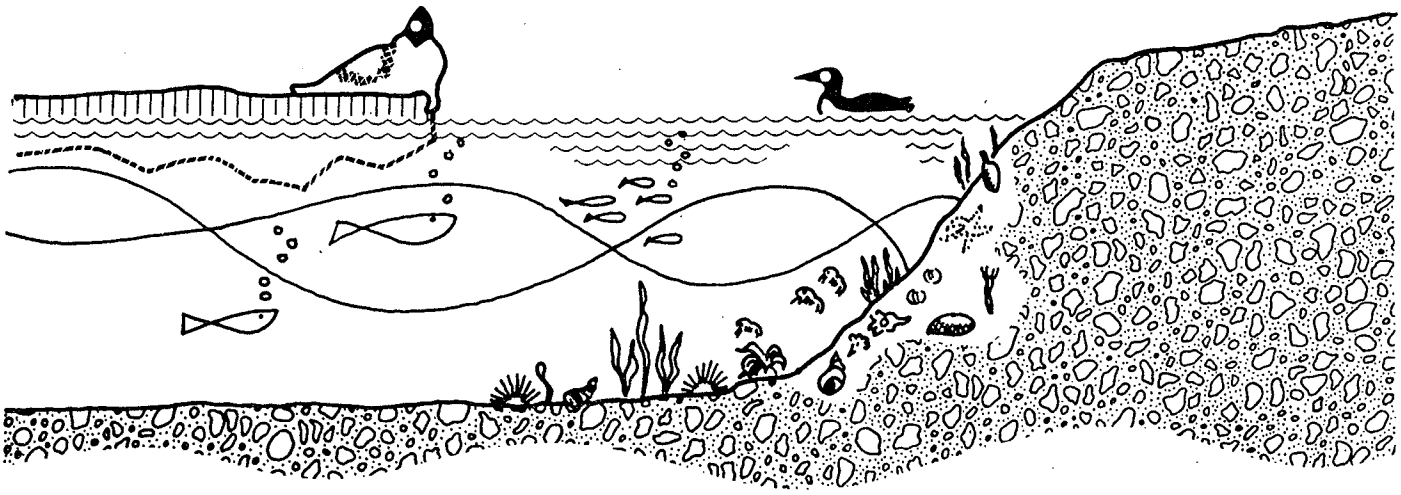
CHEMISTRY

1. Field Sampling and Environmental Chemistry



Baffin Island Oil Spill Project

WORKING REPORT SERIES

1980 STUDY RESULTS

BIOS Working Report Series

This report is the result of a contract let under the Baffin Island Oil Spill Project. This unedited version is undergoing a limited distribution to transfer the results to people working in related research. The report has not undergone rigorous technical review by the BIOS management or technical committee and does not necessarily reflect the views or policies of these groups.

For further information on the BIOS project contact:

BIOS Project Office
Room 804
9942-108th Street
Edmonton, Alberta
T5K 2J5

Phone: (403) 420-2592

Correct citation for this publication:

Green, D.R., 1981, Chemistry: 1. Field Sampling and Environmental Chemistry - 1980 Study Results. (BIOS) Baffin Island Oil Spill Project Working Report 80-1: 93 p.

BAFFIN ISLAND OIL SPILL EXPERIMENT
CHEMISTRY COMPONENT
FINAL REPORT ON BASELINE YEAR ACTIVITIES

VOLUME 1:

Field Work
Environmental Chemistry
Hydrocarbon Infrared Data

David R. Green, Ph.D
Seakem Oceanography Ltd.
20 February, 1981

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The following report summarizes the activities of Seakem Oceanography Ltd. for the baseline year of the Baffin Island Oil Spill Project. Our role, in partnership with Energy Resources Co., Cambridge, Mass., was to provide a broad spectrum of chemical services which can be divided into four categories: a field program, environmental chemistry analyses, hydrocarbon baseline analyses, and hydrocarbon analyses for the shoreline oil spill plots. A summary of the tasks performed, and the company responsible for each, is given in Table 1.1. This volume summarizes only the Seakem portion of the contract.

TABLE 1.1

CHEMISTRY COMPONENT TASKS

CATEGORY	TASKS	RESPONSIBLE COMPANY
Field Program	set-up of field laboratory; sampling; sub-sampling; preliminary sample handling; preservation, storage, and transport of samples	Seakem
Environmental Chemistry	Water Analyses: pH, DO, NO_3, PO_4, N, Chl, SS (organic), SS (iunorganic), POC, DOC Sediment Analyses: TOC, NO_3, PO_4, N, Pb-210 Beach Analyses: TOC	Seakem
Hydrocarbon Baseline Study	Water: IR, UV/F, GC/MS Sediment: IR, UV/F, GC/MS Beach: IR, UV/F, GC/MS Tissue: GC/MS	ERCO: UV/F, GC/MS Seakem: IR
Shoreline Oil Plots	GC/MS Total Hydrocarbons	ERCO Seakem

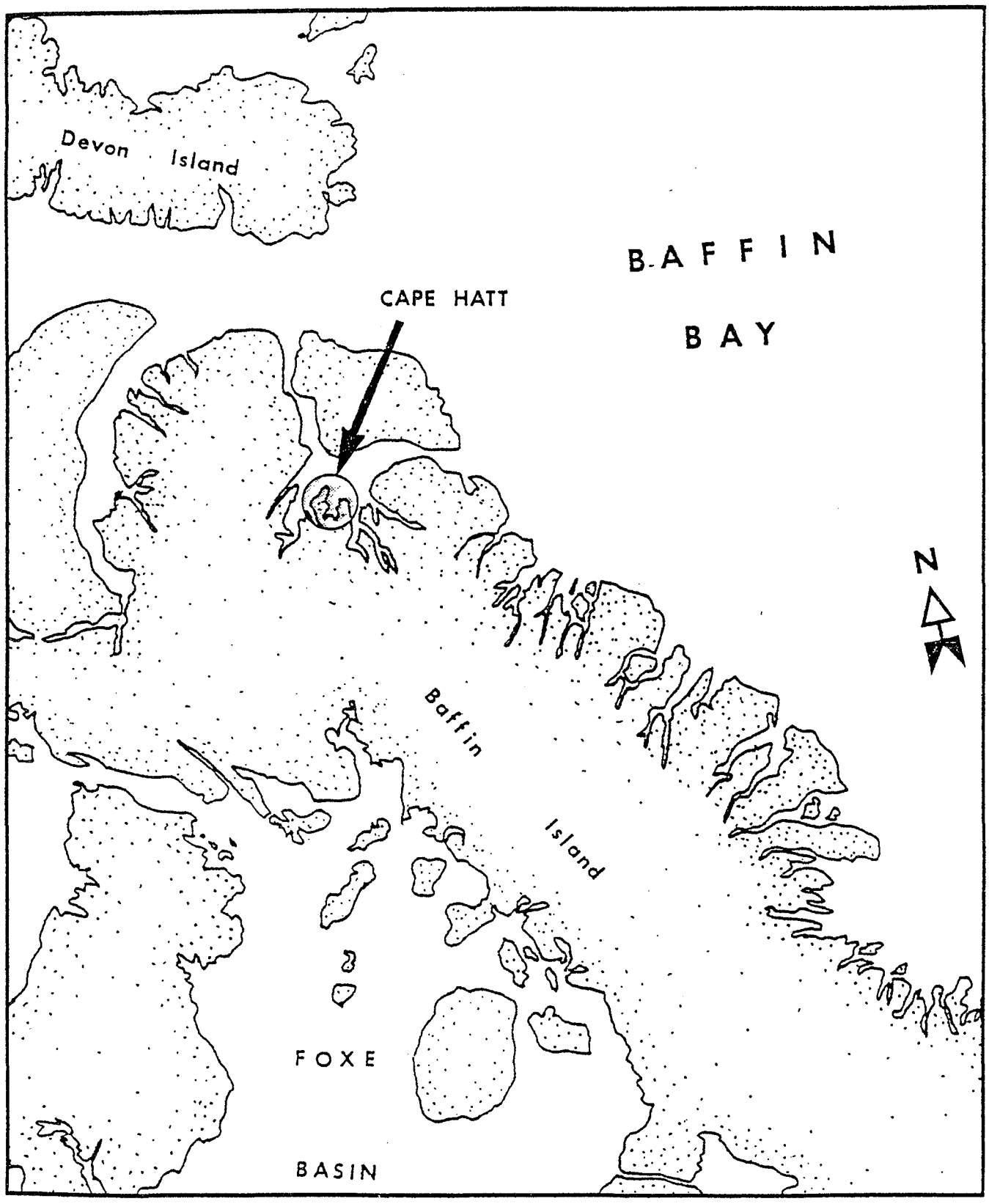


FIGURE 1.1: Location of Cape Hatt, Baffin Island.

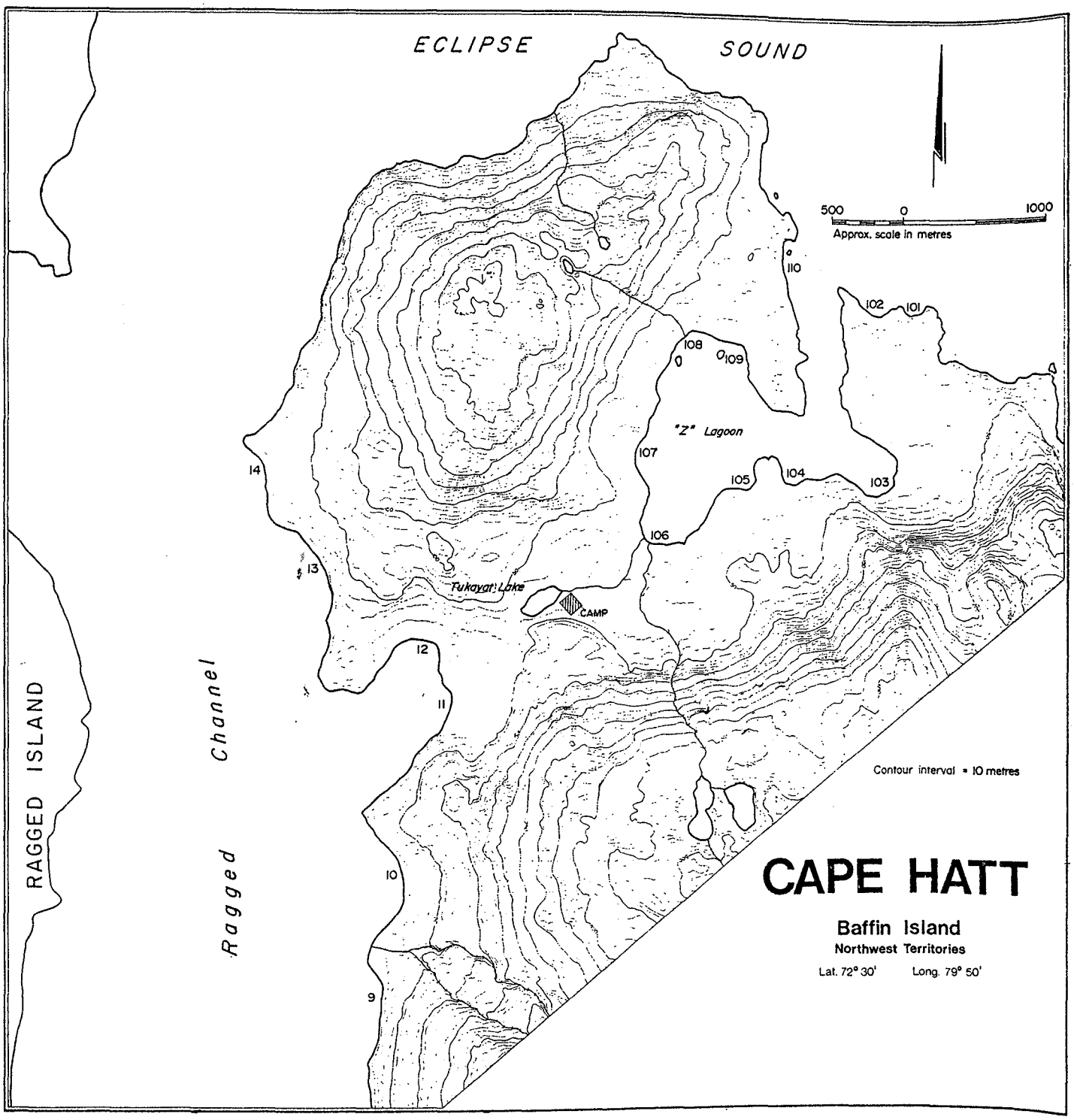


FIGURE 1.2: The Cape Hatt Site, showing the numbering of the experimental bays.

2. FIELD WORK

Chemists conducted sampling at the Cape Hatt field site during the following periods:-

5 - 23 June, 1980	(D.R. Green)
11 August - 4 September	(B. Fowler)
2 - 21 September	(D.R. Green)

We sampled for environmental chemistry analyses, for baseline hydrocarbon analyses, and for measurements of the oil budget on the oiled beach plots. Tables summarizing all of the samples taken, and maps showing approximate location of the sampling sites follow.

Various filtration and extraction work-up steps were done at the Cape Hatt laboratory, then samples were shipped to Seakem Oceanography Ltd and to Energy Resources Co. Ltd., Cambridge, Mass., for analysis.

2.1 Environmental Chemistry

2.1.1 Water Samples

In June, all sampling was conducted through holes in the ice. Sampling stations were established in 12-14 m water in bays 13, 10 and 9 in Ragged Channel at 12-14 m. Ice thickness varied from 1.5 to 2m. Water samples were taken with a Niskin 5L water sampler at 1, 5, and 10 m under the ice. The microbiology sampling team took water samples first, then the environmental chemistry samples were taken. O_2 and pH samples were drawn first, carefully avoiding the introduction of air bubbles, then nutrient and total organic carbon samples were drawn into test tubes. The remaining water was poured into a 4L bottle and filtered for chlorophyll, particulate organic carbon, and suspended solids in the field laboratory immediately after returning to camp.

We sampled in the morning every second day beginning 6 June, 1980. Two stations were sampled in each bay on each sampling day: a total of six stations (H1 to H6) sampled as follows:-

Location	Station ID	Sampling Dates
Bay 13	H1, H2	6, 12, 18 June
Bay 10	H3, H4	8, 14, 20 June
Bay 9	H5, H6	10, 16, 22 June

For comparison and out of general interest, some extra samples were collected from the bottom of the ice by divers, and from melt pools during the period 19 to 22 June.

The same pattern of sampling was followed in the August -September sampling period, except the sampling in Bay 13 was shifted to Bay 11. The sampling pattern was as follows:-

Location	Station ID	Sampling Dates
Bay 11	H1, H2	11, 19, 28 Aug 5, 12 Sept
Bay 10	H3, H4	13, 21, 30 Aug 7, 14 Sept
Bay 9	H5, H6	15, 23 Aug 1, 9, 16 Sept

Sampling was done from a zodiac at depths of 1, 5, and 10 m at each station. (Note that these depths do not correspond to the June sampling depths, which were measured from the ice bottom). The approximate locations of the sampling stations are shown in Figure 2.1.

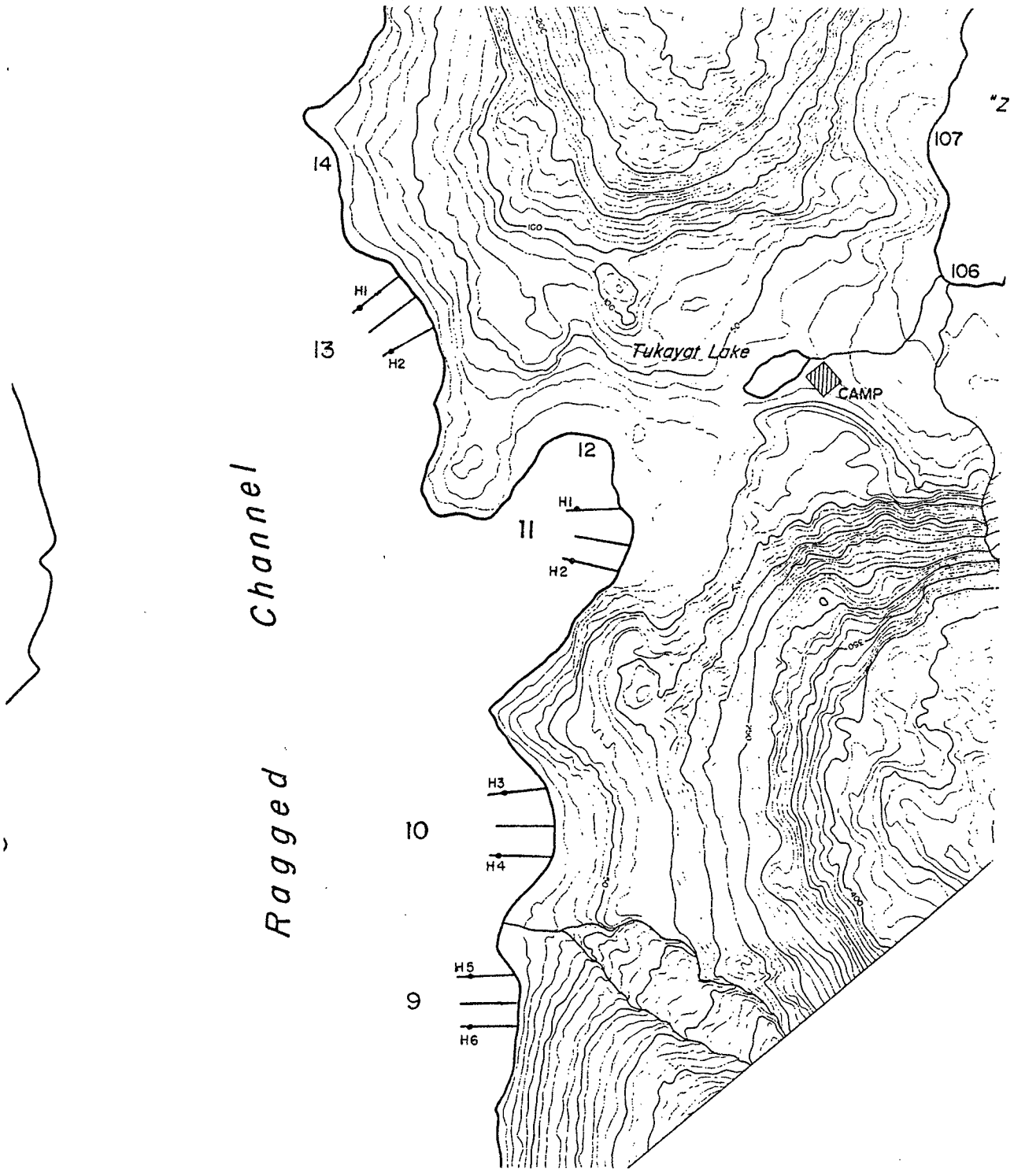


FIGURE 2.1: Locations of Environmental Chemistry water sampling stations. Note: The positions of H1 and H2 were changed from Bay 13 in June to Bay 11 in August/September.

2.1.2 Sediment Samples

In June, sediment samples for environmental chemistry purposes were collected with a Peterson grab sampler through the ice upon completion of water sampling. Because of ice-rafted rock it was often difficult to get the grab sampler to work properly. The jaws usually closed on a rock, allowing the sediment to escape. Samples were frequently missed, or were too small to press sufficient interstitial water for all of the analyses. The suite of samples was augmented with samples collected by divers through the ice holes in each bay.

In August, the same problems with the grab sampler were encountered operating from a Zodiac, so most of the samples were collected by divers, and most from 7 m depth instead of 13 m, to ensure that they came from within the 1981 experimental area.

Table 2.1 summarizes all of the sediment samples collected expressly for environmental chemistry purposes. Subsamples were also drawn from some of the baseline hydrocarbon cores for environmental chemistry and these are summarized separately in Table 2.3.

TABLE 2.1
SEDIMENT SAMPLES
ENVIRONMENTAL CHEMISTRY

Date	Location	I.D	Depth	Sampling Method	Comments
07 June	Bay 13	H2	14.5 m	grab	
08 June	Bay 10	H4	15 m	grab	
10 June	Bay 9	H5	15 m	grab	limited sample
12 June	Bay 13	H2	15 m	grab	
14 June	Bay 10	H4	15 m	grab	limited sample
16 June	Bay 9	H5	15 m	grab	limited sample
20 June	Bay 13	dive hole	12 m	diver	
21 June	Bay 10	dive hole	12 m	diver	
22 June	Bay 9	dive hole	12 m	diver	
19 Aug	Bay 11	H1	12 m	grab	
21 Aug	Bay 10	H3	11 m	grab	
		H4	12 m	grab	limited sample
23 Aug	Bay 9	H5	15 m	grab	limited sample
31 Aug	Bay 10	H3	10 m	diver	
		H4	10 m	diver	
02 Sept	Bay 9	H5	7 m	diver	
		H6	7 m	diver	
02 Sept	Bay 11	H1	7 m	diver	
		H2	7 m	diver	
06 Sept	Bay 11	H1	7 m	diver	
		H2	7 m	diver	
07 Sept	Bay 10	H3	7 m	diver	
		H4	7 m	diver	
10 Sept	Bay 9	H5	7 m	diver	
		H6	7 m	diver	
13 Sept	Bay 11	H1	7 m	diver	
		H2	7 m	diver	
14 Sept	Bay 10	H3	7 m	diver	
		H4	7 m	diver	
15 Sept	Bay 9	H5	7 m	diver	
		H6	7 m	diver	

2.2 Hydrocarbon Baseline Samples

2.2.1 Water Samples

In June, 4L water samples were taken with a National Bureau of Standards water sampler (see Figure 2.2) through the same ice holes as those used for environmental chemistry sampling. The samples were extracted in the field laboratory with 3 x 75 mL Freon 113. Extraction was done in the sampler containers by shaking for 3 minutes in a paint shaker. The three extracts were combined, then divided in half, half for analysis by ERCO (scanning UV- fluorescence) and half by Seakem Oceanography Ltd (I.R.). In addition, three 4 L water samples from Bay 9 (H5, depths 1, 5, 10 m below ice) were collected but not extracted and delivered directly to ERCO for extraction in the laboratory.

In August - September, some large volume water samples were collected from Ragged Channel. The apparatus used is shown in Figure 2.3. Problems with the generator, the pumping system, and interference by ice limited the number of samples which could be taken in this manner, so the remainder were taken with a National Bureau of Standards sampler in the same manner as in June.

The sampling location and descriptions of the samples are summarized in Table 2.2.

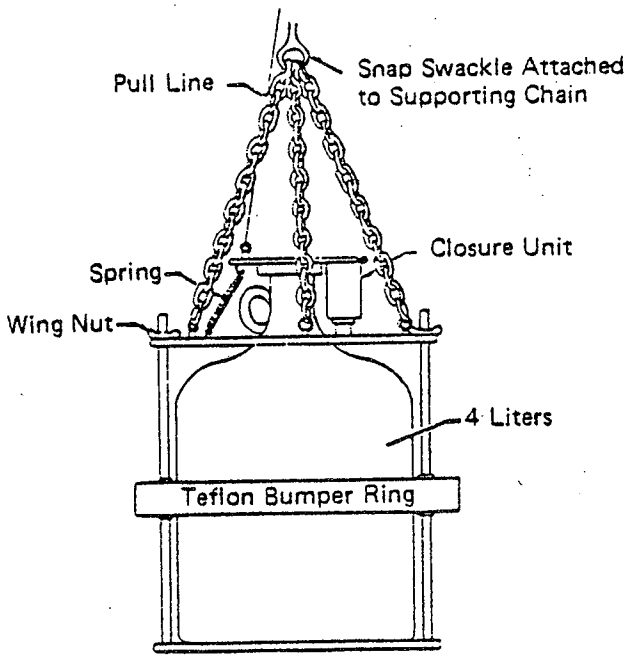


FIGURE 2.2: The National Bureau of Standards water sampler used for obtaining baseline hydrocarbon samples for IR and UV/F analyses.

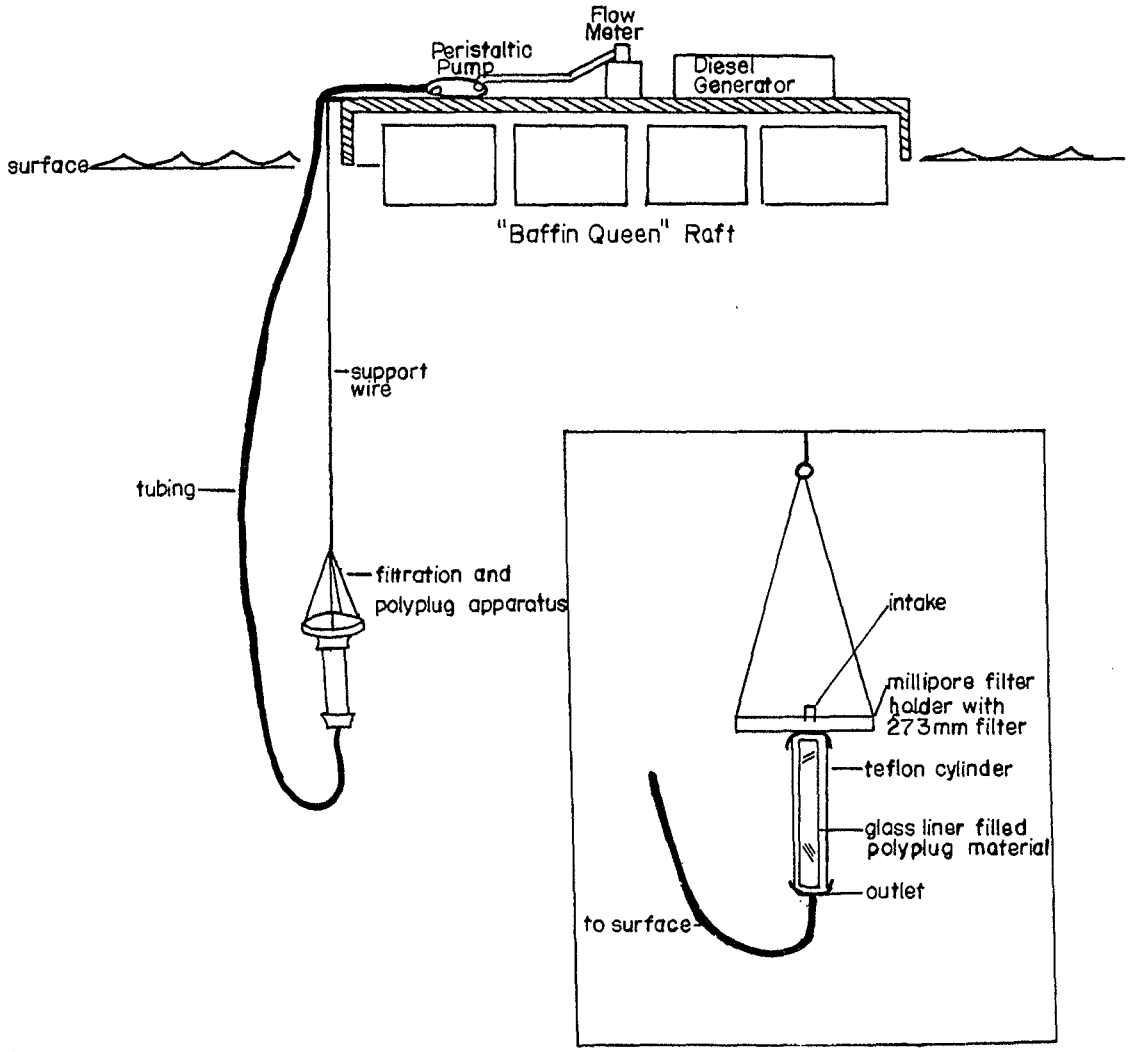


FIGURE 2.3: The large volume water sampler used for obtaining baseline hydrocarbon samples for gc/ms analyses.

TABLE 2.2

WATER SAMPLES
HYDROCARBON BASELINE STUDY

Date	Location	Depth (m)	Vol (approx)	Type of sampler	Type of analysis
14 June	Bay 9	1,5,10	4L	NBS	IR,UV/F
	Bay 10	1,5,10	4L	NBS	IR,UV/F
	Bay 11	1,5,10	4L	NBS	IR,UV/F
22 June	Bay 9	1,5,10	4L	NBS	not extracted
26 Aug	Bay 9	1,5,10	4L	NBS	IR,UV/F
	Bay 10	1,5,10	4L	NBS	IR,UV/F
	Bay 11	1,5,10	4L	NBS	IR,UV/F
20 Sept	Bay 9	1,5	4L	NBS	IR,UV/F
19 Sept	Bay 10	1,5,10	4L	NBS	IR,UV/F
18 Sept	Bay 11	1,5,10	4L	NBS	IR,UV/F
20 Sept	Bay 103	1,5	4L	NBS	IR,UV/F
07 Sept	Bay 10	1 m	210L	LVWS	GC/MS
19 Sept	Bay 10	1,5	20L	NBS	GC/MS
11 Sept	Bay 11	8 m	130L	LVWS	GC/MS
17 Sept	Bay 11	1,5 m	20L	NBS	GC/MS
20 Sept	Z-lagoon	1,5 m	20L	NBS	GC/MS

NOTE: 1. NBS = National Bureau of Standards sampler

2. LVWS = Large volume water sampler (Risebrough and de Lappe type).

2.2.2 Hydrocarbon Baseline Sediment Samples

In June, 23 core and 16 grab samples were collected from Ragged Channel, Z-lagoon, and Eclipse Sound, primarily by B. Barrie and J.M. Sempels. The cores were stored and shipped frozen in their plexiglass liners, thawed and subsampled in the ERCO Hydrocarbon Laboratory by D.R. Green, then re-frozen until analyzed. The grab samples were kept frozen until analyzed. After subsampling, some portion of thirteen cores remained for future analysis, in addition to three undisturbed cores.

In September (11-13th), another set of samples was collected for hydrocarbon baseline determinations. These samples were collected by divers with a polycarbonate tube into whirlpac bags which were sealed underwater. Six samples were collected from each of the three experimental bays in Ragged Channel, for a total of eighteen. Each sample was subdivided into four subsamples for IR, UV/F, GC/MS, and TOC (total organic carbon) analyses. The subsamples for hydrocarbon analyses were stored in solvent rinsed tins and jars, the TOC samples in Whirlpac bags. All were stored frozen until analysed. All of these samples are recorded in Table 2.3, and the sample locations are shown in Figures 2.4 and 2.5.

TABLE 2.3

SEDIMENT SAMPLES
HYDROCARBON BASELINE STUDY
JUNE, 1980

Location	Transect	Depth	Type	Size	I.D.	Subsampling
Ragged Channel						
Bay 9	N	7.4	C	23 cm	cc 18	IR & TOC surface
		18.5	C	39 cm	cc 17	GCMS - surface
	C	7.4	C	30 cm	cc 12	GCMS - surface
		14.3	C	38 cm	cc 13	Pb 210
	S	3.9	C	400 g	cc 14	IR & TOC
		14.0	C	26 cm	cc 15	IR & TOC-3 depths
		18.2	C	35 cm	cc 16	GCMS-3 depths
Bay 10	N	1.8	C	50 cm	cc 9	preserved
		11.9	C	43 cm	cc 10	GCMS - surface
	C	6.1	C	30 cm	cc 7	preserved
		10.4	C	43 cm	cc 8	IR & TOC-3 depths
		22.1	GRAB	400 g	GS 1	IR & TOC-surface
	S	5.1	C	26 cm	cc 11	GCMS - surface
		10.1.	GRAB	400 g	GS 2	IR & TOC-surface
		15.8	C	400 g	GS 3	preserved
Bay 13	N	2.7	C	32 cm	cc 2	IR & TOC-surface
		13.4	C	35 cm	cc 1	IR & TOC- 3x
	C	11.4	C	16 cm	cc 4	GCMS - surface
		16.0	C	45 cm	cc 3	PB 210
	S	3.6	C	19 cm	cc 5	GCMS - surface
		14.5	C	21.5 cm	cc 6	IR & TOC-surface
Eclipse Sound						
Bay 102		14.8	C	10 cm	cc 19	preserved
Z-lagoon						
Mid-lagoon		15.9	C	50 cm	Z-lagoon cc 21	Pb210, IR, TOC-3x
Bay 103		7.6	GRAB	800 g	GS 43	preserved
		10.1	GRAB	800 g	GS 39	preserved
		10.2	GRAB	800 g	GS 38	IR & TOC-surface
		10.6	GRAB	800 g	GS 37	preserved
Bay 104		6.5	GRAB	800 g	GS 27	preserved
		10.0	GRAB	800 g	GS 32	preserved

Location	Transect	Depth	Type	Size	I.D.	Subsampling
Bay 105		.4.1	GRAB	1600 g	GS 4	IR & TOC-surface
			GRAB	800 g	GS 16	preserved
		9.2	C	50 cm	cc 20	GCMS - surface
Bay 106		5.1	GRAB	800 g	GS 60	preserved
		5.3	GRAB	800 g	GS 54	preserved
Bay 108			GRAB	800 g	GS 20	preserved
		12.4	C	50 cm	cc 22	preserved
Bay 109		3.3	GRAB	800 g	GS 52	preserved
		3.6	GRAB	800 g	GS 48	IR & TOC-surface
		10.2	GRAB	800 g	GS 45	preserved

SEDIMENT SAMPLES
HYDROCARBON BASELINE STUDY
SEPTEMBER, 1980

Location	Transect	Depth	Type	Size	I.D.	Subsampling
Bay 9	N	2-3	DIVER	300 g	9, N, 2-3 m	IR,UV/F,GC,TOC
		6-7	DIVER	300 g	9, N, 6-7 m	IR,UV/F,GC,TOC
	C	2-3	DIVER	300 g	9, C, 2-3 m	IR,UV/F,GC,TOC
		6-7	DIVER	300 g	9, C, 6-7 m	IR,UV/F,GC,TOC
	S	2-3	DIVER	300 g	9, S, 2-3 m	IR,UV/F,GC,TOC
		6-7	DIVER	300 g	9, S, 6-7 m	IR,UV/F,GC,TOC
Bay 10	N	2-3	DIVER	300 g	10, N, 2-3 m	IR,UV/F,GC,TOC
		6-7	DIVER	300 g	10, N, 6-7 m	IR,UV/F,GC,TOC
	C	2-3	DIVER	300 g	10, C, 2-3 m	IR,UV/F,GC,TOC
		6-7	DIVER	300 g	10, C, 6-7 m	IR,UV/F,GC,TOC
	S	2-3	DIVER	300 g	10, S, 2-3 m	IR,UV/F,GC,TOC
		6-7	DIVER	300 g	10, S, 6-7 m	IR,UV/F,GC,TOC
Bay 11	N	2-3	DIVER	300 g	11, N, 2-3 m	IR,UV/F,GC,TOC
		6-7	DIVER	300 g	11, N, 6-7 m	IR,UV/F,GC,TOC
	C	2-3	DIVER	300 g	11, C, 2-3 m	IR,UV/F,GC,TOC
		6-7	DIVER	300 g	11, C, 6-7 m	IR,UV/F,GC,TOC
	S	2-3	DIVER	300 g	11, S, 2-3 m	IR,UV/F,GC,TOC
		6-7	DIVER	300 g	11, S, 6-7 m	IR,UV/F,GC,TOC

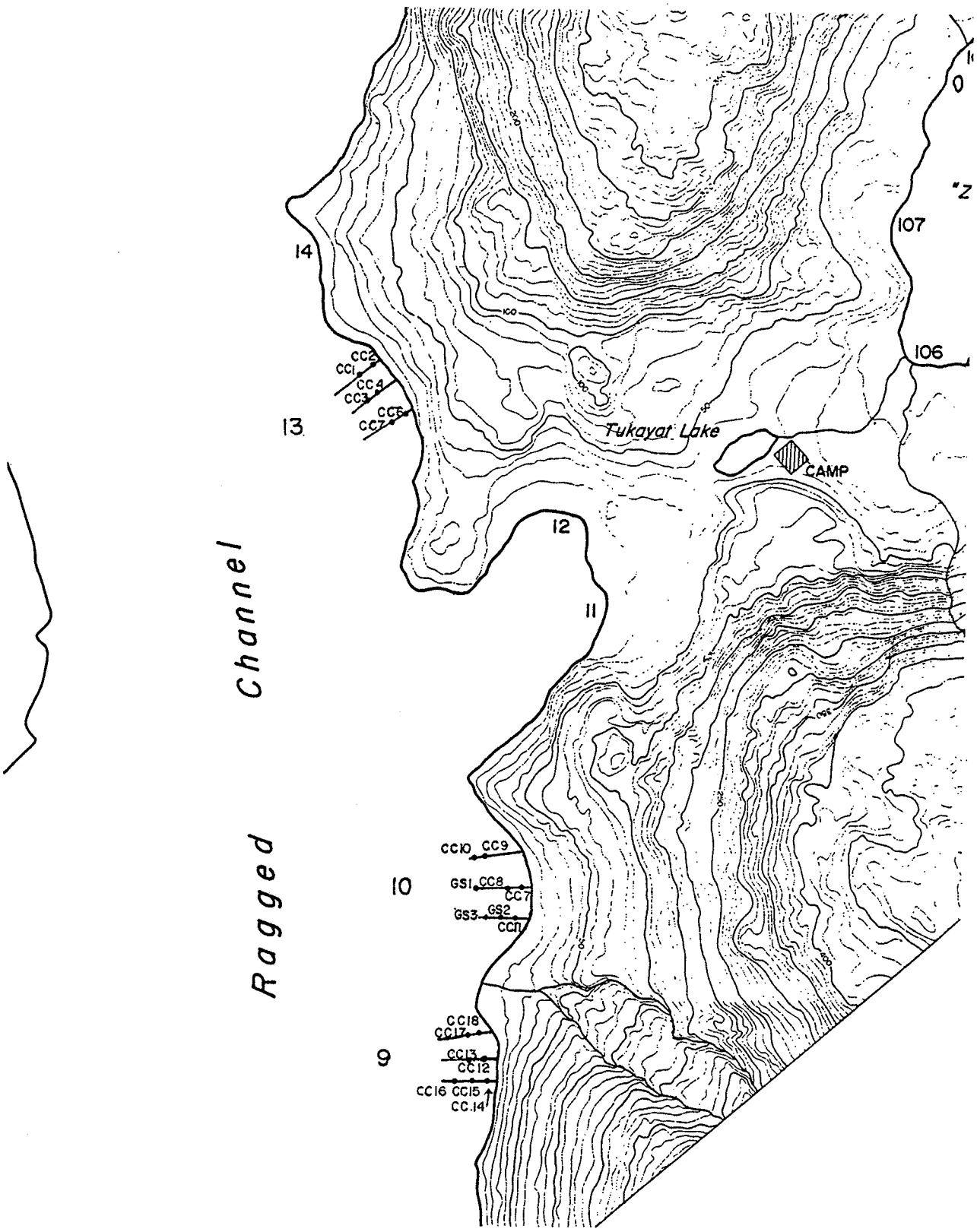


FIGURE 2.4: Locations of hydrocarbon baseline sediment samples taken from Ragged Channel, June, 1980.

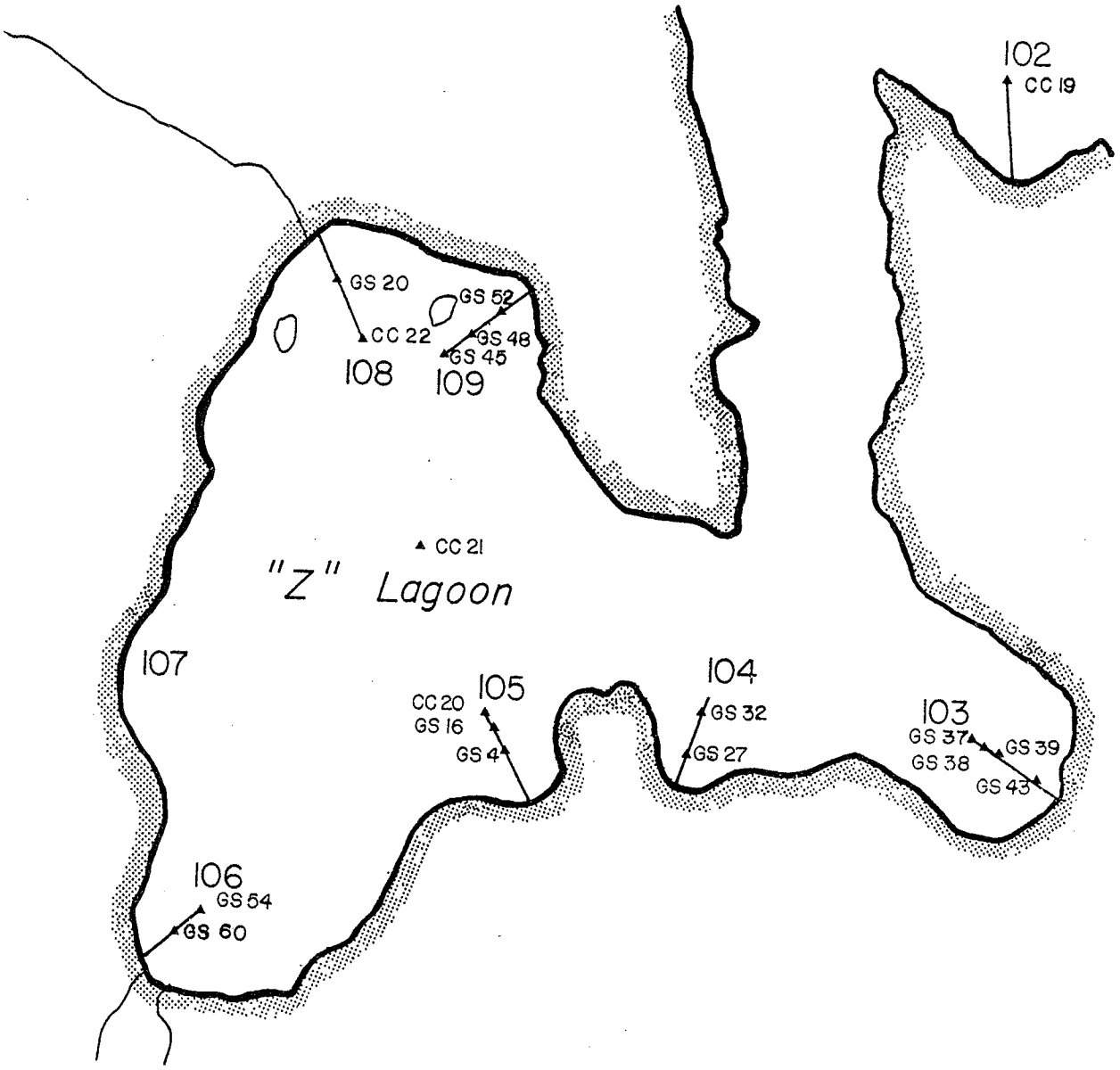


FIGURE 2.5: Locations of hydrocarbon baseline sediment samples taken from Z-Lagoon, June, 1980.

2.2.3 Hydrocarbon Baseline Beach Samples

A suite of samples was collected from along the beaches of the experimental bays in Ragged Channel. They were taken in triplicate for IR, UV/F, and GC/MS analysis from the high and low tide lines at each of three transects in the three experimental bays. (In addition, a set of samples was taken prior to the oiling experiments in Z-lagoon: these are summarized separately in the following section). These beach samples were collected with a trowel and consisted of about 200 grams of surface material for each sample. The samples were stored in solvent-rinsed tins and jars, and frozen until analyzed. All sampling was done on 22 August, 1980. This set of samples is summarized in Table 2.4.

TABLE 2.4

BEACH SAMPLES
HYDROCARBON BASELINE STUDY

Bay	Transect	Location	I.D.	Analyses
Bay 9	N	H	9-N-H	IR, UV/F, GCMS
		L	9-N-L	IR, UV/F, GCMS
	C	H	9-C-H	IR, UV/F, GCMS
		L	9-C-L	IR, UV/F, GCMS
	S	H	9-S-H	IR, UV/F, GCMS
		L	9-S-L	IR, UV/F, GCMS
Bay 10	N	H	10-N-H	IR, UV/F, GCMS
		L	10-N-L	IR, UV/F, GCMS
	C	H	10-C-H	IR, UV/F, GCMS
		L	10-C-L	IR, UV/F, GCMS
	S	H	10-S-H	IR, UV/F, GCMS
		L	10-S-L	IR, UV/F, GCMS
Bay 11	N	H	11-N-H	IR, UV/F, GCMS
		L	11-N-L	IR, UV/F, GCMS
	C	H	11-C-H	IR, UV/F, GCMS
		L	11-C-L	IR, UV/F, GCMS
	S	H	11-S-H	IR, UV/F, GCMS
		L	11-S-L	IR, UV/F, GCMS

NOTES:
1. H refers to high tide line, L to low tide line
2. UV/F and GC/MS samples delivered to ERCO
   IR samples to Seakem Oceanography Ltd.
3. Sampling date 22nd August, 1980

2.2.4 Hydrocarbon Baseline Tissue Samples

In June two sets of clam (Mya truncata) samples were collected by divers for baseline hydrocarbon and histopathology analysis. In September, a wide variety of organisms were collected for baseline hydrocarbon analysis only. The hydrocarbon samples were stored frozen; the histopathology samples were preserved in an alcohol solution. The samples are listed in Table 2.5.

TABLE 2.5

TISSUE SAMPLES
HYDROCARBON BASELINE STUDY

Sampling Period	Type of Organism	Species	Bay 9	Bay 10	Bay 11	Bay 13	Z-Lagoon	Comments
June	Clam	Mya truncata	1	1		1		for histo-pathology
	Clam	Mya truncata	1	1		1		
Sept.	Clam	Mya truncata	5	3	5		4	
		Serripes groen-landica	2		1		1	
	Starfish	Leptasterias polaris	6	3	5		3	
	Sea Urchin	Strongylocentrotus droebachiensis	4	2	6		4	
	Sea Cucumber	Psolus fabricii	1		3		1	
		Psolus sp.	3					
	Seaweed	Fucus resiculosus	1	1	1			
		Agarum sp.		1				
		Laminaria saccharina		1			1	
	Sculpin	Myoxocephalus scorpius	1				1	
	Tunicate	Rhizomolgula globularis	1	1	1		1	for vanadium analysis

Notes:

1. For smaller organisms (e.g. Mya) each sample consists of at least 10 individuals.
2. For larger organisms, each sample consists of at least 100 g tissue.

2.3. Shoreline Experiment

The shoreline experiment was conducted primarily by Woodward-Clyde Consultants, and is reviewed only briefly here. Four pairs of plots were oiled for experimental purposes: two intertidal sets, one low energy (Bay 103) and one high energy (Bay 102); and two corresponding backshore sets of plots. Each paired set of plots consisted of a 4 x 10 m test area to which 2 barrels of crude oil were applied either as 100% aged crude, or as a 50% aged crude/water emulsion, giving a 1 - 2 cm thick layer of crude. A summary of the test plots is given in Table 2.6.

Samples were taken from each test plot at various times following oil application and analyzed for total hydrocarbon content. Additional samples were taken from each test plot for analysis by GC/MS to determine the weathering characteristics of the various fractions of the oil. Table 2.7 shows the sampling scheme, which can be summarized as follows:

2.3.1 Total Hydrocarbon Samples

One 4 cm core sample was taken from each plot before the spill to measure background oil content. After the spill, samples were taken from each test plot: immediately after the spill, and at 2, 4, and 8 days after the spill. The post-spill samples were taken on each plot in 9 locations: 3 in each of the upper, middle, and lower sections of the plot which were mixed to provide one composite for each of the three sections. These samples consisted of a surface (0 - 2 cm) component and sub-surface component (4 - 8 cm).

2.3.2 GC/MS Samples

A single composite surface sample was taken from each test plot on days 1, 2, 4, 8, and 16 following oil application for GC/MS analysis.

2.3.3 Water Samples

A suite of water samples was also taken for IR and UV/F analysis in conjunction with the shoreline experiment. These are summarized in Table 2.8.

TABLE 2.6

SUMMARY OF SHORELINE EXPERIMENT TEST PLOTS

Test Plot I.D.	Test Area (m^2)	Location	Site Description	Type of Oil Spilled	Spill Date
H1	40	Bay 102	Upper intertidal open coast, high energy	aged crude	23 Aug
H2	40	Bay 102	"	50% water/oil emulsion	23 Aug
L1	40	Bay 103	Upper intertidal Z-lagoon, low energy	aged crude	21 Aug
L2	40	Bay 103	"	50% water/oil emulsion	22 Aug
LT1	40	Crude Oil Point	Control plot, backshore area	aged crude	20 Aug
LT2	40	Crude Oil Point	"	50% water/oil emulsion	20 Aug
HT1	4	Bay 102	Control plot, backshore area	aged crude	23 Aug
HT2	4	Bay 102	"	50% water/oil emulsion	23 Aug

TABLE 2.7

SUMMARY OF SAMPLING SCHEME FOR OILED PLOTS

Test Plot	Location in Plot	Before Test	Immediately After Spill	1 Day	2 Days		4 Days		8 Days		16 Days
H-1	Upper Mid Lower	IR, UV/F GC/MS	1 A,B 2 A,B 3 A,B	GC 1	4 A,B 5 A,B 6 A,B	GC2	37 A,B 38 A,B 39 A,B	GC 3	55 A,B 56 A,B 57 A,B	GC 4	GC 5
H-2	Upper Mid Lower	IR, UV/F GC/MS	7 A,B 8 A,B 9 A,B	GC 6	10 A,B 11 A,B 12 A,B	GC 7	40 A,B 41 A,B 42 A,B	GC 8	58 A,B 59 A,B 60 A,B	GC 9	GC 10
L-1	Upper Mid Lower	IR,UV/F GC/MS	13 A,B 14 A,B 15 A,B	GC 11	16 A,B 17 A,B 18 A,B	GC 12	43 A,B 44 A,B 45 A,B	GC 13	61 A,B 62 A,B 63 A,B	GC 14	GC 15
L-2	Upper Mid Lower	IR,UV/F GC/MS	19 A,B 20 A,B 21 A,B	GC 16	22 A,B 23 A,B 24 A,B	GC 17	46 A,B 47 A,B 48 A,B	GC 18	64 A,B 65 A,B 66 A,B	GC 19	GC 20
LT-1	Upper Mid Lower	IR,UV/F GC/MS	23 A,B 26 A,B 27 A,B	GC 21	28 A,B 29 A,B 30 A,B	GC 22	49 A,B	GC 23	67 A,B	GC 24	GC 25
LT-2	Upper Mid Lower	IR,UV/F GC/MS	31 A,B 32 A,B 33 A,B	GC 26	34 A,B 35 A,B 36 A,B	GC 27	52 A,B	GC 28	70 A,B	GC 29	GC 30

TABLE 2.7

SUMMARY OF SAMPLING SCHEME FOR OILED PLOTS

Test Plot	Location in Plot	Before Test	Immediately After Spill	1 Day	2 Days		4 Days		8 Days		16 Days
HT-1			201 A,B	GC 40	203 A,B	GC 42	205 A,B	GC 44	207 A,B	GC 46	GC 48
HT-2			202 A,B	GC 41	204 A,B	GC 43	206 A,B	GC 45	208 A,B	GC 47	GC 49

NOTES:

1. A denotes a surface (0-2 cm) sample
2. B denotes a sub-surface (4-8 cm) sample
3. Numbered samples are for IR (total hydrocarbon) analysis
4. See text for description of how samples were collected.

TABLE 2.8

WATER SAMPLES
SHORELINE EXPERIMENT

DATE	LOCATION	TEST PLOT	DEPTH	ANALYSIS	COMMENTS
18 Aug	Bay 102	H1 & H2	1,4 m	IR, UV/F	prespill
20 Aug	Bay 103	L1 & L2	1,5 m	IR, UV/F	pre-spill
20 Aug	Crude Oil Pt.	LT1 &LT2	1,10 m	IR, UV/F	pre-spill
21 Aug	Bay 103	L1	1,10 m	IR, UV/F	post-spill
20 Sept	Bay 103	L1 & L2	1,5 m	IR, UV/F	post-spill
20 Sept	Crude Oil Pt.	LT1 & LT2	1,5 m	GC/MS	post-spill

3. METHODS

Each of the methods used for the various environmental chemistry and hydrocarbon determinations are outlined below together with comments on intercalibrations or other verification of the methods where appropriate.

3.1 Environmental Chemistry: Water Analyses

3.1.1 Temperature and Salinity

These parameters are the domain of the physical oceanographic component of the B.I.O.S. project. However, to aid in interpretation of results, an effort was made to provide temperature and salinity readings at each of the stations and depths at which samples were collected. Three different methods of temperature measurement were used: a mercury thermometer placed in the Niskin sampler after recovery, a YSI Model 33 salinity-temperature meter, and an Applied Microsystems Model CTD-12 instrument. When quoting results, the order of preference for choosing readings was thermometer, CTD-12, YSI. For salinity, salinometer data provided by the Arctic Biological Station was used.

3.1.2 Oxygen

Two methods were used for measuring oxygen in seawater: a YSI oxygen probe and the Winkler titration method. The YSI oxygen probe was used directly in the Niskin sampler out in the field. The Winkler titration method was used for twenty-four samples as a check on the YSI probe. The Winkler titration is the standard oceanographic method for determination of oxygen and has a precision of at least 0.05 mg/L. The oxygen probe is considerably less precise. The probe is calibrated by measuring the atmospheric partial pressure of oxygen, which introduces variability, and the condition of the membrane is also a significant variable. Nevertheless, the two methods gave excellent agreement with a relative standard deviation of only 3.4%.

3.1.3 pH

pH was measured with a Sargent pH probe. Buffered standards of 4.02 and 7.40 pH were used before and after each set of samples to calibrate the probe. Determinations were made on subsamples in the field laboratory at room temperature. The probe was given about 5 minutes to stabilize before each reading.

3.1.4 Reactive Nitrate and Phosphate

20 mL nutrient samples were run on an auto-analyzer using standard procedures. The Technicon auto-analyzer and the operator were the same as used for thousands of analyses for the Patricia Bay Institute of Oceanography. The method has been extensively checked and intercalibrated with other laboratories over a period of several years.

3.1.5 Suspended Solids

Approximately 1.5L water samples were filtered through pre-baked, pre-weighed 47 mm GF/C filters. The filters were dried, weighed, ashed, and re-weighed. The difference between the dry weight and filter tare gives the total suspended solids. The difference between the ashed and dry weights is a measure of the organic suspended solids.

3.1.6 Dissolved Organic Carbon

5 mL subsamples of filtered water were added to precombusted glass ampoules, acidified with phosphoric acid, and purged with nitrogen to remove inorganic carbonate. The organics were then persulphate oxidized to carbon dioxide with heating to 130°C in a sealed ampoule. The carbon dioxide produced was measured in an Oceanography International total carbon infra-red gas analyzer. Analyses were done in quadruplicate with d-glucose standards. This method is similar to that described by Menzel and Vaccaro, 1964.

The results of this method were compared with the Arctic Biological Station results on duplicate Cape Hatt samples. Satisfactory agreement between the two methods was obtained.

3.1.7 Particulate Organic Carbon

Approximately 1.5L water were filtered through a pre-baked GF/C filter. The wet oxidation procedure described by Copin-Montegut and Copin-Montegut, 1973, was used. The method involves the addition of phosphoric acid to drive off chlorides, acid-dichromate oxidation to oxidize the available carbon, then back-titration with ferrous ammonium sulphate (diphenylamine indicator) to determine the amount of dichromate used in the oxidation of the carbon.

These results were compared with those of the Arctic Biological Station on similar samples from Cape Hatt, and agreement was not satisfactory. In looking for the source of the error, we determined that co-oxidation of chloride ion was a problem. An attempt was made to correct for chloride interference as per the graph in Figure 3.1. This gave good agreement for June samples, but serious discrepancies for August - September. An intercalibration between three laboratories was arranged, which showed satisfactory agreement between the Arctic Biological Station and the Patricia Bay Institute of Oceanography, with the Seakem titration method anomalously high (see Table 3.1). The intercalibration results were confusing, since the Seakem titration results from Cape Hatt were generally too low. Rather than pursue the matter further, the titration method was dropped as being too prone to interference, and the Arctic Biological Station results were adopted. Their method employs wet (persulphate) oxidation in a sealed ampoule, catalytic conversion of the carbon dioxide produced to methane, and determination of the methane using a gas chromatograph with a flame ionization detector.

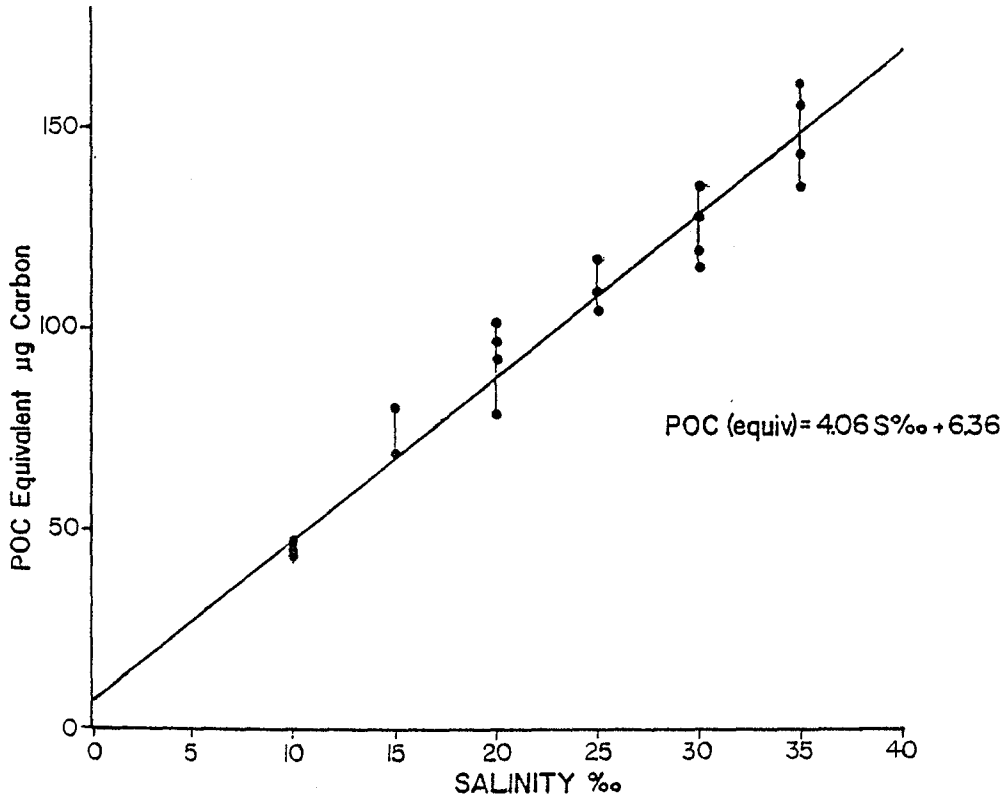


FIGURE 3.1: Graph showing the interference caused by salt in the determination of particulate organic carbon by the titration method. (Carbon-free water of varying salinity was filtered through GF/C filter papers. POC determinations on the filter papers gave the responses shown.)

TABLE 3.1

INTERCALIBRATION STUDIES

a) Chlorophyll

Laboratory	SAMPLE A		SAMPLE B	
	Chl. a $\mu g.L^{-1}$	Phaeo $\mu g.L^{-1}$	Chl. a $\mu g.L^{-1}$	Phaeo $\mu g.L^{-1}$
Seakem (immediate analysis)	1.14 ±0.09	1.38 ±0.11	1.00 ±0.06	0.85 ±0.06
Seakem (stored)	1.06 ±0.10	1.43 ±0.10	0.86 ±0.06	0.78 ±0.06
Institute of Ocean Sciences (stored)	0.79 ±0.06	1.65 ±0.12	0.74 ±0.06	1.13 ±0.08
Bedford Institute (stored)	1.79 ±0.09	1.45 ±0.11	1.81 ±0.14	0.56 ±0.08

Notes: Values are averages and standard deviations of 10 determinations.

b) Particulate Organic Carbon

Laboratory	SAMPLE A $\mu g.L^{-1}$	SAMPLE B $\mu g.L^{-1}$
Seakem[2]	98.7 ± 22.2	93.2 ± 21.0
Arctic Biological Station[3]	70.3 ± 74.7	42.8 ± 8.5
Institute of Ocean Sciences[4]	46.7 ± 19.8	33.1 ± 2.8

Notes:

1. Values are averages and standard deviations of 6 determinations.
2. Wet oxidation, back titration method, corrected for chloride interference.
3. Wet oxidation, catalytic conversion of CO_2 to methane, gas chromatograph FID detector
4. Dry oxidation, measurement of CO_2 with a gas chromatograph thermal conductivity detector.

3.1.8 Chlorophyll a and Phaeopigments

500 - 1000mL water samples were filtered through GF/C filters. The filters were stored frozen, ground in the laboratory, and extracted into acetone. The acetone slurry was filtered, and the chlorophyll content determined fluorometrically. The method is essentially that of Strickland and Parsons, 1972. Phaeopigments were also determined by the addition of acid and remeasurement of the fluorescence.

To check the validity of the chlorophyll determinations, the Turner fluorometer was recalibrated, and an intercalibration exercise was conducted with the Bedford Institute of Oceanography and the Patricia Bay Institute of Oceanography. The results of this intercalibratrion are given in Table 3.1. The Seakem analyses fall between the two sets of data from the oceanographic institutes, and are in reasonably close agreement with the Patricia Bay Institute of Ocean Sciences. Communication is continuing to determine why the Bedford results differ so markedly.

3.1.9 Total Nitrogen

The method used was that of Koroleff, 1976. In his review of methods available for determining total nitrogen in seawater, he points out that: "The determination of total and organic nitrogen is one of the most difficult tasks in marine chemistry". We concur with his comment after spending two weeks experimenting with his method in an attempt to get meaningful measurements of total nitrogen. After correcting blank problems by improved purification of the persulphate oxidant (triple recrystallization) and more careful regulation of autoclaving temperatures, the values obtained for total nitrogen were erratic and anomalously low, often less than the nitrate values.

In July, 1980, Solorzano and Sharp published a paper that identified various problems with the Koroleff method. They began their paper with the comment:

"Our understanding of dissolved organic nitrogen in the sea is poor largely because of analytical inadequacies. The determination has been hampered by technical difficulties due to uncertainly of the chemical structures of most of the organic components, the inability of existing methods to quantify some of the nitrogen compounds, and the lack of a simple, reliable, and inexpensive method for routine use".

They identified the following problems with the method:

a) Clogging of Cd-Cu nitrate reduction columns due to a precipitate released from the boro-silicate glass vessels by the oxidizing, alkaline conditions. Teflon vessels avoided the problem.

b) Insufficient base: The critical pH for complete oxidation of nitrogen compounds was found to be 10. Koroleff's method resulted in lower pH's leading to incomplete recoveries (~75%). 1.5M NaOH was recommended instead of 0.12 M as used by Koroleff.

c) Dilution factor: The dilution factor in the Koroleff procedure is about 5x which increases the scatter of the results. Dilution by 1.32x was recommended.

d) Standard: Urea instead of EDTA was recommended.

Unfortunately this paper arrived after the June analyses were complete. Analyses of seawater for total nitrogen was discontinued after the June sampling period, since the level of interest in the measurements did not warrant further experimentation with the method.

3.2 Environmental Chemistry: Sediment Analyses

3.2.1 Total Organic Carbon

1 - 5 g subsamples were required. The samples were dried, oxidized with a known amount of potassium dichromate, and the dichromate back-titrated with ferrous ammonium sulphate. This is essentially the well-known Walkley-Black method, to which there are many references including Gaudette, 1974.

The method was checked for interference by chloride ion. The chloride concentration in the sediments was measured and ranged between 2 and 10°/oo for most samples, resulting in a chloride correction of 1 to 5% to the total organic carbon determinations. This correction has not been applied to the results reported in the next section since it is relatively small, not very significant next to the subsampling errors, and not usually considered in other marine applications.

The August-September samples were analyzed in triplicate to give an estimate of the variability between subsamples.

3.2.2 Interstitial Nitrate and Phosphate

Sufficient sediment was pressed in a Reeburgh-type sediment press to produce 10-20 mL interstitial water. These samples were then analyzed by standard autoanalyzer methods, although it was found necessary to add two drops of concentrated HCl to the samples to dissolve iron precipitates.

3.2.3 Total Nitrogen

Total nitrogen in six sediment samples from the June sampling period were determined by the standard micro-Kjehdahl method (Black et al., 1965).

3.2.4 Lead-210

These samples which are used to 'date' the sediments, were analyzed under subcontract by CEP Inc., Santa Fe, New Mexico, who used the 'bismuth ingrow' technique (Koide et al., 1972).

3.3 Hydrocarbon Baseline Study

3.3.1 Water Samples: IR Analyses

Water samples were extracted in the field laboratory with 3 x 75 mL Freon 113. The extractions were done in the sample containers by shaking for 3 minutes in a paint shaker. The extracts were roto-evaporated to near dryness, made up to a known volume, and the $-CH_2-$ stretching peak at 2930 cm^{-1} measured with a Perkin-Elmer model 457 grating infra-red spectrophotometer. The peaks were quantified by comparison with a standard curve for Lagomedio crude.

3.3.2 Sediment and Beach Samples: IR Analyses

Approximately 60 g wet sediment samples were dried and extracted for 5 minutes with 3 x 40 mL Freon 113, in an ultrasonic bath. The solvent was recovered by filtration, roto-evaporated to near dryness, and made up to a known volume. The $-CH_2-$ stretch peak at 2930 cm^{-1} was measured and compared to a standard curve for Lagomedio crude. This determination was referred to as a measure of total extractables.

Because of the high organic content of the sediment relative to water, an additional columning step was necessary to remove the polar hydrocarbons. Florisil mini-columns consisting of 0.70 g of 5% deactivated Florisil in disposable pipettes were made up. The sample was added to the column as 200 µL concentrate, eluted with 2 bed volumes (1.8 mL) Freon, and the peak at 2930 cm^{-1} remeasured to determine the hydrocarbon content.

3.4 Shoreline Experiment

3.4.1 Total Hydrocarbons

Total hydrocarbon content of oiled sediment samples taken from the beach plots were determined as follows: 50 g subsamples were dried, extracted with 3 x 40 mL Freon by ultrasonification, the Freon recovered by filtration and roto-evaporated to dryness, and the extracted hydrocarbons determined both gravimetrically and by infrared spectrophotometry. The two methods correlated extremely well, with a correlation coefficient of 0.991.

4. RESULTS

4.1 Environmental Chemistry: Water Samples

The results of all of the environmental chemistry water samples are summarized in Table 4.1. Some additional melt pool and under-ice samples were collected out of general interest, and analyses of these samples are presented in Table 4.2 for comparison purposes.

TABLE 4.1: ENVIRONMENTAL CHEMISTRY: WATER ANALYSES

#	Date	Location	Depth m	Temp. °C	Salinity o/oo	Dissolved Oxygen mg.L-1	pH	Reactive Nitrate µg.at.L-1	Reactive Phosphate µg.at.L-1	Suspended Solids (organic) mg.L-1	Suspended Solids (inorganic) mg.L-1	Dissolved Organic C mg.L-1	Particulate Organic C µg.L-1	Chloro-phyll a µg.L-1	Phaeo-pigment µg.L-1
1	06/06/80	H1	1	-1.7	32.8		7.7	7.8	1.31	-	-	1.13	20	0.03	0.02
2			5	-1.7	33.1		7.7	8.3	1.28	-	-	1.23	20	0.02	0.02
3			10	-1.7	32.8		7.7	8.0	1.33	-	-	1.44	10	0.02	0.03
4		H2	1	-1.7	32.8		7.7	7.8	1.36	-	-	1.49	10	0.03	0.02
5			5	-1.7	33.0		7.7	7.8	1.30	-	-	1.56	10	0.05	0.04
6			10	-1.7	33.0		7.7	8.1	1.31	-	-	1.50	20	0.02	0.03
7	08/06/80	H3	1	-1.7	32.7		7.7	7.9	1.31	-	-	1.47	80	0.04	0.03
8			5	-1.7	32.7		7.6	7.7	1.52	-	-	1.03	40	0.02	0.04
9			10	-1.7	32.7		7.7	9.2	1.72	-	-	1.15	80	0.01	0.03
10		H4	1	-1.7	32.7		7.6	7.5	1.31	-	-	1.24	20	0.02	0.03
11			5	-1.7	32.7		7.7	7.8	1.29	-	-	0.92	10	0.02	0.03
12			10	-1.7	32.7		7.7	8.2	1.35	-	-	1.38	10	0.02	0.03
13	10/06/80	H5	1		32.6		7.6	7.9	1.32	-	-	1.28	50	0.03	0.04
14			5		32.7		7.6	8.0	1.32	-	-	1.28	10	0.04	0.03
15			10		32.7		7.7	8.2	1.31	-	-	1.03	50	0.06	0.04
16		H6	1		32.8		7.7	8.5	1.29	-	-	1.04	30	0.05	0.04
17			5		32.8		7.6	8.3	1.31	-	-	1.23	40	0.04	0.03
18			10		32.8		7.7	8.3	1.28	-	-	1.34	30	0.03	0.03

#	Date	Location	Depth	Temp.	Salinity	Dissolved Oxygen	pH	Reactive Nitrate	Reactive Phosphate	Suspended Solids (organic)	Suspended Solids (inorganic)	Dissolved Organic C	Particulate Organic C	Chloro-phyll a	Phaeo-pigment
			m	°C	°/oo	mg.L^{-1}		µg.at.L^{-1}	µg.at.L^{-1}	mg.L^{-1}	mg.L^{-1}	mg.L^{-1}	µg.L^{-1}	µg.L^{-1}	µg.L^{-1}
19	12/06/80	H1	1	-1.7	32.7		7.9	8.1	1.35	-	-	1.12	60	0.04	0.04
20			5	-1.8	32.8		8.0	8.0	1.33	-	-	1.32	30	0.04	0.04
21			10	-1.8	32.7		8.0	8.0	1.32	-	-	1.17	40	0.03	0.03
22		H2	1	-1.7	32.4		8.0	8.2	1.29	-	-	1.26	10	0.03	0.03
23			5	-1.7	32.8		8.0	8.0	1.33	-	-	1.28	30	0.03	0.02
24			10	-1.7	32.7*		8.0	8.0	1.28	-	-	1.26	10	0.02	0.02
25	14/06/80	H3	1	-1.5	32.4		7.8	7.8	1.21	-	-	-	130	0.05	0.05
26			5	-1.7	32.7		7.8	7.9	1.29	-	-	-	50	0.04	0.02
27			10	-1.7	32.8		7.8	6.9	1.32	-	-	1.00	30	0.04	0.04
28		H4	1	-0.7	29.9		7.8	7.0	1.31	-	-	1.67	110	0.07	0.10
29			5	-1.8	32.4		7.8	7.6	1.26	-	-	1.01	20	0.04	0.05
30			10	-1.7	32.8		7.8	7.9	1.28	-	-	0.99	20	0.03	0.03
31	16/06/80	H5	1	-0.9	30.6		7.9	7.4	1.24	0.72	3.08	1.24	100	0.06	0.08
32			5	-1.7	32.5		7.9	8.0	1.33	0.39	1.72	1.04	10	0.03	0.03
33			10	-1.7	32.8		7.9	8.0	1.31	0.27	1.20	1.12	20	0.02	0.03
34		H6	1	-1.2	32.0		8.0	7.0	1.15	0.56	1.98	-	70	0.15	0.09
35			5	-1.8	32.7		8.0	8.2	1.31	0.44	1.20	0.83	10	0.03	0.02
36			10	-1.8	32.8		8.0	8.1	1.31	0.37	1.48		80	0.03	0.03

* indicates salinity value taken from YSI field instrument.

#	Date	Location	Depth m	Temp. °C	Salinity °/oo	Dissolved Oxygen mg.L^{-1}	pH	Reactive Nitrate µg.at.L^{-1}	Reactive Phosphate µg.at.L^{-1}	Suspended Solids (organic) mg.L^{-1}	Suspended Solids (inorganic) mg.L^{-1}	Dissolved Organic C mg.L^{-1}	Particulate Organic C µg.L^{-1}	Chloro-phyll a µg.L^{-1}	Phaeo-pigment µg.L^{-1}
37	18/06/80	H1	1	-1.1	31.4		7.6	7.6	1.27	-	-	1.53		0.08	0.05
38			5	-1.7	32.5		7.6	8.0	1.31	-	-	1.35		0.07	0.04
39			10	-1.7	32.5		7.6	8.0	1.33	-	-	2.05		0.03	0.03
40		H2	1				7.6	7.8	1.31	-	-	1.96		0.18	0.05
41			5				7.6	8.0	1.30	-	-	1.89		0.09	0.03
42			10				7.6	8.0	1.33	-	-	2.04		0.05	0.04
43	20/06/80	H3	1				7.8	7.9	1.19	0.52	2.64	1.16		0.05	0.03
44			5				7.7	8.0	1.30	0.40	1.38	1.03		0.06	0.03
45			10				7.7	8.0	1.32	0.57	2.11	1.16		0.06	0.07
46		H4	1				7.8	7.7	1.24	0.39	1.62	1.15		0.04	0.03
47			5				7.8	7.8	1.35	0.37	1.67	0.90		0.03	0.03
48			10				7.8	8.0	1.27	0.29	1.36	1.16		0.03	0.03
49	22/06/80	H5	1				-	6.8	1.10	1.09	2.58	1.08		0.21	0.03
50			5				-	7.8	1.28	0.30	0.36	1.09		0.15	0.02
51			10				-	8.2	1.27	0.49	1.02	1.10		0.12	0.02
52	11/08/80	H1	1	4.8	14.0		-	0.5	0.29	0.46	1.10	2.64	150	0.10	0.07
53			5	3.2	22.5		-	0.0	0.52	0.51	0.69	1.60	110	0.26	0.16
54			10	1.3	30.0		-	0.1	0.77	0.74	1.30	1.87	210	0.31	0.28

#	Date	Location	Depth m	Temp. °C	Salinity °/oo	Dissolved Oxygen mg.L^{-1}	pH	Reactive Nitrate µg.at.L^{-1}	Reactive Phosphate µg.at.L^{-1}	Suspended Solids (organic) mg.L^{-1}	Suspended Solids (inorganic) mg.L^{-1}	Dissolved Organic C mg.L^{-1}	Particulate Organic C µg.L^{-1}	Chloro-phyll a µg.L^{-1}	Phaeo-pigment µg.L^{-1}
55		H2	1	4.6	14.5		-	0.2	0.28	0.76	2.38	1.57	100	0.09	0.06
56			5	3.1	23.4		-	0.0	0.44	0.50	0.88	1.60	130	0.20	0.14
57			10	1.2	30.3		-	0.1	0.72	0.69	0.88	2.03	240	0.56	0.25
58	13/08/80	H3	1	4.6	18.1	10.4	7.8	0.2	0.36	0.83	1.66	2.33	140	0.27	0.24
59			5	3.9	22.0	10.5	7.7	0.7	0.47	0.52	0.62	1.98	150	0.34	0.35
60			10	2.2	27.2	11.7	7.6	0.3	0.64	0.67	0.59	1.81	260	0.54	0.38
61		H4	1	4.5	17.6	10.5	7.7	0.2	0.37	0.61	0.87	1.58	190	0.24	0.20
62			5	3.9	21.3	10.3	7.7	0.7	0.47	0.77	1.59	1.64	140	0.33	0.28
63			10	2.6	26.5	10.4	7.8	0.3	0.65	0.76	0.87	3.33	210	0.50	0.34
64	15/08/80	H5	1	3.9	16.0	12.3	8.0	1.0	0.34	0.56	0.59	2.07	130	0.14	0.10
65			5	2.5	25.7	12.7	7.8	0.3	0.58	0.61	0.61	1.59	190	0.38	0.35
66			10	1.8	29.9	13.8	7.3	0.2	0.73	0.52	-	1.62	210	0.55	0.44
67		H6	1	4.4	15.7	12.1	7.7	0.9	0.31	0.42	0.27	1.50	280	0.25	0.15
68			5	2.8	24.9	11.6	7.8	0.7	0.51	0.52	0.67	1.30	130	0.33	0.26
69			10	1.8	29.9	12.4	7.4	0.1	0.74	0.53	1.10	2.99	190	0.40	0.42
70	19/08/80	H1	1	3.8	22.6	11.0	7.6	0.7	0.49	0.53	0.54	1.73	150	0.57	0.51
71			5	3.2	24.3	12.3	7.5	-	-	0.56	0.92	2.33	190	0.74	0.79
72			10	2.3	28.8	13.0	7.5	0.2	0.74	0.49	-	2.92	160	0.60	0.59

#	Date	Location	Depth m	Temp. °C	Salinity o/oo	Dissolved Oxygen mg.L^{-1}	pH	Reactive Nitrate µg.at.L^{-1}	Reactive Phosphate µg.at.L^{-1}	Suspended Solids (organic) mg.L^{-1}	Suspended Solids (inorganic) mg.L^{-1}	Dissolved Organic C mg.L^{-1}	Particulate Organic C µg.L^{-1}	Chloro-phyll a µg.L^{-1}	Phaeo-pigment µg.L^{-1}
73		H2	1	3.8	23.4	12.6	7.6	0.3	0.48	0.67	1.02	1.61	170	0.60	0.60
74			5	3.2	24.3	13.0	7.4	0.0	0.52	0.76	1.03	3.17	210	0.72	0.71
75			10	2.4	29.0	12.8	7.4	0.1	0.71	0.65	0.91	1.77	210	0.24	0.24
76	21/08/80	H3	1	3.0	24.1	12.10*	7.7	0.1	0.44	0.64	1.24	2.54	150	0.15	0.16
77			5	2.4	26.6	12.27*	7.8	0.1	-	0.68	0.80	2.14	160	0.46	0.61
78			10	2.2	30.4	11.88*	7.8	0.2	0.84	0.58	0.91	2.96	170	0.39	0.53
79		H4	1	3.0	24.1	11.96*	7.7	0.1	0.39	0.62	0.79	4.14	150	0.27	0.23
80			5	2.4	26.4	12.18*	7.8	0.1	0.56	0.63	0.65	3.77	150	0.38	0.38
81			10	2.4	30.7	12.45*	7.8	0.2	0.78	0.63	0.77	-	140	0.43	0.56
82	23/08/80	H5	1	4.8	23.7	11.6	7.8	0.0	0.52	0.57	0.64	2.33	170	0.28	0.24
83			5	3.8	25.6	11.5	7.8	0.0	0.54	0.60	0.61	2.40	160	0.41	0.41
84			10	2.7	29.4	11.8	7.8	4.5	0.69	0.63	0.62	4.62	150	0.56	0.56
85		H6	1	4.1	24.5	11.7	7.7	-	-	0.66	0.73	3.29	180	0.21	0.23
86			5	3.7	25.2	11.7	7.8	0.1	0.50	0.51	0.58	1.63	230	0.46	0.39
87			10	3.0	29.0	11.9	7.8	0.1	0.68	0.64	0.92	2.29	210	0.48	0.60
88	28/08/80	H1	1	3.8	25.4	11.48*	7.9	0.0	0.53	0.46	0.69	3.39	140	0.42	0.53
89			5	3.3	26.4	11.79*	7.9	0.0	0.59	0.55	0.74	2.13	110	0.49	0.67
90			10	2.6	30.5	11.97*	7.9	0.5	0.81	0.48	0.68	2.11	100	0.46	0.66

* indicates oxygen analyses were done by Winkler titration (remainder by probe).

#	Date	Location	Depth m	Temp. °C	Salinity °/oo	Dissolved Oxygen mg.L-1	pH	Reactive Nitrate µg.at.L-1	Reactive Phosphate µg.at.L-1	Suspended Solids (organic) mg.L-1	Suspended Solids (inorganic) mg.L-1	Dissolved Organic C. mg.L-1	Particulate Organic C µg.L-1	Chloro-phyll a µg.L-1	Phaeo-pigment µg.L-1
91		H2	1	3.8	25.5	11.49*	7.9	0.1	0.54	0.61	1.30	2.61	130	0.44	0.54
92			5	3.0	26.6	11.71*	7.9	0.1	0.48	0.56	1.04	2.63	180	0.54	0.59
93			10	2.5	29.8	11.88*	7.9	-	-	0.46	0.69	4.09	120	0.48	0.69
94	30/08/80	H3	1	4.1	21.0	11.80*	7.9	0.1	0.38	0.49	0.88	2.39	190	0.29	0.31
95			5	3.8	24.0	11.70*	7.9	0.0	-	0.43	-	2.98	210	0.43	0.55
96			10	3.4	27.1	11.54*	7.8	0.2	0.58	0.50	0.49	2.72	170	0.59	0.77
97		H4	1	4.2	21.1	11.78*	7.7	0.0	0.31	0.49	0.67		140	0.32	0.39
98			5	3.9	23.6	11.68*	7.9	0.0	0.44	0.57	1.11	2.75	140	0.45	0.55
99			10	3.4	27.4	11.54*	7.9	0.1	0.48	0.51	0.70	2.25	120	0.39	0.51
100	01/09/80	H5	1	4.6	22.8	11.80*	7.8	0.0	0.37	0.55	0.75	2.37	160	0.29	0.26
101			5	4.2	23.1	11.82*	7.8	0.0	0.49	0.57	0.72	2.42	240	0.37	0.50
102			10	3.3	27.0	11.76*	7.8	0.0	0.58	0.53	0.69	2.11	160	0.22	0.33
103		H6	1	4.6	19.6	11.85*	7.8	0.0	0.32	0.63	0.91	2.97	140	0.03	0.06
104			5	4.0	24.0	11.81*	7.8	0.2	0.50	0.62	1.03	3.56	190	0.42	0.66
105			10	3.3	27.4	11.71*	7.8	0.0	0.56	0.61	0.48	2.21	200	0.32	0.48
106	05/09/80	H1	1	4.5	20.1	-	7.7	0.0	0.36	0.51	1.14	2.08	150	0.26	0.20
107			5	3.2	26.8	-	7.8	0.0	0.62	0.50	1.09	2.50	170	0.21	0.30
108			10	2.0	30.5	-		0.3	0.76	0.52	1.31	1.97	170	0.52	0.79

* indicates oxygen analyses were done by Winkler titration (remainder by probe).

#	Date	Location	Depth	Temp.	Salinity	Dissolved Oxygen	pH	Reactive Nitrate	Reactive Phosphate	Suspended Solids (organic)	Suspended Solids (inorganic)	Dissolved Organic C	Particulate Organic C	Chloro-phyll a	Phaeo-pigment
			m	°C	o/oo	ppm		µg.at.L^{-1}	µg.at.L^{-1}	mg.L^{-1}	mg.L^{-1}	mg.L^{-1}	µg.L^{-1}	µg.L^{-1}	µg.L^{-1}
109		H2	1	4.5	19.9	-	7.9	0.0	0.38	0.52	1.10	1.70	-	0.31	0.23
110			5	3.2	26.8	-	7.9	0.0	0.62	0.48	0.79	2.74	100	0.22	0.39
111			10	2.1	30.4	-	7.9	0.3	0.77	0.59	1.02	2.26	230	0.51	1.00
112	07/09/80	H3	1	4.4	19.5	11.5	-	0.1	0.33	0.57	1.41	1.64	140	0.30	0.40
113			5	3.9	24.8	11.4	-	0.2	0.60	0.51	1.07	2.28	120	0.39	0.58
114			10	2.0	30.8	11.6	-	0.1	0.74	0.60	1.23	3.94	160	0.87	0.84
115		H4	1	4.5	19.3	11.4	-	0.1	0.33	0.48	0.81	2.07	120	0.33	0.19
116			5	3.3	25.8	11.3	-	0.2	0.60	0.64	1.16	3.03	140	0.39	0.50
117			10	2.0	30.8	11.9	-	0.1	0.71	0.62	1.19	2.84	200	0.66	0.60
118	09/09/80	H5	1	3.2	25.5	10.6	7.8	0.2	0.53	0.58	0.84	1.64	120	0.62	0.42
119			5	3.1	25.6	10.5	7.9	0.2	0.54	0.58	0.73	1.85	140	0.57	0.50
120			10	2.5	30.6	11.0	7.9	0.4	0.75	0.77	0.86	1.84	210	2.28	0.85
121		H6	1	3.2	25.5	11.2	8.0	0.2	0.62	0.53	0.66	1.79	130	0.67	0.50
122			5	3.0	25.5	11.2	8.0	0.2	0.54	0.43	0.66	1.75	110	0.57	0.31
123			10	2.0	30.6	11.2	8.0	0.2	0.79	0.65	0.70	1.79	250	2.06	0.49
124	12/09/80	H1	1	2.4	27.6	-	7.6	0.0	0.58	0.68	1.17	2.58	150	0.51	0.36
125			5	2.5	27.9	-	7.7	0.0	0.59	0.70	1.56	2.73	170	0.53	0.37
126			10	2.2	28.7	-	7.7	0.0	0.60	0.69	1.33	1.99	200	0.53	0.37

#	Date	Location	Depth m	Temp. °C	Salinity °/oo	Dissolved Oxygen mg.L^{-1}	pH	Reactive Nitrate µg.at.L^{-1}	Reactive Phosphate µg.at.L^{-1}	Suspended Solids (organic) mg.L^{-1}	Suspended Solids (inorganic) mg.L^{-1}	Dissolved Organic C mg.L^{-1}	Particulate Organic C µg.L^{-1}	Chloro-phyll a µg.L^{-1}	Phaeo-pigment µg.L^{-1}
127		H2	1	-	27.7	-	7.8	0.0	0.62	0.59	1.46	2.92	130	0.44	0.39
128			5	-	27.7	-	7.8	0.1	0.55	0.66	1.52	2.99	180	0.45	0.40
129			10	-	28.7	-	7.8	0.0	0.54	0.55	1.20	2.41	150	0.53	0.40
130	14/09/80	H3	1	1.1	30.1	-	-	0.3	0.62	0.64	1.19	1.83	120	0.61	0.37
131			5	1.1	30.1	-	-	1.1	0.63	0.56	1.13	1.73	130	0.69	0.28
132			10	1.2	30.2	-	-	1.5	0.64	0.58	1.09	2.12	140	0.65	0.37
133		H4	1	0.8	30.0	-	-	0.4	0.63	0.51	1.04	4.52	160	0.67	0.38
134			5	1.0	30.1	-	-	1.7	0.65	0.49	0.74	2.23	120	0.72	0.36
135			10	1.0	30.2	-	-	0.7	0.66	0.53	1.15	1.84	180	0.60	0.32
136	16/09/80	H5	1	-0.1	30.0	-	7.7	0.3	0.63	0.56	0.93	1.47	120	0.72	0.26
137			5	-0.1	30.0	-	7.5	0.6	0.60	0.58	0.94	-	80	0.50	0.31
138			10	-0.1	30.0	-	7.6	2.1	0.60	0.71	0.88	1.72	160	0.48	0.28
139		H6	1	-0.1	30.0	-	7.6	0.1	0.60	0.65	0.57	2.47	100	0.57	0.30
140			5	-0.2	30.0	-	7.6	0.2	0.60	0.62	0.58	1.71	210	0.61	0.24
141			10	-0.2	30.0	-	7.6	1.6	0.61	0.59	0.83	1.78	180	0.68	0.23

TABLE 4.2

ENVIRONMENTAL CHEMISTRY: ICE BOTTOM AND MELT POOL SAMPLES

a) Chlorophyll a

Date	Location	Description	Chl a µg.L-1	Phaeo-pigment µg.L-1
19/06/80	Bay 13	ice bottom (#1A)	6.92	2.36
19/06/80	Bay 13	ice bottom (#1B)	5.19	2.65
19/06/80	Bay 13	ice bottom (#2A)	14.59	6.95
19/06/80	Bay 13	ice bottom (#2B)	9.61	10.57
19/06/80	Bay 13	ice bottom (#3A)	13.78	10.24
19/06/80	Bay 13	ice bottom (#3B)	11.60	11.50
21/06/80	Bay 9	ice bottom (#1)	1.48	0.07
21/06/80	Bay 9	ice bottom (#2A)	14.70	2.71
21/06/80	Bay 9	ice bottom (#2B)	12.19	1.96
21/06/80	Bay 10	ice bottom (#1A)	0.56	0.55
21/06/80	Bay 10	ice bottom (#1B)	0.86	0.54
21/06/80	Bay 10	ice bottom (#2)	0.34	0.06
21/06/80	Bay 10	ice bottom (#3)	0.46	0.10
22/06/80	Bay 11	melt pool (#1)	0.44	0.00
22/06/80	Bay 11	melt pool (#2)	0.34	0.07

b) Nutrients

Date	Location	Description	Nitrate	Phosphate
			$\mu g.L^{-1}$	$\mu g.L^{-1}$
21/06/80	Bay 9	ice bottom (#1)	6.8	1.28
21/06/80	Bay 9	ice bottom (#2)	6.8	1.38
21/06/80	Bay 10	ice bottom (#1)	6.0	0.89
21/06/80	Bay 10	ice bottom (#2)	4.6	0.62
21/06/80	Bay 10	ice bottom (#3)	5.4	1.03
22/06/80	Bay 11	melt pool (#1)	3.0	0.24
		melt pool (#2)	2.4	0.23

4.2 Environmental Chemistry: Sediment Samples

4.2.1 Total Organic Carbon

The total organic carbon analyses of sediment and beach samples are summarized in Table 4.3.

4.2.2 Interstitial Nitrate and Phosphate

The results of interstitial water nutrient analyses are presented in Table 4.4. The core samples (June only) were, of necessity, frozen, thawed for sub-sampling at ERCO laboratories, the sub-samples refrozen, then thawed and pressed in the Seakem laboratories. In view of the repeated thawing and freezing, these data should be treated with caution.

4.2.3 Total Nitrogen Analyses

The total nitrogen contents of six sediment samples from the June sampling period are presented in Table 4.5.

4.2.4 Lead-210 Analyses

Three cores were selected for dating of the sediments at Cape Hatt. They were analysed for their lead-210 content, which can provide an estimate of the age of sediments up to about 100 years. The results are presented in Table 4.6.

TABLE 4.3

TOTAL ORGANIC CARBON ANALYSES
SEDIMENT SAMPLES
JUNE SAMPLING

Date	Location	Sample I.D.		TOC % dry weight
25/05/80	Bay 13	cc 1	0- 3 cm	0.55
			9-11 cm	0.68
			14-17 cm	0.67
25/05/80		cc 2	0- 2 cm	0.33
28/05/80		cc 6	3- 7 cm	0.73
30/05/80	Bay 10	cc 8	2- 4 cm	0.57
			10-12 cm	0.59
			16-18 cm	0.49
31/05/80		GS-1		0.61
03/06/80		GS-2		0.96
06/06/80	Bay 9	cc 14		0.31
06/06/80		cc 15	0- 2 cm	0.72
			8-10 cm	0.71
			15-17 cm	0.68
18/06/80		cc 18	0- 2 cm	0.70
11/06/80	Z-Lagoon	cc 21	0- 4 cm	0.55
			10-14 cm	0.55
			19-22 cm	0.58
			19-22 cm	0.49
13/06/80	Bay 103	GS-38		0.41
11/06/80	Bay 105	GS-4		1.02
14/06/80	Bay 109	GS-48		1.28
07/06/80	Bay 13	H2		0.93
08/06/80	Bay 10	H4		0.67
10/06/80	Bay 9	H5		0.77
12/06/80	Bay 13	H2		0.83
14/06/80	Bay 10	H4		0.76
16/06/80	Bay 9	H5		0.59
20/06/80	Bay 13	Dive Hole		0.76

Note: Sample cc 1, 0-3 cm was analyzed five times with a mean of 0.55%, standard deviation 0.03%.

TABLE 4.3 (continued)

TOTAL ORGANIC CARBON ANALYSES
SEDIMENT SAMPLES
AUGUST/SEPTEMBER SAMPLING

Date	Location	Sample I.D.	Depth	TOC	
				% dry weight	
				$\bar{x}$	σ
21/08/80	Bay 10	H 3	11 m	2.15	0.06
		H 4	12 m	0.66	0.02
23/08/80	Bay 9	H 5	15 m	0.63	0.01
		H 6		0.68	0.01
02/09/80	Bay 11	H 1	7 m	0.42	0.08
		H 2	7 m	0.50	0.04
31/08/80	Bay 10	H 3	10 m	0.48	0.15
		H 4	10 m	0.82	0.07
02/09/80	Bay 9	H 5	7 m	0.30	0.01
		H 6	7 m	0.35	0.02
06/09/80	Bay 11	H 1	7 m	0.64	0.04
		H 2	7 m	0.71	0.04
07/09/80	Bay 10	H 3	7 m	0.29	0.01
		H 4	7 m	0.39	0.03
10/09/80	Bay 9	H 5	7 m	0.56	0.07
		H 6	7 m	0.37	0.02
13/09/80	Bay 11	H 1	7 m	0.89	0.11
		H 2	7 m	0.70	0.06
14/09/80	Bay 10	H 3	7 m	0.42	0.04
		H 4	7 m	0.54	0.02
15/09/80	Bay 9	H 5	7 m	0.27	0.03
		H 6	7 m	0.70	0.04

Note: Values are the mean and standard deviation of three replicate determinations

Date	Location	Transect	Depth	TOC	
				% dry weight	
				$\bar{x}$	σ
12/09/80	Bay 9	S	2-3 m	0.29	0.03
			6-7 m	0.29	0.04
		C	2-3 m	0.45	0.04
			6-7 m	0.36	0.04
		N	2-3 m	0.26	0.01
			6-7 m	0.53	0.01
13/09/80	Bay 10	S	2-3 m	0.14	0.01
			6-7 m	0.42	0.02
		C	2-3 m	0.18	0.01
			6-7 m	0.35	0.01
		N	2-3 m	0.31	0.02
			6-7 m	0.34	0.02
11/09/80	Bay 11	S	2-3 m	0.20	0.07
			6-7 m	0.43	0.07
		C	2-3 m	0.13	0.05
			6-7 m	0.51	0.03
		N	2-3 m	0.17	0.05
			6-7 m	0.43	0.09

Note: Values are the mean and standard deviation of three replicate determinations.

TABLE 4.3 (continued)

TOTAL ORGANIC CARBON ANALYSES
BEACH SAMPLES
AUGUST/SEPTEMBER SAMPLING

Date	Location	Transect	Beach Position	TOC	
				% dry weight $\bar{x}$	σ
22/08/80	Bay 9	S	L	0.05	0.01
			H	0.07	0.02
		C	L	0.07	0.02
			H	0.04	0.01
		N	L	0.04	0.01
			H	0.038	0.001
22/08/80	Bay 10	S	L	0.022	0.003
			H	0.039	0.004
		C	L	0.29	0.03
			H	0.029	0.006
		N	L	0.20	0.03
			H	0.037	0.007
22/08/80	Bay 11	S	L	0.036	0.009
			H	0.147	0.009
		C	L	0.041	0.002
			H	0.033	0.01
		N	L	0.030	0.006
			H	0.079	0.002

Note: Values are the mean and standard deviation of three replicate determinations.

TABLE 4.4

NUTRIENT ANALYSES
INTERSTITIAL WATER SAMPLES

Sampling Date	Location	I.D.		Nitrate ug.at.L^{-1}	Phosphate ug.at.L^{-1}	Comments
07/06/80	Bay 13	H2		44	740	grab
08/06/80	Bay 10	H4		13	660	
10/06/80	Bay 9	H5		17	21	
12/06/80	Bay 13	H2		7.5	9.3	grab
20/06/80	Bay 13	dive hole		3.4	3.7	diver
21/06/80	Bay 10	dive hole		2.1	2.0	
22/06/80	Bay 9	dive hole		5.2	1.4	
25/05/80	Bay 13	cc 1	7- 9 cm	480	101	frozen core sample
			12-14 cm	48	17	
			17-19 cm	4.4	5.4	
25/05/80		cc 2	4- 6 cm	13	2.0	frozen core sample
28/05/80		cc 6	0- 3 cm	6.9	36	frozen core sample
30/05/80	Bay 10	cc 8	2- 4 cm	24	17	frozen core sample
			10-12 cm	1.7	8.0	
			16-18 cm	153	7.5	
06/06/80	Bay 9	cc 15	2- 4 cm	12.7	7.2	frozen core sample
			10-12 cm	56	13.7	
			19-21 cm	2.0	14.9	
23/08/80	Bay 9	H6		9.0	6.5	grab
02/08/80	Bay 11	H1		1.8	10.2	
		H2		5.5	8.6	
31/08/80	Bay 10	H3		2.4	7.4	
		H4		3.1	12.0	
02/08/80	Bay 9	H5		2.5	9.0	
		H6		1.1	20.1	

Sampling Date	Location	I.D.	Nitrate ug.at.L^{-1}	Phosphate ug.at.L^{-1}	Comments
06/09/80	Bay 11	N, 7 m	0.9	18.2	diver
		S, 7 m	1.6	24.5	
07/09/80	Bay 10	N 7 m	0.6	12.5	
		S, 7 m	0.5	13.0	
10/09/80	Bay 9	N, 7 m	0.5	13.4	
		S, 7 m	0.3	14.3	
		S, 7 m	0.3	15.5	
13/09/80	Bay 11	N, 7 m	1.9	27.7	diver
		S, 7 m	2.5	34.8	
14/09/80	Bay 10	N, 7 m	6.0	9.1	
		S, 7 m	8.8	20.0	
15/09/80	Bay 9	N, 7 m	4.0	11.6	
		S, 7 m	0.6	52.3	

TABLE 4.5

TOTAL NITROGEN ANALYSES
SEDIMENT SAMPLES

Sampling Date	Location	I.D.	% Total Nitrogen Mean	(Duplicates)
07/06/80	Bay 13	H2	0.21%	(0.21, 0.21)
08/06/80	Bay 10	H4	0.12%	(0.12, 0.12)
10/06/80	Bay 9	H5	0.11%	(0.11, 0.11)
12/06/80	Bay 13	H2	0.17%	(0.17, 0.17)
14/06/80	Bay 10	H4	0.10%	(0.10, 0.10)
16/06/80	Bay 9	H5	0.17%	(0.175, 0.17)

Note: Sediment samples for total nitrogen analyses were collected in the June sampling period only.

TABLE 4.6

LEAD-210 ANALYSES
CORE SAMPLES

Sampling Date	Bay	Core	Depth in Core	Lead-210 pCi/g
26/05/80	13	cc 3	0- 4 cm	1.4 ± 0.2
			7-11 cm	0.0 ± 0.1
			14-19 cm	0.3 ± 0.1
			21-25 cm	0.8 ± 0.2
			28-32 cm	0.2 ± 0.1
			35-39 cm	0.2 ± 0.1
			42-44 cm	0.3 ± 0.1
04/06/80	9	cc 13	0- 4 cm	0.0 ± 0.1
			7-10 cm	0.4 ± 0.1
			10-12 cm	1.0 ± 0.3
			14-16 cm	0.0 ± 0.1
			21-24 cm	0.0 ± 0.1
			28-30 cm	1.1 ± 0.3
			36-38 cm	0.0 ± 0.1
11/06/80	Z-Lagoon	cc 21	0- 2 cm	0.4 ± 0.1
			4- 7 cm	0.6 ± 0.1
			7- 9 cm	0.0 ± 0.1
			11-13 cm	0.4 ± 0.1
			14-16 cm	0.3 ± 0.1
			20-22 cm	0.6 ± 0.1
			25-27 cm	0.5 ± 0.1
			30-32 cm	0.6 ± 0.1
			36-38 cm	0.4 ± 0.1

Note: Analyses performed by Controls for Environmental Pollution, Inc., Santa Fe, New Mexico.

4.3 Hydrocarbon Baseline Study

4.3.1 Water Samples IR Analyses

The results of the infra-red analyses of seawater samples are given in Table 4.7.

4.3.2 Sediment Samples IR Analyses

The results of the IR analyses of sediment samples are given in Table 4.8. Both total extractable organics and non-polar hydrocarbons are reported (see Methods section for explanation).

4.3.3 Beach Samples IR Analyses

The results of the IR analyses of beach samples are given in Table 4.9.

TABLE 4.7

WATER SAMPLES: IR ANALYSES
HYDROCARBON BASELINE STUDY

Date	Location	Depth	Total Hydrocarbons µg.L-1	Comments
14/06/80	Bay 9	1 m	D.L.	June sampling
		5 m	D.L.	
		10 m	D.L.	
14/06/80	Bay 10	1 m	D.L.	
		5 m	D.L.	
		10 m	126	
14/06/80	Bay 13	1 m	D.L.	
		5 m	D.L.	
		10 m	D.L.	
26/08/80	Bay 9	1 m	D.L.	August sampling
		5 m	D.L.	
		10 m	D.L.	
26/08/80	Bay 10	1 m	26	
		5 m	D.L.	
		10 m	D.L.	
26/08/80	Bay 11	1 m	D.L.	
		5 m	D.L.	
20/09/80	Bay 9	1 m	D.L.	Sept. sampling
		5 m	D.L.	
19/09/80	Bay 10	1 m	D.L.	
		5 m	D.L.	
		10 m	80	
18/09/80	Bay 11	1 m	D.L.	
		5 m	72	
		10 m	1138	non-polar material

Date	Location	Depth	Total Hydrocarbons $\mu g.L^{-1}$	Comments
18/08/80	Bay 102	1 m 4 m	D.L. 62	prespill
18/08/80	Bay 103	1 m 7 m	D.L. D.L.	prespill
21/08/80	Bay 103	1 m 7 m	D.L. D.L.	prespill
20/09/80	Bay 103	1 m 5 m	150 D.L.	
20/09/80	Z-Lagoon (middle)	1 m 10 m	D.L. D.L.	

Note: 1. Units are in micrograms of Lagomedio crude oil equivalents per litre of sea water.

2. D.L. means the response is below the detection limit of 13 $\mu g.L^{-1}$.

TABLE 4.8

SEDIMENT SAMPLES: IR ANALYSES
HYDROCARBON BASELINE STUDY

Sampling Date	Bay	Transect	Sample I.D.		Water Content	Total Extractable Organics	Total Hydro-carbons
					%	$\mu g.g^{-1}$	$\mu g.g^{-1}$
06/06/80	9	S	cc 14		26.3	3.52	0.37
06/06/80		S	cc 15	0- 3 cm	24.3	4.48	0.65
				9-11 cm	30.6	2.44	0.14
				17-19 cm	27.7	2.59	0.41
18/06/80		N	cc 18	1- 3 cm	20.9	5.38	0.18
30/05/80	10	C	cc 8	1- 3 cm	28.7	4.79	1.66
				8-10 cm	29.9	1.87	0.16
				14-16 cm	19.8	1.42	0.14
31/05/80		C	GS 1		45.4	11.11	3.11
03/06/80		S	GS 2		72.5	11.43	1.35
25/05/80	13	C	cc 1	3- 7 cm	27.2	3.04	0.50
				11-13 cm	29.0	3.81	1.58
				16-18 cm	27.6	1.69	0.68
25/05/80		C	cc 2	1- 3 cm	13.7	1.66	0.14
28/05/80		S	cc 6	3- 7 cm	39.4	4.62	1.90
11/06/80	Z-lagoon	middle	cc 21	0- 4 cm	31.1	3.82	1.58
				10-14 cm	41.3	1.69	0.37
				19-22 cm	41.1	1.45	0.50
13/06/80	103		GS 38		44.1	5.58	1.72
11/06/80	105		GS 4		66.8	12.52	3.82
14/06/80	109		GS 48		52.5	6.92	1.18
12/09/80	9	S	9, S,	2-3 m	26.2	35.9	2.0
			9, S,	6-7 m	23.3	7.1	0.6
		C	9, C,	2-3 m	23.2	23.0	D.L.
			9, C,	6-7 m	25.8	22.4	0.9
		N	9, N,	2-3 m	21.5	9.8	D.L.
			9, N,	6-7 m	30.0	22.7	1.5

Sampling Date	Bay	Transect	Sample I.D.		Water Content	Total Extractable Organics	Total Hydro-carbons
					%	$\mu g.g^{-1}$	$\mu g.g^{-1}$
13/09/80	10	S	10, S,	2-3 m	21.1	15.0	0.4
			10, S,	6-7 m	27.3	12.9	2.6
		C	10, C,	2-3 m	17.7	7.2	0.3
			10, C,	6-7 m	24.9	9.4	1.2
		N	10, N,	2-3 m	21.6	24.5	D.L.
			10, N,	6-7 m	23.8	7.3	0.6
11/09/80	11	S	11, S,	2-3 m	32.1	18.6	0.3
			11, S,	6-7 m	24.1	10.9	1.5
		C	11, C,	6-7 m	32.5	14.4	1.4
		N	11, N,	2-3 m	22.4	26.7	D.L.
			11, N,	6-7 m	14.4	11.8	1.4

Notes:

1. Units are in micrograms Lagomedio crude oil equivalents per gram of dry sediment.
2. D.L. means the response is below the detection limit of approximately 0.3 $\mu g.g^{-1}$.
3. For September samples, Freon extracts had a strong sulphide smell. June samples did not.

TABLE 4.9

BEACH SAMPLES: IR ANALYSES
HYDROCARBON BASELINE STUDY

Date	Location	Sample I.D.	Water Content	Total Extractable Organics	Total Hydro-carbons
			%	$ug.g^{-1}$	$ug.g^{-1}$
22/08/80	Bay 9	9-S-L	7.4	0.69	0.37
		9-S-H	2.3	0.64	DL
		9-C-L	10.1	0.38	DL
		9-C-H	2.2	1.18	0.48
		9-N-L	7.0	1.00	1.00
		9-N-H	4.1	0.73	0.39
22/08/80	Bay 10	10-S-L	8.4	2.99	2.30
		10-S-H	13.4	0.33	DL
		10-C-L	11.9	1.26	0.60
		10-C-H	7.8	0.32	0.32
		10-N-L	12.0	0.60	0.44
		10-N-H	9.1	0.41	DL
22/08/80	Bay 11	11-S-L	13.7	0.69	0.29
		11-S-H	12.9	1.37	0.42
		11-C-L	5.5	0.67	DL
		11-C-H	14.1	0.89	0.89
		11-N-L	10.8	1.06	-
		11-N-H	14.0	1.22	DL
20/08/80	crude oil point	T-1 prespill		0.43	0.27
		T-2 prespill		2.47	1.77
17/08/80	Bay 102	prespill		DL	DL
17/08/80	Bay 103	prespill		1.29	0.48

Notes:

1. Sample ID's give bay, transect and indicate high (H) or low (L) tide mark at which sample was collected.
2. Concentrations are in micrograms of Lagomedio crude oil equivalents per gram of dried sediment.
3. D.L. means response is below detection limit of approximately 0.25 µg.g.

4.4 Shoreline Experiment

4.4.1 Total Hydrocarbons

The total hydrocarbon concentrations in samples taken from the oiled beach plots are presented in Table 4.10.

TABLE 4.10:

HYDROCARBON ANALYSES OF BEACH SAMPLES FROM OILED BEACH PLOTS		HIGH WAVE ACTION				LOW WAVE ACTION				BACKSHORE PLOT (Z LAGOON)				BACKSHORE PLOT (ECLIPSE SOUND)			
		AGED		EMULSIFIED		AGED		EMULSIFIED		AGED		EMULSIFIED		AGED		EMULSIFIED	
		% OIL IN SEDIMENT				% OIL IN SEDIMENT				% OIL IN SEDIMENT				% OIL IN SEDIMENT			
		Surface	Sub-Surface	Surface	Sub-Surface	Surface	Sub-Surface	Surface	Sub-Surface	Surface	Sub-Surface	Surface	Sub-Surface	Surface	Sub-Surface	Surface	Sub-Surface
IMMEDIATELY FOLLOWING TEST	UPPER	2.04	1.04	1.59	2.80	0.67	0.88	0.19	0.05	2.24	1.65	0.94	0.91				
	MIDDLE	1.16	1.49	0.19	0.13	0.87	1.30	0.45	0.22	5.37	1.88	1.27	0.95	4.62	2.94	5.10	0.17
	LOWER	7.74	1.16	2.32	0.22	3.60	2.46	0.37	no sample	4.43	3.43	1.73	2.75				
2 DAYS AFTER TEST	UPPER	0.001	0.056	0.001	0.002	0.46	0.80	0.021	0.011	5.17	1.68	2.82	1.08				
	MIDDLE	0.019	0.88	0.002	0.001	0.47	0.09	0.032	0.006	3.79	1.70	1.20	2.31	4.96	1.52	10.2	0.46
	LOWER	0.001	0.055	0.001	0.001	0.61	0.69	0.014	0.005	8.53	5.62	1.90	4.74				
4 DAYS AFTER TEST	UPPER	0.007	0.18	0.010	0.11	0.45	0.77	0.008	0.002								
	MIDDLE	0.005	1.62	0.001	0.003	0.25	0.94	0.034	0.001	3.38	3.50	1.27	1.33	5.42	3.27	2.89	6.15
	LOWER	0.016	0.22	0.001	0.001	0.47	0.47	0.006	0.001								
8 DAYS AFTER TEST	UPPER	0.037	2.74	0.005	no sample	0.57	1.26	0.037	0.002								
	MIDDLE	0.32	0.010	0.0003	0.0004	0.77	1.83	0.001	0.016	6.58	1.71	6.00	5.81	4.04	4.77	5.80	0.050
	LOWER	0.001	0.26	0.0009	0.0008	0.60	1.08	0.001	0.005								

TABLE 4.11: MOISTURE CONTENT OF BEACH SAMPLES, BIOS SHORELINE EXPERIMENT

		MOISTURE CONTENT (% by weight)							
		Day 0		Day 1		Day 4		Day 8	
Plot	Tran	A	B	A	B	A	B	A	B
H1	U	1.8	2.2	1.1	1.5	1.8	1.5	1.4	4.8
	M	1.9	2.3	1.5	1.7	3.2	2.2	2.9	4.2
	L	3.9	1.9	1.6	2.0	3.9	1.5	1.9	2.5
H2	U	3.8	8.1	3.2	1.5	3.9	1.6	3.6	-
	M	0.8	1.0	2.9	1.4	5.8	3.6	4.0	4.1
	L	5.7	1.9	2.9	1.6	7.1	1.8	6.1	3.0
L-1	U	0.1	0.6	1.0	1.0	1.0	1.1	0.8	3.1
	M	0.6	2.2	1.5	7.6	0.8	5.6	1.3	3.2
	L	2.6	4.6	5.9	2.8	3.2	9.2	1.9	4.4
L-2	U	3.5	10.7	5.8	8.2	7.2*	9.7*	4.1	10.5
	M	5.7	12.2	4.0	14.1	10.9*	9.0*	19.0	10.4
	L	9.1	-	16.4	10.8	12.7*	10.3	19.9	9.0
LT-1	U	1.6	3.1	3.2	2.2	3.7	5.4	6.9	3.2
	M	2.0	-	2.0	2.1	-	-	-	-
	L	1.5	3.2	3.8	3.7	-	-	-	-
LT-2	U	1.1	1.9	2.6	1.2	2.3	2.4	8.9	8.5
	M	2.7	3.5	1.9	3.7	-	-	-	-
	L	3.0	6.3	2.3	7.5	-	-	-	-
HT-1		3.0	2.9	3.6	4.1	3.3*	3.2*	7.7	6.5
HT-2		14.0	5.1	15.9	10.3	5.9	13.8	10.4	8.0

Notes:

1. Moisture content = % weight loss upon drying sediment at 40°C for 16 hours.
2. A = surface sample (0-2 cm). B = subsurface sample (4-8 cm).
3. Plot Identification: H = high energy intertidal plot
   L = low energy intertidal plot
   T - backshore test plot
4. Tran = transect: U = upper transect
   M = mid transect
   L = lower transect
5. * samples collected by Woodward-Clyde Consultants (remainder by Seakem)

5. DISCUSSION

5.1 Environmental Chemistry: Water Analyses

5.1.1 Temperature and Salinity

The water column in June was monotonic at approximately -1.7°C and 32.7 °/oo salinity, except for a thin lens of fresh water that gradually developed under the ice cover as the ice melted.

Upon returning 11 August, 1980, the surface waters (1 m) had warmed to approximately 4.5 °C, and the deep water (10 m) to 1.8 °C. Fresh water run-off had brought salinities down to about 15 °/oo at 1 m. During the first week in September the fresh water run-off quite abruptly stopped, and the water column rapidly cooled as air temperatures dropped below freezing and storms mixed the water column. By 16 September, the last sampling date, water temperatures had fallen below zero at all three sampling depths, and salinity was fairly uniform with depth at 30 °/oo. Graphs of the temperature and salinity of the water column over the summer period are shown in Figures 5.1 and 5.2.

5.1.2 Dissolved Oxygen

The dissolved oxygen concentrations in the water column were uniformly high. Considering only the more precise Winkler titration analyses, they averaged 11.83 ± 0.24 $mg.L^{-1}$ (24 values). Considering as well the YSI oxygen probe determinations, they averaged 11.71 ± 0.68 $mg.L^{-1}$ (60 values). (Uncertainties are always one standard deviation.)

The saturation levels of oxygen in sea water depend on the salinity and temperature of the water. For the range of conditions at Cape Hatt, theoretical saturation levels are:

for 4 °C, 16 °/oo	:	11.84 $mg.L^{-1}$
for 1.8°C, 30 °/oo	:	11.36 $mg.L^{-1}$

(note: 1 $mg.L^{-1}$ = 1.43 $mL.L^{-1}$)

The percent oxygen saturation at the Cape Hatt stations varied from 85% to 120%, with most values in the 100-110% range. These saturation-plus oxygen conditions have been widely reported in Arctic surface waters, including Frobisher Bay (Arctic Biological Station data), Jones Sound (Apollonio, 1976), the Amundsen Gulf (MacDonald et al., 1978), the Beaufort Sea (Wong et al., 1980), and the North Alaskan Shelf (Hufford, 1974).

5.1.3 pH

Measured values varied from 7.4 to 8.0. The mean value was 7.75 ± 0.15 (119 values) with no discernible trends with time or depth.

The pH of sea water in the open ocean rarely falls outside the range of 7.8 - 8.2. In surface and coastal waters, some diurnal variation in pH is expected due to CO_2 production and consumption by biological processes. Variations of 0.4 (winter) to 0.8 (summer) units over a 24 hour period are possible, with the maximum occurring during the day (Riley and Chester, 1971). Seasonal variations also occur, for the same reasons. Finally, a decrease in pH due to fresh water run-off would be expected at the surface.

None of these effects could be detected in the data from Cape Hatt. The diurnal variation, if present, was missed by sampling at the same time each day. The seasonal and freshwater effects were presumably too small to show through the 'noise' of the instrument scatter, and must have been less than about 0.1 pH units.

5.1.4 Reactive Nitrate and Phosphate

The analytical methods for nitrate and phosphate are probably the most reliable of the environmental chemistry methods. The precision of the autoanalyzer method is excellent, and the use of Sagami nutrient standards, which are distributed worldwide, ensures the method's accuracy. (The nitrate determination, it should be noted, actually gives a measure of nitrate plus nitrite. However, nitrite in well-oxygenated surface waters is usually undetectable.)

In June, the nutrient concentrations were relatively high, with nitrate nitrogen averaging 7.9 ± 0.4 $\mu g.at.L^{-1}$ (51 values, all depths), and phosphate phosphorus averaging 1.31 ± 0.08 $\mu g.at.L^{-1}$ (51 values, all depths). For comparison,

Atlantic deep water has 15-20 $\mu g.at.L^{-1}$ nitrate, 0.5-1.5 $\mu g.at.L^{-1}$ phosphate (Sverdrup et al., 1942).

The surface (1 m) concentrations of both nutrients began to decrease on 16 June, and by 22 June were each about 15% lower than the 10 m concentrations (See Figures 5.3 and 5.4 for graphs).

Upon returning to Cape Hatt on 11 August, nitrate at all three sampling depths had been virtually exhausted. Phosphate had been 75% depleted at the surface (1 m), and about 50% depleted at 10 m. Nitrate stayed at near zero levels at all three depths until 12 September, when some recovery at 5 and 10 m was evident. Phosphate maintained its depth stratification, with low values at the surface and higher values at 10 m, until about 9 September, when surface concentrations began to recover. The average values for the August/September period were:

nitrate nitrogen		0.28 ± 0.41 $\mu g.at.L^{-1}$ (85 values, all depths)
phosphate phosphorus	1 m	0.44 ± 0.12 $\mu g.at.L^{-1}$ (30 values)
	5 m	0.55 ± 0.06 $\mu g.at.L^{-1}$ (27 values)
	10 m	0.69 ± 0.09 $\mu g.at.L^{-1}$ (29 values)

Apollonio, 1976, in a three-year study of Jones Sound (350 km north of Cape Hatt near Devon Island) obtained a remarkably similar set of data : high nitrate (6-11 $\mu g.at.L^{-1}$) until late June, with rapid depletion to near zero in July through August; phosphate in June 1.2 - 1.4 $\mu g.at.L^{-1}$, declining in July to 0.2-0.6 $\mu g.at.L^{-1}$, at the surface, 0.40 to 0.75 $\mu g.at.L^{-1}$ at 5-10 m. The similarity of these data (also chlorophyll data) to those at Cape Hatt is striking, and implies that the environmental observations from the experimental site are more broadly applicable to this region of the Arctic.

The depletion of nitrate from the water column was undoubtedly due to the July bloom of phytoplankton which would have occurred just before and during ice break-up. The expected utilization ratio of nitrate to phosphate is 16:1 in the open ocean (Redfield et al., 1963). The apparent nitrate utilization at Cape Hatt was circa 8 $\mu g.at.L^{-1}$ versus phosphate 0.75 $\mu g.at.L^{-1}$, or a ratio of 11:1. Nitrate was in short supply, and presumably was the limiting nutrient in the ecosystem.

5.1.5 Suspended Solids

The suspended solids data is obtained by filtration and weighing of the filter paper, as described in the Methods section. Distinguishing between organic and inorganic suspended solids relies upon driving the organic matter from the filter by heating to 500°C. Organic material begins to ignite at 200°C and is completely ignited at 550°C. Inorganic compounds will also decompose with heating. Specifically, $CaCO_3$ will calcine to CaO, but this process does not occur until 700 - 800°C (Dean, 1974). There is obviously some room for uncertainty in the determination since the crossover from organic to inorganic decomposition is unlikely to be clearcut. Some further error is inherent in the method due to tightly bound water being driven off with the organic compounds, leading to systematically high organic suspended solids determinations. These intrinsic limitations of the method should be borne in mind when considering the results.

The June filtrations were done with a screw-closure type apparatus that was awkward to use. The tendency for this apparatus to leak decreased the precision of the June analyses, as well as perhaps introducing a positive systematic error due to salt residue on the fringes of the filter paper. The problem was overcome in the August/September sampling periods, and this later data must be considered of higher quality.

No trends were apparent in the August/September data set, either with depth or time (see graphs in Figures 5.5 and 5.6). The averages were as follows:

organic suspended solids	0.58 ± 0.09 mg.L^{-1} (90 values)
inorganic suspended solids	0.93 ± 0.32 mg.L^{-1} (86 values)
total suspended solids	1.5 ± 0.4 mg.L^{-1} (86 values)

By way of comparison, deep Atlantic water suspended solids are in the range 0-0.1 mg.L^{-1} (Riley and Chester, 1971, p. 287) but surface waters are much higher and more variable. The author was unable to locate any other suspended solids data from the eastern Arctic. The western Arctic is quite different because of the massive influx of Mackenzie River silt.

The ratio of organic to total suspended solids is significant. For a healthy plankton population the percentage of organic matter is usually 50-60% of the total

suspended solids. Less than about 20% organic material indicates that resuspended sediment, detritus and/or silt are dominant in the water column. At Cape Hatt, for the August/September period, the suspended solids averaged 39% organic material.

5.1.6 Dissolved Organic Carbon

Dissolved organic carbon (DOC) was determined by wet oxidation with infrared detection of the CO_2 generated. A parallel set of analyses was performed by the Arctic Biological Station, again with wet oxidation, but with detection as methane by gas chromatograph with an FID detector. The two sets of data agreed well. Both methods may give systemically low (approximately 15%) results due to incomplete oxidation of refractory organic material in the wet oxidation step (Gershey, 1979).

The DOC levels in June were relatively constant over time and depth at 1.27 $\pm$ 0.29 $mgC.L^{-1}$ (47 values, all depths). The Arctic Biological Station values averaged 1.51 $\pm$ 0.23 (36 values).

In August/September there was much more scatter in the data, with variations up to a factor of two occurring between stations in the same bay at the same time. Trends with depth and time are obscured by this scatter, which is apparently a real phenomenon due to the near shore and near bottom sampling locations. The Arctic Biological Station showed a very similar degree of scatter. The Seakem average for the August/September period was 2.35 $\pm$ 0.74 $mgC.L^{-1}$ (87 values); the Arctic Biological Station average was 2.15 $\pm$ 0.79 (90 values).

The data indicates an increase of circa 1 $mgC.L^{-1}$ over the June DOC concentrations. This increase can be attributed in part to the July plankton bloom. The utilization of 8 $\mu g.at.L^{-1}$ nitrate in the water column by the bloom should be associated with the fixing of circa 55 $\mu g.at.L^{-1}$ carbon, or approximately 0.7 $mgC.L^{-1}$. During the bloom the DOC is produced by phytoplankton as an extracellular exudate. After the bloom, decomposition of dead plankton contributes to the DOC levels in the water column. Additional DOC is contributed by fresh water run-off.

By way of comparison, open ocean DOC concentrations generally vary between the relatively narrow limits of 0.3 to 1.2 $mgC.L^{-1}$ (Rily and Chester, 1971, p. 200). In nearshore areas considerably higher values are common. For instance, Parsons (1979) reports monthly averages of 3 $mgC.L^{-1}$ for the summer months in the Strait of Georgia.

5.1.7 Particulate Organic Carbon

The analyses for particulate organic carbon (POC) were those of the Arctic Biological Station. The Seakem analyses, which used a titration method, were discarded as being too prone to inteference. The Arctic Biological Station method uses wet oxidation and determines the carbon as methane on a gas chromatograph with FID detector. There are many available methods for determining particulate organic carbon: this one is fairly unique. The use of the very sensitive FID detector allows a very small volume of water to be filtered. In fact, the precision of the method is probably limited by the small volume filtered (100 mL versus at least one litre for most methods).

The method may have some systematic errors. Gershey et al. (1979) estimate that wet oxidation gives values that are about 15% low due to incomplete oxidation of refractory organic matter. Another possible problem is absorption of dissolved organic carbon on the filters.

In June POC values were very low. For 5 and 10 m depths, the average was 28 ± 21 $\mu g.C.L^{-1}$ (24 values). At 1 m depth higher values were obtained, particularly towards the end of the month, giving an average 57.5 ± 41 $\mu gC.L^{-1}$. The higher values were presumably due to the increasing productivity immediately under the ice towards the end of June.

In August and September the POC jumped to an average of 162 ± 41 $\mu gC.L^{-1}$ (88 values). The 10 m samples tended to be slightly higher than the shallower samples, possibly due to resuspended sediments in the more turbulent open water conditions of late summer.

The August/September POC values averaged 28% of the organic suspended solids. 'Organic suspended solids' is a measure of the total weight of organic matter in the water, whereas POC is a measure of the weight of carbon alone. If all of the organic material in the water column was carbohydrate, the proportion of POC to total organic material would be expected to be 40%. The 28% value indicates the presence of sulphur, chlorine, organo-metals, and other components of the organic matter that lower the percentage of carbon by weight.

The ratio of POC to chlorophyll a is instructive. Ratios of less than about 200 occur in a healthy phytoplankton population. Ratios of over about 500 indicate most of the suspended material is dead detritus, resuspended sediment, or particulate material from a terrogenous source (Holm-Hansen, 1969; Tanoue and Handa, 1979). The ratio in June was 760, indicating primarily non-living material. In August and September the ratio had improved to 340 suggesting a reasonably healthy phytoplankton population was prominent in the water column.

5.1.8 Chlorophyll a and Phaeopigments

The methods for determining chlorophyll, although very widely used, are not without their pitfalls. The fluorometric method used here is a recent technique, largely displacing the absorption method that was prevalent 5-10 years ago. The fluorometric method is favoured because it is quicker and more sensitive. The spectrophotometric technique can, however, distinguish between the various chlorophyll pigments, providing information on their relative concentrations. Both methods suffer from calibration problems. Chlorophyll as a pure compound is not stable, so reliable standards are not available. The result is that the precision of the methods is good, but the accuracy is circa ± 15%.

The June values were extremely low, averaging 0.05 ± 0.04 $\mu g.L^{-1}$ (51 values, all depths). There is no variation with depth, but some indication that concentrations were just beginning to increase on the last day of sampling. The large bloom that undoubtedly occurred in July during and after ice break-up was missed. From comparison with other data, the peak value probably was in the range of 8-15 $\mu g.L^{-1}$ (Apollonio, 1976).

In August and September, concentrations averaged 0.48 ± 0.31 $\mu g.L^{-1}$ (90 values) and were fairly constant with time and depth, other than a peak at 10 m on 9

September for which there is no readily apparent explanation. These results are very similar to the data reported by Apollonio, 1976, from Allen Bay who reported average concentrations for August of 0.7 $\mu g.L^{-1}$ (69 values). (The chlorophyll concentrations are graphed in Figure 5.9.).

Table 4.1 also reports phaeopigment concentrations which are useful in assessing the condition of the phytoplankton stock. In June the phaeopigment averaged 46% of the total pigment (chlorophyll plus phaeopigment) indicating a senescent phytoplankton population. On the last sampling day in June, however, when the spring bloom was apparently about to start, the percentage phaeopigment dropped abruptly to 15%, indicating a rapidly growing phytoplankton population. In August the average was 47% $\pm$ 10% (excepting a drop to 23% for the 9 September chlorophyll peak) again indicating a fairly senescent phytoplankton population.

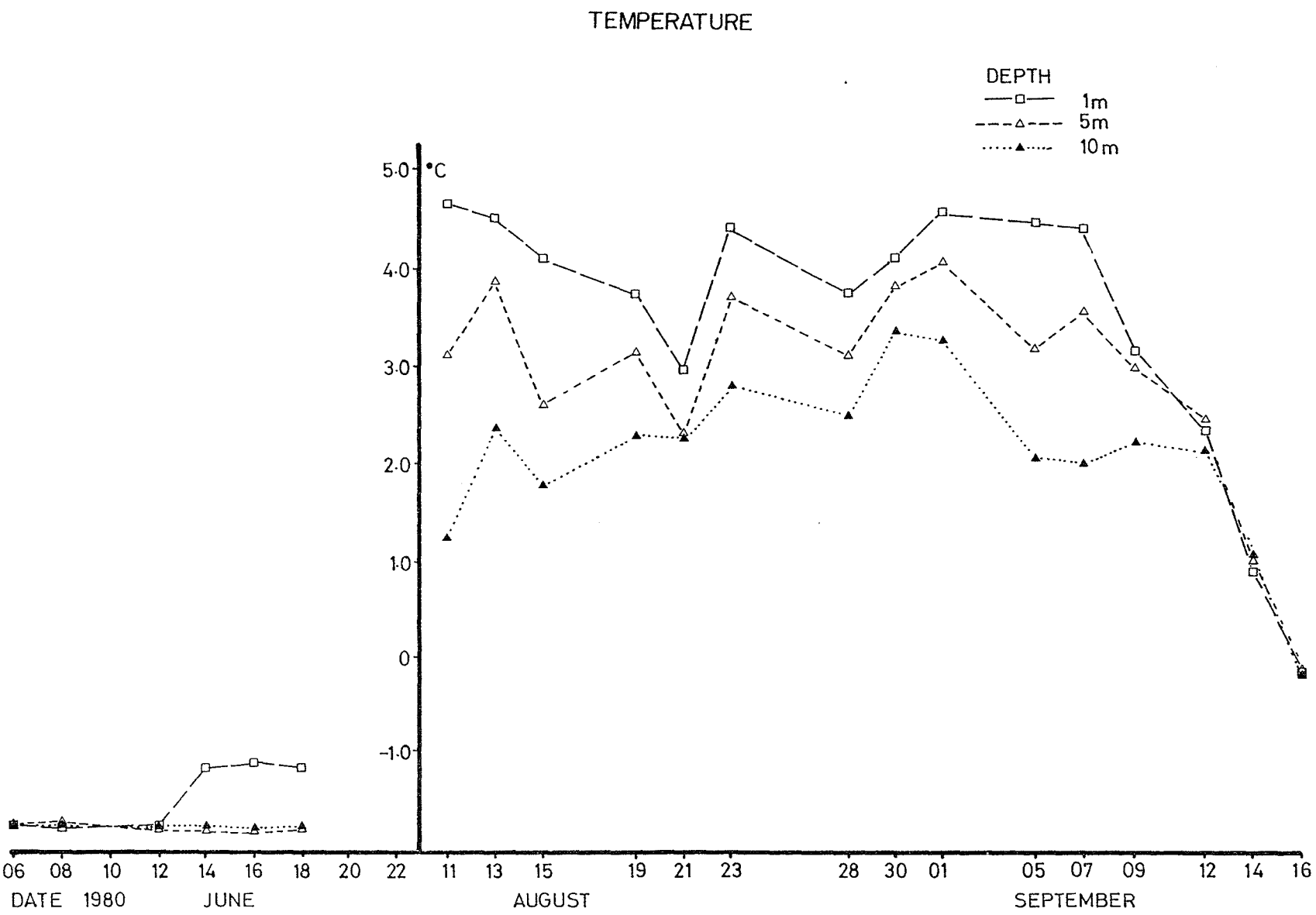


Figure 5.1: Seawater Temperature in Ragged Channel, Summer, 1980

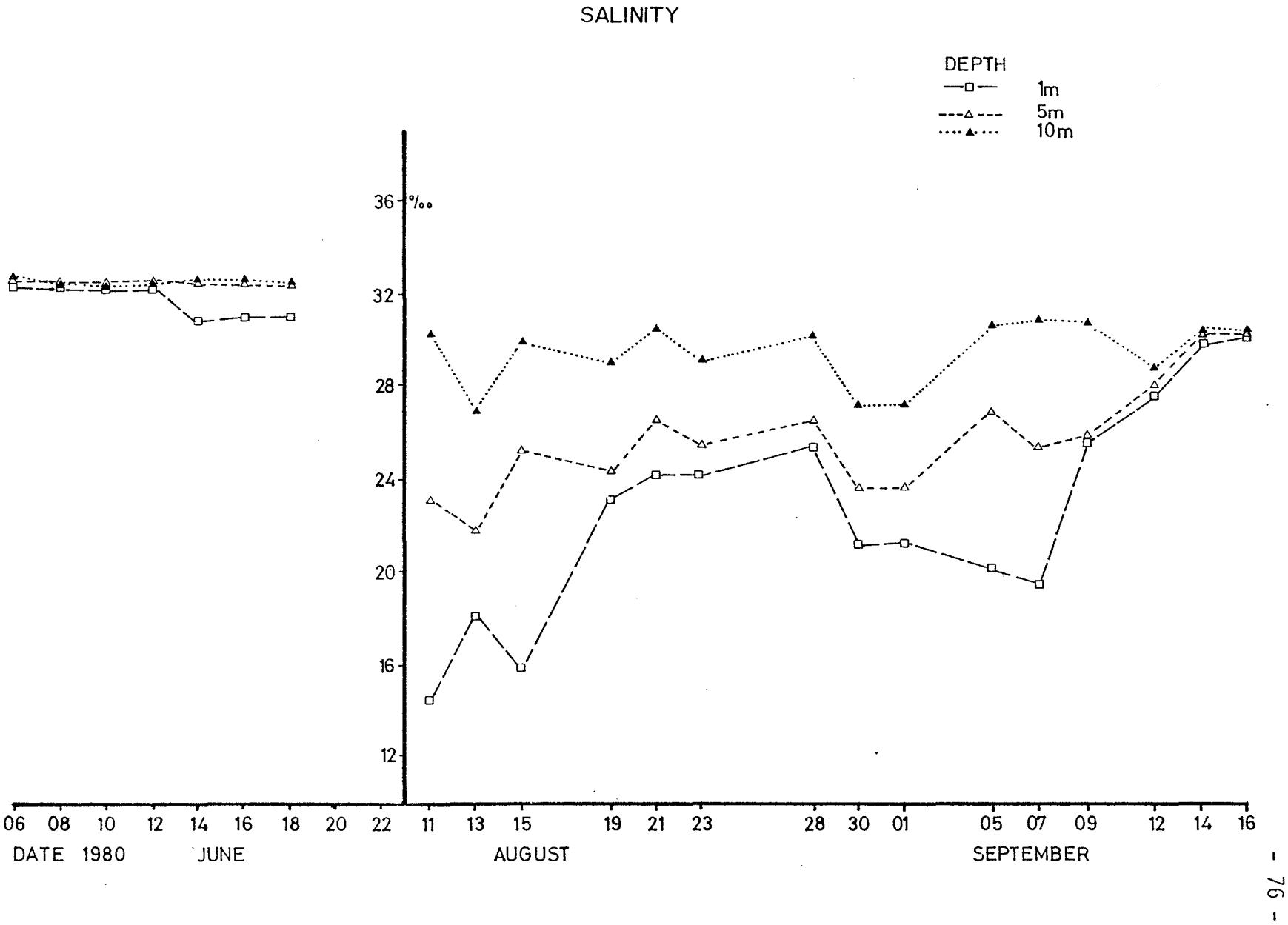


Figure 5.2: Seawater Salinity in Ragged Channel, Summer, 1980.

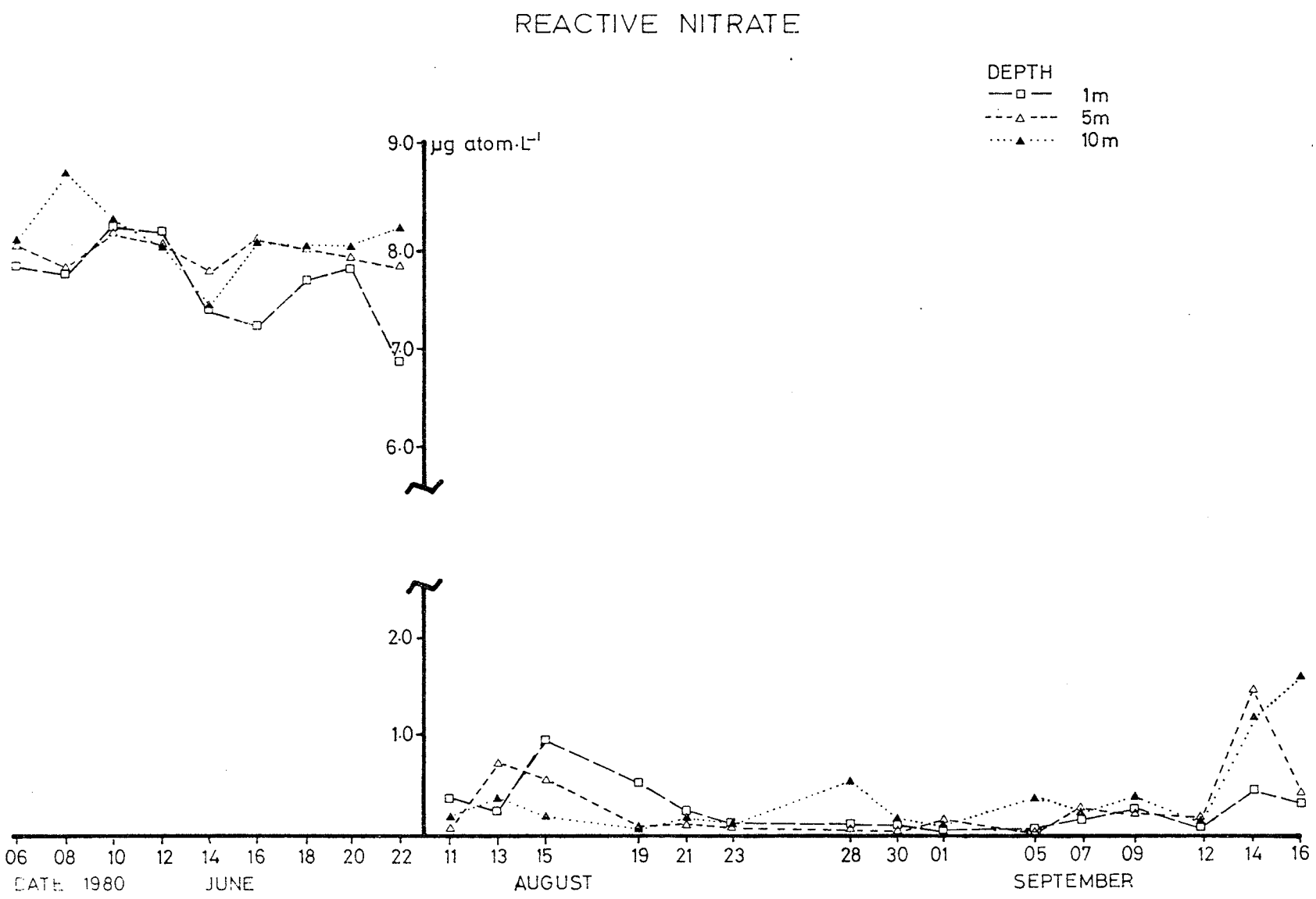


Figure 5.3: Seawater Nitrate in Ragged Channel, Summer, 1980

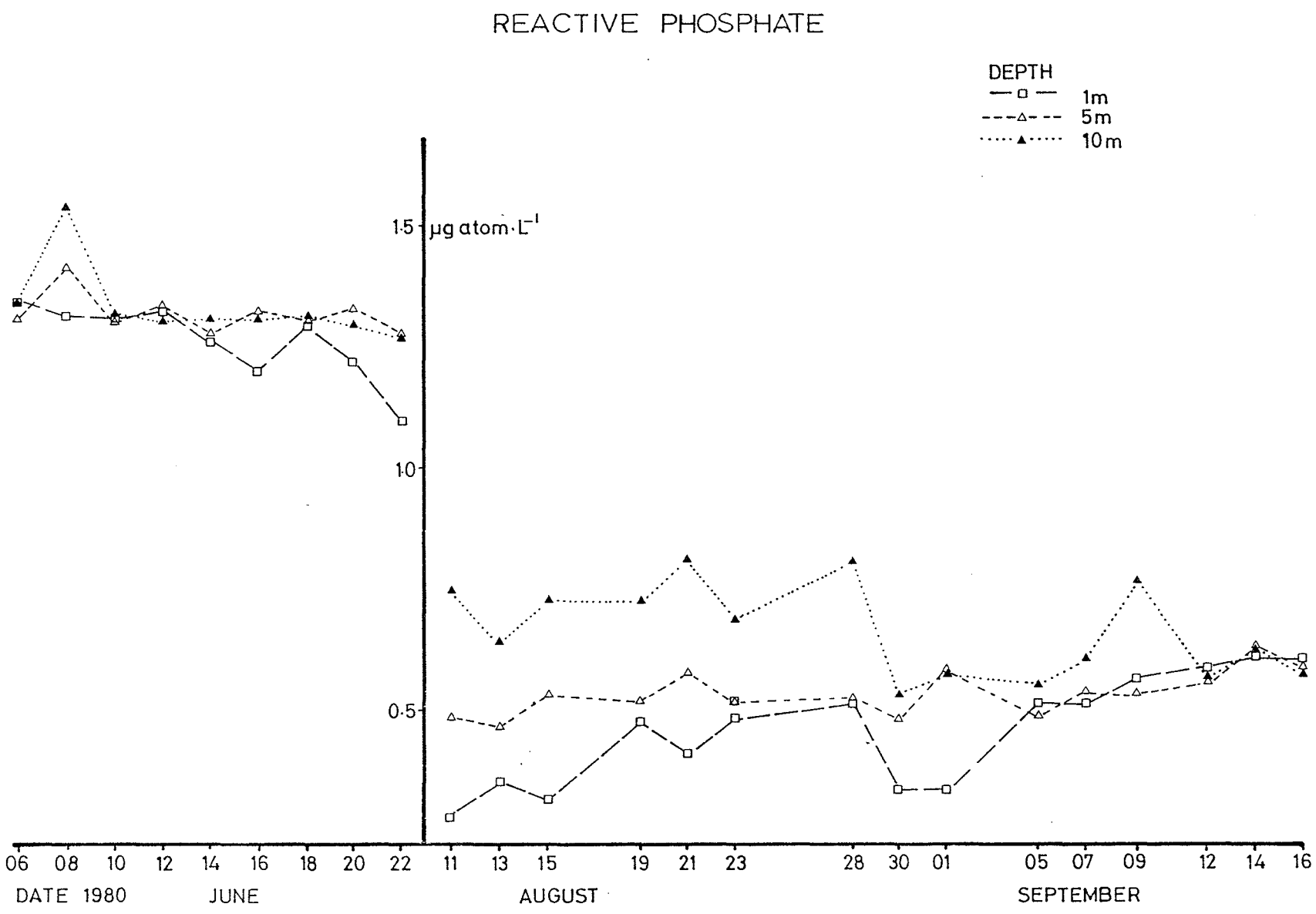


Figure 5.4: Seawater Phosphate in Ragged Channel, Summer, 1980.

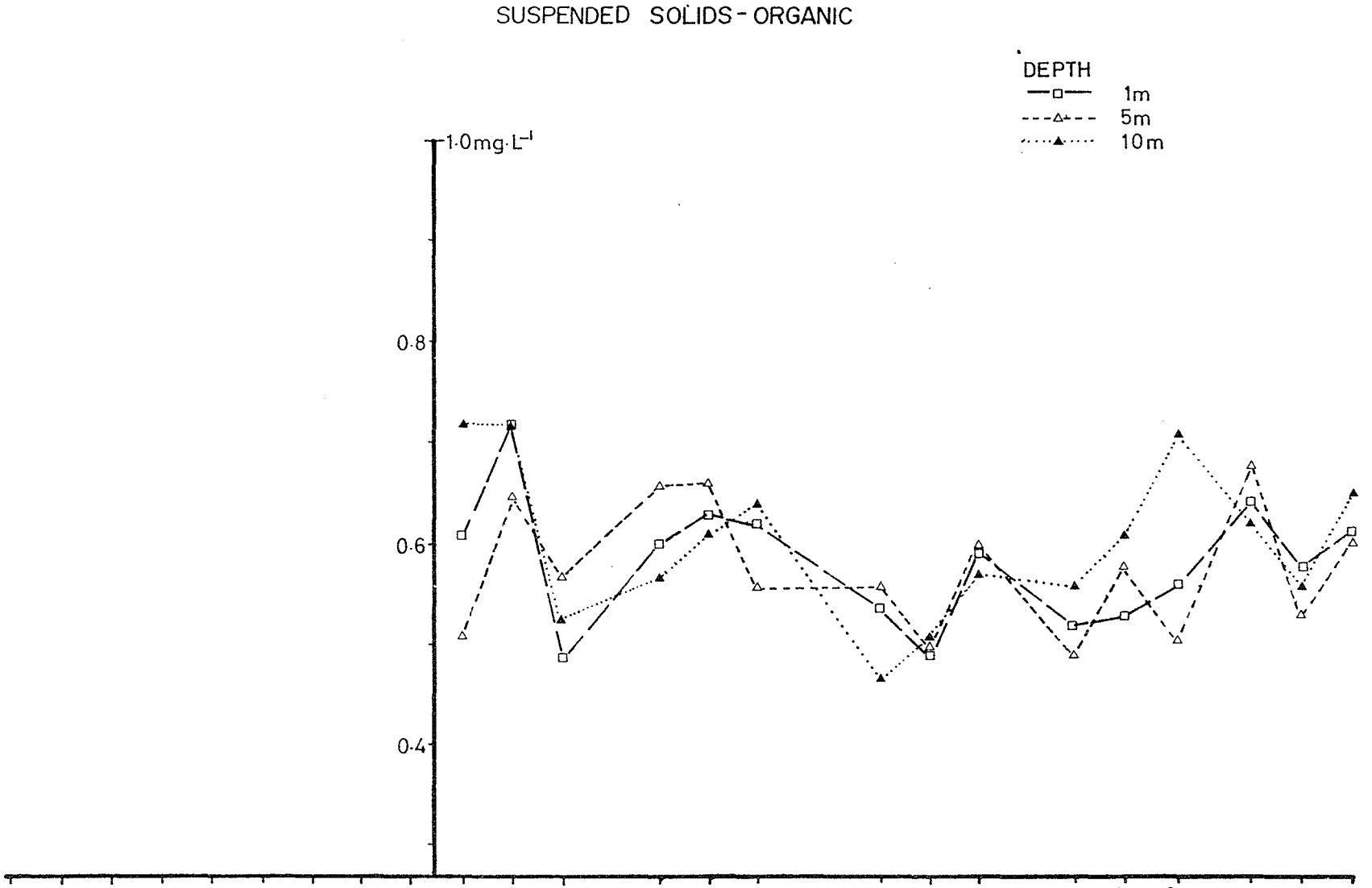


Figure 5.5: Organic Suspended Solids in Ragged Channel, Summer, 1980.

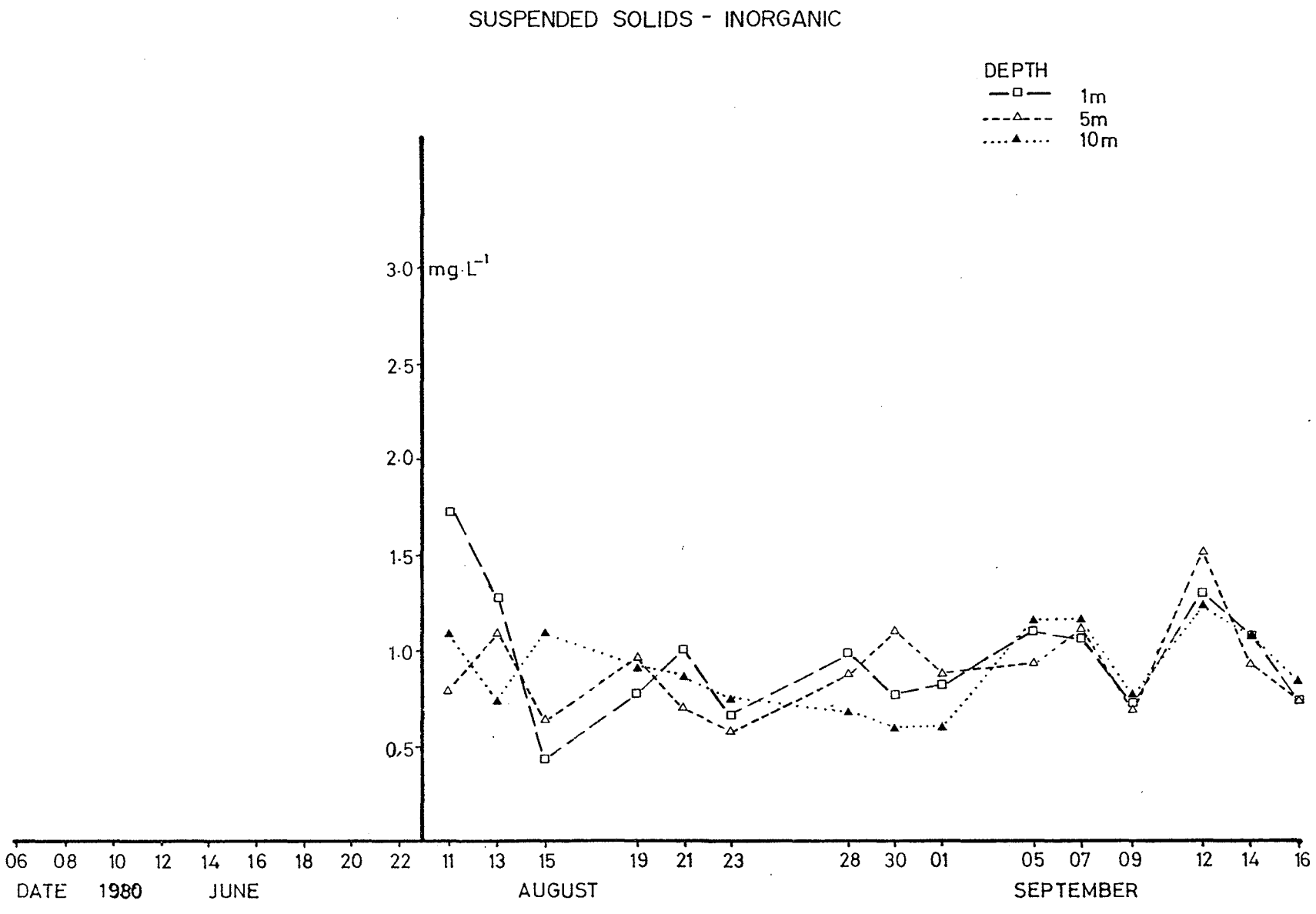


Figure 5.6: Inorganic Suspended Solids in Ragged Channel, Summer, 1980.

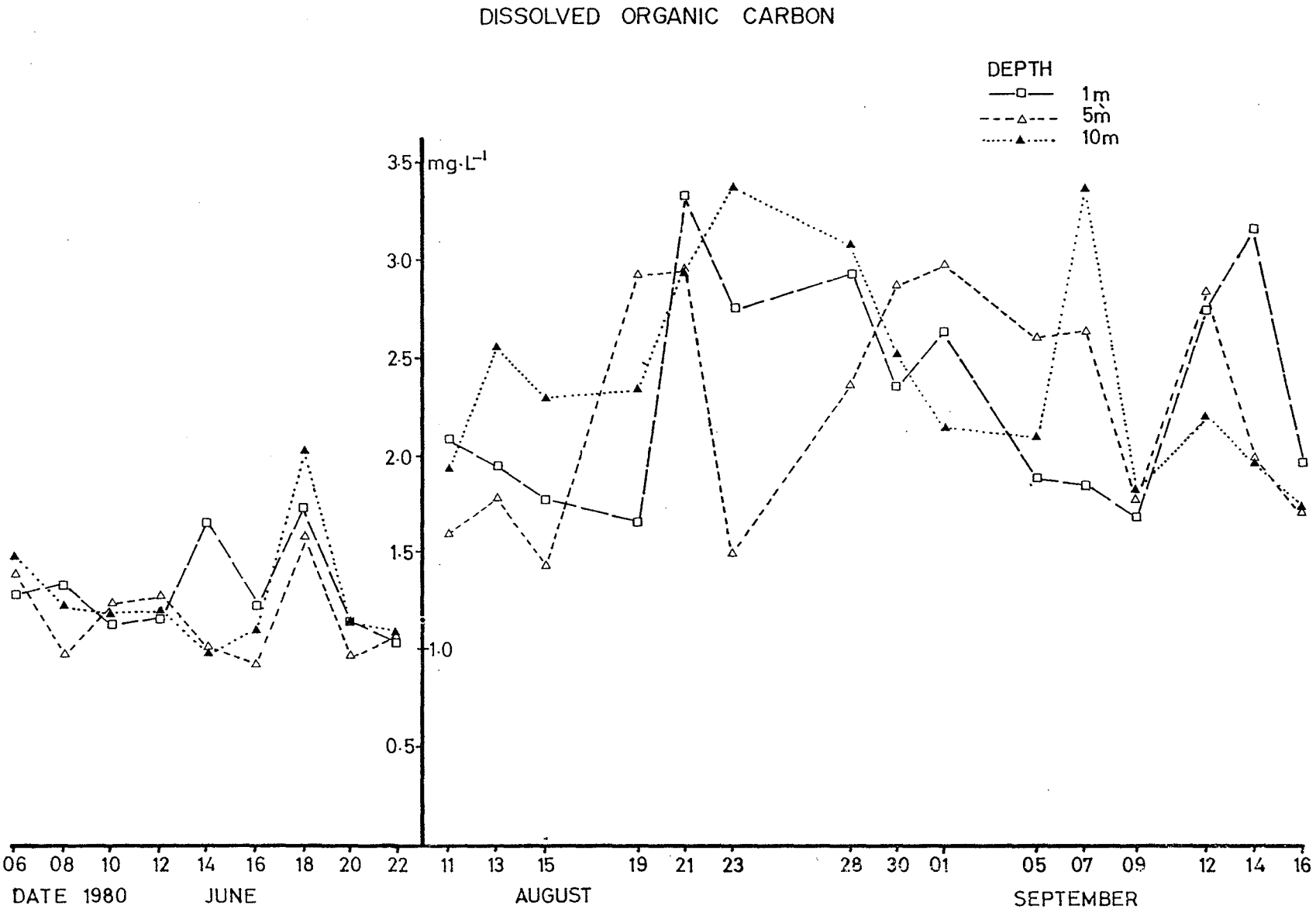


Figure 5.7: Dissolved Organic Carbon in Ragged Channel, Summer, 1980.

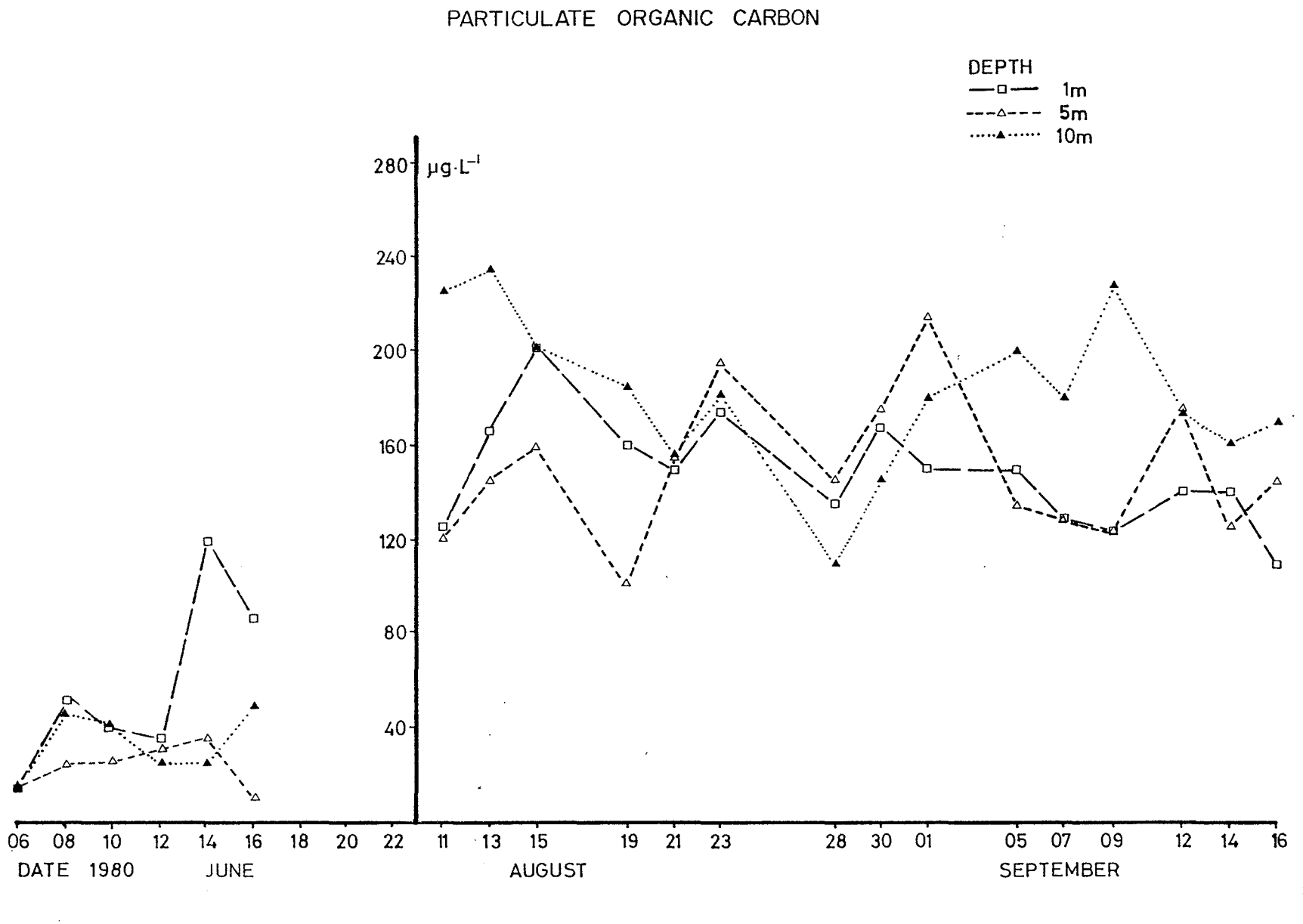


Figure 5.8: Particulate Organic Carbon in Ragged Channel, Summer, 1980.

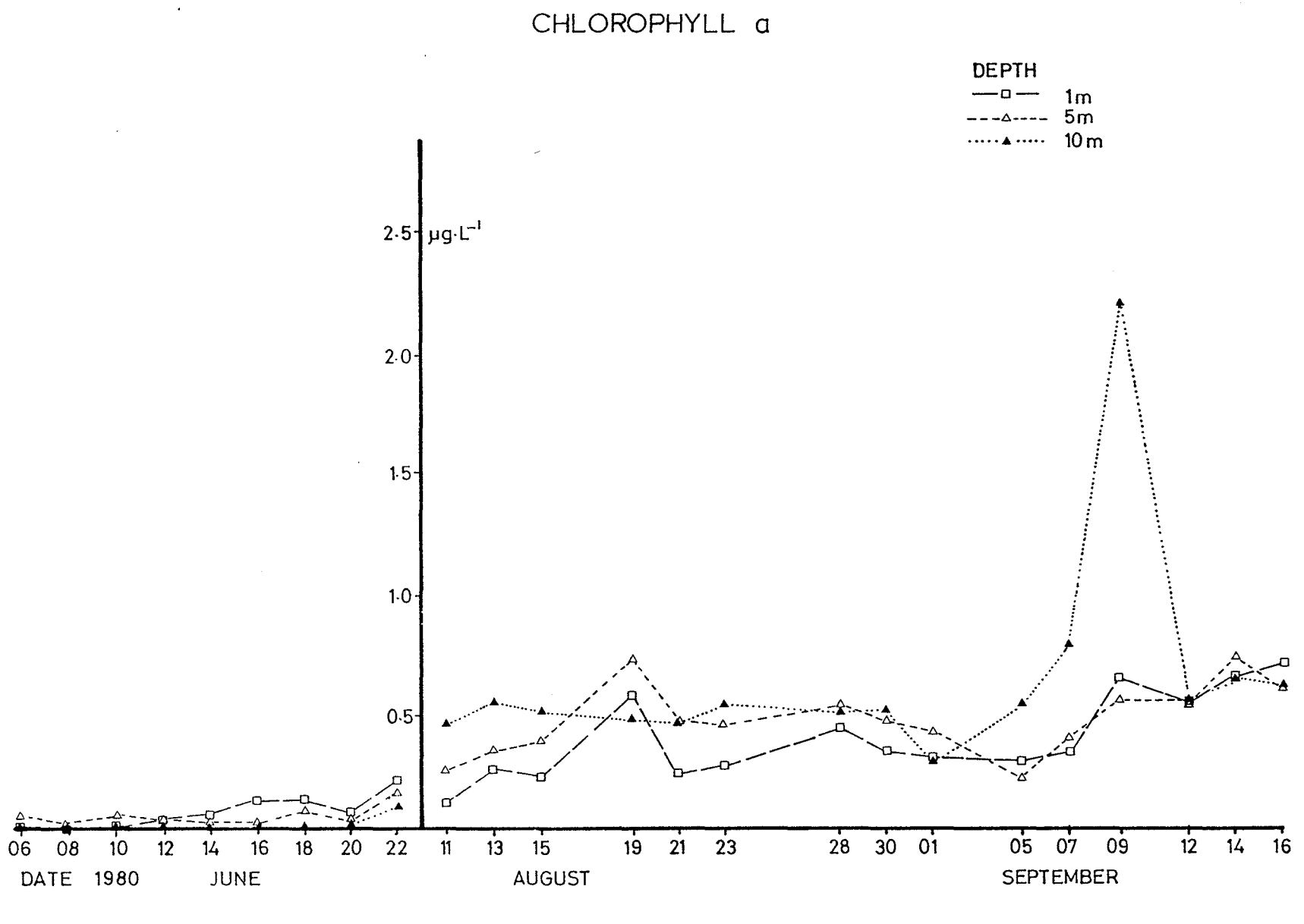


Figure 5.9: Chlorophyll a in Ragged Channel, Summer, 1980.

5.2 Environmental Chemistry: Sediment Analyses

5.2.1 Total Organic Carbon

The method used for total organic carbon (TOC) is the same wet oxidation and back-titration technique that Seakem attempted for particulate organic carbon. However, the levels of organic carbon are far higher in the sediment than in the water column, and interferences are proportionately less of a problem. Nevertheless a check was made by determining the salinity for all of the samples and determining the size of the chloride interference which results. The method was found to report systematically high TOC due to this inteference, with the systematic error averaging about +5% (1-10% spread). The method also suffers from the assumption that the redox state of the sedimentary organic scatter is the same as in the sucrose standards. Finally, oxidation of the more refractory organic carbon in the sediments is probably not complete, resulting in values that are systematically low by about 15% (Gersey et al., 1979). Although the method suffers from a variety of systematic errors, the precision of replicate samples was found to be good. Despite the inhomogeneity of the Cape Hatt sediments, triplicate analyses gave relative standard deviations that averaged 10%.

The TOC values do not show any variation with depth in the core samples, suggesting limited bacterial activity at depth. Neither was there any discernible change in the surface samples over the summer sampling period. The average value of all of the samples was 0.60 $\pm$ 0.28% carbon by weight (52 samples). This excludes the series of shallow (2-3 m) samples collected in August/September which were significantly lower than the 6-7 m or 13-15 m samples, averaging 0.24 $\pm$ 0.10% carbon by weight (9 samples). The beach samples were different again, and extremely low in organic carbon, averaging 0.07 $\pm$ 0.07% (18 samples).

By way of comparison, open ocean sediments average 0.3% organic carbon (Riley and Chester, 1971, p. 213).

5.2.2 Interstitial Nutrients

The measurement of interstitial nutrients in marine sediments is not a routine type of analysis. There are a variety of sampling and analytical problems which have been reported in the literature. In reducing sediments, high phosphate

concentrations of several hundred µg at L^{-1} can exist a few centimeters from the sediment-water interface. This rapid gradient in nutrient concentrations with depth requires careful sampling. Another problem is contamination of the interstitial water with overlying sea water after sampling. There are virtually as many sampling methods as sets of results reported in the literature. These include samplers which extract the interstitial water from the sediment in situ, such as the syringe type (Sayles et al., 1976) and the perforated cup type (Zimmermann et al., 1978) as well as the more conventional corers, grabs and diver-held samplers.

There are further complications in pressing water from sediment samples. The temperature of pressing has been found to have an effect on silica and pH results (Fanning and Pilson, 1971). Pressing sediments in air has been shown to decrease phosphate concentrations, due to formation of iron precipitates. An inert atmosphere is recommended (Bray et al., 1973). Freezing of the interstitial water often causes formation of magnesium- or iron- precipitates (Martens et al., 1978) which must then be redissolved with acid prior to analysis.

The samples collected for this data set were obtained in three different ways. The first set were collected by grab samplers, the second by corers, and the third by divers. The grab sampling method was perhaps the most reliable. The diver sampling may have resulted in some contamination of the pore waters with overlying sea water. The core samples had to be frozen, thawed and refrozen prior to squeezing and analysis, so degradation of these samples, perhaps by precipitation of phosphate, may have been a problem.

The results from the cores were so variable that it is difficult to comment. The expected pattern for phosphate with depth in core samples is for deep samples to be enriched, containing 50 to 500 µgat L^{-1} depending on the organic content and redox potential of the sediment (e.g. Murray et al., 1978). The enrichment of PO_4 is due to regeneration from organic matter by oxidation reactions in the sediment. Nitrate, however, is usually zero at depth, because once oxygen is used up, nitrate becomes the electron acceptor for the oxidizing process in the sediments, and it is reduced to ammonia or nitrogen (Bender et al., 1977). Most sediments contain no nitrate a few centimeters below the water interface. The erratic results from the core samples at Cape Hatt suggests that the samples did not survive the refreezing steps in their handling, or that other problems occurred in the analyses.

The grab- and diver- collected samples of the surface sediment at the microbiology stations gave more consistent results. Excluding the first set of three results from June, which were very high and appear to be contaminated, the averages of the remaining 24 samples are:

Nitrate - nitrogen	3.0 ± 2.7	µg at L^{-1}	(24 values)
Phosphate - phosphorus	14.9 ± 11.3	µg at L^{-1}	(24 values)

A third of these samples were collected by grab sampling, the remainder by divers. There was no significant difference between the two sets of results. In June only the phosphate was enriched in the interstitial water relative to the bottom water. In August - September both nutrients were an order of magnitude higher in the interstitial water than in the bottom water, presumably due to mineralization of organic matter under oxygenated conditions in the surface sediments.

5.2.3 Total Nitrogen

The total nitrogen levels in the sediment averaged 0.15 ± 0.04% by weight. The interstitial nitrate - nitrogen expressed in the same units, averages 0.0000042% by weight, and so does not contribute significantly. Total organic carbon in these samples averages 0.60% carbon by weight. The atomic ratio of carbon : nitrogen is therefore 4.7 : 1.

In plankton the average carbon - nitrogen ratio is about 6.6 : 1 (Redfield et al., 1963). Presumably then, most of the nitrogen is bound up in detritus, with perhaps some additional nitrogen contributed by ammonia from decaying sediments at depth.

5.2.4 Lead-210 Dating

Lead-210 dating can be used to establish the geochronology of marine sediments up to about 100 years. Three cores were collected from Cape Hatt for dating purposes and subsampled at seven to nine depths each (0 - 45 cm). The results for lead-210 determinations are all in the range of 0 - 1.4 pCi/g which are background

levels. There is no sign of any gradient with depth. By way of comparison, a core from Santa Barbara basin showed a gradient from 6.9 pCi/g at the surface to background levels of 1.0 pCi/g at 24 cm (Koide et al., 1972). The lack of such a gradient in the Cape Hatt cores implies that the lead-210 in the surface samples has already decayed to the background levels of the deeper samples. The sedimentation rates must therefore be very slow, and for the amount of reworking of the sediment by biological activity and ice scouring, must be sufficient to mix freshly deposited lead-210 rich sediments down into the sub-surface, destroying any surface accumulations.

5.3 Hydrocarbon Baseline Study

5.3.1 Water Samples, IR Analyses

Most of the infrared determinations on the water samples were below the detection limit of 13 $\mu g.L^{-1}$ (relative to a weathered Lagomedio crude oil standard). The exceptions (7 out of 35) may be due to natural organic matter. Most of the UV/fluorescence determinations on the same samples by ERCO (see volume 2) are also below the detection limit of that method of 3 $\mu g.L^{-1}$. The four exceptions are not the same samples that are high by IR analyses. This implies that the high IR values are not due to petroleum hydrocarbons which usually contain fluorescent aromatic material and therefore should show a UV/fluorescence response.

5.3.2 Sediment Samples, IR Analyses

Both the total extractable organics and the non-polar hydrocarbons were measured in the sediment samples. The total extractable organics of the June samples were significantly lower than for the September samples: 4.6 ± 3.4 $\mu g.g^{-1}$ versus 16.5 ± 8.3 $\mu.g^{-1}$ for the later period. This difference is perhaps due to the fresh detritus deposited in the late summer. The non-polar hydrocarbon levels were, however, consistent between the two sampling periods: 1.1 ± 1.0 $\mu g.g^{-1}$ (21 values) in June versus 0.86 ± 0.78 $\mu g.g^{-1}$ (17 values) in September. This measure of non-polar hydrocarbons should give a reliable baseline against which to compare the sediment after the experimental oil spill.

5.3.3 Beach Samples, IR Analyses

The total extractable organics are much lower for beach samples than for sediment samples, averaging about 10% of the sediment concentrations (0.94 ± 0.68 $\mu g.g^{-1}$, 21 values). The trend parallels the total organic carbon results: beach TOC levels were 12% of levels in the sediment. The non-polar hydrocarbon contents were more consistent, averaging circa 50% of levels in the sediment (0.52 ± 0.57 $\mu g.g^{-1}$, 21 values)

(Note: all IR determinations are expressed in weathered Lagomedio crude oil equivalents per gram of dried sediment.)

5.4 Shoreline Experiment

5.4.1 Total Hydrocarbons, IR Analyses

The significance of the total hydrocarbon measurements made for the shoreline oil spill experiments is discussed fully by the Woodward-Clyde B.I.O.S. report. It should be noted that some improvement is required in the sampling procedures to obtain a better measure of the mass balance of oil in the plots because of the high 'intra-plot' variability. Larger samples, more fully integrated across the plots, will be taken in the future.

6. CONCLUSIONS

The environmental chemistry data presented here describes the biochemical characteristics of the water column, and to a lesser extent the sediment, quite thoroughly, ranking Cape Hatt among the better characterized marine systems in the Arctic. Where comparative data is available (e.g. nutrients, chlorophyll, oxygen) it suggests that Cape Hatt is quite typical of the eastern Arctic nearshore environment.

The hydrocarbon data presented here will provide a good baseline against which to follow the fate of the experimental oil spills, as is discussed in more detail in Volume 2 of this report.

7. REFERENCES

Apollonio, S. 1976. Primary Production in the Canadian Arctic Archipelago, 1961-63. Contribution No. 76016, Bigelow Laboratory for Ocean Sciences, West Boothbay Harbour, Maine 04575, U.S.A.

Bender, M.L., K.A. Fanning, P.N. Froelich, G.R. Heath, V. Maynard. 1977. Interstitial nitrate profiles and oxidation of sedimentary organic matter in the eastern equatorial Atlantic. Science 198, pp. 605-609.

Black, C.A. 1965. Methods of Soil Analysis, Volume 2; pp. 1149-1175. Amer. Soc. Agron.

Bray, J.T., O.P. Bricker, B.N. Troup. 1973. Phosphate in interstitial waters of anoxic sediments: oxidation effects during sampling procedures. Science 180 pp. 1362-1364.

Copin-Montegut, C., G. Copin-Montegut. 1973. Comparison between two processes of determination of particulate organic carbon in sea water. Marine Chemistry 1 pp 151-156

Dean, W.E. 1974. Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: comparison with other methods. J. Sedimentary Petrology 44: pp. 242-248.

de Lappe, B.W., R.W. Risebrough, A.M. Springer, T.T. Schmidt, J.C. Shropshire, E.F. Letterman, J.R. Payne. 1979. The sampling and measurement of hydrocarbons in natural waters. In Hydrocarbons and Halogenated Hydrocarbons in the Aquatic Environment. B.K. Afghan, D. McKay, editors. Plenum Press, N.Y.

Fanning, K.A., M.E.Q. Pilson. 1971. Interstitial silica and pH in marine sediments: some effects of sampling procedures. Science 173, pp. 1228-1231.

Gaudette, H.E. 1974. Titration method for organic carbon. J. Sedimentary Petrology 44: pp. 249-253.

Gershey, R.M., M.D. MacKinnon, P.J. le B. Williams, R.M. Moore. 1979. Comparison of three oxidation methods used for the analysis of the dissolved organic carbon in seawater. Marine Chemistry 7: pp. 289-306.

Grainger, E.H. 1974. Nutrients in the Southern Beaufort Sea. In The Arctic Coast and Shelf of the Beaufort Sea, J.C. Reed and J.E. Slater, editors. ARctic Institute of North America.

Holm-Hansen, O. 1969. Determination of microbial biomass in ocean profiles. Limnol. Oceanogr. 14, 740-747.

Hufford, G.L. 1974. Dissolved oxygen and nutrients along the North Alaskan Shelf. In The Coast and Shelf of the Beaufort Sea, J.C. Reed and J.E. Slater, editors. Arctic Institute of North America.

Kalil, E.K., M. Goldhaber. 1973. A sediment squeezer for removal of pore waters without air contact. J. Sed. Petro. 43, p. 553-7.

Koide, M., A. Soutar, E.D. Goldberg. 1972. Marine geochronology with Lead-210. Earth and Planetary Science Letters 14: pp. 249-253.

Koroleff, F. 1976. Total and organic nitrogen. In Methods of Seawater Analysis, K. Grasshoff, editor. Verlag. Chem.

Macdonald, R.W., M.E. McFarland, S.J. de Mora, D.M. Macdonald and W.K. Johnson. 1978. Oceanographic Data Report, Amundsen Gulf, August-September, 1977. Institute of ocean Sciences, Sidney, B.C.

Martens, C.S., R.A. Berner, J.K. Rosenfeld. 1978. Interstitial water chemistry of anoxic Long Island Sound sediments. 2. Nutrient regeneration and phosphate removal. Limnol. Oceanogr. 23, pp. 605-617.

Menzel, D.W., R.F. Vaccaro. 1964. The measurement of dissolved and particulate carbon in seawater. Limnology and Oceanography 9, pp. 138-142.

Murray, J.W., V. Grundmanis, W.M. Smethie, Jr. 1978. Interstitial water chemistry in the sediments of Saanich Inlet. Geochimica and Cosmochemica Acta 42, pp. 1011-1026.

Parsons, T.R. 1979. The Strait of Georgia Programme. Marine Production Mechanisms. M.J. Dunbar, editor, pp. 133-149.

Redfield, A.C., B.H. Ketchum, F.A. Richards. 1963. In The Sea, Volume 2, p. 26, Wiley, N.Y.

Riley, J.P., R. Chester. 1971. Introduction to Marine Chemistry. Academic Press. New York.

Sayles, F.L., P.C. Mangelsdorf, T.R.S. Wilson, D.N. Hume. 1976. A sampler for the in situ collection of marine sedimentary pore waters. Deep-Sea Res. 23, pp. 259-264.

Strickland, J.D., T.R. Parsons. 1972. A Practical Handbook of Seawater Analysis. Bulletin 167, Journal of Fisheries Research Board Canada.

Sverdrup, H.U., M.W. Johnson, R.H. Fleming. 1942. The Oceans, Prentice Hall, Englewood Cliffs, N.J.

Wong, C.S., R.W. Macdonald, R.D. Bellegay, P. Erickson. 1980. Baseline Data on Chemical Oceanography in the Southern Beaufort Sea, 1974-5. Beaufort Sea Technical Report #14, Institute of Ocean Sciences, Sidney, B.C.

Zimmermann, C.F., M.T. Price, J.R. Montgomery. 1978. A comparison of ceramic and Teflon in situ samplers for nutrient pore water determinations. Estuarine and Coast Marine Science 6.