THE IMPACT OF AERATED SEWAGE LAGOON EFFLUENT ON WATER QUALITY IN FIELD LAKE

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EXECUTIVE SUMMARY

In 1983, the Town of Lac La Biche began using a new sewage treatment plant which discharged treated effluent to nearby Field Lake. Formerly, the effluent drained to Lac La Biche, but it was decided for health, aesthetic and environmental reasons to find a new site for disposal of the effluent. The use of Field Lake was agreed upon because few other alternatives were available, even though it was recognized that there would be an impact on this small lake.

To assess the impact, Alberta Environment sampled the water quality of Field Lake for two years before the effluent discharge began and then for four years afterwards (1981 – 1986). Occasional samples were also collected from Red Deer Creek, which drains from Field Lake to Lac La Biche. In 1997, the lake and creek were sampled again to assess their condition after a decade of receiving treated effluent.

Field Lake was eutrophic before the effluent discharge began, but it is now hypereutrophic. The additional phosphorus and nitrogen contributed by the discharge was highly stimulatory to algal populations even the first year after the discharge began (1983); chlorophyll *a* concentrations more than doubled over levels in 1981. The phosphorus concentration in the lake continued to increase through early 1987, but chlorophyll *a* concentrations appeared to have stabilized. Ten years later, in 1997, the average phosphorus concentration had doubled over the 1986 level, and the chlorophyll *a* level was also higher than in any other year. It is one of the most productive lakes ever sampled by Alberta Environmental Protection.

The effluent discharge has resulted in a dominance of blue-green algae in the lake, and dissolved oxygen levels are reduced to zero during the winter. Ammonia-nitrogen concentrations frequently exceed the Canadian Water Quality Guideline for the protection of aquatic life. Levels of fecal coliform bacteria in Field Lake did not increase, however, and even in 1997 were found to be at background concentrations. Samples collected on Red Deer Creek showed fairly high concentrations of nutrients, but data are insufficient to assess how the creek has changed since sewage effluent began discharging to Field Lake.

The sampling program conducted in Field Lake in 1997 suggests that the lake's water quality has not yet achieved a balance with its nutrient supply. As the effluent discharge continues, the lake water will increasingly resemble treated sewage effluent. If the effluent discharge were to be discontinued, the lake bottom sediments would continue to supply phosphorus to the lake water for years, perhaps for decades. Thus, the lake would continue to have blue-green algal blooms, noxious odors, depletion of dissolved oxygen and toxic levels of ammonia for the foreseeable future.

ACKNOWLEDGEMENTS

Various staff of the present Monitoring Branch collected samples during the 1981-1986 study; during 1997, Chris Ware of Monitoring Branch led the sampling effort. Samples were analyzed at the Alberta Environmental Centre in Vegreville during the early study and at EnviroTest Laboratories in 1997. Bacteriological analyses were conducted by the Provincial Laboratory of Public Health for both studies. Morna Hussey of Monitoring Branch analyzed chlorophyll *a* in Field Lake samples. Bridgette Halbig formatted the report and constructed figures. David Trew reviewed the report.

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1.0 INTRODUCTION

In the late 1970s, the Town of Lac La Biche concluded that any further municipal development would require expansion of their sewage treatment system. After discussion with Alberta Environment on possible alternatives, the Town suggested building a new facility to the south, with discharge to Field Lake rather than to Lac La Biche. The discharge to Lac La Biche had been highly controversial for health, aesthetic and environmental reasons, because the lake is used as a water supply and for swimming and boating. In addition, relocation of the sewage treatment facility allowed the release of valuable land within the town for development.

Alberta Environment viewed this alternative as a compromise, because Field Lake would be adversely impacted. Approval was given, however, because the use of Field Lake as a recipient of treated sewage effluent was deemed preferable to continued use of Lac La Biche, and no other alternative was found. It was postulated that Field Lake would remove a large percentage of nutrients and other substances in the effluent.

The effluent discharge was expected to begin in spring 1983. The former Water Quality Control Branch of Alberta Environment began a monitoring program on Field Lake and its outlet creek in March 1981, which continued through 1986. Thus, two years of data were collected to establish baseline conditions in the lake, and then there were four years of data collected after effluent discharge began. The purpose of this program was to assess the impact of the treated sewage effluent on Field Lake. The expected impact was primarily that of eutrophication: high nutrient levels and abundant growth of algae and macrophytes (weeds), with a higher risk of mortality of fish and other organisms in the lake due to deoxygenation and toxic ammonia.

In 1997, the Water Sciences Branch of Alberta Environmental Protection conducted a subsequent sampling program on Field Lake during the summer to assess changes in water quality that may have occurred over the decade since the first sampling program terminated in 1986.

Field Lake was eutrophic before the effluent began entering the lake in 1983. It had summer algal blooms and extremely low or no oxygen in late winter. It was somewhat less productive than Lac La Biche, but more productive than several other lakes in the area, such as Beaver, Skeleton and North Buck lakes. As a result of the effluent, the lake is now one of the most productive ever sampled by Alberta Environmental Protection.

This report summarizes the information gathered on the water quality of Field Lake during the initial period of study (1981 - 1986) and from three sets of samples collected during the summer of 1997. The impact of the effluent discharge is assessed by comparing 1) water quality two years before and four years after the discharge began, 2) concentrations of substances in the lake water with relevant Alberta and Canadian water quality guidelines, and 3) 1985-86 data with 1997 data.

2.0 BACKGROUND

Field Lake is located about five kilometers south of the town of Lac La Biche and only 250 m north of the Beaver River (Figure 1). Despite the Beaver River's proximity to Field Lake, the normal outlet of the lake is at its opposite end. According to local residents, the lake has overflowed to the Beaver River during periods of high water, although a pipeline and a road between the lake and the river may now restrict overflow.

A hydrographic survey of Field Lake was conducted in 1986 (Figure 2). Field Lake is small and very shallow (Table 1). The surrounding watershed is 12 times larger than the lake area; this ratio is typical of many central Alberta lakes. The largest inlet creek is the intermittent stream that flows from the small lake to the west, known locally as McCarthy Lake. Field Lake has no public access in summer, and the shoreline is marshy at the north and south ends. Aquatic vegetation grows along the entire shoreline.

The sewage treatment plant, located north of the lake, is a three-cell aerated lagoon with a continuous discharge of approximately 2000 m^3/day (0.023 m^3/s). Because the discharge line enters the lake very close to the natural lake outlet, the town was required to install a diffuser line down the center of the lake to disperse the effluent and allow for some processing before it enters the outlet. Initially there were problems with gas buildup in the diffuser line, which lifted to the surface in places. This problem has been alleviated.

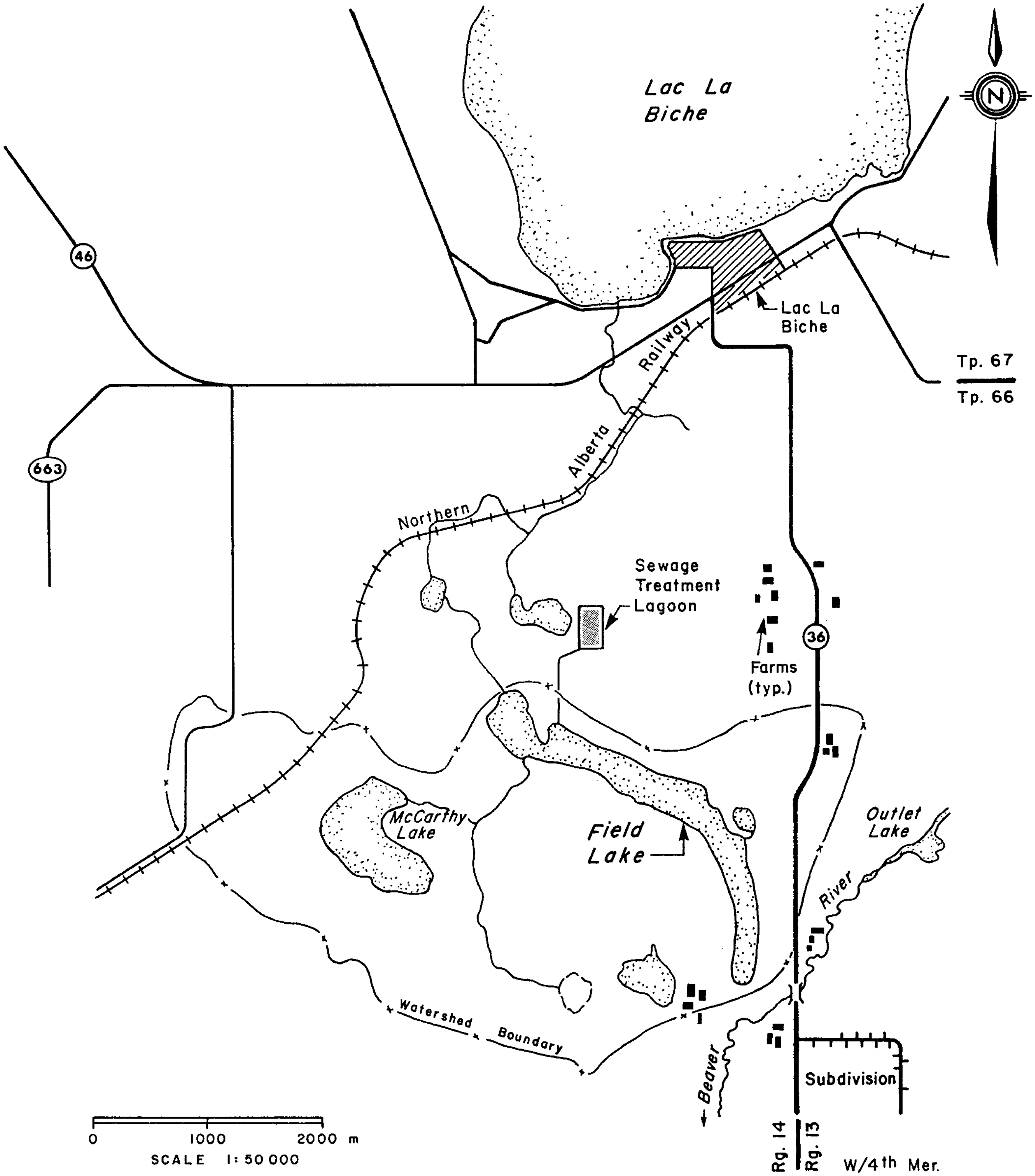

Figure 1. Field Lake Location Map

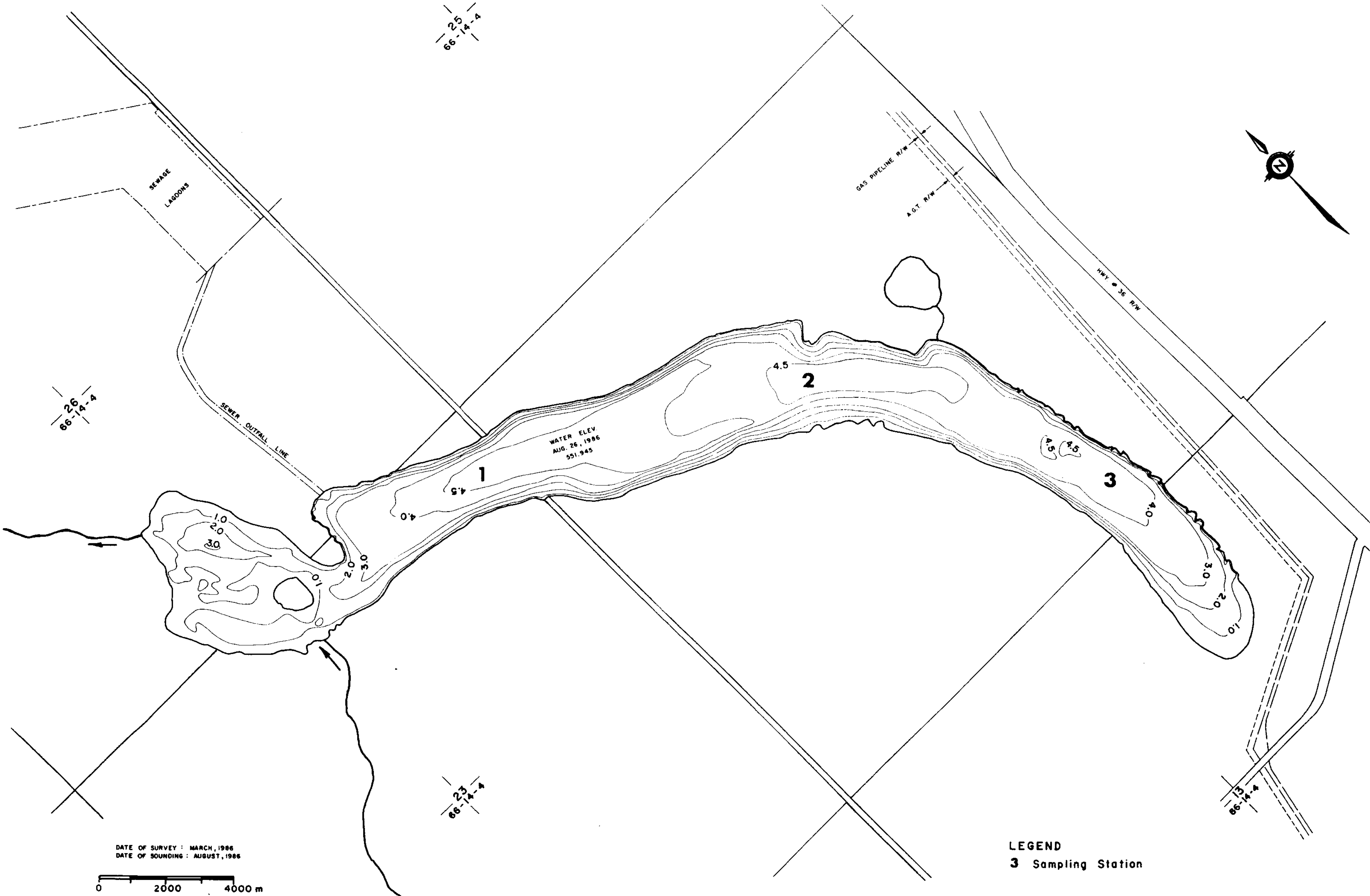

Figure 2. FIELD LAKE
HYDROGRAPHIC SURVEY

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Table 1. Hydrological characteristics of Field Lake.	
Elevation in August 1986 (date of sounding)	551.945 m
Watershed Area, excluding lake	11.89 km^2
Lake Area	0.98 km^2
Lake Volume	2.9 million m^3
Maximum Depth	4.5 m
Mean Depth	3 m

3.0 METHODS

From 1981 through 1986, Field Lake was sampled approximately monthly during the period of open water. Sampling was also conducted in late winter most years. At each of three sites (Figure 2), grab samples from depths of 1 m, 2 m and 3 m were combined into one sample for chemical analyses and for phytoplankton biomass estimates. In addition, whole-lake composite samples were collected monthly during the last two years of the study. Dissolved oxygen, specific conductance, temperature and pH were measured with HydroLab equipment at one-metre intervals from the lake surface to the bottom at each site. Table 2 lists variables measured during the study.

For the 1997 study, samples were collected on three occasions only: June, July and early September. On each sampling trip, a euphotic composite was collected from the whole lake, as occurred in 1985 and 1986. Grab samples were also collected from the north and south ends of the lake on the September sampling trip. As in the previous study, field variables were measured with HydroLab equipment at one-metre depth intervals.

Water chemistry samples were analyzed at the Alberta Environmental Centre in Vegreville or at EnviroTest Laboratories; total phosphorus and chlorophyll *a* were analyzed at McIntyre Centre, the Water Management Division field facility. Bacteriological samples were analyzed at the Provincial Laboratory of Public Health.

Table 2. Variables measured during the Field Lake impact assessment study, 1981-1986 and 1997.

VARIABLE	WHEN MEASURED
Depth	all years
Temperature	all years
Dissolved Oxygen	all years
PH	all years
Conductivity	all years
Calcium	all years
Magnesium	all years
Hardness	all years
Sodium	all years
Potassium	all years
Chloride	all years
Fluoride	all years
Carbonate	all years
Bicarbonate	all years
Alkalinity	all years
Sulfate	all years
Iron	all years
Total Dissolved Solids	all years
Total Phosphorus	all years
Dissolved Phosphorus	all years
Ammonia-Nitrogen	all years
Nitrate + Nitrite – N	all years
Total Kjeldahl Nitrogen	all years
Silica	all years
Dissolved Organic Carbon	all years
Chlorophyll *a*	all years
Fecal Coliform Bacteria	all years
Escherichia Coli	1997 only
Phytoplankton	1981-1986 only
BOD	1986 and 1997 only
Phenols	1986 and 1997 only

4.0 RESULTS AND DISCUSSION

4.1 TROPHIC STATUS

Compared with most surface waters, sewage effluent contains high concentrations of plant nutrients such as phosphorus and nitrogen. The expected impact of such an effluent on a lake is an abundant growth of algae and shoreline vegetation (macrophytes). Phosphorus is usually a limiting nutrient for aquatic plants, especially for the suspended algae, or phytoplankton. This means that the size of the aquatic plant population is directly related to the availability of phosphorus, and if the phosphorus supply should increase, the amount of algae in the lake will increase as well. However, if the nutrient supply is large enough, phosphorus may be so plentiful that it is no longer limiting, and some other factor, usually light, limits the population.

In Field Lake, the impact of the Lac La Biche treated effluent has been eutrophication – an increase in nutrient levels and algal biomass. The impact was observed the first summer of the effluent discharge (Figure 3). The additional phosphorus and nitrogen contributed by the discharge was highly stimulatory to algal populations in the lake in 1983; chlorophyll *a* concentrations more than doubled over levels in 1981. The phosphorus concentration in the lake continued to increase through early 1987, but chlorophyll *a* levels appeared to stabilize. Ten years later, in 1997, the average phosphorus concentration had doubled over the 1986 level. The chlorophyll *a* concentration was also higher in 1997 than in any other year studied, but the increase was not proportional to the increase in phosphorus. It is likely that light or other nutrients are now limiting the algal population in the lake.

Loading estimates for phosphorus and nitrogen are presented in Table 3. The estimated load before the start-up of the sewage treatment plant is based on rates of nutrient export from the land or the atmosphere, as measured on other lakes in Alberta. These rates provide a reasonably good estimate of nutrient input to the lake, even though the natural loading was not measured.

The number of cattle along the shore of Field Lake is not known, and therefore an estimate for nutrient input from this source is not included in the table. Cattle on lakeshores can have serious water quality impacts, but it is likely that the impact of sewage effluent is much greater in Field Lake. Phosphorus and nitrogen input is 10 times higher than it was before the effluent discharge began.

It was anticipated that as the trophic state of Field Lake changed, the size and composition of the phytoplankton community also would change. Data are available for the year before the discharge began and years through 1986. The total average biomass (average from the three sites) increased approximately 3-fold; this increase is statistically significant for each post-discharge year except 1985 (Wilcoxon's signed rank test, $P < 0.01 – 0.001$, n =

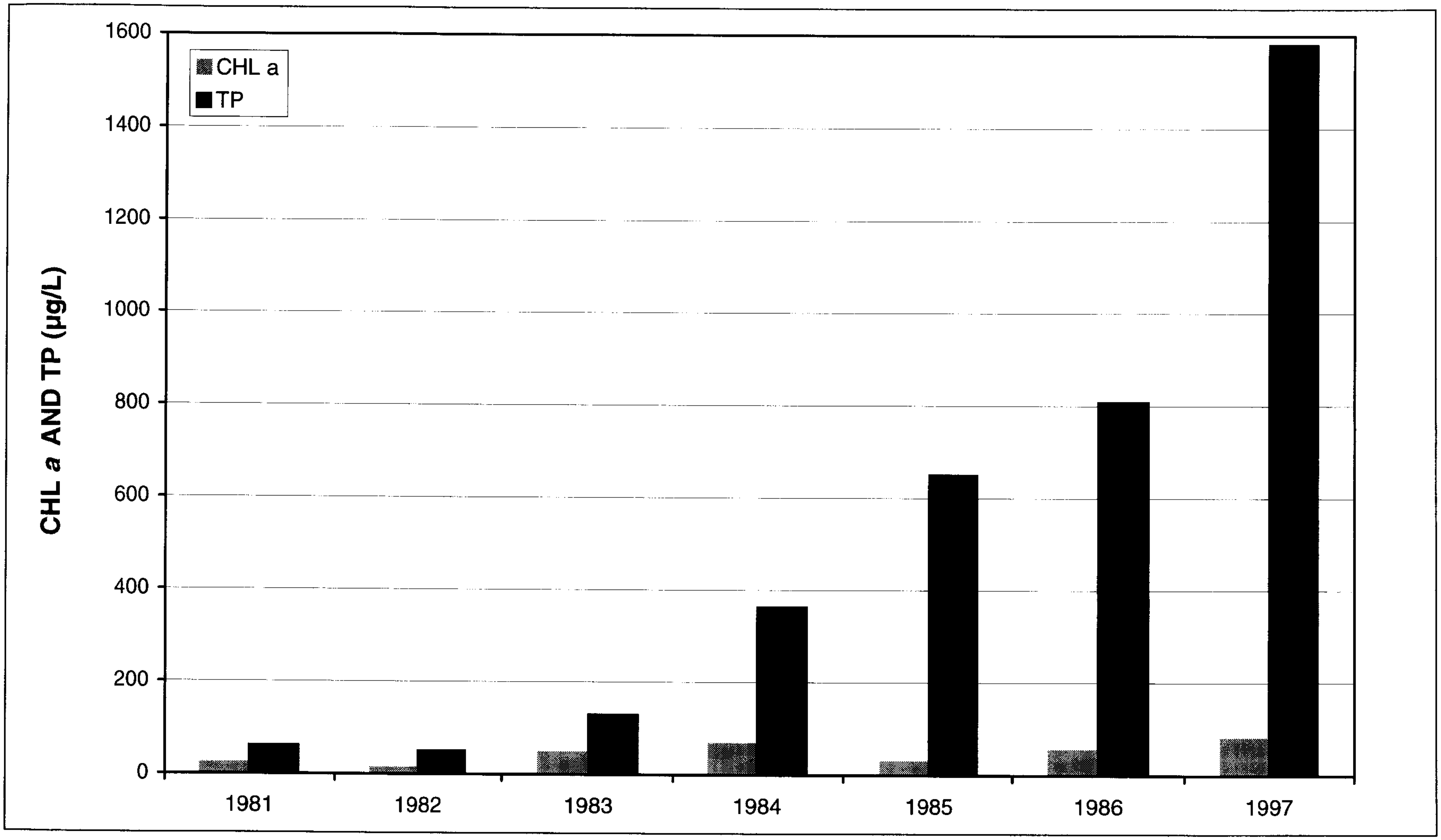

Figure 3. Average concentrations of chlorophyll *a* and total phosphorus in Field Lake, May-September, 1981-1997.

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Table 3. Annual loading of phosphorus and nitrogen to Field Lake before and after sewage effluent discharge. "After" is based on information obtained in 1997. Loads in kg/year.

SOURCE	BEFORE		AFTER	
	PHOS.	NITRO.	PHOS.	NITRO.
Watershed[1]	134	1066	134	1066
From McCarthy Lake[1]	15	155	15	155
Atmospheric Deposition[1]	21	453	21	453
Sewage Effluent[2]	0	0	3161	19882
Total	300	2174	3331	21556

1. Based on coefficients developed for Lake Wabamun (Mitchell 1985).
2. Load calculated from approximate flow volume (1997) and measured concentrations of phosphorus and nitrogen in effluent (1993-94).

approximately 7 per site per year). In 1985, the average chlorophyll and phytoplankton biomass were low compared with that of other post-discharge years, largely because the early summer biomass (June and July) was low. The water was very clear at that time (the Secchi depth was near the bottom of the lake, about 4 m). The zooplankter *Daphnia* was particularly abundant in the lake during this period; it probably grazed down the algae, reducing chlorophyll *a* levels and increasing transparency.

An important difference between the phytoplankton populations present in 1982 and in post-diversion years was the large increase in biomass of blue-green algae (Cyanophyta) after 1983. This is illustrated in Figure 4. In 1982, the dominant species of blue-green algae was *Oscillatoria limnetica,* whereas in 1983, the dominant blue-greens were species typical of highly eutrophic lakes in summer: *Aphanizomenon flos-aquae, Microcystis aeruginosa* and *Anabaena flos-aquae.* These species were not usually present in 1982 samples, and they never made up more than 7% of the total biomass on any sampling date in 1982. A shift to a greater proportion blue-green algae is a further indication of the increase in fertility in Field Lake.

Diatoms (Bacillariophyta) also may have increased in dominance in Field Lake. These algae tend to have the largest populations in spring and fall when the water is cool, so the short sampling season in 1982 missed the largest populations if they were present. Even in May 1983, however, before the start-up of the effluent discharge, diatoms comprised less than 4% of the total biomass. In May 1986, they comprised over 55% of the total biomass. *Cyclotella*

Figure 4. Biomass of phytoplankton groups at Field Lake site 1 before (1982) and after (1986) sewage effluent discharge.

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glomerata and *C. meneghiniana,* the dominant diatoms in the spring and fall 1984-1986, were not recorded at all in 1982 or 1983.

4.2 DISSOLVED OXYGEN

Dissolved oxygen profiles were measured in March 1981 and 1982, and on several occasions during the summers of 1981 and 1982, before the effluent discharge began. Figure 5 shows data for 1981 and 1986, the final year of sampling for the early study. Dissolved oxygen concentrations were high in Field Lake in late March 1981, but it is likely that lower concentrations would have been measured earlier in the winter. In March 1982, the lake was completely anoxic. Because of the disparity of these background data, it is not possible to determine whether the rate of winter oxygen depletion has been affected by the effluent discharge, but it is likely that it has. On most winter sampling trips between 1983 and 1987, the lake was completely anoxic. In 1986, concentrations were above zero on the first sampling trip (January), but the lake was anoxic at all sites on the next sampling trip, in late February.

In the summers of 1981 and 1982, dissolved oxygen concentrations were high throughout the water column on each sampling trip. After the effluent discharge began in 1983, and for each year afterward, levels of dissolved oxygen approached zero near the bottom when temperatures were high (Figure 5). This occurred even when there was no apparent thermal stratification. The lake water was supersaturated with oxygen in spring and fall 1986. The fall data were confirmed with Winkler titrations. On both spring and fall sampling trips, chlorophyll *a* levels exceeded 100 µg/L, suggesting intense generation of oxygen from photosynthetic activity. In summer 1997, conditions were similar to those in previous years, with supersaturation of oxygen at the lake surface, and low concentrations near the bottom.

4.3 AMMONIA

Ammonia is a form of nitrogen that is toxic to fish in its un-ionized form, especially at high pH and temperature. Sewage effluent generally has high concentrations of ammonia, so it was expected that levels would increase in Field Lake. Table 4 shows the percentage of samples not complying with the Canadian Water Quality Guideline for the protection of aquatic life (CCREM 1987), and the mean and ranges of values for each year sampled. Note that all

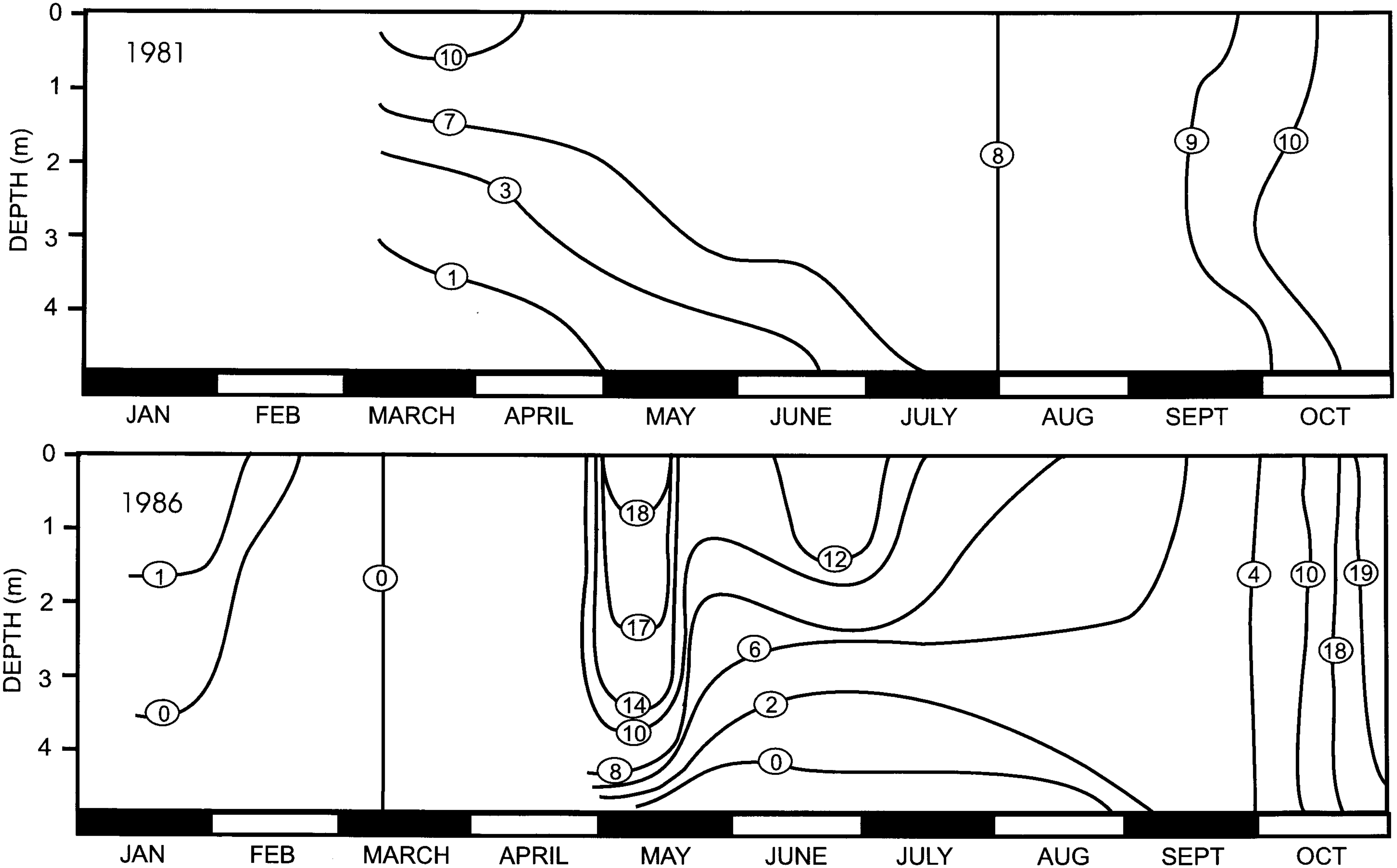

Figure 5. Dissolved oxygen (mg/L) in Field Lake before (1981) and after (1986) sewage effluent discharge began. Average values for three sites.

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Table 4. Percentage of samples collected on Field Lake in which total ammonia (NH_3) exceeded the Canadian Water Quality Guideline for protection of aquatic life. Concentrations in mg/L. Mean and range values are for three sites or composite sample, all dates.

	PERCENTAGE NON-COMPLIANCE	NUMBER OF SAMPLES	MEAN VALUE	RANGE
1981	0	15	0.058	0.030 – 0.135
1982	0	15	0.856	0.028 – 2.10
1983	46	24	0.747	0.018 – 3.79
1984	18	17	0.317	0.014 – 1.85
1985	42	24	1.020	0.187 – 2.54
1986	30	30	0.708	0.022 – 3.94
1997	33	3	0.450	0.048 – 1.25

samples complied in 1981 and 1982, although the samples collected in October 1982 were very close to the guideline value for the pH and temperature measured on that day. As well, samples collected in spring 1983, before the effluent discharge began, had ammonia concentrations that exceeded the Canadian Water Quality Guideline. When pH and temperature are high, as occurs in mid-summer, there is an increased probability that toxic ammonia levels could be high enough to harm aquatic life.

In the fall of 1985, water samples from Field Lake were tested for toxicity to forage fish (fathead minnows) using standard bioassay techniques (Heming 1985). A solution of 10% effluent in Field Lake water and 100% lake water were tested. The control was laboratory water. The initial level of ammonia in the 10% effluent solution was 0.022 mg/L. No dead fish were observed in any of the three test solutions (control, 100% Field Lake, 10% effluent in Field Lake water). It is likely that if the test were run in early spring or midsummer, when toxic levels of ammonia in the lake tend to be highest, mortality would have been higher.

The 1997 data fall into the ranges of data collected during the previous study, and there does not seem to be an increase in ammonia concentrations over the 10-year period since the lake was last sampled. However, fewer samples were collected in 1997, and samples were not collected during the late winter-early spring period when excursions occurred formerly.

4.4 BACTERIA

Another concern arising from sewage effluent discharge to Field Lake is the possibility of pathogenic bacteria in the lake. This would only be a concern to recreational users, because the lake water is not used as a drinking water supply. Fecal coliform bacteria and the fecal organism *Escherichia coli* are used as indicators of fecal contamination by warm-blooded animals and humans. Table 5 presents data for fecal coliform bacteria in samples collected throughout the study from Field Lake and Red Deer Creek at Lac La Biche. The numbers of indicator bacteria were low or undetectable in most samples. The only time that fecal coliform bacteria were high was in the winter of 1986, when it was known that sewage effluent was accumulating at Site 1 because the diffuser system was not working. The low temperatures in winter allow bacterial populations to remain alive for relatively long periods, whereas in summer these bacteria are short-lived.

A few samples were collected from Red Deer Creek at the outlet of Field Lake and at the point of its entrance into Lac La Biche. As the data in Table 5 indicate, counts of bacteria in summer samples were considerably higher than in Field Lake. It is not possible to distinguish bacteria originating in the sewage effluent from those coming from cattle, wildlife or waterfowl inhabiting the drainage basin between Field Lake and Lac La Biche. The possibility that bacteria in sewage would survive long enough to pass along the creek to its mouth is highly unlikely during the high temperatures of July and August. The levels of fecal coliform bacteria measured in these samples are not particularly high, although several would exceed the Alberta interim guideline level for contact recreation of 200 counts per 100 mL (based on the geometric mean of five samples collected within a 30-day period). The range for the 1997 samples falls into the ranges for the earlier study, suggesting that levels of bacteria have not increased in the creek over the 10-year period. Additional samples collected at other times of the year would be needed to confirm this, however.

4.5 OTHER VARIABLES OF CONCERN

Metals, phenols and other constituents were analyzed in samples from Field Lake on four occasions in 1985 and 1986. Table 6 lists the mean value, range and the guideline value for each substance for the three sites and four dates. Phenols concentrations were relatively high in

Table 5. Fecal coliform bacteria in Field Lake and Red Deer Creek, 1985-86 and 1997. Units are counts/100 mL sample.

FIELD LAKE	SITE 1	SITE 2	SITE 3
June 5, 1985	10	10	10
July 3, 1985	0	0	0
July 25, 1985	2	0	2
August 27, 1985	10	10	10
September 24, 1985	10	10	
January 14, 1986	6	0	0
February 24, 1986	700	<10	<10
March 10, 1986	5300	120	<10
May 7, 1986	<10	<10	<10
May 29, 1986	4	0	0
July 23, 1986	<10	<10	10
August 21, 1986	<10	<10	<10
September 17, 1986	<10	<10	10
October 22, 1986	<10	<10	<10
June 26, 1997		<4	
July 31, 1997		4	
September 9, 1997	<4	4	4
RED DEER CREEK	**AT FIELD LAKE OUTLET**	**AT LAC LA BICHE**	
November 6, 1985	20	16	
April 16, 1986	0	0	
April 23, 1986	<10	<10	
April 30, 1986	<10	<10	
May 7, 1986	<10	<10	
May 29, 1986		49	
June 25, 1986	290	140	
July 24, 1986		100	
August 19, 1986	250		
August 28, 1986	600	500	
September 24, 1986	64		
September 9, 1997		270	
October 30, 1997		6	

Table 6. Metals and other substances analyzed in samples collected from Field Lake, 27 August 1985, 14 January 1986, 24 February 1986 and 21 August 1986. Mean and range is for all sites and dates. Units are mg/L unless indicated otherwise.

SUBSTANCE	MEAN	RANGE	GUIDELINE*	COMPLIANCE	NO. SAMPLES
Aluminum	0.025	<0.02 – 0.052	0.100	100%	12
Arsenic	0.0012	0.0009 – 0.0015	0.050	100%	12
BOD	4.25	1 – 9.3	n.a.		9
Cadmium	0.002	<0.001 – 0.009	0.0018	66%	12
Chromium	0.003	<0.001 – 0.004	0.002	25%	12
Copper	0.001	<0.001 – 0.002	0.004	100%	12
Lead	<0.003	<0.003	0.007	100%	12
Mercury	<0.0001	<0.0001 – 0.0002	0.0001	92%	9
Nickel	0.006	<0.001 – 0.009	0.110	100%	12
Phenols	0.012	0.005 – 0.014	0.001	0%	12
Zinc	0.002	<0.001 – 0.007	0.030	100%	12

*Canadian Water Quality Guidelines for the protection of aquatic life (CCREM 1987)

Field Lake, but are well below the level that might be toxic to aquatic life; the guideline given in Table 6 was established to prevent the tainting of fish flesh. Many phenolic compounds occur naturally, so it is not possible to determine if the source is the sewage effluent. Phenols data from before the onset of the discharge are not available.

Most of the metals data meet Canadian Water Quality Guidelines, although levels of chromium and cadmium were sometimes above their respective guideline concentration. The guideline value used for chromium (0.002 mg/L) is one for protecting the aquatic community rather than for fish; the guideline for protection of fish is 0.020 mg/L. This level was never reached in samples from Field Lake. A few samples had concentrations of cadmium that exceeded the old Canadian Water Quality Guideline for the protection of aquatic life, but it is likely that most samples would exceed the new guideline (1996) of 0.00006 mg/L. The data could not be compared with this level because analytical methods during the mid-1980s were not able to attain such low concentrations. A possible result of high cadmium levels is reproductive impairment of zooplankton such as Daphnia.

Field Lake is not used as a drinking water supply, nor does it support a sport fishery. However, livestock belonging to local farmers have access to Field Lake, and there are horses and cattle along the creek between the lakes. In the 1980s, the farmers expressed concern that the lake and creek were unfit for watering their livestock. In December 1985 and March 1986, the Veterinary Toxicology Laboratory of Alberta Agriculture conducted tests for organisms causing livestock disease on water collected from Field Lake and from the outlet creek. Although there were no organisms identified which would positively cause disease in livestock, the very rich growth of bacteria was considered to be potentially detrimental. Other constituents in the water, including major ions, toxic substances and other inorganic chemicals are well within the guidelines for livestock watering listed in the Canadian Water Quality Guidelines (CCREM 1987). Blue-green algae could be a problem if toxic strains develop; this has occurred rarely in a few lakes in the province, but has not been tested in Field Lake.

5.0 DISCUSSION AND CONCLUSIONS

The sewage effluent from the town of Lac La Biche lagoons has had a major impact on the water quality of Field Lake. Even at the end of the first study, four years after effluent discharge began, the average phosphorus concentration was 14 times higher than was measured before the discharge began. In 1997, the average concentration was 28 times higher than before the discharge, with concentrations similar to dilute treated sewage effluent. Nitrogen fractions show much less change; the average total nitrogen concentration doubled between 1980-81 and 1997. It is likely that nitrogen is continually being lost from the system via sedimentation and denitrification. Phosphorus also is lost to the sediments, but a portion would be returned to the water column each summer through sediment release.

Chlorophyll *a* concentrations have also increased in Field Lake, but not to the extent that would be expected based on phosphorus levels. The lake has moved from eutrophic to hypereutrophic, based on both chlorophyll *a* and phosphorus concentrations. With the increase in algal biomass, there was a shift in the species composition of the phytoplankton to a dominance by blue-green algae.

Game fish would not have overwintered in Field Lake most years before the effluent discharge began because of oxygen depletion. Since 1983, however, other species such as minnows have probably been affected as well, based on field observations during the first study. An additional factor related to fish production is the increase in levels of un-ionized ammonia during periods of high temperature and pH.

When the effluent discharge began, there was public concern that sewage effluent was getting into Lac La Biche via Red Deer Creek. However, before 1983 this effluent went directly into Lac La Biche without benefit of treatment by the marshes and creeks between Field Lake and Lac La Biche. One requirement imposed by Alberta Environment on the Town was to install a diffuser line at the end of the discharge pipe. The purpose of this line was to disperse the effluent throughout the lake, allowing assimilation of nutrients and reduction of organic matter and bacteria. It was expected that the lake would complete the treatment process, rendering the effluent harmless except for higher nutrient levels. During the first years of the discharge, there were problems with diffuser line, so that the sewage effluent short-circuited into Red Deer Creek via the lake outlet. This problem has since been fixed. The impact on Lac La Biche is much reduced over the former sewage treatment system, and would not be measurable in Lac La Biche as a whole.

Another concern mentioned was the health risk associated with canoeing on Field Lake. Based on the three years of coliform data (1985-86 and 1997), there appears to be little risk. Fecal coliform counts were generally lower than levels considered to be background in surface waters.

There appears to be a concern with respect to cattle drinking Field Lake water at the discharge pipe or in the outlet, because it was shown in the early study that heterotrophic bacterial levels were high. It is not known whether this is still true now that the diffuser line is functioning properly.

A very real problem to local residents was noxious odors along the shore. Properly functioning aerated sewage lagoons are usually odor-free, so there is no reason to assume that sewage effluent was the direct cause. Field Lake has very high amounts of organic matter; odors are possible during decomposition under anaerobic conditions. As well, odors are often generated during the collapse and decomposition of blue-green algal blooms, as residents of Lac La Biche are probably aware. There is no practical solution to the problem.

Conditions in Field Lake will achieve a balance with the annual input of nutrients, but this does not appear to have occurred as of 1997. The nutrient supply in the lake is likely in excess for the needs of growing plants, so that other factors such as light become limiting. This means that the increase in the amount of algae in the lake is leveling off, even though phosphorus concentrations continue to increase.

The use of Field Lake as a recipient of Lac La Biche treated sewage effluent was deemed the best alternative for disposing of this wastewater, and the treatment facility is complying with the required best practicable technology. Alternatives to the present system have been considered, but most involve some discharge to a receiving water, that is, Lac La Biche, the Beaver River or natural ponds and sloughs.

If an alternative to the present system is found, or the nutrient supply to Field Lake decreased, there would likely be no effect on algal biomass until phosphorus again becomes the limiting nutrient. Because the sediments are being loaded, there is a strong possibility that the lake would remain hypereutrophic for many years, even without the effluent discharge.

6.0 LITERATURE CITED

Alberta Environmental Protection. 1993. Alberta Surface Water Quality Interim Guidelines.

Canadian Council of Resource and Environment Ministers (CCREM). 1987. Canadian Water Quality Guidelines. CCREM Task Force on Water Quality Guidelines. Environment Canada, Ottawa.

Heming, T.A. 1985. Acute toxicity of fathead minnows (*Pimephales promelas*) of a dilute municipal sewage. Internal Report. Aquatic Toxicology Section, Alberta Environmental Centre. 3 p.

Mitchell, P. 1985. Preservation of water quality in Lake Wabamun. Water Quality Control Branch, Alberta Environment. 26 p.

Spink, D. 1985. Effluent upgrading and disposal alternatives for Lac La Biche sewage treatment plant. Internal Report. Standards and Approvals Division, Alberta Environment. 5 p. + Tables.

Appendix 1. Field Lake and Red Deer Creek data.

FIELD LAKE 1997

Variable	26-Jun-97 Comp.	26-Jun-97 Bottom	31-Jul-97 Comp.	31-Jul-97 Bottom	9-Sep-97 Comp	9-Sep-97 Bottom S	9-Sep-97 Bottom N	Average
Secchi Depth, m	4.5		0.6		0.3			1.8
Ammonia-N, mg/L	1.25	1.4	0.048	0.099	0.051	0.126	0.086	0.450
TKN, mg/L	3.3		4.08		4.27			3.88
NO2+NO3, mg/L	0.409		0.024		0.456			0.296
Total Phosphorus, mg/L	1.447	3.54		1.87	1.71	2.00	2.09	1.58
Total Diss. P, mg/L	0.182				1.64			0.91
Chlorophyll *a* , ug/L	4		151		82.8			79.27
Fecal Coliforms, cts/100	<4		4		4	<4	4	4.00
E.coli, cts/100	<4		4		4	<4		4.00
DOC, mg/L	20		22		20			20.67
BOD, mg/L					7			
Bicarbonate, mg/L	322		260		281			288
Chloride	51.6		51.4		54.5			52.5
Carbonate	<5		34		20			27
Conductivity	748		713		760			740
Fluoride	0.6		0.58		0.65			0.61
Hardness	247		254		240			247
Calcium	56.4		57.5		54.7			56.2
Iron	0.021		0.031		0.018			0.023
Potassium	10.4		10.2		9.7			10.1
Magnesium	25.7		26.7		25.2			25.9
Sodium	72		68		65			68
Sulphate	70.2		73.4		71.5			71.7
NitrateNitrite	0.409		0.024		0.456			0.296
pH	8		9		8.8			8.6
Silica	7.9		12.4		14.4			11.6
Total Alkalinity	264		261		263			263
TDS (Calc.)	444		444		438			442
TSS	4		26		29			20

FIELD LAKE HISTORICAL DATA

Average May-Sept. for three sites, or comp	1981	1982	1983	1984	1985	1986	1997	
Total Phosphorus, mg/L	0.061	0.05	0.129	0.363	0.65	0.807	1.58	
Dissolved Phosphorus	0.015	0.026	0.049	0.222	0.596	0.736	0.91	
Chlorophyll *a* , mg/m3	22.3	12.6	46.7	66.7	28.9	54	79	
Secchi Depth, m							1.8	
Ammonia N, mg/L	0.043	0.368	0.398	0.192	1.074	0.363	0.45	
Total Kjeldahl Nitrogen	2.07	1.96	2.68	2.95	3.05	3.01	3.88	
NO2 + NO3 - N	*0.025*	0.003	0.062	0.043	0.182	0.028	0.296	
Total Nitrogen, mg/L	2.095	1.963	2.742	2.993	3.232	3.038	4.176	
BOD, mg/L						7.8	7	
DOC, mg/L	23	20.4	22.5	24.2	22.5	22		
TDS, mg/L		379	407	390	402	424	442	
TSS, mg/L	6.8	7	8.9	13.3	5.8			
Sodium	58	63	71	65	66	69	68	
Fecal Coliform Bacteria					6	9	4	

RED DEER CREEK 1997

Variable	9-Sep-97	30-Oct-97
TSS, mg/L	5	<2
Ammonia-N, mg/L	0.529	0.048
TKN, mg/L	1.98	2.16
NO2+NO3, mg/L	<0.006	0.011
Total P, mg/L	1.41	0.778
Tot. Diss. P, mg/L	1.34	0.778
Fecal Coliforms, cts/100	270	6
E.coli, cts/100	190	4
DOC, mg/L	23	30
BOD, mg/L	8	5