ARDEX 2004 : The Arctic River-Delta Experiment

Cruise Report

5 August 2004

Summary

ARDEX is a satellite program of CASES (Canada Arctic Shelf Exchange Study) designed to extend offshore measurements from CCGS Amundsen into the Mackenzie River, freshwater-saltwater transition zone and delta. The overarching objectives of ARDEX are to evaluate the properties of dissolved organic matter (DOM) in the river and coastal waters, and the photochemical, geochemical and biological processes regulating DOM dynamics. Field sampling and experiments were undertaken to address the hypotheses that the combined effects of photobleaching and microbial degradation of DOM in the river and marine delta environment provide a major mechanism for ventilating Arctic soil carbon stocks into the atmosphere; that coloured DOM (CDOM) regulates primary production; that zooplankton release DOM with a distinct fluorescence signature; that parts of this river-delta system are net sources of CO_2 to the atmosphere; and that terrestrial carbon contributes to the food web productivity of the Mackenzie River and coastal zone. Measurements during ARDEX included CTD and optical profiling; discrete and integrated sampling for nutrient and other biogeochemical analyses; sampling for photodegradation experiments and DOM analysis; primary and bacterial production measurements; pumped zooplankton sampling for CDOM experiments; zooplankton and seston sampling for food web analyses; and pCO_2 and pO_2 transects via continuous and discrete sample systems. The initial sampling phase of the work was by helicopter (July 21-26, 2004), and the second phase was a research cruise on the CCGS Nahidik, from 26 July–3 August 2004.

CONTENTS

1. Science Personnel

Surname, First name	Position	Tasks
Canada:		
Vincent, Warwick	PI	Chief scientist; spectral effects of CDOM
Lesack, Lance	PI	Biogeochemical analyses
Retamal, Leira	PhD student	Effects of CDOM on microbial processes
Ramlal, Patricia	Postdoc	pCO_2 and pO_2 dynamics
Rautio, Milla	Research Associate	CDOM and zooplankton
Casper, Andrew	PhD student	Food web relationships (stable isotopes)
Emmerton, Craig	MSc student	Hydrogeochemstry
Vallières, Catherine	MSc student	CDOM and bacteria
Biggar, John	Hydrographer	Hydrographic support
Tobio, David	Technician	Hydrographic support
Noksana, Margaret	School student	Joint Fisheries Management intern
USA:		
Osburn, Chris	PI	Photochemical assays and CDOM
Urbana Rich, Juanita	PI	Zooplankton and CDOM

2. Introduction

Global circulation models all converge on the prediction that future warming trends will be amplified at high northern latitudes (Moritz et al. 2002), and recent observations have indicated the onset of climate impacts in the Arctic coastal environment (Mueller et al. 2003, and references therein). A key feature of the coastal Arctic Ocean is the enormous quantities of freshwater that discharge into it, in particular from the great Siberian rivers and from the Mackenzie River, NWT, Canada. This discharge has a wide-ranging influence on all coastal ecosystem properties including heat and water balance, stratification and biogeochemical processes (Macdonald et al. 1998).

The large arctic rivers contain high concentrations of dissolved organic matter (DOM), and vast quantities of DOM are transferred in their waters from terrestrial soils and vegetation to the Arctic Ocean (3-10 Tg per year, Opsahl et al. 1999). Preliminary modelling shows that the 'coloured dissolved organic matter' (CDOM) fraction of this organic loading is likely to have a controlling influence on underwater UV radiation and light availability for photosynthesis, as well as on microbial food web and mineralisation processes (Vincent & Belzile 2003). The conversion of DOM to CO_2 by microbial processes or by photo-oxidation (Miller & Zepp 1995) and its subsequent ventilation to the atmosphere could provide a major transfer mechanism of carbon from the tundra and boreal forest into the global pool of greenhouse gases. It is also possible that this material changes its chemical and optical properties across the freshwater-saltwater transition zone (FSTZ), but whether this increases or decreases its lability, fluorescence and specific absorption is not known.

The overarching objectives of the Arctic River-Delta Experiment (ARDEX) are to evaluate the properties of CDOM in the Mackenzie River and the

photochemical, geochemical and biological processes regulating its dynamics within the river and across the Freshwater-Saltwater Transition Zone. We are addressing the hypotheses that the combined effects of photobleaching and microbial degradation of these organics in the river and inshore delta environment provide a major mechanism for ventilating Arctic soil carbon stocks into the atmosphere; that these materials are also influenced by zooplankton feeding; that part of this system are net sources of CO_2 to the atmosphere; and that allochthonous carbon contributes to the Mackenzie River and coastal food webs.

Our research took place via a joint Canada-US research cruise aboard the CCGS Nahidik, with preliminary sampling at certain river sites by helicopter. The work was timed for July–August 2004 during open water conditions to allow comparisons with a broader range of measurements from CGGS Amundsen in the oceanographic program CASES (Canada Arctic Shelf Exchange Study) in the offshore Beaufort Sea.

3. Scientific Objectives

The ARDEX scientific objectives were to:

1) characterize the CDOM in fresh, brackish and saltwater environments in the Mackenzie River, and Delta via bio-optical and chemical analysis;

2) determine and model the effects of CDOM on spectral UV and PAR penetration;

3) assess the loss of CDOM via photochemical degradation to CO and to CO_2;

4) determine the rates of microbial mineralisation of DOM and CDOM. This and objectives 3 and 7 have major implications for our assessment of how much of Canada's tundra and boreal carbon stocks may be mobilised and converted to greenhouse gases and ventilated to the atmosphere via riverine transport to the Arctic Ocean;

5) estimate the production of CDOM by zooplankton (sloppy feeding, ejestion and excretion) in part using novel fluorescence techniques;

6) evaluate biogeochemical characteristics of the fresh, brackish and saltwater components of the system, including reactive nutrients, CDOM and major ions, and chemical transformations across the FSTZ.

7) determine the spatial and temporal variations in pCO2 and pO2 in the river, transition zone and offshore waters.

8) evaluate the relative importance of autochthonous versus allochthonous materials as the source of organic carbon in the metazoan food web, and variations across the freshwater-saltwater gradient.

Additional samples were collected for Don Deibel (Memorial University). Huixang Xie (ISMER),Connie Lovejoy (Université Laval), Sylvia Bonilla (Université Laval) and Vincent St Louis (U of Alberta).

ARDEX also aims to contribute towards public outreach and science liaison with local communities. A 16-year old student from Tuktoyaktuk school participated in the cruise and science activities, and her report is below. A novel, web-based link between elementary schools in the USA and Arctic Canada is also being created (see below).

4. Cruise Overview

The 600 km (R1-R9-R1) cruise track was planned to allow sampling over a broad range of conditions, from freshwater to across the freshwater-saltwater transition (see Fig. 1), including 24 hours onsite at 2 stations to allow zooplankton migration and drift patterns to be established, or in the case of the marine influenced sites, to span a series of tidal cycles. The cruise track began in Inuvik, extended to 50 km offshore in the Beaufort Sea (inner station of CCGS Amundsen – station 65 in CASES 2002), and then returned to Inuvik. The weather was initially warm and clear skies, turning to cold and overcast for most of the cruise. In the final 3 days there were strong northerlies over the Beaufort Sea, delta and river, resulting in a storm surge increase in water depth (c. 30 cm) throughout the river to Inuvik.

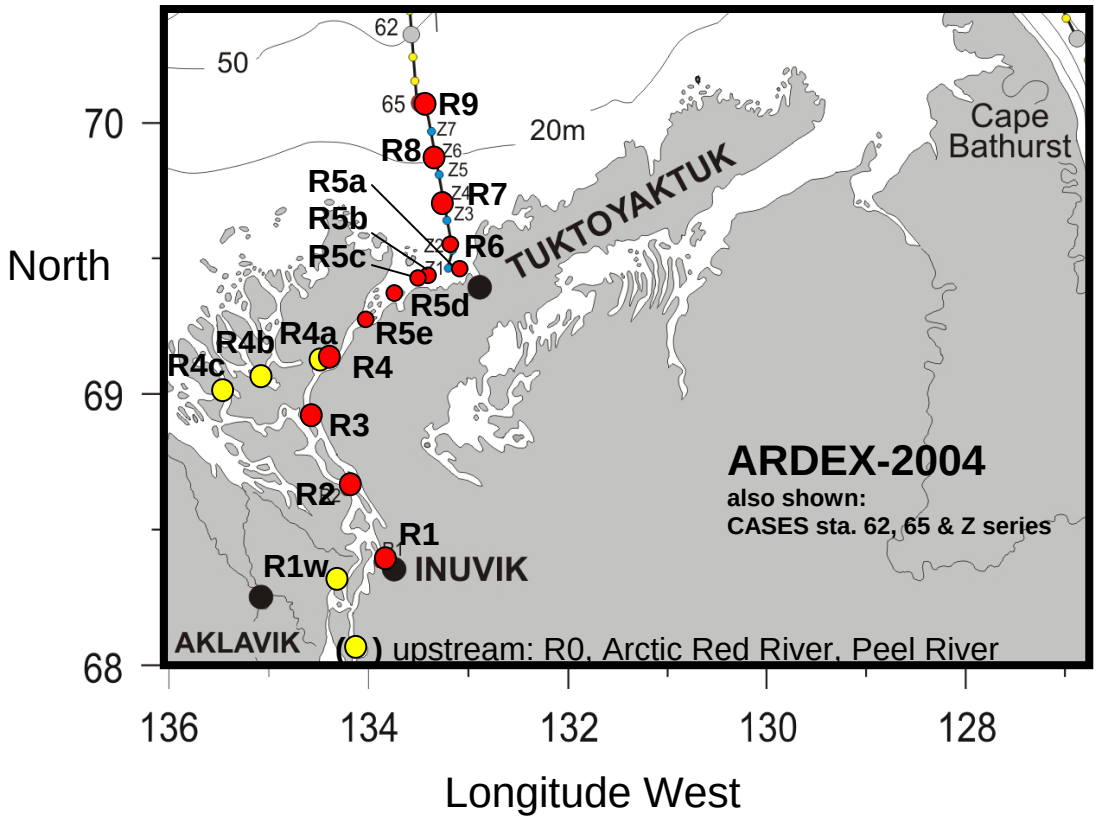
We employed the following methods appropriate to each objective. 1) CTD profiling, radiometric profiling, measurements of surface-leaving upwelling radiance (of relevance to future remote sensing applications) and water column sampling for CDOM and seston characterization by chemical analysis, spectrophotometry and spectral fluorescence (Osburn & Morris 2003). We will model apparent optical properties of these waters using the shipboard, profiling and laboratory measurements of inherent optical properties, the radiative transfer model Hydrolight, and other bio-optical models and indices such as 'weighted transparency' (T* as in Pienitz & Vincent 2000, and as modified by other laboratories). 2) Xie and Osburn will use a solar simulator to determine rates of photochemical degradation (with CO measurements as in Xie et al. 2002) and DOC fractions that were concentrated on board the ship for subsequent analysis, specificclly issolved lignin by peristaltic pumping through filters and Sephadex columns. 3) Microbial measurements were made using shipboard radio-tracer methods as employed by Vincent et al. (1996) in the FSTZ of the St Lawrence River, Québec (specifically, low activity 3H-leucine). 5)Zooplankton were obtained by horizontal and vertical net hauls, and by pumping 6) the geochemical team applied a broad range of geochemical analytical methods (Lesack et al. 1998). Further details on all objectives are given by each investigator or team below.7) pCO2 and pO2 measurements were made using a novel continuous flow system; 8) zooplankton and size-fractionated seston samples were collected to assess food web relationships using stable isotope and lipid analyses.

5. Cruise track and dates

During the Nahidik cruise, nine stations were sampled in full in the Mackenzie River and Delta: from upstream freshwater R1 at Inuvik (R1) to offshore coastal seawater station R9 over the 30 m isobath (equivalent to CCGS Amundsen station 65), ca. 300 km from R1 (see station positions in Fig. 1 and appendix). Further measurements were made at an additional 9 sampling times. The dates, stations and sampling for ARDEX 2004 were as follows:

Date	Station	Sampling
24-26 July	Channels	Sampling by helicopter: R1a, Arctic Red, Peel, R4a,R4b,R4c
26 July	R1	First freshwater sampling by Nahidik, 3h at Inuvik, CTD
27 July	R4	CTD, 3h sampling and experiments (night in Tuk)
28 July	R9	CTD and 24h sampling (offshore, saltwater)
28 July	R9b	Repeat R9, night sampling
29 July	R9c	Repeat R9 sampling
30 July	R8	CTD, 3h sampling (offshore)
30 July	R7	CTD, 3h sampling (offshore)
31 July	R6	surface only
31 July	R5a	Transition zone, 3 h sampling and experiments
31 July	R5b	Transition zone, CTD only
31 July	R5c	Transition zone, CTD only
1 August	R5d	Transition zone, 3 h sampling and experiments
1 August	R5e	Freshwater, CTD
1 August	R3	Freshwater, 3h sampling and experiments
1 August	R2	Freshwater, 24h sampling
2 August	R2a	Freshwater, night sampling, CTD
2 August	R2b	Freshwater, morning sampling
2 August	R2c	Freshwater noon CTD
2 August		Arrive Inuvik pm
3 August		Disembark at Inuvik

6. Station map (see Appendix 3 for exact positions)
Yellow: Helicopter stations; Red: Nahidik stations



7. Individual Cruise Reports

7.1 Chris Osburn

Naval Research Laboratory
Washington DC
USA
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My project is focused on the transport and reactivity of terrestrial DOM (T-DOM) from the Mackenzie River in the Beaufort Sea. To achieve this objective I used the terrestrial biomarker, lignin, to trace the influence of terrestrial DOM in the Beaufort Sea. Moreover, I have a hypothesis that the long sunlight periods (though at low sun angle) provides a T-DOM removal mechanism in the Beaufort Sea. Thus, I planned to run some sunlight exposures of samples collected along the transition from freshwater to saltwater.

Samples were filtered for particulate lignin through pre-cleaned and baked Whatman GF/F filters; filtrate was processed with whole water samples through serial 3 micron and then 0.2 micron Gelman PALL filters. Samples were collected for d13C of DOC and DIC, amino acid and carbohydrate, and spectroscopy (EEM, synchronous fluorescence, Near IR reflectance) and DOC.

Three photobleaching experiments were run. Experiment 1 was a bulk photobleaching of 2 L of 0.2 micron filtered water from R9 and R4; the goal was to establish photoreactivity of fresh water and marine water end members. Experiment 2 was a photobleaching of R7 water under optical cutoff filters. This experiment was performed to determine the wavelength depende ncy of photobleaching in samples within the Mackenzie plume of the Beaufort Sea. Experiment 3 was a photobleaching experiment of R3 and R5d waters. The goal of this expeirment was to determine rates of photobleaching for another river station and the fresh-salt transition zone.

Dissolved lignin extractions on water samples were performed.

A PUV radiometer was stationed above the wheehouse to measure ambient UVR for experiments performed and in comparison to the Hyperspectral probe.

Station	Note	d13C dic/doc	AA/CH2O	D Lignin	Particulate Lignin	1 L archive (EEM, SF, IR, DOC)	Depths (S, M, B)
R1	Inuvik	x	x	x	x	x	S
R2		x	x	x	x	x	S
R3		x	x	x	x	x	S, B
R4	Lousey Pt	x	x	x	x	x	S
R4 a	Middle Channel	x	x	x	x	x	
R4 b	Reindeer Channel	x	x	x	x	x	
R4 c	Lousey Pt	x	x	x	x	x	
R5 a		x	x	x	x	x	S
R5 b		x	x	x	x	x	S
R5 d	Fresh-salt transition	x	x	x	x	x	S, B
R7		x	x	x	x	x	S

R8		x	x	x	x	x	S
R9		x	x	x	x	x	S, M, B

7.2 Patricia Ramlal
Freshwater Institute,
Winnipeg, Canada

Objective: My goal was to measure carbon dioxide (CO_2) and oxygen (O_2) fluxes to/from surface waters of the Mackenzie River and Delta. This was done using a continuous flow of surface water through a gas equilibrator that splits the gas flow between an oxygen sensor and a LiCor GasHound infrared CO_2 analyzer (hereafter referred to as the "CO_2 boxes"). The data will be used in conjunction with climate data from the Environment Canada Inuvik and Tuktoyaktuk climate stations in the application of the thin boundary layer model to determine gas fluxes.

Measured Variables:

1. Where appropriate the data collection system was turned on to measure CO_2 and O_2 at 1 minute intervals or at 1 hour intervals. In general the 1 minute intervals were used while the ship was moving in the Mackenzie River. The 1 hour intervals were used when the ship remained on station for some time. Surface water temperature is also measured each time the water is sampled in the CO_2 boxes.
2. Discrete samples were collected manually for P_{CO2} and DIC on several occasions to ground truth the CO_2 boxes and to measure P_{CO2} in the water column.
3. In marine waters profiles were collected at sampling stations for P_{CO2} and DIC.
4. Secchi depth
5. *Times are recorded for samples and boxes as Inuvik time. GPS coordinates from Jon Biggar are recorded based on UMT. Boxes set to CST. All will ultimately be presented in the same time frame.*

Mode	Station	Start	Start	End	End	Notes
survey	R1	26-Jul-04	15:45	26-Jul-04	21:20	download at 18:15
monitor		26-Jul-04	21:20	27-Jul-04	7:00	pump problems, repaired and working
survey		27-Jul-04	7:45	27-Jul-04	10:00	use data collected after 8:15
survey	R4	27-Jul-04	10:25	27-Jul-04	14:53	passed Swimming Point at 8:20; 8:30 speed slowed to 3 knots; on station R4 at 10:35; 3 knot zoop tow for 20 minutes
monitor		27-Jul-04	18:15	27-Jul-04	19:10	
survey	R9	28-Jul-04	12:00	28-Jul-04	14:00	
monitor	R9	28-Jul-04	14:00	29-Jul-04		moving around R9, high waves possible intermittent sampling
monitor	R8	29-Jul-04	18:30	30-Jul-04	12:00	arrive at R8 at 18:30 boxes continued to let run in monitor mode.
survey	R8	30-Jul-04	6:40	30-Jul-04	6:55	
monitor	R8	30-Jul-04	6:55	30-Jul-04	12:00	
monitor	R8-R7	30-Jul-04	12:00	30-Jul-04	14:05	moving from R8 to R7 at high speed; likely not pumping well; 14:00 sample may be contaminated

monitor	R7	30-Jul-04	14:05	30-Jul-04	16:30	
monitor	R6	30-Jul-04	18:00	30-Jul-04	18:10	
monitor	Tuk Harbour	30-Jul-04	20:00	31-Jul-04	7:15	
survey	R5A to R5D	31-Jul-04	7:15	31-Jul-04	19:53	R5A on 8:25 off 11:50; R5B 13:25 to 13:42; R5C 14:05 to 17:15; R5D 19:25 to 19:53
survey	R5D to Swimming Point	31-Jul-04	21:50	01-Aug-04	7:30	
survey	Swimming Point to R3	01-Aug-04	7:30	01-Aug-04	9:45	
monitor	R3	01-Aug-04	9:45	01-Aug-04	13:45	
monitor	R2	01-Aug-04	16:30	02-Aug-04	15:10	

Date	Station		Secchi (m)	Depth (m)	Time	Start °C	End °C	PCO2-1	PCO2-2	DIC
26-Jul-04	R1	fresh		0	14:45	20.0	20.8	D1817	D1849	E641
26-Jul-04	R1	fresh		air	18:15			D1891		
27-Jul-04	R4	fresh		0	10:52	18.6	19.6	D1813	D1900	E644
27-Jul-04	R4	fresh		0	12:40	18.9	19.9	D1911	D1883	E654
27-Jul-04	R4	fresh		air	12:40			D1826		
27-Jul-04	R4	fresh		6	12:40	18.9	20.0	D1838	D1860	E632
28-Jul-04	R9	marine	14.0	0	13:00	9.7		D1863	D1885	E645
28-Jul-04	R9	marine		air				D1829		
28-Jul-04	R9	marine		12.7		1.2	3.0	D1818	D1871	E619
28-Jul-04	R9	marine		10		1.4	3.5	D1852	D1890	E629
28-Jul-04	R9	marine		8		2.8	4.5	D1844	D1855	E650
28-Jul-04	R9	marine		6		4.7	6.1	D1882	D1905	E653
28-Jul-04	R9	marine		5		4.9	6.0	D1877	D1903	E623
28-Jul-04	R9	marine		4		5.2	6.3	D1851	D1868	E642
28-Jul-04	R9	marine		21		-1.1	1.4	D1821	D1896	E626
28-Jul-04	R9	marine		2		7.4	7.9	D1857	D1889	E615
28-Jul-04	R9	marine		0.1		9.7	10.1	D1843	D1909	E627
28-Jul-04	R9	marine		30		-1.2	0.7	D1811	D1846	E620
29-Jul-04	R9	marine		0	0:04	8.7	8.6	D1853	D1878	E630
29-Jul-04	R8	marine		0	18:30	6.8	6.9	D1823	D1902	E658
30-Jul-04	R8	marine	9.9	14		-0.5	0.8	D1835	D1906	E625
30-Jul-04	R8	marine		7		2.8	3.2	D1814	D1879	E656
30-Jul-04	R8	marine		air				D1899		
30-Jul-04	R8	marine		0	8:15	7.5	7.4	D1875	D1893	E618
30-Jul-04	R7	marine	2.4	6.5		3.1	4.2	D1840	D1864	E614
30-Jul-04	R7	marine		5		6.1	6.7	D1856	D1858	E622
30-Jul-04	R7	marine		0		9.0	9.3	D1832	D1884	E649
30-Jul-04	R6	marine		0	18:00	11.9	12.1	D1831	D1836	E616
31-Jul-04	R5A	transition	0.7	0		12.5	13.1	D1874	D1876	E646
31-Jul-04	R5A	transition		2.5		11.7	12.3	D1827	D1842	E651
31-Jul-04	R5A	transition		1.5		11.7	12.3	D1837	D1845	E628
31-Jul-04	R5B	transition	0.6					no vials		
31-Jul-04	R5C	transition						no vials		
31-Jul-04	R5D	transition	0.25	0		13.2	13.2	D1812	D1859	E624
31-Jul-04	R5D	transition		3.4		13.3	12.7	D1825	D1847	E648
31-Jul-04	R5D	transition		2		13.1	13.1	D1880	D1904	E608
31-Jul-04	R4	fresh	0.25							
01-Aug-04	R3	fresh	0.24	0	11:00	15.5	14.8	D1819	D1866	E636

01-Aug-04	R3	fresh		28		15.2	15.4	D1901	D1908	E643
01-Aug-04	R3	fresh		air				D1869		
01-Aug-04	R2	fresh	0.25	0	20:00	17.3	16.1	D1873	D1895	E637
01-Aug-04	R2	fresh		20	20:45	17.2	16.7	D1841	D1912	E639
02-Aug-04	R2	fresh	0.3	0	9:00	16.0	15.10	D1820	D1887	E640
02-Aug-04	R2	fresh		air				D1888		
02-Aug-04	R2	fresh		15		16.5	15.8	D1861	D1907	E611

Date	Time	Conductivity (mS/cm)	°C surface	
30-Jul-04	18:00	31.30		R6
31-Jul-04	8:00	12.49		
31-Jul-04	8:05	19.66		
31-Jul-04	8:10	17.36		
31-Jul-04	8:15	14.52		
31-Jul-04	8:20	13.79		
31-Jul-04	8:25	10.52		R5A
31-Jul-04	11:25	11.90		
31-Jul-04	11:30	11.84		
31-Jul-04	11:35	11.38		
31-Jul-04	11:40	11.00		
31-Jul-04	11:45	10.19		
31-Jul-04	11:50	10.95	12.8	
31-Jul-04	11:55	13.12		
31-Jul-04	12:00	14.45		
31-Jul-04	12:05	14.85		
31-Jul-04	12:10	18.23		
31-Jul-04	12:15	19.79		
31-Jul-04	12:20	18.86		
31-Jul-04	12:25	18.00		
31-Jul-04	12:30	17.62		
31-Jul-04	12:35	17.83		
31-Jul-04	12:40	18.35		
31-Jul-04	12:45	11.81		
31-Jul-04	12:50	9.24		
31-Jul-04	12:55	9.34		
31-Jul-04	13:00	9.50	13.2	
31-Jul-04	13:05	9.34		
31-Jul-04	13:10	9.00	13.6	
31-Jul-04	13:15	8.40	13.9	
31-Jul-04	13:20	7.55	14.2	
31-Jul-04	13:25	7.08	14.4	
31-Jul-04	13:30	6.99	14.4	R5B
31-Jul-04	13:45	7.64	14.2	
31-Jul-04	13:50	8.09		
31-Jul-04	13:55	7.41		
31-Jul-04	14:00	6.64	14.5	
31-Jul-04	14:05	6.56		R5C
31-Jul-04	17:25	15.38	12.3	
31-Jul-04	17:30	15.49		
31-Jul-04	17:35	15.12	12.7	
31-Jul-04	17:40	14.44	12.9	
31-Jul-04	17:45	13.26	13.2	

31-Jul-04	17:50	11.98	13.4	
31-Jul-04	17:55	11.95	13.4	
31-Jul-04	18:00	11.44	13.6	
31-Jul-04	18:05	10.65	13.2	
Date	**Time**	**Conductivity (mS/cm)**	**°C surface**	
31-Jul-04	18:10	10.18	13.8	
31-Jul-04	18:15	6.07	14.2	
31-Jul-04	18:21	2.79	14.5	
31-Jul-04	18:26	0.50	14.6	
31-Jul-04	18:31	0.90	14.8	
31-Jul-04	18:36	0.60	14.8	
31-Jul-04	18:52	0.70		
31-Jul-04	19:00	5.20		
31-Jul-04	19:20	4.06		R5D

7.3 Andy Casper & Milla Rautio,
Dépt de biologie
Université Laval

PATTERNS OF INCORPORATION OF ALLOCHTHONOUS, AUTOCHTHONOUS AND MARINE CARBON BY ZOOPLANKTON IN THE MACKENZIE RIVER DELTA

This portion of ARDEX examines whether there is differential incorporation of carbon into the Mackenzie River pelagic foodweb. Seston characteristics may either reflect a decreasing terrestrial-allochthonous gradient across the estuarine transition zone or dominance by terrestrial or marine separated by a sharp estuarine transition zone. Thus carbon assimilated by zooplankton should reflect either the signature of the locally dominant seston or one of the three principal types of carbon (marine, freshwater, terrestrial) is preferentially assimilated.

Samples Taken

Station	1	2	3	4	5a	5D	6	7	8	9
Lipid GFF (2 filters)	X	X	X	X	X	X		X	X	X
Lipid blank	X	X	X	X	X	X		X	X	X
surface ^{13}C bulk seston (1 filter)	X	X	X	X	X	X		X	X	X
surface ^{13}C >5 um seston (1 filter)	X	X	X	X	X	X		X	X	X
surface ^{15}N bulk seston (1 filter)	X	X	X	X	X	X		X	X	X
surface ^{15}N >5 um seston (1 filter)	X	X	X	X	X	X		X	X	X
isotope blank	X	X	X	X	X	X		X	X	X
deep ^{13}C bulk seston (1 filter)	X	X	X	X	X	X		X	X	X
deep ^{13}C >5 um seston (1 filter)	X	X	X	X	X	X		X	X	X
deep ^{15}N bulk seston (1 filter)	X	X	X	X	X	X		X	X	X

deep ^{15}N >5 um seston (1 filter)	X	X	X	X	X	X	X	X	X
surface DIC ^{13}C (2 bottles)	X	X	X	X	X	X	X	X	X
surface DIN ^{15}N (2 bottles)	X	X	X	X	X	X	X	X	X
deep DIC ^{13}C (2 bottles)	X	X	X	X	X	X	X	X	X
deep DIN ^{15}N (2 bottles)	X	X	X	X	X	X	X	X	X
surface zooplankton <63 um for taxonomy	X	X	X	X	X	X	X	X	X
deep zooplankton <63 um taxonomy	no	X	X	X	X	X	X	X	X
surface zooplankton <500 um $^{13}C/^{15}N$	X	X	X	X	X	X	X	X	X
deep zooplankton <500 um $^{13}C/^{15}N$	X	X	X	X	X	X	no	X	X

Nahidik – ARDEX Net Haul Log

R2: 20 m site highly turbid surface and bottom (12 m) tows very similar at first glance – lots of organic plant detritus, seems to be highly degraded plant matter in transport (perhaps due to all the recent rain?). Plankton is limited to a few Stone flies (?Isoperlids?) and Heptageniidae mayflies only (very few copepods seen). All the organic matter prevents me from separating enough copepods for isotope analysis. Surface sample volume: 968256 - 038290, Deep sample volume: 047913 - 128604

R3: Deep site (30 m), highly turbid surface and bottom (12 m) tows very similar at first glance – lots of organic plant detritus, perhaps due to all the recent rain? Plankton is limited to a few Stone flies (?Isoperlids?) and Heptageniidae mayflies only. All the organic matter prevents me from separating enough copepods for isotope analysis. Surface sample volume: 858076 – 898841, Deep sample volume: 898841- 967119

R4: Had trouble pulling off a good tow, however did get smelt (adults and larvae), stoneflies but not a lot of CTOM at the surface. Tow distance 3208 m from 69-08.369/134-18.639W to 69-09.848N/134-16.140W. Surface sample volume: 359744 – 460847, Deep sample volume: 460847 - 532783

R5d: The site is 3 m deep and highly turbid, which means I only did a surface tow, but it was loaded with small copepods (Oithonia oncea?), stonefly & mayfly larvae, one stickleback, and adult & larvae smelt. There was a lot of Equisetum and some adult midges in the flotsam & jetsum. Sample volume: 673302 - 746768

R5a: The site is 3 m deep and highly turbid, which means I only did a surface tow but it was loaded with small copepods (?Oithonia oncea?) and a single species of fish larvae. Sample volume:

R7: This was a 7m deep site, thus only one 20 minute tow at 2-3 m depth. Strangely, almost no animals or even material in the net; 1 spp of fish larvae, 1 jelly, and

Calanus (?hyperborealis?). Juanita's vertical haul had lots of fish larvae but she went to 5.5 m while I towed at 3 m. Sample volume: 622391 - 673277

R8: Good horizontal tows, 20 minutes at each depth. Surface had more jellies (at least three species) and pteropods (shelled and unshelled species) than deep but no fish larvae or mysids to speak of. Deep (~12 m) had numerous fish larvae of least 3 species, both species of amphipods, and no terrapods. Got larvacians in the vertical haul. Surface tow had lots of pteropods (2 species, one with and one without shells), 3 fish larvae. Surface sample volume: 57835 – 601070, Deep sample volume: 601070 - 622372

R9: Lots of phytoplankton and (off the bottom of the ice?) and jelly detritus in both samples. Surface had numerous pteropods and some fish larvae.Surface sample volume: 532778 – 558642,
Deep sample volume: 558642- 576286

7.4 Lance Lesack and Craig Emmerton

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Background and General Goals:

The general goals of Lesack and Emmerton participating in the ARDEX Cruise include the following. One long-term goal of Lesack's research on the biogeochemistry of lakes in the Mackenzie Delta is to assess the role of the Mackenzie Delta in modifying outflow of river water to the Beaufort Sea. About a third of the Mackenzie River flow during the spring peak discharge period goes into storage in lakes of the Mackenzie Delta where that water has the potential to be stripped or enhanced in nutrient composition, and dissolved organic matter has significant potential to be photobleached while the water is temporarily stored in the vast array of delta lakes. As of result of the interaction of Mackenzie River water with the delta system, we feel that the nutrient composition of the water flowing into the Mackenzie Delta at Arctic Red River (the only long-term nutrient database available for the lower Mackenzie River) is unlikely to represent the nutrient composition of water that leaves the delta to be exported into the Beaufort Sea. We have postulated that photobleaching of CDOM and nutrient stripping will be

important effects of the delta on Mackenzie River water as it flows through the system.

Emmerton is conducting an MSc thesis project to make a first order assessment of the potential delta stripping effect via fieldwork conducted during the summers of 2003 and 2004. One element of this assessment is enhanced sampling (weekly) over the open water season of the Mackenzie River at Arctic Red River, Arctic Red River, and the Peel River (each at the long term gauging stations of Water Survey Canada). A second element of this assessment is to compare nutrient and DOM composition from upstream to downstream of the delta via sampling stations located on the major outflow channels of the lower delta (using the full set of sediment monitoring stations used in the analysis of Carson et al., 1999) versus the major inflows to the delta (full grid of all stations sampled twice during 2003 and three times during 2004). Participation of Emmerton on the Nahidik Cruise will allow (1) a higher resolution gradient of stations from mid-delta into the Beaufort Coastal zone to be sampled and will provide supporting nutrient data for the variety of other investigations associated with the Cruise. Other objectives associated with Emmerton's project include (2) assessing potential water column structure that may be present in the sampling grid that would not be picked up via sampling only surface waters. The presence of (3) enhanced particle load in water near the river bed will be assessed in the lower sections of the river. The position of (4) the seawater front relative to Mackenzie River outflow will be used to assess the representativeness of the outer delta sampling grid that has been established. The degree of (5) river water layering and nutrient distributions over seawater on the Beaufort Coast is a final element that would flesh out Emmerton's thesis project.

Additional information on our on-going work in the Mackenzie Delta is available from <http://www.sfu.ca/limnology>. A useful analysis of the sediment budget on the Mackenzie Delta, including an assessment of sediment outflow to the Beaufort Sea from the outer delta, is available from Carson et al. (1999). A brief but useful summary of the basic Mackenzie River hydrology is available in Rouse et al. (1997)

Sampling Strategies:

In the river stations R1 through R4, we expected the water column to be well mixed and the CDT profiles confirmed this. This means the dissolved constituents ought to be well mixed throughout the water column, but it's common for particulates to increase near the river bed in a zone of transition between suspended load versus bed load. The general strategy was thus to sample surface and bottom waters for dissolved constituents, with the bottom sample expected to pick up increased particulates. To obtain a sample representative of the full water column, we also took integrated samples via a slow filling bottle that was rapidly lowered and raised through the water column.

In the transition and coastal stations, the sampling strategy involved inspection of the CTD profile prior to deciding on sampling depths. We generally planned on a surface sample to represent the mixed surface layer. A bottom sample was also generally taken to capture any constituent increases towards the bottom, then additional samples to capture the salinity gradient, if present between the surface layer and the bottom,

and additional features such as the deep chlorophyll maximum which was common at the offshore coastal stations.

The same general set of chemical analyses will be done at each station and depth at each station. The basic measurements include:

1) Inorganic nutrients - PO4 (SRP), NH4, NO3/NO2, Si, plus major cations and anions (river water only)

2) Organic nutrients - TDN (DON = TDN - NH4 + NO3), TDP (DOP = TDP - SRP), DOC

3) Particulates - PC (Total C = PC + DOC), PN (Total N = PN + TDN), PP (Total P = PP + TDP), and TSS

4) Chlorophyll a

Additional measurements include:

5) Absorbance at 330 nm that we use as a routine index of CDOM to compare with database for our work on Mackenzie Delta lakes

6) Fluorescence scans of DOC following McKnight approach to develop index of terrestrially derived DOC versus aquatic DOC - this is of particular interest in lakes of the Mackenzie Delta

7) Possible separations of DOC based on molecular weight - we are still developing the details of this and are not yet sure how well this will work

8) Measurements of total and methyl Hg via the lab of Vince St Louis and Jenny Graydon at the University of Alberta.

A general summary of the various depths sampled and the timing of sampling at the various stations is summarized in Table 1 below.

Table 1: Station sampling and subsequent analyses to be completed.

Station	**Date**	**Samples Collected**	**Sample Analyses**
R1-Inuvik	July 26/04	Surface-A Surface-B	NO_3^- / Anions Si / Cations DOC TDN/TDP PO_4^{3-} / NH_4^+ Particulate N, P, C Chlorophyll-a Total Suspended Solids Mol. Wt / Fluorescence Index CDOM Total/Methyl Hg (surface only)
R2-Lousy Pt.	July 27/04	Surface	Same as above

		Bottom (6m) Integrated	
R9	July 28/04 July 29/04	Surface 5 m Middle (12m) Bottom (21m) 30 m Surface (time 2, 01:00) Surface (time 3, 13:00)	Same as above
R8	July 30/04	Surface 7 m Bottom (12m) 14 m	Same as above
R7	July 30/04	Surface Middle (5m) Bottom (6.5m)	Same as above
R6	July 30/04	Surface	Same as above, no Hg
R5A	July 31/04	Surface Middle (1.5m) Bottom (2.5m)	Same as above
R5B	July 31/04	Surface	Same as above, no Hg
R5C	Not sampled		
R5D	July 31/04	Surface Middle (2m) Bottom (3.4m)	Same as above
R5E	July 31/04	Surface	Same as above, no Hg
R3	Aug. 01/04	Surface Bottom (~28m) Integrated	Same as above
R2	Aug. 01/04 Aug. 02/04	Surface Bottom (20m) Integrated Surface (time 2) Bottom (time 2, 16m) Surface Bottom (15m) Integrated	Same as above Same as above, no Hg Same as above, no Hg

7.5 Juanita Urban-Rich

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The scientific and educational objectives of this project are:

1. Examine the horizontal and vertical distribution of grazing zooplankton in the Mackenzie River and at the freshwater/saltwater interface
2. Examine the fate of zooplankton derived DOM and CDOM
3. Develop a website that features video and digital images from the field project
4. Initiate a school pen pal program involving data exchange on topics such as temperature, light, seasons, animals, etc between the Moose Kerr School in Aklavik, NWT Canada in the Arctic and Helen Keller Elementary School in Franklin MA USA

Sampling and Analysis

Samples were collected for the horizontal and vertical distribution of grazing zooplankton by using an *in situ* pump that permitted me to collect water at intervals as fine as one meter. The samples collected from the pump system will be analyzed using fluorescence excitation-emission matrices (EEMs) for the presence of the zooplankton derived fluorescent material. Three excretion experiments over the salinity transect were conducted to verify that Arctic zooplankton release the same fluorescence tracer material found for temperate zooplankton. Samples for DOC analysis were also collected from every pump depth. Vertical net tows were conducted at each station so that general zooplankton community composition can be determined along the salinity transect.

The fate of marine zooplankton derived DOM and CDOM was examined in two experiments. Bacterial utilization of zooplankton derived DOM/CDOM was examined by adding bacteria to filtered water enriched with zooplankton excreta and comparing it to surface water without zooplankton excreta. Aliquots of this water were also exposed to sunlight to determine the photo oxidation rate and fate. The combined effect of sunlight and bacteria was also examined by adding bacteria to zooplankton excreta and surface water after it had been exposed for 24 h to natural light and incubating it in the dark. Bacterial production, abundance and fluorescent EEMs and DOC samples were taken from every experiment.

Margaret Noksana conducted interviews of all the scientists on board for me. Margaret is a high school student from Tuk who is participating in the FJMC (Fisheries Joint Management Committee) program for local high school and college students. Many digital still images were taken and a daily log of events has been recorded. This material will be posted on a website within one week of my returning home.

Prior to the cruise, I met with Velma Illasiak, principal of the Moose Kerr School and started dialog on the school exchange program. The actual program will start in October/November.

Table 1: List of depths samples taken and the location of the experiments.

Station	**Pump**	**Vertical Net**	**Experiments**	**Comments**
R1				Not sampled
R2	0, 5, 10.5 m at 2230h, 0200h,	0-18 m at 2230, 0200	Excretion experiment	

	1000 h and a bottom sample 20, 16.5 and 15 m.	and 1000 h.	conducted with animals collected from the vertical net tow at 1000 h.	
R3	28, 10, 5 and 0 m.	0-25 m net tow		
R4	6, 4, 2 and 0 m			
R5A	2.5, 1.5, 0 m.	0-2 m net tow	Excretion experiment	
R5B	0 m			
R5D	3.4, 2 and 0 m	0-3 m net tow		
R6				Not sampled
R7	6.5, 5, 2.5 and 0 m	0-5 m net tow		
R8	14, 12, 10, 8, 6, 7, 4, 2 and 0 m	0-13 m net tow		
R9-day	30, 21, 12.7, 10, 8, 5.8, 5, 4, 2 and 0 m			
R9-Night	21, 9.2, 8, 6, 4, 2 and 0	0-22 m net tow	Excretion experiment and water for microbial decay and photo oxidation experiments obtained excretion experiments here.	Lots of larvaceans here.

7.6 Jon Biggar and David Tobio
Canadian Hydrographic Service (CHS)
Burlington
Ontario

Our main role in the ARDEX program was that of coordination/logistical support and providing precise navigation for the CCGS Nahidik. CHS operated and provided real-time differential corrected Global Positioning System (DGPS) positions and depth information for the project.

Refer appendices for coordinates and maps produced by our team.

7.7 Leira Retamal, Milla Rautio, Patricia Ramlal and Warwick F Vincent

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The aim of this section of ARDEX is to evaluate the influence of CDOM on underwater light and photosynthesis. At each station, CTD casts were made to the bottom of the water column (RBR XR-620 CTD with paired fluorometers and transmissometer). Profiling with a PUV-500 was then undertaken to define the coefficients of attenuation for PAR and 4 UV wavebands (308, 320, 340, and 380 nm), and transmittance as a function of depth. In addition, profiles of downwelling spectral PAR (350-820 nm) were obtained at a representative range of stations: R9, R5a, R4, and R1. At the river stations R1 and R4, upwelling spectral; radiance was also measured. Incident spectral irradiance was measured at each of these stations, and also during the 24h experiment at R2. During the latter period, incident UV irradiance was also monitored continuously by PUV-500. Secchi measurements were also made at each station.

Surface and deep waters were sampled at each station by pump and/or Kemmerer, with a third additional depth at offshore stations. These were first analysed for turbidity (NTU) and in vivo fluorescence of chlorophyll (calibrated in ug/L) with a Turner Designs fluorometer/nephelometer. Samples were fractionated through a 3 um filter (47 mm, Poretics) and then through a 47mm GF/F for Chla (100-1000mls) and HPLC (250-1000mls). These were stored immediately in the onboard ultrafreezer at –80C.

Unfiltered samples for DIC were analysed by Gran titration using an automatic burette, with measurements of the initial pH. Samples for DOC and CDOM (SF, EEMs, a(lambda)) analysis were filtered through sterile 47mm 0.2um cellulose acetate filters and stored cold but unfrozen for subsequent analysis.

TSS samples were obtained using precombusted preweighed 47mm GF/Cs. POC samples were obtained using precombusted 25 mm GF/F. Additional samples for spectral absorption measurements of the phytoplankton were obtained by filtration through 25mm GF/F filters and stored in tissue baskets at –80C.

P versus E curves (11 measured 4pi irradiances (+ dark) in Rae boxes exposed to the sun in temperature controlled water baths) were determined at the following stations and depths to estimate primary production and photosynthetic parameters:

R1 - surface
R4- surface
R9- surface and deep chla maximum
R8 –surface and deep chla maximum
R5a – surface
R5d – surface
R3-surface
R2-surface (21h00)
R2-surface (09h00)

7.8 Catherine Vallières and Warwick F Vincent
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Bacterial production

Bacterial production was measured by the ^{3}H-leucine incorporation method. In order to separate the bacteria attached to particles from the free bacteria, the water sample was fractionated on 3 µm 47 mm Polycarbonate filters. At each station, 3 replicates of 1.25 ml and 2 controls were incubated for 2 h in the dark and at the *in situ* temperature. The final concentration of ^{3}H-leucine was 10 nM, and the labelled protein was extracted and concentrated by microcentrifugation aboard the ship.

Microplankton sampling

- *Bacteria*
  Samples from the fractionated water sample (3 µm 47 mm Polycarbonate filters) and of the total water sample were fixed with formaldehyde (2 % final concentration) and kept in the cold and dark for 1 to 6 h. They were then stained with DAPI and filtered on 0.2 µm 25 mm black Nucleopore membrane.

- *Picocyanobacteria and picoeukaryotes*
  10 ml of river water or 20 to 30 ml of sea water were filtdered on 0.2 µm 25 mm Anodisk filters.

- *Nanoflagellates and nanociliates*
  10 ml of river water or 20 to 30 ml of sea water were fixed (glutaraldehyde 1 % final concentration), stained with DAPI and filtrated on 0.6 µm 25 mm black Polycarbonate filters.

- *Protists and phytoplankton*
  225 ml of water were fixed with 25 ml of FNU.

Carbon limitation experiment
I hypothesized that the bacteria in the Mackenzie River system are limited by the supply of available carbon substrates. To address this hypothesis, samples were enriched with glucose in three contrasting regimes. Specifically, at freshwater station, a saltwater station and a brackish water station, 2 polypropylene bottles filled with 1 L of non-filtrated water were enriched with 5 µM of glucose and incubated in the dark for 24 h at the simulated *in situ* temperature. 1 control bottle was also incubated in the same condition. At the end of the incubation, the bacterial production was measured and the bacteria were sampled.

Bacterial growth rate

At a freshwater and a saltwater stations, 2 polypropylene bottles were filled with 900 ml of water filtrated on 0.2 µm (____) and inoculated with 100 ml of the natural bacterial community (water filtrated on 0.8 µm 47 mm polycarbonate Nuclepore membrane). The bottles were incubated for at least 2 d and sampled twice each day for the bacterial counting.

Photochemistry impact on the bio-availablility of DOC for bacteria

At two stations, water samples from Dr Chris Osburn's photodegradation experiments were taken and inoculated with the natural bacterial community (water filtered on 0.8 µm 47 mm polycarbonate Nucleopore membrane) with a 1:9 ratio. The samples were incubated for 24 h at the simulated *in situ* temperature. Subsequently, the bacterial production of each sample was measured.

Long term biodegradation and carbon lability

At a freshwater, a saltwater and a brackish water station, 1 L of water was filtered on 0.2 µm filters and brought to the Laval University in polycarbonate bottles. The water will be separate in 300 ml BOD bottles (2 replicates), inoculated with a natural bacterial community (water filtrated on 0.8 µm 47 mm polycarbonate Nucleopore membrane) and incubated for several days. Regularly, the bottles will be sampled to measure the DOC degradation.

Station sampling

Station	Depth	Bacterial production	Micro-plankton sampling	Carbon limitation	Bacterial growth rate	Photo degra dation	Long term biodegrad ation
R1	0 m	x	x				
R2	0 m	x	x				
	18 m	x	x				
R3	0 m	x	x				
	26 m	x	x				
R4	0 m	x	x	x	x	x	x
	6 m	x	x	x			
R5a	0 m	x	x				
	2.5 m	x	x				
R5b	0 m	x	x (bacteria only)	x			x
R5c	------		x				
R5d	0 m	x	x				
	3.4 m	x	x				
R6	------		x				
R7	0 m	x	x				
	6.5 m	x	x				
R8	0 m	x	x				
	12 m	x	x				
R9	0 m	x	x	x	x	x	x
	15 m	x	x	x			
	21 m	x	x	x			
R9 (night sampling)	0 m	x	x (bacteria only)				

7.7 Margaret Noksana

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Objective: I came here to find out what goes on during a research cruise. The activities I conducted were: daily interviews of all the scientists by video; work with the GPS during transects; participation in sampling; assistance with data entry; CTD deployment.

My summary of science activities:

Warwick Vincent: The head scientist, he was out here working on organizing the cruise.

Leira Retamal: she was working in the lab most of the time. She was working on the phytoplankton from the water samples.

Andy Casper: Andy was working with the net and he was looking for animals near the surface.

Catherine Vallières: she was also working in the lab and she was looking and running tests with the bacteria.

Milla Rautio: Milla was here to help with the samples and analyses.

Chris Osburn: he was looking to see if the sun bleaches the water (CDOM).

Patricia Ramlal: she was watching the pump system and measuring CO_2.

Craig Emmerton: he was a student working with Lance on his Masters (water chemistry).

Lance Lesack: he was a scientist working with Craig and they were measuring the nutrients in the water.

Juanita Urban-Rich: she was my supervisor and I saw her doing a lot of pumping to find and working on zooplankton, and she was also working on public outreach for education.

8. Acknowledgements

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Appendix 1: Station sampling dates and positions

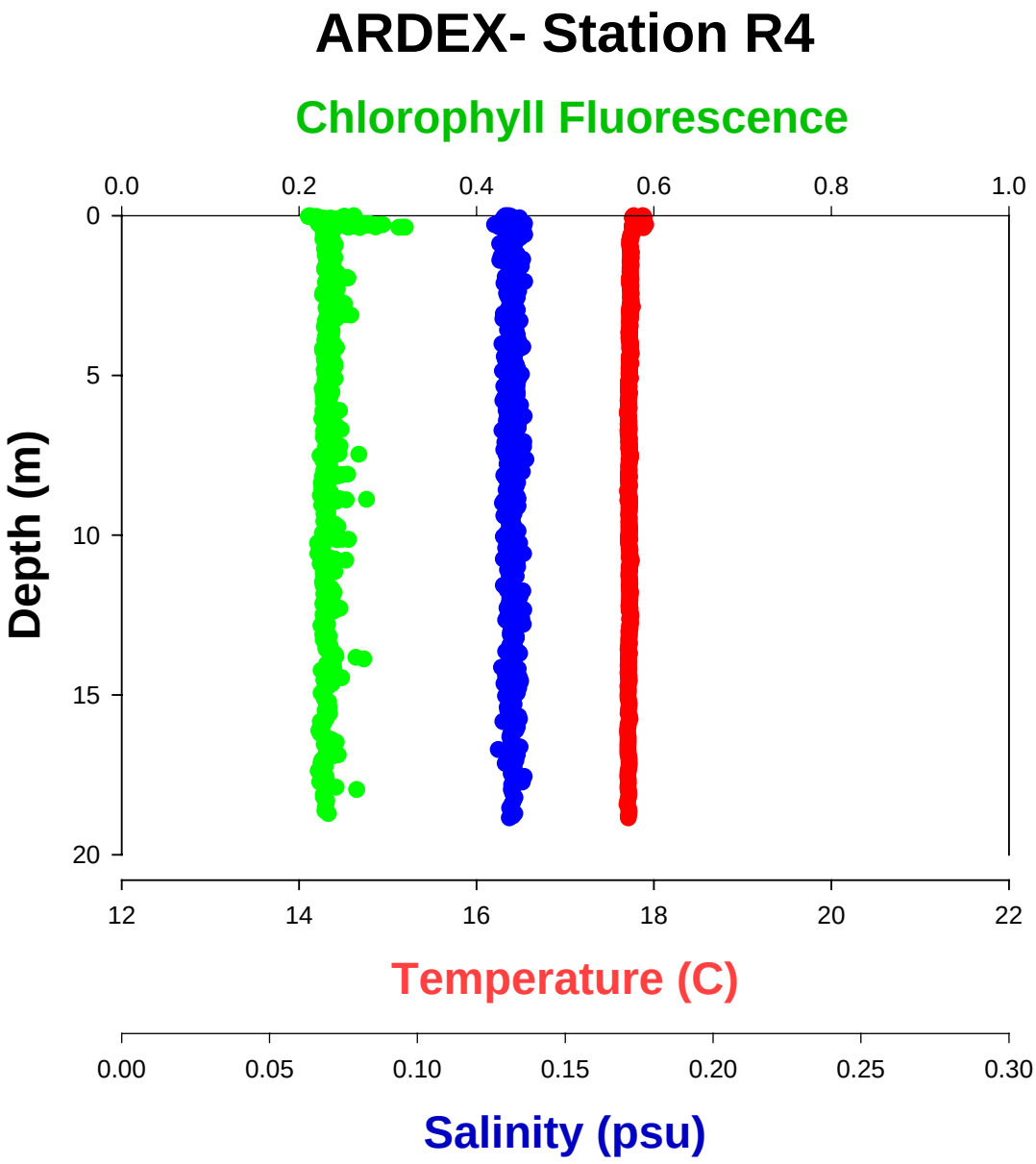
Helicopter

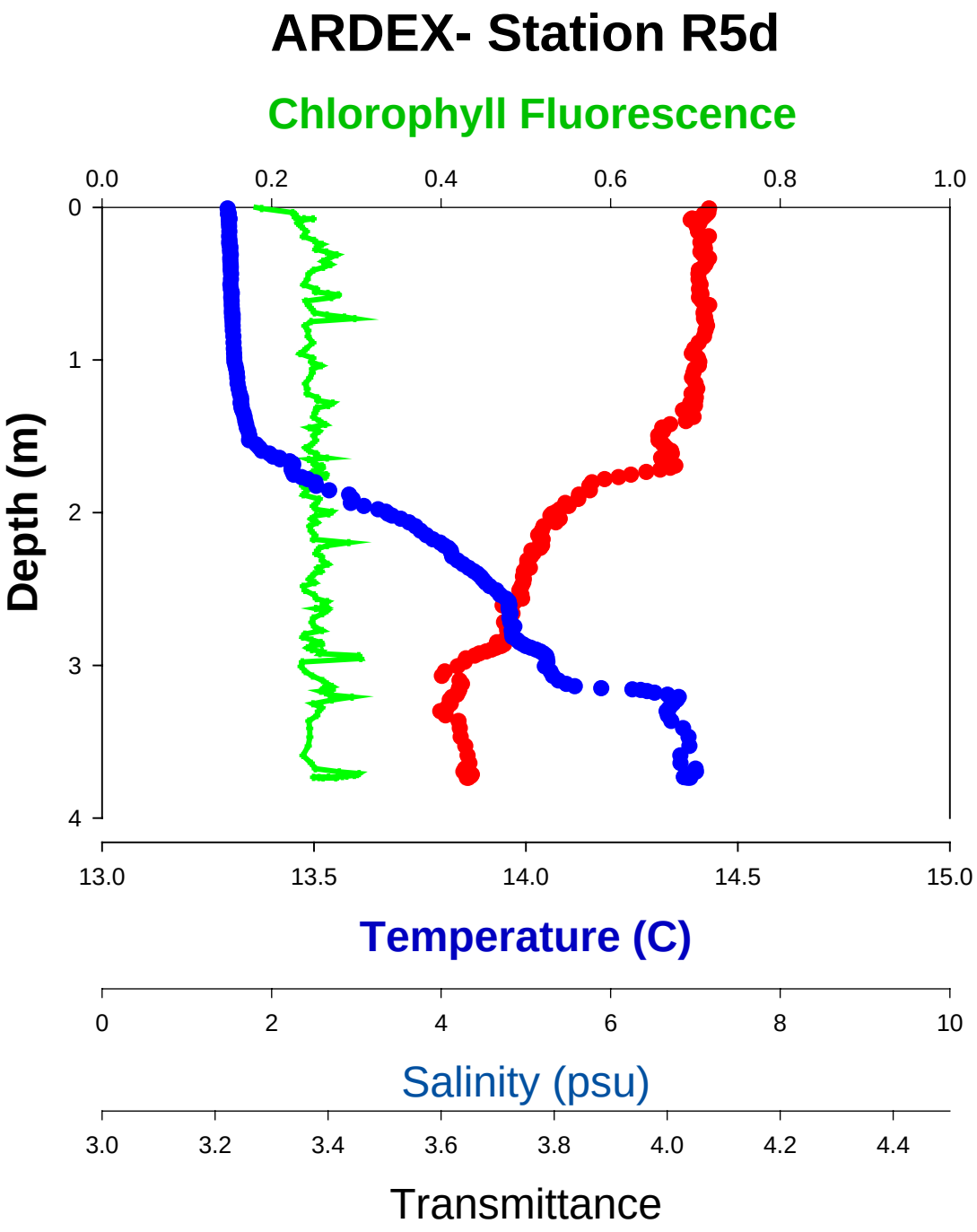
Station	Date	Latitude	Longitude
R4a (Middle Channel)	24 July	69.065	135.087
R4b(Reindeer Channel)	24 July	69.012	135.551
R4c(E Channel, Lousy Pt)	24 July	69.225	134.239
R1w (Middle Channel)	27 July	68.290	134.393
R0 (above Arctic Red R.)	27 July	Lance & Craig's	usual sites
Arctic Red River	27 July	"	"
Peel River	27 July	"	"

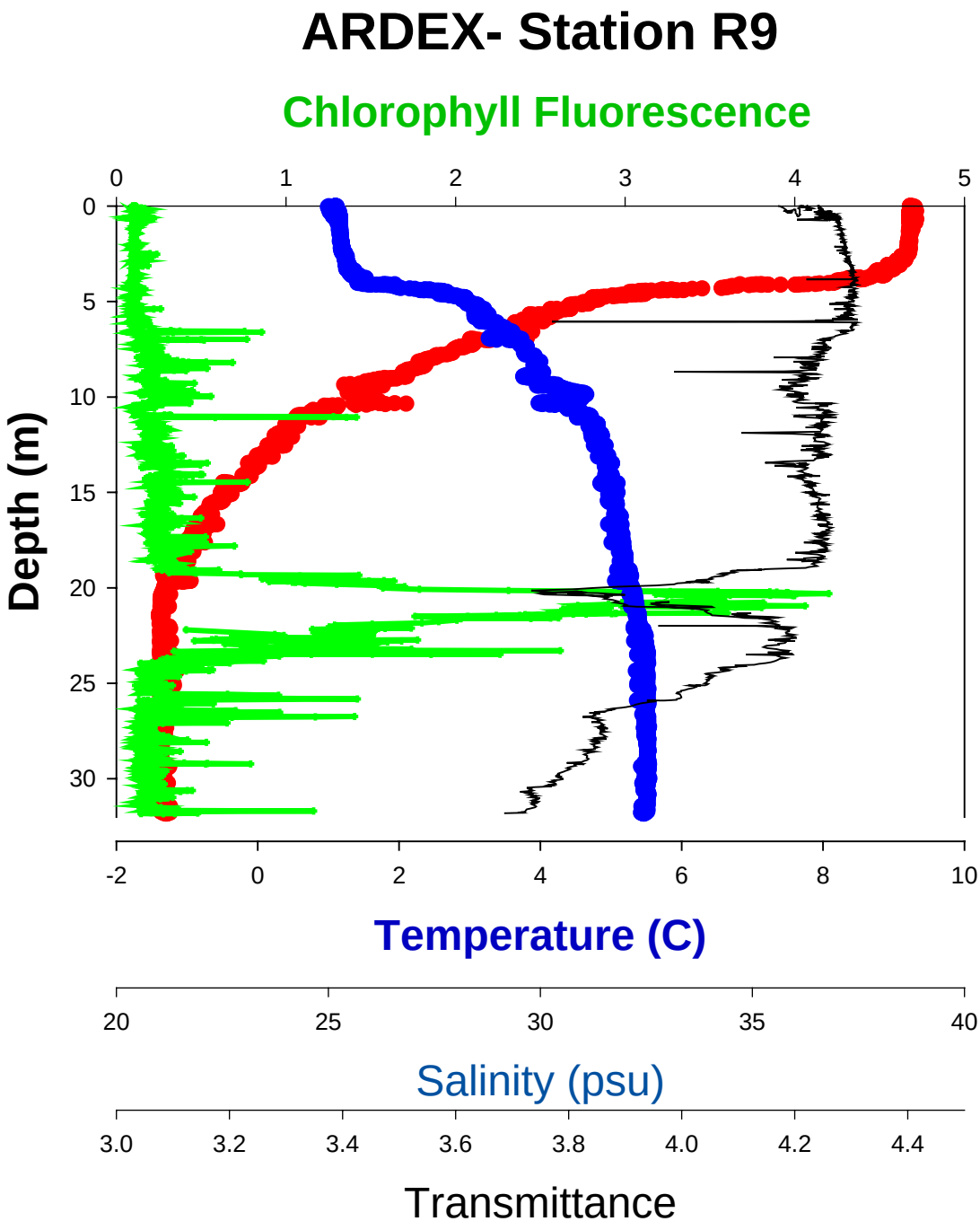
Nahidik

Station	Date	Latitude	Longitude
R1(E-Ch, Inuvik)	26 July	68.356	133.737
R4(LousyPt, Channel)	27 July	69.227	134.227
R9(Offshore)	28 July	70.05	133.417
R9b (night)	28 July	70.05	133.417
R9c (day2)	29 July	70.05	133.417
R8(offshore)	30 July	69.882	133.42
R7(offshore)	30 July	69.718	133.417
R6(inshore)	30 July	69.551	133.42
R5a(transition zone)	31 July	69.456	133.147
R5b(transition zone)	31 July	69.416	133.521
R5c(transition zone)	31 July	69.41	133.542
R5d(transition zone)	31 July	69.362	133.74
R5e(upstream)	31 July	69.281	133.97
R3(upstream, Middle)	1 August	68.842	134.63
R2(upstream, Middle)	1 August	68.626	134.188
R2a(upstream, Middle)	2 August	68.626	134.188
R2b(upstream, Middle)	2 August	68.626	134.188

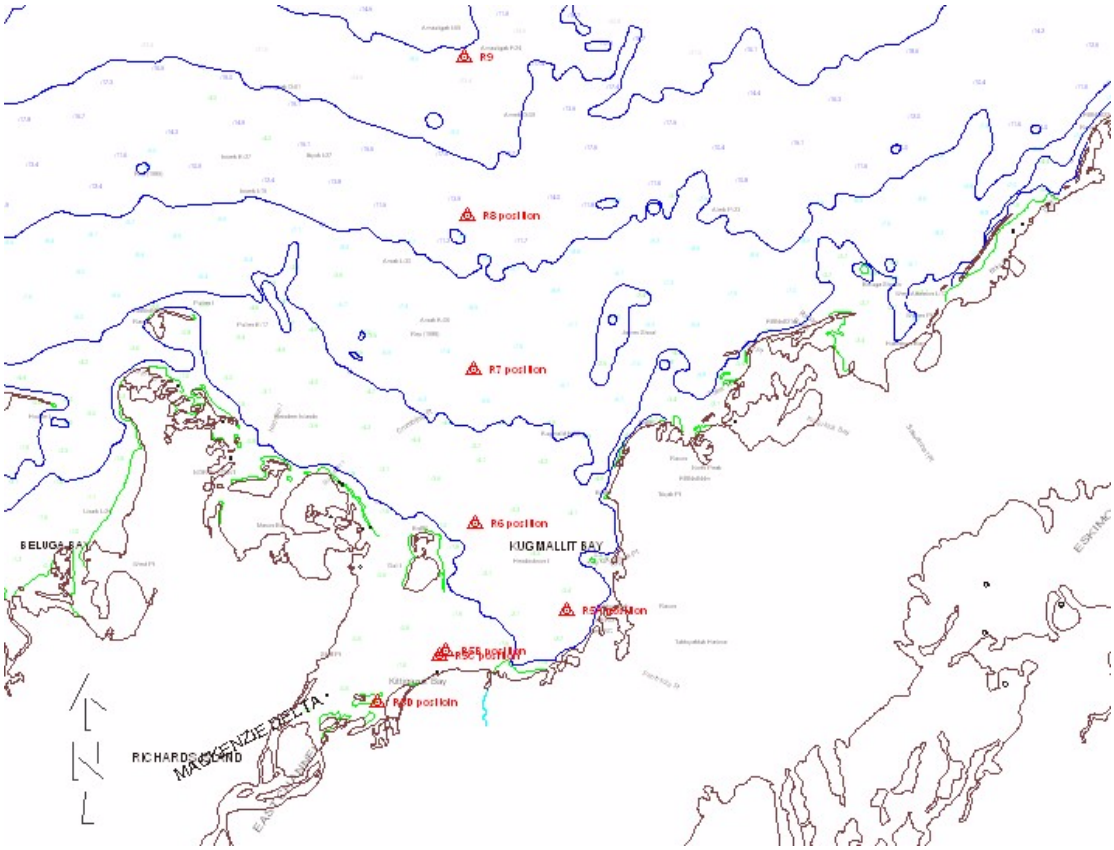
Appendix 2: Illustrative CTD profiles



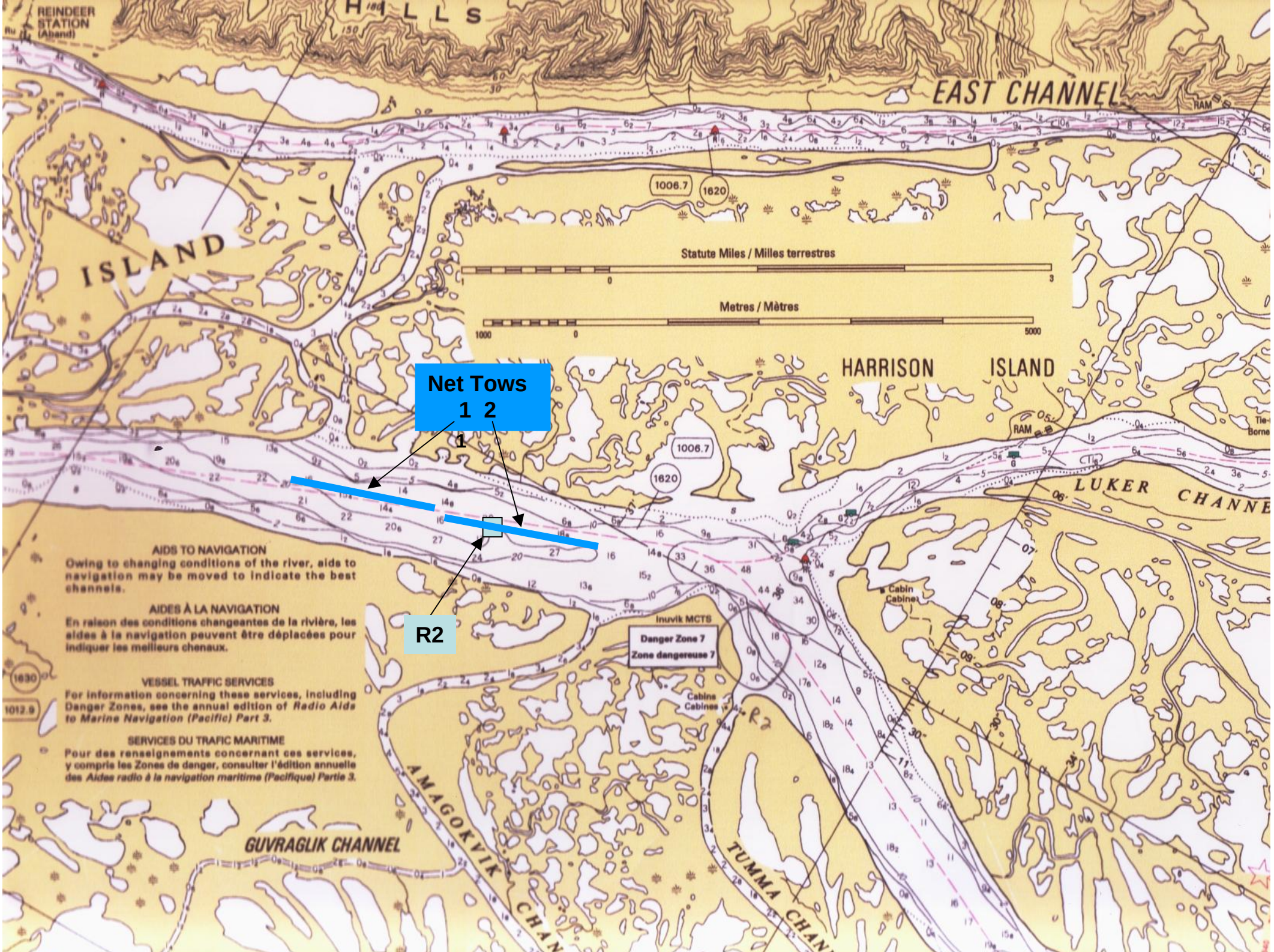

ARDEX- Station R5d
Chlorophyll Fluorescence
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
4
Depth (m)
13.0
13.5
14.0
14.5
15.0
Temperature (C)
0
2
4
6
8
10
Salinity (psu)
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
Transmittance


ARDEX- Station R9
Chlorophyll Fluorescence
0
1
2
3
4
5
Depth (m)
0
5
10
15
20
25
30
-2
0
2
4
6
8
10
Temperature (C)
20
25
30
35
40
Salinity (psu)
3.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4
Transmittance

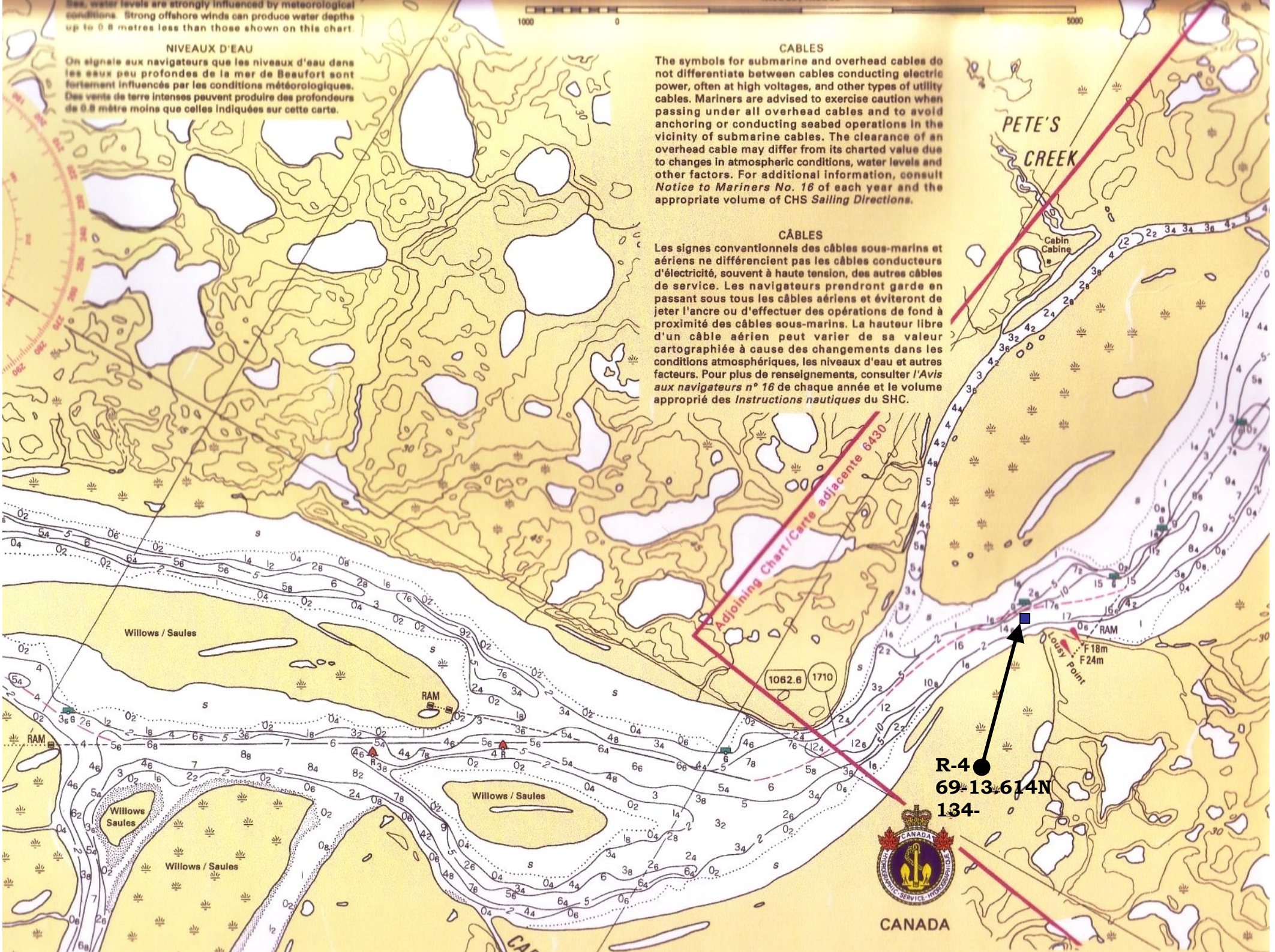
Appendix 3 Maps from the Hydrography Team

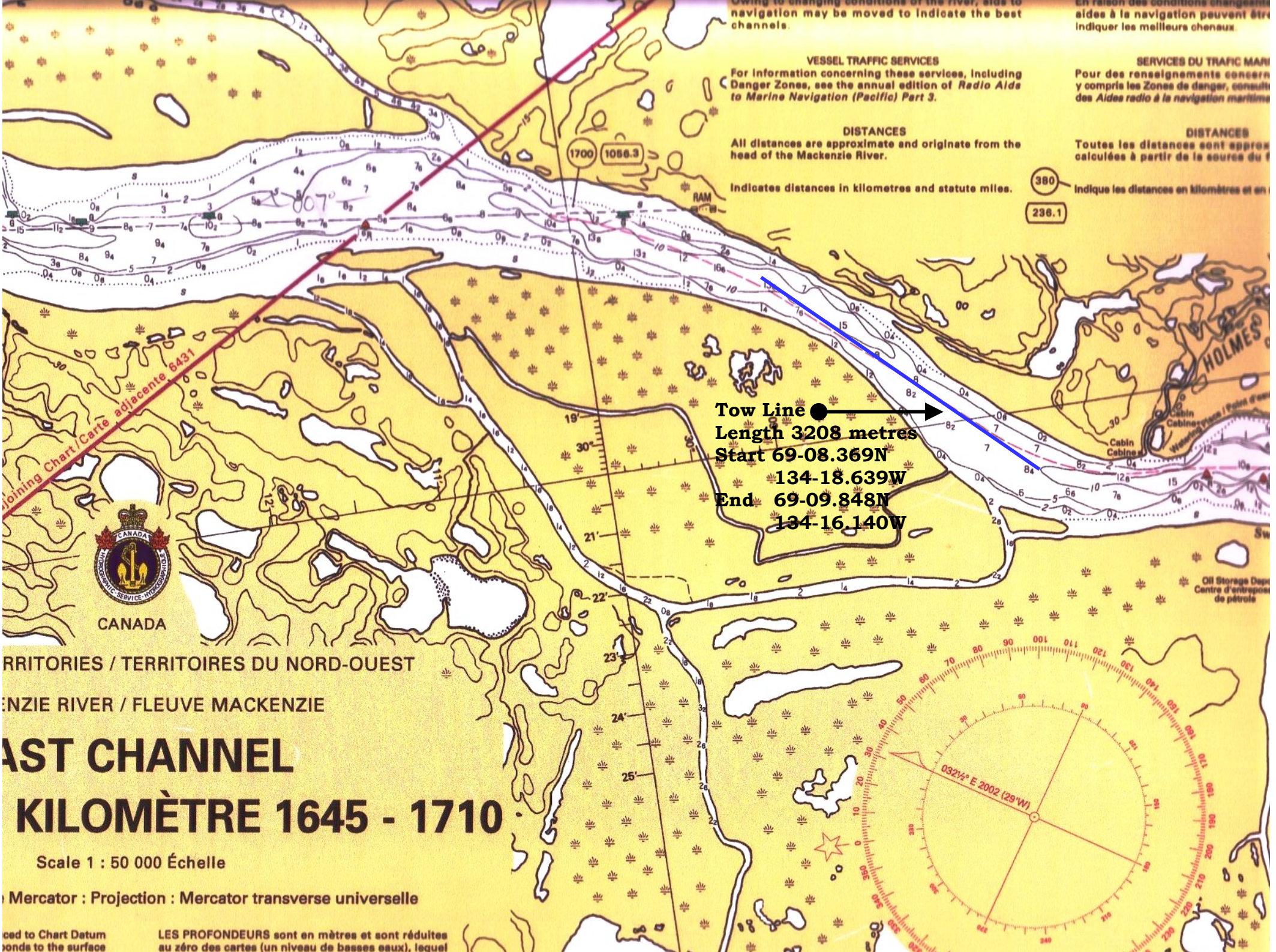


Offshore stations


REINDEER STATION (Abandoned)
EAST CHANNEL
ISLAND
Statute Miles / Milles terrestres
Metres / Mètres
Net Tows
1 2
1
HARRISON ISLAND
LUKER CHANNEL
R2
AIDS TO NAVIGATION
Owing to changing conditions of the river, aids to navigation may be moved to indicate the best channels.
AIDES À LA NAVIGATION
En raison des conditions changeantes de la rivière, les aides à la navigation peuvent être déplacées pour indiquer les meilleurs chenaux.
VESSEL TRAFFIC SERVICES
For information concerning these services, including Danger Zones, see the annual edition of Radio Aids to Marine Navigation (Pacific) Part 3.
SERVICES DU TRAFIC MARITIME
Pour des renseignements concernant ces services, y compris les Zones de danger, consulter l'édition annuelle des Aides radio à la navigation maritime (Pacifique) Partie 3.
Inuvik MCTS
Danger Zone 7
Zone dangereuse 7
Cabins
Cabines
GUVRAGLIK CHANNEL
AMAGOKVIK CHANNEL
TUMMA CHANNEL
1006.7
1620
1630
1012.9


Net
R3
MIDDLE CHANNEL
MARCUS CHANNEL
LEWIS CHANNEL
Cut Bank / Berge érodée
1660
1031.5
Adjoining Chart/Carte adjacente 6429
Adjoining Chart/Carte adjacente 6436


Sea, water levels are strongly influenced by meteorological conditions. Strong offshore winds can produce water depths up to 0.8 metres less than those shown on this chart.
NIVEAUX D'EAU
On signale aux navigateurs que les niveaux d'eau dans les eaux peu profondes de la mer de Beaufort sont fortement influencés par les conditions météorologiques. Des vents de terre intenses peuvent produire des profondeurs de 0.8 mètre moins que celles indiquées sur cette carte.
1000
0
5000
CABLES
The symbols for submarine and overhead cables do not differentiate between cables conducting electric power, often at high voltages, and other types of utility cables. Mariners are advised to exercise caution when passing under all overhead cables and to avoid anchoring or conducting seabed operations in the vicinity of submarine cables. The clearance of an overhead cable may differ from its charted value due to changes in atmospheric conditions, water levels and other factors. For additional information, consult Notice to Mariners No. 16 of each year and the appropriate volume of CHS Sailing Directions.
CÂBLES
Les signes conventionnels des câbles sous-marins et aériens ne différencient pas les câbles conducteurs d'électricité, souvent à haute tension, des autres câbles de service. Les navigateurs prendront garde en passant sous tous les câbles aériens et éviteront de jeter l'ancre ou d'effectuer des opérations de fond à proximité des câbles sous-marins. La hauteur libre d'un câble aérien peut varier de sa valeur cartographiée à cause des changements dans les conditions atmosphériques, les niveaux d'eau et autres facteurs. Pour plus de renseignements, consulter l'Avis aux navigateurs n° 16 de chaque année et le volume approprié des Instructions nautiques du SHC.
PETE'S CREEK
Cabin
Cabine
Adjoining Chart/Carte adjacente 6430
1062.6
1710
RAM
F 18m
F 24m
Loutsy Point
Willows / Saules
Willows
Saules
R-4
69-13-614N
134-
CANADA


VESSEL TRAFFIC SERVICES
For information concerning these services, including Danger Zones, see the annual edition of Radio Aids to Marine Navigation (Pacific) Part 3.
DISTANCES
All distances are approximate and originate from the head of the Mackenzie River.
Indicates distances in kilometres and statute miles.
380
236.1
1700
1056.3
Tow Line
Length 3208 metres
Start 69-08.369N
134-18.639W
End 69-09.848N
134-16.140W
HOLMES
Cabin
Oil Storage Depot
CANADA
RRITORIES / TERRITOIRES DU NORD-OUEST
NZIE RIVER / FLEUVE MACKENZIE
AST CHANNEL
KILOMÈTRE 1645 - 1710
Scale 1 : 50 000 Échelle
Mercator : Projection : Mercator transverse universelle
032½° E 2002 (29°W)
LES PROFONDEURS sont en mètres et sont réduites au zéro des cartes (un niveau de basses eaux), lequel

Appendix 4. Station/tow coordinates from the Hydrography team

Station	Easting	Northing	Latitude	Longitude	Time (GMT)	Date	Comments
R4 position			69.22690000	-134.22760000	18:00:00	27/07/04	depth 20 metres
Start line#1 R4			69.13948300	-134.31065000	16:05:00	27/07/04	speed approx 3.5 knots
End line#2 R4			69.16413000	-134.26900000	15:45:00	27/07/04	length 3208 metres
R9 position	560287.1	7772232.1	70.04999996	-133.41666655	17:22:23	28/07/04	depth 34 metres
Start line#1 - R9	560313.0	7771655.6	70.04482661	-133.41638096	18:27:55	28/07/04	average speed 3.6 knots
End line#1 - R9	561529.8	7774991.7	70.07444309	-133.38212309	18:46:21	28/07/04	length 2526 metres
Start line#2 - R9	561388.9	7774908.6	70.07373252	-133.38588337	19:02:36	28/07/04	average speed 2.7 knots
End line#2 - R9	560407.7	7772567.8	70.05298063	-133.41327314	19:27:53	28/07/04	length 3558 metres
R8 position	560641.9	7753519.8	69.88218328	-133.42008330	12:47:17	30/07/04	depth 16.5 metres
Start line#1 R8	559547.5	7753910.4	69.88593713	-133.44832394	18:14:52	30/07/04	length 2075 metres
End of line#1 R8	561470.4	7754670.5	69.89230491	-133.39772029	18:35:56	30/07/04	depth 17.3 m,speed 3.2 knots
Start line#2 R8	561175.2	7754672.4	69.89239101	-133.40540991	18:45:29	30/07/04	speed 4.3 knots
End line#2 R8	558750.0	7753271.6	69.88039073	-133.46951159	19:06:43	30/07/04	length 2815 metres
R7 position	561267.4	7735132.7	69.71721657	-133.41621748	22:33:09	30/07/04	depth 7.5 metres
start line#1 -R7	561284.4	7734926.3	69.71536243	-133.41591657	22:48:03	30/07/04	R7, speed 3.3 knots
End line#1 - R7	561457.0	7733108.0	69.69902316	-133.41267934	23:05:45	30/07/04	length 1830 metres
R6 position	561593.7	7716651.6	69.55147336	-133.42013539	00:10:20	31/07/04	depth 3.5 metres
R5A position	572571.9	7706273.9	69.45568800	-133.14677913	14:34:22	31/07/04	
Start line#1 - R5A	572543.4	7706161.5	69.45468853	-133.14759281	17:30:36	31/07/04	speed 3.0 knots
End line #1 R5A	570318.2	7705418.4	69.44862211	-133.20493661	17:51:33	31/07/04	speed 4.0 knots
R5B position	558026.0	7701445.7	69.41595836	-133.52103353	19:31:37	31/07/04	
R5C position	557200.5	7700858.0	69.41086764	-133.54242206	20:08:50	31/07/04	
Start line#1 R5D	549240.9	7694960.5	69.35957425	-133.74825544	00:24:20	01/08/04	
End line#1 R5D	547785.7	7694457.4	69.35532622	-133.78549031	00:39:42	01/08/04	speed 3.5 knots
Start line#2 R5D	548619.8	7694869.2	69.35886819	-133.76408567	00:52:35	01/08/04	speed 3.3 knots
End line#2 R5D	550522.9	7695695.7	69.36592761	-133.71528283	01:09:32	01/08/04	speed 4.2 knots
R5D position	549918.5	7695324.6	69.36271372	-133.73084256	01:19:55	01/08/04	

CTD			69.28126666	-133.97478333	05:26:00	01/08/04	Lousy Point area
Surface water			69.22963333	-134.35513333	06:16:00	01/08/04	Lousy Point area
R3 position	515046.07	7636303.58	68.83763469	-134.62654504	17:08:46	01/08/04	depth 34.3 metres
Start line#1 R3	515158.18	7636838.12	68.84242243	-134.62368119	20:03:31	01/08/04	depth 27.8, speed 3.7 knots
End line#1 R3	514522.87	7638677.16	68.85894953	-134.63918493	20:22:15	01/08/04	37.6 metres, speed 3.1 knots
Start line#2 R3	514813.9	7638211.64	68.85475917	-134.63202386	20:36:03	01/08/04	depth 41.2 m, speed 3.8 knots
End line#2 R3	515226.13	7636301.99	68.83761056	-134.62207617	20:53:13	01/08/04	depth 12.1 m, speed 4.1 knots
Start line #1 R2	532151.77	7615637.71	68.65084774	-134.20860843	22:27:57	01/08/04	depth 19.1 m, speed 3.9 knots
End line#1 R2	532871.05	7613959.41	68.63571328	-134.19144897	22:43:57	01/08/04	depth 14.0 m
Start line#2 R2	532620.54	7613592.04	68.63244821	-134.19772800	23:00:28	01/08/04	depth 17.6 m, speed 3.1 knots
End line#2 R2	533509.59	7611587.17	68.61436370	-134.17652529	23:20:22	01/08/04	depth 19.1 metres
R2 position	533030.01	7612858.77	68.62582424	-134.18789674	12:54:30	02/08/04	depth 21-23 metres

Appendix 5. ARDEX Science Team

Plus John Biggar and Dave Tobio (Hydrography Team)