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DATA REPORT SERIES NO. 83-4

BIOLOGICAL OCEANOGRAPHIC STUDIES OF THE LA GRANDE RIVER PLUME, JAMES BAY - WINTER 1980

VOLUME I

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BIOLOGICAL OCEANOGRAPHIC STUDIES OF THE LA GRANDE RIVER PLUME, JAMES BAY - WINTER 1980. VOLUME 1. NUTRIENTS AND SESTON.

by

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Final Report to Supply and Services Canada
Contract No. FP830-0-0090
Serial No. OSE80-00106

May, 1983
(First published January, 1981)

ABSTRACT

During the winter of 1980, a multidisciplinary survey was conducted on the under-ice LaGrande River plume, in James Bay. This report contains salinity, nutrient and seston data that was collected as part of the biological and chemical survey of the LaGrande River, its plume, deep James Bay waters, and from the snow and ice cover. Thirty-four water stations and 13 ice stations were occupied in two main surveys during February and March.

Nutrients measured included total phosphorus, total dissolved phosphorus, total Kjeldahl nitrogen, total dissolved Kjeldahl nitrogen, reactive nitrate plus nitrite, reactive nitrite and reactive silicate. Seston was subsampled for particulate organic carbon, particulate organic nitrogen, ATP, chlorophyll <u>a</u> and phaeopigments.

ACKNOWLEDGEMENTS

At this time, I have the distinct pleasure of acknowledging the many people who assisted in the research and writing of this report. In particular, I thank Dr. J.C. Roff, Department of Zoology, University of Guelph; Dr. N.G. Freeman, Dr. N.H.F. Watson, and Mr. D.J. Brooks and staff at Ocean Science and Surveys, Burlington; Dr. B.K. Burnison, National Water Research Institute, Burlington; Dr. R.N. Pandee, Guelph Chemical Laboratories, Ltd; and Drs. F. Philbert and O. El-Kei and staff at the Water Quality Laboratory, Canada Centre for Inland Waters, Burlington.

I am indebted to J. Anning, J. Crawford, H. Dale, N. Freeman, A. Perley, J. Roff, G. Rogers, and A. Smits for generous assistance during field data collection and analysis.

This data report was financed by a Department of Supply and Services Contract (No. FP830-0-0090, Serial No. OSE80-00106) to Mr. R.J. Pett.

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1. INTRODUCTION

In November 1979, LG2, the largest of four generating stations in the massive LaGrande Complex, officially came on line, sending hydroelectric power south. The winter of 1980 saw an increase in the LaGrande River flow to between 3 and 3.5 times the normal winter discharge, or to approximately 1400 $m^3\ s^{-1}$ (pers. comm. N. Freeman). As part of a continuing series of oceanographic surveys of the LaGrande River and James Bay by Ocean Science and Surveys, Central Region, the 1980 Winter Oceanographic Survey combined detailed physical, chemical and biological observations on the under-ice LaGrande River plume during the first winter of increased flow conditions (Brooks 1980).

The chemical-biological program was designed to investigate: 1) inorganic and organic nutrient, and seston inputs from the LaGrande River and deep James Bay waters; 2) phytoplankton and zooplankton composition in plume and deep marine waters; 3) possible use of biological and chemical properties as conservative tracers of water movement in modelling studies; and 4) nutrient, seston and phytoplankton from the relatively unknown snow and ice cover of James Bay.

In this first volume on the "Biological Oceanographic Studies of the LaGrande River Plume, James Bay - Winter 1980," nutrient and seston data from the under-ice plume, deep marine waters, and snow and ice are summarized. Work on zooplankton and phytoplankton collections will form the subjects of further reports in this series.

2. THE STUDY AREA

2.1 The LaGrande Complex

The LaGrande Complex, a vast hydro-electric project, is situated on the east coast of James Bay, in the Province of Quebec. The total project occupies some 1.77 x 10^5 km^2, and encompasses the LaGrande River watershed (55% of the total area), and parts of two adjacent watersheds; the Canipiascau (a diversion of waters flowing to Ungava Bay), and the Eastmain-Opinaca River system (a diversion of another James Bay tributary) (Environment Canada 1975). At the end of projected developments, a regulated flow of approximately 3,400 m^3 s^{-1} can be expected at the mouth of the LaGrande River (Peck 1976). As a direct consequence of flow regulation, winter discharges will be increased by almost 400%, with a maximum of 560% occurring between February and April (Peck 1976).

2.2 The LaGrande Watershed

The huge drainage basin of the LaGrande Complex (1.77 x 10^5 km^2) lies wholly on the Superior Province of the Canadian Shield (Stearn et al 1979). Abundant granites, gneisses and schists found here were believed to have formed approximately 2.5 billion years ago. Both the geological structure and the hydrologic systems characteristically trend east-west in this region of the Superior Province (Eade 1966). However, owing to more recent glacial scouring and depositional patterns, the drainage system as a whole is much more complex. Penn (1975) notes that 10 to 25% of the total LaGrande Complex surface area is covered by lakes, rivers, ponds and swampy marshes, marsh areas being most prevalent along the James Bay coast (Eade 1966).

Vegetation classification of this area is exceedingly difficult due to the variety of environments within the LaGrande Complex. Much of the northern watershed is typically barren or sparsely vegetated (hence a Subarctic classification), while the southerly areas are covered by heavy black spruce stands of potential economic value (true boreal forest) (Eade 1966, Saville 1968). Transitional environments constitute the bulk of the watershed.

2.3 Winter Conditions in James Bay

Beginning in late November, ice begins to form over large portions of James Bay, and by early spring (March to April), it has reached its annual maximum of approximately 1 to 1.5 m (Lardner 1968, Markham 1976). Breakup does not occur until May or June. Over five months of the year then, James Bay is completely ice covered, with the exception of a persistent shore lead (polynya) approximately 15 km from the coast (Markham 1976).

This extensive ice cover is of significant importance to winter oceanographic studies as it permits the development of sizeable lenses of fresh and brackish waters adjacent to major river systems (Barber 1974, Barber and Murty 1977). These under-ice plumes were particularly evident off the LaGrande and Eastmain Rivers in 1975 and 1976 (Peck 1976). During the winter of 1980, the LaGrande River plume could be traced approximately 80 km north of the river mouth (pers. comm. N. Freeman).

3. METHODS AND MATERIALS

3.1 LaGrande River and Plume Water Surveys

Between February 9 and March 13, 1980, 34 stations in the LaGrande River and its plume in James Bay were sampled in two main surveys, for a number of seston variables, total and dissolved nutrients, and salinity (Appendix 1). Travel between stations was accomplished by Canadian Coast Guard helicopter service. Within the framework of the overall plume survey, three sub-sampling schemes were designed to test several hypotheses, and to provide a data base for later modelling purposes. These included:

LaGrande River Source Variability Study (3.1.1);
Primary Transect Plume Sampling Program (3.1.2); and a
Secondary Transect Plume Sampling Program (3.1.3).

3.1.1 LaGrande River Source Variability Study

In order to document variability in nutrient and particulate biomass (seston) inputs from the LaGrande River, surface samples were taken on a weekly basis for five consecutive weeks, from a small open lead immediately above the new Fort George (Chisisaubi) townsite (16.7 km from the mouth - see Figure 1). Samples were then analyzed for a number of seston variables, and total and dissolved nutrients.

Seston variables measured included: adenosine 5'-triphosphate (ATP), chlorophyll a (corrected for phaeopigments), phaeopigments, particulate organic carbon (POC) and particulate organic nitrogen (PON). Unfiltered water samples were also subsampled for total phosphorus (TP), total Kjeldahl nitrogen (TKN), and reactive silicate (SiO_2).

The filtrate collected from seston filtrations was subsampled for total dissolved phosphorus (TDP), total dissolved Kjeldahl nitrogen (TDKN), and reactive nitrate plus nitrite ($NO_3 + NO_2$).

3.1.2 Primary Transect Plume Sampling Program

During the five-week plume water survey, two main surveys of the LaGrande Plume and James Bay were performed (Appendix 1). However, shortly after arrival at Fort George, two plume stations (0250, 6144), and a site near the LG2 dam were sampled in order to give a preliminary picture of nutrient and seston variability. The first major survey followed this (February 19 to 26), 11 stations along the plume axis being occupied over the eight-day period (Figure 1). Water samples, both in the plume and below it, were analyzed for ATP, chlorophyll a, phaeopigments, POC, PON, salinity, TP, TDP, TKN, TDKN, and $NO_3 + NO_2$.

Replicate sampling of station 0350 at high and low tides was also done during the first survey, to investigate the influence of tidal cycle on nutrient and seston variability. Chlorophyll a and phaeopigments were not measured on these occasions.

An increase in the LaGrande River discharge as a fourth generator came on line at LG2, late February, facilitated study of the plume under changing flow conditions. Twelve stations (including one additional station, 0621 added after the first survey) were sampled between March 6 and 13 (Figure 1). Along with the variables mentioned in Section 3.1.1, reactive silicate was also determined during the second survey.

3.1.3 Secondary Transect Plume Sampling Program

Concurrent with the two main plume surveys, two stations (0257, 6155) on a secondary transect, normal to the primary plume axis, were sampled for the same nutrient and seston variables, and salinity, as in the Primary Transect Plume Sampling Program (Figure 1).

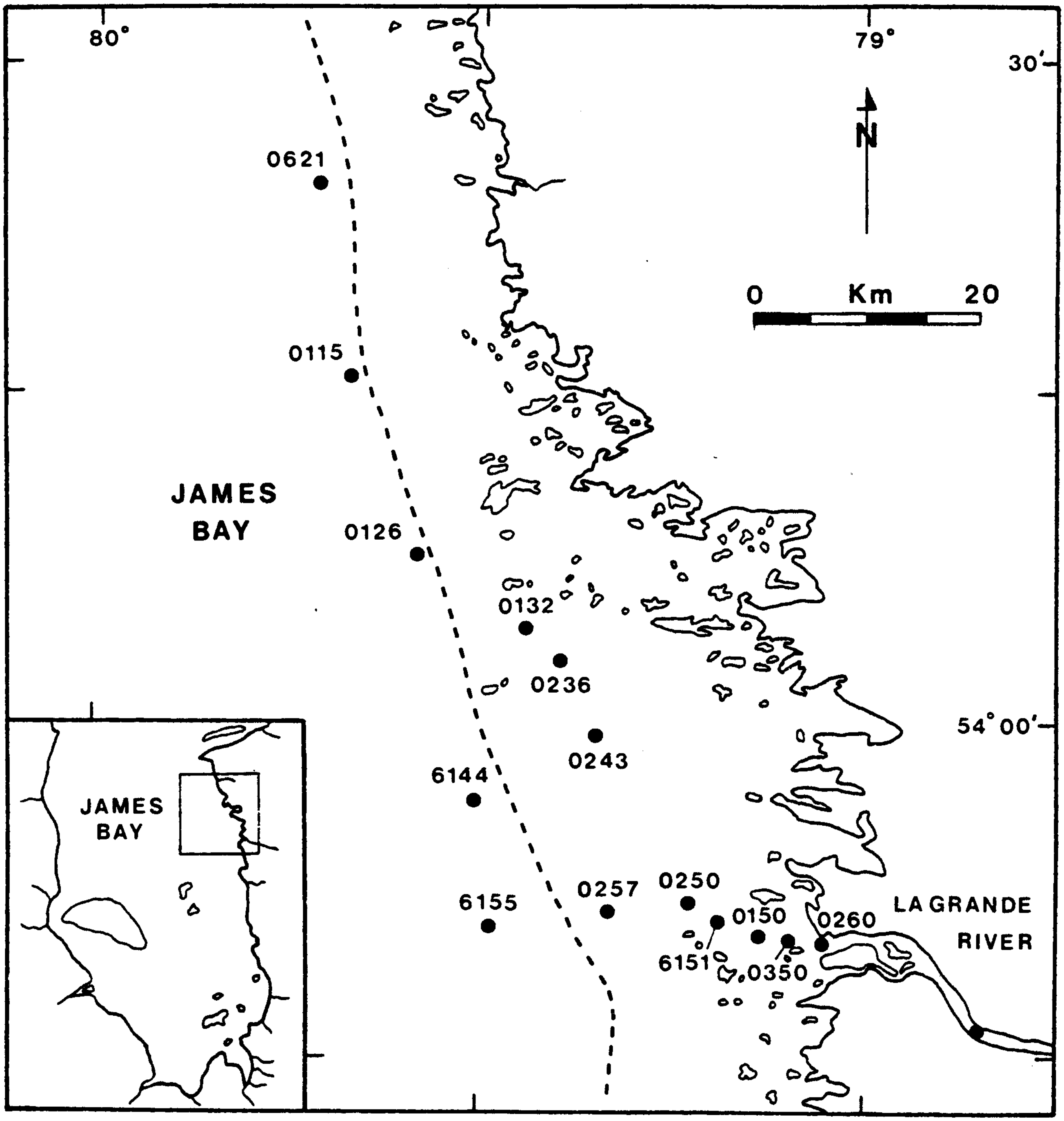

Figure 1. LaGrande River and major plume water sampling stations in James Bay, Winter 1980. Dotted line indicates edge of shorefast ice. Insert shows location in James Bay.

3.2 Ice and Snow Surveys

On each of two surveys, ice from six stations along the primary axis of the plume and in the LaGrande River (Figure 2, Appendix 2) were sampled for chlorophyll a (corrected for phaeopigments), phaeopigments, POC, PON, salinity, TP, TDP, TKN, TDKN, and NO_3 + NO_2. Due to its possible use as an index of decomposition processes and living activity of ice biota (Buinitsky 1977, Oradovskiy 1974), reactive nitrite (NO_2) determinations were added to the second ice survey. Snow samples were also taken on both surveys, but from only three stations (LaGrande River, 0132, 0115). Subsamples were taken for POC, PON, TP, TDP, TKN, TDKN, NO_3 + NO_2 determinations. The second survey was conducted between March 13 and 18; the first from February 27 to March 2. Once again Canadian Coast Guard helicopter service was the exclusive means of travel between stations.

On February 15, 1980, a preliminary sampling of ice from the LaGrande River, near its mouth, was also accomplished (Appendix 2). Only POC and PON were determined at that time.

3.3 Sample Collection

3.3.1 Water Samples

Surface samples from the LaGrande River, and an open lead station, 6144, were collected in 10 ℓ polyethylene jerricans. At all other plume stations, samples were collected with specially built 6 ℓ PVC and polycarbonate Kemmerer bottles (J.C. Roff modification) from lead edges or through holes bored in the ice (8-inch diameter Jiffy auger used). Sampling depths at plume stations were usually 2 m, and 8 m; sampling depths were measured from the water surface.

At four plume stations (five in the second survey - Stations 0250, 0236, 0126, 0115, and 0621), more detailed vertical profiles were taken. Depths sampled were representative of: the plume; either below the pycnocline (where it was distinct) or in the middle of the pycnocline (at far field stations); and intermediate depths and near

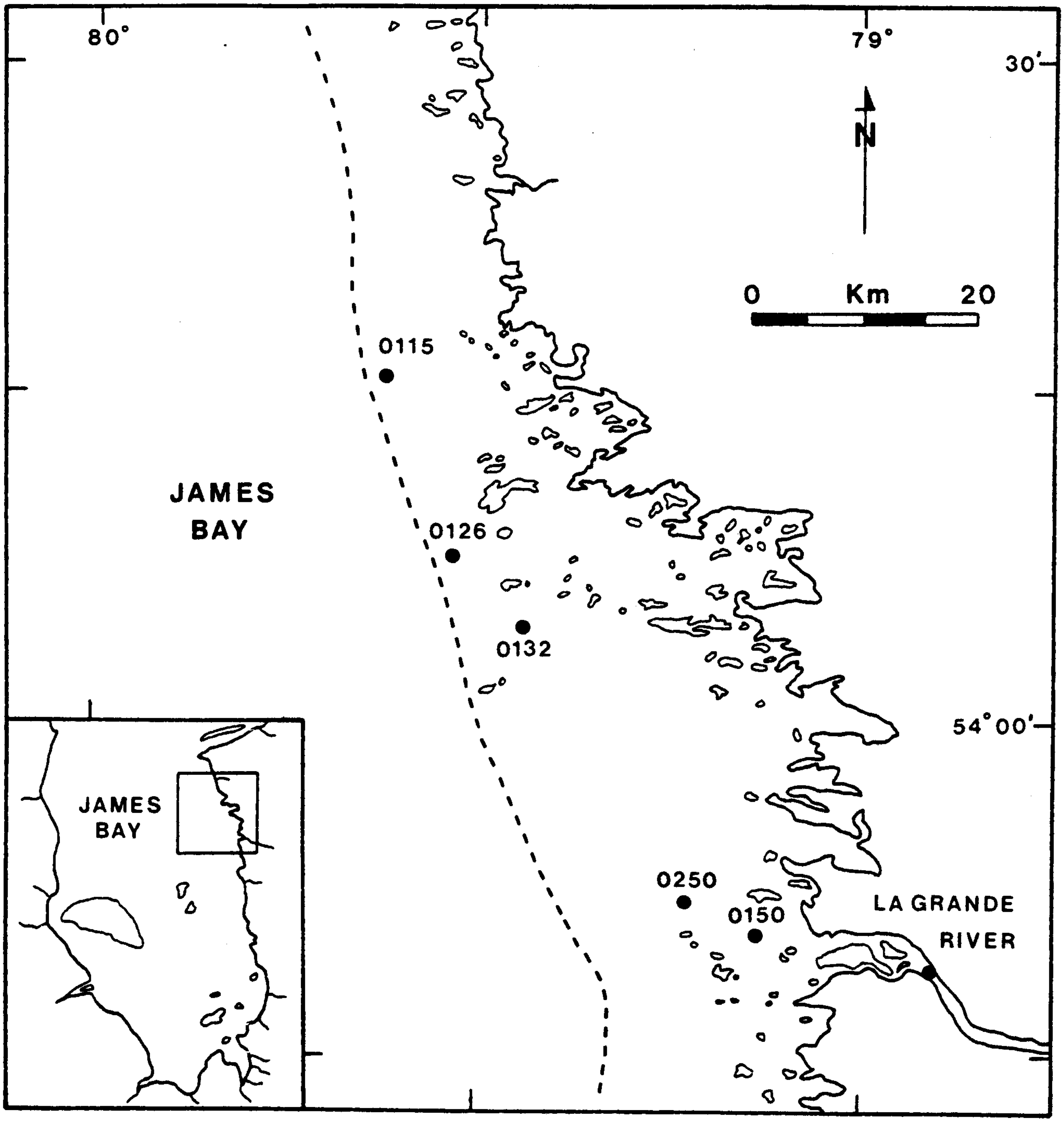

Figure 2. LaGrande River and James Bay ice and snow stations, Winter 1980. Dotted line indicates edge of shorefast ice. Insert shows location in James Bay.

bottom, depth permitting. Pycnocline depth was determined prior to sampling from CTD data collected by the physical oceanographic team.

At most stations, ice thickness was also recorded (Appendix 1).

3.3.2 Snow and Ice Samples

Upon arrival at snow and ice stations, average snow depth was initially determined before proceeding with collections of ice and snow samples (Appendix 2). Snow samples were obtained with a small snow shovel. Samples of ice were taken from two levels within the ice layer: the top 10 cm (approximately), using an ice pick; and from the bottom of the ice, by boring most of the way through the ice-layer (using an 8-inch diameter Jiffy auger), and removing the last 20 cm or so by a combination of auger and ice pick. Finally, ice thickness was measured (Appendix 2).

At all stations, snow and ice samples were stored in polyethylene bags and later allowed to thaw in them (or clean polyethylene buckets).

3.4 Seston Analyses

All filtrations employed 4.25 cm diameter, Whatman GF/C microglass filter papers (nominal pore size 0.5 to 1.0 μm), except for ATP determinations, where 2.4 cm diameter GF/C papers were used. In all filtrations, suction did not exceed 250 mm Hg (7 psi).

3.4.1 ATP

Sampling methodology adopted is that of Mackinnon (1976) as originally proposed by Holm-Hansen and Booth (1966). Prior to the survey, 5.0 ml of a 0.02 M Tris (Hydroxymethyl-methylamine) buffer, adjusted to pH 7.75 (25.0°C) with 1 N HCl (Sigma TRIZMA electrode No. E-4503 used), was added to polyethylene scintillation vials, autoclaved, and frozen until later use. Whatman GF/C filter papers were pre-ashed in a muffle furnace at 500°C, for one hour.

Shortly before sampling time, a sufficient number of vials for duplication of each depth, plus two blanks, were brought out of the freezer to thaw. Several minutes before the filtration of a sample, a vial was brought to 100°C in a water bath. A 100 ml sample was then filtered using a Mini Millipore filtration apparatus. Immediately following the filtration step, the filter paper was immersed into a vial containing boiling Tris buffer. An exact five-minute extraction period, at 100°C, followed. Vials were then stored frozen until analysis.

A Lab-Line ATP photometer (Model No. 2000) was used to analyze all ATP samples. The luciferin-luciferase (enzyme-substrate) extract, buffer tablets, and reaction cuvettes necessary for the bioluminescence reaction were contained in a Dupont ATP reagent kit (Cat No. 760145). Sterile, deionized, distilled water was used as needed.

A standard curve relating ATP concentration to photometer counts per minute was developed after production of four standard ATP concentrations: 0.5, 1.0, 5.0, and 10.0 ng ATP/ml. Sigma Grade 1, crystalline, disodium adenosine 5"-triphosphate (Cat. No. A-2383) was used to make the standards. All four standards were checked together twice daily, and occasionally with each enzyme-substrate batch. Blank levels were taken as the photon emission of Tris buffer alone.

Carbon associated with living biomass (BIOC) was subsequently calculated as ATP x 250 (Holm-Hansen 1973).

3.4.2 Chlorophyll a and Phaeopigments

Sample volumes of 500 ml to 2 ℓ were filtered in a multiple Millipore filtration manifold. Near the end of this filtration, approximately 0.2 ml of a 1% w/v mg CO_3 suspension was added. After the filtration, the filter cup was rinsed with deionized distilled water. The filter paper was folded in half with forceps, placed in a pre-labelled Whatman #1 filter paper, and paper clipped. These were then frozen until later analysis. Duplicate samples and blanks were taken approximately every twentieth sample.

All determinations for chlorophyll a and phaeopigments in ice samples were performed in the field. Extraction for these samples followed methods outlined in Strickland and Parsons (1972). Absorbances of pigment extracts were measured in 2 cm path length cells in a Bausch and Lomb Spectronic 70 spectrophotometer.

Following the survey, frozen samples from all plume waters were fluorometrically analyzed for chlorophyll a and phaeopigments by Guelph Chemical Laboratories, Ltd. Methodology also followed that given in Strickland and Parsons (1972). Pigment extracts were measured with a Turner Designs Model 111 fluorometer which was previously calibrated with purified chlorophyll a (Sigma Chemical Company, Cat. No. C-5753).

3.4.3 POC and PON

Sample volumes of 500 ml or 1 ℓ were filtered through pre-ashed Whatman GF/C filter papers (500°C for one hour) in a multiple Millipore filtration manifold, then fitted with a specially designed Millipore filtration cup. This filtration cup had a 1 x 3 cm rectangular opening in its base. At the completion of filtration, samples were first washed with 2 to 5 ml of carbon-free (double distilled) water, then given a 2 to 5 ml wash with 0.3% v/v H_2SO_4 solution, followed by a final 2 to 5 ml wash with carbon-free water. The vacuum pressure was broken between each of these washes. Methodology followed that given in the Analytical Methods Manual (Environment Canada 1979). Filters were then placed in small plastic petri dishes, sealed, labelled and frozen. Duplicate samples and blanks were taken approximately every twentieth sample.

Samples were analyzed for POC and PON by Guelph Chemical Laboratories, Ltd. Prior to analysis, filters were dried in a vacuum dessicator. A Hewlett-Packard Model 185B CHN analyzer was used for all sample analyses. Analytical methodology and calibration procedures followed those given in Hewlett-Packard operating and service manual (Hewlett-Packard 1971). Tests were standardized with cyclohexane 2-4-dinitrophenyl-hydrazone and acetanilide.

3.5 Salinity Determinations

Unfiltered samples for salinity determinations were temporarily stored in tightly capped, 500 ml amber polyethylene bottles, prior to analysis by a Guildline Model 8400 Autosal salinometer (standardized with Copenhagen seawater). Salinity values were derived from Autosal conductivity ratios (tank temperature of 24°C) using Bennett's formula (Walker and Chapman 1973).

3.6 Total and Dissolved Nutrient Analyses

3.6.1 TP, TDP, TKN and TDKN

A 100 ml unfiltered sample was added to an acid-washed 125 ml glass bottle, acidified with 1 ml of a 30% v/v H_2SO_4 solution, and tightly capped with a special polyethylene lined cap. The sample was stored for later analysis. Duplicate samples and blanks were taken approximately every fifteenth sample.

All samples were analyzed by the Water Quality Branch at CCIW. Methodology and standardization is given in the Analytical Methods Manual (Environment Canada 1979).

Sample handling and analyses for TDP and TDKN were identical to that given to TP and TKN samples, except that a 100 ml filtered sample was used.

3.6.2 SiO_2

Unfiltered samples for SiO_2 determinations were frozen for up to a week after collection in acid-washed polyethylene bottles. Analytical methodology and calibration for this method are given in Strickland and Parsons (1972). Duplicate samples were taken occasionally. A Bausch and Lomb Spectronic 70 spectrophotometer and 2 cm path length cells were used to measure the sample absorbances.

3.6.3 $NO_3 + NO_2$, and NO_2

Samples for these determinations were all stored frozen in individual, acid-washed 125 ml polyethylene bottles. Analyses commenced shortly after the survey ended.

Analytical methodology and calibration for both methods are given in Strickland and Parsons (1972). Duplicate samples were taken approximately every fifteenth sample. A Bausch and Lomb Spectronic 70 spectrophotometer and 2 cm path length cells were used to measure the sample absorbances.

4. RESULTS

This data report tabulates salinity, nutrient and seston data collected from the LaGrande River, its plume in James Bay, and from snow and ice samples in the LaGrande region of James Bay, Winter 1980. Interpretations of the data are not included here. A preliminary description of this data and the processes occurring in the LaGrande River plume can be found in Freeman et al (1981).

In this report, data has been organized into 6 major tables:

1. LaGrande River Source Samples, Winter 1980
2. Primary Transect Plume Water Samples, Survey 1, February 19 to 26, 1980.
3. Primary Transect Plume Water Samples, Survey 2, March 6 to 13, 1980.
4. Secondary Transect Plume Samples and Preliminary Water Samples, Winter 1980.
5. Preliminary LaGrande River Ice Sample, and First Ice and Snow Survey, February 27 to March 2, 1980.
6. Second Ice and Snow Survey, March 13 to 18, 1980.

Data within each table is listed by variable.

In data table headings, date is given as day - month, and sampling time in GMT hours. In the body of the data tables, depth is expressed in metres, salinity in parts per thousand, nutrient variables in microgram-atoms per litre, seston variables in micrograms per litre.

In any test where the result was below the limit of detection of the analytical method used, the detection limit is preceded by an "L." Thus "L.50" means less than 0.50, where 0.50 is the detection limit of the particular method (following the convention used by Water Quality Branch, Inland Waters Directorate, Environment Canada).

Coefficients of variation were determined for each duplicate analysis of all variables used in the survey. Averaged coefficients of analytical variation (CV) were then calculated as the pooled average of all duplicate analyses for a given variable. These are summarized in Table 7. The percent CV is defined as:

$$CV = 100 \times \text{standard deviation/mean.}$$

The standard deviation of any sample therefore equals the observed value multiplied by its corresponding CV.

TABLE 1. LaGrande River source samples, Winter 1980.

Date Time	TP	TDP	TKN	TDKN	NO_3 + NO_2	SiO_2	BIOC	POC	PON	Chl *a*	Phaeo
09 Feb 16:15	0.67	0.14		9.08				91	13	0.14 0.21	0.10 0.04
16 Feb 18:00	0.29	L.12	8.41	6.44	1.19		7.4 7.2	106	14		
22 Feb 13:00	0.35	0.23	8.19	9.80	1.23		6.0 5.3	85	7	0.12	0.01
05 Mar 15:45	0.25	L.12	8.19	7.80	1.39	4.09	6.5 5.1	143	L2	0.12	0.01
16 Mar 16:30	0.71	0.33	10.12	8.09	1.47		6.4 6.3			0.30	0.01

TABLE 2. Primary transect plume water samples, Survey 1, February 19 to 26, 1980.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
Date Time	19 Feb 13:30	24 Feb 14:30	24 Feb 20:15	19 Feb 15:30	19 Feb 16:00	19 Feb 14:30	21 Feb 16:15	23 Feb 20:45	21 Feb 19:15	25 Feb 15:30	26 Feb 15:45
Depth											

TABLE 2.1. Salinity.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2		0	0			1.71	3.04	7.01	11.82	21.96	24.17
3	0			0.68	1.13						
4		0	0								
5										22.04	24.17
6				17.53	16.85			20.56			
8						21.02	21.61	22.06	14.33		
10						22.17		22.59		23.39	24.23
12										24.16	
15											25.05
20						23.89					25.94
30						24.55					

TABLE 2.2. TP.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2		0.29	0.29			0.29	0.35 0.35	0.35	0.55	0.77 0.67	0.74
3	0.29			0.51	0.48						
4		0.29	0.45								
5											0.77
6				0.87	1.19			0.85			
8						0.71	0.93	0.80	0.58		
10						1.03		1.45		0.77	0.80
12										1.06	
15											0.90
20						1.03					0.87
30						0.90					

TABLE 2.3. TDP.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2		0.17	L.12			0.20	0.23 0.23	0.27	0.46	0.65 0.59	0.75
3	L.12			0.14	0.17						
4		0.17	0.23								
5										0.65	0.75
6				0.53	0.59			0.69			
8						0.46	0.69	0.56	0.56		
10						0.56		0.78		0.85	0.75
12										0.72	
15											0.75
20						0.75					0.85
30						0.75					

TABLE 2.4. TKN.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2		9.91	12.69			9.41	9.55 9.41	11.69	10.48	14.48 13.55	11.91
3	13.27			12.41	11.34						
4		8.12	17.84								
5										18.91	12.91
6				18.69	16.19			14.19			
8						12.41	12.41	15.41	12.55		
10						13.12		17.27		13.62	15.77
12										14.27	
15											12.77
20						15.55					15.77
30						16.05					

TABLE 2.5. TDKN.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2		8.30	9.87			7.66	8.30 7.23	9.51	8.23	12.66 11.87	14.73
3	8.87			11.66	9.87						
4		9.94	15.30								
5										11.73	12.80
6				17.01	16.51			12.87			
8						11.66	9.80	11.94	10.66		
10						11.37		14.23		14.16	11.37
12										13.80	
15											12.09
20						14.01					14.51
30						15.37					

TABLE 2.6. $NO_3 + NO_2$.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2		0.43	1.28			0.98	0.88	1.78	2.15	3.17 2.88	2.85
3	1.24			1.12	1.13						
4		1.36	1.39								
5										2.87	3.00
6				1.82	2.34			2.69			
8						1.70	2.35	3.01	2.34		
10								3.01		2.99	2.89
12										2.98	
15											3.21
20						1.83					2.99
30						2.39					

TABLE 2.7. BIOC.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2		8.0 7.8	8.7 7.0			3.8 2.9	2.5 1.4	3.4 3.4	1.9 1.8	2.6 2.5	2.9 2.1
3	8.5 7.7			5.3 4.1	6.7 4.7						
4		7.9 4.9	10.3 8.0								
5										2.5 2.4	3.0 2.4
6				2.0 1.8	2.8 2.6			2.6 2.4			
8						2.4 2.2	2.7 2.6	1.9 1.8	3.0 2.3		
10						4.0 2.2		2.9 1.8		4.1 2.5	3.1
12										3.0 1.7	
15											2.8 2.4
20						2.3 2.0					2.4 1.9
30						3.9 2.3					

Table 2.8. POC.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2		220	135			138	153 148	57	112	73	84
3	126			142	203						
4		183	119								
5										74	64
6				151	98			62			
8						66	47	77	115		
10						88		90		66	63
12										77	
15											60
20											71
30						89					

Table 2.9. PON.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2		9	10			5	16 12	8	L2	L2	L2
3	16			14	12						
4		4	11								
5										L2	L2
6				L2	10			9			
8						8	L2	10	L2		
10						11		12		L2	L2
12										2	
15											L2
20											L2
30						13					

TABLE 2.10. Chlorophyll *a* (Corrected for Phaeopigments).

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2						0.07	0.06	0.04	0.03	0.09	0.12
3	0.10			0.10	0.10						
6				0.06	0.07						
8						0.04	0.04	0.06	0.06	0.09	0.07

TABLE 2.11. Phaeopigments.

Station	0260	0350	0350	0150	6151	0250	0243	0236	0132	0126	0115
2						0.04	0.03	0.09	0.02	0.02	L.01
3	0.05			0.05	0.06						
6				0.02	0.03						
8						0.03	0.02	0.03	0.02	0.03	L.01

TABLE 3. Primary transect plume water samples, Survey 2, March 6 to 13, 1980.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
Date	06 Mar	06 Mar	06 Mar	07 Mar	07 Mar	08 Mar	08 Mar	12 Mar	13 Mar	12 Mar	09 Mar
Time	15:15	15:45	16:15	20:30	21:30	19:15	18:45	19:45	14:30	19:00	14:30
Depth											

TABLE 3.1. Salinity.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		0	0.02	0.05	0.74	1.80	2.70	7.48	21.54	25.54	25.83
3	0										
4		0									
5									22.15	26.00	25.98
8			20.42	17.48	22.81	22.22	22.20	22.52			
10					23.47		23.15		24.75	27.32	26.05
15							23.76			27.80	
20					24.96				27.40	28.02	26.54
30					25.30				27.99		27.09

TABLE 3.2. TP.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		0.25	0.29	0.32	0.48	0.32	0.35	0.42 0.38	0.77	0.67	1.25
3	0.25										
4		0.25									
5									0.71	0.74	0.90
8			0.96	0.80	1.06	1.00	1.29	0.67			
10					0.80		1.16		0.80	0.74	0.84
15							1.03			0.80	
20					0.90				0.84	0.96	0.84
30					1.06				0.84		0.96

TABLE 3.3. TDP.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		0.23	0.17		0.46	0.23	0.33	0.27 0.27	0.65	0.69	0.75
3	L.12										
4		0.20									
5									0.69	0.65	0.75
8			0.65	0.59	0.91	0.75	1.11	0.65			
10					0.72		0.85		0.78	0.69	0.75
15							0.94			0.72	
20									0.78	1.04	0.78
30					0.78				0.72		0.69

TABLE 3.4. TKN.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		10.48	8.98	11.62	14.62	8.62	18.62	9.69 9.69	11.05	9.91	15.91
3	9.41										
4		8.48									
5									10.69	11.62	12.41
8			14.34	12.27	13.48	14.98	14.41	12.76			
10					11.55		13.98		9.91	11.27	12.55
15							14.19			9.77	
20					11.48				10.55	12.19	
30					14.69				9.91		14.91

TABLE 3.5. TDKN.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		9.94	7.94	10.09		8.51	8.51	8.94 7.87	10.66	10.80	12.09
3	9.80										
4		9.16									
5									9.66	10.16	12.80
8			11.51	11.16	12.80	11.87	12.23	13.01			
10					11.37		13.09		9.23	9.87	12.16
15							12.73			10.16	
20					16.01				9.80	11.09	
30					12.80				9.23		14.30

TABLE 3.6. $NO_3 + NO_2$.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		1.36	1.60	1.38	1.51	1.48	1.77	1.98 1.92	3.03	3.19	3.54
3	1.57 1.33										
4		1.84									
5									2.80	3.19	3.61
8			2.67	3.00	2.90	3.15	3.07	3.35			
10					3.02		3.11		3.25	3.24	3.42
15							3.35			3.27	
20					3.09				3.35	3.20	3.64
30					3.51				3.39		3.91

TABLE 3.7. SiO_2.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		3.2	3.3	4.1	9.2 8.9	15.0	18.2	33.5	19.8	15.4	14.6
3	4.2										
4		3.7									
5									19.5	14.6	15.1
8			20.4	20.6	17.7	18.3	10.4	24.1			
10					16.8		18.3		16.1	14.1	14.6
15							17.4			12.6	
20					14.7				12.9	12.2	14.3
30					15.6				12.2		13.9

TABLE 3.8. BIOC.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		4.2 3.7	5.3 4.9	3.7 3.3	1.4 0.4	1.9 1.3	1.0 0.4	2.8 2.7	2.6 2.3	2.5 2.4	1.0 0.9
3	5.3 4.5										
4		2.9									
5									3.0 1.3	2.5 2.0	1.3 1.0
8			1.4 1.3	1.2 1.0	1.3 1.2	1.4 0.9	1.2 1.1	4.6			
10					1.0 0.7		1.1		2.5 2.2	2.8 2.4	0.8 0.8
15							1.0 0.8			2.1 1.8	
20					2.5 1.7				2.2 1.9	1.8 1.8	2.4 0.8
30					1.7 1.2				1.4 1.1		1.2 0.7

TABLE 3.9. POC.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		185	195	151	139	169	72	126 112	64	33	53
3	181										
4		146									
5									41	34	28
8			174	152	136	68	41	72			
10					71		64			40	34
15							89			31	
20					55				38	61	45
30					53				62		60

TABLE 3.10. PON.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		L2	L2	L2	10	L2	L2		L2	L2	L2
3	L2										
4		7									
5									L2	L2	L2
8			2	10	12	L2	L2	L2			
10					L2		L2		L2	L2	L2
15							L2			L2	
20					L2				L2	L2	L2
30					L2				L2		3

TABLE 3.11. Chlorophyll a (Corrected for Phaeopigments).

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		0.12	0.07	0.09	0.05	0.02	0.02	0.03	0.06	0.04	0.02
3	0.27										
4		0.09									
8			0.04	0.03	0.03	0.03	0.03	0.03			
10									0.03	0.04	0.04

TABLE 3.12. Phaeopigments.

Station	0260	0350	0150	6151	0250	0243	0236	0132	0126	0115	0621
2		0.04	0.03	0.02	0.04	0.07	0.07	0.03	0.01	0.01	0.01
3	0.08										
4		L.01									
8			0.03	0.02	0.01	0.02	0.01	0.03			
10									0.01	0.02	0.01

TABLE 4. Secondary transect plume samples, and preliminary water sample, Winter 1980.

Station	0257	6155	0257	6155	0250	6144	LG 2
Date	23 Feb	27 Feb	08 Mar	08 Mar	12 Feb	14 Feb	12 Feb
Time	21:15	15:15	14:00	14:30	19:15	21:15	16:30
Depth							

TABLE 4.1. Salinity.

Station	0257	6155	0257	6155	0250	6144	LG 2
Surface						21.37	
2	6.62	22.83	5.63	23.50			
3					1.01		0
6					17.31		0
8	21.52	23.22	22.33	23.67			

TABLE 4.2. TP.

Station	0257	6155	0257	6155	0250		LG 2
2	0.38	0.77 0.67	0.48	1.06			
3					0.35		0.10
6					0.74		0.19
8	0.71	0.74	0.77	0.80			

TABLE 4.3. TDP.

Station	0257	6155	0257	6155	0250	LG 2
2	0.27	0.69 0.65	0.36	0.69		
3					0.20	L.12
6					0.53	0.27
8		0.72	0.72	0.65		

TABLE 4.4. TKN.

Station	0257	6155	0257	6155	0250	LG 2
2	11.55	11.84 10.98	8.48	14.27		
3					12.19	10.69
6					15.84	10.19
8	13.69	11.62	13.19	17.12		

TABLE 4.5. TDKN.

Station	0257	6155	0257	6155	0250	LG 2
2	10.30	11.59 10.80	6.37	11.16		
3					10.94	9.94
6					12.01	13.09
8	15.59		11.30	10.94		

TABLE 4.6. $NO_3 + NO_2$.

Station	0257	6155	0257	6155
2	1.70	2.83 2.75	2.19	3.28
8	3.14	2.75	3.59	3.39

TABLE 4.7. SiO_2.

Station	0257	6155
2	25.4	16.8
8	17.8	16.8

TABLE 4.8. BIOC.

Station	0257	6155	0257	6155	0250	6144	LG 2
Surface						3.1 2.7	
2	4.2 2.8	5.2 4.4	3.9 3.7	6.1 6.0			
3					3.1 1.4		3.1 1.4
6					8.8 8.6		8.8 8.6
8	2.9 2.6	2.5	3.8	4.6 3.5			

TABLE 4.9. POC.

Station	0257	6155	0257	6155	0250	6144	LG 2
Surface						65	
2	128	49 48	175	82			
3					313		202
6					133		221
8	22	65	94				

TABLE 4.10. PON.

Station	0257	6155	0257	6155	0250	6144	LG 2
Surface						L2	
2	4	L2 L2	L2	2			
3					27		16
6					17		17
8	L2	L2	L2				

TABLE 4.11. Chlorophyll a (Corrected for Phaeopigments).

Station	0257	6155
2	0.22	0.07 0.07
8	0.07	0.07

TABLE 4.12. Phaeopigments.

Station	0257	6155
2	L.01	L.01
		L.01
8	0.01	L.01

TABLE 5. Preliminary LaGrande River ice sample, and first ice and snow survey, February 27 to March 2, 1980.

Station	LaGrande River	LaGrande River	0150	0250	0132	0126	0115
Date	15 Feb	03 Mar	28 Feb	02 Mar	27 Feb	28 Feb	27 Feb
Time	14:30	14:00	19:30	20:00	19:00	20:45	18:30
Level							

TABLE 5.1. Salinity.

Station	LaGrande River	LaGrande River	0150	0250	0132	0126	0115
Top Ice	0	0	0.19	1.11	6.91	8.04	10.38
Bottom Ice	0	0	0	0.07	5.12	7.37	10.41

TABLE 5.2. TP.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	L.10			L.10		0.67
Top Ice	0.29	0.38	0.13	0.32	0.51 0.32	0.48
Bottom Ice		L.10	L.10	0.19		0.55

TABLE 5.3. TDP.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	L.12			L.12		0.49
Top Ice	0.14	L.12	L.12	0.20	0.27 0.20	0.40
Bottom Ice		L.12	L.12	0.27		0.40

TABLE 5.4. TKN.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	1.77			13.19		15.62
Top Ice	22.05	16.41	17.69	14.55	20.34 20.12	23.05
Bottom Ice		12.19	19.34	12.41		18.19

TABLE 5.5. TDKN.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	3.77			12.09		13.51
Top Ice	23.59	11.16	16.94	10.23	16.23 15.59	24.80
Bottom Ice		11.44	4.94	12.09		13.44

TABLE 5.6. $NO_3 + NO_2$.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	17.34			11.20		
Top Ice	4.74	13.14	1.09	2.25	3.79	2.53
Bottom Ice		0.63	0.44	0.93	0.78	1.32

TABLE 5.7. Chlorophyll a (Corrected for Phaeopigments).

Station	LaGrande River	0150	0250	0132	0126	0115
Top Ice	0.33	0.48	0.16	L.10	L.10	L.10
Bottom Ice		0.16	0.16	0.57	30.71 29.28	1.44

TABLE 5.8. Phaeopigments.

Station	LaGrande River	0150	0250	0132	0126	0115
Top Ice	L.10	L.10	L.10	L.10	0.11	0.22
Bottom Ice		L.10	L.10	0.29	13.64 10.88	0.63

TABLE 5.9. POC.

Station	LaGrande River	LaGrande River	0150	0250	0132	0126	0115
Snow		66					468
Top Ice	382	720	292	307	267	347	482
Bottom Ice	704		653	275	276	1181	402

TABLE 5.10. PON.

Station	LaGrande River	LaGrande River	0150	0250	0132	0126	0115
Snow		9					35
Top Ice	32	52	15	29	7	45	74
Bottom Ice	39		83	8	16	210	64

TABLE 6. Second ice and snow survey, March 13 to 18, 1980.

Station	LaGrande River	0150	0250	0132	0126	0115
Date	18 Mar	16 Mar	16 Mar	16 Mar	13 Mar	16 Mar
Time	14:15	21:30	20:45	14:45	15:15	14:00
Level						

TABLE 6.1. Salinity.

Station	LaGrande River	0150	0250	0132	0126	0115
Top Ice	0	0.14	1.73	5.01	8.14	6.62
Bottom Ice	0	0	0.26	1.91	5.12	7.66

TABLE 6.2. TP.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	0.19 0.16			0.19		1.10
Top Ice		0.77	0.35	0.32	0.35	0.67
Bottom Ice	0.38	1.19	0.61	0.32	0.38	0.29

TABLE 6.3. TDP.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	L.12			L.12		L.12
	L.12					
Top Ice	0.23	0.17	0.14	0.17	0.30	0.17
Bottom Ice	L.12	0.14	0.14	0.14	0.14	0.14

TABLE 6.4. TKN.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	17.55			10.48		7.84
	16.84					
Top Ice	16.84	11.34	13.05	13.05	20.69	14.55
Bottom Ice		12.91	9.41	17.62	22.69	12.34

TABLE 6.5. TDKN.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	16.16			8.01		8.09
	16.01					
Top Ice	14.94	9.16	9.87	9.44	19.59	9.94
Bottom Ice		9.23	8.51	14.01	16.51	10.87

TABLE 6.6. $NO_3 + NO_2$.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	19.73 18.09			14.85		16.23
Top Ice	2.76	9.40	5.09	2.87	1.28	4.30 4.23
Bottom Ice	0.47	0.53	0.81	0.73	0.77	1.58

TABLE 6.7. NO_2.

Station	LaGrande River	0150	0250	0132	0126	0115
Top Ice	0.10	0.10	0.12	L.10	0.11	0.17 0.14
Bottom Ice	L.10 L.10	L.10	L.10	0.12	0.20	0.10

TABLE 6.8. Chlorophyll a (Corrected for Phaeopigments).

Station	LaGrande River	0150	0250	0132	0126	0115
Top Ice	0.17	0.17	L.10	0.65	0.16	L.10
Bottom Ice	L.10	0.18	0.16	7.65	3.31 3.28	9.09 8.63

TABLE 6.9. Phaeopigments.

Station	LaGrande River	0150	0250	0132	0126	0115
Top Ice	0.54	L.10	L.10	0.10	0.12	L.10
Bottom Ice	0.17	0.20	0.30	3.29	1.54 1.32	4.59 4.00

TABLE 6.10. POC.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	373			383		375
Top Ice	1731	708	568	372	504 419	199
Bottom Ice	1512	566	783	401	542	572

TABLE 6.11. PON.

Station	LaGrande River	0150	0250	0132	0126	0115
Snow	25			40		52
Top Ice	145	69	56	52	57 46	26
Bottom Ice	128	55	34	63	59	72

TABLE 7. Average coefficients of analytical variation (CV) for nutrient and seston variables.

Variable	CV %	Number of Duplicates
TP	11.9	6
TDP	5.4	6
TKN	2.5	6
TDKN	5.3	6
$NO_3 + NO_2$	5.0	6
NO_2	6.9	2
SiO_2	1.2	2
BIOC (ATP X 250)	16.8	69
POC	6.3	4
PON	10.6	3
Chlorophyll *a* - Spectrophotometer	2.6*	3
Chlorophyll *a* - Fluorometer	14.2+	2
Phaeopigments - Spectrophotometer	12.2*	3
Phaeopigments - Fluorometer	30.3+	2

* Value for ice samples.

+ Value for water samples.

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6. APPENDICES

6.1 LaGrande River and Plume Water Sampling Stations, James Bay, Winter 1980

APPENDIX 1. LaGrande River and plume water sampling stations, James Bay, Winter 1980.

Station	Latitude (N) Longitude (W)	Distance from Mouth (Km)	Date	Time (GMT)	Ice Thickness (m)
Preliminary Samples					
LG 2		-121.0	12 Feb	16:30	0.5
0250	53° 53' 79° 13'	11.0	12 Feb	19:15	1.2
6144	53° 57' 79° 27'	30.8	14 Feb	21:15	Lead
LaGrande River Source Samples					
1	53° 45' 78° 52'	-16.7	09 Feb	16:15	Lead
2	53° 45' 78° 52'	-16.7	16 Feb	18:00	Lead
3	53° 45' 78° 52'	-16.7	22 Feb	13:00	Lead
4	53° 45' 78° 45'	-16.7	05 Mar	15:45	Lead
5	53° 45' 78° 52'	-16.7	16 Mar	15:30	Lead
Primary Transect Plume Survey 1					
0260	53° 50' 79° 03'	0.0	19 Feb	13:30	0.9

APPENDIX 1. Continued.

Station	Latitude (N) Longitude (W)	Distance from Mouth (Km)	Date	Time (GMT)	Ice Thickness (m)
0350	53° 50' 79° 06'	2.3	24 Feb	14:30	0.7
0350	53° 50' 79° 06'	2.3	24 Feb	20:15	0.7
0150	53° 51' 79° 08'	5.0	19 Feb	15:30	0.7
6151	53° 51' 79° 11'	8.3	19 Feb	16:00	0.8
0250	53° 53' 79° 13'	11.0	19 Feb	14:30	0.8
0243	54° 00' 79° 19'	26.3	21 Feb	16:15	0.9
0236	54° 02' 79° 24'	33.0	23 Feb	20:45	0.7
0132	54° 04' 79° 26'	37.5	21 Feb	19:15	0.7
0126	54° 07' 79° 34'	46.8	25 Feb	15:30	Lead
0115	54° 15' 79° 39'	62.3	26 Feb	15:45	Lead
Secondary Transect Plume Survey 1					
0257	53° 52' 79° 19'	17.3	23 Feb	21:15	0.7
6155	53° 51' 79° 29'	27.5	27 Feb	15:15	Lead

APPENDIX 1. Continued.

Station	Latitude (N) Longitude (W)	Distance from Mouth (km)	Date	Time (GMT)	Ice Thickness (m)
Primary Transect Survey 2					
0260	53° 50' 79° 03'	0.0	06 Mar	15:15	1.0
0350	53° 50' 79° 06'	2.3	06 Mar	15:45	0.8
0150	53° 51' 79° 08'	5.0	06 Mar	16:15	0.9
6151	53° 51' 79° 11'	8.3	07 Mar	20:30	1.1
0250	53° 53' 79° 13'	11.0	07 Mar	21:30	1.0
0243	54° 00' 79° 19'	26.3	08 Mar	19:15	0.9
0236	54° 02' 79° 24'	33.0	08 Mar	18:45	
0132	54° 04' 79° 26'	37.5	12 Mar	19:45	1.0
0126	54° 07' 79° 34'	46.8	13 Mar	14:30	Lead
0115	54° 15' 79° 39'	62.3	12 Mar	19:00	0.5
0621	54° 23' 79° 43'	81.0	09 Mar	14:30	Lead

APPENDIX 1. Continued.

Station	Latitude (N) Longitude (W)	Distance from Mouth (Km)	Date	Time (GMT)	Ice Thickness (m)
Secondary Transect Plume Survey 2					
0257	53° 52' 79° 19'	17.3	08 Mar	14:00	
6155	53° 51' 79° 29'	27.5	08 Mar	14:30	Lead

6.2 Snow and Ice Sampling Locations in the LaGrande River and James Bay, Winter 1980

APPENDIX 2. Snow and ice sampling locations in the LaGrande River and James Bay, Winter 1980.

Station	Latitude (N) Longitude (W)	Distance from Mouth (Km)	Date	Time (GMT)	Snow Depth (cm)	Ice Thickness (m)
Preliminary Sample						
LaGrande River	53° 50' 79° 01'	-2.0	15 Feb	14:30		0.8
Survey 1						
LaGrande River	53° 48' 78° 55'	-10.8	03 Mar	14:00	35	0.6
0150	53° 51' 79° 08'	5.0	28 Feb	19:30	30	0.8
0250	53° 53' 79° 13'	11.0	02 Mar	20:00	30	1.2
0132	54° 04' 79° 25'	37.5	27 Feb	19:00	15	0.8
0126	54° 07' 79° 34'	46.5	28 Feb	20:45	5	0.8
0115	54° 15' 79° 36'	62.0	27 Feb	18:30	5	1.1
Survey 2						
LaGrande River	53° 48' 78° 55'	-10.8	18 Mar	14:15	35	0.8
0150	53° 51' 79° 08'	5.0	16 Mar	21:30	30	1.1

APPENDIX 2. Continued.

Station	Latitude (N) Longitude (W)	Distance from Mouth (Km)	Date	Time (GMT)	Snow Depth (cm)	Ice Thickness (m)
0250	53° 53' 79° 13'	11.0	16 Mar	20:45	35	1.7
0132	54° 04' 79° 25'	37.5	16 Mar	14:45	15	1.0
0126	54° 07' 79° 32'	46.5	13 Mar	15:15	15	0.9
0115	54° 15' 79° 35'	62.0	16 Mar	14:00	5	1.0