OXYGEN CONDITIONS IN THE ATHABASCA RIVER SYSTEM, WITH EMPHASIS ON WINTERS 1990-93

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OVERVIEW

This report presents the findings of dissolved oxygen monitoring and surveys on the Athabasca River system in the years 1990-93. Dissolved oxygen (DO) has been monitored by means of longitudinal synoptic surveys, recording oxygen meters, and a network of regular sampling sites. Most of the sampling has been concentrated in the winter because that is the season of potential declines in dissolved oxygen. Some additional data prior to 1990 are included where appropriate.

In all winters, DO exhibited a general downstream decline from about 11-12 mg/L upstream of Hinton to 6.5-10 mg/L near Grand Rapids. Reaeration in the rapids raises DO about 3-4 mg/L, after which DO resumes a gradual decline to levels of about 10 mg/L in the Athabasca Delta. Because it has higher DO than the Athabasca mainstem at their confluence, the Lesser Slave River also provides a boost to DO in proportion to its volume of flow. At any given site, the actual concentrations vary from winter to winter, and also through each winter, in response to a number of factors. For example, photosynthesis under ice became significant in 1993 and raised DO to levels in excess of saturation in the Grand Rapids-Ft. McMurray reach in late March.

All oxygen data in the 1990-93 period for the Athabasca and Lesser Slave rivers met the Alberta interim guideline of 5 mg/L and the Canadian guideline of 6.5 mg/L. In 1989 DO had dropped below 6.5 mg/L for part of the winter upstream of Smith. That was due to a combination of low flow, cold weather, and high BOD load from a new pulp mill. Subsequent BOD discharges from pulp and paper mills have been lower.

A more detailed examination of DO conditions in the river's headwaters upstream of Hinton suggested that winter DO fluctuations there are influenced by air temperature such that when the weather turns cold, DO may decline 1-2 mg/L. This may be due to a growth of ice cover and a consequent decline in reaeration.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

Oxygen is required by aquatic organisms for aerobic respiration. Dissolved oxygen (DO) concentrations in water are controlled by temperature, air pressure, reaeration, photosynthesis, respiration, and biochemical oxygen demand. In northern Alberta rivers during winter, ice and snow cover greatly reduce reaeration and photosynthesis, such that the rivers are often less than saturated with DO. The recent expansion in the pulp and paper industry on the Athabasca River has raised concerns about river oxygen conditions since the industry discharges oxygen-demanding wastewaters. As a result, monitoring and surveys on the Athabasca River system have increased substantially since 1987.

The findings of monitoring and surveys in 1988 and 1989 have been reported by Noton and Shaw (1989). The purpose of this report is to present the findings of the 1990-93 oxygen monitoring and surveys on the Athabasca River system. Data are presented and described for winter synoptic surveys, recording oxygen meters, and network monitoring sites. Some data prior to 1990 are also included for comparison. A detailed interpretation of DO conditions upstream of Hinton (headwaters) is provided, since headwater oxygen input is an important factor influencing DO conditions downstream. The headwater interpretation is a contribution to the larger evaluation of winter oxygen dynamics and oxygen modelling being carried out by the Northern River Basins Study (NRBS), the Alberta Forest Products Association (AFPA), and Alberta Environmental Protection (AEP).

2.0 METHODS

The data collection program on the Athabasca River system in the 1990-93 period has been of three types: an annual winter 'synoptic' survey; recording oxygen meters; and a network of medium- or long-term fixed sites. These are described below. The general field and lab procedures used were common to each type.

2.1 GENERAL FIELD PROCEDURES

River grab samples were collected in the channel centre, from holes drilled through the ice or from open water leads. For ice conditions, the samples were taken from below the ice surface. Oxygen was measured with calibrated, polarographic meters (Hydrolab Corp. models 4041 and H2O) and with the azide-Winkler method at most locations. Samples for Winkler analysis were collected in replicate with a displacement-type APHA sampler (Greenberg et al. 1992) which fills the sample bottles through tubes inserted to the bottom of the bottle, overflowing 2-3 times the bottle volume. Samples were fixed on site with manganous sulphate and alkali-iodide-azide. Oxygen in effluent was usually measured with meters because of the possibility of chemical interference in the Winkler method.

2.2 SYNOPTIC SURVEYS

During 1990-93, the winter synoptic water quality surveys were carried out once each year, in the January-March period. About 60 sampling sites have been included, involving mainstem, tributaries, and effluents (Figure 1). The sampling started upstream of Hinton and progressed downstream at approximately the river's time of travel to Lake Athabasca. A number of other variables besides oxygen were sampled during these surveys as well.

2.3 RECORDING OXYGEN METERS

Dissolved oxygen was measured at selected sites with recording, submersible polarographic meters (Hydrolab Corp., Data Sondes I, IIH, and H2O) in order to more thoroughly monitor conditions at important locations (Figure 2). The meters were deployed under the ice in protective cages, near channel centre or to one side provided that the channel was well mixed with respect to DO. This was checked on a cross channel transect. The meters measured and recorded DO at hourly or half-hourly intervals and were left *in situ* for

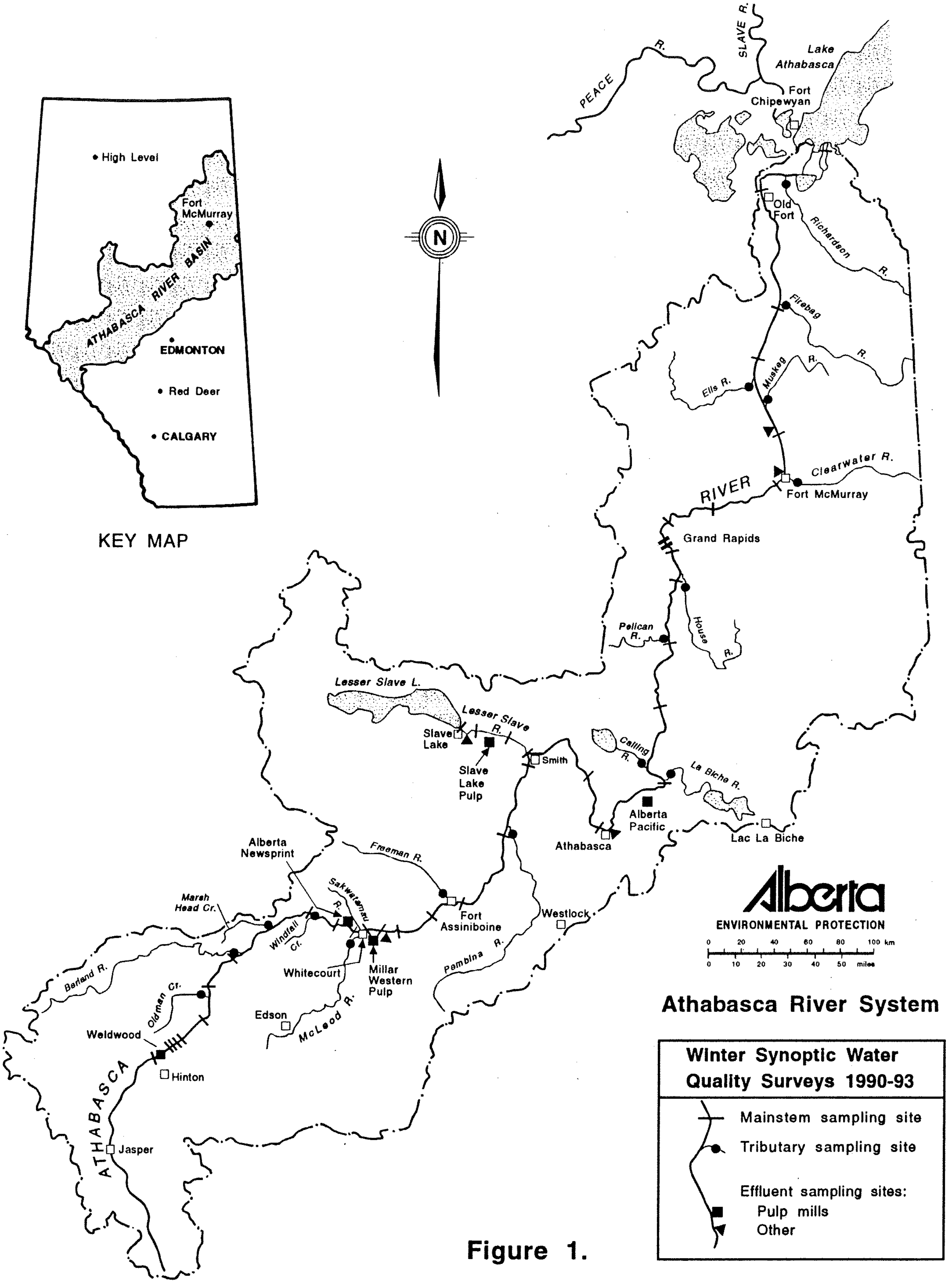

Figure 1.

E.A.MOTTON-4

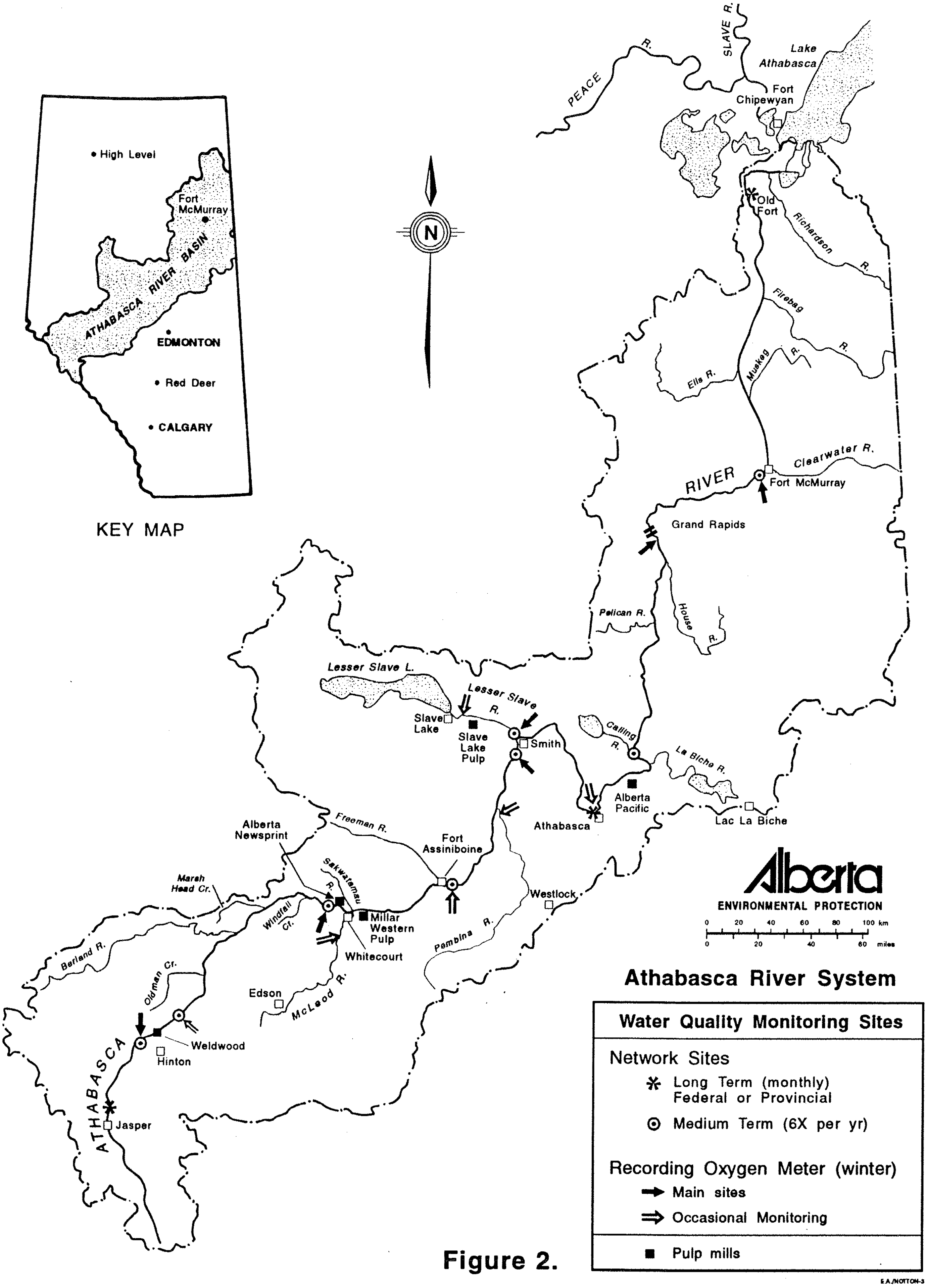
High Level
Fort McMurray
ATHABASCA RIVER BASIN
EDMONTON
Red Deer
CALGARY
KEY MAP
N
PEACE R.
SLAVE R.
Lake Athabasca
Fort Chipewyan
Old Fort
Richardson R.
Firebag R.
Muskeg R.
Ells R.
Clearwater R.
RIVER
Fort McMurray
Grand Rapids
House R.
Pelican R.
Lesser Slave L.
Lesser Slave R.
Slave Lake
Slave Lake Pulp
Smith
Calling R.
La Biche R.
Alberta Pacific
Athabasca
Lac La Biche
Freeman R.
Fort Assiniboine
Alberta Newsprint
Sakwatamau R.
Marsh Head Cr.
Windfall Cr.
Millar Western Pulp
Whitecourt
Westlock
Pembina R.
Berland R.
Oldman Cr.
Edson
McLeod R.
Weldwood
Hinton
ATHABASCA
Jasper
Alberta
ENVIRONMENTAL PROTECTION
0 20 40 60 80 100 km
0 20 40 60 miles
Athabasca River System
Water Quality Monitoring Sites
Network Sites
✻ Long Term (monthly) Federal or Provincial
⊙ Medium Term (6X per yr)
Recording Oxygen Meter (winter)
➡ Main sites
⇒ Occasional Monitoring
■ Pulp mills
E.A./NOTTON-3

Figure 2.

periods up to 2 weeks. Samples for Winkler analysis were taken at installation and retrieval, and occasionally in between. The recorded data were recovered on retrieval of the instrument, although selected sites were configured with telemetering such that data were transmitted daily to Edmonton. This involved connecting the meter to a data control platform (Handar 570A) coupled with a satellite radio transmitter. Transmission was via the GOES satellite system. Data were downloaded daily from these sites by River Forecast Centre (AEP) into the Water Resources Data Acquisition System (DACQ).

2.4 NETWORK SITES

Two long-term and seven medium-term monitoring sites are operated on the Athabasca River system by Alberta Environmental Protection (AEP). An additional long-term site is operated by Environment Canada and an additional medium-term site was started in 1993 by AEP near the Calling River (Figure 2). Oxygen has been sampled monthly at the long-term sites and 6 times per year at the medium-term sites, using Winkler and meter methods.

2.5 LAB PROCEDURES AND DATA HANDLING

The azide-Winkler analyses were carried out within 24 hr. of sample collection, using regularly standardized titrant as per 'Standard Methods' (Greenberg et al. 1992). All data from Winkler and meter measurements were inspected by the sampler and project manager. Aberrant data were discarded if there was reason to suspect a problem in the collection or analysis. Oxygen data from the recording meters had to be within 0.5 mg/L of paired Winkler analyses or the meter data were discarded for that period. Verified data were stored electronically and transferred to spreadsheets for compilation and graphing.

2.6 HEADWATER OXYGEN ASSESSMENT

Data were assembled for the Athabasca River in the Hinton - Entrance reach. Historical dissolved oxygen data obtained by the Winkler method for the December through March period were compiled from NAQUADAT and data files of the Water Quality Section. Data prior to 1970, which had not been entered in NAQUADAT, were screened for anomalies and some excluded as a result. The sampling prior to the recent 1988-93 work utilized the azide-Winkler method and the same field and lab techniques as described above (R. Tchir, pers. comm.).

Discharge data were obtained from the Water Survey of Canada for the Athabasca River at Hinton (station 00AL07AD002) or at Entrance (00AL07AD001). Climate data were obtained from the Atmospheric Environment Service, Canada, for Entrance (station 3062440), Hinton (3063340), Jasper (3053520) and Ft. McMurray (3062693). Some of the 1993 discharge and climate data are still preliminary. Recent data for the Jasper sewage effluent were obtained from Municipal Branch, Alberta Environmental Protection (AEP). Literature concerning oxygen under ice in rivers was searched in the data base "Water Resources Abstracts".

3.0 RESULTS AND DISCUSSION

3.1 ATHABASCA RIVER MAINSTEM

3.1.1 Synoptic Surveys

Most of the work on oxygen has focused on Athabasca River mainstem sites. The results of the synoptic surveys are compiled in Appendix 1 and the Winkler DO data are graphed in Figure 3. The method of the synoptic surveys has been to sample the river by travelling downstream at the same rate as the river water travels so that the same 'parcel' of water, more or less, is being sampled. Figure 3 therefore represents DO conditions and how they changed in the parcel sampled during each of the 4 years. Also shown is the 100% saturation concentration for the prevailing winter water temperature of 0°C. The saturation value increases downstream because of decreasing elevation and increasing atmospheric pressure. Another purpose of these surveys has been to sample during mid- to late- winter, when DO is likely to be at its lowest. However, because each winter varies and conditions can not be forecast accurately, the synoptic surveys have not always coincided with the winter low. This can be seen in the results from the recording meters, described in the next section.

During the surveys, DO declined in a downstream direction from about 11-12 mg/L in the Hinton area to 8.5-10.2 mg/L upstream of the Lesser Slave River inflow (Figure 3). This river has had higher DO concentrations than the Athabasca in winter and consequently has boosted DO in the latter, in proportion to its contribution to the combined volume of flow. This was quite noticeable in 1990 (Figure 3). Downstream of the Lesser Slave, concentrations then declined to 8.5-9.5 mg/L upstream of Grand Rapids. The rapids provide significant reaeration, accounting for the sharp increase in DO there. The rising DO upstream of Grand Rapids in 1993 (Figure 3) was probably due to photosynthesis under ice (discussed in Section 3.1.4.1), which also produced supersaturated conditions between Grand Rapids and Ft. McMurray. In the other three years, oxygen resumed its gradual decline downstream of the rapids, reaching levels of 10-11 mg/L in the Athabasca Delta.

This general downstream decline was also observed during the 1988-89 surveys (Noton and Shaw 1989), although much lower levels occurred during some surveys in those years (Figure 4). The March 1989 condition was attributable in part to the input of high BOD loads from pulp mills that winter (Figure 5), including that from the new pulp mill at

Figure 3. ATHABASCA RIVER - WINTER SYNOPTIC SURVEYS - 1990-93 - OXYGEN

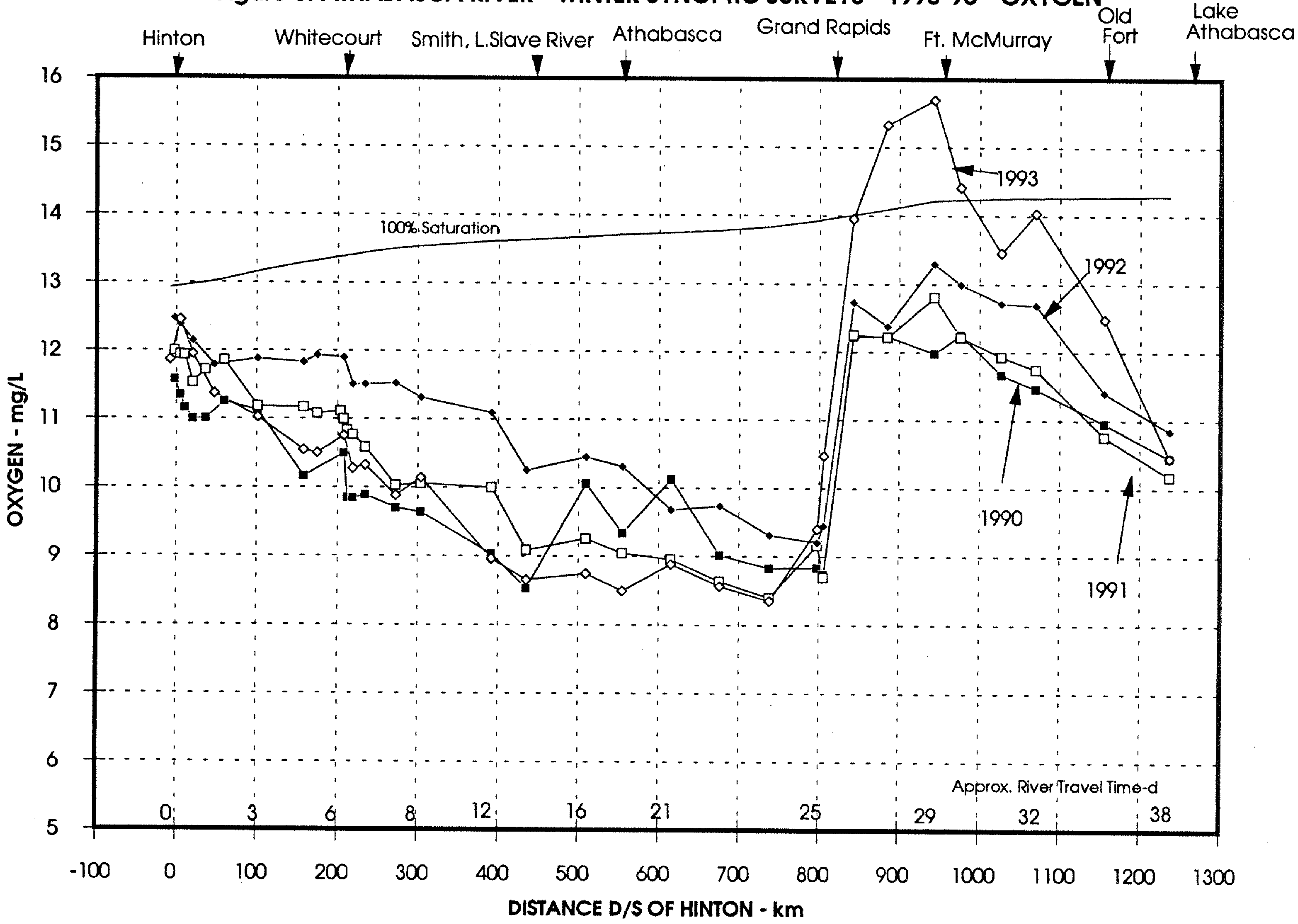

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Figure 4. ATHABASCA RIVER - WINTER SYNOPTIC SURVEYS - 1989,90,93 - OXYGEN

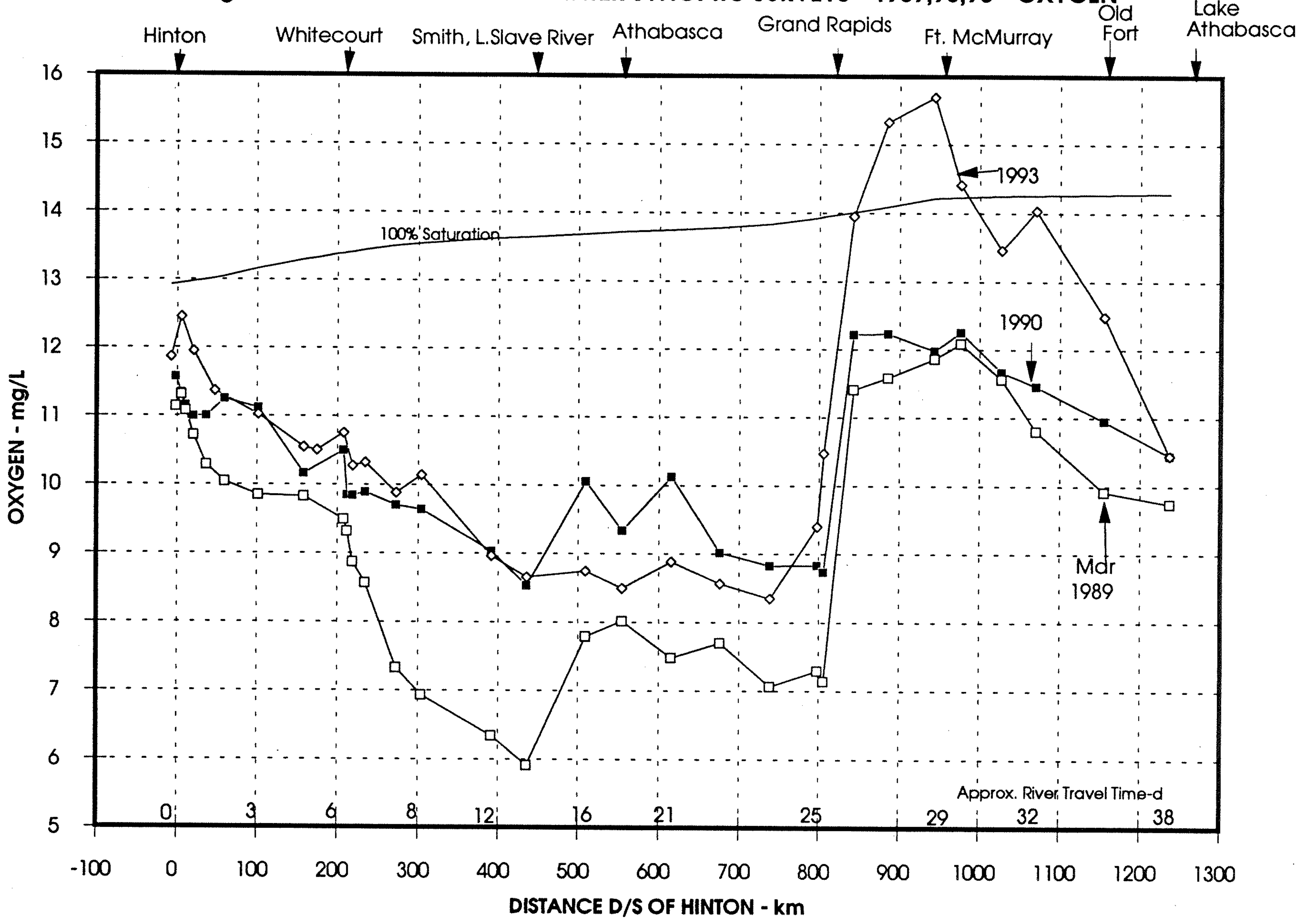

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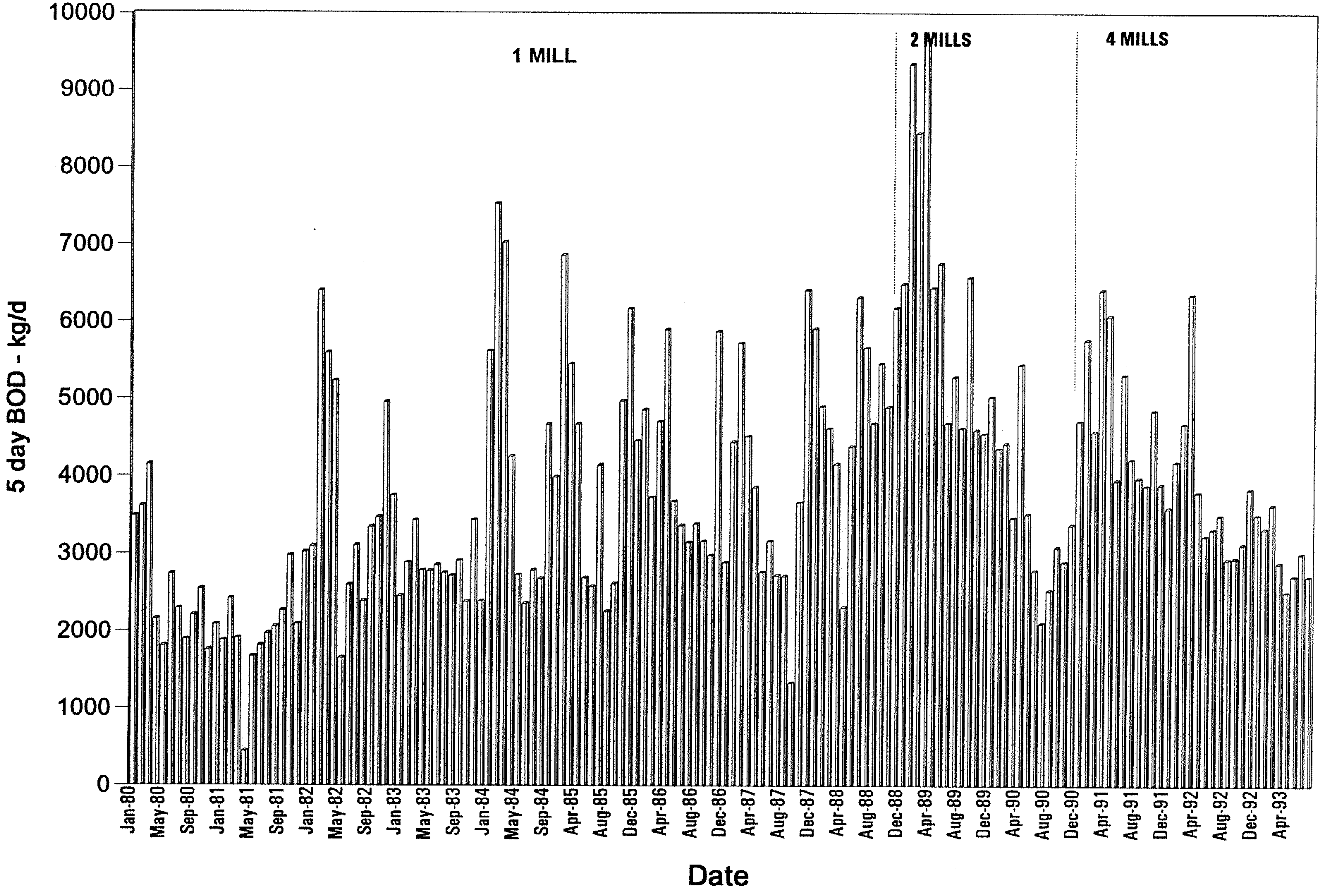
FIGURE 5. TOTAL PULP MILL BOD LOADING TO THE ATHABASCA RIVER 1980 - 1993 (Monthly Averages)



Whitecourt. Such loads were lower in 1990-93. A general downstream decline in DO in ice-covered rivers in winter has been observed in other northern areas and may be a normal condition (Schallock and Lotspeich 1974; Schreier et al. 1980; Whitfield and McNaughton 1986). A more complete assessment of all factors controlling winter DO in the Athabasca mainstem is underway by the NRBS, the AFPA, and AEP.

3.1.2 Recording Oxygen Meters

Monitoring with the recording oxygen meters has concentrated on locations where the potential sag in DO has been of most concern, for example u/s of Smith, u/s of Grand Rapids, and at Windfall (Table 1). Other locations on the Athabasca mainstem have also been monitored at a lower intensity. Mean daily DO from the five main sites (upstream of Hinton, Windfall, u/s of Smith, u/s of Grand Rapids, u/s of Ft. McMurray) are graphed in Figures 6 to 10 respectively, and discussed briefly below. Data for the 1989-93 period are included. The recordings from the five sites for the most recent year, 1993, are graphed together in Figure 11.

Table 1. List of continuous oxygen recordings to 1993, Athabasca River system

LOCATIONS	WINTER OF:				
	88-89	89-90	90-91	91-92	92-93
AR u/s Hinton	J,F,M, a	j,f	d,J,F,m		J,F
AR at Obed Coal Br.	m				
AR at Windfall Br.	J,F,M	J,F,M	d,J,F,M	J,F	J,F,M
McLeod R. at Mouth	j,f				
AR at Ft. Assiniboine	f				
Pembina R. at Mouth	m,a				
AR u/s Smith	J,F,M	J,F,M	J,F,M,a	d,J,F,M	J,F,M
Lesser Slave River					
- Mitsue Bridge			J,F,m		
- Mouth	m	J	F,M	f,m	J,F,M
AR at Athabasca	J,F,M				
AR u/s Grand Rapids	f,m	J,F,M	J,F,M,a	j,F,M	J,F,M
AR d/s Grand Rapids	f,m				
AR u/s Ft. McMurray	F,M,a	J,f,M	m	M	J,F,M

AR = Athabasca River; D = December; J = January; F = February; M = March; A = April
Lower case indicates less than half the month recorded.

FIGURE 6. ATHABASCA RIVER u/s of HINTON
Winter Dissolved Oxygen

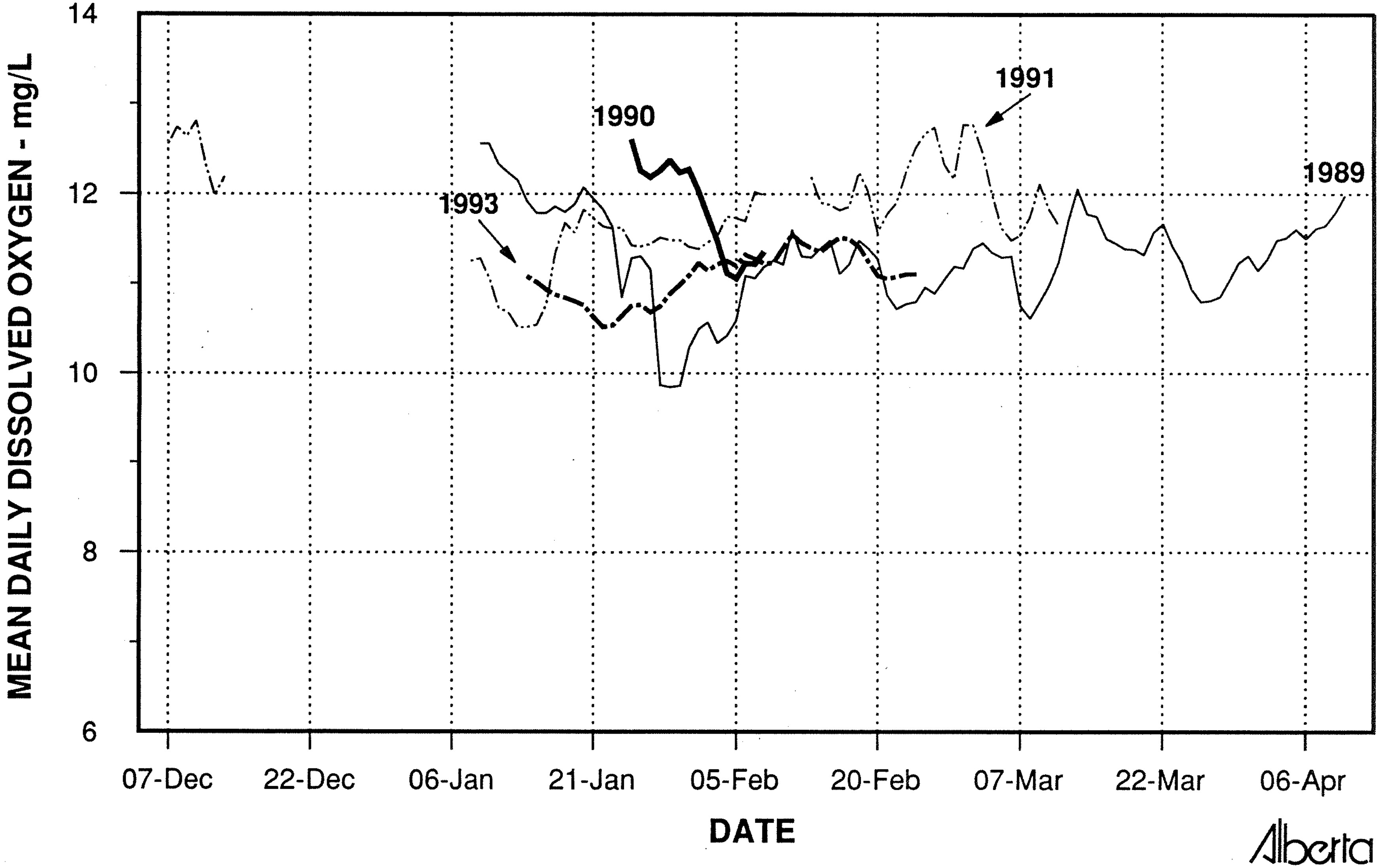


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FIGURE 7. ATHABASCA RIVER at WINDFALL BRIDGE
Winter Dissolved Oxygen

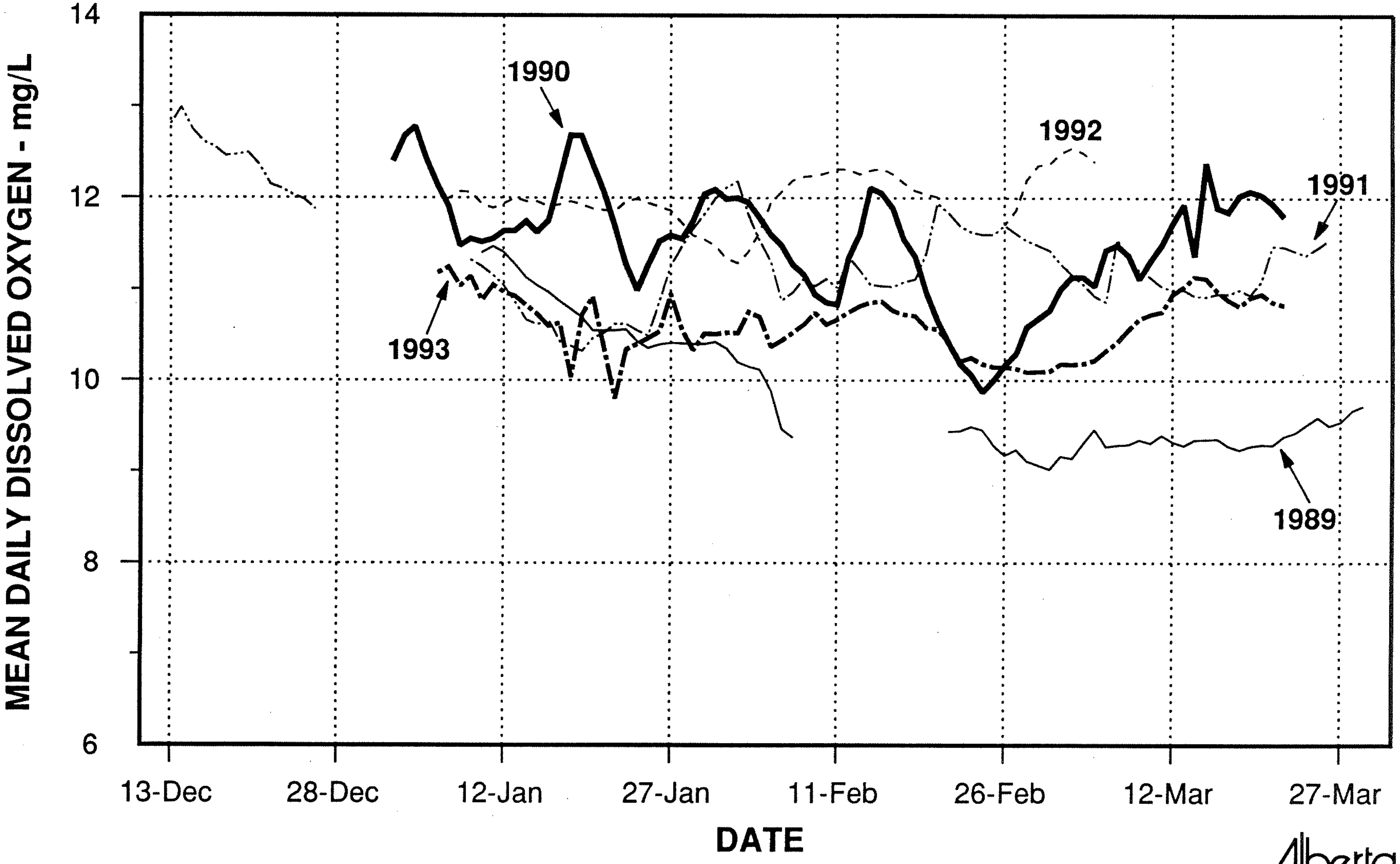

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FIGURE 8. ATHABASCA RIVER u/s of SMITH
Winter Dissolved Oxygen

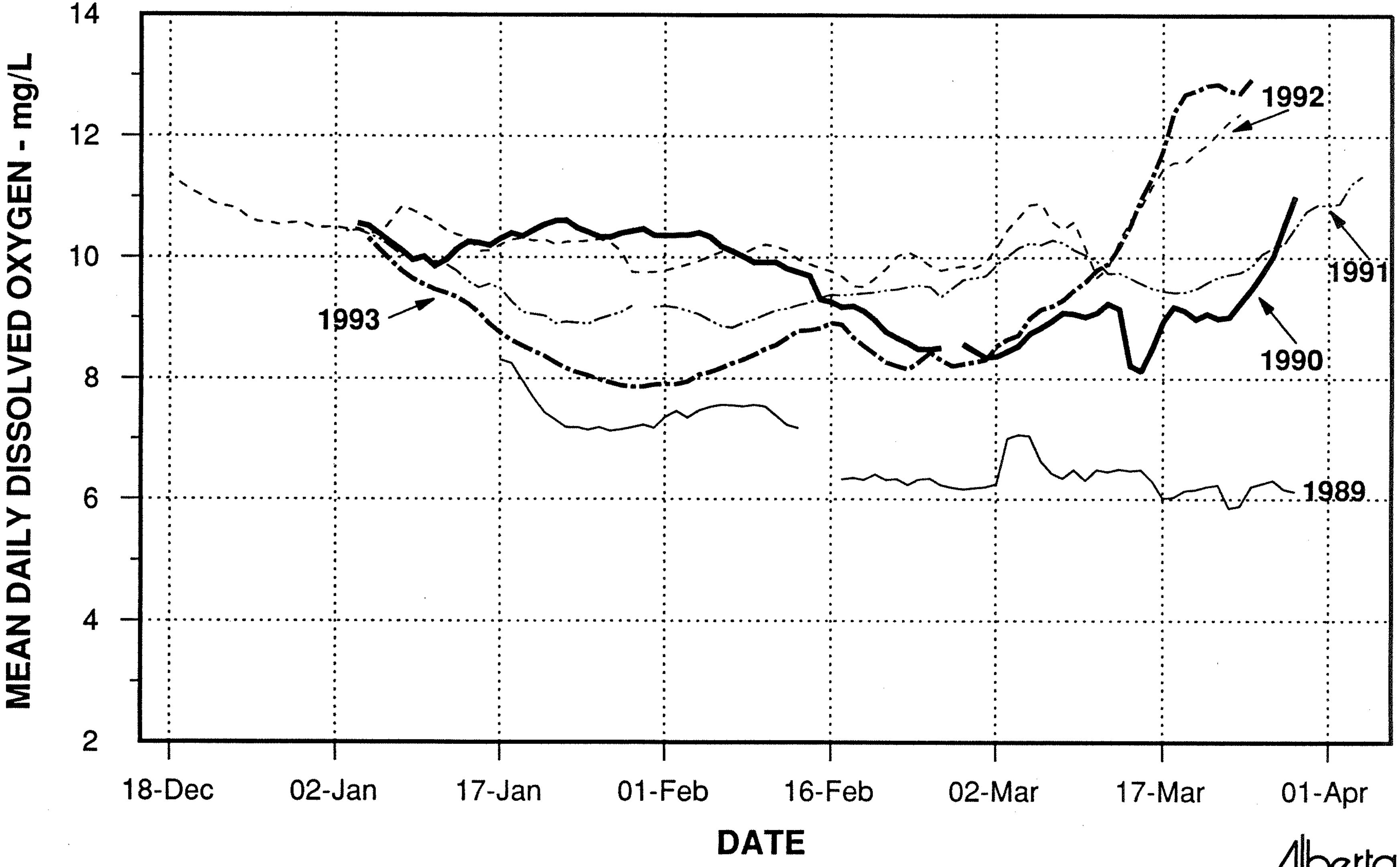

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FIGURE 9. ATHABASCA RIVER u/s of GRAND RAPIDS Winter Dissolved Oxygen

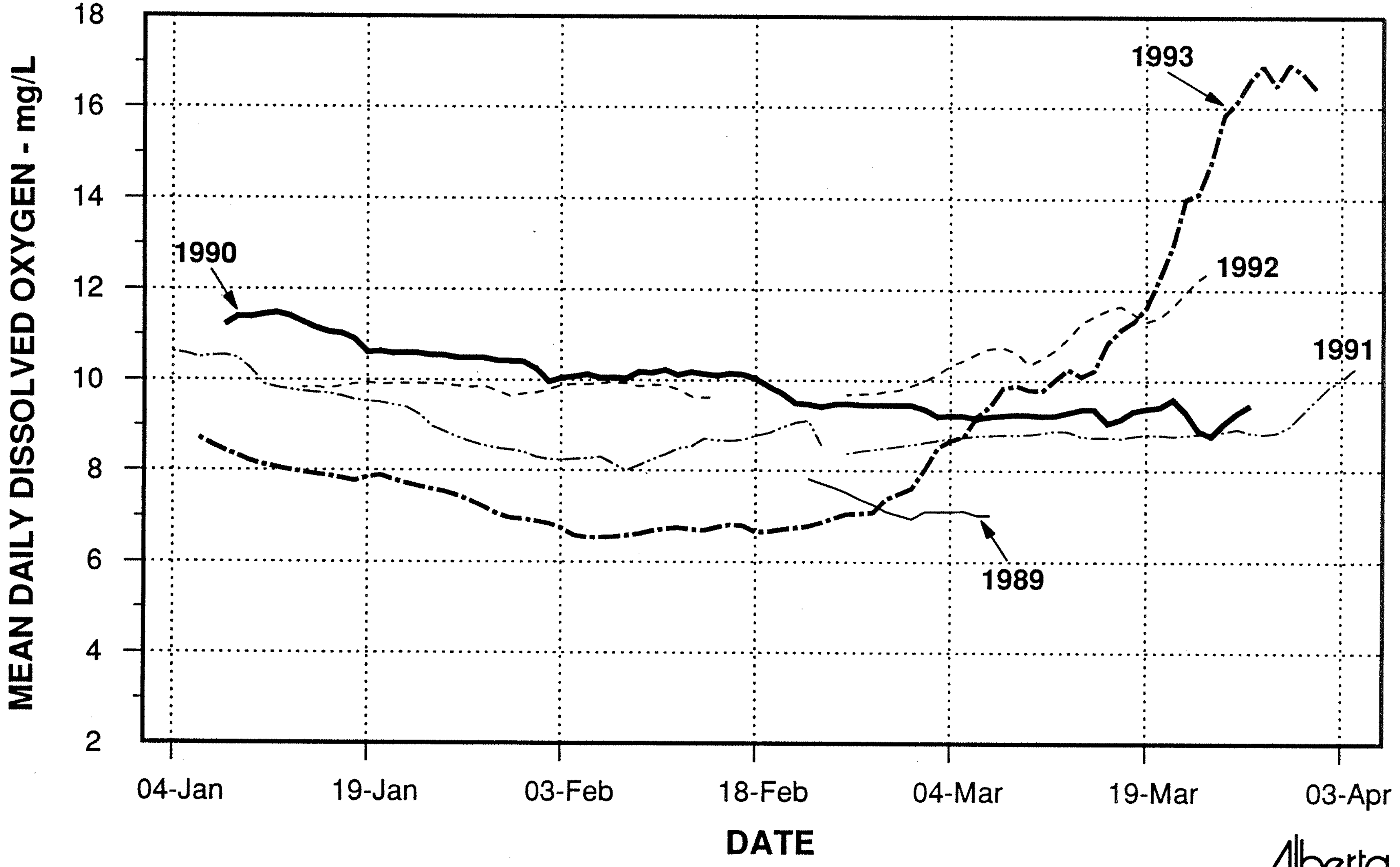

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FIGURE 10. ATHABASCA RIVER u/s of FORT MCMURRAY
Winter Dissolved Oxygen

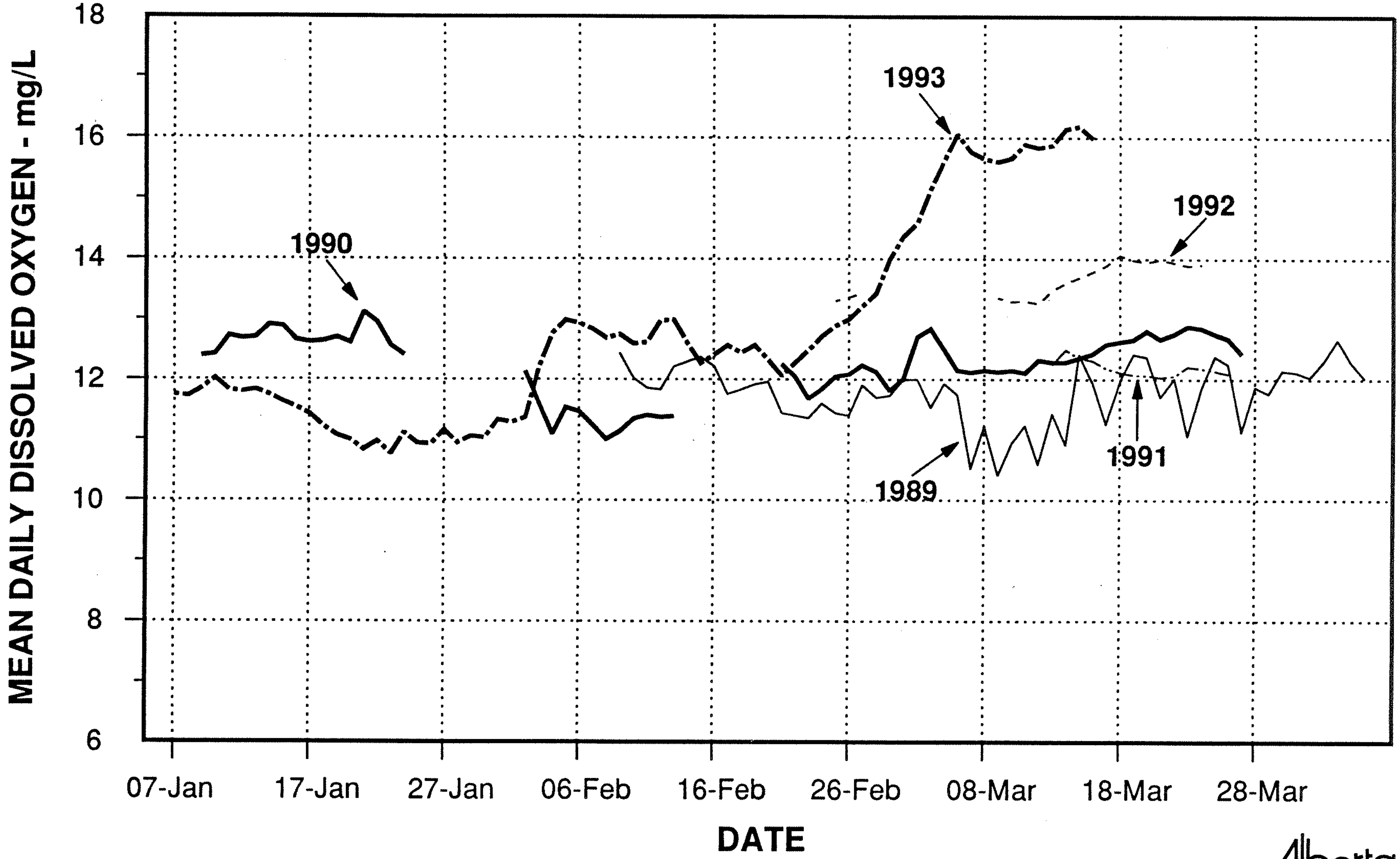

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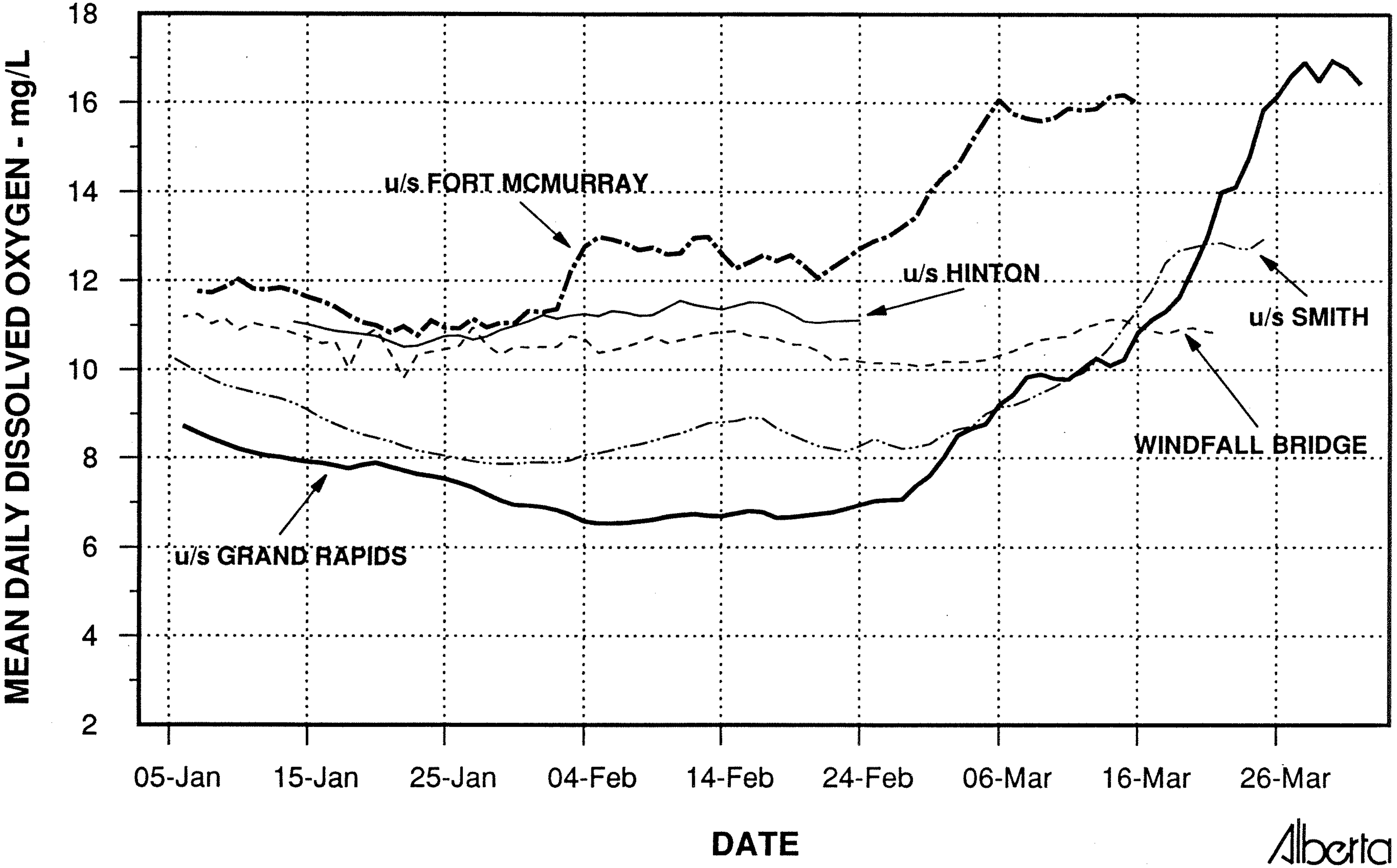
FIGURE 11. ATHABASCA RIVER
Winter Dissolved Oxygen 1993



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3.1.2.1 Upstream of Hinton

Continuous recording of DO has been done in the Athabasca River at or upstream of Hinton in the winters of 1989,-90,-91, and -93 (Figure 6). The installation in 1989 was in the intake of the Hinton pulp mill while in subsequent winters the meters were installed directly in the river. Dissolved oxygen during the January-March period has been in the 10-13 mg/L range, with a typical fluctuation of 2 mg/L during the January-February period of any given year. Oxygen conditions in these headwaters are discussed further in Section 3.1.5.

3.1.2.2 Windfall

This site is at the bridge near Windfall, u/s of the new mills at Whitecourt (Figure 2), where recordings have been taken in the years 1989-1993 inclusive (Figure 7). Oxygen has tended to fluctuate in the 10 to 12 mg/L range in the January - March period, with 1989 having had the lowest concentrations.

3.1.2.3 Upstream of Smith

Oxygen has been monitored at or near the Hwy #2 bridge, which is u/s of Smith and the Lesser Slave River inflow (Figure 2), for all of the five years (Figure 8). In the January - mid-March period, DO has generally fluctuated in the 8 to 11 mg/L range, with the exception of 1989 when it was in the 6 to 8 mg/L range. There was a combination of lower than average flow, a new pulp mill at Whitecourt discharging significant amounts of BOD, and a fairly long, cold winter that year, all of which may have contributed to the low DO. In the second half of March of 1990-93, DO rose with the onset of warmer weather, particularly in 1993 when there appeared to be photosynthetic production of oxygen under the ice. This is discussed further in Section 3.1.5.

3.1.2.4 Upstream of Grand Rapids

This location is just upstream of Grand Rapids, in which major reaeration occurs and boosts DO. The monitoring site is thus at the point of lowest DO in this reach of the river, sometimes termed the 'sag point'. In the January to mid-March period, DO has generally been in the 7 to 11 mg/L range with 1993 and 1989 having the lowest levels (Figure 9). In the four years with fairly complete records, the time of the winter minimum has ranged from February 4 to March 24, perhaps in response to the particular weather conditions at the time. Note that the synoptic surveys (Figure 3) have not always coincided with the lowest DO at this site in any given winter. In 1993, DO rose to supersaturated levels in late March, as a result of photosynthesis under the ice. This is discussed further in Section 3.1.5.

3.1.2.5 Upstream of Fort McMurray

Oxygen concentrations upstream of Fort McMurray have generally been between 11 and 13 mg/L (Figure 10). The main exception to this occurred in late winter 1993 when DO rose to about 16 mg/L as a result of the photosynthesis under ice mentioned earlier. Day-to-day fluctuations in DO were greatest in 1989, however, the meter was situated in the city water intake that year, and experience indicated that meters in water intakes exhibited greater fluctuations than did those in the river, even though they met the ±0.5 mg/L criteria.

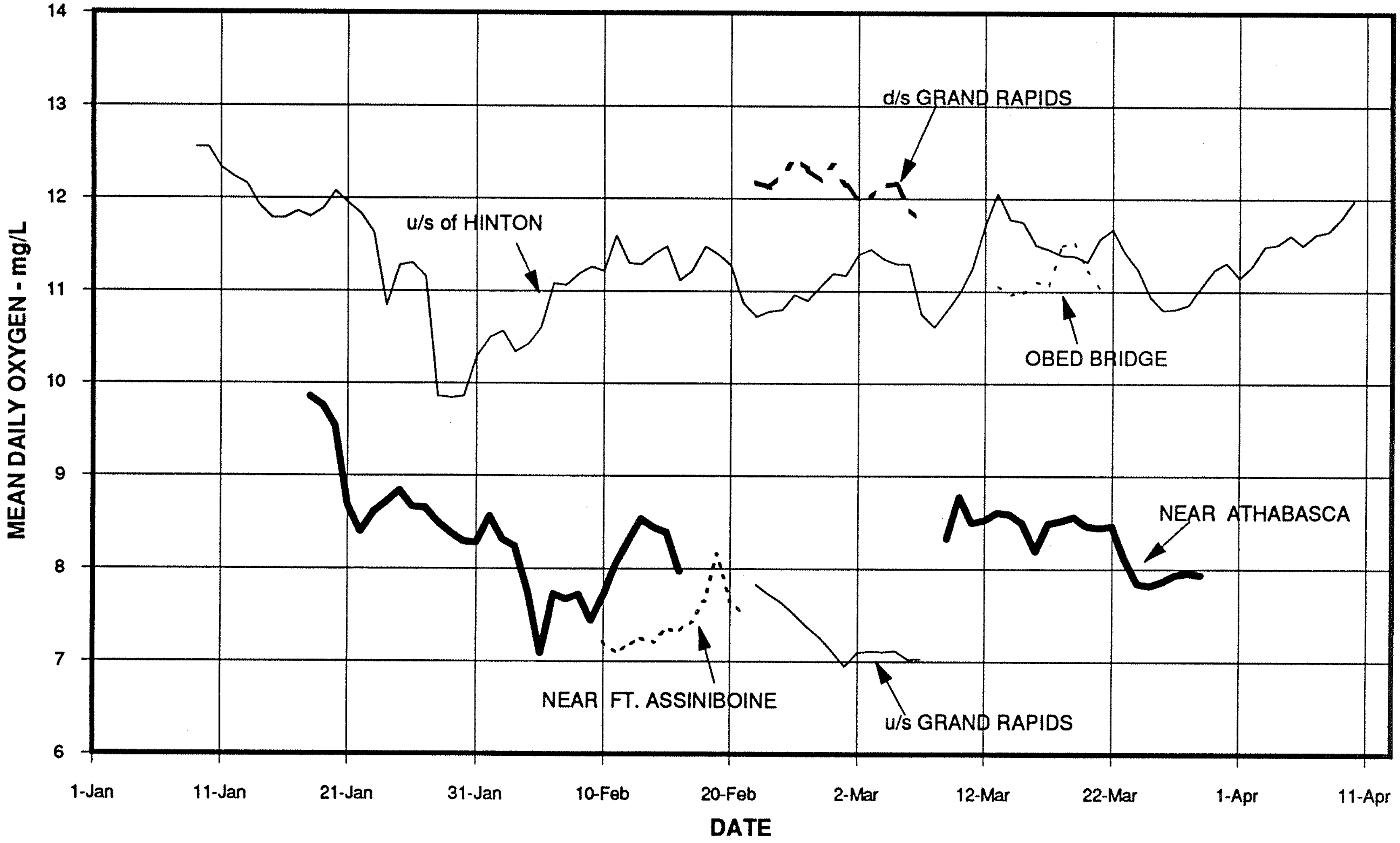
3.1.2.6 Other Athabasca River Sites

In 1989, oxygen recordings were made at some additional sites, including Obed Bridge, Fort Assiniboine, Town of Athabasca, and immediately downstream of Grand Rapids. The data are plotted in Figure 12, along with the data from u/s of Hinton and u/s of Grand Rapids for comparison. Note that DO at Obed Bridge, some 20 km d/s of Hinton, was similar to DO u/s of Hinton, that is, the two did not differ by more than the error of the meter during this limited sampling. However, DO d/s of Grand Rapids was about 5 mg/L higher than u/s of the rapids, reflecting the reaeration that occurs in the rapids. This boost in DO through the rapids was greater in 1989 than in 1990-93 (Figures 3 and 4), likely because DO was lower, and therefore the saturation deficit greater, u/s of the rapids in 1989.

3.1.3 Network Sites

Nine fixed monitoring sites are operated on the Athabasca River mainstem (Figure 2). Oxygen data from these sites are grab samples, and are compiled in Appendix 2 for the years 1989-93. The concentrations of DO observed at these sites in the winter are similar to those reported above from the synoptic surveys and the recording meters, where the sites and times are similar. The minimum winter DO observed in these grab samples from Old Fort, at the head of the Delta, has ranged from 10.2 mg/L to 11.2 mg/L in the 1989-

Figure 12. OTHER ATHABASCA RIVER SITES - WINTER OXYGEN - 1989



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93 period, somewhat lower than the concentrations observed during most synoptic surveys (Figure 3). During open water conditions, DO is often lower than in winter at most sites due to warmer water having less capacity to dissolve oxygen.

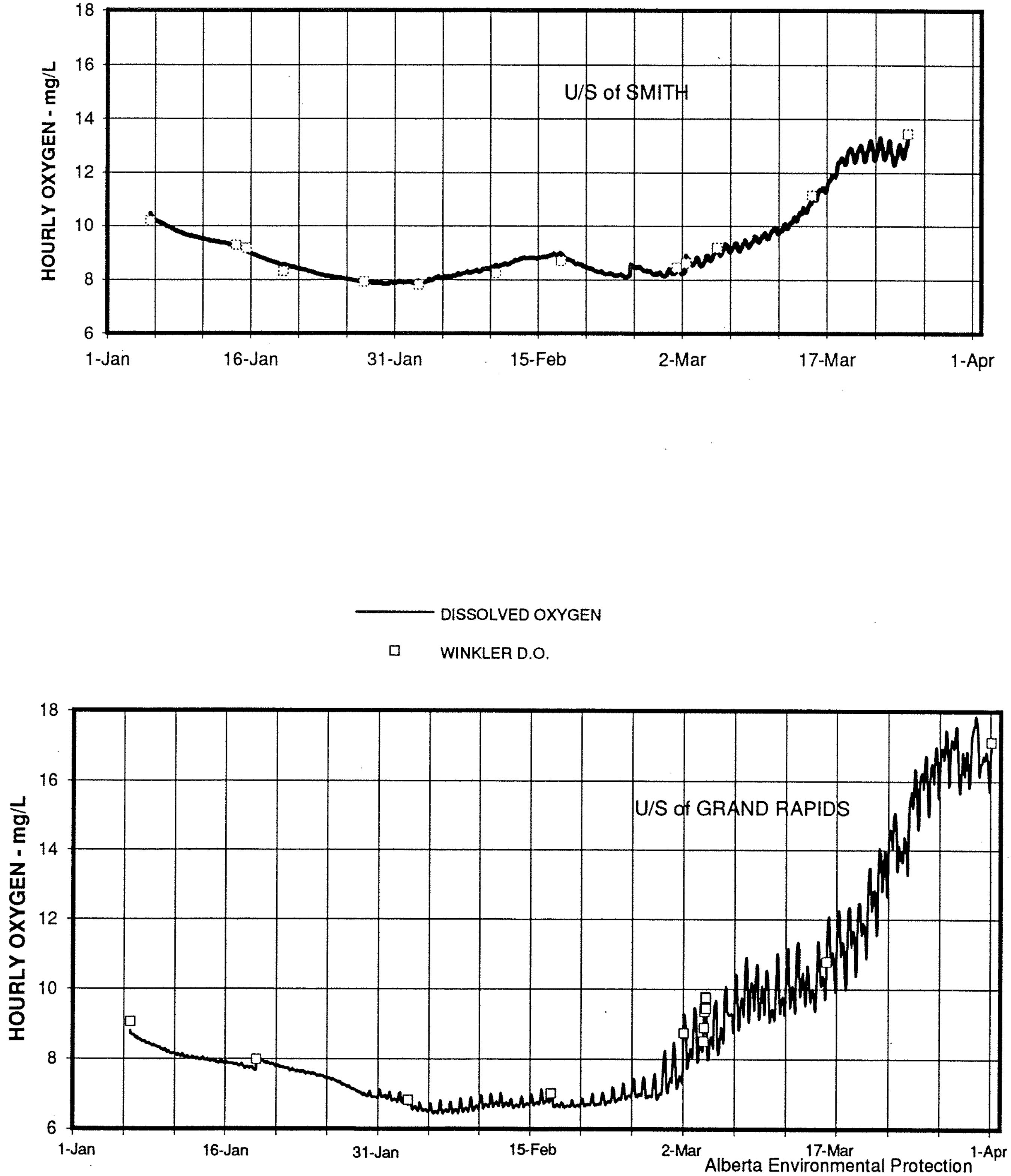
3.1.4 General

3.1.4.1 Photosynthesis Under Ice

During the winter of 1993, a noticeable diurnal cycle in DO concentrations developed at the monitoring sites u/s of Smith and u/s of Grand Rapids (Figure 13). The fluctuations were confirmed with a series of Winkler measurements and a second recording meter, installed nearby. The diurnal cycling first became evident in early February u/s of Grand Rapids and intensified with time, reaching a daily fluctuation of about 2 mg/L. Cycling u/s of Smith started later and was not as pronounced. The cause of the cycle was presumed to be photosynthesis, as evidenced by the DO peaks occurring near mid-day and by the fact that as winter progressed, more attached algae became evident on rocks and meter cages, particularly u/s of Grand Rapids. Whitfield and McNaughton (1986) noted a DO rise under ice in late winter in some Yukon rivers, which they also attributed to photosynthesis.

Diurnal cycling of DO has not been observed in every winter in which oxygen recordings have been made. Of the sites and months monitored (Table 1), no such cycling was apparent in 1988-89 nor 1989-90. In winter 1990-91 some cycling was present in March u/s of Hinton, u/s of Smith, and u/s of Grand Rapids, with the Smith site having the highest diurnal fluctuations (~0.5 mg/L). In 1991-92, slight diurnal cycles (~0.2 mg/L) were present in late February at Windfall and in March u/s of Smith. At Grand Rapids and Ft. McMurray in March 1992, DO fluctuated 0.5 mg/L diurnally. The much greater fluctuation in 1993 appears to have been due to the very thin snow cover on the river ice, a cover that became negligible by March. This allowed significant light penetration through the ice. On 5 March 1993 u/s of Smith, penetration of photosynthetically available radiation (PAR) through a variety of clear and cloudy ice types on the river ranged from 21 to 54% of incident light at mid-day. Light penetration through ice and snow cover in most years is about 1 % or less. Snow cover is probably the most significant variable influencing the magnitude of under-ice photosynthesis from year to year.

Figure 13. Athabasca River Upstream of Smith and Upstream of Grand Rapids
HOURLY DISSOLVED OXYGEN WINTER 1993



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The greater diurnal fluctuation u/s of Grand Rapids than u/s of Smith in 1993 may be related to the higher concentrations of phosphorus, nitrogen, and chlorophyll *a* in the water column at the former site (AEP unpublished data from synoptic surveys). Nutrients were even lower upstream of Hinton than at Smith and there was no discernible diurnal cycle in DO there even though snow cover was negligible there as well in 1993. The Hinton location is discussed further in Section 3.1.5. In the three years in which diurnal cycling of DO has been observed, there has been a general tendency for the magnitude of the cycling to increase downstream.

Photosynthetic production of oxygen under the ice in late March 1993 was such that DO became supersaturated at some sites. Concentrations reached 17 mg/L u/s of Grand Rapids and 16 mg/L u/s of Ft. McMurray (Figure 11), well in excess of 14 mg/L, the approximate saturation value for that elevation and a water temperature of 0°C. During supersaturated conditions Grand Rapids became a de-oxygenation feature: Winkler analysis of grab samples on 1 April, 1993, showed that DO was 17.1 mg/L u/s of the rapids but 15.2 mg/L near Buffalo Creek d/s of the rapids.

3.1.4.2 Water Quality Guidelines

The Alberta Surface Water Quality Guidelines (Alberta Environment 1993) specify a minimum of 5 mg/L oxygen at any time. All data collected on the Athabasca River in the 1990-93 period met this guideline. The Canadian Water Quality Guidelines (CWQG) recommend 6.5 mg/L for the protection of all cold water biota except early life stages (CCREM 1987). Oxygen had dropped below this value in 1989 u/s of Smith (Figure 8), but all sites were at or above this concentration in 1990-93 although DO reached 6.5 mg/L u/s of Grand Rapids in February of 1993 (Figure 9). The CWQG also recommend 9.5 mg/L for the protection of early life stages of cold water biota, based on over-wintering eggs in river gravel. Much of the middle reach of the Athabasca River has not met this guideline, however there is uncertainty as to whether this guideline is appropriate for the river. The oxygen requirements of fish of the Athabasca River are under study by the NRBS.

3.1.5 Headwater Oxygen

3.1.5.1 General Conditions

Winter oxygen conditions in the Athabasca River upstream of Hinton have been reported in several earlier studies (e.g. Alberta Health, 1968; Clayton, 1972; Hamilton et al. 1985; Noton and Shaw, 1989;), but the entire data record has not been compiled previously. The data are listed in Appendix 3 and graphed by date for all years combined in Figure 14. Over the 1956-93 period of record, lowest DO has generally occurred in early February at which time DO has averaged about 11 mg/L, with a lower limit of about 10.5 mg/L. The recent years 1989, 1991, and 1993, when recording meters have been used, have the most complete records (Figure 6). The mean lower limit in those years was 10.3 mg/L, and lows occurred from mid- to late- January. In general, the amount of fluctuation in DO during the January-February period in any given year has been about 2 mg/L. At a temperature of 0°C and the river elevation at Entrance, 100% saturation is about 12.9 mg/L, a value not exceeded by any of the meter records (Figure 6).

3.1.5.2 Factors Influencing Winter Oxygen

a. Photosynthesis

The detailed hourly DO data for u/s of Hinton were inspected for any diurnal fluctuations which might be indicative of photosynthetic production of oxygen in the river headwaters during winter. The monitoring work during the 1960's included some diurnal grab sampling and those results (AEP unpublished data) were also inspected. No diurnal fluctuation was apparent in the latter. The hourly data from the recording meters did not usually show any diurnal cycle with the exception of some occasions in the late February-March period. On those occasions DO fluctuated about 0.1-0.3 mg/L, a fairly small amount. It therefore seems unlikely that photosynthetic production is significant in the headwater oxygen balance during the January-February period of most winters. However, it may become a factor later in the winter as sun angle increases and snow and ice cover decrease.

b. Weather and Flow

In 1993, declines in DO had been observed in the Athabasca River when the weather turned cold, although usually after a lag period. River discharge (flow) was also suspected of influencing DO, and therefore climate and flow data for u/s of Hinton were assembled for the three years with the most complete DO data (1989,-91,-93). Oxygen was plotted against flow and mean daily air temperature near Entrance (Figures 15 to 17), which showed that at least in 1991 and 1993, there appeared to be a positive correlation between air temperature and DO a few days later. Linear regression analysis was performed for DO

Figure 14. ATHABASCA RIVER u/s of HINTON - WINTER OXYGEN GRAB SAMPLES - 1956-93

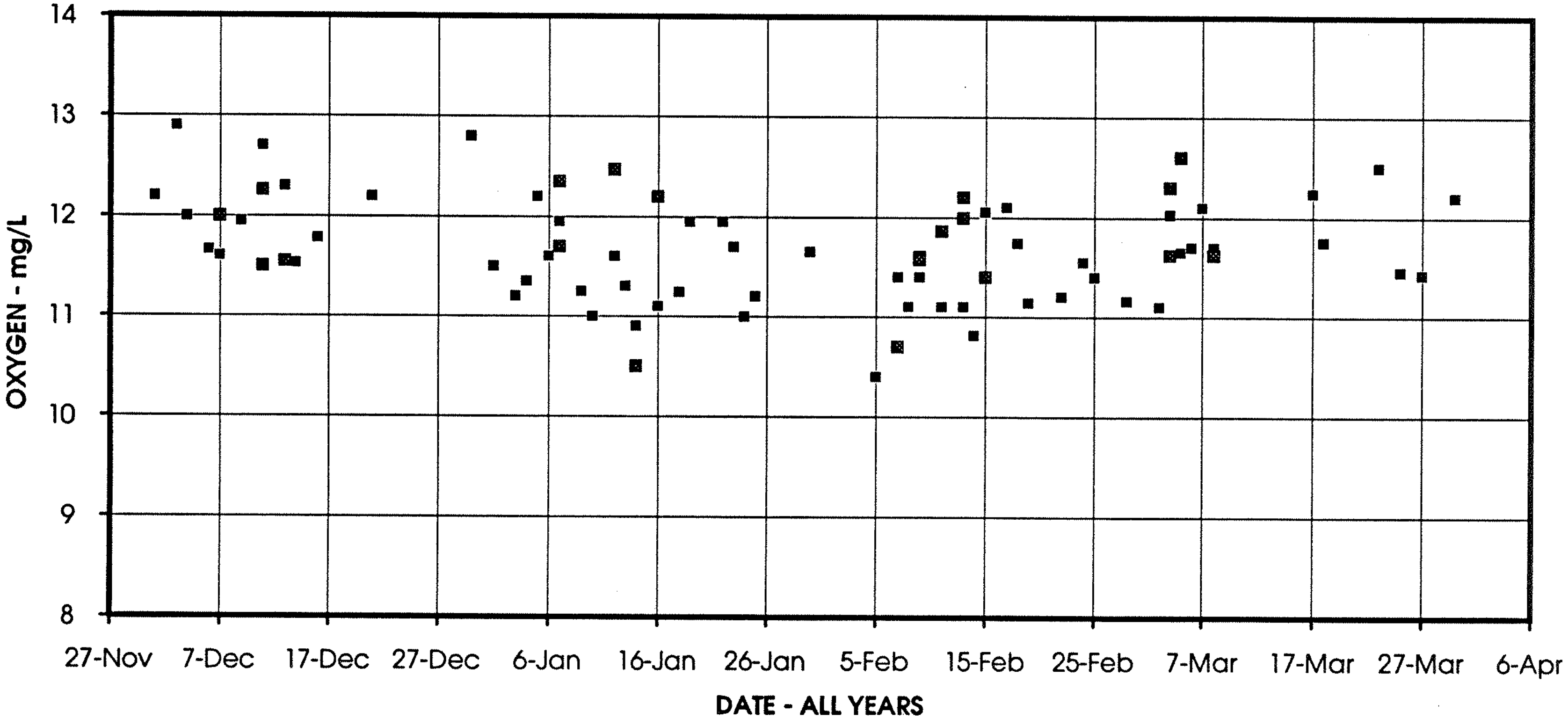

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Figure 15. ATHABASCA RIVER u/s of HINTON - AIR TEMPERATURE, OXYGEN, DISCHARGE - 1989.

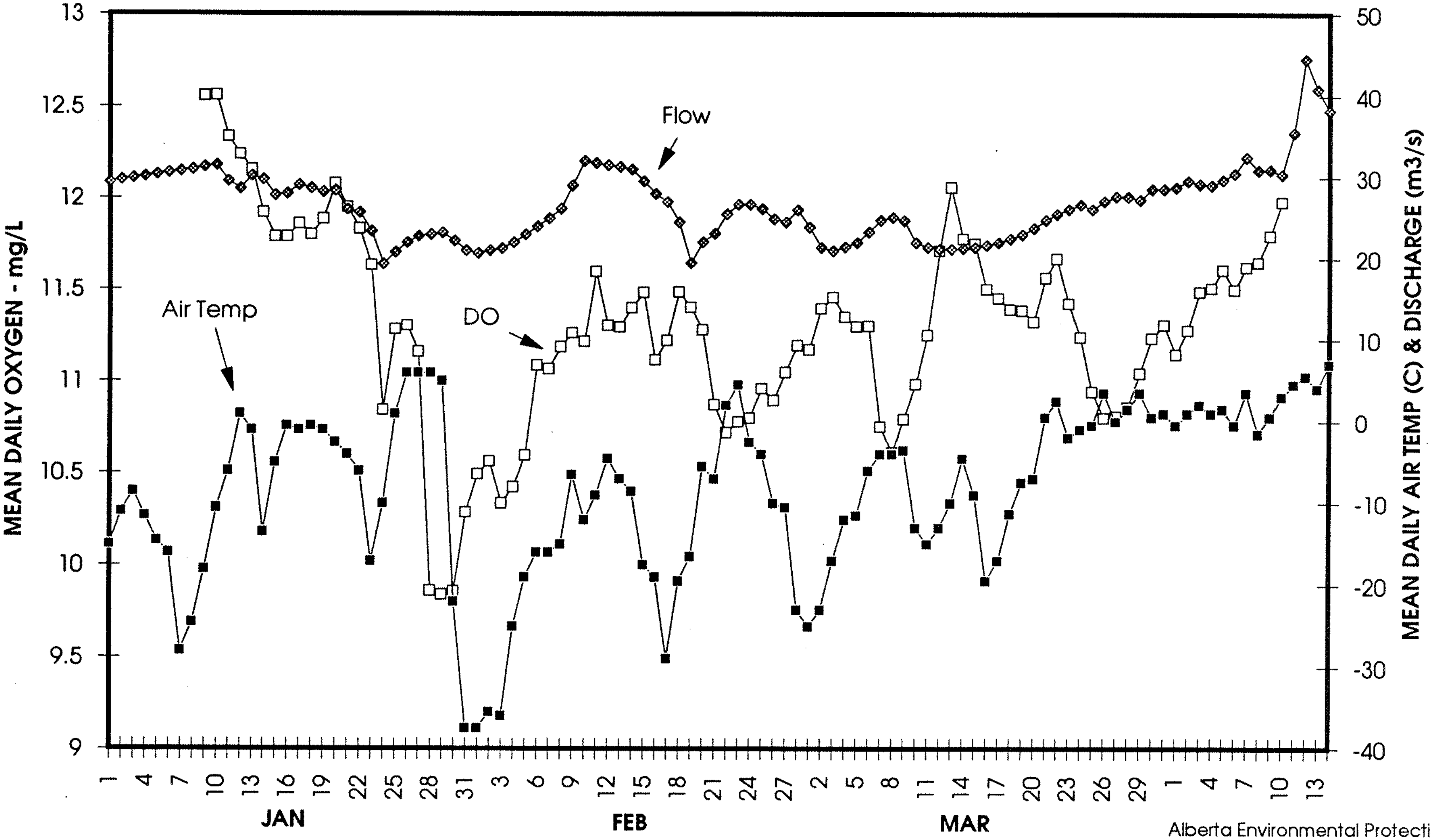

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Figure 16. ATHABASCA RIVER u/s of HINTON - OXYGEN, AIR TEMPERATURE, DISCHARGE - 1991.

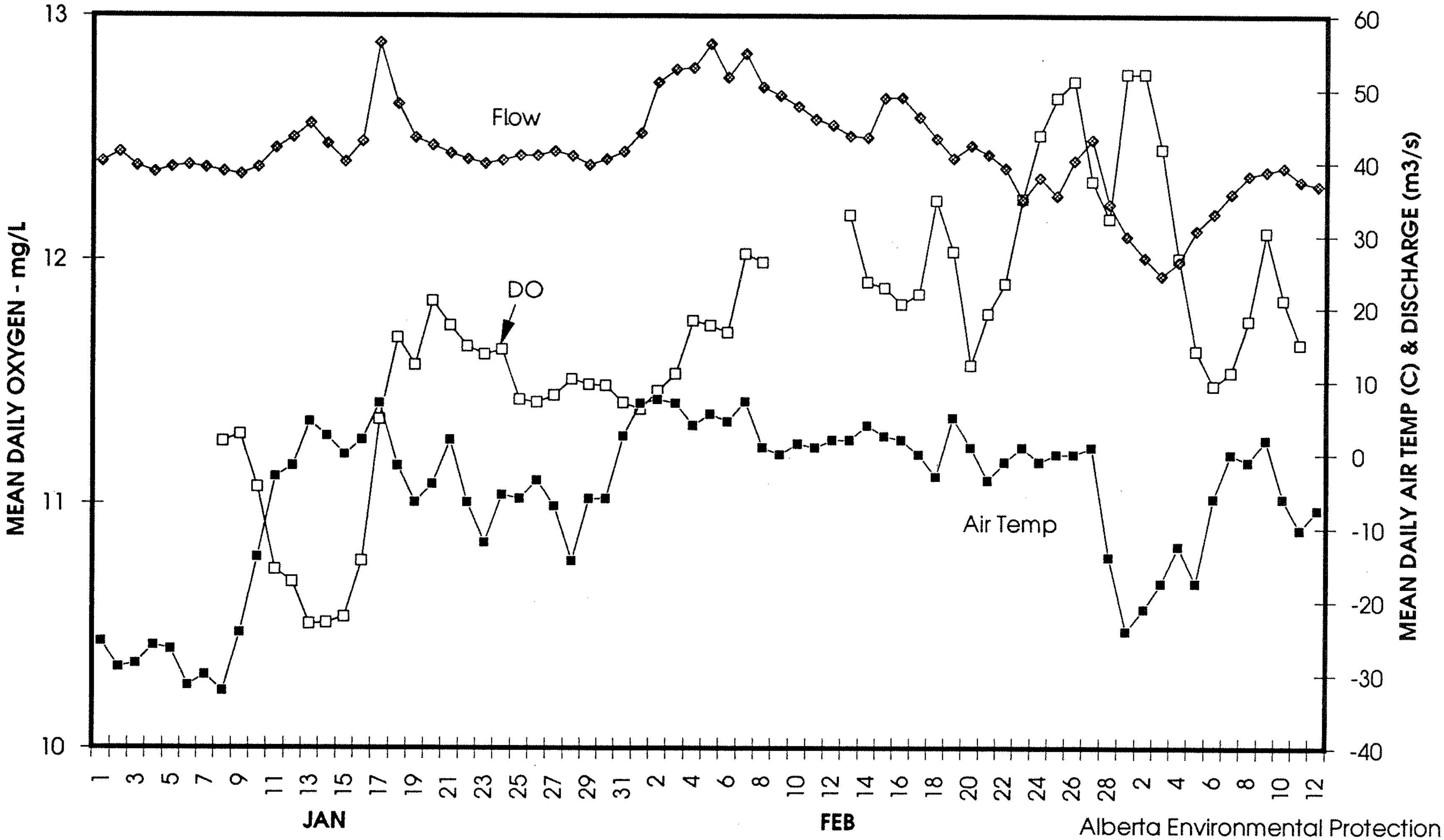

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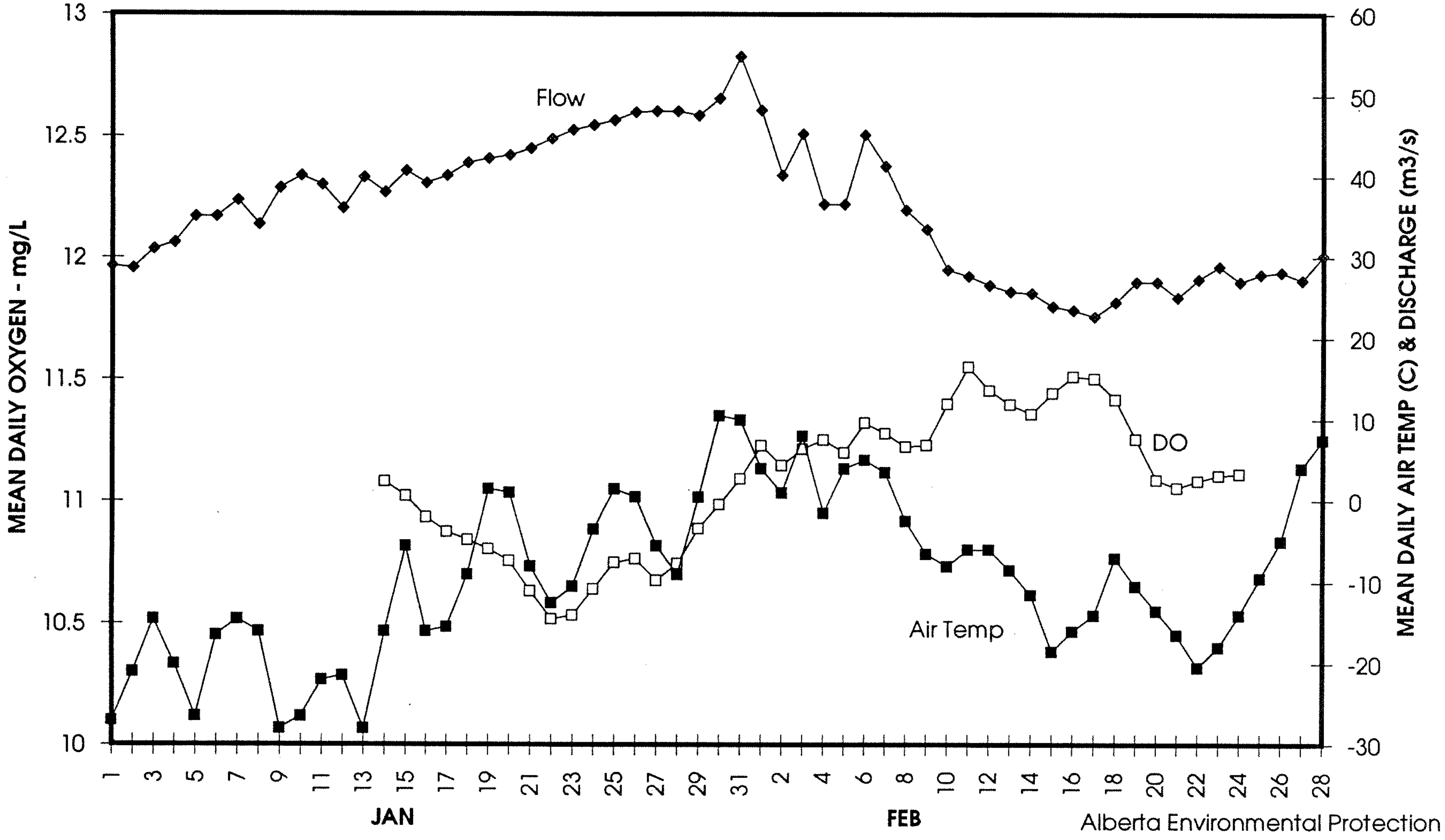
Figure 17. ATHABASCA RIVER u/s of HINTON - AIR TEMPERATURE, OXYGEN, DISCHARGE - 1993.



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with flow, and DO with air temperature, for lag periods of 3 to 14 days. Significant relationships ($p<0.01$) were found between DO and air temperature near Entrance in 1991 and 1993 (Figure 18). Table 2 lists the coefficient of determination (r^2) for the lag periods having the highest r^2 of those tested (the 'optimal' lag).

Table 2. Relationships of oxygen to air temperature and flow, upstream of Hinton.

YEAR	OXYGEN AND TEMP			OXYGEN AND FLOW	
	Optimal lag	r^2 Entrance	r^2 Jasper	Lag	r^2
1989					
Jan-Mar	8 d	0.01	0.04	4 d	0.33**
Feb-Mar	7 d	0.07			
1991	7 d	0.48**	0.51**	7 d	0.01
1993	12 d	0.73**	0.75**	12 d	0.19

Note DO and flow from u/s of Hinton; air temp from Entrance or Jasper as shown. **$p<0.001$

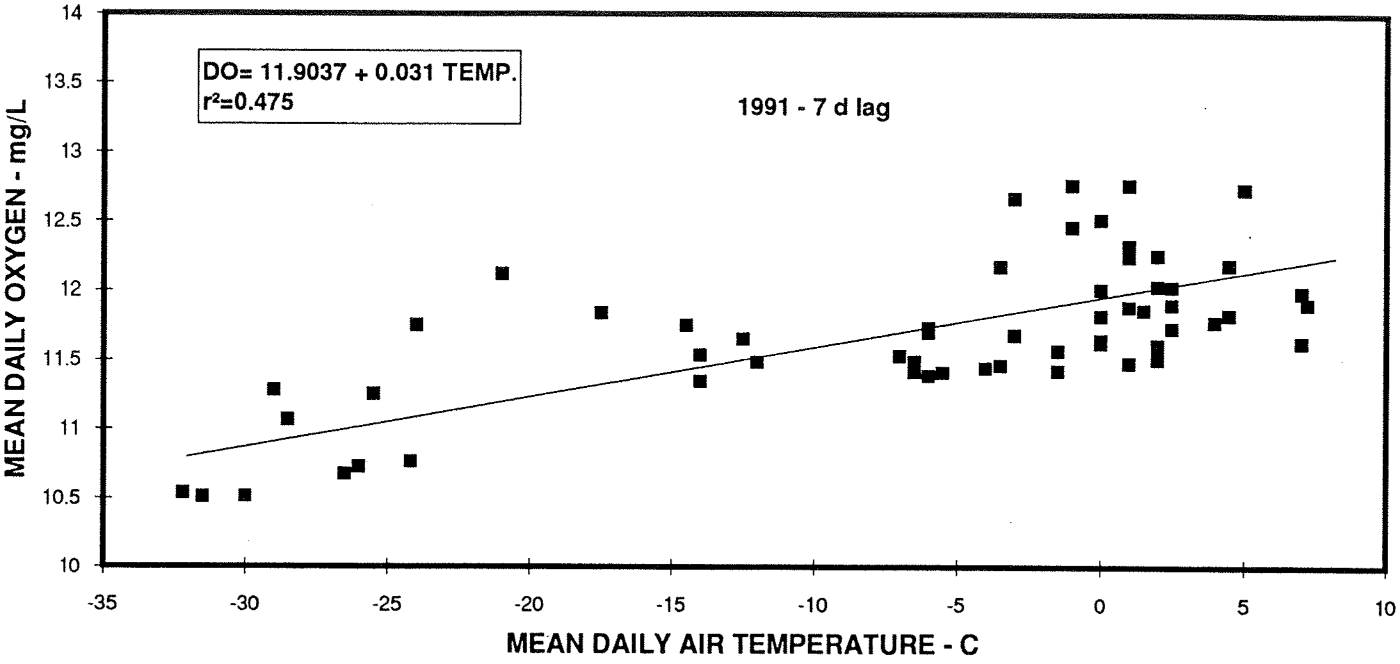
For 1989 the full January-March period was tested, and also the February-March period since DO was declining steadily in January and may not have been in equilibrium with ice cover. However, neither period exhibited a relationship between air temperature and DO, although DO appeared to be related to flows, with a 4 d lag. Why there was a positive relationship between DO and air temperature in 1991 and 1993, but not 1989 is not clear. One possibility is that since the 1989 hourly data (AEP file data) were more variable than in subsequent years, the greater variation may have obscured any relationship to air temperature.

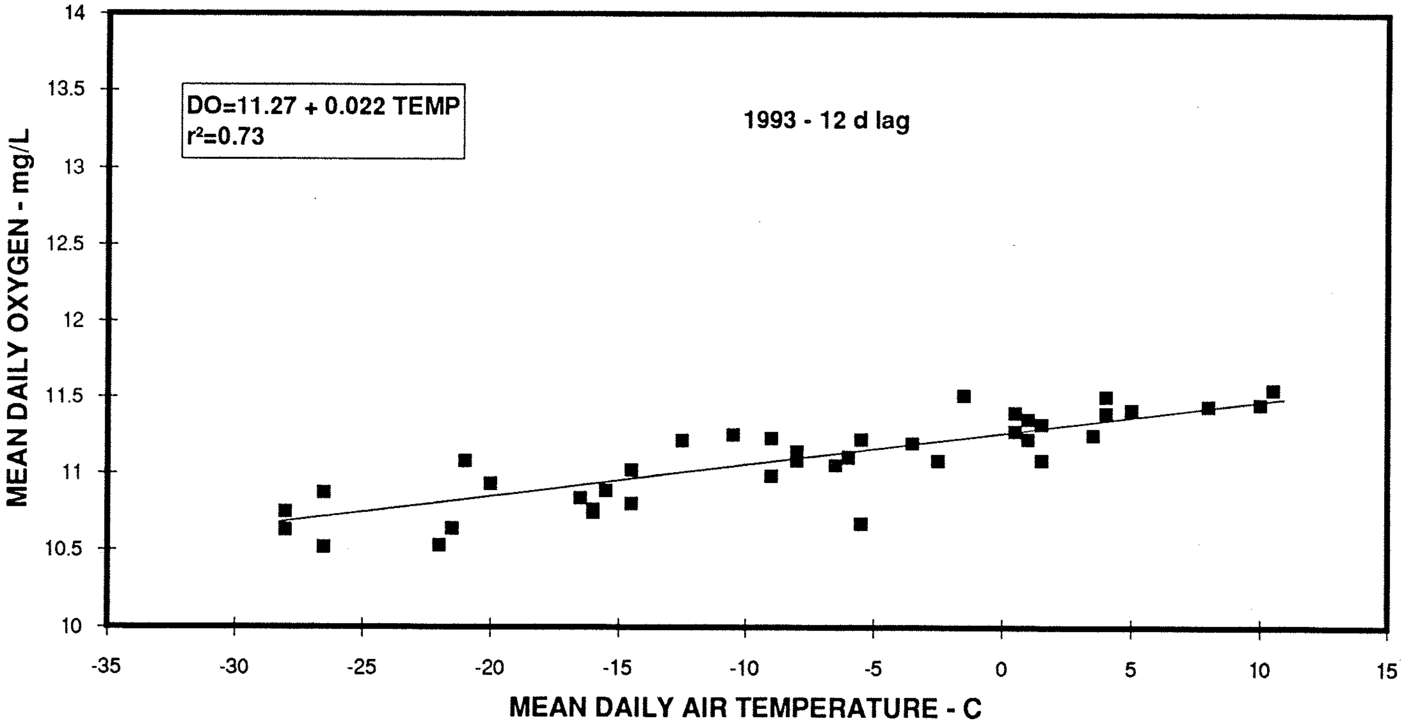
The lag in the response of DO to air temperature could result in part from river travel time, which suggests that air temperature farther u/s than Entrance may be a better predictor of DO. This may be the case - temperatures from Jasper were regressed with DO and slightly greater r^2 values found (Table 2).

c. Ice Cover and Reaeration Rate

The positive relationship between DO and air temperature, after a lag of a few days, suggests that the reaeration rate at open-water leads is correlated to air temperature, and/or that ice-cover grows or melts back in response to air temperature changes. The importance of open-water leads in reaeration during winter has been pointed out by McBean

Figure 18. ATHABASCA RIVER U/S of HINTON - AIR TEMPERATURE and OXYGEN (lagged).





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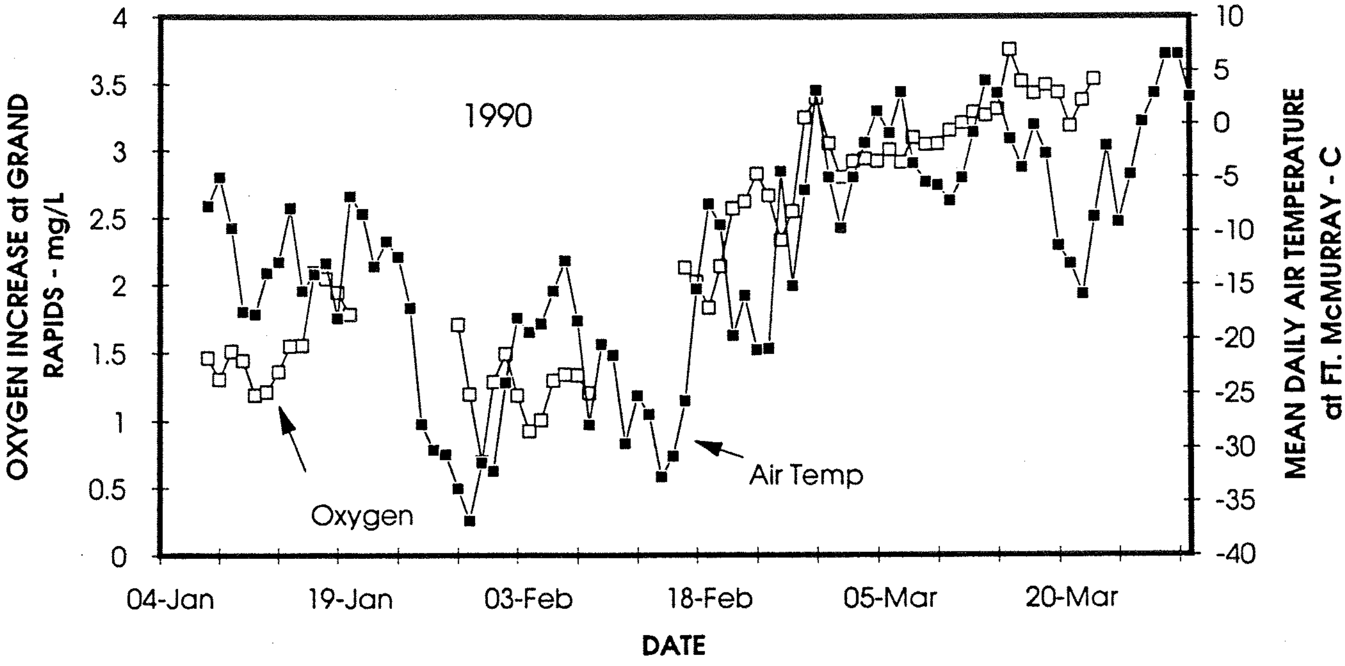
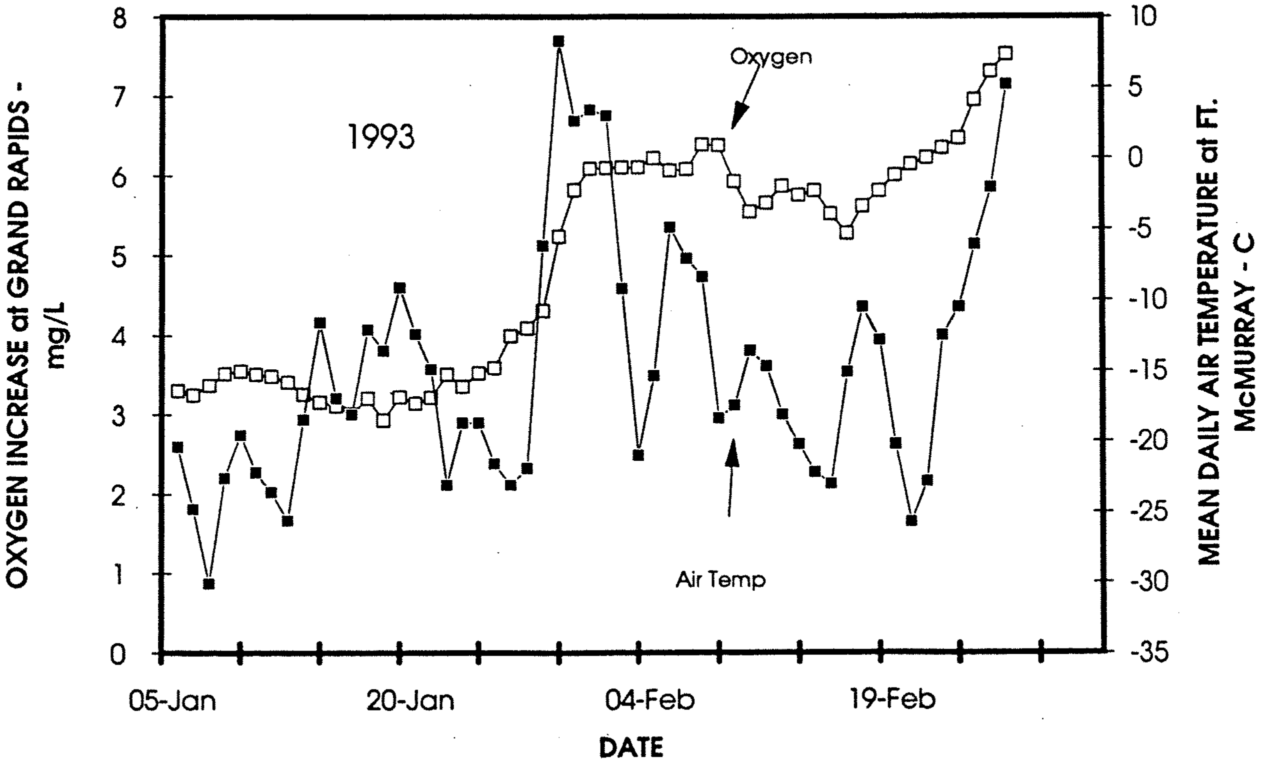
et al. (1979). The lag may result if most of the re-aeration occurs some distance upstream, and/or if it takes some time for the open-water leads to change in area in response to changes in weather. Temperatures above freezing are common during winter in the Hinton-Jasper area (Figures 15-17).

Macdonald et al. (1989) measured reaeration rates in two reaches downstream of Hinton, one ice-free and one largely ice-covered. They found significant reaeration in the former but no measurable reaeration in the latter. It was beyond the scope of their work to test the influence of air temperature on reaeration. However, since diffusion from the air across the water surface is a factor in reaeration, it seems possible that the temperature of the air may affect the reaeration rate. Although there has been much research on the influence of water temperature on rearation (e.g. Chao et al. 1987; Eheart and Park 1989) there seems to have been little if any on the influence of air temperature. An additional factor that may be involved is that as air temperature declines below freezing, increasing amounts of frazil ice will form near the water surface which could further impede transfer of oxygen from the air into the water column. For example, thin sheets of skim ice have been seen forming and drifting downstream in the open-water plume of the Hinton combined effluent during very cold weather in the synoptic surveys.

To further explore this topic, data from Grand Rapids were examined. The rapids provide a major increase in DO by turbulent reaeration and this increase was examined to see if it was related to air temperature or ice cover. The increase in DO through the rapids was calculated as DO at Ft. McMurray minus DO u/s of Grand Rapids 4 days earlier (to allow for the river travel time estimated by Van Der Vinne and Andres 1992). No other time lag was applied to the data since, unlike u/s of Hinton, it appears that Grand Rapids is the only reaeration point in this reach. The DO increase was plotted with air temperature for 1990 and 1993 (Figure 19), the years with sufficient data at both sites. There was some tendency for the amount of reaeration (i.e. the increase in DO) to be positively related to air temperature: the coefficient of determination (r^2), which indicates the portion of variance in reaeration associated with the variance in air temperature, was 0.30 in 1990 and 0.21 in 1993, both $P<0.01$. It was uncertain whether the relationship was due to changes in ice cover or oxygen transfer rates per unit surface area. In 1994, an air temperature recorder and an extra recording DO meter were installed to better assess the question, and regular observations were made of ice cover in the rapids. The relationship of DO increase to air

Figure 19. REAERATION AND AIR TEMPERATURE - ATHABASCA RIVER AT GRAND RAPIDS





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temperature was slightly weaker, however, and ice observations indicated that the amount of open water in the rapids tended to increase during the same period that reaeration in the rapids increased (AEP unpublished data). Overall, this suggests that the amount of open water is the factor most probably controlling reaeration in Grand Rapids.

Ice cover itself is not routinely quantified in the Hinton area, although some observations are available from the synoptic surveys, air photos, and other opportunistic sources. There was a considerable amount of open water in the Entrance-Hinton reach in 1991 during the synoptic survey and overall DO concentrations that winter were higher than in 1989 or 1993 (Figure 6). Field observations in 1993 and air photos from 1989 indicated fewer open water leads there in those years. In the Brule Lake-Entrance reach, observations in 1993 revealed a fairly complete ice cover from mid-December to late January, then a 2-4 km ice-free lead in mid-February through March, starting in the Brule Lake outflow-Soloman Creek area (EQMB field observations; T. Clayton, pers. comm.). Dissolved oxygen began to rise at Hinton in late January of 1993 (Figure 6). Overall, this suggests that DO is positively correlated to the extent of open water during winter, as would be expected.

To examine this further, the grab sample data for the period of record (1956-1993) were compared to climate and flow data. Oxygen data for the 15 January to 15 February window of each winter were compared to the mean daily air temperature for the 15-November to 15 January window (as a possible indicator of ice cover), and also to mean January flow. However, the relationships were poor (DO vs air temp: $r^2=0.08$; DO vs flow: $r^2=0.03$) and the findings inconclusive. This is not to say that DO is not related to ice cover (it probably is), only that the grab sample and ice data over the 1956-93 period are not sufficient to quantify a relationship.

d. Other Factors

A number of other variables were also examined with respect to their influence on headwater DO. Snow cover might affect DO by controlling the amount of light available for photosynthesis. However, under-ice photosynthesis does not seem to be significant in the January-February period u/s of Hinton, even when there is no snow cover. In 1991 and 1993 there was negligible snow cover on the ice in early February (observations during synoptic surveys), but there was still no discernible diurnal DO fluctuation indicative of photosynthesis (see 3.1.5.2.a above).

The town of Jasper discharges treated sewage from an aerated lagoon to the Athabasca River and its BOD load was assessed as to its possible influence on winter DO in the river. In winter the sewage volume has usually been less than 5000 m^3/d and the BOD_5 less than 20 mg/L (L. Williams, pers. comm.). Taking these as maxima, and assuming a BOD_u:BOD_5 of 2 (Macdonald and Hamilton 1989), this amounts to 200 kg/d of total BOD. For a typical winter flow of 25 m^3/s at Hinton, this would consume a maximum of 0.1 mg/L of DO. This is insignificant, especially in view of the distance between Jasper and Hinton and the opportunity there for re-aeration.

The influence of groundwater on DO levels is difficult to assess directly since groundwater inflow is not measured. It undoubtedly will be much lower in DO and constitute more of the river's flow in winter, an assumption supported by higher TDS concentrations in winter. This will contribute to the decline in DO with the onset of ice cover and has been cited as a probable factor in declines in other natural ice-covered rivers (Schreier et al. 1980; Babin and Trew 1985; Whitfield and McNaughton 1986). However, it would be unlikely to fluctuate markedly in the course of days or weeks and so would not directly account for the DO fluctuations observed in mid-winter. During cold weather and ice-building on the river, flow may be abstracted into ice with a consequent greater proportion of groundwater in the water column and a decline in DO. Again however, evidence is lacking for this because under this condition flow should decline along with DO, whereas in fact there was a poor relationship between them in two of the three years examined (Table 2).

3.1.5.3 Discussion

A number of other studies have found DO saturation deficits under winter ice in unimpacted northern rivers (Schallock and Lotspeich 1974; Schreier et al. 1980; Whitfield and McNaughton 1986) and the subject has been recently reviewed by Cheng et al. (1993). Other Alberta rivers also exhibit a winter deficit in reaches little affected by human activity, for example the upper Wapiti and Smoky rivers (Noton 1992) and the Sand River (Babin and Trew 1985). These deficits have generally been attributed to some combination of DO-deficient groundwater input and oxygen demand in the water column and streambed. However, these factors themselves were not investigated, nor were DO fluctuations during the winter assessed in detail in those studies. Groundwater inflow and oxygen demand both likely contribute to the saturation deficit in the upper Athabasca River during winter, however, they are unlikely to fluctuate in such a way as to cause the fluctuations in DO observed in the January-February period. This is more likely due to fluctuations in reaeration rate, as influenced by the extent of ice cover and possibly the gas transfer rate in open water areas.

Considering all of the above, the following sequence of conditions is hypothesized to occur and affect the concentration of oxygen in the Athabasca River upstream of Hinton in winter:

- During late November and into December, ice accumulates along the banks and as pan ice floating in the channel. As ice cover increases, re-aeration is reduced and DO declines due to the oxygen demand in the water and streambed (however small), and also due to the greater importance of groundwater which contains less DO than the river.

- Eventually, the ice cover coalesces over much of the river, although open reaches remain. The open areas may shrink or expand in response to air temperatures. Oxygen continues to decline due to the increasing amount of ice cover which precludes re-aeration.

- By late January, ice cover is usually at a maximum and is not greatly increased by further cold weather.

- With milder weather beginning sometime in February (on average) ice cover is lost from some areas (e.g. d/s of Brule Lake) as a result of combinations of local groundwater inflow, local inflow of surface melt, and local hydraulic conditions. Re-aeration occurs in these areas and overall DO levels increase. Cold snaps during this period can reverse this trend and lower DO.

- Warming continues through February and March with open water areas slowly increasing and with further input of meltwater, which probably is near saturation with DO. Some under-ice photosynthesis also occurs and the overall result is an increase in DO as spring approaches.

The interaction of climate with ice cover and possibly re-aeration rate, combined with river discharge, unknown amounts of groundwater inflow, and at least some oxygen demand in the water column and streambed, constitutes a complex situation. It is not too surprising that no one factor is clearly and consistently related to DO fluctuations, the more so when only about 2 mg/L of fluctuation is involved.

3.1.5.4 Conclusion

Oxygen is less than saturated in the Athabasca River upstream of Hinton during winter, due to oxygen demand from the water column and streambed, input of groundwater, and reduced reaeration. DO fluctuates during the winter, with some positive correlation to air temperature but lagging by several days. Air temperature may affect river DO by influencing the extent of ice cover.

3.2 LESSER SLAVE RIVER

The synoptic surveys on the Athabasca River have included a series of sites on the Lesser Slave River in each winter (Figure 1). Oxygen data from the surveys are compiled in Appendix 1, and plotted in Figure 20. The river flows from Lesser Slave Lake in a near-saturated condition of about 12-13 mg/L DO, and over its course of about 72 km to the Athabasca, drops about 1-2 mg/L. This is supported by the data from the recording oxygen meters (Figure 21), which have been installed near the mouth in most winters and near Mitsue Bridge in 1991. The additional grab sample data from the medium-term monitoring site at the mouth show DO concentrations of about 10.5 to 12.5 mg/L in winter (Appendix 2). All DO measurements made on the Lesser Slave River have met the Alberta and Canadian water quality guidelines.

3.3 OTHER TRIBUTARIES

In addition to the Lesser Slave River, several tributaries of the Athabasca have been sampled for oxygen as part of the winter synoptic surveys. The data are compiled in the tributary section of Appendix 1. Dissolved oxygen concentrations in them have shown a wide range, from 1-2 mg/L in the Pembina and La Biche rivers in some winters, to near saturation in others such as the Pelican. Recording meters were placed in the McLeod and Pembina rivers in 1989 to confirm the synoptic grab samples and showed that DO was fairly low that winter (Figure 22). This probably reflects the low flows in those tributaries that year. Other years had higher flows and higher DO concentrations (Appendix 1 and Figure 23). A detailed assessment of factors controlling DO in the tributaries is beyond the scope of this report, but some observations can be supplied.

Some tributaries seem to have relatively high DO in all winters, for example the Berland River, Marsh Head Creek, Pelican River and Clearwater River. This may result from their gradient and numerous rapids or falls which keep them aerated all winter. Tributaries in the foothills such as the Berland and Marsh Head Creek may also be oligotrophic such that there is very little organic matter present to decompose and consume oxygen in winter.

A second group seems to fluctuate with flow such that in winters of lower flow, DO is also low. This includes the McLeod and Pembina rivers (Figure 23). The Pembina in particular has low DO and may be one of the most eutrophic of the Athabasca River's tributaries. It receives several sewage effluents and flows through extensive farmland. It's low gradient in the lower reaches may also contribute to the low DO there in winter by increasing travel time and precluding turbulent rapids.

Some other tributaries seem to have an irregular winter oxygen pattern, perhaps reflecting complete freezing to the bottom in some years or other factors operating upstream of their mouths which were not apparent during the synoptic surveys. The Calling River falls into this group and has ranged from 5.1 to 12.7 mg/L DO during the winter surveys of 1990-93.

Obviously, not all of these tributaries met the Alberta or Canadian water quality guidelines for oxygen. In particular, the Pembina has less than 5 mg/L DO in most winters near its mouth, and the McLeod River has less than 5 mg/L in some winters. Details on the other tributaries' winter DO conditions are listed in Appendix 1.

Figure 20. LESSER SLAVE RIVER - WINTER SYNOPTIC SURVEYS - 1990-93 - OXYGEN

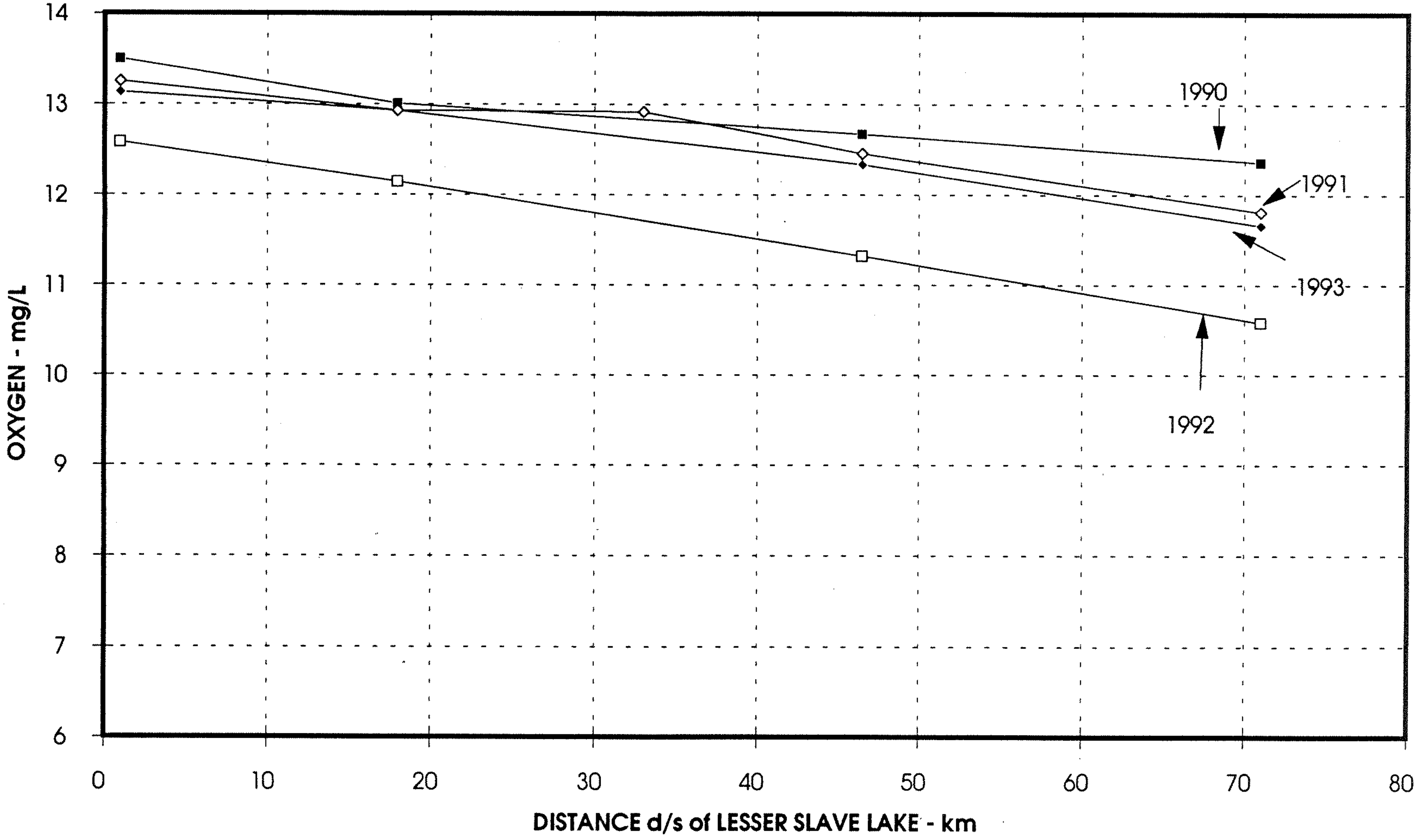

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Figure 21. LESSER SLAVE RIVER - RECORDING METERS 1989-93 - OXYGEN

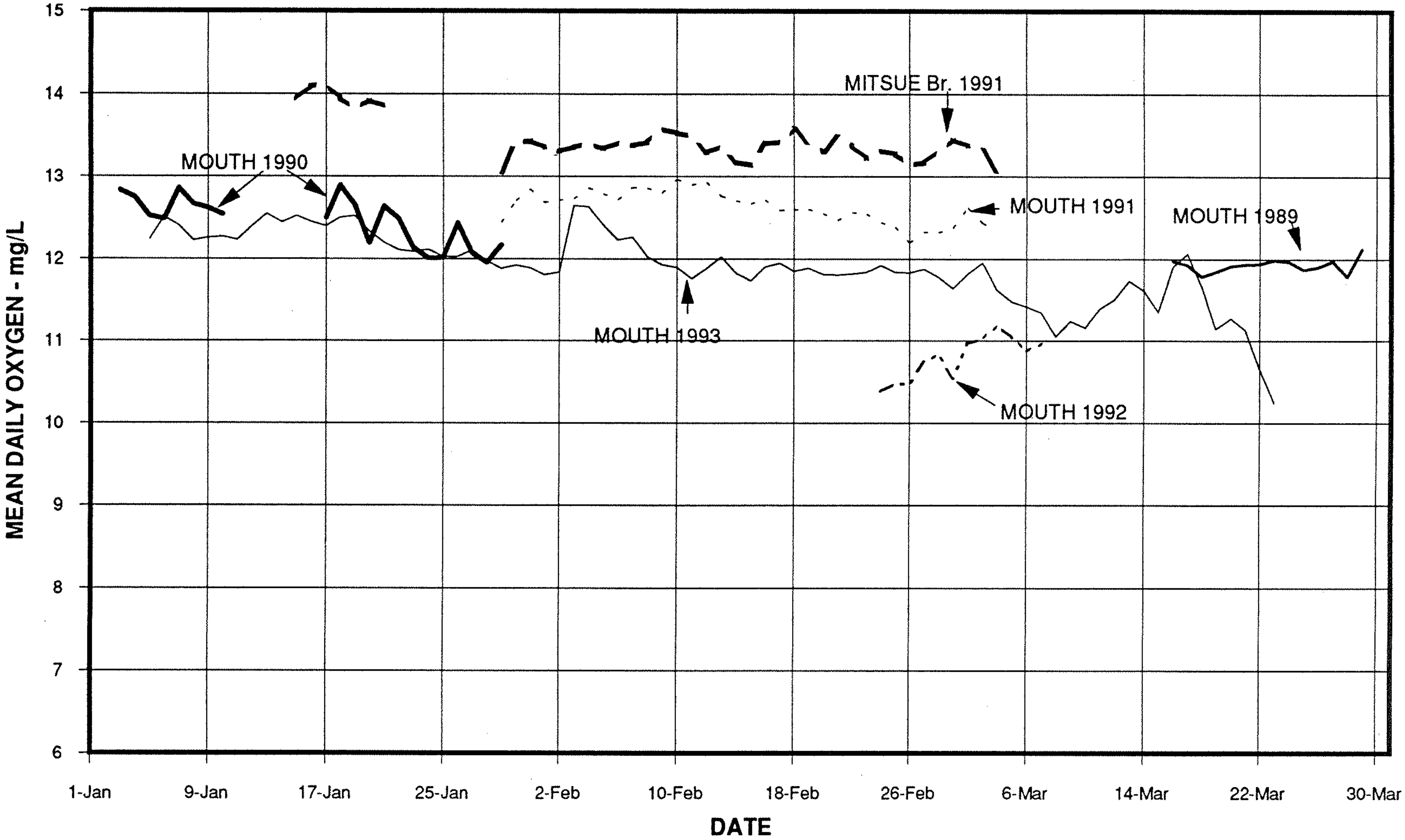

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Figure 22. TRIBUTARIES TO THE ATHABASCA RIVER - WINTER OXYGEN 1989.

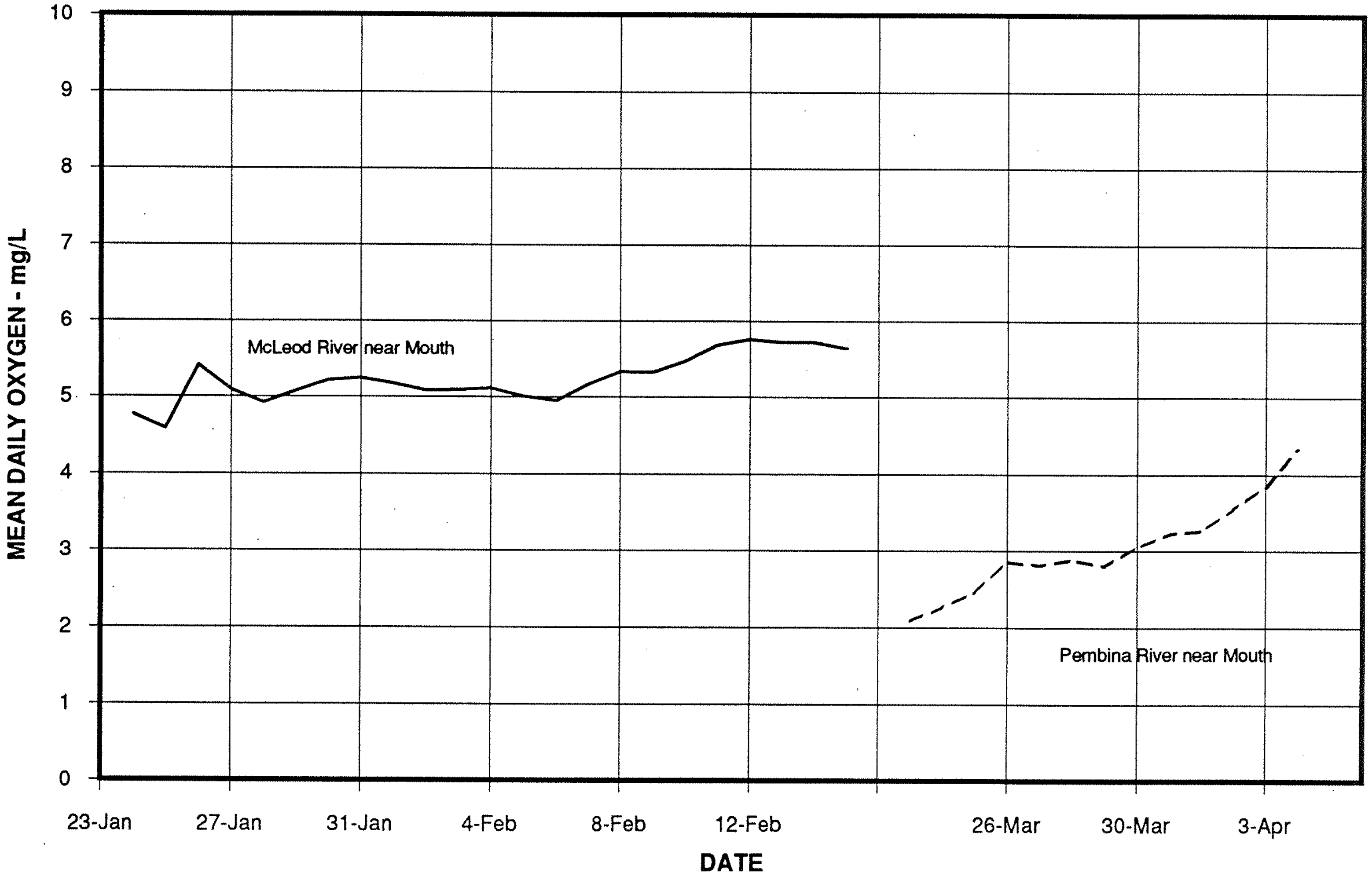

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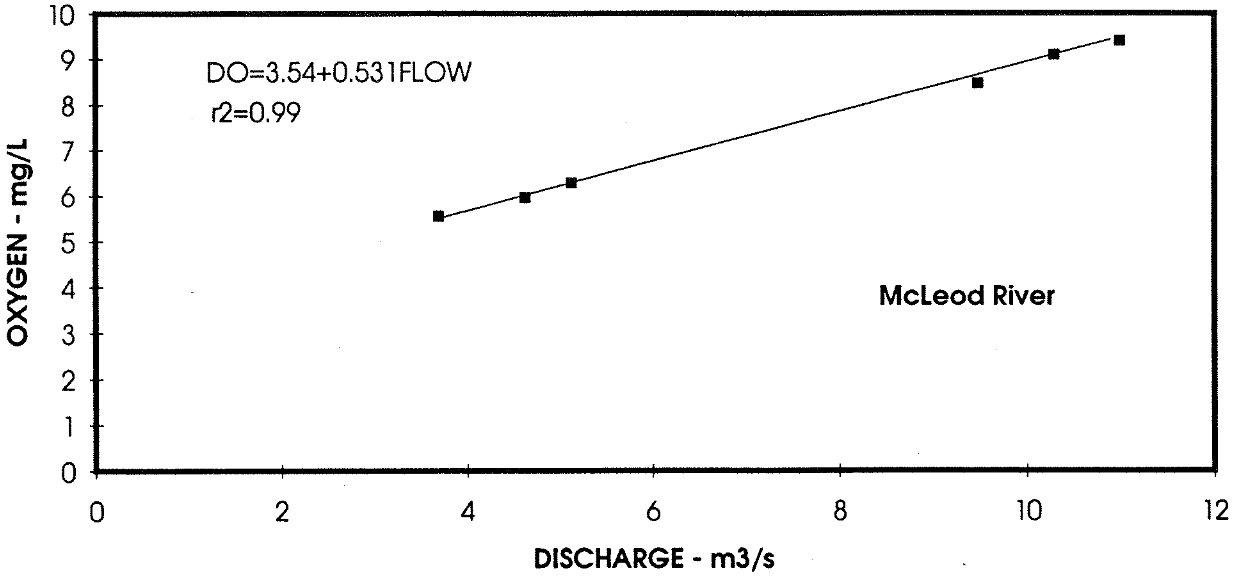
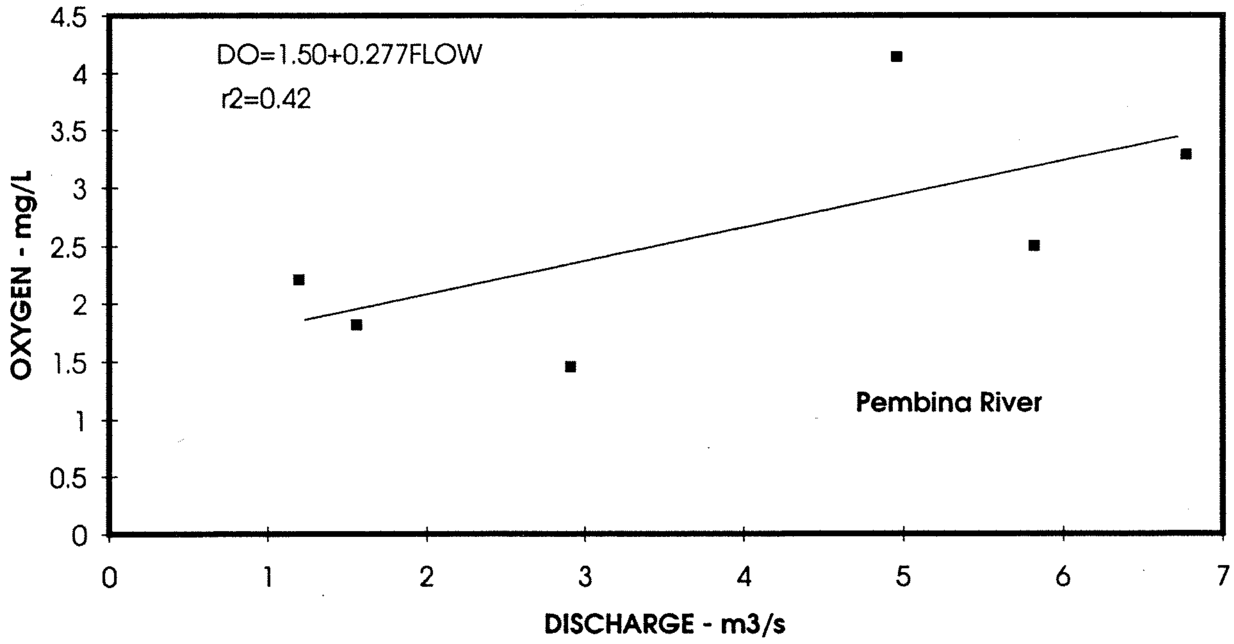
Figure 23. McLEOD AND PEMBINA RIVERS - WINTER FLOW AND OXYGEN - 1989-93





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APPENDICES

APPENDIX 1. ATHABASCA RIVER WINTER SYNOPTIC WATER QUALITY SURVEYS - 1990-93 - OXYGEN

					-----1990----				----1991----				----1992----				----1993----	
STATION	CODE	DISTANCE RIVER km	D	M	OXYGEN METER mg/L 08102F	OXYGEN WINKLR mg/L 08101L	D	M	OXYGEN METER mg/L 08102F	OXYGEN WINKLR mg/L 08101L	D	M	OXYGEN METER mg/L 08102F	OXYGEN WINKLR mg/L 08101L	D	M	OXYGEN METER mg/L 08102F	OXYGEN WINKLR mg/L 08101L
ATH R U MASKUTA CR	00AL07AD1040	1249.1													11	2	11.8	11.83
	00AL07AD1040																	11.93
	00AL07AD1040																	11.82
	00AL07AD1040																	11.86
ATH R U HINT INTK-C	00AL07AD1085	1243.4	14	2		11.58	7	2	12.3	11.98	30	1	12.4	12.43				
	00AL07AD1085		14	2		11.54	7	2		11.98	30	1		12.43				
	00AL07AD1085		14	2		11.6	7	2		12.02	30	1		12.55				
ATH R 1 KM D HCE-C	00AL07AD1180	1240.4	14	2		11.53	7	2	12.4	11.7								
	00AL07AD1180						7	2		11.75								
ATH R 1 KM D HCE - RB	00AL07AD1190	1240.4													11	2	11.9	11.88
	00AL07AD1191																	11.76
ATH R D CENTER CK-L	00AL07AD1200	1235.9					7	2	12.7	12.08								
ATH R D CENTER CK-C	00AL07AD1210	1235.9	14	2		11.32					30	1	12.3	12.22	11	2	12.3	12.71
	00AL07AD1210		14	2		11.36					30	1		12.54				12.21
ATH R D CENTER CK-R	00AL07AD1220	1235.9					7	2	12.4	11.8								
ATHAB R D TRAIL CK-C	00AL07AD1280	1230.5	15	2	11.7	11.11	7	2	12.5	11.84								
	00AL07AD1280		15	2		11.2	7	2		12.03								
ATHAB R D TRAIL CK-R	00AL07AD1290	1230.5					7	2	12.6									
ATHAB R OBED CL BR-C	00AL07AD1380	1220.5	15	2	11.5	10.99	7	2	12.2	11.48	30	1	12.1	12.22	11	2	11.9	11.94
	00AL07AD1380		15	2		11	7	2		11.58	30	1		12.06				11.96
ATHAB R AT OBED FY-C	00AL07AD1565	1204.8	16	2	10.6	11.23	8	2	11.3	11.61								
	00AL07AD1565		16	2		10.77	8	2		11.83								
ATH R EMERSON BR	00AL07AD1680	1193.8									31	1	12.4	11.89	12	2	11.6	11.37
	00AL07AD1680										31	1		11.68				11.37
ATH R D OLDMAN CK-C	00AL07AD1765	1181.2	16	2	10.7	10.85	8	2	11.7	11.97								
	00AL07AD1765		16	2		11.65	8	2		11.74								
ATHAB R U BERLAND-C	00AL07AD2060	1139.6	16	2	10.9	10.92	8	2	11.3	11.09	31	1	12.1	11.86	12	2	11.2	11.04
	00AL07AD2060		16	2		11.16	8	2		11.27	31	1		11.89				10.99
	00AL07AD2060		16	2		11.27												
ATHAB R D TWO CK-L	00AL07AE1260	1082.9	20	2	10.1	10.16	12	2		11.15	4	2	12.3	11.78	16	2	10.5	10.58
	00AL07AE1260						12	2		11.18	4	2		11.88				10.49
ATHAB R WINDFALL BR-C	00AL07AE1285	1066.3					12	2		11.04	8	1	12.5	12.44	16	2	10.3	10.46
	00AL07AE1285						12	2		11.1	4	2	12.1	11.69				10.53
	00AL07AE1285						12	2		11.1	4	2		11.66				
ATH R 5KU HWY43BR SCH	00AL07AE1370	1038					12	2		11.2								
	00AL07AE1370						12	2		11.26								
ATH R 5KU HWY43BR NCH	00AL07AE1380	1038					12	2		11.02								
	00AL07AE1380						12	2		10.98								
ATHAB R AT HWY43BR-C	00AL07AE1495	1033.6	20	2		10.46					4	2	12.1	11.9	16	2	10.7	10.76
	00AL07AE1495		20	2		10.49	12	2	11.4	10.98								10.74
	00AL07AE1495		20	2		10.53	12	2		11								
ATH R 3K D MCLEOD R-C	00AL07AH0660	1029.4	21	2	9.9	9.73	13	2	11.1	10.96								
	00AL07AH0660		21	2		9.95	13	2		10.7								
ATH R 10K D MCLD R-C	00AL07AH1044	1022.3	21	2	10.2	9.78	13	2		10.68	5	2	11.9	11.57	17	2	10.1	10.27
	00AL07AH1044		21	2		9.89	13	2		10.84	5	2		11.45				
ATH R BLUERIDGE BR-L	00AL07AH1080	1007.2									5	2	11.8					
ATH R BLUERIDGE BR-C	00AL07AH1085	1007.2	21	2	10.2	9.86	13	2	10.2	10.61	5	2	11.8	11.47				
	00AL07AH1085		21	2		9.91	13	2		10.56	5	2		11.54				
ATH R BLUERDGE BR-RB	00AL07AH1090	1007.2									5	2	11.7		17	2		10.39
	00AL07AH1090																	10.25
ATHAB R 5KD 5MI IS-C	00AL07AH1150	969	21	2	10.0	9.66	13	2	10.0	10.16	6	2	11.7	11.52	17	2	9.4	9.89
	00AL07AH1150		21	2		9.73	13	2		9.89	6	2		11.53				9.88
ATH R NR FT.ASSIN-C	00AL07AH1310	937.6	21	2	9.8	9.79	13	2	9.9	10.09	6	2	11.3	11.35	18	2	9.6	10.14
	00AL07AH1310		21	2		9.48	13	2		10.01	6	2		11.27				10.13
ATHAB R .5KU PEMB R-C	00AL07BD0500	850	26	2	9.3	9.03	19	2	10.3	9.96	11	2	11.9	11.15	23	2	8.9	9
	00AL07BD0500						19	2		10.04	11	2		11.03				8.92
ATHAB R HWY 2 BR-C	00AL07BD1000	805.9	28	2	8.4	8.65	21	2	9.6	9.07	12	2	10.0	10.07	24	2	8.7	8.65
	00AL07BD1000		28	2		8.41	21	2		9.1	12	2		10.42				8.72
	00AL07BD1000		28	2		8.52	21	2		9.08								8.64
	00AL07BD1000																	8.62
	00AL07BD1000																	8.62
	00AL07BD1000																	8.63
ATH R 45KU ATHAB -C	00AL07BE2200	732.3	1	3	9.2	9.97	23	2	9.4	9.2	14	2	10.2	10.48	26	2	8.7	8.75
	00AL07BE2200		1	3		10.14	23	2		9.3	14	2		10.41			8.8	8.74
ATH R @ ATHABASCA	00AL07BE2320	687	1	3	9.1	9.36	23	2	9.2	9	14	2	10.0	10.3	26	2	8.4	8.47
	00AL07BE2320		1	3		9.3	23	2		9.1	14	2		10.34			8.6	8.52
	00AL07BE2320		1	3		9.35	23	2		9.02	14	2		10.26				
ATH R .5KU LBICHE R-C	00AL07CB2410	626	6	3		10.81	26	2	9.6	8.97	20	2	9.8	9.64	4	3	9.0	8.91
	00AL07CB2410		6	3	8.9	9.44	26	2		8.93	20	2		9.72				8.86

STATION	CODE	RIVER km	D	M	-----1990---		D	M	----1991----		D	M	----1992---		D	M	----1993---	
					METER O2	WINKLR O2			METER O2	WINKLR O2			METER O2	WINKLR O2			METER O2	WINKLR O2
ATH R NR MCMILLAN L	00AL07CB3300	565.5	6	3	8.6	9.16	26	2	9.1	8.63	20	2	9.7	9.79	4	3	8.5	8.64
	00AL07CB3300		6	3		8.87	26	2		8.64	20	2		9.67				8.49
ATH R1.7KU PELICANR-C	00AL07CB3800	503	8	3	8.7	8.79	26	2	8.8	8.38	24	2	9.4	9.33	4	3	8.4	8.33
	00AL07CB3800		8	3		8.86	26	2		8.41	24	2		9.29				8.36
ATHAB R U HOUSE R	00AL07CB4150	443.5	8	3	8.7	8.72	5	3	9.7	9.16	24	2	9.2	9.22	9	3	9.2	9.42
	00AL07CB4150		8	3		9.01					24	2		9.19				9.38
	00AL07CB4150		8	3		8.77												
AR U/S GRAND RAPIDS	00AL07CC2050	435.8	8	3	8.8	8.73	5	3	9.4	8.69	24	2	9.5	9.42	9	3	10.2	10.49
	00AL07CC2050		8	3		8.73	5	3		8.72	24	2		9.47			10.3	10.45
	00AL07CC2050		8	3		8.75	5	3		8.67								
ATHAB R U BUFFALO CK	00AL07CC3050	398.5	14	3	12.5	12.18	5	3	13.3	12.41	24	2	13.0	12.89	9	3	13.3	13.95
	00AL07CC3050		14	3		12.24	5	3		12.1	24	2		12.56				
	00AL07CC3050		14	3		12.23												
ATH R U BOILERRAPIDS	00AL07CC4050	355.9	14	3	12.5	12.23	5	3	13.0	12.25	24	2	12.7	12.72	10	3	14.4	15.03
	00AL07CC4050		14	3		12.23	5	3		12.19	24	2		12.04				15.62
ATH R .1KU HORSE R-L	00AL07CC0600	297.6	14	3	12.0	11.96	6	3	13.0	12.8	25	2	13.4	13.26	10	3	15.1	15.68
	00AL07CC0600		14	3		11.96					25	2		13.34				15.7
	00AL07CC0600		14	3		12.03					25	2						
ATHAB R U SUNCOR-C	00AL07DA0985	265.2	15	3	12.2	12.3	7	3	12.6	12.23	26	2	13.4	12.96	11	3	14.1	14.44
	00AL07DA0985		15	3		12.21	7	3		12.21	26	2		13.03				14.39
ATH R 5KD BITUMOUNT-C	00AL07DA4250	214.4	15	3	11.9	11.67	7	3	12.3	11.95	26	2	12.9	12.69	11	3	13.0	13.43
	00AL07DA4250		15	3		11.66	7	3		11.91	26	2		12.73				13.48
ATHAB R U FIREBAG R-C	00AL07DA5050	171.4	15	3	11.6	11.5	14	3	12.2	11.84	10	3	13.1	12.79	16	3	13.6	14
	00AL07DA5050		15	3		11.42	14	3		11.65	10	3		12.58				14.07
ATHAB R AT OLD FORT	00AL07DD0900	86.6	21	3	11.2	10.92	14	3	11.2	10.72	10	3	12.0	11.37	16	3	11.8	12.42
	00AL07DD0900		21	3		10.96	14	3		10.72	10	3		11.43				12.54
	00AL07DD0900		21	3		10.98	14	3		10.83								
ATH R BIG PT CHAN MTH	00AL07DD1800	4.7	21	3	10.7	10.39	14	3	10.6	10.14	10	3	11.2	10.71	16	3	10.1	10.4
	00AL07DD1800		21	3		10.5	14	3		10.2	10	3		10.97				10.48
	00AL07DD1800																	
RIV DE ROCH U REV COUF	00AL07NA0700		21	3	12.2	12.16	27	3	12.4	11.95								
	00AL07NA0700						27	3		11.85								
SLAVE R 2KU LABUT CK-L	00AL07NA3000		21	3	12.0	11.96	27	3	12.3	12.18								
	00AL07NA3000						27	3		12.14								
SLAVE R 2KU LABUT CK-R	00AL07NA3050		21	3	12.0	12.06	27	3	12.4	12.12								
	00AL07NA3050						27	3		12.15								
OLDMAN CK MOUTH	00AL07AD1700		16	2	12.8	12.8												
BERLAND R MOUTH	00AL07AC1000		20	2	9.7	9.81	8	2	10.8	10.88	31	1	11.1	11	12	2	10.1	10.01
	00AL07AC1000		20	2		9.8	8	2		11.22	31	1		11.06				9.96
SPR ATHR13.5KDBER R-L	00AL07AE0501		20	2	12.0	11.87												
MARSH HEAD CREEK MTH	00AL07AE0900		20	2	12.3	11.97	12	2	12.6	12.3	4	2	13.1	12.63	16	2	11.8	12.08
	00AL07AE0900						12	2		12.3	4	2		12.59				12.04
WINDFALL CREEK MOUTH	00AL07AE1290		20	2	11.4	11.3												
SAKWATAMAU R NR MOUT	00AL07AH0350		20	2		9.8	12	2	9.3	9.2	4	2	11.3	11.23	17	2		8.12
	00AL07AH0350		20	2		10.11	12	2		8.95	4	2		11.06				8.08
MCLEOD R HWY43 BR-C	00AL07AG2060		20	2		8.51	12	2	9.1	9.23	4	2	9.4	9.39	17	2		6.24
	00AL07AG2060		20	2		8.41	12	2		8.95								6.23
	00AL07AG2060																	6.34
FREEMAN R WEST MOUTH	00AL07AH1990		21	2	9.0	8.69	13	2	9.4	10.05								
	00AL07AH1990						13	2		10.22								
PEMB R NR ATHAB R-C	00AL07BC0990		26	2	3.2	3.36	19	2	2.6	2.56	11	2	6.0	4.13	23	2	1.7	1.75
	00AL07BC0990		26	2		3.21	19	2		2.44	11	2		4.15				1.89
LSR AT BR NR L OUTF-C	00AL07BK2100		26	2	13.7	13.5	19	2	13.9	13.24	11	2	13.2	12.54	23	2	13.1	13.15
	00AL07BK2100						19	2		13.27	11	2		12.62				13.12
LSR AT MITSUE BR-C	00AL07BK2110		26	2	13.5	13.01	19	2	13.5	12.98	11	2	12.4	12.18	23	2	12.9	12.92
	00AL07BK2110						19	2		12.9	11	2		12.11				12.94
LSR U OTAUWAU R	00AL07BK2120						21	2	13.1	12.95								
	00AL07BK2120						21	2		12.89								
LSR .5KU DRIFTWOODR-C	00AL07BK2130		1	3	13.2	12.67	21	2	12.9	12.48	12	2	11.9	11.32	24	2	13.1	12.44
	00AL07BK2130						21	2		12.43								12.23
LSR AT ATHAB R MTH	00AL07BK2150		1	3	12.8	12.36	21	2	12.4	11.75	12	2			24	2	12.6	11.56
	00AL07BK2150						21	2		11.86	12	2	10.7	10.62				11.75
	00AL07BK2150										12	2		10.54				
LA BICHE R MOUTH	00AL07CA1500		6	3	4.5	4.86	26	2		2.76	20	2	6.0	5.43				
	00AL07CA1500						26	2		2.72	20	2		5.61				
CALLING R MOUTH	00AL07CB2500		6	3	12.6	11.56					20	2	12.7	12.72	4	3	5.3	5.1
	00AL07CB2500										20	2		12.5				5.14
PELICAN R MOUTH	00AL07CB3900		8	3	13.6	12.33	26	2	13.4	12.91	24	2	13.8	12.76	4	3	10.1	
	00AL07CB3900						26	2		12.72	24	2		13.05				
HOUSE R MOUTH	00AL07CB4500		8	3	12.1	11.55	5	3	9.8	9.83	24	2	12.8	12.38	9	3	10.7	10.54
	00AL07CB4500						5	3		9.92	24	2		12.34				10.5

					-----1990----				----1991---				----1992----				----1993----	
STATION	CODE	RIVER km	D	M	METER O2	WINKLR O2	D	M	METER O2	WINKLR O2	D	M	METER O2	WINKLR O2	D	M	METER O2	WINKLR O2
CLEARWTR R NR WATERW	00AL07CD1200		14	3	12.5	11.89	6	3	13.1	13.37	25	2	13.3	13.26	10	3	12.1	12.51
	00AL07CD1200		14	3		11.95	6	3		13.03	25	2		13.14				12.49
	00AL07CD1200						6	3		12.69								
MUSKEG R AT MOUTH	00AL07DA2650		15	3	11.5	11.23	7	3	6.5	5.71	26	2	9.2	9.13	11	3	4.1	4.03
	00AL07DA2650						7	3		5.62	26	2		9.36				3.99
ELLS R AT MOUTH	00AL07DA3350		15	3	11.1	10.9	7	3	8.8	8.31	26	2	12.9	12.57	11	3	9.5	9.73
	00AL07DA3350						7	3		8.34	26	2		12.7				9.8
FIREBAG R AT MOUTH	00AL07DC0900		15	3	6.0	6.3	26	3	5.9	6.15	10	3	6.7	6.68	16	3	4.1	4.57
	00AL07DC0900		15	3		6.34	26	3		6.08	10	3		6.8				4.47
RICHARDSON R AT MOUTH	00AL07DD1140		21	3	8.0	7.91	14	3	6.5	6.21	10	3	8.9	8.93	16	3	7.6	8.22
	00AL07DD1140						14	3		6.22	10	3		8.92				7.88
WELDW FINAL EFFL GRAB	20AL07AD1000		14	2	10.3		7	2	6.9		29	1	6.6		11	2	6.2	
	20AL07AD1000		15	2	9.8		8	2	7.4		30	1	6.3					
A.N.C. FINAL EFFLGRAB	20AL07AE1000						11	2	5.6		3	2	7.9		16	2	8.2	
	20AL07AE1000						12	2	6.8		4	2	6.8					
M.W.P.L. FNL EFF GRAB	20AL07AH1000		20	2	5.2		12	2	3.8		4	2	5.3		17	2	6.0	
	20AL07AH1000		21	2	4.0		13	2	3.7		5	2	5.5					
S.L.P.C. FNL EFF GRAB	20AL07BK4000						20	2	6.6		11	2	6.1		24	2	6.3	
	20AL07BK4000						20	2	6.0		12	2	5.6					
	20AL07BK4000						21	2	6.7									
SUNC FINAL EFF GRAB	20AL07DA1000		14	3	2.6		6	3	5.5		25	2	3.5	2.44	11	3	4.5	
	20AL07DA1000		14	3	2.6						25	2		2.29				
WHITECOURT SEWAGE EF	21AL07AH0200		20	2	5.2	5.7	12	2	5.9		5	2	5.6	5.65	17	2		5.95
	21AL07AH0200																	5.94
SLAVE L STP FNLEFFGRB	21AL07BK5000		26	2		0.74	19	2		4.12	11	2	0.0	0	23	2	2.4	1.93
	21AL07BK5000						19	2		4.04	11	2		0				2.1
ATHAB STP FNLEFF GRB	21AL07CB0100		6	3		2.39					14	2	5.8	5.62	26	2	0.6	< 0.1
	21AL07CB0100					2.31					14	2		5.82				
	21AL07CB0100																	
FT MCM FNLEFFL GRAB	21AL07DA1000		14	3	13.0	12.36	6	3	10.5		25	2	12.2	10.93	10	3	12.5	
	21AL07DA1000		14	3		12.28					25	2		11.1				
SYNCRUDE STP EFF GRB	20AL07DA2008														11	3	13.1	

APPENDIX 2. ATHABASCA RIVER SYSTEM MEDIUM AND LONG TERM MONITORING SITES - 1989-93 - OXYGEN

STATION	CODE	D	M	Y	OXYGEN METER mg/L 08102F	OXYGEN WINKLR mg/L 08101L
ATHABASCA R u/s HINTON	00AL07AD1085	9	1	89	12.0	11.7
	00AL07AD1085	9	1	89		11.7
	00AL07AD1085	9	1	89		11.56
	00AL07AD1085	6	2	89		11.2
	00AL07AD1085	6	2	89		11.11
	00AL07AD1085	13	2	89		11.16
	00AL07AD1085	13	2	89		11.08
	00AL07AD1085	13	2	89		11.17
	00AL07AD1085	21	3	89		11.72
	00AL07AD1085	21	3	89		11.52
	00AL07AD1080	17	5	89	9.8	9.62
	00AL07AD1080	11	10	89	11.5	
	00AL07AD1080	13	12	89	12.4	
	00AL07AD1090	17	5	89	10.2	9.84
	00AL07AD1090	11	10	89	11.5	
	00AL07AD1090	13	12	89	12.0	12.26
	00AL07AD1080	16	1	90	11.6	
	00AL07AD1085	14	2	90		11.58
	00AL07AD1085	14	2	90		11.54
	00AL07AD1085	14	2	90		11.6
	00AL07AD1090	16	1	90	11.8	12.12
	00AL07AD1090	31	7	90	8.7	9.2
	00AL07AD1090	16	10	90	12.9	12.23
	00AL07AD1015	8	1	91	11.4	11.25
	00AL07AD1085	7	2	91	12.3	11.98
	00AL07AD1085	7	2	91		11.98
	00AL07AD1085	7	2	91		12.02
	00AL07AD1015	11	3	91	12.0	11.75
	00AL07AD1085	10	5	91	10.9	
	00AL07AD1090	20	8	91	8.8	9.08
	00AL07AD1010	26	8	91	9.6	
	00AL07AD1015	17	10	91	12.3	12.72
	00AL07AD1085	7	1	92	12.5	12.35
	00AL07AD1085	30	1	92	12.4	12.43
	00AL07AD1085	30	1	92		12.43
	00AL07AD1085	30	1	92		12.55
	00AL07AD1015	3	3	92	12.4	12.3
	00AL07AD1085	5	5	92	10.1	10.16
	00AL07AD1085	14	7	92	9.8	9.76
	00AL07AD1085	8	10	92	11.6	11.71
	00AL07AD1085	7	1	93	11.2	11.24
	00AL07AD1040	11	2	93	11.8	11.83
	00AL07AD1040	11	2	93		11.82
	00AL07AD1040	11	2	93		11.86
	00AL07AD1085	11	3	93	11.9	12.24
ATHABASCA R OBED COAL BRIDGE	00AL07AD1380	9	1	89	11.3	10.93
	00AL07AD1380	9	1	89		10.99
	00AL07AD1380	9	1	89		11
	00AL07AD1380	13	2	89	10.5	10.73
	00AL07AD1380	13	2	89		10.7
	00AL07AD1390	17	5	89	10.0	9.45
	00AL07AD1370	17	5	89	10.0	9.37
	00AL07AD1390	11	10	89	11.3	
	00AL07AD1370	11	10	89	11.4	
	00AL07AD1390	13	12	89	12.8	
	00AL07AD1370	13	12	89	12.0	11.92
	00AL07AD1370	16	1	90	11.5	11.67
	00AL07AD1380	15	2	90	11.5	10.99
	00AL07AD1380	15	2	90		11
	00AL07AD1380	20	3	90	12.1	11.85
	00AL07AD1370	31	7	90	8.7	9.04
	00AL07AD1390	31	7	90	8.7	9.21
	00AL07AD1390	16	10	90	13.0	12.42
	00AL07AD1370	16	10	90	12.8	
	00AL07AD1380	8	1	91	11.2	11.05
	00AL07AD1380	7	2	91	12.2	11.48
	00AL07AD1380	7	2	91		11.58
	00AL07AD1380	11	3	91	12.6	12.05
	00AL07AD1380	10	5	91	10.8	
	00AL07AD1390	20	8	91	8.6	9.09
	00AL07AD1370	20	8	91	8.6	
	00AL07AD1380	27	8	91	9.8	
	00AL07AD1380	17	10	91	12.7	
	00AL07AD1380	7	1	92	12.7	12.42
	00AL07AD1380	30	1	92	12.1	12.22
	00AL07AD1380	30	1	92		12.06
	00AL07AD1380	3	3	92	12.3	12.08
	00AL07AD1380	5	5	92	9.7	10.16
	00AL07AD1380	14	7	92	9.7	9.64
	00AL07AD1380	8	10	92	11.8	11.66

STATION	CODE	D	M	Y	OXYGEN METER mg/L 08102F	OXYGEN WINKLR mg/L 08101L
ATHABASCA R OBED COAL BRIDGE	00AL07AD1380	7	1	93	11.2	11.28
	00AL07AD1380	11	2	93	11.9	11.93
	00AL07AD1380	11	2	93		11.96
	00AL07AD1380	11	3	93	12.5	12.7
ATH R WHITECOURT BR	00AL07AE1495	12	1	89	11.0	10.31
	00AL07AE1495	12	1	89		10.37
	00AL07AE1495	12	1	89		10.44
	00AL07AE1495	26	1	89	10.5	9.61
	00AL07AE1495	26	1	89		9.43
	00AL07AE1495	26	1	89		9.63
	00AL07AE1495	15	2	89	9.4	9.52
	00AL07AE1495	15	2	89		9.33
	00AL07AE1495	15	2	89		9.62
	00AL07AE1490	17	5	89	10.2	9.64
	00AL07AE1500	17	5	89	9.7	9.85
	00AL07AE1500	11	10	89	11.4	
	00AL07AE1490	11	10	89	11.3	
	00AL07AE1495	13	12	89	12.8	12.65
	00AL07AE1495	16	1	90	11.5	11.65
	00AL07AE1495	20	2	90		10.46
	00AL07AE1495	20	2	90		10.49
	00AL07AE1495	20	2	90		10.53
	00AL07AE1495	20	3	90		11.82
	00AL07AE1490	1	8	90	9.3	
	00AL07AE1500	1	8	90	9.1	9.38
ATHABASCA R WINDFAI BRIDGE	00AL07AE1286	16	10	90	13.3	12.7
	00AL07AE1284	16	10	90	13.2	
	00AL07AE1285	9	1	91	11.4	11.32
	00AL07AE1285	12	2	91		11.04
	00AL07AE1285	12	2	91		11.1
	00AL07AE1285	12	2	91		11.1
	00AL07AE1285	20	3	91	11.6	11.36
	00AL07AE1285	10	5	91	10.8	
	00AL07AE1286	21	8	91	9.1	9.25
	00AL07AE1284	21	8	91	9.2	
	00AL07AE1285	28	8	91	9.3	
	00AL07AE1285	17	10	91	12.4	
	00AL07AE1285	8	1	92	12.5	12.44
	00AL07AE1285	4	2	92	12.1	11.69
	00AL07AE1285	4	2	92		11.66
	00AL07AE1285	5	3	92	12.3	12.1
	00AL07AE1285	5	5	92	10.1	
	00AL07AE1285	14	7	92	9.4	9.55
	00AL07AE1285	8	10	92	11.8	11.79
	00AL07AE1285	6	1	93	11.1	11.58
	00AL07AE1285	16	2	93	10.3	10.46
	00AL07AE1285	16	2	93		10.53
	00AL07AE1285	10	3	93	10.9	10.66
ATHABASCA R FT ASSINIBOINE	00AL07AH1310	16	1	89	7.6	7.54
	00AL07AH1310	16	1	89		7.76
	00AL07AH1310	16	1	89		7.64
	00AL07AH1310	27	1	89	8.0	8.06
	00AL07AH1310	27	1	89		7.94
	00AL07AH1310	27	1	89		7.81
	00AL07AH1310	10	2	89		6.9
	00AL07AH1310	20	2	89	7.0	7.01
	00AL07AH1310	20	2	89		6.92
	00AL07AH1310	20	2	89		6.87
	00AL07AH1310	29	3	89		7.59
	00AL07AH1310	29	3	89		7.53
	00AL07AH1320	17	5	89	9.8	9.3
	00AL07AH1320	11	10	89	11.5	
	00AL07AH1300	11	10	89	11.6	
	00AL07AH1320	13	12	89	12.2	
	00AL07AH1300	13	12	89	12.0	12.26
	00AL07AH1310	16	1	90	10.8	10.75
	00AL07AH1310	21	2	90	9.8	9.79
	00AL07AH1310	21	2	90		9.48
	00AL07AH1310	21	3	90		11.75
	00AL07AH1300	1	8	90	8.8	
	00AL07AH1320	1	8	90	8.6	8.74
	00AL07AH1320	17	10	90	12.9	
	00AL07AH1300	17	10	90	12.8	12.75
	00AL07AH1310	17	1	91	10.3	10.78
	00AL07AH1310	13	2	91	9.9	10.09
	00AL07AH1310	13	2	91		10.01
	00AL07AH1310	13	3	91	10.0	10.5
	00AL07AH1310	10	5	91	9.7	9.61
	00AL07AH1310	27	8	91	9.3	9.13

STATION	CODE	D	M	Y	OXYGEN METER mg/L	OXYGEN WINKLR mg/L
ATHABASCA R FT ASSINIBOINE	00AL07AH1310	29	8	91	10.2	
	00AL07AH1310	17	10	91	11.4	11.07
	00AL07AH1310	8	1	92	12.1	11.78
	00AL07AH1310	6	2	92	11.3	11.35
	00AL07AH1310	6	2	92		11.27
	00AL07AH1310	11	3	92	12.5	11.94
	00AL07AH1310	5	5	92	9.7	
	00AL07AH1310	14	7	92	9.2	9.39
	00AL07AH1310	8	10	92	11.5	11.52
	00AL07AH1310	6	1	93	10.3	10.57
	00AL07AH1310	18	2	93	9.6	10.14
	00AL07AH1310	18	2	93		10.13
	00AL07AH1310	17	3	93	11.7	11.81
ATH R HWY 2 BR u/s SMITH	00AL07BD1000	18	1	89	7.4	7.58
	00AL07BD1000	18	1	89		7.65
	00AL07BD1000	18	1	89		7.74
	00AL07BD1000	6	2	89	6.3	7.46
	00AL07BD1000	6	2	89		7.68
	00AL07BD1000	6	2	89		6.95
	00AL07BD1000	22	2	89	5.5	5.89
	00AL07BD1000	22	2	89		5.62
	00AL07BD1000	22	2	89		6.21
	00AL07BD1000	16	3	89		6.59
	00AL07BD1000	16	3	89		6.49
	00AL07BD1000	16	3	89		6.69
	00AL07BD1000	29	3	89	5.6	5.85
	00AL07BD1000	29	3	89		5.73
	00AL07BD1040	17	5	89	9.1	9.31
	00AL07BD1020	17	5	89	9.7	9.27
	00AL07BD1020	11	10	89	11.2	
	00AL07BD1040	11	10	89	11.7	
	00AL07BD1040	13	12	89	11.6	11.93
	00AL07BD1020	13	12	89	11.6	
	00AL07BD1000	16	1	90	10.1	9.99
	00AL07BD1000	28	2	90	8.4	8.65
	00AL07BD1000	28	2	90		8.41
	00AL07BD1000	28	2	90		8.52
	00AL07BD1000	21	3	90		10.23
	00AL07BD1020	1	8	90	8.6	8.67
	00AL07BD1040	1	8	90	8.6	
	00AL07BD1000	17	10	90	12.5	
	00AL07BD1000	7	1	91	10.6	9.73
	00AL07BD1000	21	2	91	9.6	9.07
	00AL07BD1000	21	2	91		9.1
	00AL07BD1000	21	2	91		9.08
	00AL07BD1000	11	3	91	9.7	9.68
	00AL07BD1000	10	5	91	9.6	9.63
	00AL07BD1000	27	8	91	9.0	
	00AL07BD1000	17	10	91	11.6	
	00AL07BD1000	14	1	92	11.0	10.35
	00AL07BD1000	12	2	92	10.0	10.07
	00AL07BD1000	12	2	92		10.42
	00AL07BD1000	6	3	92	11.0	10.78
	00AL07BD1000	5	5	92	9.6	9.82
	00AL07BD1000	14	7	92	8.9	9.13
	00AL07BD1000	8	10	92	11.2	11.18
	00AL07BD1000	5	1	93	9.9	10.14
	00AL07BD1000	24	2	93	8.7	8.65
	00AL07BD1000	24	2	93		8.62
	00AL07BD1000	15	3	93	11.2	11.14
LESSER SLAVE R-LAKE OUTFLOW	00AL07BK2100	11	2	92	13.2	12.54
	00AL07BK2100	11	2	92		12.62
	00AL07BK2100	13	5	92	10.7	
	00AL07BK2100	10	6	92	9.1	9.38
	00AL07BK2100	15	7	92	9.0	
	00AL07BK2100	13	8	92	10.0	10.11
	00AL07BK2100	16	9	92	11.1	10.82
	00AL07BK2100	14	10	92	11.9	12.21
	00AL07BK2100	23	2	93	13.1	13.15
	00AL07BK2100	23	2	93		13.12
LESSER SLAVE R AT ATH R CONFLUENCE	00AL07BK2150	18	1	89	12.5	12.34
	00AL07BK2150	18	1	89		12.18
	00AL07BK2150	6	2	89	12.2	12.12
	00AL07BK2150	6	2	89		12.26
	00AL07BK2150	23	2	89	12.3	12.11
	00AL07BK2150	23	2	89		12.01
	00AL07BK2150	17	5	89	10.7	9.94
	00AL07BK2150	11	10	89	11.6	
	00AL07BK2150	13	12	89		11.85
	00AL07BK2150	16	1	90	12.2	11.9
	00AL07BK2150	1	3	90	12.8	12.36
LESSER SLAVE R AT AT RIVER CONFLUENCE	00AL07BK2150	21	3	90		12.15
	00AL07BK2150	1	8	90	8.3	8.35
	00AL07BK2150	17	10	90	12.6	12.44
	00AL07BK2150	10	1	91	12.9	12.66
	00AL07BK2150	7	2	91		12.03
	00AL07BK2150	21	2	91	12.4	11.75
	00AL07BK2150	21	2	91		11.86
	00AL07BK2150	11	3	91	12.5	12.4
	00AL07BK2150	10	5	91	10.3	10.33
	00AL07BK2150	27	8	91	8.2	7.76
	00AL07BK2150	17	10	91	11.8	11.34
	00AL07BK2150	14	1	92	11.9	
	00AL07BK2150	12	2	92	10.7	10.62
	00AL07BK2150	12	2	92		10.54
	00AL07BK2150	19	3	92	12.1	11.2
	00AL07BK2150	5	5	92	10.1	10.23
	00AL07BK2150	14	7	92	8.2	8.18
	00AL07BK2150	8	10	92	11.2	11.04
	00AL07BK2150	5	1	93	12.4	
	00AL07BK2150	24	2	93		11.56
	00AL07BK2150	24	2	93		11.75
	00AL07BK2150	15	3	93	11.3	
ATH R u/s FT MCMURRA	00AL07CC0600	8	2	89	12.5	11.91
	00AL07CC0600	8	2	89		12.22
	00AL07CC0600	8	3	89	12.0	12.06
	00AL07CC0600	8	3	89		11.75
	00AL07CC0600	8	3	89		11.78
	00AL07CC0600	9	5	89	9.5	9.66
	00AL07CC0600	12	7	89	8.6	8.82
	00AL07CC0600	12	9	89	9.9	9.89
	00AL07CC0600	9	1	90	12.3	12.25
	00AL07CC0600	20	2	90	12.3	11.3
	00AL07CC0600	14	3	90	12.0	11.96
	00AL07CC0600	14	3	90		11.96
	00AL07CC0600	14	3	90		12.03
	00AL07CC0600	23	5	90	9.8	9.2
	00AL07CC0600	18	7	90	8.9	9.03
	00AL07CC0600	25	10	90	14.3	
	00AL07CC0600	10	1	91	12.6	12.69
	00AL07CC0600	7	2	91	11.2	12.41
	00AL07CC0600	6	3	91	13.0	12.8
	00AL07CC0600	4	6	91	9.4	9.77
	00AL07CC0600	15	8	91	8.3	8.52
	00AL07CC0600	24	10	91	14.4	13.55
	00AL07CC0600	14	1	92	12.8	13.17
	00AL07CC0600	25	2	92	13.4	13.26
	00AL07CC0600	25	2	92		13.34
	00AL07CC0600	24	3	92	12.0	13.46
	00AL07CC0600	21	4	92	11.6	12.05
	00AL07CC0600	13	8	92	8.8	8.7
	00AL07CC0600	6	10	92	12.1	
	00AL07CC0600	7	1	93	11.6	11.78
	00AL07CC0600	2	2	93	11.6	11.65
	00AL07CC0600	10	3	93	15.1	15.68
	00AL07CC0600	10	3	93		15.7
ATHABASCA R AT ATHABASCA	00AL07BE0001	20	1	89	8.8	
	00AL07BE0001	23	2	89	7.8	
	00AL07BE0001	21	3	89		7.3
	00AL07BE0001	27	4	89	11.6	
	00AL07BE0001	24	5	89	10.9	
	00AL07BE0001	14	6	89		8.52
	00AL07BE0001	11	7	89	8.4	
	00AL07BE0001	15	8	89	7.6	
	00AL07BE0001	13	9	89	10.2	
	00AL07BE0001	26	10	89	11.3	
	00AL07BE0001	20	11	89		13.4
	00AL07BE0001	19	12	89	12.0	
	00AL07BE0001	16	1	90		11
	00AL07BE0001	22	2	90	11.1	
	00AL07BE0001	13	3	90	9.1	
	00AL07BE0001	30	4	90	11.0	11.21
	00AL07BE0001	29	5	90	8.7	8.4
	00AL07BE0001	28	6	90	8.5	8.7
	00AL07BE0001	26	7	90		8.94
	00AL07BE0001	22	8	90		8.75
	00AL07BE0001	26	9	90	9.7	9.9
	00AL07BE0001	17	10	90	12.7	
	00AL07BE0001	5	12	90	12.4	11.93
	00AL07BE0001	10	1	91	10.4	10.17
	00AL07BE0001	7	2	91	9.1	9.1
	00AL07BE0001	21	3	91	9.5	9.6
	00AL07BE0001	29	4	91		10.47

STATION	CODE	D	M	Y	OXYGEN METER mg/L	OXYGEN WINKLR mg/L
ATHABASCA R AT ATHABASCA	00AL07BE0001	4	6	91	9.3	9.42
	00AL07BE0001	4	7	91	9.0	8.78
	00AL07BE0001	24	7	91	7.8	
	00AL07BE0001	27	8	91	8.9	8.81
	00AL07BE0001	26	9	91	10.0	9.99
	00AL07BE0001	17	10	91	11.7	
	00AL07BE0001	10	12	91	13.0	12.03
	00AL07BE0001	14	1	92	11.0	10.68
	00AL07BE0001	14	2	92	10.0	
	00AL07BE0001	10	3	92	11.3	10.75
	00AL07BE0001	7	4	92	12.6	12.78
	00AL07BE0001	5	5	92	9.8	10.06
	00AL07BE0001	11	6	92	8.7	9.1
	00AL07BE0001	9	7	92	8.8	9.34
	00AL07BE0001	20	8	92	8.6	9.15
	00AL07BE0001	21	9	92	10.8	10.95
	00AL07BE0001	15	10	92	12.4	12.46
	00AL07BE0001	12	11	92	13.5	
	00AL07BE0001	15	12	92	12.3	12.43
	00AL07BE0001	14	1	93	9.4	9.52
	00AL07BE0001	26	2	93	8.4	8.5
	00AL07BE0001	17	3	93	11.2	11.18
	00AL07BE0001	20	4	93	12.8	12.57
ATHABASCA R ATOLD FORT	00AL07DD0010	15	2	89	10.7	
	00AL07DD0010	15	3	89	10.7	
	00AL07DD0010	8	5	89	9.8	
	00AL07DD0010	6	6	89	8.5	
	00AL07DD0010	13	7	89	8.1	
	00AL07DD0010	12	9	89	9.4	
	00AL07DD0010	26	10	89		10.2
	00AL07DD0010	19	12	89	11.5	
	00AL07DD0010	19	1	90	11.2	
	00AL07DD0010	2	3	90	10.9	10.62
	00AL07DD0010	21	3	90		10.95
	00AL07DD0010	19	4	90		12.28
	00AL07DD0010	24	5	90		9.15
	00AL07DD0010	13	6	90	9.3	9.2
	00AL07DD0010	18	7	90	8.0	8.1
	00AL07DD0010	21	8	90	8.6	9.07
	00AL07DD0010	26	9	90		10.8
	00AL07DD0010	25	10	90	14.1	13.59
	00AL07DD0010	11	12	90	11.5	
	00AL07DD0010	23	1	91	10.3	10.18
	00AL07DD0010	7	3	91	10.9	10.73
	00AL07DD0010	26	3	91	11.1	10.81
	00AL07DD0010	4	6	91	9.2	9.05
	00AL07DD0010	17	7	91	7.9	8.04
	00AL07DD0010	15	8	91	7.7	7.7
	00AL07DD0010	18	9	91		10.48
	00AL07DD0010	24	10	91	14.0	13.51
	00AL07DD0010	4	12	91	13.0	12.25
	00AL07DD0010	14	1	92	11.5	11.23
	00AL07DD0010	12	2	92	12.2	11.49
	00AL07DD0010	21	4	92	12.7	13.26
	00AL07DD0010	26	5	92	10.0	9.92
	00AL07DD0010	25	6	92	8.9	9.28
	00AL07DD0010	5	8	92	8.4	8.7
	00AL07DD0010	9	9	92	10.5	10.5
	00AL07DD0010	6	10	92	10.8	10.6
	00AL07DD0010	12	11	92	14.0	13.64
	00AL07DD0010	16	12	92	12.1	12.06
	00AL07DD0010	19	1	93	10.2	10.18
	00AL07DD0010	17	2	93	10.2	10.35
	00AL07DD0010	16	3	93	11.8	12.49

NOTE: More than one code indicates sample site has varied within the general location.
The Whitecourt site was moved to Windfall Bridge in 1990.

APPENDIX 3.
ATHABASCA RIVER UPSTREAM OF HINTON - WINTER OXYGEN
GRAB SAMPLE DATA FOR PERIOD OF RECORD, DEC THRU MAR

STATION	CODE 00AL07-	D	M	Y	OXYGEN WINKLER 08101L mg/L
HINTON	NC	24	1	56	11
U/S HINTON	NC	10	12	57	12.2
	NC	6	1	58	11
	NC	7	1	58	11.6
	NC	4	2	58	11.4
	NC	25	2	58	11.4
ABOVE PUMPHO	NC	16	12	59	12
UPSTREAM	NC	19	1	60	11.95
	NC	23	2	60	12.05
	NC	22	3	60	11.7
	NC	1	12	60	11.95
	NC	16	1	61	11.35
	NC	14	3	61	11.65
	NC	5	12	61	11.66
	NC	3	1	62	11.2
ABOVE HINTON	NC	14	2	62	11.4
	NC	7	3	62	11.1
	NC	13	12	62	12.3
	NC	30	1	63	11.1
	NC	12	3	63	12.03
	NC	9	12	63	12.2
	NC	7	1	64	11.95
	NC	12	2	64	11.2
	NC	18	3	64	12.1
	NC	7	12	64	11.55
	NC	25	1	65	11.7
	NC	15	2	65	11.55
	NC	15	3	65	11.45
	NC	22	12	65	11.78
	NC	24	1	66	11.95
	NC	14	2	66	10.81
	NC	17	3	66	11.62
ABOVE HINTON	NC	7	12	66	11.53
HINTON - AR1	NC	11	1	67	11.5
	NC	9	2	67	12.1
	NC	8	3	67	12.6
HINTON - AR1	NC	13	12	67	13.8
	NC	9	1	68	12.2
	NC	5	2	68	10.7
	NC	13	3	68	12.5
	NC	18	12	68	14.4
	NC	28	1	69	10.9
	NC	19	2	69	11.1
	NC	9	12	69	12.7
U/S MILL INT	AD1070	13	1	70	12.2
	AD1070	11	2	70	11.4
	AD1070	8	12	70	11.6
	AD1070	5	1	71	11.2
	AD1070	3	2	71	11.1
	AD1070	4	3	71	11.7
	AD1070	7	12	71	12.8
	AD1070	25	1	72	10.5
	AD1070	8	2	72	11.1
	AD1070	5	12	72	12.9
	AD1070	23	1	73	11.7
	AD1070	6	2	73	11.6
	AD1070	30	1	74	11.3
	AD1070	27	3	74	12.2
	AD1070	4	12	74	12
	AD1070	18	2	75	10.4
	AD1070	4	12	75	11.5
ENTRANCE - RB	AD1010	17	2	87	12.2
U/S INTAKE - C	AD1085	1	2	88	11.74
	AD1085	4	3	88	11.42
	AD1085	9	1	89	11.65
	AD1085	6	2	89	11.16
	AD1085	13	2	89	11.14
	AD1085	21	3	89	11.62
RB	AD1090	13	12	89	12.26
	AD1080	16	1	90	11.6
	AD1085	14	2	90	11.57
ENTRANCE - C	AD1015	8	1	91	11.25
	AD1085	7	2	91	11.99
	AD1085	11	3	91	11.75
	AD1085	7	1	92	12.35
	AD1085	30	1	92	12.47
	AD1085	3	3	92	12.3
	AD1085	7	1	93	11.24
U/S MASKUTA CF	AD1040	11	2	93	11.86
	AD1085	11	3	93	12.24

If more than one value per date, mean value is used
If cross channel grabs were taken, centre value is used.
NC=not coded