EFFECT OF FIELD LAKE OUTFLOW ON WATER QUALITY IN RED DEER BROOK

Prepared by:

Patricia Mitchell, M.Sc., P.Biol.

Water Sciences Branch
Water Management Division
Natural Resources Service
Alberta Environment

March, 2000

W0002

Pub. No: T/713
ISBN: 0-7785-3028-0 (Printed Edition)
ISBN: 0-7785-3029-9 (On-Line Edition)
Web Site: http://www3.gov.ab.ca/env/info/infocentre/publist.cfm

Any comments, questions, or suggestions regarding the content of this document may be directed to:

Environmental Monitoring and Evaluation Branch
Alberta Environment
10th Floor, Oxbridge Place
9820 – 106th Street
Edmonton, Alberta T5K 2J6
Phone: (780) 427-6277
Fax: (780) 422-6712

Additional copies of this document may be obtained by contacting:

Information Centre
Alberta Environment
Main Floor, Great West Life Building
9920 – 108th Street
Edmonton, Alberta T5K 2M4
Phone: (780) 944-0313
Fax: (780) 427-4407
Email: env.infocent@gov.ab.ca

EXECUTIVE SUMMARY

Since 1983, treated sewage effluent from the Town of Lac La Biche has discharged to Field Lake, a small shallow eutrophic lake south of the town. The lake outflow, called Red Deer Brook, flows into Lac La Biche. In 1997, Alberta Environment recognized that there was little information on the water quality of Red Deer Brook, especially with respect to spawning of Northern Pike in spring. In 1998, Alberta Environment began a spring sampling program to answer some of the questions raised by department staff and officials of the Town of Lac La Biche. The main question was whether Red Deer Brook has been adversely affected by outflow from Field Lake. The focus of the study was on nutrients, ammonia-nitrogen and dissolved oxygen, all of which could directly or indirectly affect fish spawning in the lower portions of the creek.

Four sites between the outflow from Field Lake and the mouth at Lac La Biche were sampled during spring runoff in 1998 and 1999. Conditions in the creek before and after the commencement of sewage discharge to Field Lake were estimated by calculating: 1) the potential contribution of nutrients to Red Deer Brook from Field Lake, 2) the theoretical natural supply of nutrients from the Red Deer Brook watershed. The results were then compared with actual water quality measurements in the creek.

The volume of spring runoff was higher in 1998 than 1999, but flow in the creek was more erratic in 1998. It was likely that flow out of Field Lake reached Lac La Biche in 1999, but it was not clear that it did in 1998. Spring runoff was approximately 30% of long-term average runoff in 1998 and 10% of average in 1999, based on a reference hydrometric station on Pine Creek west of Lac La Biche.

Phosphorus and nitrogen concentrations at all creek sites were comparable to those from Alberta streams draining areas of high agricultural intensity. Mass loads were higher in 1998 than in 1999, mainly because the flow volume in the creek was higher in 1998. The highest loads were at the site farthest downstream (“Mouth”). The largest source of nutrients to the creek during the two study years was Field Lake.

The natural or background supply of nutrients from the Red Deer Brook watershed without the Field Lake outflow was estimated with phosphorus and nitrogen export coefficients developed from other studies on Alberta creeks. The estimated supply was found to be higher than the measured present supply, which includes Field Lake outflow. This indicates that the natural supply from the creek during the study years was very low. This probably reflects the low runoff for the two years, or there may be substantial biological processing or retention in the creek before it reaches Lac La Biche.

Even with the outflow from Field Lake, the impact of Red Deer Brook on Lac La Biche as a whole is likely negligible, because the measured nutrient load from Red Deer Brook was very small compared with the natural load from the Lac La Biche watershed. This would probably be true even for years with high runoff.

Ammonia-nitrogen and dissolved oxygen concentrations in the upper reaches of Red Deer Brook often did not meet pertinent water quality guidelines for the protection of aquatic life. The highest ammonia-nitrogen concentrations and lowest dissolved oxygen levels occurred in early spring. In the lower reaches, all but one ammonia-nitrogen concentration met the guideline level, and data collected at the Mouth site in other years indicated very low concentrations. Dissolved oxygen concentrations were low at the Mouth site in spring 1998 as the marsh above the site drained. For most years, pike probably would not be adversely affected by high ammonia and low dissolved oxygen levels because, based on existing data, concentrations are suitable by the time pike move into the creek. Confirmation of this would require study of spawning areas at the time pike are in the creek, especially during higher runoff years.

ACKNOWLEDGEMENTS

Chris Ware and other staff of Monitoring Branch conducted the water quality and flow sampling program on Red Deer Brook. Chemical analyses were conducted at EnviroTest Labs, quality assurance samples by Alberta Research Council at Vegreville, and bacteriological analyses by the Provincial Laboratory of Public Health. Bridgette Halbig produced the graphs and formatted the report. David Trew, Anne-Marie Anderson and Asoke Weerasinghe reviewed the manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Effect of Field Lake Outflow on
Water Quality in Red Deer Brook

1.0 INTRODUCTION

The Town of Lac La Biche (population 2611) developed a new sewage lagoon in the early 1980s. The Town decided to discontinue the former discharge to Lac La Biche by relocating the facility further south, with discharge to a nearby water body called Field Lake. Field Lake drains north to Lac La Biche via a small creek, Red Deer Brook. When the water level in the lake is high, it can drain south to the Beaver River, but this rarely occurs. Although Alberta Environment approved the facility, it was viewed as a compromise because it was expected that Field Lake would be negatively affected. There were no other practical alternatives, however, and discharge to Field Lake seemed preferable to discharging to Lac La Biche, which is used as a water supply and for recreation. Sewage treatment consists of a three-cell aerated lagoon with a continuous discharge. The discharge to Field Lake began in 1983, and Alberta Environment conducted a water quality monitoring program on the lake before and after its commencement (Mitchell 1998).

It was speculated that Field Lake would remove a large percentage of nutrients and other substances contributed by the effluent, so that the water entering Red Deer Brook would be of relatively good quality. A diffuser line was installed down the centre of the lake to enhance biological processing of the effluent in the lake before it entered the creek. It was also thought that there would be further processing and dilution along the creek on its way to Lac La Biche. Although Red Deer Brook was not sampled along its length during the first study, a few samples were collected in 1986 near the Field Lake outflow and at the mouth of the creek where it joins Lac La Biche. Occasional additional samples were collected at the mouth site in 1988, 1989 and 1997.

In 1997, Alberta Environment recognized that there was little information on the water quality of Red Deer Brook, especially with respect to spawning of Northern Pike in spring. Staff of the Northeast Boreal Region, Water Sciences Branch and the Town of Lac La Biche met in August and decided that a study was needed. Questions that were raised included:

- Has Field Lake impacted water quality in Red Deer Brook?
- Could pike spawning in the lower end of Red Deer Brook be negatively affected by the Field Lake discharge?

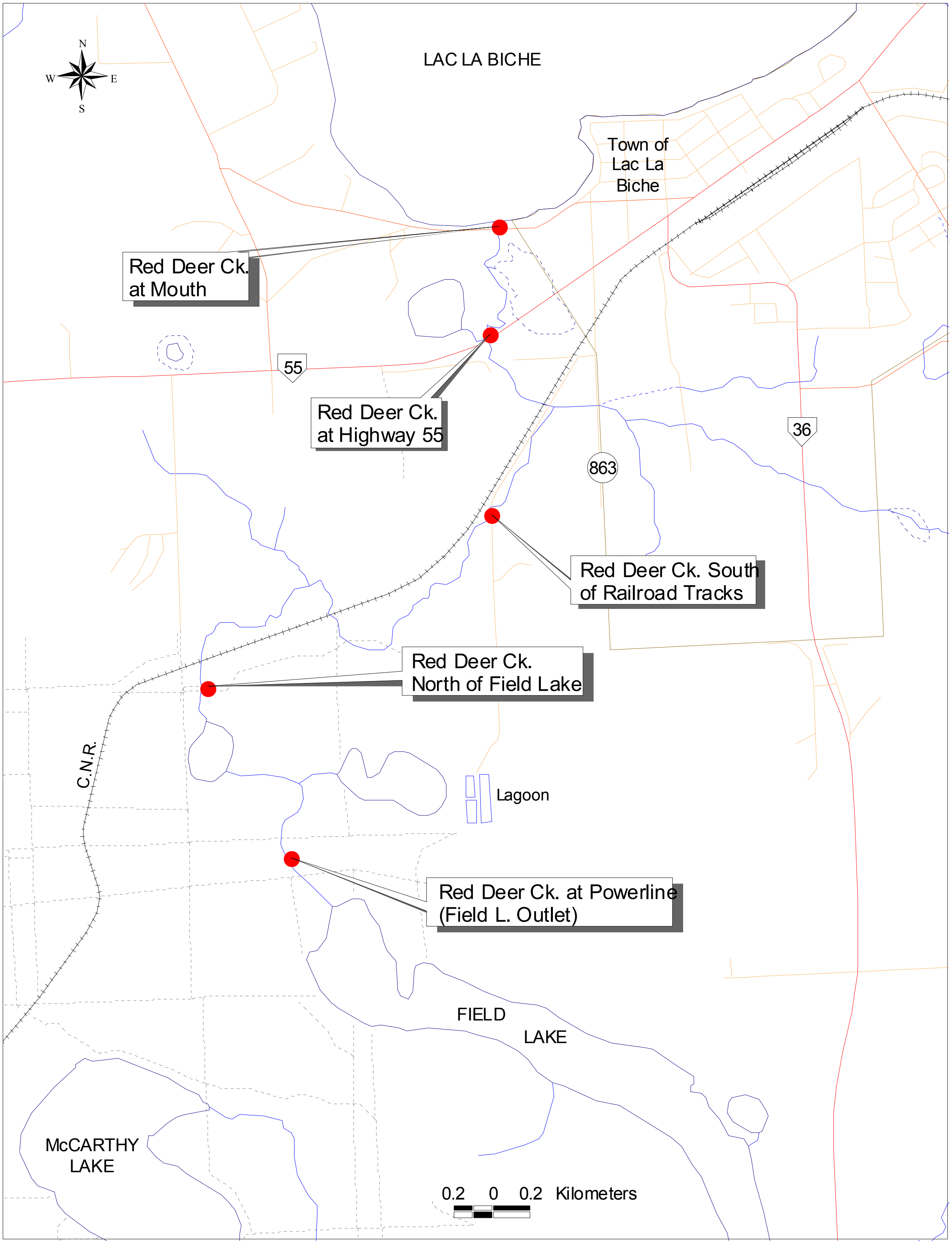
- How does water quality in the Field Lake outflow change as it moves toward Lac La Biche?

Water Sciences Branch began a study to address these questions in March 1998; the study continued in the spring of 1999. The focus of the study was on nutrients, because sewage contains high concentrations of phosphorus and nitrogen (including ammonia-nitrogen). The creek and its fish population could be adversely affected if high nutrient concentrations promote excessive aquatic plant growth, which could lead to fluctuating dissolved oxygen concentrations and toxic levels of ammonia-nitrogen. The ammonia and dissolved oxygen data gathered in 1998-99 were compared with appropriate water quality guidelines. These guidelines provide an indication of the health of the aquatic system. The following report is a synopsis of the findings of the sampling program.

2.0 METHODS

Field Sampling. Samples were collected at four locations along Red Deer Brook during 1998-1999 (Figure 1 and Table 1). Note that the local name "Red Deer Brook" has been used in this report. Alberta Environment data are stored under the name "Red Deer Creek." In addition, samples were collected at the Mouth site in 1986 and occasionally in other years. The outlet of Field Lake ("Red Deer Creek at Powerline" – see Figure 1) was also sampled in 1986, on seven occasions from March through August. All samples were collected as grabs, usually by filling clean and rinsed sample bottles directly from the stream. During 1998-1999, the flow rate of the creek was measured each time a sample was collected. Variables measured in these grab samples (Table 1) included major ions and related substances, nutrients, organic carbon, bacteria, and field characteristics such as temperature and dissolved oxygen concentrations. Chemistry samples were analyzed at EnviroTest Laboratories and microbiological samples at the Provincial Laboratory of Public Health.

Nutrient Contribution from Field Lake. The theoretical contribution of phosphorus and nitrogen to Red Deer Brook from Field Lake was estimated by multiplying the estimated spring flow volume of the sewage effluent added to Field Lake by the measured concentration of phosphorus and nitrogen in the lake in early summer 1997. This estimate assumes that the amount of water entering the creek from Field Lake is the same as the amount of sewage effluent entering the lake. Net evaporation losses would reduce this volume, but on the other hand, the



Alberta Environment
Water Management Division

Figure 1. Location of water quality sampling sites during the Red Deer Creek survey, 1998-1999

Table 1. Water quality sites sampled, including WDS* station, the sampling period, number of samples collected and variables measured. Drainage areas listed exclude the immediate Field Lake watershed.

Site Sampled	Drainage Area (km^2)	Year	Sampling Period	No. of Samples
Red Deer Creek North of Field Lake (AB07CA0740)	2.57	1998	March 25 to April 30	11
		1999	April 1 to April 22	8
Red Deer Creek South of Railroad Tracks (AB07CA0750)	9.17	1998	March 25 to May 5	10
		1999	April 1 to April 22	8
Red Deer Creek at Highway 55 (AB07CA0760)	27.22	1998	April 6 to May 5	9
		1999	April 1 to April 22	8
Red Deer Creek at Mouth (AB07CA0020)	27.64	1986	February 24 to August 19	10
		1988	June 7 to July 5	2
		1989	May 30	1
		1997	September 9 to October 30	2
		1998	March 25 to May 5	10
		1999	April 1 to April 22	8

VARIABLES MEASURED:

Water Temperature	Chloride, dissolved	Total Phosphorus
Dissolved Oxygen	Fluoride, dissolved	Total Dissolved Phosphorus
pH	Carbonate	Total Ammonia-Nitrogen
Specific Conductance	Bicarbonate	Nitrite+Nitrate-Nitrogen, diss.
Calcium, dissolved	Total Alkalinity	Total Kjeldahl Nitrogen
Magnesium, dissolved	Sulphate, dissolved	Silica, dissolved
Total Hardness	Iron, tot. and diss.	Total Organic Carbon
Sodium, dissolved	Total Dissolved Solids	Fecal Coliform Bacteria
Potassium, dissolved	Total Suspended Solids	Escherichia Coli

*WDS = Alberta Environment Water Data System

June lake concentrations that were used would likely be lower than actual lake concentrations in April. Thus, these estimates provide a rough estimate only of potential nutrient loads that could affect the creek.

Natural Supply of Nutrients in Red Deer Brook. *Export coefficients* were used to calculate the nutrient loads that would naturally be in Red Deer Brook without the outflow from Field Lake. These are phosphorus or nitrogen supply rates for a given land area in a year. No coefficients were available for streams in the area, so two sets of coefficients from other Alberta studies were examined to see how they might compare when applied to the Red Deer Brook watershed. One set is from a study on Lake Wabamun, which has a watershed containing mixed agriculture (16 kg TP/km^2 per year and 127 kg TN/km^2 per year; Mitchell 1985). The other was obtained from a 1995 and 1996 study on agricultural impacts on water quality throughout Alberta (the CAESA studies, Anderson et. al 1998). The closest stream monitored in this study is Flat Creek near Boyle. Its watershed has low agricultural intensity. The phosphorus export coefficients derived for that stream were 8 kg (1995) and 38 kg (1996) TP/km^2 per year, and for nitrogen 92 and 349 kg TN/km^2 per year, respectively. The ranges of these coefficients were used to obtain theoretical phosphorus and nitrogen loads for the Red Deer Brook watershed, excluding Field Lake outflow.

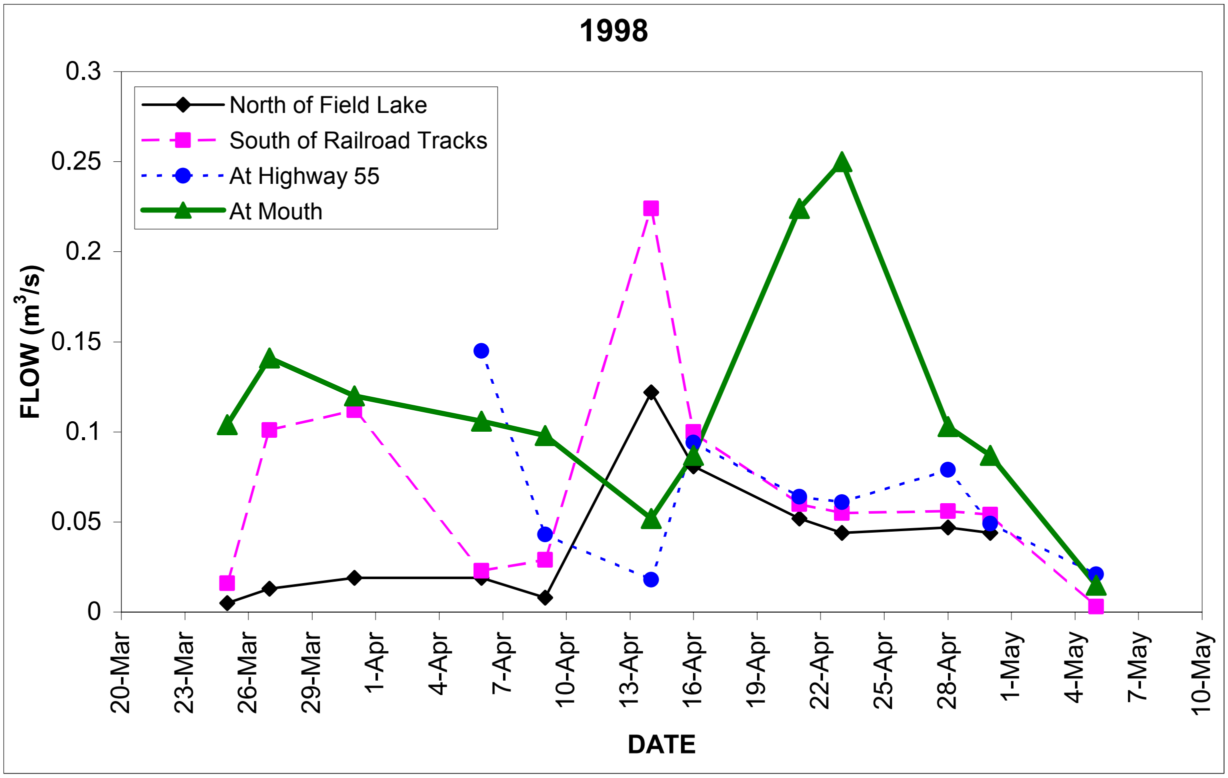
3.0 RESULTS AND DISCUSSION

3.1 HYDROLOGY

Red Deer Brook has a drainage area of about 40 km^2, including the drainage area of Field Lake. Below the outlet of Field Lake, Red Deer Brook's drainage area is about 27 km^2 (Table 1). There are several tributaries along its route from Field Lake to Lac La Biche, and several of these drain sloughs and ponds (see Figure 1). As well, there is a large marsh just above the creek's confluence with Lac La Biche. Most of the watershed runoff drains through one culvert under Highway 55, which was monitored both years.

During the spring of 1998 and 1999, the amount of runoff in the Lac La Biche area was below average. The water survey reference station closest to Red Deer Brook is Pine Creek, west of Lac La Biche. For the March – May period, flow in 1998 was 13th lowest of the 33 year record and in 1999 it was 4th lowest. Spring runoff was approximately 30% of average in 1998 and 10% of average in 1999 (M. Seneka, pers. comm.).

The moderate snow cover in the spring of 1998 resulted in measurable runoff. However, flow in the creek did not move downstream in a stable fashion. One would expect the sampling site furthest downstream to have the greatest flow, but as Figure 2 shows, this was often not the case. It is possible that low areas along the creek's length filled up slowly, then released quickly, producing the staggered peaks in the graphs. Flow in the upstream sites, North of Field Lake and South of Railroad Tracks, was highest on April 13. It is likely that flow out of Field Lake reached the South of Railroad Tracks site (but would also have included local and tributary runoff). At the Mouth site, there was a high flow rate on April 21 and 23. Before this period, water was ponding in the marsh between Highway 55 and the mouth. In mid-April, rocks and debris were removed from the creek downstream of the bridge at the mouth, allowing



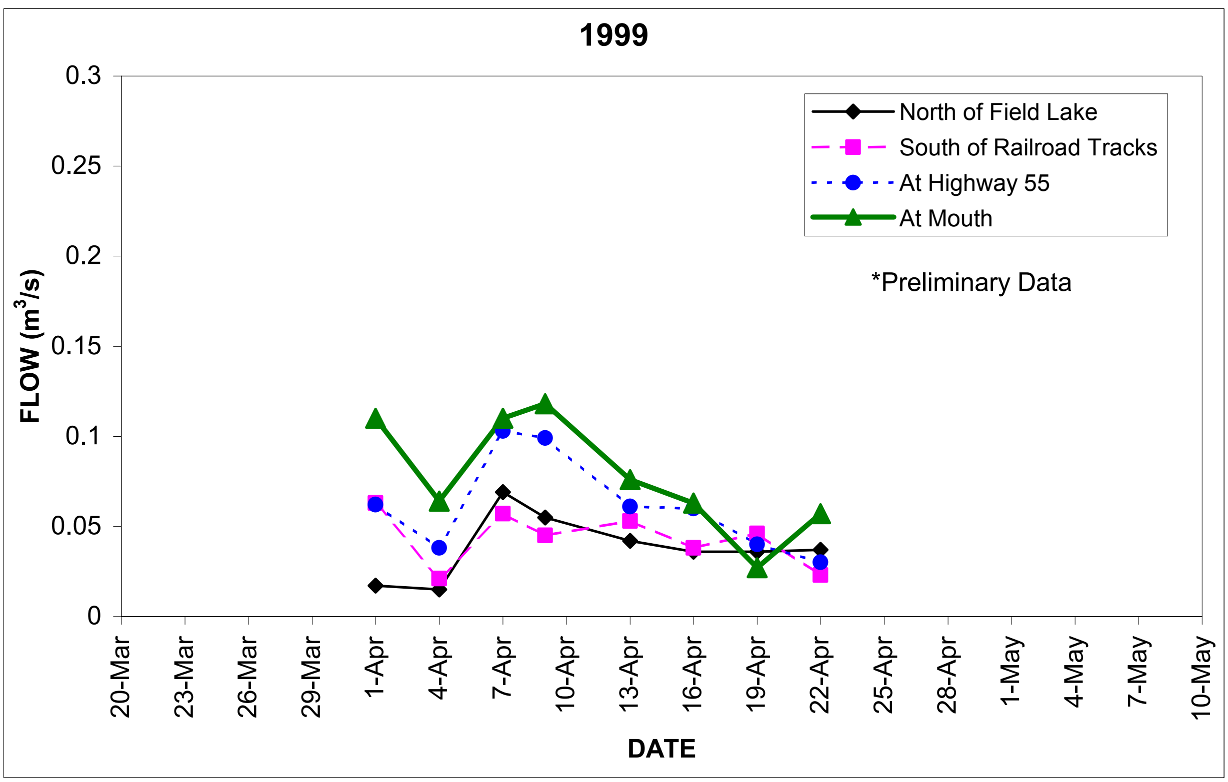


Figure 2. Daily flows in Red Deer Creek sites, 1998 and 1999

better drainage from the marsh and facilitating pike movement up the creek. This resulted in the peak flows shown on the graph.

In 1999, the flow pattern at these sites was much more consistent than in 1998, even though runoff and creek flows were lower. The creek channel was more defined, and there was less ponding in the marsh above the mouth. There was some clearing of the channel by landowners in upper reaches, as well. On most dates, the flow was lowest at the North of Field Lake site and highest at the Mouth site, as would be expected. Field observations confirmed that there was flow out of Field Lake in 1999, and it is likely it reached Lac La Biche, although considerably diluted by flow from side tributaries.

3.2 NUTRIENTS

High nutrient concentrations and toxic levels of ammonia-nitrogen are typical concerns related to the impacts of sewage effluent on aquatic systems. High nutrient levels promote luxuriant growth of aquatic plants, which in turn leads to fluctuating levels of dissolved oxygen. Low dissolved oxygen or high ammonia-nitrogen concentrations at the time of pike spawning could jeopardize survival of eggs or fry, or pike could avoid the creek altogether.

Table 2 summarizes data for nutrient fractions and total suspended solids (TSS) for the two sampling periods. The inclusion of TSS data in the sampling program gives an indication of the amount of particulate material in the water. If TSS is high, total phosphorus and nitrogen could also be high, but high particulate phosphorus and nitrogen may not have the environmental consequences of high concentrations of dissolved nutrients. For each year, the data in the table are arranged in the direction of flow. Note that the highest concentrations of total and dissolved phosphorus and most nitrogen fractions were at the site nearest Field Lake, and that average concentrations tended to decline with each site closer to Lac La Biche. This is to be expected because nutrients bound in particulates (e.g., soil particles, algal cells or organic matter) can settle out.

Phosphorus concentrations at all sites are relatively high. The stream sites between Field Lake and Lac La Biche averaged between 0.8 and 1.7 mg/L TP in spring 1998-1999. The highest total phosphorus concentrations generally occurred in early April both years (Figures 3a and 3b), but stayed relatively high. In comparison, the total phosphorus (TP) concentration in streams draining to Lac Ste. Anne and Lake Isle, which have moderate agricultural intensity in

Table 2. Flow-weighted mean, range and number of samples for nutrient fractions in Red Deer Creek sites, 1998 and 1999.

		Total Phosphorus	Total Dissolved Phosphorus	Total Ammonia Nitrogen	Total Kjeldahl Nitrogen	Nitrite+Nitrate Nitrogen, diss.	Total Suspended Solids
1998							
Red Deer Ck. N. of Field Lake	Mean:	1.51	1.27	0.541	3.18	0.004	6.5
	Minimum:	1.28	0.89	0.031	1.69	L0.006	L2
	Maximum:	2.29	2.23	4.190	6.33	0.017	16
	No. Samples:	11	11	11	11	11	11
Red Deer Ck. S. of Railroad Tracks	Mean:	1.21	0.96	0.214	2.75	0.043	8.8
	Minimum:	0.98	0.67	0.054	1.91	L0.006	L2
	Maximum:	1.86	1.37	2.030	4.35	0.346	19
	No. Samples:	10	10	10	10	10	10
Red Deer Ck. at Hwy 55	Mean:	1.13	0.86	0.220	2.70	0.017	5.7
	Minimum:	0.69	0.47	0.029	2.07	L0.006	L2
	Maximum:	3.63	2.23	0.589	3.15	0.044	15
	No. Samples:	9	9	9	9	9	9
Red Deer Ck. at Mouth	Mean:	1.04	0.93	0.329	2.70	0.013	3.6
	Minimum:	0.58	0.47	0.108	2.20	L0.006	L2
	Maximum:	2.57	2.39	2.280	4.76	0.107	7
	No. Samples:	10	10	10	10	10	10
1999							
Red Deer Ck. N. of Field Lake	Mean:	1.71	1.38	2.04	4.69	0.031	12.3
	Minimum:	1.2	0.48	0.042	2.81	0.010	L3
	Maximum:	2.12	1.79	4.270	6.38	0.063	24
	No. Samples:	8	8	8	8	8	8
Red Deer Ck. S. of Railroad Tracks	Mean:	1.60	1.19	1.34	3.56	0.132	3.4
	Minimum:	1.02	0.84	0.048	2.27	0.042	L3
	Maximum:	3.46	1.52	3.440	5.73	0.247	8
	No. Samples:	8	8	8	8	8	8
Red Deer Ck. at Hwy 55	Mean:	1.00	0.88	0.94	3.16	0.116	6.9
	Minimum:	0.59	0.50	0.031	2.02	0.012	L3
	Maximum:	1.42	1.32	2.350	4.52	0.191	15
	No. Samples:	8	8	8	8	8	8
Red Deer Ck. at Mouth	Mean:	0.78	0.72	0.647	2.72	0.171	3.6
	Minimum:	0.54	0.48	0.098	2.02	0.041	L3
	Maximum:	1.21	1.21	1.730	3.89	0.280	7
	No. Samples:	8	8	8	8	8	8

All values are milligrams per litre.
"L" = less than analytical detection limit. Half the detection limit was used for the mean calculation.

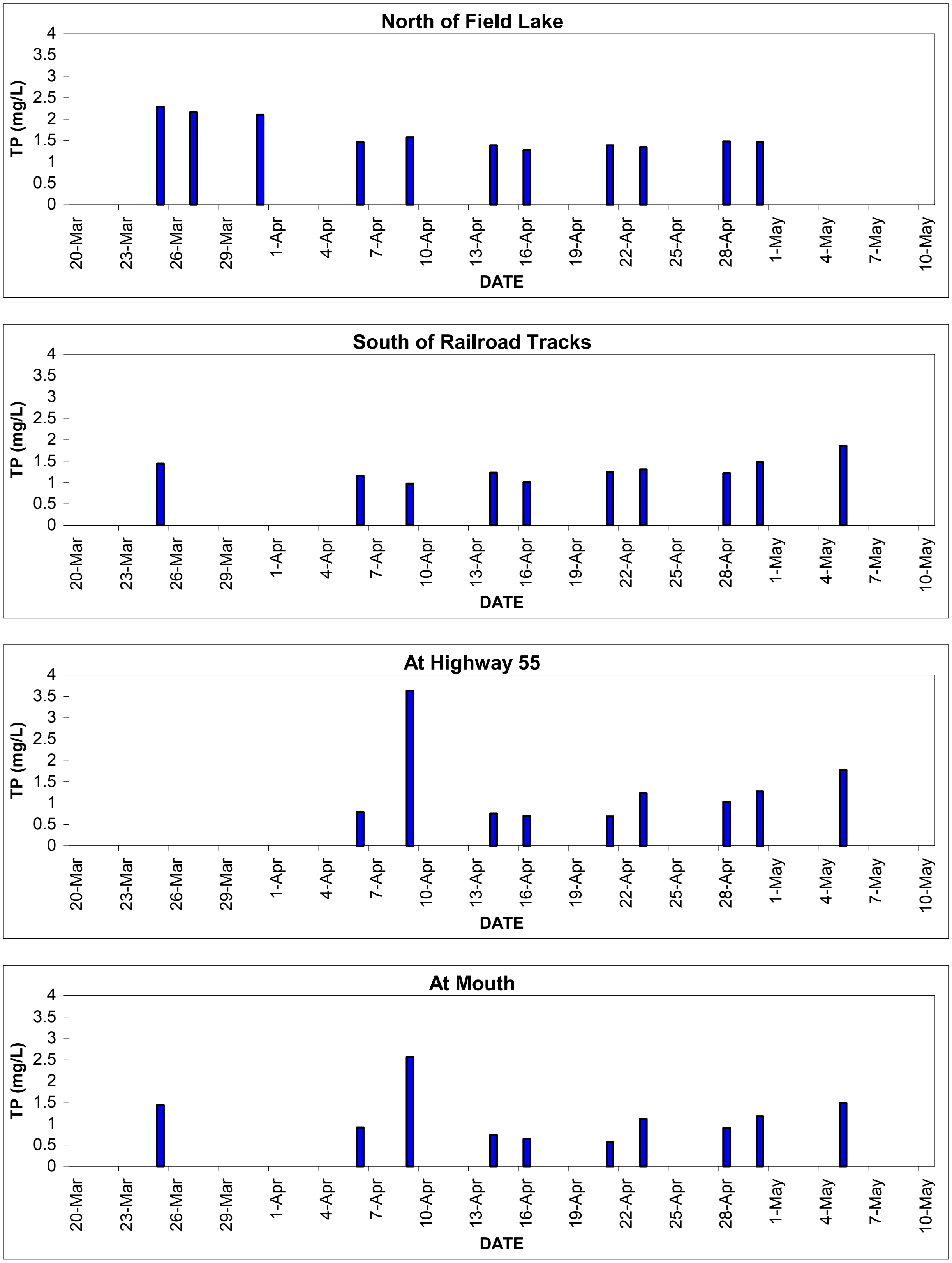


Figure 3a. Total phosphorus levels in Red Deer Creek sites, 1998

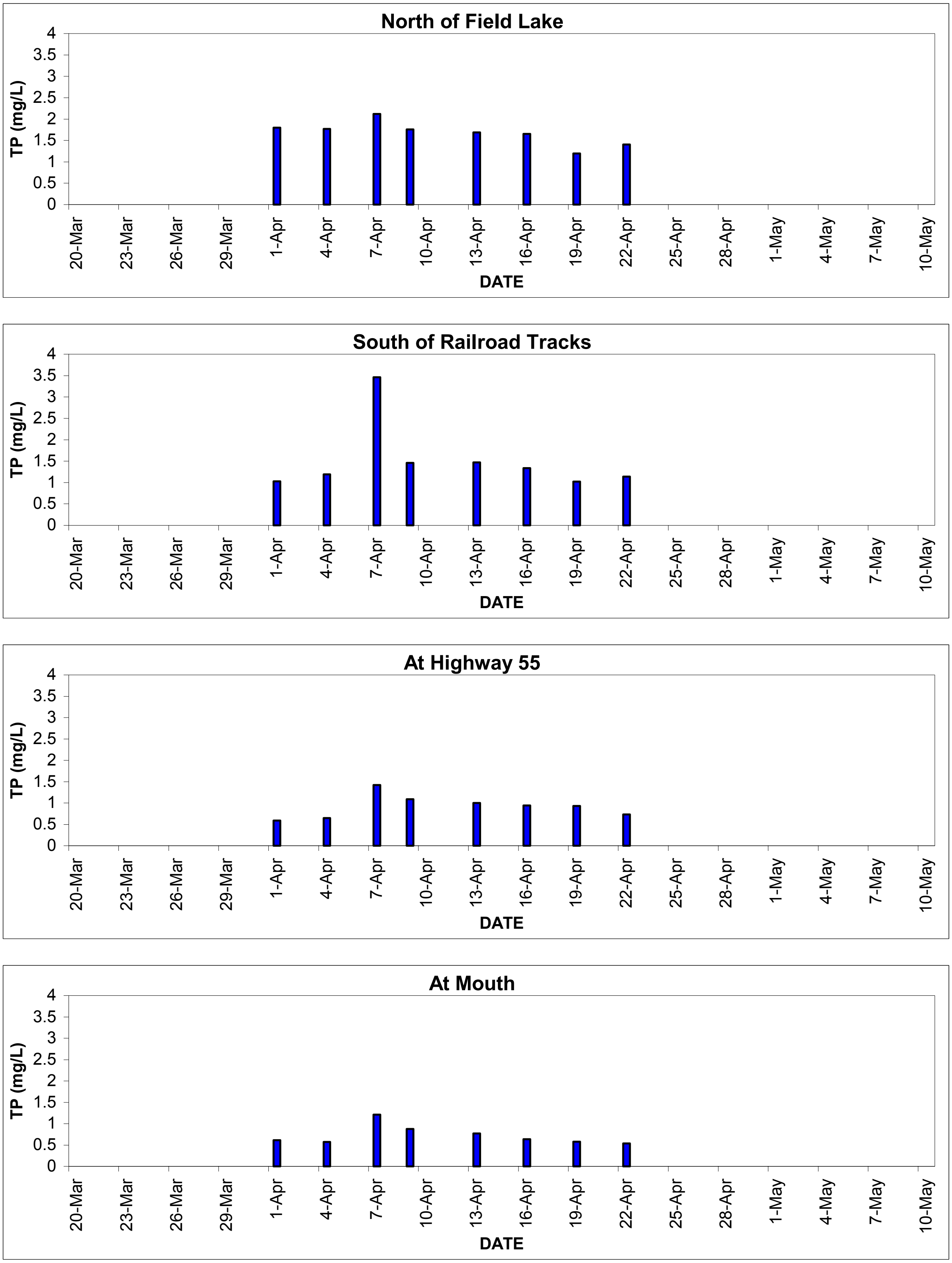


Figure 3b. Total phosphorus levels in Red Deer Creek sites, 1999

their watersheds, averaged between about 0.2 and 0.5 mg/L in the spring (1997) (Mitchell 1999); concentrations declined as the spring progressed. The outflow from Field Lake probably maintains higher concentrations in Red Deer Brook.

The concentrations measured in Red Deer Brook are similar to those in streams draining areas of high agricultural intensity, which were sampled during the Anderson, et al. (1998) study to assess the impact of agriculture on surface water (range 0.14-1.96 mg/L). Total phosphorus concentrations in samples collected from the mouth of Red Deer Brook in spring 1986 were slightly lower than those observed in 1998-99, but are probably within the range of year to year variation. Historical data for other creeks in the area are not available, but it is likely that concentrations would be lower than were observed in Red Deer Brook. Nitrogen concentrations are also in the range of data for streams draining areas of intensive agriculture. Nitrite+nitrate-nitrogen (NO_2+NO_3 – N) did not follow the pattern of other nutrient fractions. It can be taken up by growing plants and lost to the stream through denitrification, and added to by nitrification of ammonia-nitrogen under aerobic conditions.

To determine the overall effect of Field Lake water on the stream, mass loads were calculated for the spring sampling period in 1998 and 1999 for various nutrient fractions (Table 3). A mass load is the weight of a particular substance in the water over a specific period of time. Calculation of mass loads along a stream can help determine locations of sources. In addition to nutrient loads, the mass load for sodium was also calculated. Unlike nutrients, sodium should not be added to or removed by biological processes or physical retention, and therefore the amount in the stream should increase in a downstream direction via contributions from tributaries, groundwater or other sources. As Table 3 shows, sodium increased between the site nearest Field Lake and the site at Lac La Biche. The sodium concentration varies little from site to site, but because the flow volume increases, the load does as well. Calculation of loads for conservative substances such as sodium serves as a check on the validity of the data.

The total loads of all nutrients were higher in 1998 than in 1999, mostly because the flow volume in 1998 was higher. The sodium data for 1998 are difficult to interpret because the load at the site south of the railroad tracks was higher than that at the next site downstream. Concentrations were similar at all sites, but the flow volume in the stream varied. The high load at the mouth reflected the high flow volume out of the marsh in mid-April. The phosphorus data followed similar patterns. Concentrations of TP and TDP did not vary appreciably from one site

Table 3. Nutrient and sodium loads (kg) at four sites along Red Deer Brook, spring 1998 and 1999. Loads are for the whole sampling period: 25 March-5 May, 1998; 1 April – 22 April, 1999.

		Red Deer Ck. N. of Field Lake	Red Deer Ck S. of RR Tracks	Red Deer Ck at Hwy 55	Red Deer Ck at Mouth
Total Phosphorus	1998	102	161	106	230
(TP)	1999	63	65	59	57
Total Diss. Phos.	1998	86	133	80	207
(TDP)	1999	50	49	52	53
Ammonia-N	1998	40	84	23	127
(NH_3-N)	1999	74	53	54	47
Total Kjeldahl N	1998	215	411	255	633
(TKN)	1999	172	145	187	200
Nitrite+Nitrate-N	1998	0.29	6.3	1.8	5.9
(NO_2+NO_3)	1999	1.2	5.4	6.8	12
Sodium	1998	3786	6777	4617	10020
(Na)	1999	2653	2818	3764	4864

to the next, so the loads reflected the water flow volume. This was true to some extent for nitrogen fractions as well, although concentrations of inorganic nitrogen were much more variable. For all nutrient fractions, however, the highest loads along the creek were at the Mouth site.

The 1999 data were more consistent. The mass load of sodium increased in a downstream direction. These calculated loads suggest that in spring 1999, 2650 kg of sodium were contributed by Field Lake, and then tributaries and perhaps groundwater contributed another 2200 kg of sodium to the creek as it moved downstream. This increase is not apparent for the phosphorus data, because the mass load for TP (and TDP) was similar at all four sites (it is lower at the mouth, but this variation may be within measurement error). It is unlikely that the phosphorus contribution from tributaries was negligible, based on the sodium calculation. It is possible that biological uptake and physical retention (such as settling out of particles) removed a portion that was roughly equivalent to the amount added by sources along the creek. In any case, Field Lake appeared to be a major source of sodium and nutrients to Red Deer Brook during the study years.

Another validation step is to calculate theoretical loads of phosphorus, nitrogen and sodium that might be expected to flow out of Field Lake in spring. The Field Lake outflow load estimates are based on sewage effluent flow volume and nutrient concentrations in Field Lake in 1997. Spring lake data were not available, so June 1997 data were used. Table 4 summarizes these data. It is likely that water quality in Field Lake would be poorer in early spring than in June, and therefore these estimates could have been higher. The "Theoretical Spring Loads" and the "North of Field Lake" data are surprisingly similar, considering how much inherent error there would be in these calculations. This again suggests that the main source of nutrients to Red Deer Brook is Field Lake.

The nutrient load discharged from Field Lake has increased since sewage effluent has been entering it, because both nutrient concentrations and the flow volume leaving the lake have increased. For example, the total phosphorus concentration measured in the lake in 1981, before sewage effluent entered it, was 0.057 mg/L; now it is about 1.5 mg/L. If the flow volume leaving Field Lake in spring 1981 were half of that estimated for 1998-99 (about 2000 m^3/day, in Table 4), the total phosphorus load leaving the lake would be 2 kg rather than the 123 kg estimated for spring 1998. Even so, Field Lake has been reducing nutrient loads from sewage effluent. For the spring of 1998 and 1999, processes in the lake reduced the phosphorus load in sewage effluent entering the lake by about 65% and the nitrogen load by 86%, based on estimated inflow volumes and concentrations (annual load of total phosphorus estimated at 3139 kg: sewage effluent inflow volume estimated at 1800-2000 m^3/day and 1993-94 average concentration 4.3 mg/L TP; L. Williams, pers. comm. 1997).

Table 4. Theoretical phosphorus, nitrogen and sodium loads (kilograms) in Field Lake outflow into Red Deer Brook, and observed for "North of Field Lake" site, spring 1998 and 1999 (from Table 3). Concentration data were measured in Field Lake June 1997, and in Red Deer Creek N. of Field Lake during spring.

	Total Phosphorus	Total Nitrogen	Sodium
Lake Concentration, mg/L	1.5	3.71	72
Outflow Volume, m^3/day	2000	2000	2000
# Days 1998	41	41	41
# Days 1999	22	22	22
Theoretical Spring load from Lake 1998	**123**	**304**	**5904**
Theoretical Spring load from Lake 1999	**66**	**163**	**3168**
N. of Field Lake 1998, kg	**102**	**215**	**3786**
N. of Field Lake 1999, kg	**63**	**173**	**2653**

There has also been public concern about the impact of Red Deer Brook on Lac La Biche since Field Lake has been receiving sewage effluent. The total phosphorus and nitrogen load that Red Deer Brook contributes to Lac La Biche can be compared with the theoretical load if Field Lake did not drain into Red Deer Brook. This estimate assumes that the only source of nutrients is the watershed below Field Lake. It is done with annual nutrient “export coefficients”, which are phosphorus loss factors derived from stream monitoring studies in other areas of the province. They are used for “ballpark” comparisons only, because data for the creek before the sewage treatment plant was built are not available, nor are there data for other creeks in the Lac La Biche drainage basin (see Methods section for how this was done). Using coefficients from other studies, the theoretical annual range of loads from the watershed excluding Field Lake is 200-1000 kg TP and 2500-9000 kg TN, depending on the coefficients used. The loads actually measured at the Red Deer Creek at Mouth site were 57-230 kg TP and 212-639 kg TN (see Table 3). It is obvious that the measured loads are lower, but these are for the spring only, whereas the theoretical watershed loads are annual loads. However, spring nutrient loads in central Alberta streams are usually at least half of the annual load. This means that the phosphorus load measured for Red Deer Brook at the Mouth is in the lower end of the range of the loads that might be expected for a watershed without Field Lake outflow, but measured nitrogen loads are considerably lower. Intuitively, one would expect the opposite – that the present loading from Red Deer Brook would be higher than that from a natural stream. It appears that the natural loading from the Red Deer Brook watershed was very low, probably because runoff during the study period was well below average. Alternatively, the stream bed and associated ponds and marshes may be taking up excess nutrients contributed by Field Lake.

In spite of the increased nutrient loading to Lac La Biche from Red Deer Brook since the sewage effluent began entering Field Lake, the impact on Lac La Biche as a whole is negligible. In the past, when sewage effluent entered Lac La Biche directly, the phosphorus contribution from the town was estimated at about 1300 kg per year (Mitchell 1980). This is because the estimated annual phosphorus supply to Lac La Biche from all sources is about 38,000 kg (Mitchell and Prepas 1991). Red Deer Brook’s present TP contribution represents less than 1% of this total supply. Most of the phosphorus contributed in sewage effluent would have been directly usable as a nutrient by growing algae in the lake, whereas the phosphorus in Red

Deer Brook is somewhat less useable (i.e. *bioavailable)*. Thus, there has been a net decrease in nutrient loading to Lac La Biche by transferring sewage effluent disposal to Field Lake.

3.3 AMMONIA-NITROGEN

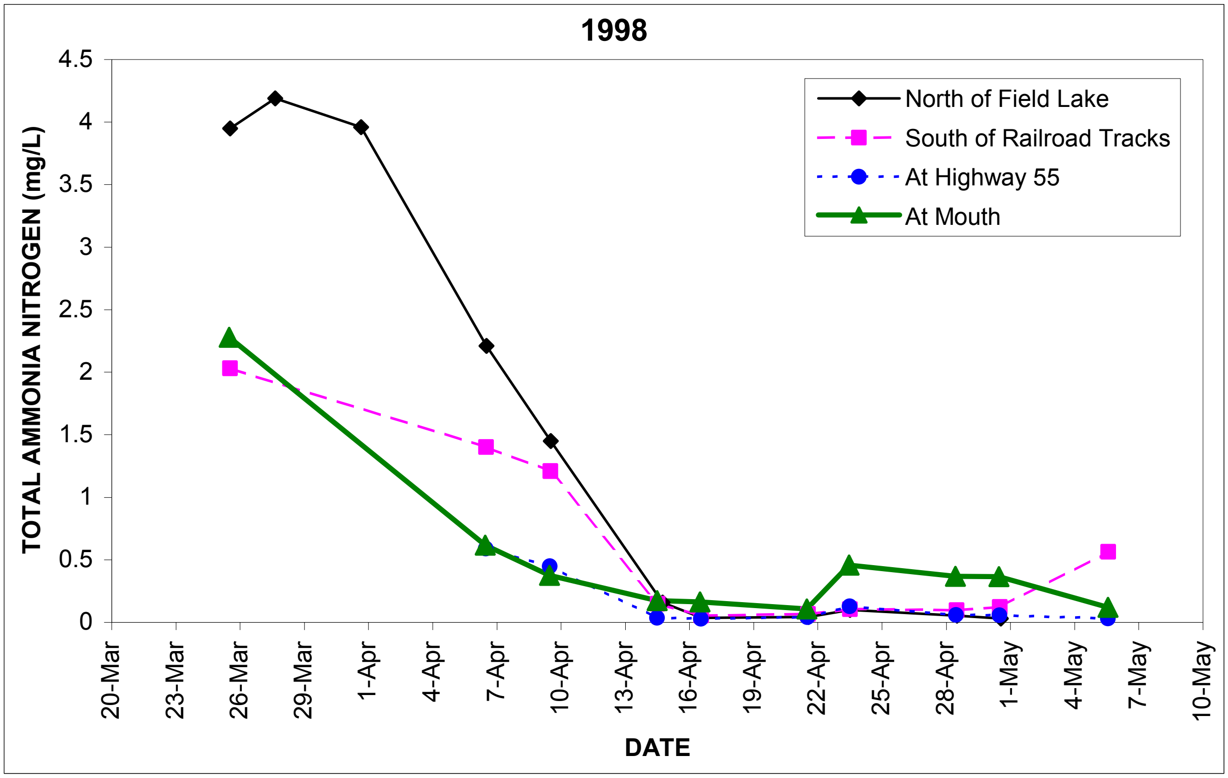
Ammonia is a concern in surface waters because under certain conditions it can be toxic to fish and other aquatic animals. It was measured in Red Deer Brook on each sampling occasion in 1998 and 1999. As Figure 4 indicates, the highest ammonia-nitrogen values occurred at the sampling site nearest Field Lake; only 58% of the samples collected there met the Canadian Water Quality Guideline (CCREM 1987) for the protection of aquatic life (Table 5). Because the guidelines are reported as total ammonia, they were recalculated as ammonia-nitrogen so that they could be compared with the data (NH_3-N = total ammonia x 0.82). These are chronic guidelines; it is presumed that this concentration would be an average over a period of days or weeks.

The measured levels are much lower than USEPA acute guidelines (Alberta Environment 1999), which would be calculated as a one-hour average concentration. For example, the highest ammonia-nitrogen concentration measured during the study was 4.27 mg/L. On this day, the acute USEPA guideline level would be 26 mg/L.

New draft Canadian guidelines have been developed for ammonia-nitrogen; when the pH of the water sample is high, the new ammonia guidelines are much more restrictive than the old guidelines, but less restrictive at low pH and temperature. For the Red Deer Brook data set, two values that met the old guideline would not meet the new guideline, but three values that exceeded the old guideline would now meet the new guideline. Thus, overall compliance would be essentially the same under the two sets of guidelines.

The highest concentrations occurred in early spring, and then declined to low levels by the end of April or beginning of May. This site is most influenced by the outflow from Field Lake, which had fairly high ammonia-nitrogen concentrations during the open water period in 1997. During spring, before the ice comes off the lake, ammonia concentrations in the lake would likely be higher than those measured during open water, and probably higher than those measured in Red Deer Brook.

Only one sample each was non-compliant with the CWQG (1987) at the Highway 55 and Mouth sites. These occurred when the marsh was draining in early April 1999. The



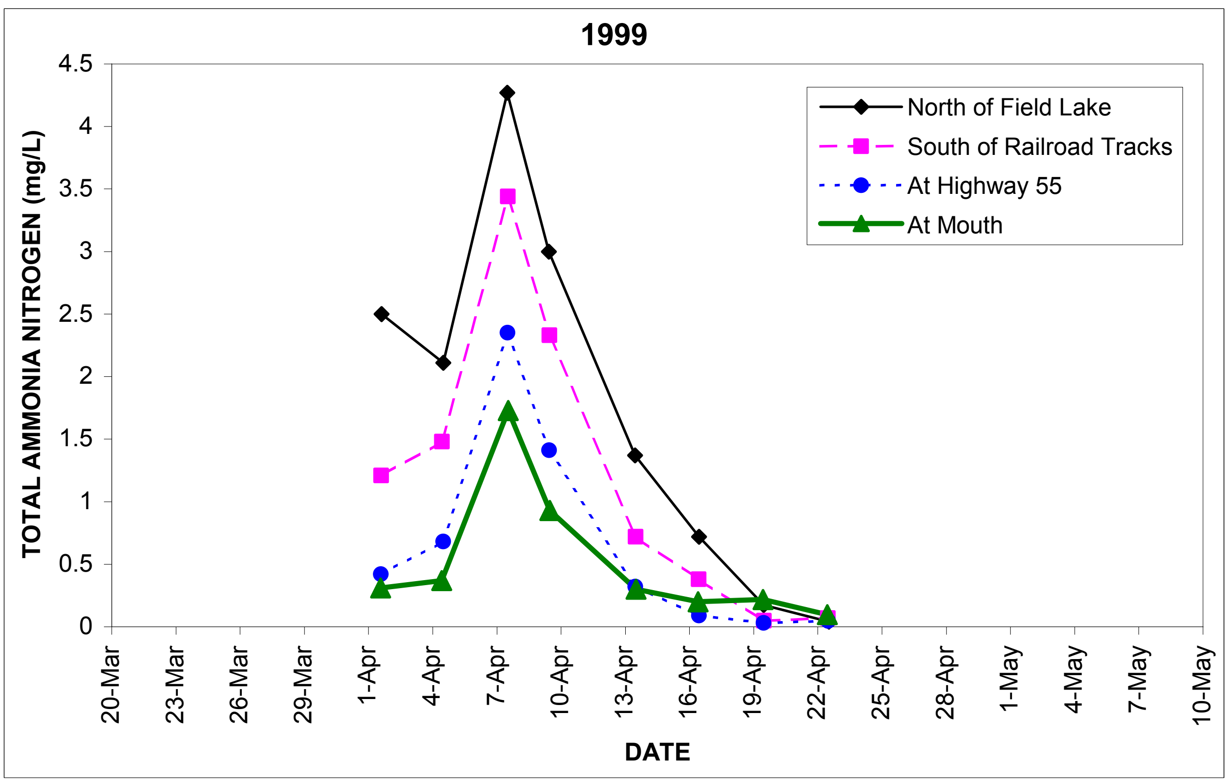


Figure 4. Total ammonia-nitrogen levels in Red Deer Creek sites, 1998 and 1999

Table 5. Percentage of samples collected in Red Deer Brook in which ammonia (NH_3-N) met the Canadian Water Quality Guideline (1987) for protection of aquatic life. Concentrations in mg/L. Mean and range values are for all data from 1998-99 for each site.

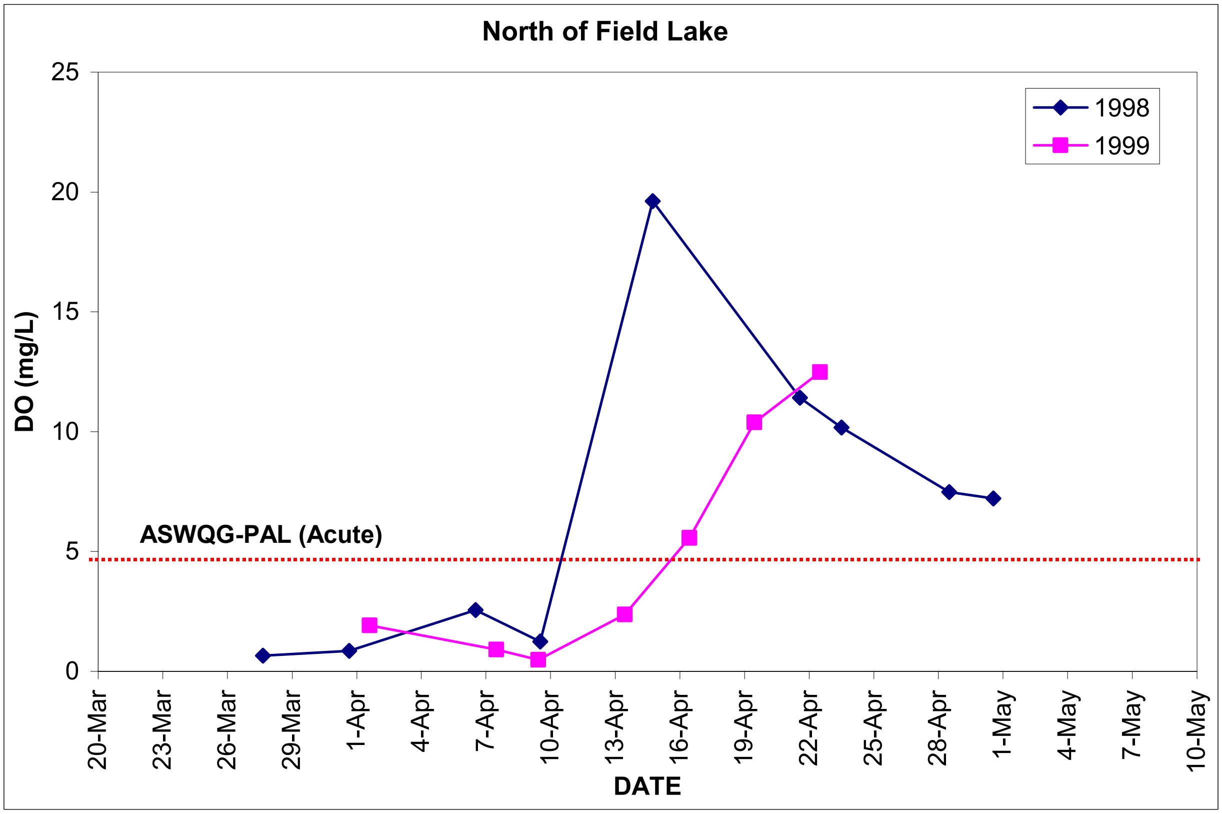
Site	Percentage Compliance	Total Number of Samples	Mean Value	Range
N. of Field Lake	58%	19	1.60	0.031 – 4.27
S. of RR Tracks	88%	17	0.791	0.054 – 3.44
At Hwy 55	94%	17	0.398	0.029 – 2.35
Mouth	94%	18	0.510	0.098 – 2.28

concentrations measured at that time were very close to the guideline value, and probably would not have had adverse consequences for fish in the area. As well, this is likely before pike would be moving up the creek to spawn (D. Watters, pers. comm.). Samples collected from the mouth site during the summer in 1986, 1988-89 and 1997 had very low concentrations of ammonia. The situation is less clear at the site south of the railroad tracks. Ammonia-nitrogen concentrations were lower here than at the more upstream site, but a few were non-compliant. The lowest concentrations occurred later in the spring, although one higher value (but well below the 1987 guideline level) was measured in May 1998 when the flow in the creek had virtually ceased. Because the guideline values have built-in safety factors, rare exceedences of the chronic guidelines are not necessarily a cause for concern.

3.4 DISSOLVED OXYGEN

Dissolved oxygen (DO) concentrations were low at the North of Field Lake site in early spring both years (Figure 5), and did not meet the Alberta acute guideline of 5.0 mg/L. By mid-April, however, concentrations had increased to well above the Alberta acute and chronic guideline levels (at least during the day when it was measured). In fact, the water was supersaturated with dissolved oxygen in mid-April 1998 at this site. This site is undoubtedly influenced by outflow from Field Lake, which becomes anoxic under ice. At the South of Railroad Tracks site, all DO measurements for both years met guideline levels. At Highway 55, the early April 1998 DO concentrations were slightly below the Alberta acute guideline, but were very high even at the beginning of April in 1999.

At the Mouth site, DO concentrations were very low in spring 1998. The average concentration for the ten samples was 3.0 mg/L, and only two samples complied with the Alberta



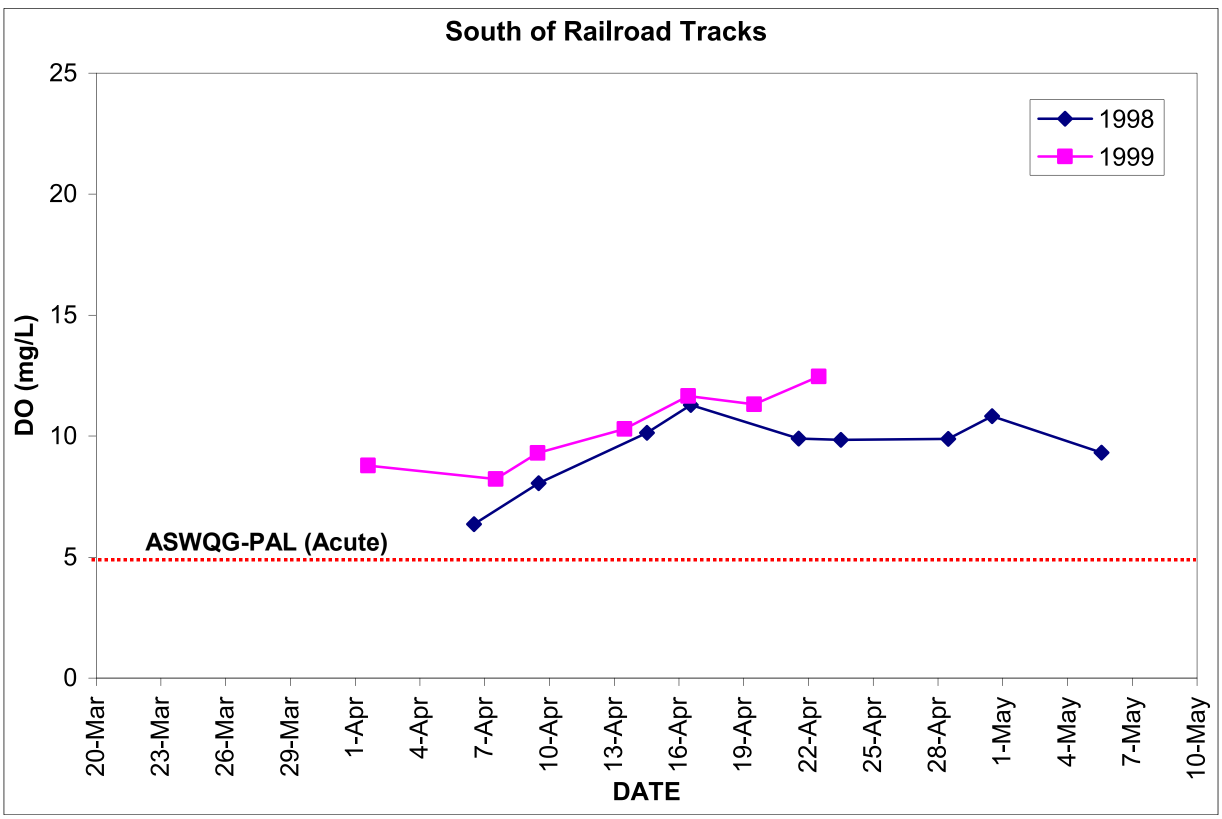


Figure 5. Dissolved oxygen concentrations at four sites in Red Deer Creek, 1998-99. Alberta acute guideline to protect aquatic life indicated.

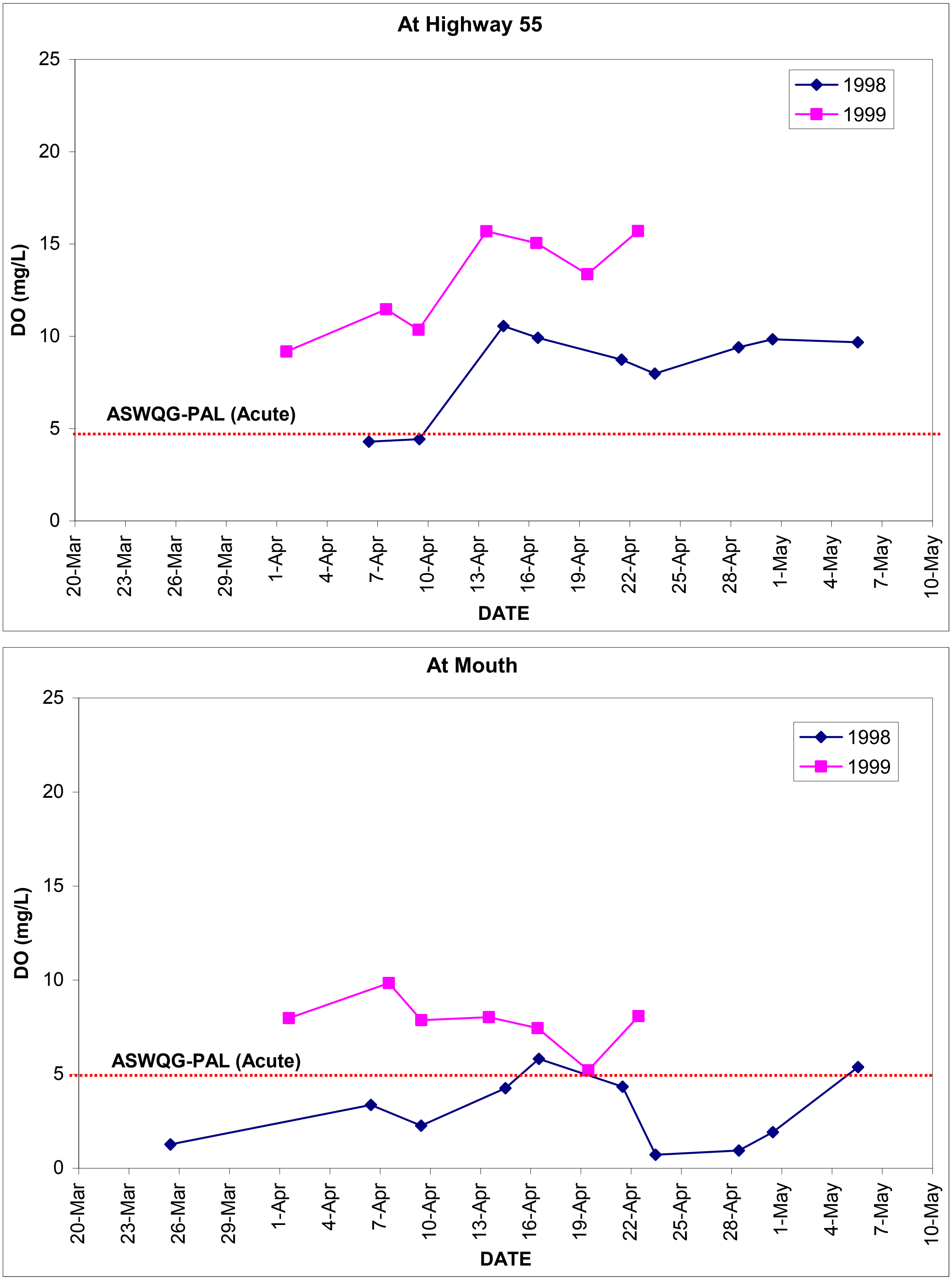


Figure 5. continued.

acute guideline. It appears that water in the marsh above this site was anoxic over the winter, so that water draining out of it into Lac La Biche had very low DO concentrations. Pike would probably not go up the creek under these circumstances, but they might be affected adversely if they did. In 1999, when there appeared to be more flow through the marsh, concentrations were above the guideline level in all samples.

3.5 BACTERIA

Counts of fecal coliform bacteria and *E. coli* were below 100 per 100 mL in all samples collected from Red Deer Brook in 1998-99. Most results were below the analytical detection limit (usually 10 counts per 100 mL). All of the results were at levels considered background in Alberta surface water systems.

4.0 CONCLUSIONS

Red Deer Brook has been affected by outflow from Field Lake. Nutrient concentrations are similar to those of Alberta streams in areas of high agricultural activity. Although it is not possible to determine what the nutrient concentrations in the creek were before Field Lake began receiving effluent, they were likely many times lower. Mass load calculations for the two study years suggest that most of the phosphorus and nitrogen in Red Deer Brook originates from Field Lake. This would be true in high runoff years as well, because outflow from the lake would increase unless the water level was below the outlet sill. The impact on Lac La Biche would likely be negligible in both high and low runoff years, because the amount of phosphorus and nitrogen contributed by the creek is minimal compared with the estimated total supply from the Lac La Biche watershed.

Ammonia-nitrogen concentrations were relatively high at the site nearest Field Lake, but declined in a downstream direction. Just over half of the samples collected upstream complied with the Canadian Water Quality Guideline for the protection of aquatic life. At the two downstream sites, nearly all ammonia-nitrogen samples complied. In early spring, dissolved oxygen concentrations were low at the site nearest Field Lake, probably because Field Lake water was anoxic. Dissolved oxygen concentrations at the Mouth site did not always meet Alberta water quality guidelines for the protection of aquatic life, especially in early spring.

Counts of fecal coliform bacteria have not become elevated as a result of the outflow from Field Lake.

The main impact of Field Lake on Red Deer Creek is likely one of prolonged eutrophication, and seasonal ammonia toxicity/dissolved oxygen depletion. Because sampling occurred only in spring, it is not possible to determine conditions during other seasons. This assessment suggests, however, that the nutrient supply to the creek has greatly increased. This may have changed the flora and fauna of the creek somewhat, especially in areas nearest Field Lake. It also means that the marsh near Lac La Biche probably becomes anoxic during some winters, but there is no scientific information to determine whether this occurred before Field Lake became the recipient of treated sewage effluent. Pike move up creeks to spawn at the end of April, deposit eggs, and then move back downstream. The eggs take about two weeks to hatch, and then once the fry are mobile, drift downstream, perhaps in May (D. Watters, pers. comm. Feb. 2000). Potentially, pike spawning in Red Deer Creek has been adversely affected, either because the adults would not move into water that was high in ammonia or low in dissolved oxygen, or because conditions for egg and fry survival are not suitable. Confirmation of this would require a fairly detailed study of the spawning areas of pike at the time they are in the creek. This should be done under conditions of low and high runoff.

5.0 REFERENCES

Alberta Environment. 1999. Surface Water Quality Guidelines for Use in Alberta. Environmental Sciences and Water Management Divisions. 20 p.

Anderson, A.-M., D.O. Trew, R.D. Neilson, N.D. MacAlpine, R. Borg. 1998. Impacts of agriculture on surface water quality in Alberta. Part II: Provincial stream survey. Alberta Environmental Protection and Alberta Agriculture, Food and Rural Development. 91 p + appendices.

Canadian Council of Resource and Environment Ministers. 1987. Canadian Water Quality Guidelines (CWQG). Environment Canada, Ottawa.

Mitchell, P. 1980. Trophic status of Lac la Biche. Water Quality Control Branch, Alberta Environment. 19 p.

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

Mitchell, P. 1998. The impact of aerated sewage lagoon effluent on water quality in Field Lake. Water Sciences Branch, Alberta Environment. 20 p + appendix.

Mitchell, P. 1999. Water quality management in Lac Ste. Anne and Lake Isle: a diagnostic study. Water Sciences Branch, Alberta Environment. 40 p + appendices.

Mitchell, P and E. Prepas. 1991. Atlas of Alberta Lakes. University of Alberta Press, Edmonton.

Seneka, Michael. March 2000. Personal communication. Hydrology Section, Water Sciences Branch, Alberta Environment.

Town of Lac La Biche Administration Office. March 2000. Personal Communication.

Watters, Daryl. February 2000. Personal communication. Fisheries and Wildlife Management, Alberta Environment.

Williams, Larry. November 1997. Personal communication. Northeast Boreal Region, Environmental Services, Alberta Environment.