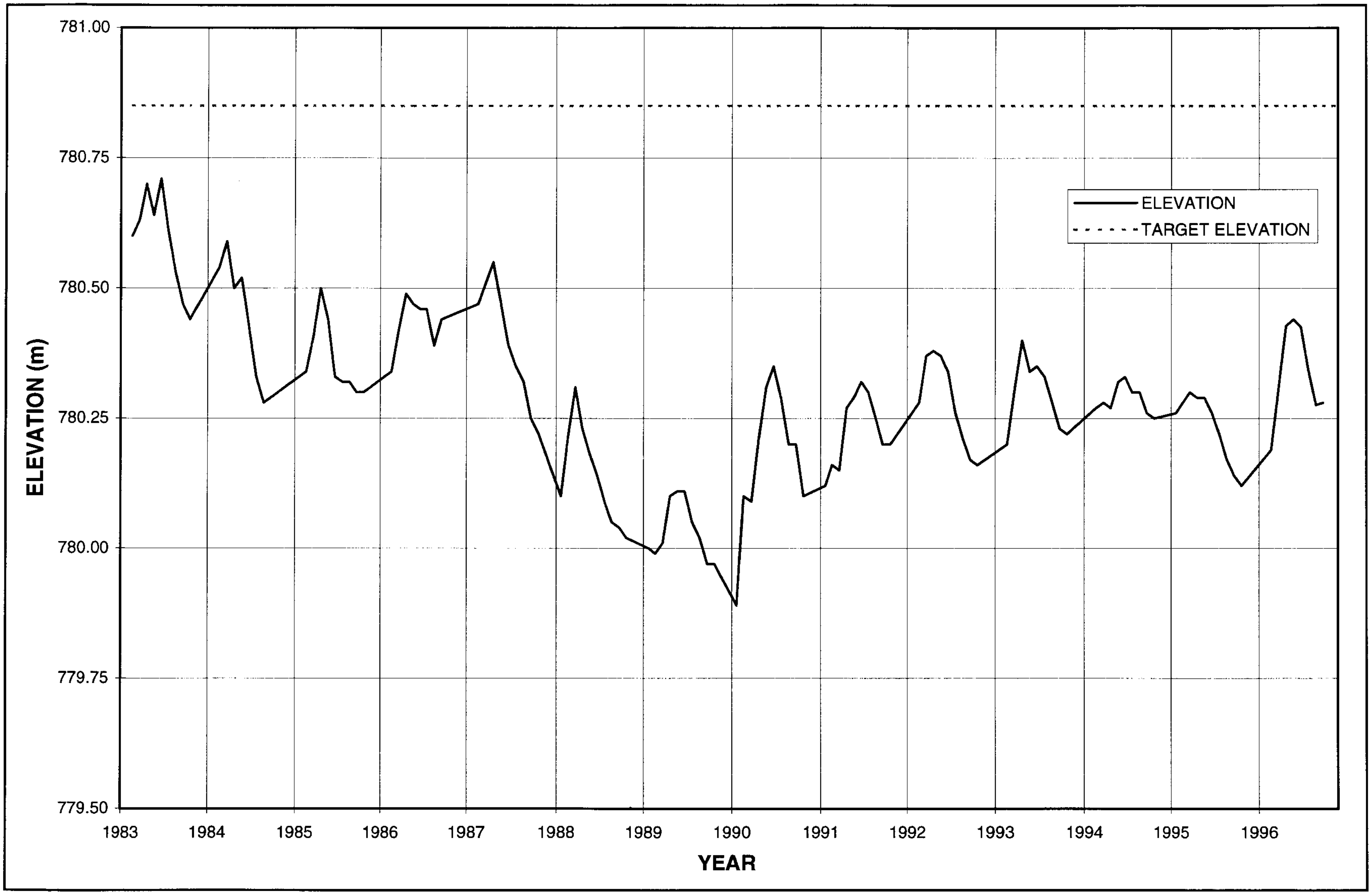


Figure 2. Monthly mean lake levels in Buffalo Lake near Erskine (05CD005), 1983-1996.

July 1996 it was 780.43 m, an increase of 0.17 m. The target elevation is 780.85 m. If all of the 1996 diversion water were added to Buffalo Lake directly and at once, the increase in lake level would be less than 0.05 m (2 inches), based on the area of the lake when it was sounded in 1965. The maximum water level in Buffalo Lake in 1996 (780.47 m) occurred on June 5, only two days after the diversion began. The natural 1996 runoff flow in Parlby Creek at Mirror contributed 17.7 million m^3, primarily during spring, and there would have been runoff from other parts of the watershed as well (amounting to approximately 25% of the volume in Parlby Creek, according to W-E-R Engineering 1990).

3.2 SALINITY

Salinity, or saltiness, of water is indicated by its level of total dissolved solids (TDS) or its electrical conductivity. Average 1996 values for routine water chemistry in the Red Deer River diversion and at sites along the conveyance route are shown in Table 1. Initially, water from the Red Deer River mixed with water in ponds, Alix Lake, Parlby Creek and Spotted Lake,

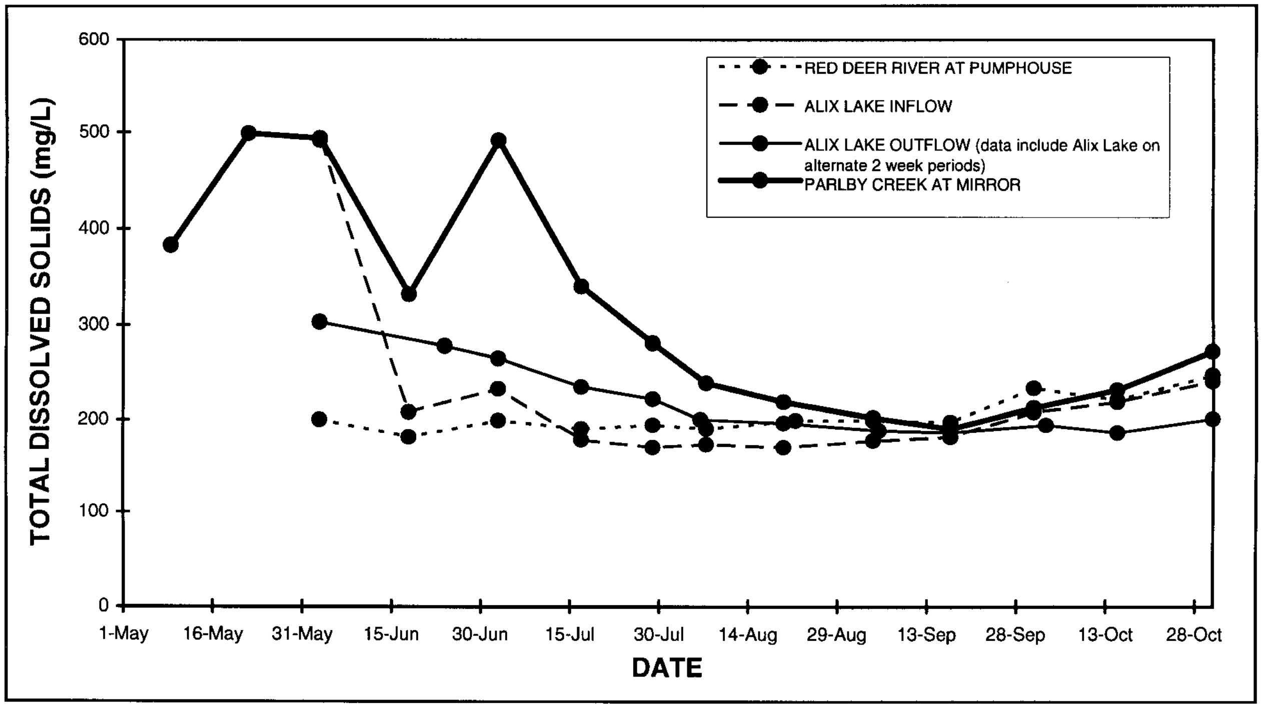
Table 1. Average concentrations of major ions and related variables for the Red Deer River at the pumphouse, Alix Lake and its inflow and outflow, and Parlby Creek at Mirror, during diversion period (June through October 1996).

	RED DEER RIVER	ALIX LAKE INFLOW	ALIX LAKE	ALIX LAKE OUTFLOW	PARLBY CREEK
pH (range)	8.05 - 8.80	8.17 - 8.68	8.32 - 8.77	8.42 - 8.76	8.11 - 9.05
Conductivity, uS/cm	361	387	384	395	494
Total Diss. Solids, mg/L	204	221	219	223	292
Calcium, mg/L	46.5	37.4	31.8	29.6	38.9
Magnesium, mg/L	14.8	20.0	22.2	23.9	26.0
Total Hardness, mg/L	177	176	171	172	204
Sodium, mg/L	10.5	17.3	19.8	21.0	36.0
Potassium, mg/L	1.7	2.4	3.3	3.7	4.4
Sulphate, mg/L	30.8	40.8	39.5	41.2	48.1
Chloride, mg/L	2.7	2.7	2.4	3.0	4.0
Silica, mg/L	2.2	1.4	1.5	0.93	2.0
Total Alkalinity, mg/L as $CaCO_3$	160	164	164	165	221
Bicarbonate, mg/L	189	194	191.8	187	250
Carbonate, mg/L	3	3	4	7	9.7
Number of Samples	12	12	5	7	12

and became more saline before it entered Buffalo Lake. However, the seasonal plots for TDS in Figure 3 show that over the summer, these water bodies were flushed out to some extent and water in Parlby Creek at Mirror became more like Red Deer River water. The plot for Alix Lake Outflow includes lake data, which was sampled on alternate two-week periods with the outflow. The water chemistry of Alix Lake should be similar, if not identical, to its outflow chemistry. The slight differences in the average values between the two sites (Alix Lake and Alix Lake Outflow) in Table 1 probably relate to timing and number of samples collected.

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, or 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 are presented in Table 2a. Note that the volume of water measured at the pumphouse and at the inflow to Alix Lake (Total Flow column) were very similar, suggesting little water loss along this portion of the diversion route. As well, loads of most of these constituents were similar at the two sampling sites. However, the amount of sodium, sulphate and magnesium at the inflow to Alix Lake was slightly greater than in the Red Deer River. The water flowing out of Alix Lake generally had higher concentrations of most substances than the water flowing in, and therefore there was a net loss from the lake. For example, there was nearly twice as much potassium leaving the lake as entering it. The calculated loss would be even greater if the measured flow at Alix Lake Outflow were used instead of the flow volume of the diversion. On the other hand, there was slightly less calcium leaving Alix Lake than entered it; calcium carbonate likely precipitated out in the lake, removing calcium.

The flow in Parlby Creek at Mirror includes natural flows in Parlby Creek and inflows to Spotted Lake as well as diversion water, and therefore the discharge at this site was higher than that for Alix Lake outflow. Mass loads of all the major ions were higher at the Parlby Creek site than at the three upstream sites sampled. For many constituents, the mass loads in the summer of 1996 were similar to those measured for the same period in 1995, even though the volume of flow was higher in 1996. This may reflect the lower concentration of some of these variables as a result of the diversion. The total mass of these constituents in Buffalo Lake is also presented in Table 2b for comparison.



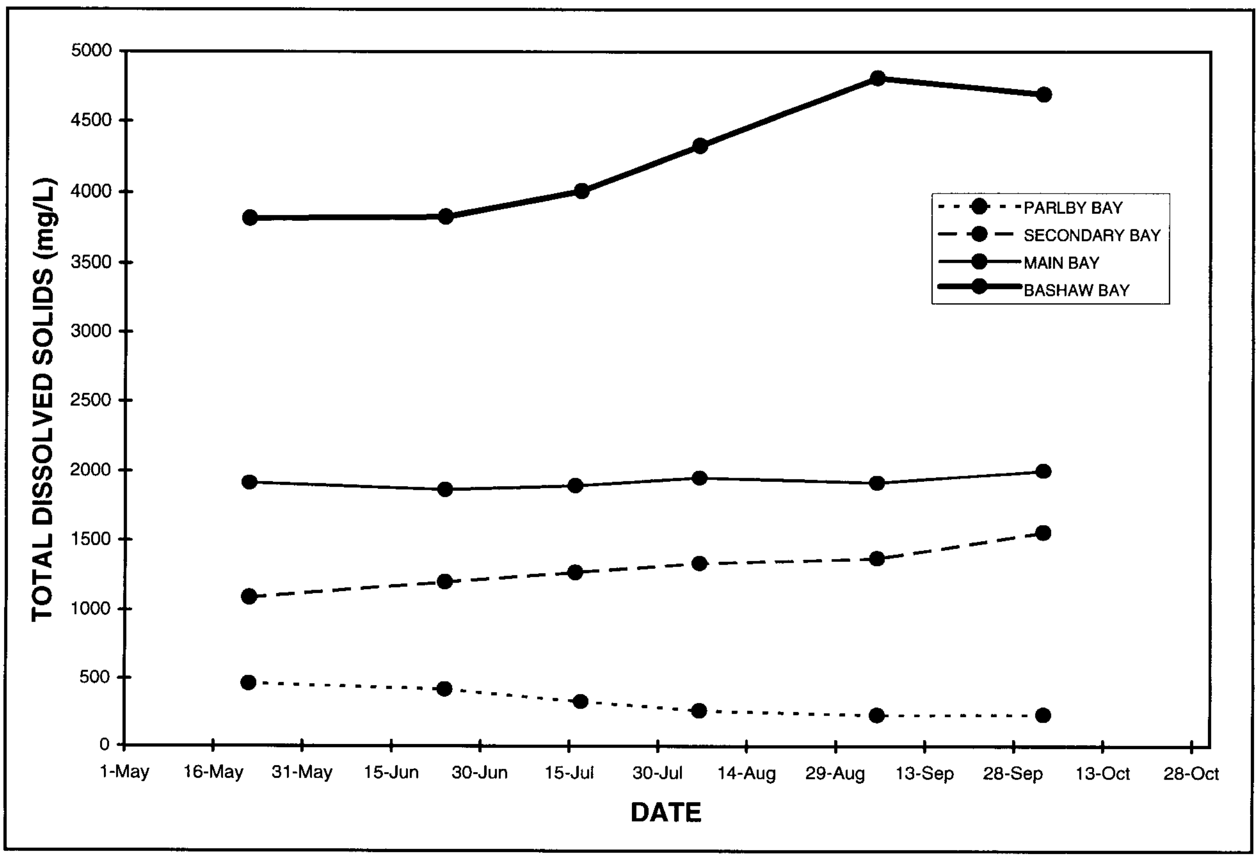


Figure 3. Concentrations of total dissolved solids along the diversion route (sites are listed in direction of flow) and in Buffalo Lake, 1996.

Table 2. Summary of mass loads of various constituents in the diversion to Buffalo Lake and in Buffalo Lake, 1996.

2a. Buffalo Lake diversion loading, June - October, 1996.

Site	Total Flow million m^3	Na kg	SO_4 kg	Cl kg	K kg	TDS kg	Total CO_3* kg	Mg kg	Ca kg	TP kg	TDP kg	TKN kg	NH_3-N kg
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	89
Inflow to Alix Lake	4.57	63,299	158,414	11,660	8,983	915,993	418,617	80,179	167,809	85	41	1,987	88
Outflow from Alix Lake	(4.56)	93,501	184,683	12,543	16,021	1,008,746	449,657	105,816	139,111	127	48	2,957	148
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	790
Parlby Cr. at Mirror, Total Flow Mar. - Oct.	22.24												
1995 Parlby Cr. at Mirror (June-October)	5.01	312,372	354,928	29,349	42,513	2,093,804	962,130	207,673	180,454	327	151	5,922	106

2b. Mass in Buffalo Lake, May and October, 1996.

Site	Volume** m^3	Na kg	SO_4 kg	Cl kg	K kg	TDS kg	Total CO_3* kg	Mg kg	Ca kg	TP kg	TDP kg	TKN kg	NH_3-N kg
May 1996													
Parlby Bay	600,000	46,140	41,760	4,260	5,760	277,800	123,240	18,960	35,280	68	26	1,044	42
Secondary Bay	49,522,838	15,451,125	12,727,369	544,751	1,366,830	53,979,893	20,135,986	2,624,710	950,838	3,615	1,387	103,008	1,486
Main Bay	245,077,162	140,674,291	119,597,655	3,823,204	10,685,364	468,097,379	171,406,967	19,361,096	1,335,671	14,705	8,333	612,693	14,705
October 1996													
Parlby Bay	400,000	9,360	15,120	1,320	1,524	93,200	42,920	9,280	13,160	12	7	208	16
Secondary Bay	43,133,668	18,245,542	19,927,755	621,125	1,535,559	67,331,656	22,860,844	2,937,403	862,673	4,874	1,639	85,405	4,011
Main Bay	236,975,332	148,820,508	116,591,863	4,241,858	11,540,699	474,187,639	169,152,992	20,332,483	1,305,734	13,982	8,057	452,623	78,202

* Includes bicarbonate

**May elevation = 780.441 m, October elevation = 780.279 m (volumes based on data in W-E-R water balance analysis report 1990)

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Water chemistry for sites in Buffalo Lake for 1995 and 1996 is listed in Table 3. Bashaw Bay was not sampled in 1995; the 1980-81 data presented are the only historical data for the bay.

Of the lake sites, Parlby Bay showed the most dramatic change in water quality. Except for calcium, average levels of all the major ions and related variables decreased between 1995 and 1996. Conductivity levels in the latter part of the summer were lower than had previously been recorded in sampling programs conducted in Parlby Bay in the 1980s and 1990s. Figure 3 shows the decline in total dissolved solids in Parlby Bay over the summer of 1996 compared with levels in other areas of Buffalo Lake. It is not surprising that water in Parlby Bay came to resemble that in Parlby Creek at Mirror by October. The total volume of water that flushed through Parlby Bay during the diversion period (7.24 million m^3) is 12 times more than the estimated volume of the bay. The average concentration of total dissolved solids (TDS) and

Table 3. Average concentrations of major ions and related variables for Buffalo Lake, May-October 1995 and 1996. Number of samples = 6 for each area per year, except Bashaw Bay = 2 historical samples from 1980-81. Units are mg/L except where indicated otherwise.

	PARLBY BAY		SECONDARY BAY		MAIN BAY		BASHAW BAY		OUT. POND
	95	96	95	96	95	96	80-81	96	96
pH (range), pH units	8.49 - 9.84	8.56 - 9.41	9.16 - 9.30	8.98 - 9.12	9.29 - 9.32	9.17 - 9.29	9.03 - 9.33	9.24 - 9.32	8.67 - 8.97
Conductivity, uS/cm	721	545	2428	1971	2825	2865	2731	5904	3283
Total Diss. Solids	447	323	1673	1305	1980	1920		4249	2208
Calcium	30	32	9	16.9	5	5.3	11.4	6.1	15
Magnesium	36	29	77	60.9	80.3	80.5	64.2	79.4	64
Total Hardness	223	200	336	293	363	345		342	299
Sodium	92	50	502	368	607	579	544	1442	740
Potassium	9	6	37	31.8	43.0	44.9	32	63.1	37
Sulphate	73	54.0	414	327	508	482	430	1345	408
Chloride	8	5	15.1	13.1	16.3	17.0	14.2	44	31
Silica	5.4	1.7	2.1	5.9	1.2	1.4	3.2	2.3	12.5
Total Alkalinity as $CaCO_3$	333	242	1033	803	1194	1176	1080	2095	1501
Bicarbonate	315	254	950	800	1051	1037		1711	1544
Carbonate	45	20	152	88	199	193		414	141

sodium in Parlby Bay declined by 28% and 46%, respectively, from 1995 to 1996; the TDS concentration in October 1996 (233 mg/L) was 40% lower than in October 1995 (391 mg/L). Part of this loss in salinity occurred during spring runoff, because TDS concentrations in Parlby Bay in May 1996 were already lower than in October 1995. Calcium levels in Parlby Bay in 1995 and 1996 were fairly similar, at least in comparison with changes in other major ions. Calcium was high in the diversion water, and was reduced as it passed along the diversion route. But in Parlby Bay, concentrations were lower than those observed in Parlby Creek at Mirror, suggesting calcite precipitation in the bay.

In Secondary Bay, salinity (as indicated by average TDS and conductivity) was lower in 1996 than in 1995 (Table 3). Only levels of calcium were higher in 1996, perhaps because the slightly lower pH values in the bay in 1996 resulted in less calcium carbonate precipitation than in 1995. Flushing from natural spring runoff and the diversion was high in the bay. For example, the total inflow from Parlby Creek (assuming all passed through Parlby Bay) was roughly 60% of the volume in Secondary Bay. The average level of total dissolved solids and sodium declined by 22% and 27%, respectively, from 1995 to 1996. Figure 4 shows that average May - September conductivity in Secondary Bay in 1996 was in the lower part of its (measured) historical range.

Even though salinity in Secondary Bay was lower in 1996 than in the previous year, TDS levels increased over the summer (Figure 3). This increase in TDS concentration can also be seen as an increase in total mass between May and October (Table 2b). The mass increase of the major ions between May and October cannot be accounted for by loading from Parlby Bay. For example, the loading of sodium from Parlby Bay to Secondary Bay between June and October amounted to about 387,000 kg, but sodium increased by 2.8 million kg in Secondary Bay. Part of this increase may have resulted from natural inflow during the latter part of May, but offsetting this is another large quantity that presumably passed into Main Bay from Secondary Bay. The reason for the increase in mass of major ions (except calcium) over the summer cannot be determined with the available data. It seems possible that flushing of the bottom sediments or movement of water from areas with higher salinity (for example, from Main Bay) contributed mass to the open water of Secondary Bay.

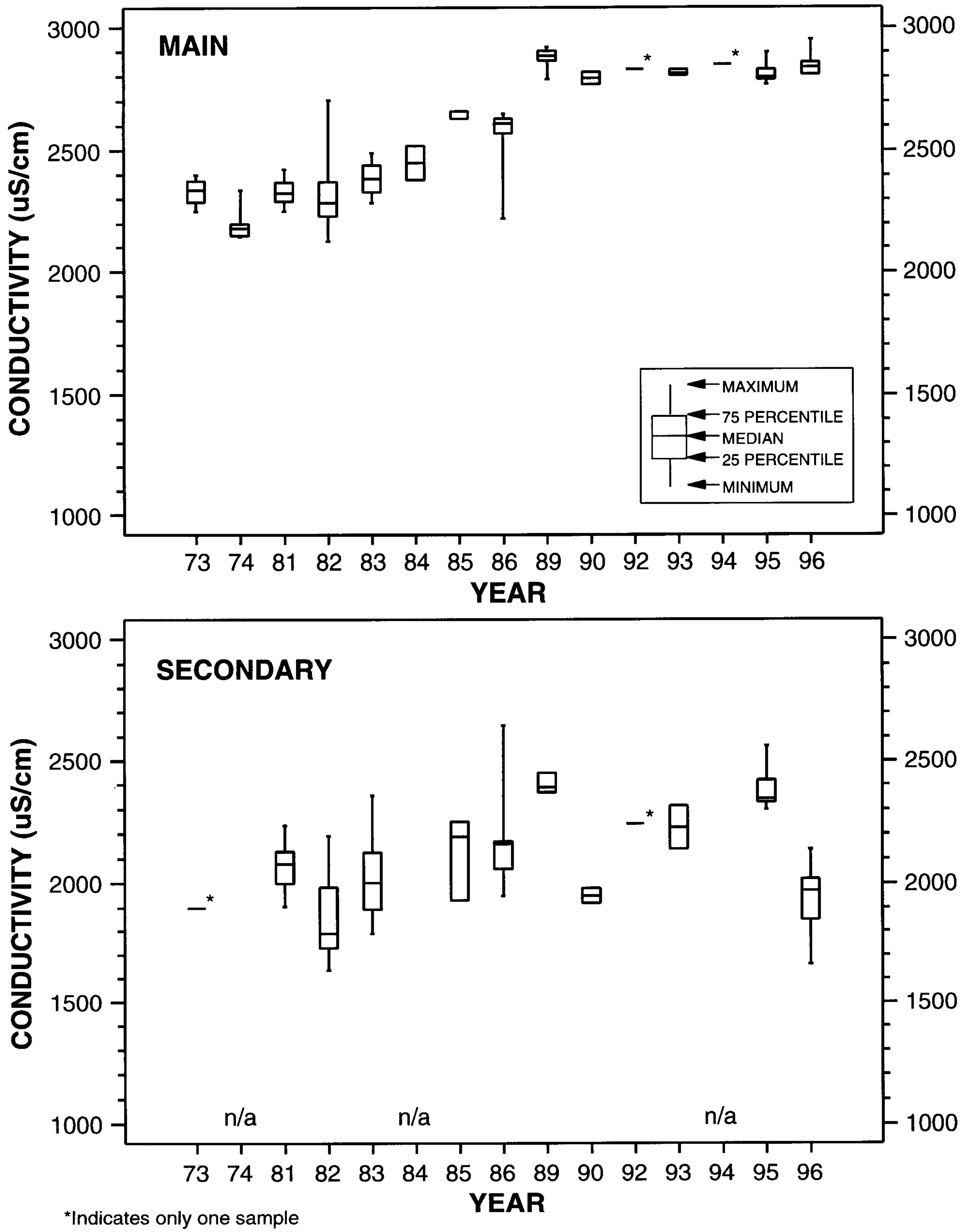


Figure 4. Conductivity in Buffalo Lake, April to September, 1973 to 1996.

In Main Bay, levels of most major ions and related variables in 1996 were similar to levels in 1995 (Table 3). Because the water level in the lake was higher than it had been in nearly ten years (Figure 2), one might expect a lower conductivity. There is a strong inverse statistical relationship between water level and salinity in Buffalo Lake (Mitchell 1996); surface inflow and precipitation in excess of evaporation would dilute substances in the lake water as well as increase the water level. However, the conductivity was about 10% higher than in 1986, when the water level was similar (Figure 4).

Over the summer, evaporation resulted in a slight increase in TDS concentration (Figure 3), as occurs most years. But there was also an increase in mass of 6 million kg (Table 2b). This can probably be accounted for by the mass loading from Secondary Bay, although the estimates are rough because the actual volume of water that moved between the bays is not known. The estimated mass of TDS that moved from Secondary Bay to Main Bay, if one assumes the entire Parlby Creek flow volume of 7.24 million m^3 passed between the bays, is 9.4 million kg for the June to October period.

Bashaw Bay is a very saline water body, with much higher levels of total dissolved solids, conductivity and most major ions than Main Bay (Table 3). The salinity has increased considerably between 1980-81 and 1996. At present there is no surface connection between Bashaw Bay and Main Bay; even if connecting channels are restored as the water level in the lake increases, there would likely be very little effect of the diversion on this portion of the lake.

Outlet Pond, on the south end of Secondary Bay, is a small water body in or near the former outlet channel from Buffalo Lake. There was no connection with the lake in 1996. The pond is very shallow (less than 0.5 m) with a soft bottom and surrounded by reeds and cattails. Over the summer the water level declined considerably and conductivity increased. The water is more saline than the Main Bay of Buffalo Lake (Table 3). There are no historical data for this water body.

3.3 NUTRIENTS

Phosphorus and nitrogen are important indicators of recreational water quality measured during 1996 (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. 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. The types of algae in the lake may shift, however, if concentrations of nitrogen are low relative to concentrations of phosphorus. Phosphorus is measured as dissolved (DP) and total (TP); the latter includes phosphorus incorporated into particles of soil or other matter suspended in the water (particulate phosphorus). Nitrogen is measured as ammonia-nitrogen (NH_4-N), nitrite + nitrate - nitrogen (NO_2+NO_3-N) and total kjeldahl nitrogen (TKN), which includes organic nitrogen and ammonia.

Average 1996 concentrations of phosphorus and nitrogen along the diversion route are listed in Table 4. The average concentration of total and dissolved phosphorus at Alix Lake Inflow was lower than in the Red Deer River, whereas TKN concentrations were higher. In the early part of the diversion period, there appeared to be an uptake of phosphorus but a flushing of

Table 4. Average concentrations of nutrients and bacteria for the Red Deer River at the pumphouse, Alix Lake inflow and outflow, Alix Lake and Parlby Creek at Mirror, June to October 1996. Units are mg/m³ unless indicated otherwise.

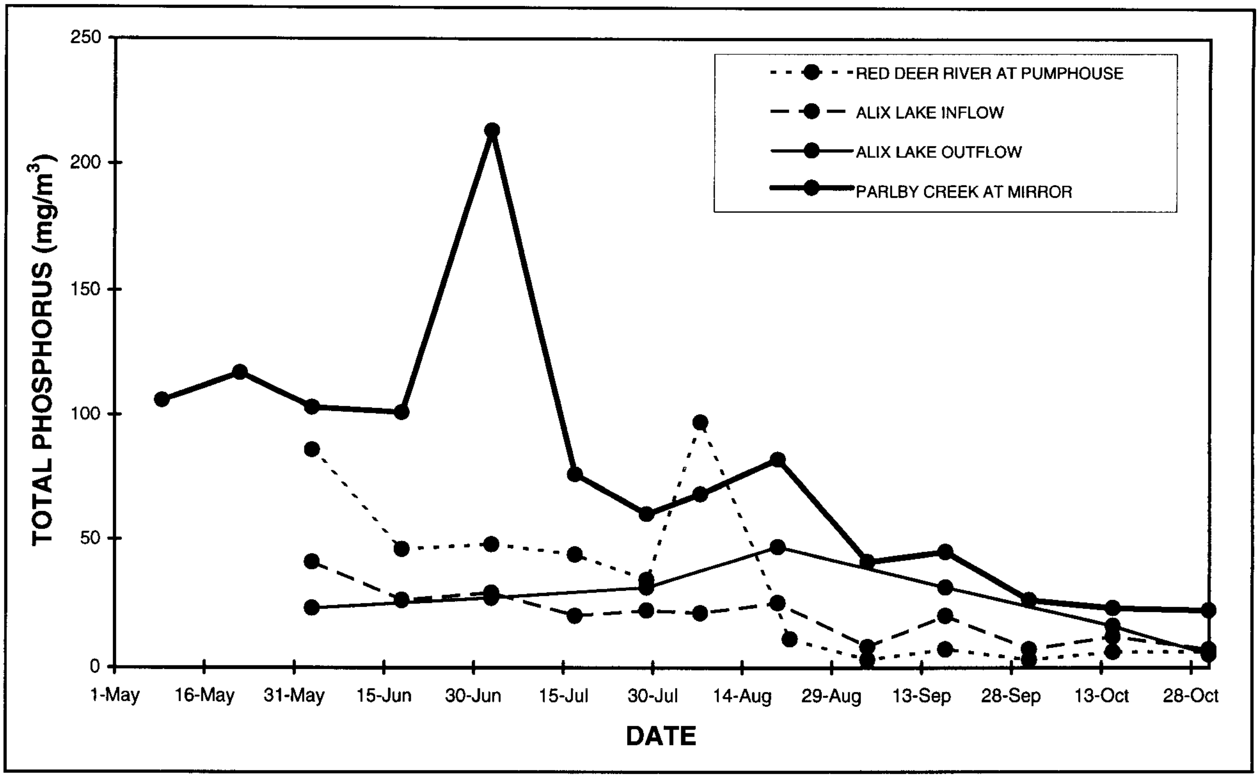
	RED DEER RIVER	ALIX LAKE INFLOW	ALIX LAKE	ALIX LAKE OUTFLOW	PARLBY CREEK
Total Phosphorus	32.6	19.8	30.7	25.7	71.7
Total Dissolved Phosphorus	12.8	9.9	10.0	10.7	44.5
Total Kjeldahl Nitrogen	333	532	644	651	749
Total Ammonia Nitrogen	20	21	65	9	53
Silica, mg/L	2.2	1.4	1.5	0.9	2.0
Fecal Colif. Bacteria, cts/100 mL	43	30			97
E. coli, cts/100 mL	34	25			85
Number of Samples	12	12	5	7	12

nitrogen along this section of the diversion route (upper graph, Figures 5 and 6). Toward the end of the summer, TKN levels at Alix Lake Inflow were similar to those in the river, but TP levels were somewhat higher than those in the river.

In Alix Lake, the average concentration of TP was higher than was measured in the inflow, but the DP concentration was similar. The higher total phosphorus concentration was due to particulate phosphorus, which was probably contained in algae suspended in the water. The average 1996 TP concentration in Alix Lake was about half the average value recorded for 1992 (60 mg/m^3), and the average DP concentration in 1996 was nearly one-third of that for 1992 (27 mg/m^3). Total phosphorus varied little over the summer in Alix Lake (Figure 5), unlike the seasonal fluctuations in Main and Secondary bays. There was some indication of release of phosphorus from the bottom sediments, because the TP concentration increased between 17 July and 6 August, though the inflow water concentration was stable. TKN was also considerably lower in 1996 than in 1992, and concentrations declined over the summer (Figure 6). Average nutrient concentrations in the outflow from Alix Lake were slightly different from average concentrations in the lake, but this may relate to differences in timing of sample collection. An exception is the average for ammonia-nitrogen in Alix Lake, which was biased by a single high value in June (270 mg/m^3). There was no obvious reason for the high value.

Phosphorus concentrations were higher in Parlby Creek at Mirror than in the other diversion route sites monitored, but levels dropped over summer as water from the Red Deer River flushed through the channel and natural runoff in the basin declined.

Mass loads of nutrients at the diversion sites are presented in Table 2a. The total amount of phosphorus decreased between the Red Deer Diversion site and the inflow to Alix Lake, and more phosphorus and nitrogen came out of the lake than entered it. Based on measurements of inflow and outflow phosphorus, 42 kg more TP left the lake than entered it over the summer. However, the estimated decrease in mass in the lake was only about 27 kg (assuming that the lake volume estimate of 1.2 million m^3, cited in Shaw 1994, is accurate). The reason for this discrepancy may be that phosphorus entered the lake water from the bottom sediments, which in most shallow lakes is a major source. The flushing of Alix Lake with diversion water appears to have removed phosphorus recycled from the bottom sediments.



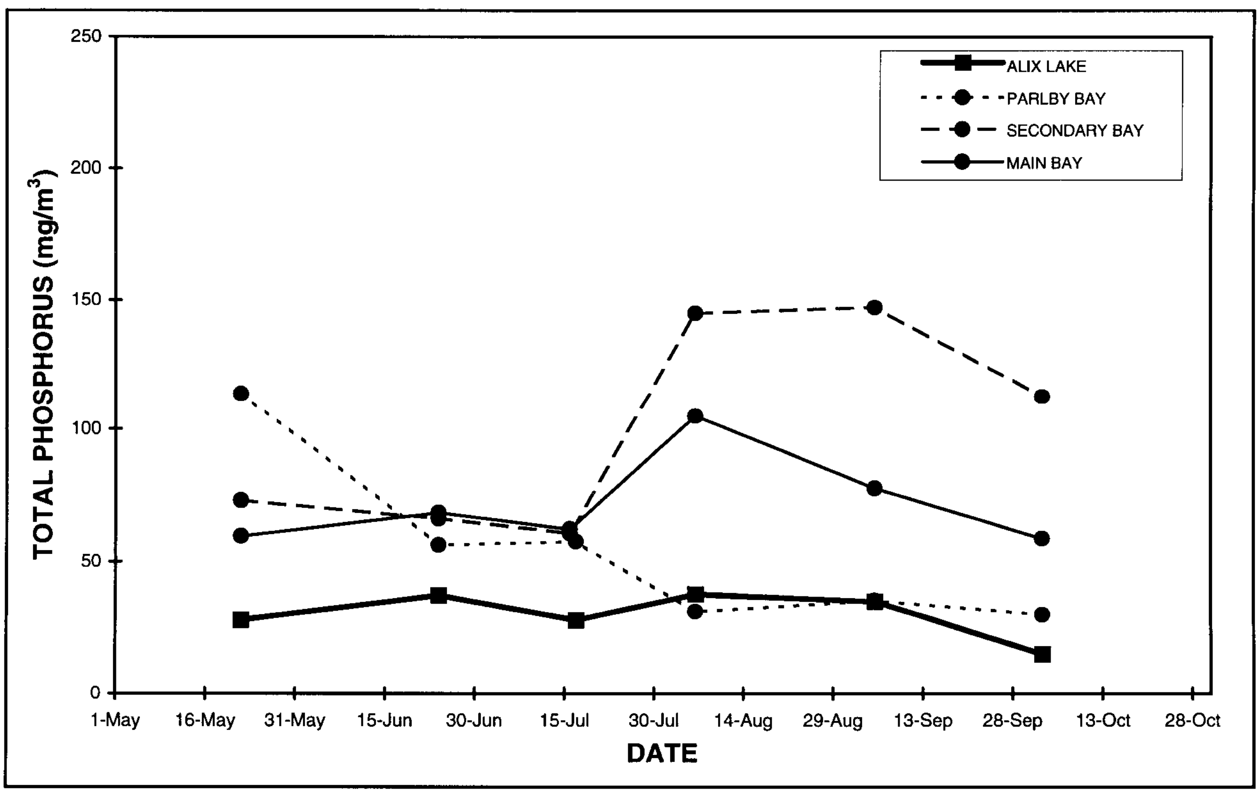
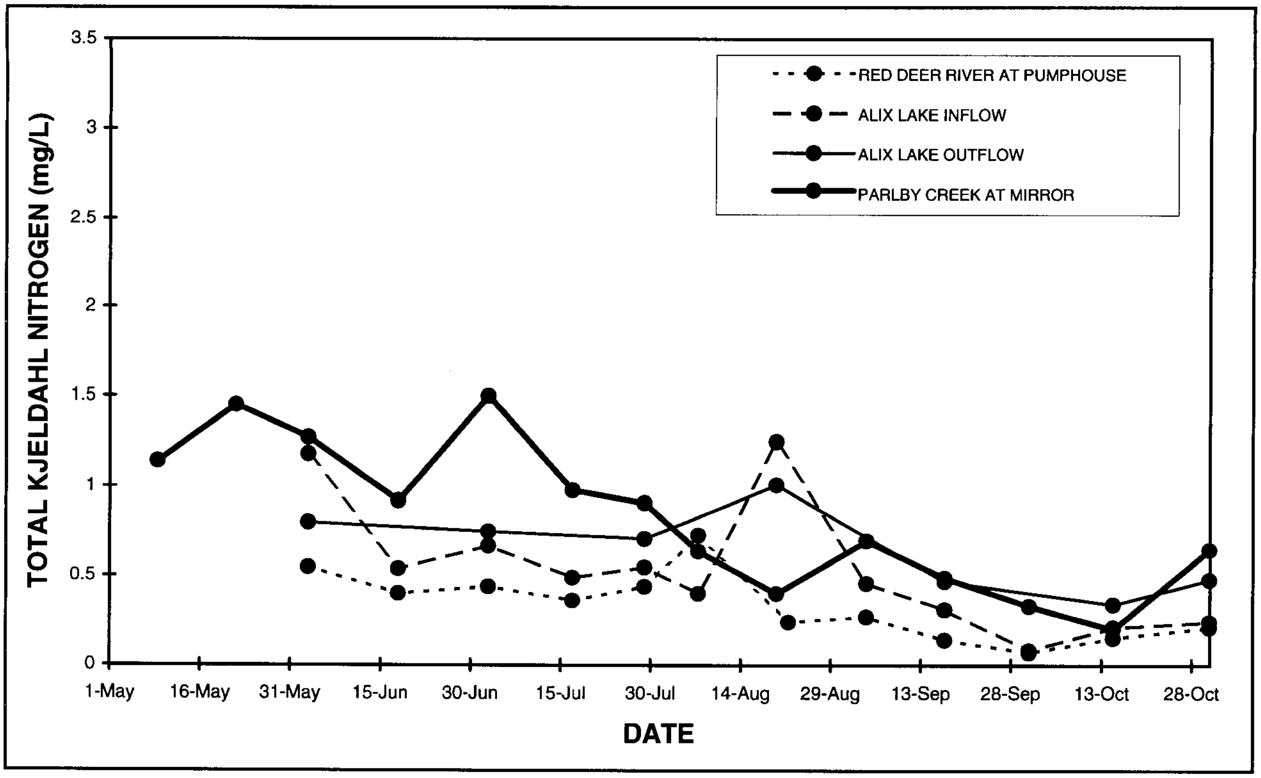


Figure 5. Concentrations of total phosphorus along the diversion route (sites are listed in direction of flow) and in Buffalo Lake, 1996.



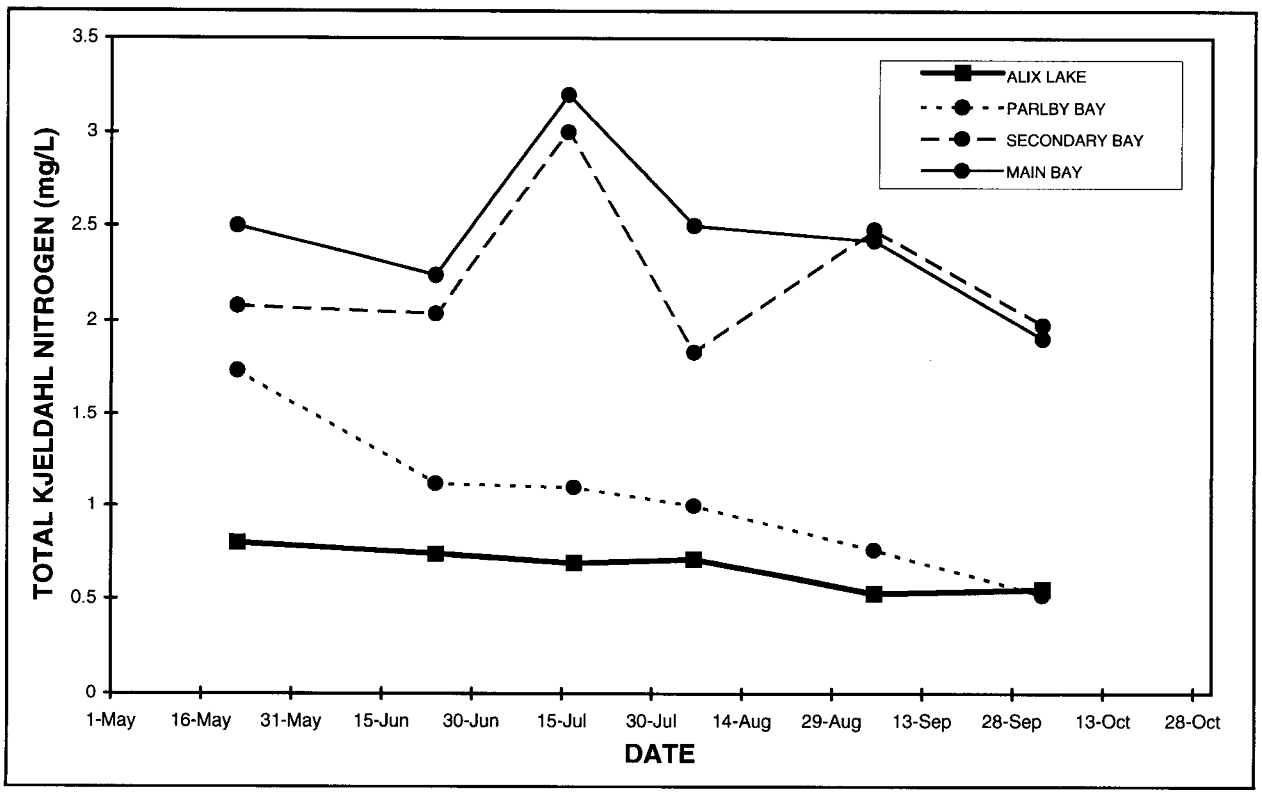


Figure 6. Concentrations of total kjeldahl nitrogen along the diversion route (sites are listed in direction of flow) and in Buffalo Lake, 1996.

The total mass of phosphorus and nitrogen measured in Parlby Creek at Mirror was much higher than at Alix Lake Outflow. It was also higher than was measured the previous year during the summer. Nutrient concentrations were not measured during spring runoff, but for many streams, the highest concentrations occur during the spring. The spring loading of phosphorus to Buffalo Lake may have amounted to several times more than the amount measured during the June - October period.

Average concentrations of nutrients for Buffalo Lake in 1995 and 1996 are listed in Table 5. In Parlby Bay, the 1996 summer average concentration was lower than in 1995. Both phosphorus and nitrogen concentrations in Parlby Bay in 1996 declined over the summer (Figures 5 and 6). For phosphorus, this pattern is opposite to that for 1995, in which total phosphorus increased over the summer to a maximum in October (140 mg/m^3). As can be seen in Table 2b, there was a loss of 56 kg of total phosphorus in Parlby Bay between May and October. Some of this would have passed into Secondary Bay, but some was likely deposited onto the bottom sediments or taken up into macrophyte biomass.

The 1996 average total phosphorus concentration in Secondary Bay was higher than in 1995, and higher than the historical average (Figure 7); the peak concentration in summer 1996 (Figure 5) was also higher than had been recorded previously (although data are limited).

Table 5. Average concentrations of nutrients and chlorophyll *a* (mg/m^3), and Secchi depth (m), for Buffalo Lake, May-October 1995 and 1996. Number of samples = 6 for each area per year.

	PARLBY BAY		SECONDARY BAY		MAIN BAY		BASHAW BAY	OUTLET POND
	95	96	95	96	95	96	96	96
Total Phosphorus	72.7	54.1	80.4	101	67.3	72.2	626	109
Total Diss. Phosphorus	29.5	26.1	30.2	31.6	35.8	36.2	437	62.8
Total Nitrogen	1732	1049	3026	2265	2798	2475	3594	4531
Total Kjeldahl N	1729	1040	3024	2237	2789	2462	3503	3707
Nitrite + Nitrate-N	3	11	2	28	9	14	109	8
Ammonia-N	29	67	25	63	32	113	237	237
Chlorophyll *a*	9.1	6.1	8.1	19.0	9.4	10.0	11.4	8.8
Secchi depth	bot.	bot.	1.2	0.8	1.9	1.7	0.4	bottom

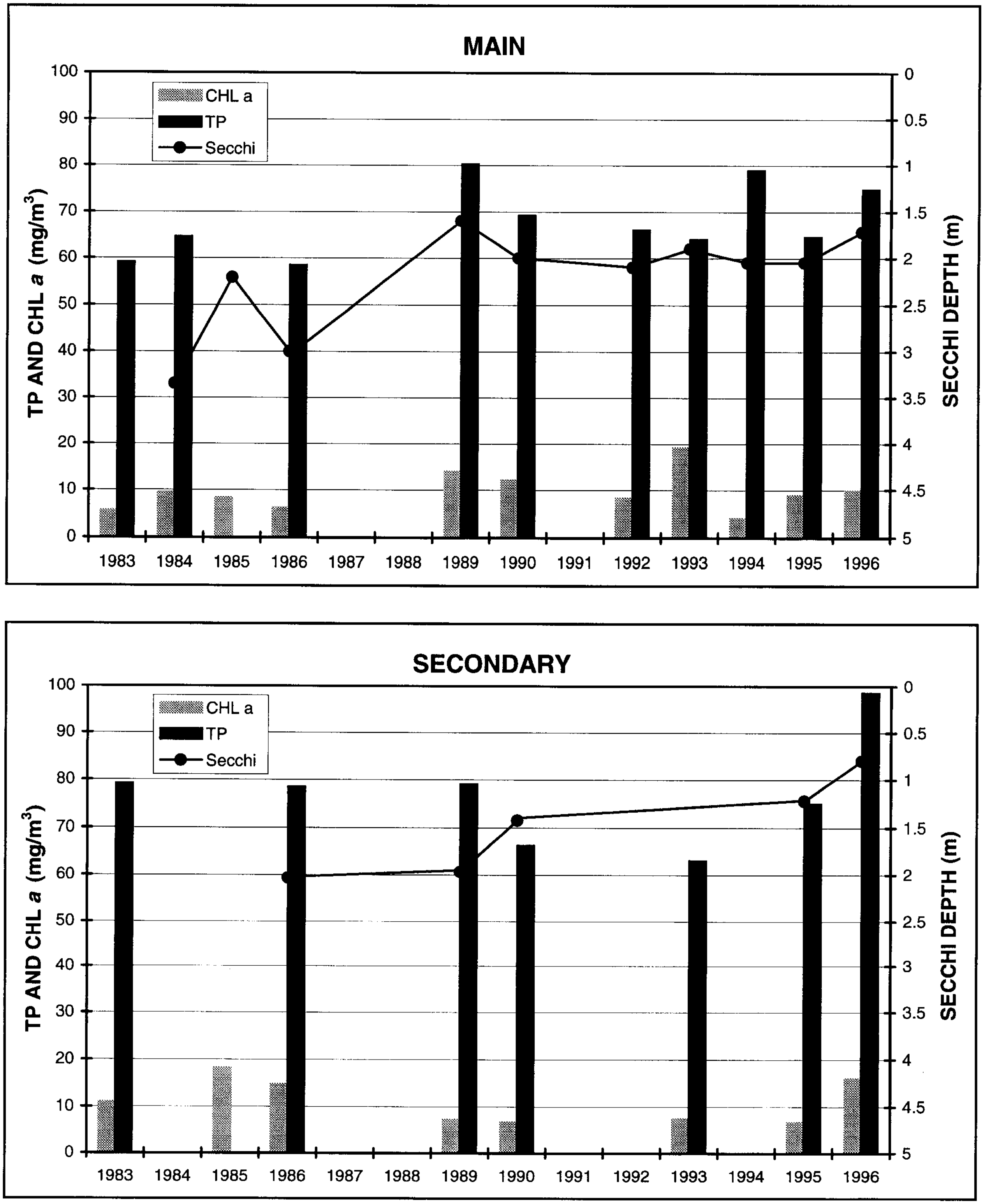


Figure 7. Average open-water Secchi depth and concentrations of chlorophyll *a* and total phosphorus in Buffalo Lake, May-September.

The source of the large increase in phosphorus in summer 1996, which was not observed in 1995, was likely the bottom sediments. Internal phosphorus loading, or sediment release, occurs in many Alberta lakes, but has not been a major feature in Buffalo Lake in the past (although it probably occurred). The increase cannot be attributed to external inputs of phosphorus, because the water moving from Parlby Bay had lower concentrations than in Secondary Bay and flows in Parlby Creek were steady or declining through this period (precipitation data are unavailable). As well, the movement of water from Secondary Bay to Main Bay would also reduce the phosphorus mass in Secondary Bay. The reason for the apparent increase in internal loading of phosphorus is not clear, but may relate to the inflow of dilute water from Parlby Bay, which could have increased the concentration gradient between the sediments and the overlying water. Whatever the reason, there was a larger mass of phosphorus in the bay by October (Table 2b). Levels of total kjeldahl nitrogen in Secondary Bay were lower in 1996 compared with 1995, but fluctuations over the summer were similar. Ammonia-nitrogen concentrations were much higher in 1996 (see below).

Nitrogen and phosphorus concentrations in Main Bay of Buffalo Lake were within historical ranges (Table 5, Figure 7), and patterns of fluctuation over the summer were also similar to those of other years. Phosphorus peaked in midsummer, but the peak was somewhat lower than was observed in Secondary Bay (Figure 5). The total mass of phosphorus in Main Bay was lower in October than in May (Table 2), indicating a net loss over the summer, likely through sedimentation. Nitrogen concentrations followed a pattern similar to that in Secondary Bay (Figure 6).

Phosphorus concentrations in Bashaw Bay were among the highest recorded in lake studies conducted by the Water Sciences Branch. Most of the phosphorus measured was in the dissolved form (up to 80%). Phosphorus was also high in Outlet Pond, but more in the range of Buffalo Lake Main and Secondary.

Ammonia concentrations are potentially a concern in Buffalo Lake. At high pH, a portion of ammonia-nitrogen is toxic to fish and other aquatic life. Ammonia accumulates as plant material dies and decomposes, so levels tend to be highest in the early spring or in the fall. Values recorded in Parlby Bay, Secondary Bay and Alix Lake in 1996 were well below Canadian

Water Quality Guideline levels to protect fish (Canadian Council of Resource and Environment Ministers 1987), even though average levels in 1996 were higher than in 1995. In Main Bay, one measurement (330 mg/m^3, October) exceeded the guideline level (160 mg/m^3 total ammonia-N for temperatures less than 20°C). In Bashaw Bay, two measurements exceeded the guideline (360 mg/m^3 and 650 mg/m^3, September and October); similar levels were measured in Outlet Pond for the same months. None of the ammonia values recorded in 1995 exceeded guideline levels, but a few values in fall and winter from sampling programs before 1995 approached or exceeded the guideline. These higher ammonia levels cannot be attributed to the diversion, because its ammonia levels averaged 20 mg/m3. Fish inhabiting Buffalo Lake may be adapted to levels of ammonia that occasionally exceed established guidelines.

3.4 CHLOROPHYLL *a*

Chlorophyll *a*, the photosynthetic pigment in algal cells, is easily measured in a water sample, and 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 summer of 1996, 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 was lower than when the lake was monitored in 1992 (1996 - 7.8 mg/m^3, 1992 - 16.1 mg/m^3). The 1996 average concentration falls between the mesotrophic and eutrophic categories for Alberta lakes, whereas in 1992 the lake was eutrophic.

The average chlorophyll *a* concentration in Parlby Bay for the summer of 1996 (Table 5) was slightly lower than the average for 1995, and levels declined (Figure 8) as the bay was flushed and phosphorus concentrations decreased. The average chlorophyll concentration for 1996 was higher than the overall historical average, but the 1996 data are biased by a high concentration in May, before the diversion began. Without this high value, the average concentration would fall into the mesotrophic range of productivity. These productivity categories may not be appropriate for Parlby Bay, because of its dense macrophyte population.

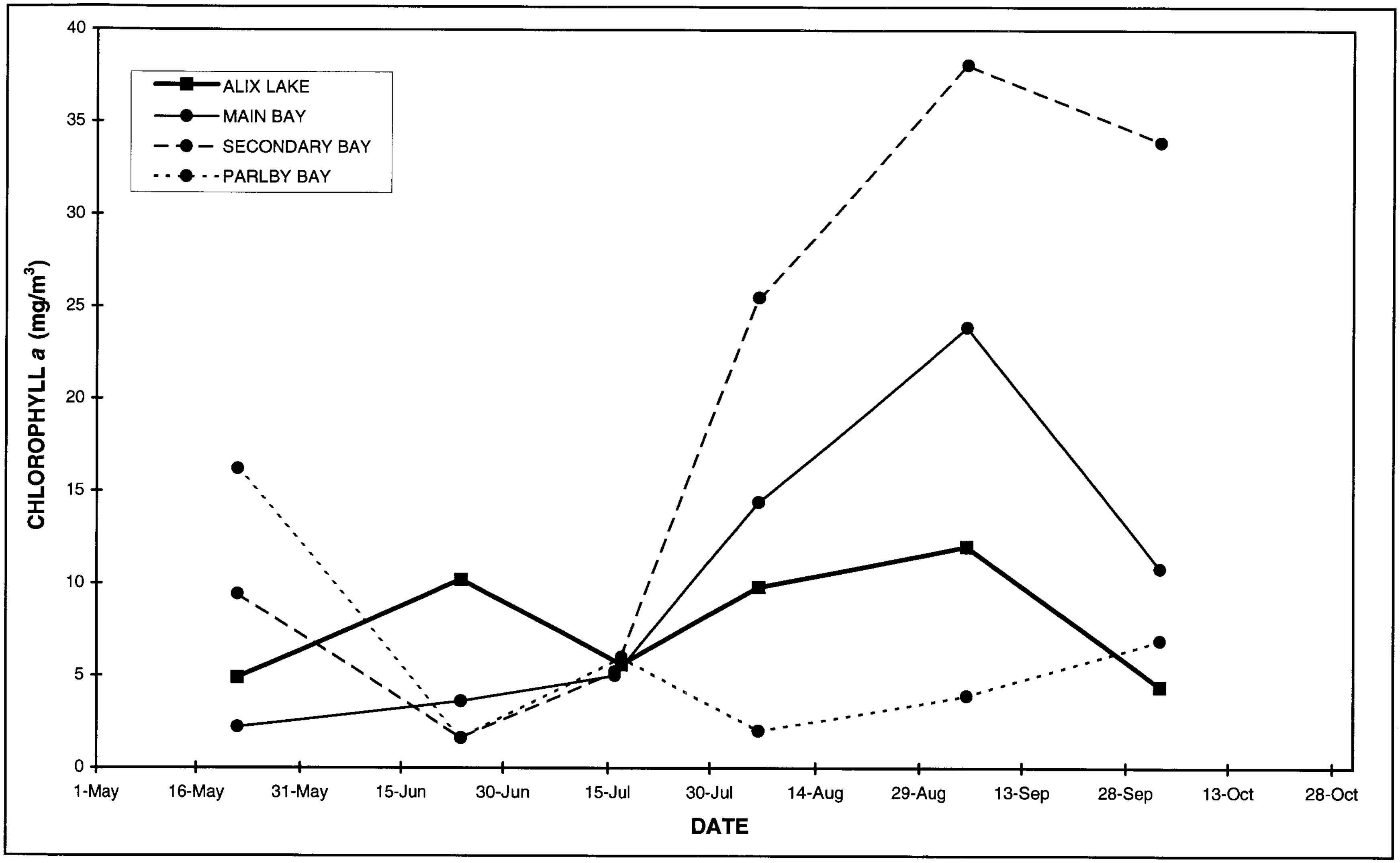


Figure 8. Concentrations of chlorophyll *a* in Alix Lake and Buffalo Lake Main, Secondary and Parlby bays, 1996.

Secondary Bay had higher concentrations of chlorophyll *a* in 1996 than in 1995. The average chlorophyll concentration in summer 1996 was more than double that of the previous summer, although it falls into the historical range for the bay (Figure 7). However, measurements in September and October were higher than had been recorded at any time in past sampling programs. This is likely a result of increased internal loading of phosphorus in the bay, but the lower salinity in the bay may also have been a factor.

Chlorophyll *a* concentrations in Main Bay in 1996 were very similar to those from 1995 and previous sampling programs, and the seasonal pattern was similar to that of other Alberta lakes, with a peak in late summer. The shallow and highly saline Bashaw Bay and Outlet Pond had moderate levels of chlorophyll, in spite of high phosphorus levels.

3.5 BACTERIA

Fecal coliform bacteria and *E. coli*, a species of intestinal bacteria in warm-blooded animals, were monitored in the diversion water at the Red Deer pumphouse, at Alix Lake Inflow and in Parlby Creek at Mirror, the final sampling site before diversion water entered Buffalo Lake. Counts of bacteria were generally low, although there were a few mid-summer and fall samples from Parlby Creek that were above typical background levels (maximum 240 fecal coliform cts/100 mL, September). The source of these bacteria is unknown, but may be waterfowl on ponds or lakes upstream.

Bacteriological surveys were conducted in August 1996 along the shoreline at Rochon Sands and Pelican Point in Buffalo Lake. The survey at Pelican Point revealed very high counts of fecal coliform bacteria and *E. coli* (maximum 25,000 *E. coli* per 100 mL), but background levels at Rochon Sands. It was noted during the surveys that there were many gulls resting in the water and on the shore at Pelican Point, but few or none at Rochon Sands sites. These birds are undoubtedly the source of these bacteria. The survey was repeated several weeks later, with similar results. Again gulls were noted at Pelican Point. The results of the survey at Rochon Sands indicate no apparent contamination of the nearshore lake water with sewage from cottages; results of the Pelican Point survey cannot be used for this assessment. Fecal coliform and *E. coli* samples were also collected from the open water of Main Bay throughout the summer; all sample results were less than 10 counts/100 mL, and most were below the analytical detection limit.

Samples collected from a small pond in the Summer Village of Rochon Sands revealed no evidence of sewage contamination from nearby cottages; all counts were typical of background levels (range 8 to 50 counts per 100 mL).

3.6 METALS

Selected metals were analyzed in samples collected from the Red Deer pumphouse and from Parlby Creek at Mirror (Table 6). There were a few samples with concentrations higher than the Canadian Water Quality Guideline for the protection of aquatic life for cadmium, copper, iron, lead, and zinc (CCREM 1987). Most of these are only one exceedence, but for copper there were two at each site. A cause for the higher values is not obvious, although 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.

Table 6. Average concentrations of metals in two 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. Number of samples = 6. Units are mg/m^3.

	GUIDELINE	RED DEER R. AT PUMPHOUSE		PARLBY CREEK AT MIRROR	
		AVG	NO. SAMPLES MEETING GUIDELINE	AVG	NO. SAMPLES MEETING GUIDELINE
Cadmium	1.3	<0.2	5	<0.2	6
Copper	3	3.2	4	3.2	4
Iron	300	330	4	200	5
Lead	4	1.8	5	3.2	5
Manganese	none	13	---	43	---
Mercury	0.1	<0.05	6	<0.05	6
Nickel	110	7.0	6	7.4	6
Zinc	30	18	5	14	6

4.0 DISCUSSION

The water quality of the Red Deer River diversion at the pumphouse was very good, especially after mid-summer when turbidity levels declined. Compared with the water quality of Buffalo Lake, levels of dissolved materials such as major ions, nutrients and organic carbon were very low. Indicator bacteria in the diversion water were measured at levels considered natural or background. Levels of certain metals exceeded water quality guidelines on one or two occasions, but concentrations were near the guideline value and would likely pose no risk to aquatic life. Mercury concentrations were below the analytical detection limit in all samples.

The measured amount of total phosphorus in the diversion water at the pumphouse over the summer, 149 kg, was less than 1% of the total phosphorus mass in Main Bay of Buffalo Lake. Although this measured mass of total phosphorus is considerably lower than the 475 kg used by Goudey et al. (1990) for pre-project impact predictions, only part of the pumping capacity was used during the summer of 1996. If the phosphorus concentration is extrapolated to the full capacity of the pumphouse (1.42 m^3/s), the total amount of phosphorus in the diverted water would be 609 kg.

The summer mass loads of various substances, including nutrients, increased along the diversion route toward Buffalo Lake. For example, the total load of sodium was seven times higher in Parlby Creek at Mirror than in the diverted Red Deer River water, and the total load of phosphorus increased nearly five-fold. Although a portion of the difference in mass at these two sites may be attributed to the higher flow volume in Parlby Creek than in the diversion, concentrations were also considerably higher at the Parlby Creek site. These increases are likely due to natural concentrations of these substances in Parlby Creek, and to flushing over bottom sediments in the diversion channel, Alix Lake and Spotted Lake. The increase in phosphorus concentrations along the route is opposite to predictions by Goudey et al. (1990); they suggested that there would be uptake of phosphorus, particularly in Spotted Lake, and therefore reduction along the route. The first year of the diversion is probably not valid for assessing this prediction, however, because the system was not in steady-state.

Even though the total diversion-period load of most substances was higher in a downstream direction, the water chemistry at various sampling sites along the diversion route gradually came to resemble that of the Red Deer River over the summer. The small water bodies and the channel itself were quickly flushed with the diversion water. By mid-July, the total dissolved solids content of the water at the inflow to Alix Lake was very similar to that in the Red Deer River. Concentrations in the outflow from Alix Lake were usually higher than in the inflow, while levels in the lake declined through flushing and precipitation of calcium carbonate. The Alix Lake outflow joined the water in Parlby Creek and then entered Spotted Lake. At the monitoring site between Spotted Lake and Buffalo Lake (Parlby Creek at Mirror), the water chemistry eventually became more like that of the Red Deer River. This occurred only when the diversion water was a major portion of the flow in Parlby Creek, after mid-July. Even so, the phosphorus concentration at this site was always higher than in the Red Deer River.

Although comparative pre-diversion data are limited, it appears that the water quality in Alix Lake has improved, even after one summer of diversion. Concentrations of total dissolved solids, nutrients and chlorophyll *a* were considerably lower in 1996 compared with data collected in 1992. 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 a 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 shown the greatest change in water quality as a result of the diversion. The combined effect of the relatively large spring runoff and the diversion has resulted in greatly reduced salinity in the bay, so that its water quality resembled that of Parlby Creek by the end of summer. Water quality in Parlby Bay has improved. Nutrient and chlorophyll concentrations in 1996 were lower than in 1995. 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.

The greatest negative change appears to have occurred in Secondary Bay. The large spring runoff and continued inflow via the diversion over summer reduced salinity, but undoubtedly increased the phosphorus loading to the bay. Levels of phosphorus and chlorophyll measured in the bay during the summer were higher than recorded in previous sampling programs. This supports the prediction in early studies that Secondary Bay would have higher algal biomass under project conditions (Alberta Environment 1984). On the other hand, predictions in a later report by Goudey et al. (1990) are refuted, at least for this year. They 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, whereas the 1996 average chlorophyll concentration in Secondary Bay was twice this level. As flushing continues next year, the amount of suspended algal growth in the bay may increase further, particularly if the magnitude of phosphorus recycling from the bottom sediments is the same as in 1996 or greater. It is not known how a further reduction in salinity would affect levels of chlorophyll *a* in Secondary Bay. According to Noton (1984), freshening of the bay would not increase algal biomass, if phosphorus concentrations remained the same. He found that phosphorus was the main factor influencing the level of algal biomass in mixtures of Buffalo Lake and Red Deer River water, even when salinity remained high. On the other hand, Bierhuizen and Prepas (1985) found that salinity was negatively correlated with algal biomass in a series of lakes with different salinities. They present equations that enable prediction of summer chlorophyll concentration from conductivity. For example, if salinity (conductivity) in Secondary Bay is reduced by the same percentage in 1997 as between 1995 and 1996 (about 19%), the average summer chlorophyll concentration in the bay could increase by 50%, assuming no increase in phosphorus; that is, the June-August average chlorophyll concentration would be 17 mg/m^3, instead of 11 mg/m^3 as in 1996 (note that the overall average for the open-water period in 1996 was 19 mg/m^3, because chlorophyll levels increased markedly in the latter half of the sampling season, biasing the average). The algal population appears to have responded to the increased phosphorus concentration at that time (mainly from the sediments), in spite of the still-high salinity in the bay, as Noton suggested may occur.

Over the next few years, chlorophyll levels in Secondary Bay may continue to increase as the bay is flushed with water from the diversion. Eventually, if water is diverted most years, water quality could gradually improve as low-nutrient water replaces the enriched water now in the bay. As well, phosphorus tied up in the bottom sediments should also decline and reach a new steady-state with the overlying water, as occurred in sediment experiments conducted on Eagle Lake near Calgary (Environmental Management Associates 1991).

The water quality of Main Bay was not affected by the diversion, 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. The estimated phosphorus loading from Secondary Bay (assuming the same flow rate as the diversion) would contribute about 400 kg to Main Bay. This contribution would increase the total phosphorus concentration in Main Bay by only 2 mg/m^3, an amount that is within measurement error and natural variation in the bay.

The 1996 conductivity and total dissolved solids concentration of Main Bay were similar to those of 1995, in spite of an increase in water level. The salinity of Main Bay has been fairly stable since 1989. Although a large portion of the surface runoff water entering Main Bay passes through Secondary Bay, it is not possible at this time to predict whether freshening of Main Bay will occur, nor whether phosphorus concentrations, and therefore chlorophyll *a* levels, might increase. Goudey et al. (1990) predicted that there would be no effect on Main Bay, but it seems possible that the diversion, combined with several years of normal or above normal runoff, might affect chlorophyll levels in Main Bay as well. These are the conditions that led to higher chlorophyll levels in Secondary Bay in 1996, but the timing for this to occur in Main Bay cannot be predicted, if it occurs at all.

Bashaw Bay is a very highly saline, productive and shallow portion of Buffalo Lake. It would not support fish or many other types of aquatic life. It is unlikely that the diversion would affect the bay, even if a connection between it and the main portion of the lake is re-established. Similarly, Outlet Pond is more saline than Buffalo Lake Main Bay. Water quality data on saline Alberta ponds are limited, so the pond cannot readily be compared with others. The data gathered in 1996, however, will provide background water quality information for conditions in the pond after the outlet channel is constructed.

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 cannot be sampled when birds are in the area, as fecal coliform bacteria in their droppings cannot be distinguished from those in sewage.

For those water quality characteristics monitored in 1996, 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 and Bashaw Bay. Conditions observed in 1996 are transitory, however. Water quality along the diversion route and in Buffalo Lake has not reached equilibrium with the water chemistry of the diversion water. The fast-flushing water bodies, Alix Lake and Parlby Bay, will reach equilibrium first, but the slow-flushing Main Bay of Buffalo Lake may never show an effect of the diversion.

Macrophyte populations in the lakes were not examined in 1996, but species and coverage may change in the basins most affected by the diversion. The diversion is expected to continue in 1997. If the full pumping capacity is used, water quality effects may be more apparent than in 1996. The sampling program will continue in 1997 and future years to assess changes in limnological characteristics when and if they occur.

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 was greater than the volume of the diversion water, and therefore water quality in Buffalo Lake was most influenced by natural conditions.

3. The concentration of nutrients, total dissolved solids and other substances increased along the diversion route toward Buffalo Lake.

4. The water quality of Alix Lake was better in 1996 than in 1992, mainly because of flushing with diversion 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 declined between 1995 and 1996.

6. The greatest negative change in water quality occurred in Secondary Bay, where phosphorus and chlorophyll *a* concentrations were much higher in 1996 than in 1995.

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

8. Bashaw Bay and Outlet Pond, water bodies that are isolated from Buffalo Lake, were higher in salinity and nutrient concentrations than Main Bay.

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, 1996.

Appendix I. Buffalo Data, 1996.

Parlby Creek - Buffalo Lake Water Management Project - 1996 LAKES DATA.

MAIN BAY									lab	field			
Sampling	Chlorophyll *a*	Total P	TDP	TN	NO2+NO3	NH3	TKN	TOC	COND	pH	TDS	TSS	Total CO3
Date	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	uS/cm	units	g/m3	g/m3	g/m3
22-May-96	2.2	59.8	34.2	2.51	0.01	0.06	2.5	37.6	2810	9.2	1910	0.4	699
24-Jun-96	3.6	68.6	38.1	2.252	0.012	0.15	2.24	38.4	2810	9.19	1860	0.4	691
16-Jul-96	5.0	62.5	39.7	3.2015	0.0015	0.02	3.2	37.1	2860	9.17	1890	0.4	698
06-Aug-96	14.4	105.2	35.2	2.5015	0.0015	0.03	2.5	37.4	2839	9.2	1948	6	699
05-Sep-96	23.9	77.8	33.8	2.441	0.021	0.09	2.42	39.2	2955	9.26	1912	3	718
03-Oct-96	10.8	59.0		1.945	0.035	0.33	1.91	36.5	2914	9.29	2001	3	714
average	**10.0**	**72.2**	**36.2**	**2.475**	**0.014**	**0.113**	**2.462**	**37.7**	**2865**		**1920**	**2**	**703**
June-Oct.	**11.54**	**74.6**	**36.7**	**2.468**	**0.014**	**0.124**	**2.454**	**37.7**	**2876**		**1922**	**3**	**704**
May-Sept.	9.8	74.8											

SECONDARY BAY									lab	field			
	Chlorophyll *a*	Total P	TDP	TN	NO2+NO3	NH3	TKN	TOC	COND	pH	TDS	TSS	Total CO3
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	uS/cm	units	g/m3	g/m3	g/m3
22-May-96	9.4	73.1	28.1	2.089	0.009	0.03	2.08	27.9	1660	9.01	1090	15	407
24-Jun-96	1.6	66.4	31.9	2.048	0.008	0.07	2.04	29.1	1850	9.03	1200	0.4	455
16-Jul-96	5.2	61	30.2	3.043	0.043	0.08	3	30.1	1970	8.98	1270	0.4	477
06-Aug-96	25.5	145	30.1	1.854	0.014	0.03	1.84	33.1	2019	9.05	1337	29	501
05-Sep-96	38.1	147.3	37.6	2.506	0.026	0.08	2.48	37.4	2138	9.09	1373	22	519
03-Oct-96	33.9	113		2.048	0.068	0.09	1.98	33.9	2187	9.12	1561	25	530
average	**18.95**	**101**	**31.6**	**2.265**	**0.028**	**0.063**	**2.237**	**31.9**	**1971**		**1305**	**15**	**482**
June-Oct.	**20.86**	**106.5**	**32.45**	**2.300**	**0.032**	**0.07**	**2.268**	**32.7**	**2033**		**1348**	**15**	**496.4**
May-Sept.	16.0	99											

PARLBY BAY									lab				
	Chlorophyll *a*	Total P	TDP	TN	NO2+NO3	NH3	TKN	TOC	COND	pH	TDS	TSS	Total CO3
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	uS/cm	units	g/m3	g/m3	g/m3
22-May-96	16.2	113.8	42.9	1.74		0.07	1.74	20.5	752	8.56	463	20	205
24-Jun-96	1.6	56.5	30.6	1.1215	0.0015	0.23	1.12	18.1	699	8.58	421	1	192
17-Jul-96	6.0	57.8	25.2	1.114	0.014	0.01	1.1	19	573	8.87	328	0.4	145
06-Aug-96	2.0	31.2	14.9	1.003	0.003	0.02	1	15.7	440	9.41	263	2	116
05-Sep-96	3.9	35.5	17.1	0.782	0.022	0.03	0.76	14.6	396	9.16	229	1	102
03-Oct-96	6.9	30		0.533	0.013	0.04	0.52	9.5	411	8.81	233	4	107
average	**6.1**	**54.1**	**26.1**	**1.049**	**0.011**	**0.067**	**1.040**	**16.2**	**545**		**323**	**5**	**145**
June-Oct.	**4.08**	**42.2**	**21.95**	**0.911**	**0.011**	**0.066**	**0.9**	**15.4**	**504**		**295**	**2**	**132.4**
May-Sept.	5.9	59.0											

BASHAW BAY									lab				
	Chlorophyll *a*	Total P	TDP	TN	NO2+NO3	NH3	TKN	TOC	COND	pH	TDS	TSS	Total CO3
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	uS/cm	units	g/m3	g/m3	g/m3
22-May-96	24.6	596.4	314.5	5.25		0.1	5.25	69	5200	9.3	3820	68	1092
24-Jun-96	2.7	505	391.3	2.113	0.093	0.14	2.02	87	5470	9.29	3830	6	1160
17-Jul-96	9.0	656	502.7	2.584	0.134	0.1	2.45	82	5683	9.25	4011	14	1203
06-Aug-96	26.0	682.3	453.5	4.055	0.005	0.07	4.05	91	5932	9.34	4331	50	1276
05-Sep-96	3.7	645.3	521.8	4.016	0.016	0.36	4	129	6687	9.28	4811	10	1429
03-Oct-96	2.2	673		3.548	0.298	0.65	3.25	106	6453	9.31	4693	26	1373
average	**11.4**	**626.3**	**436.8**	**3.594**	**0.109**	**0.237**	**3.503**	**94**	**5904**		**4249**	**29**	**1256**
June-Oct.	**8.72**	**632.3**	**467.325**	**3.263**	**0.109**	**0.264**	**3.154**	**99**	**6045**		**4335**	**21**	**1288.2**
May-Sept.	13.2	617.0											

OUTLET POND									lab				
	Chlorophyll *a*	Total P	TDP	TN	NO2+NO3	NH3	TKN	TOC	COND	pH	TDS	TSS	Total CO3
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	uS/cm	units	g/m3	g/m3	g/m3
22-May-96	2.2	67.8	44.7	3.6		0.13	3.6	52.8	2870	8.67	1950	20	780
24-Jun-96	7.3	98.4	48.7	3.1015	0.0015	0.15	3.1	73	2970	8.91	2040	5	808
17-Jul-96	5.1	138.6	62.4	3.004	0.004	0.03	3	81.5	3322	8.93	2197	0.4	915
06-Aug-96	5.0	79.1	51.9	4.303	0.003	0.07	4.3	82	3475	8.95	2316	2	952
05-Sep-96	3.0	149.3	106.5	3.7015	0.0015	0.57	3.7	83	3879	8.97	2606	1	1057
03-Oct-96	30.3	122		4.531	0.031	0.47	4.5	66	3180	8.87	2138	6	886
average	**8.8**	**109.2**	**62.8**	**3.707**	**0.008**	**0.237**	**3.700**	**73.1**	**3283**		**2208**	**6**	**900**
June-Oct.	**10.14**	**117.5**	**67.375**	**3.728**	**0.008**	**0.258**	**3.72**	**77.1**	**3365**		**2259**	**3**	**923.6**
May-Sept.	4.5	106.6											

ALIX LAKE									lab				
	Chlorophyll *a*	Total P	TDP	TN	NO2+NO3	NH3	TKN	TOC	COND	pH	TDS	TSS	Total CO3
	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	uS/cm	units	g/m3	g/m3	g/m3
22-May-96	4.9	28.1	9.1	0.8		0.005	0.8	10	531	8.37	311	2	138
24-Jun-96	10.2	37.5	9.3	0.74015	0.00015	0.27	0.74	11.2	477	8.32	278	0.2	126
17-Jul-96	5.6	27.9	10.8	0.693	0.003	0.005	0.69	10.7	413	8.55	235	0.2	104
06-Aug-96	9.8	38.0	10	0.715	0.005	0.04	0.71	9.8	355	8.77	200	0.2	92
05-Sep-96	12.0	35.1	9.7	0.53015	0.00015	0.005	0.53	10	337	8.34	188	2	86
03-Oct-96	4.4	15		0.553	0.003	0.005	0.55	7.6	336	8.52	194	0.2	85
average	**7.8**	**30.3**	**9.8**	**0.672**	**0.002**	**0.055**	**0.670**	**9.9**	**408**		**234**	**1**	**105**
June-Oct.	**8.4**	**30.7**	**9.95**	**0.646**	**0.002**	**0.065**	**0.644**	**9.9**	**384**		**219**	**1**	**98.6**
May-Sept.	8.5	33.32											

Less than values = 0.5 of det. limit

Prepared by WATER SCIENCES BRANCH Alberta Environmental Protection

Appendix I. Buffalo Data, 1996.

Parlby Creek - Buffalo Lake Water Management Project - 1996 LAKES DATA.

Sampling Date	Ca	Mg	K	Na	SO4	Cl	HCO3	CO3	T. Alk.	Hardness	Silica	Secchi	FCOL
MAIN BAY													
	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3 CaCO3		mg/L	m	cts/100 mL
22-May-96	5.45	79	43.6	574	488	15.6	1030	193	1170	339	1.7	3.0	<4
24-Jun-96	4.61	74.8	40.4	545	475	16.7	1030	185	1160	319	1.25	1.4	<4
17-Jul-96	4.4	80.5	43.6	548	487	17.3	1040	187	1170	342	1.3	1.9	4
06-Aug-96	5.78	85.5	48.3	606	478	16.7	1028	194	1166	366	1.55	1.1	8
05-Sep-96	6	77.6	44.9	570	470	17.2	1049	202	1197	334	1.39	1.2	<4
03-Oct-96	5.51	85.8	48.7	628	492	17.9	1047	199	1191	367	1.35	1.4	<4
average	**5.3**	**80.5**	**44.9**	**579**	**482**	**17**	**1037**	**193**	**1176**	**345**	**1.4**	**1.7**	**<4**
June-Oct	**5.26**	**80.84**	**45.2**	**579**	**480**	**17.2**	**1039**	**193**	**1177**	**346**	**1.368**	**1.4**	**<4**
SECONDARY BAY	Ca	Mg	K	Na	SO4	Cl	HCO3	CO3	T. Alk.	Hardness	Silica	Secchi	
	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3 CaCO3		mg/L	m	
22-May-96	19.2	53	27.6	312	257	11	687	68.8	678	266	6.5	0.9	
24-Jun-96	16.3	55.6	28.4	336	288	12.9	770	76	758	270	4.63	1.2	
17-Jul-96	13.6	62.5	31.3	357	306	13.2	795	86.1	796	291	4.55	1.2	
06-Aug-96	15.6	62.5	34.1	388	316	12.9	820	97.4	835	296	5.75	0.3	
05-Sep-96	16.4	63.5	33.8	389	330	13.9	852	100	866	302	8.1	0.4	
03-Oct-96	20	68.1	35.6	423	462	14.4	877	98.7	884	330	7.8	0.3	
average	**16.9**	**60.9**	**31.8**	**368**	**327**	**13.1**	**800**	**88**	**803**	**293**	**5.9**	**0.8**	
June-Oct	**16.38**	**62.44**	**32.6**	**379**	**340**	**13.5**	**823**	**92**	**828**	**298**	**6.166**	**0.68**	
												0.8	
PARLBY BAY	Ca	Mg	K	Na	SO4	Cl	HCO3	CO3	T. Alk.	Hardness	Silica	Secchi	
	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3 CaCO3	mg/L	mg/L	m	
22-May-96	58.8	31.6	9.6	76.9	69.6	7.1	409	4.3	343	277	4.7	0.8	
24-Jun-96	44.3	35.9	7.99	65.6	66.1	5.7	362	14.2	321	259	3	0.8	
17-Jul-96	21.3	28.9	5.61	56.2	64.2	4.8	260	17.4	242	172	1	0.8	
06-Aug-96	16.3	28.6	5.17	45.8	45.5	4.1	168	33.1	193	158	0.25		
05-Sep-96	15.4	27.9	5.13	32.5	40.8	3.5	126	40.4	171	153	0.95	0.5	
03-Oct-96	32.9	23.2	3.81	23.4	37.8	3.3	200	9	179	178	0.4	0.5	
average	**32**	**29**	**6**	**50**	**54.0**	**5**	**254**	**20**	**242**	**200**	**1.7**	**0.7**	
June-Oct	**26.04**	**28.9**	**5.5**	**45**	**51**	**4.3**	**223**	**23**	**221**	**184**	**1.12**	**0.65**	
BASHAW BAY	Ca	Mg	K	Na	SO4	Cl	HCO3	CO3	T. Alk.	Hardness	Silica	Secchi	
	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3 CaCO3		mg/L	m	
22-May-96	4.66	76.3	58.4	1340	1210	28	1480	364	1820	326	1.4	0.2	
24-Jun-96	4.77	77.4	61.1	1220	1260	32.7	1630	359	1940	331	3.3	0.5	
17-Jul-96	4.8	71.3	57.1	1330	1300	31.1	1675	379	2005	305	3.15	0.4	
06-Aug-96	5.39	83.7	67.3	1510	1340	34.6	1731	425	2128	358	2.53		
05-Sep-96	5.38	82.1	69.4	1670	1500	39.5	1876	507	2384	351	2.2	0.5	
03-Oct-96	11.8	85.7	65.5	1580	1460	99	1874	452	2291	382	1.4	0.3	
average	**6.1**	**79.4**	**63.1**	**1442**	**1345**	**44**	**1711**	**414**	**2095**	**342**	**2.3**	**0.4**	
June-Oct	**6.428**	**80.04**	**64.1**	**1462**	**1372**	**47.4**	**1757**	**424**	**2150**	**345**	**2.516**	**0.425**	
OUTLET POND	Ca	Mg	K	Na	SO4	Cl	HCO3	CO3	T. Alk.	Hardness	Silica		
	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3 CaCO3		mg/L		
22-May-96	10.4	61.3	34.3	653	370	26.3	1430	76.4	1300	278	7.6		
24-Jun-96	19.6	64.8	36.4	694	374	30	1460	90.6	1350	316	6.65		
17-Jul-96	14	66.6	38	736	385	30	1545	155	1526	309	9.2		
06-Aug-96	10.5	69.8	42	758	438	32.5	1530	200	1588	314	14.1		
05-Sep-96	14.7	60.8	39.4	925	458	36	1782	181	1764	287	20		
03-Oct-96	20.7	57.9	34.6	671	424	30.8	1516	141	1478	290	17.2		
average	**15**	**64**	**37**	**740**	**408**	**31**	**1544**	**141**	**1501**	**299**	**12.5**		
June-Oct	**15.9**	**63.98**	**38.1**	**757**	**416**	**31.9**	**1567**	**154**	**1541**	**303**	**13.43**		
ALIX LAKE	Ca	Mg	K	Na	SO4	Cl	HCO3	CO3	T. Alk.	Hardness	Silica	Secchi	
	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3	g/m3 CaCO3	mg/LCaCO3	mg/L	m	
22-May-96	36.7	33.1	6.83	34.7	55.2	4.4	280	0.5	230	228	1.15	2.5	
24-Jun-96	33.6	30.5	5.18	29	48.9	2.9	250	2.9	210	210	0.9	2.4	
17-Jul-96	35.9	19	3	23.2	45.6	2.5	197	7.2	174	168	1.25	2.4	
06-Aug-96	25.6	20.9	3.12	19.2	35.1	2.1	168	9.5	154	150	2.5	1.5	
05-Sep-96	30.1	20.1	2.68	14.6	31.6	2	173	0.5	142	158	2.2	1.3	
03-Oct-96	33.9	20.3	2.34	13.2	36.3	2.3	171	0.5	140	168	0.5	2.2	
average	**32.6**	**24.0**	**3.9**	**22.3**	**42.1**	**2.7**	**207**	**4**	**175**	**180**	**1.4**	**2.1**	
June-Oct	**31.82**	**22.16**	**3.3**	**20**	**40**	**2.4**	**192**	**4**	**164**	**171**	**1.47**	**1.96**	
May-Sept												2.02	

Appendix I. Buffalo Data, 1996.

Parlby Creek-Buffalo Lake Water Management Project - 1996 DIVERSION DATA.

RED DEER RIVER AT PUMPHOUSE									lab				
Sampling	**Avg. Flow**	**Total P**	**TDP**	**TN**	**NO2+NO3**	**NH3**	**TKN**	**TOC**	**COND**	**pH**	**TDS**	**TSS**	**Total CO3**
Date	m3/sec	mg/m3	mg/m3	g/m3	mg/m3	mg/m3	mg/m3	mg/m3	uS/cm	units	g/m3	g/m3	g/m3
03-Jun-96	0.3496	86	44	0.676	0.126	0.005	0.55	8	347	8.05	200	30	94
18-Jun-96	0.3496	46	18	0.4		0.005	0.4	7.8	331	8.44	181	12	89
03-Jul-96	0.3496	48	6	0.44		0.005	0.44		346	8.55	199	0.4	92
17-Jul-96	0.3496	44	10	0.402	0.042	0.005	0.36	7.5	350	8.73	190	7	93
29-Jul-96	0.3496	34	21	0.44		0.12	0.44	8.1	345	8.67	194	2	93
07-Aug-96	0.3496	97	26	0.73		0.02	0.73	12.6	339	8.28	190	4.5	94
22-Aug-96	0.3496	11	6	0.24		0.02	0.24	5.8	341	8.80	199	1	95
04-Sep-96	0.3496	3	3	0.27		0.005	0.27	5.1	357	8.54	199	0.4	91
17-Sep-96	0.3496	7	7	0.14		0.005	0.14	2.3	366	8.44	197	0.4	90
01-Oct-96	0.3496	3	3	0.07		0.01	0.07	3.7	388	8.38	234	0.4	104
15-Oct-96	0.3496	6	6	0.15		0.005	0.15	3.5	388	8.40	221	0.4	100
31-Oct-96	0.3496	6	3	0.21		0.03	0.21	3.5	431	8.58	248	0.4	115
average		**32.6**	**12.8**	**0.347**	**0.084**	**0.020**	**0.333**	**6.2**	**361**		**204**	**5**	**96**

ALIX LAKE INFLOW									lab	field			
	Avg. Flow	**Total P**	**TDP**	**TN**	**NO2+NO3**	**NH3**	**TKN**	**TOC**	**COND**	**pH**	**TDS**	**TSS**	**Total CO3**
	m3/sec	mg/m3	mg/m3	g/m3	mg/m3	mg/m3	mg/m3	mg/m3	uS/cm	units	g/m3	g/m3	g/m3
03-Jun-96	0.046	41	27	1.186	0.006	0.01	1.18	19	796	8.31	492	2	195
18-Jun-96	0.389	26	12	0.54		0.005	0.54	10.2	377	8.39	208	14	100
03-Jul-96	0.345	29	12	0.67		0.12	0.67		391	8.64	233	3	98
17-Jul-96		20	14	0.51	0.02	0.005	0.49	9.2	323	8.66	178	4	83
24-Jul-96	0.39												82
29-Jul-96		22	14	0.55		0.01	0.55	8.8	308	8.64	170	5	81
07-Aug-96	0.387	21	6	0.4		0.02	0.4	8	307	8.68	173	7.5	80
20-Aug-96	0.34	25	16	1.25		0.03	1.25	10.6	309	8.35	170	11	84
04-Sep-96		8	3	0.46		0.01	0.46	6.5	330	8.37	177	2	83
17-Sep-96	0.431	20	4	0.31		0.005	0.31	3.7	341	8.26	181	7	80
01-Oct-96	0.424	7	3	0.08		0.02	0.08	4	345	8.17	208	4	90
15-Oct-96	0.438	12	5	0.21		0.005	0.21	4.1	390	8.23	219	0.4	99
31-Oct-96	0.309	7	3	0.24		0.01	0.24	3.8	425	8.27	241	3	110
average		**19.8**	**9.9**	**0.534**	**0.013**	**0.021**	**0.532**	**8.0**	**387**		**221**	**5**	**97**

ALIX LAKE OUTFLOW (data include Alix Lake on alternate 2 week periods)							Alix Lake		lab				
	Avg. Flow	**Total P**	**TDP**	**TN**	**NO2+NO3**	**NH3**	**TKN**	**TOC**	**COND**	**pH**	**TDS**	**TSS**	**Total CO3**
	m3/sec	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	uS/cm	units	g/m3	g/m3	g/m3
03-Jun-96	0.085	23	21	0.821	0.021	0.005	0.8	11.6	518	8.42	303	2	132
24-Jun-96	0.886	37.5	9.3	0.74015	0.00015	0.27	0.74		477	8.32	278		126
03-Jul-96	1.1	27	6	0.75		0.01	0.75	11.6	451	8.58	265	0.2	115
17-Jul-96	0.39	27.9	10.8			0.005	0.69		413	8.55	235		104
29-Jul-96		31	21	0.71		0.01	0.71	15	387	8.76	222	0.2	96
06-Aug-96	0.522	38	10			0.04	0.71		355	8.77	200		92
20-Aug-96	0.579	47	9	1.01		0.01	1.01	10.9	350	8.69	196	1	89
05-Sep-96		35.1	9.7			0.005	0.53		337	8.34	188		86
17-Sep-96	0.449	31	11	0.47		0.005	0.47	7.4	364	8.59	186	0.2	82
03-Oct-96	0.427	15				0.005	0.55		336	8.52	194		85
15-Oct-96	0.556	16	4	0.34		0.005	0.34	5.8	332	8.71	186	0.2	83
31-Oct-96	0.825	5	3	0.48		0.02	0.48	5.1	361	8.49	201	0.2	92
average	0.5819	**27.8**	**10.4**	**0.665**	**0.011**	**0.033**	**0.648**		**390**		**221**	**0.6**	**99**

PARLBY CREEK AT MIRROR (gauging site)									lab				
	Avg. Flow	**Total P**	**TDP**	**TN**	**NO2+NO3**	**NH3**	**TKN**	**TOC**	**COND**	**pH**	**TDS**	**TSS**	**Total CO3**
	m3/sec	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	mg/m3	uS/cm	units	g/m3	g/m3	g/m3
09-May-96	1.53	105.9	56.6	1.1415	0.0015	0.02	1.14	20.6			383	0.2	173
22-May-96	0.685	117	66	1.45		0.005	1.45	19.2	806	8.46	499	3	233
03-Jun-96	0.882	103	99	1.274	0.004	0.09	1.27	20.8	806	8.20	494	3.5	222
18-Jun-96	0.819	101	73	0.92		0.005	0.92	13.3	572	8.77	332	5	157
3-Jul-96	1.15	213	151	1.5		0.34	1.5		808	8.28	492	0.2	220
17-Jul-96	0.287	76	50	1.009	0.029	0.02	0.98	17.1	531	9.02	340	3	149
29-Jul-96	0.256	60	60	0.91		0.03	0.91	15	474	9.05	281	0.2	125
07-Aug-96	0.524	68	25	0.64		0.02	0.64	12.6	405	8.99	239	2.5	109
20-Aug-96	0.286	82	38	0.4		0.02	0.4	12.3	382	8.88	219	6	101
04-Sep-96	0.349	41	5	0.7		0.005	0.7	11.3	368	8.74	202	5	97
17-Sep-96	0.429	45	17	0.49		0.005	0.49	7.9	342	8.15	190	2	92
01-Oct-96	0.414	26	6	0.33		0.02	0.33	7.7	354	8.28	213	10	95
15-Oct-96	0.426	23	7	0.2		0.005	0.2	7.4	407	8.44	232	7	104
31-Oct-96	0.253	22	3	0.65		0.08	0.65	7.2	481	8.11	273	6	124
average	0.592142857	**77.4**	**46.9**	**0.830**	**0.012**	**0.048**	**0.827**	**13.3**	**518**		**314**	**4**	**143**
June - Oct.		**71.7**	**44.5**	**0.752**	**0.017**	**0.053**	**0.749**	**12.1**	**494.2**		**292.3**		**133**

Appendix I. Buffalo Data, 1996.

Parlby Creek-Buffalo Lake Water Management Project - 1996 DIVERSION DATA.											
RED DEER RIVER AT PUMPHOUSE											
Sampling Date	**Ca** g/m3	**Mg** g/m3	**K** g/m3	**Na** g/m3	**SO4** g/m3	**Cl** g/m3	**HCO3** g/m3	**CO3** g/m3	**T. Alk.** g/m3 CaCO3	**Hardness**	**Silica**
03-Jun-96	49.5	14.3	2.74	8.79	25.5	2.9	190	0.5	156	183	4.8
18-Jun-96	41.4	12.8	1.8	7.57	25.4	1.9	180	0.25	148	156	2.65
03-Jul-96	49	14.9	1.61	9.07	29.1	2.4	180	3	153	184	3.4
17-Jul-96	41.9	12.7	1.38	7.48	30.1	1.7	185	1.8	155	157	4.3
29-Jul-96	46.2	14.6	1.39	9.04	25.9	1.7	174	7.9	156	176	3.65
07-Aug-96	44.1	13.7	2.89	11.3	20.1	2.6	190	0.25	156	167	5.7
22-Aug-96	46.7	15	0.95	8.42	30.3	1.9	172	10.3	158	178	0.75
04-Sep-96	45.6	14.4	1.3	8.65	34.4	1.9	185	0.25	152	173	0.025
17-Sep-96	43.9	14.9	1.36	8.55	35	2	182	0.25	149	171	0.025
01-Oct-96	48.1	16.2	2	21.8	36.8	4	208	1.6	173	187	0.025
15-Oct-96	47.9	16.7	1.29	12.7	35.9	4.6	195	4.1	167	188	0.025
31-Oct-96	53.8	17	1.55	13	40.6	4.4	222	6.3	193	204	1.3
average	**46.5**	**14.8**	**1.7**	**10.5**	**30.8**	**2.7**	**189**	**3**	**160**	**177**	**2.2**
ALIX LAKE INFLOW											
	Ca g/m3	**Mg** g/m3	**K** g/m3	**Na** g/m3	**SO4** g/m3	**Cl** g/m3	**HCO3** g/m3	**CO3** g/m3	**T. Alk.** g/m3 CaCO3	**Hardness**	**Silica**
03-Jun-96	46.8	53.6	8.43	60.4	121	3.8	385	5.6	325	338	2
18-Jun-96	36.6	18.8	2.51	13.4	33.2	2.2	202	0.25	166	169	1.35
03-Jul-96	39	21.2	2.6	21.7	45.2	3.6	185	7.5	164	185	1.65
17-Jul-96	29.1	15.8	1.69	11.9	33.6	1.6	155	6.4	138	138	1.75
							151	7.4			
29-Jul-96	32.4	15.7	1.53	9.77	26.6	1.4	148	8.3	135	146	2.2
07-Aug-96	34	16.5	1.61	9.55	27.8	1.5	148	7.7	134	153	2.6
20-Aug-96	31.7	15.5	2.03	10.7	23.4	1.6	165	2.8	140	143	2.9
04-Sep-96	33	14.9	1.43	9.52	30.9	2.2	169	0.25	139	144	1.33
17-Sep-96	34.6	15.9	1.73	9.9	34.5	2.3	163	0.25	134	152	0.65
01-Oct-96	37.4	17.2	2.54	22	34.8	3.4	182	0.25	149	164	0.2
15-Oct-96	44	17.8	1.52	14.8	37	4.4	200	0.25	164	183	0.025
31-Oct-96	49.8	17.6	1.6	13.4	41.8	4.2	224	0.25	184	197	0.4
average	**37.4**	**20.0**	**2.4**	**17.3**	**40.8**	**2.7**	**191**	**4**	**164**	**176**	**1.4**
ALIX LAKE OUTFLOW											
	Ca g/m3	**Mg** g/m3	**K** g/m3	**Na** g/m3	**SO4** g/m3	**Cl** g/m3	**HCO3** g/m3	**CO3** g/m3	**T. Alk.** g/m3 CaCO3	**Hardness** mg/L	**Silica** mg/L
03-Jun-96	31.7	33.7	6.79	35.5	55.9	4.5	262	3.4	221	218	0.5
24-Jun-96	33.6	30.5	5.18	29	48.9	2.9	250	2.9	210	210	0.9
03-Jul-96	31.9	30.3	5.23	28.6	48.7	2.9	219	7.8	193	204	0.6
17-Jul-96	35.9	19	3	23.2	45.6	2.5	197	7.2	174	168	1.25
29-Jul-96	26.2	25.4	3.87	23.1	43.5	2.7	170	12.4	160	170	1.2
06-Aug-96	25.6	20.9	3.12	19.2	35.1	2.1	168	9.5	154	150	2.5
20-Aug-96	24.1	21.8	3.12	17.8	35.9	2.1	162	9.8	149	150	2.85
05-Sep-96	30.1	20.1	2.68	14.6	31.6	2	173	0.5	142	158	2.2
17-Sep-96	29	18.4	2.98	16.3	33.6	2.7	163	1.9	137	148	1.3
03-Oct-96	33.9	20.3	2.34	13.2	36.3	2.3	171	0.5	140	168	0.5
15-Oct-96	29.8	19.6	1.92	12.9	33.6	3.2	157	6.3	139	155	0.025
31-Oct-96	34.2	18.4	1.92	12.6	37.2	3.1	179	4.2	154	161	0.025
average	**30.5**	**23.2**	**3.5**	**20.5**	**40.5**	**2.8**	**189**	**6**	**164**	**172**	**1.154167**
PARLBY CREEK AT MIRROR (gauging site)											
	Ca g/m3	**Mg** g/m3	**K** g/m3	**Na** g/m3	**SO4** g/m3	**Cl** g/m3	**HCO3** g/m3	**CO3** g/m3	**T. Alk.** g/m3 CaCO3	**Hardness**	**Silica**
09-May-96	48.6	25	9.36	60.8	58.1	5.8	351	0.5	288	224	11.1
22-May-96	65	31.9	7.11	87.6	62.5	7.5	459	7.5	389	294	3.3
03-Jun-96	66.7	36	8.05	73.2	77.7	6.4	452	0.25	371	315	4.7
18-Jun-96	33.4	32.2	6.04	41.8	54	4.6	288	15.2	262	216	1.4
3-Jul-96	56.9	35.7	6.8	88.9	72.8	6.5	447	0.25	367	289	9.3
17-Jul-96	53	29.5	4.59	44.4	52.8	4.4	255	23.4	248	254	1.25
29-Jul-96	32.6	28.3	4.53	38.5	47.5	3.5	195	28.8	208	198	1.1
07-Aug-96	30.8	25.5	4.06	26.5	39.6	2.9	181	19.6	181	181	1.02
20-Aug-96	26.4	22.9	3.73	22.7	38.4	2.8	167	18.8	168	160	0.5
04-Sep-96	27.5	18.6	2.94	17.8	33.7	2.8	185	6.3	162	145	0.94
17-Sep-96	27.5	18.6	2.44	14.1	32.2	2.2	187	0.25	153	145	1
01-Oct-96	35.1	20.2	3.04	18.2	37.1	3	187	2.6	158	171	1.1
15-Oct-96	35.9	22.3	3.02	20.4	41.7	3.8	210	0.25	172	182	0.95
31-Oct-96	41.2	22.2	3.18	25.1	49.9	5.1	252	0.25	207	194	1.3
average	**41**	**26**	**5**	**41**	**49.9**	**4**	**273**	**9**	**238**	**212**	**3**
June-Oct	**38.9**	**26.0**	**4.4**	**36.0**	**48.1**	**4.0**	**250.5**	**9.7**	**221.4**	**204.2**	**2.0**

Appendix I. Buffalo Data, 1996.

Parlby Creek-Buffalo Lake Water Management Project - 1996 DIVERSION DATA.

RED DEER RIVER AT PUMPHOUSE

Sampling Date	FCOL	ECOL	Cd mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Mn mg/L	Hg ug/L	Ni mg/L	Zn mg/L
03-Jun-96	68	36								
18-Jun-96	96	92	<0.0002		0.34	0.0059	0.031	<.05	0.021	0.007
03-Jul-96	34	34								
17-Jul-96	49	37	<0.0002	0.0022	0.18	0.0013	0.026	<.05	0.0025	0.008
29-Jul-96	34	34								
07-Aug-96	160	100	<0.0002	0.0048	1.38	0.0009	0.019	<.05	0.0086	0.01
22-Aug-96	6	6								
04-Sep-96	20	20	0.0026	0.0055	0.03	0.0019	0.001	<.05	0.0005	0.029
17-Sep-96	40	40								
01-Oct-96	4	4	<0.0002	0.0007	0.01	0.0003	0.001	<.05	0.0005	0.035
15-Oct-96	4	4								
31-Oct-96	2	2	<0.0002	0.003	0.01	0.0003	0.001	<.05	0.0091	0.02
average	**43.1**	**34.1**	**<0.0002**	**0.0032**	**0.33**	**0.0018**	**0.013**	**<.05**	**0.0070**	**0.018**

ALIX LAKE INFLOW

	FCOL	ECOL
03-Jun-96	64	44
18-Jun-96	76	46
03-Jul-96	49	49
17-Jul-96	11	9
29-Jul-96	17	11
07-Aug-96	11	11
20-Aug-96	51	51
04-Sep-96	20	20
17-Sep-96	46	46
01-Oct-96	8	2
15-Oct-96	4	2
31-Oct-96	4	4
average	**30**	**25**

PARLBY CREEK AT MIRROR (gauging site)

	FCOL	ECOL	Cd mg/L	Cu mg/L	Fe mg/L	Pb mg/L	Mn mg/L	Hg ug/L	Ni mg/L	Zn mg/L
09-May-96										
22-May-96	10	10								
03-Jun-96	40	40								
18-Jun-96	100	100	<0.0002	0.0018	0.21	0.0003	0.029	<.05	0.0172	0.0049
3-Jul-96	200	200								
17-Jul-96	180	130	<0.0002	0.0019	0.07	0.0006	0.018	<.05	0.0047	0.005
29-Jul-96	120	120								
07-Aug-96	40	40	<0.0002	0.0086	0.05	0.0169	0.146	<.05	0.0168	0.0284
20-Aug-96	49	26								
04-Sep-96	92	92	0.0013	0.0052	0.31	0.0005	0.03	<.05	0.0005	0.018
17-Sep-96	240	180								
01-Oct-96	28	28	<0.0002	0.0015	0.33	0.0003	0.02	<.05	0.0005	0.021
15-Oct-96	63	63								
31-Oct-96	6	6	<0.0002	0.0002	0.23	0.0003	0.014	<.05	0.0044	0.006
average	**90**	**80**								
June-Oct	**97**	**85**	**<0.0002**	**0.0032**	**0.20**	**0.0032**	**0.043**	**<.05**	**0.0074**	**0.014**

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