

**1976
OCEANOGRAPHIC ACTIVITIES
OF THE
INSTITUTE OF OCEAN SCIENCES
(Patricia Bay)**

**Submitted to the Canadian Committee on Oceanography
and the Pacific Sub-Committee on Oceanography
The material in this report will also appear
in the annual manuscript report
of the Institute of Ocean Sciences**

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January 1977**

INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY

FISHERIES AND MARINE SERVICE

DEPARTMENT OF THE ENVIRONMENT

1976 REPORT ON OCEANOGRAPHIC ACTIVITIES

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HYDROGRAPHIC DIVISION

M. Bolton - Regional Hydrographer

The past year has demanded the utmost in flexibility and adaptability from Hydrography. The decision taken late in 1975 to lay-up CSS William J. Stewart, the ice damage suffered by CSS Parizeau in July 1976 and the increased impetus of the decentralization (or regionalization) of the chart production process were three major factors influencing the eventual 1976 program.

The lack of major ship time forced an increase in shore party activities, which had to be restricted to southern British Columbia waters. The disabling of CSS Parizeau wiped out the planned Amundsen Gulf program. The regionalization of chart production increased staff through man-year transfers from Ottawa, while creating severe production and training pressures. These should be alleviated in 1977 as the Chart Projection Section adapts to the increased workload and new staff become more proficient.

Mr. S.O. Wigen, Regional Tidal Superintendent continued for a second year as Associate Director of the International Tsunami Information Center in Honolulu. Mr. W.J. Rapatz continued as Acting Superintendent.

Major programs for 1977 have required a considerable planning effort. They will include extensive calibration of the Pacific Coast Loran-C chain; detailed bathymetric and tidal current surveys in the seaward approaches to Kitimat in connection with the development of a possible tanker terminal in Kitimat; continuation of the disrupted western Arctic charting program and a major re-survey of Vancouver Harbour.

TIDAL AND CURRENT SURVEY SECTION

S.O. Wigen - Regional Tidal Superintendent

W.J. Rapatz - Acting Regional Tidal Superintendent

This section conducted several major programs in the Arctic and Pacific regions. In the Beaufort Sea a program of storm surge monitoring was continued. Tide gauges were operated in support of hydrographic surveys throughout the region. Four major current survey programs were conducted. A considerable part of this section's efforts was spent on providing information and consulting services to government agencies, the general public, universities and engineering firms.

Hydraulic Research

A.B. Ages - In charge
A.L. Woollard - Computing Services

A detailed and continuing program was undertaken to investigate the behaviour of the salinity wedge in the main arm of the Fraser River, following a request by the Department of Public Works to determine causes of excess sedimentation in certain reaches of the navigable portion of the river. The field project was carried out in close cooperation with DPW and Water Surveys of Canada. Measurements were made from a launch equipped with a CSTD and analog recorder, and covered several representative tidal cycles and discharges.

An existing numerical model of the Fraser River was used to provide tidal information to government agencies and private industry involved in studies of pollution and river engineering.

The calibration of a two-dimensional numerical model of Burrard Inlet was continued.

A computer program to predict the movement of oil spills in the straits of Georgia and Juan de Fuca was further refined.

Current Surveys

W.S. Huggett - In charge	J.J. Manson
A.N. Douglas - Computing Services	F.V. Hermiston
W.J. Harris	M.J. Woodward

Three field projects were carried out. In Johnstone Strait two current meter arrays were moored 10 kilometres apart with one on the cross-section that was surveyed in 1973. Temperature and salinity profiles were taken at the beginning, middle and end of the survey. Off the Iona jetty in the Fraser delta, three current meter arrays and two thermistor chains were moored and temperature and salinity profiles were also taken. Both surveys were a continuation of previous surveys at the two localities, and the data will be used for navigational purposes as well as for studies of oceanographic processes. The latter aspect is discussed by Thomson in the Offshore Oceanography section of this report.

The third field operation was a joint survey with Coastal Zone Oceanography and included the mooring of four current meter arrays at the south end of Haro Strait. The arrays were in place for two months. The mooring line of one of the arrays was cut by a tow line and the array sank to the bottom. The instruments were recovered later by the submersible Pisces IV.

In June three days were spent on Bowie Seamount recovering a tide gauge placed there in 1974 at our request by the United States National Ocean Survey. The features of Bowie Seamount are quite regular, and therefore by searching with Pisces IV around the sea-

mount at the depth the gauge was laid, 180 m in this case, the gauge was soon found. The acoustic release gear had released, but was somehow missed by the recovery vessel. Three days were spent on Cobb Seamount looking for another tide gauge, this one moored for us by the United States Coast Guard. The bottom topography on the seamount is very rugged and a strong current is present and the gauge was not recovered.

In early August four days were spent on the MOT ship Nahidik at Herschel Island in the Beaufort Sea. A current meter array moored about 20 miles north of Herschel Island in August 1975 was recovered after considerable effort. Two hundred and five days of current observations were obtained. Unfortunately, a tide gauge which had been part of the instrument array was not recovered.

All the data tapes for the above surveys have been read, edited and processed except those of the Haro Strait survey, which have been contracted out to a local firm for processing. All current meter data obtained prior to 1973 has been re-analyzed in the new current ellipse form, and all current data has been brought up to the same standard (i.e. same units, significance, and uniform ID headers), and placed in two tapes for easy access. Numerous plots of observed and predicted current in Juan de Fuca Strait, Georgia Strait and those given by the numerical model of the Strait of Georgia have been done as part of the work on verifying the model. A break in the current meter data taken at Race Rocks over a sixteen month period was filled in by predicting the missing four week period. From the then 'complete' record we were able to extract the annual and semi-annual changes in the residual current, which allow for the run-off of the Fraser River.

A Teletronix scope with x and y cursors was acquired, and programs have been written for statistical comparisons between two current stations. This will allow the number of secondary current stations given in the Tide Tables to be greatly increased in the future.

Tidal Survey

F.E. Stephenson - In charge	A.C. Ma
R.E. Brown	* L.E. Ponse
C.C. Carracedo	A.J. Smedley
D.E. Hilder	* W. Tario

* Left in 1976

An extensive program was again undertaken in the western Arctic. The monitoring of storm surges in the Beaufort Sea was continued with the installation of four gauges along the shoreline. Data from these gauges, and three additional gauges which were installed at critical locations on the numerical model, will be used to refine the tidal and storm surge model. The Mackenzie River hydrographic party worked primarily in the Eskimo Lakes and the Mackenzie delta this year, and a total of nine tidal markers was installed and maintained in support of these surveys. The search for oil and

gas in the Beaufort Sea area has resulted in an increased number of requests for tidal information in and around the delta. As a result, the tidal program in this area was extended to increase our knowledge of the interaction between the Mackenzie River discharge and the tidal forces.

Two Aanderaa pressure gauges were installed in August at three stations, Tuktoyaktuk, Cape Parry and Cambridge Bay. These instruments, one in the water and the other on shore recording the atmospheric pressure, will be recovered and replaced next summer. It is hoped that these Aanderaa gauges will provide a continuous record of tidal heights at permanent Arctic stations, a condition not fulfilled at present by conventional analog recorders.

Invaluable offshore tide data was acquired with the recovery of the pressure gauge from Bowie Seamount containing 416 days of tidal record. Two tide gauges were installed in Johnstone Strait as part of the tidal and oceanographic study of the area. These instruments are to be recovered in January 1977. New tide gauge facilities were constructed at Little River and Port Renfrew, the latter under contract by DPW. The large number of hydrographic shore parties this year kept the section busy in the spring installing tide gauges, or, in some cases, supplying the instrumentation. The tidal section is currently in the process of converting all permanent and temporary stations to metric.

A thorough revision of volume 6 of the Tide and Current Tables was completed early in the year. These changes will be introduced in the 1978 tables. This was the last of the three tide and current tables within the Pacific Region to be updated.

The data processing section of Tidal Survey processed monthly records of 23 stations, permanent and temporary, on the Pacific Coast. In addition, it processed the records of 25 temporary gauges operated within the region by hydrographic and tidal field parties. A total of over 300 months of tidal data was processed.

OCEAN CHEMISTRY DIVISION

C.S. Wong - Chief of Division

MARINE CARBON BUDGET SECTION

C.S. Wong - Head

C.S. Wong - Global carbon cycle, Air-sea CO₂ exchange
R.D. Bellegay
P.S. Munro
C.M. Jackson
J.S. Page - Carbon cycle modelling

Our effort to document the increase in background atmospheric CO₂ over the ocean is now in its eighth year of operation at Ocean Weather Station P (50°N, 145°W). Weekly air samples were collected on the weatherships CSS Quadra and CSS Vancouver and analyzed in our infrared CO₂ laboratory, which also performed air CO₂ analysis and reference gas calibrations for other Canadian CO₂ stations, at Sable Island and at Alert, Ellesmere Island, manned by the Atmospheric Environment Service. Continuous air CO₂ records by infrared analysis on the weatherships were started in April, 1976. The air CO₂ time series, both from flask samples and from continuous chart recording, form an important data basis for our understanding of the global carbon budget.

The atmospheric CO₂ increase over the ocean amounts to about one part per million per year from our Station P time series. This represents only about half of the total yearly input from burning of fossil fuels such as gas, oil and coal, for home-heating and industrial activities. The rest, one-third to one-half of the total input into the atmosphere, is absorbed either by the ocean or the biosphere. These absorption processes are poorly known at present. In particular, the oceanic processes are very complex. Carbonate chemistry of the surface mixed layer, global oceanic circulation and marine organic carbon cycle have to be considered. Thus, at Station P, time series are also studied for carbonate chemistry, partial pressure of CO₂, 13-C/12-C ratio and radiocarbon in the surface waters and the marine atmosphere.

The effect of the marine biosphere on the CO₂ cycle is being studied using a CEPEX enclosure of seawater covered by a specially constructed plastic dome to simulate a simple air-sea system. The pH of the enclosed 'ocean' was adjusted to 7.2, an upper limit pH value in the year 2070 when maximum release of fossil fuel CO₂ is expected, and the control was at pH 8.2 in seawater under natural carbonate chemistry conditions. Another bag was adjusted to 7.2 but with free exchange with the atmosphere in the natural state. Samples of phosphate, nitrate, silicate, chlorophyll-a, 14-C productivity, plankton biomass, pH at 25°C, alkalinity, total CO₂ by

Sillen-Dyrssen titration, $^{13}\text{C}/^{12}\text{C}$ ratios, particulate organic carbon, dissolved organic carbon, temperature, salinity and detritus carbon were analyzed. The plastic dome was damaged shortly after the first week by a storm, but the experiment was salvaged by observations on the open CO_2 bag acidified to pH7.2. Similar to the observations in 1975 when the pH was lowered to 7.6, the preliminary results this year indicated that, due to the lowering of pH, a time lag of one to two days occurred in both the increase of photosynthetic activity and the increase in the biomass of plankton (indicated by the Chlorophyll-a content in seawater).

MARINE HYDROCARBONS SECTION

W.J. Cretney - Head

W.J. Cretney - Hydrocarbons in the marine environment
P.A. Christensen (NRC Postdoctoral Fellow to December 3) - GC/MS
System, PCB
R.W. Macdonald - LMW hydrocarbon gases
C.S. Wong - Environmental effects
F. McLaughlin

The objective of the program is to understand the occurrence, pathways and fate of hydrocarbons (natural, petroleum-based and halogenated) in the marine environment. The main effort of the work in 1976 was on analysis of samples of seawater, sediments and marine organisms collected during the Pandora II cruise in Southern Beaufort Sea last year and on the production of reports on the baseline levels of hydrocarbons in Southern Beaufort Sea and the distribution of tar and other particulate pollutants along the Beaufort Sea coast and offshore islands.

The baseline studies showed that the present-day Beaufort Sea is very clean with respect to petroleum pollution. The extremely low concentrations of polycyclic aromatic hydrocarbons in seawater and marine organisms required great care in work-up inside clean rooms, of environmental samples collected in the 1975 cruise. The levels of polycyclic aromatic hydrocarbons in Beaufort Sea seawater are low, comparable in cleanliness to those of uncontaminated seawater in the N.E. Pacific Ocean. The levels of low-molecular weight hydrocarbons, with the exception of natural methane from sediment, are low or close to the detectable limits indicating the absence of petrogenic inputs. The non-polar hydrocarbons in fish suggest marginal presence of petroleum hydrocarbons in the tissues. The non-polar hydrocarbons in marine sediments show characteristics typical of a mixture of marine and terrestrial hydrocarbons, suggesting the influx of terrestrial plant material via the Mackenzie River, which also flows through areas with known natural seepage and petroleum drilling activity.

Survey of the Beaufort Sea coast of Mackenzie Bay, the western portion of the Tuktoyaktuk Peninsula, the Yukon coast and the offshore islands of the Mackenzie River delta again indicated a very

clean environment with respect to tar pollution. No natural seepage was evident, although some isolated occurrences of asphalt near Drift Point and grease near Shingle Point and around Tuft Point and Warren Point were encountered. However, plastic wastes, in particular explosive cannister fragments originating from marine seismic activities, were prevalent and were found to have re-inundated beaches that were cleaned up during the 1975 survey.

An analytical technique has been developed by the Division using a combination of a PROMIN (Programmable multiple-ion monitor) method and an isotopic dilution concept, for use of the Finnigan 3300E gas chromatograph/mass spectrometer system. For analysis of polycyclic aromatics, a fully deuterated analogue of the compound studied was added as a standard, and the PROMIN was set to the values of the deuterated and non-deuterated species for mass monitoring throughout the gas chromatograph run. This new technique eliminates difficulties in other methods due to preferential loss through workup of one component compared to the other and discrepancies due to difference in the response to the analysis method between the standard and the compound being analyzed, a common difficulty in fluorescence, UV and GC determinations of petroleum compounds.

The concept of the fluorescent extractable compounds (FEC) was investigated to determine its significance in hydrocarbon studies. Our Beaufort Sea work indicates that the FEC in seawater can be a combination of both polycyclic aromatic hydrocarbons (PAH) and non-PAH compounds which fluoresce. An inverse relationship between PAH or FEC and salinity was also deduced from the Beaufort Sea data, suggesting possible terrestrial contributions via the Mackenzie River.

A trace hydrocarbon sampler, made of only teflon and stainless steel, was developed on contract through an unsolicited proposal by Seakem Oceanography Ltd. under supervision of Ocean Chemistry Division. The sampler is capable of full protection of the sample walls and the sample on passage through the surface microlayer.

TRACE METALS SECTION

C.S. Wong - Head

C.S. Wong - Trace metals, ocean dumping chemistry

K. Kremling (Visiting scientist, Institut für Meereskunde, University of Kiel, W.Germany) - Cadmium in seawater

J. Piuze (NRC Postdoctoral Fellow to March 31; Research Scientist, Fisheries Management, Quebec Region, on secondment, to August 31) - Anodic stripping voltametry

E. Matsumoto (NRC Postdoctoral Fellow, from Geological Survey of Japan, to October 20) - Lead-210 dating, marine sediments

R.W. Macdonald - Ocean dumping chemistry

W.K. Johnson

The main objective of the Section is to assess the natural and anthropogenic inputs of physiologically significant trace metals

into the marine environment and their interactions with the marine biota and sediments, with special reference to the B.C. coastal waters and the open ocean. In the marine environment, special research problems exist for different reservoirs. For seawater, the key problem is the reliability of the sampling and analysis of trace metals at the parts per trillion or sub-parts per billion level. There is also the question of the detection of the chemical species of the analytical chemistry of trace metal detection in a complex biological matrix, and in the assessment of the physiological significance at such metal levels. For marine sediments, mobilization and fluxes of metals, rather than their analytical chemistry, are important for our understanding of the behavior and pathways of metal contaminants in ocean management problems.

Universal contamination of our environment by lead aerosols has caused serious unreliability in lead determination. Thus, the study of the levels of lead in the environment requires an integrated approach with extreme care in every step of sample collection, handling, work-up and analysis to ensure sample integrity at all time. In our laboratory, special cleaning procedures and highly purified reagents were used. An unique contaminant-free water sampler without metallic components, based on a piston principle, was developed under Ocean Chemistry supervision on a DSS contract to Seakem Oceanography Ltd. (unsolicited proposal). To provide a clean environment for sample handling, a shipboard clean room with carbon filtered air at the intake and similar shore laboratory were used. Lead analysis was carried out using a PE 503 flameless atomic absorption spectrometer with a carbon furnace or using a Nuclide 12-90-SU mass spectrometer. Trace metal levels in the Strait of Georgia were studied in connection with the ocean dumping project, using a clean laboratory. Preliminary results indicated much lower values for dissolved metal concentrations than previously obtained. Our values are for cadmium, 0.01-0.07 µg/kg, copper, 0.1-1.4, zinc 0.3-3.3, mercury, 0.0-0.07 and lead 0.03-0.7 (lead by mass spectrometry, 0.04-0.27 µg/kg).

In response to an urgent survey of mercury concentrations in the north of Canada, Ocean Chemistry conducted a crash program to analyze the plankton, fish and surface sediment samples previously collected during the 1975 Beaufort Sea cruise, and accelerated data processing of shipboard results of seawater mercury levels. The seawater and surface sediment in southern Beaufort Sea were found to have the lowest reported values of mercury, averaging about 11 ng/l of seawater and about 67 ng/g dry weight of surface sediments. The fish, Cisco species, had a mercury level of about 50 ng/g dry weight. The plankton, with about 900 ng/g dry weight, appeared to be high relative to reported oceanic values.

Major effort was devoted to chemical studies of ocean dumping problems to understand the variability in chemical parameters associated with the dispersion of dumped material against a natural background of river suspended matter in the Fraser estuarine area. The dumping ground off Point Grey (50° 15.3'N, 123° 22.10'W) near Vancouver is the largest dumpsite in Canada for disposal of dredge spoils from river channels and from building construction and ex-

cavation. To study the behaviour of dispersion of dumped material, an experiment was conducted using the chartered vessel Sea Lion as the mothership for chemical sampling, and the chartered vessel Seatech II as the tracking vessel of the plume of dispersed material. Chemical sampling of seawater for trace metals, suspended matter and other water characteristics was carried out after controlled dumps from the DPW dredge ship Fort Langley and a large barge of spoils from the north arm of the Fraser River and from False Creek respectively. Positioning was aided by a Mini-Fix navigational system, aerial surveillance and current drogues. Particle size distribution spectra were shown to be effective "fingerprints" of the dumped material, which showed a marked increase by a factor of up to 10, in the number of fine particles in the 0.03-4.5 μm range. Relatively high sub-surface metal values for copper, cadmium and lead were also observed after dumping, suggesting possible release of metals from dumped material.

To explore the possibility of a chemical screening test for potential dump material, a laboratory study was made on the release or absorption of trace metals (lead, copper, zinc, cadmium and mercury) from a dredge spoil sample from False Creek, when placed in seawater at a suspended matter concentration similar to natural conditions. Lead and mercury showed an initial fourfold increase before dropping back to initial concentrations later. A more comprehensive study of the release of mercury from resuspended sediment contaminated by industrial wastes from the FMC plant at Howe Sound under different conditions of temperature, salinity and pH in seawater is being conducted to investigate the impact of dredging high mercury sediments.

To reveal the anthropogenic input through dumping in the sedimentary record, undisturbed sediment cores were collected off Point Grey, Port Mellon and Vancouver harbour using the Soutar-Bruland undisturbed coring device. Sections of the cores, immediately frozen after collection, were X-rayed for template reference and sub-sampled for trace metal analysis and lead-210 dating. Lead-210 dating appears to be a very powerful tool in ocean dumping investigations, being applicable to sedimentation events up to about 100 years ago. Preliminary results indicated a sharp discontinuity in lead-210 dates when ocean dumping took place. The same technique was also applied to our Beaufort Sea work to assess the sedimentation rates in nearshore areas as a measure of the time-scale of burial of pollutants in case oil spills occur during drilling.

CHEMICAL OCEANOGRAPHY SECTION

R.W. Macdonald - Head

R.W. Macdonald - Coastal chemical oceanography, arctic chemistry
C.S. Wong - Deep-sea chemical oceanography, marine pollution
R.D. Bellegay - Station P
C.M. Jackson
P.S. Munro
F. McLaughlin

Chemical Monitoring Program at Station P

Long-term trends of chemical parameters at Ocean Weather Station P (50°N, 145°W) were monitored as a continuing effort of the Division.

Neuston-net tows were made between Victoria and Station P to collect tar balls and other surface pollutants. Samples of total dissolved aromatic hydrocarbons in surface waters were also collected. Weekly samples of atmospheric CO₂, surface alkalinity, total CO₂ and surface radiocarbon were taken. Continuous shipboard infrared measurements of marine air CO₂ and pCO₂ were made on a quarter-yearly basis. Samples of nutrients were taken at Station P to provide information about long-term fluctuations in relation to circulation and the marine food chain. The weather ship program also included collection of tritium samples and measurements of mercury and dissolved aromatic hydrocarbons in seawater. (Bellegay, Jackson)

Chlorine Release in Seawater

On February 19, 1975, four tank cars filled with liquid chlorine were lost from a barge being towed in the vicinity of Malaspina Strait in B.C. coastal waters. Since rupture is inevitable in future within 2-20 years, Ocean Chemistry Division started an examination of the chemical aspects of the chlorine-seawater system in order to predict the likely sequence of events following tank car failure. A literature search was made to construct the phase diagrams and to predict the likely speciation of chlorine and its effects. In order to fill in gaps in our knowledge of the chlorine seawater system, chlorine demand experiments in seawater were performed on seawater collected from Saanich Inlet and on surface sediments from the Strait of Georgia.

On August 20, 1976, some small-scale chlorine release experiments were performed in Saanich Inlet at a series of depths from 25m to 145m with a specially designed hydraulic system to release chlorine from a gas cylinder attached to the submersible PISCES IV. The behaviour corresponded quite closely to that predicted on thermodynamic grounds. At 145m chlorine emerged as green liquid drops without observable hydrates. At 90m, green liquid and white flakes of hydrates were observed. At 45m, liquid chlorine, hydrates and gaseous chlorine were all seen. At 25m, chlorine came out not as a liquid but as a steady gas plume. No violent explosion was observed and gasous explosion caused by localized superheating of liquid chlorine is not expected to be a problem at the anticipated water temperature. (Macdonald, Jackson, Wong)

Chemical Transfer Studies in CEPEX

C.S. Wong - Chief co-ordinator

P.S. Munro - Co-ordinator, CEPEX chemical studies

The Controlled Ecosystem Pollution Experiment (CEPEX) is an international cooperative program, involving Canadian, American, British, Japanese and West German scientists, to study the effects of pollutants on mixed trophic levels of pelagic marine organisms, using large enclosures of natural seawater in Saanich Inlet. Ocean Chemistry participation is in its third year with three full-scale experiments performed on carbon dioxide cycle, cadmium and lead, using a 1/4-scale CEE (Controlled Ecosystem Enclosure) with about 60,000 liters of seawater, and two associated experiments on petroleum and low-molecular weight hydrocarbons utilizing the full-scale CEE for hydrocarbons manned by Skidway Institute.

The CEPEX study of cadmium was carried out in cooperation with Dr. Klaus Kremling of the Institut für Meereskunde, University of Kiel, under a Canada-West Germany scientific exchange program, and with Dr. J. Piuze of Fisheries Management, Quebec Region. Results from our 1975 experiment have shown the insignificance of the removal of cadmium by organic matter and the association of low cadmium content in the particulates with high productivity. From May 1 to June 4, 1976, a second cadmium experiment was conducted using two 1/4-scale CEEs, one as control, one spiked with about 1 µg/l. Work is in progress on chemical analysis of samples of dissolved cadmium, particulate cadmium and detritus material. (Kremling, Piuze, Johnson, Wong)

A lead experiment was carried out from July 31 to August 25, 1976 using three 1/4-CEEs, with one as a control, one spiked with lead-210 and lead-206, and one with tetra-ethyl lead. The control was also spiked with an ultra-trace quantity of lead-210 to trace lead behaviour in a natural state. Preliminary results showed that lead decreased by about 50% of its concentration in seawater during high productivity period of the plankton bloom, and during the levelling off of productivity, the lead levels remained constant. Unusually high productivity occurred in the CEE spiked with tetraethyl lead but the reason is unknown. (Wong, Matsumoto, Berrang, Johnson)

The CO₂ experiment is described under Marine Carbon Budget.

During the period of the full-scale hydrocarbon experiment of Dr. D. Lee of Skidway Institute, from August 16-30, two hydrocarbon experiments were carried out by Ocean Chemistry Division. In one, deuterated labelled benz-a-anthracene was added to study the fate of polycyclic aromatic hydrocarbons, by analyzing the samples using the isotope dilution technique using a GC/MS/PROMIN system. (Cretney, Christensen, McLaughlin)

In the recent experiment, measurements of low-molecular-weight hydrocarbons were made in the full-scale CEE at 3, 7 and 19m depths to study the variability of methane, ethylene, ethane and propane with the changing productivity and water conditions in the CEE.

All the LMW hydrocarbon profiles showed the same initial increase at all depths during the high production period. (Macdonald)

Coastal Chemical Oceanography

About ten coastal cruises were conducted in 1976 on various ships in the Pacific Region, including Parizeau, Vector, Pandora II and the chartered ship Sea Lion. These cruises were related to programs in trace metals, hydrocarbons, ocean dumping, carbon dioxide and instrument testing. Highlights of some of the findings were described under the Section headings.

COASTAL POLLUTION SECTION

J.A.J. Thompson - Head

J.A.J. Thompson - Heavy metals pollution
D.W. Paton

Dr. Thompson and Mr. Paton were transferred from the Pacific Environment Institute in July, 1976. The main thrust has been to set up facilities in connection with ocean dumping studies in Howe Sound on the biotransformation of inorganic mercury into methyl mercury in the sediment. The levels of heavy metals (lead, cadmium, zinc, mercury, copper and chromium) in benthic organisms collected in the dumping areas near Point Grey are being studied.

OCEAN PHYSICS DIVISION

P.W. Nasmyth - Chief of Division

COASTAL ZONE OCEANOGRAPHY SECTION

D.M. Farmer - Head

W.H. Bell

R.H. Bigham

L.F. Giovando

G. Kamitakahara

A.P. Lee

J.H. Meikle

D.G. Sieberg

L.A. Spearing

J.A. Stickland

D.J. Stucchi

In cooperation with Tides and Currents Section we undertook a current-meter observation program in Haro Strait in July and August. Our intention was to examine some of the gross characteristics of the mixing and exchange processes occurring in the strait and to establish space and time scales of the major fluctuations. Instruments were moored at eight locations in a line across the channel. Despite a number of technical problems, including large vertical excursions of subsurface moorings induced by cable drag in the rapid currents, it appears that a good data set was obtained. The current-meter program was supported with CTD profiling, thermistor chain measurements and remote sensing observations. Preliminary data analysis has disclosed large changes in (tidally averaged) salinity and temperature structure between spring and neap tides as well as more rapid fluctuations occurring within each tidal cycle. Fronts travelling through the strait produced visible surface effects which were recorded by camera from San Juan Island.

As part of a program designed to examine the mechanism involved in fiord circulation we conducted a pilot study in Knight Inlet with the University of Washington (J. Smith) in November. Time series temperature, salinity and current observations from a moored vessel, taken to determine potential sampling problems, have revealed the presence of a large amplitude surge possibly generated by interaction of the sill. A rapid deepening of the fresher surface layer accompanied by large amplitude internal waves of about ten minute periods occurred about three hours into the flood tide at our anchor station located a few kilometers up-inlet of the sill. Further measurements to study these and other effects are planned for August 1977.

Studies of ocean dumping in coastal waters were undertaken, mainly by contract. These included a review of existing dumping technology, mathematical models for dispersion of dumped material, and a survey of oceanographic data in B.C. dumping sites. Dumping activities in Alberni Inlet motivated a study of deep water exchange based on historical data from that region. A watching brief was maintained on current developments in dumping technology.

Investigation of some practical mooring problems associated with drag due to fast currents was carried out by numerical simulations and also two test moorings. Problems were encountered in one test mooring due to instability of cylindrical buoys, as well as instrument failure, and further tests are required. But a trial mooring of a new cable fairing indicated a useful improvement in performance despite some handling problems.

A monthly sequence of CTD observations was undertaken in Saanich Inlet, Satellite Channel and Haro Strait to provide background data for our continuing study of deep water exchange in Saanich Inlet and our study of exchange processes in Haro Strait. The launch-based CTD profiling system now operates well and our effort has turned to development of a current meter profiling capability using an ultrasonic current speed sensor.

Our program of salinity and temperature observations from B.C. lighthouses has been continued. A review of some of the historical lighthouse time series has been undertaken and a study initiated to critically examine the present program in the light of the varied needs of data users. A submission on the physical oceanography of B.C. coastal waters was prepared for the Coastal Zone Resource Committee and two reports prepared summarising results of studies conducted under the auspices of the Beaufort Sea Project.

Analysis of the large body of data obtained in Rupert and Holberg Inlets in 1975 has continued, with the emphasis on elucidating the principal mechanisms for deep water exchange. Observations taken by recording instruments in Quatsino Narrows suggest a sensitive relationship between salinity in the Narrows and the form of exchange that takes place. However a problem has been encountered due to the effect of mine-tailings on instrumentation. Magnetic particles in the water interfered with observations of both current speed and conductivity, posing major difficulties in data analysis. Some additional current measurements were taken in Rupert Inlet in support of a study of mine-tailings movement by the Institute of Oceanography, UBC.

NUMERICAL MODELLING SECTION

R.W. Stewart - Head

P.B. Crean

P.J. Richards - Computing Services

R.F. Henry

M.G. Foreman - Computing
Services

Georgia Strait Modelling

Analysis of data from an extended run of the numerical model (4km mesh size) simulating tide between Vancouver Island and the mainland shows the existence of significant non-linear interactions between the dominant tidal constituents. These interactions are primarily due to frictional dissipation in the region of the San Juan Islands. Earlier versions of the model of more limited regional extent, though consistent with general practice, were too dynamically insensitive to permit the degree of adjustment required to reproduce the interactions.

Data from this model are being employed to operate a finer scale barotropic model (2km mesh size) of Juan de Fuca Strait, the southern Strait of Georgia and the region of the San Juan and Gulf Islands.

An exploratory 'upper layer' model is being developed to simulate the Fraser River plume. Extensive field observations are being obtained to assist in the design and operation of this model. It is proposed that data from the fine grid model, referred to above, will provide the effects of the tides and streams in the Strait of Georgia on the motions of the plume. This is a collaborative study with Dr. P. LeBlond and Mr. J. Stronach of the Institute of Oceanography, University of British Columbia. (Crean)

Simulation of Tides and Storm Surges

A barotropic model was developed for simulation of semidiurnal tides in the Beaufort Sea and Amundsen Gulf. Until now cotidal charts have been based on observations only, and were confined to the Mackenzie Bay - Cape Bathurst shelf area. The model results permit provisional extension of the charts for the semi-diurnal constituents to Amundsen Gulf and waters off Banks Island.

Further development work was carried out on storm surge models of the Beaufort Sea. Preliminary study and data preparation was undertaken towards the development of a barotropic model of Queen Charlotte Sound. (Henry)

OFFSHORE OCEANOGRAPHY SECTION

J.F. Garrett - Head

C. de Jong
P. Kimber
L.E. Kuwahara
J. Love

B.G. Minkley
M. Miyake
S. Tabata
R.E. Thomson
W. Wood (summer)

As in previous years, the Offshore Oceanography Section initiated a variety of research programs in 1976. In addition to the 'traditional' Station Papa monitoring program, studies of the current regimes off the British Columbia coast were made using drifting satellite-tracked drogues and ship-drift measurements reported in U.S. and Japanese Pilot Charts for the North Pacific Ocean. Contouring of the temperature, salinity and sigma-t values measured along Line P since 1969 was also begun and should provide further information on coastal currents. There was also a current metering program in the Strait of Georgia off the Fraser River Delta and in Johnstone Strait, and an investigation of the oceanography off Johnstone Strait from Cape Mudge to Queen Charlotte Strait. Details of these and other projects are found in the following subsections.

WeatherShip Oceanography

This was the 20th year of the oceanographic time series at Ocean Weather Station P (50°N, 145°W) with all nine of 1976 patrols manned by oceanographers.

WeatherShip oceanography on the CCGS Vancouver was under contract to Offshore Oceanography with three patrols contracted to Seakem Oceanography of Victoria and one to Chemex Laboratories of North Vancouver.

Manning of the CCGS Quadra was under contract to Ocean Chemistry, all five patrols being contracted to Seakem Oceanography Ltd.

In addition to the shipboard data and sample collection a contract was let to Seakem Oceanography to carry out the physical oceanographic data processing and final production of data reports.

Physical oceanographic data was published in seven reports, bringing the series up to volume 73. (de Jong).

FGGE Buoy Observing System

A number of activities directed towards meeting the need for observations of barometric pressure and surface water temperature during the First GARP Global Experiment (FGGE) in 1979 were carried on as part of Canada's contribution to that experiment. Under contract, Beak Consultants Ltd. completed a study of the feasibility of deploying the proposed drifting buoy array from volunteer ships, concluding that the ships of the ten nations willing to help could deploy at least 210 buoys and that a reasonable approximation to the required array could be obtained. A follow-on study of the capabilities of island stations to deploy buoys was also begun late in the year.

In May, a series of tests was begun to determine whether some promising commercial pressure transducers were stable enough to ensure the desired pressure measurement overall accuracy of one millibar. Six pairs of instruments including ones from Hamilton-Standard, Paroscientific and Setra have been cycled between 0° and 30°C several hundred times, with one transducer of each pair being subjected to 4 Hz 1.6 g accelerations about 25% of the time. Eight times during the period each transducer was calibrated with a dead weight tester at eight different pressures and three temperatures. After 200 days one Hamilton Standard and two Paroscientifics were still within 1 mb of their original value.

Hermes Electronics Ltd. of Halifax, as part of the Canadian Ocean Data System contract, constructed 25 prototype drifting buoys for testing in the Southern Hemisphere with the Nimbus-6 satellite in early 1977. The small size and advanced design of these buoys permit them to be easily deployed from ships with decks as high as 50 feet above the water without using cranes or davits and without stopping the ship, so that they are ideally suited for use during the FGGE. The tests will determine reliability and life time under the actual conditions anticipated during the experiment. (Garrett)

Drift Buoys

Five locally-produced drifting buoys tracked by the Nimbus-6 satellite were launched at about 58° 45'N, 145° 40'W on December 13, 1975. These buoys were initially equipped with large drogues or sea anchors suspended at a depth of 20 meters. As long as the drogues remained attached the movement of the buoys was reasonably representative of the movement of the water. Once the drogue was lost the buoy motion was mainly controlled by wind and waves. The buoys were initially launched in a line about two miles long. Within two weeks one was about 20 miles north of the others, even though all were within 20 miles of their starting point.

During most of January the buoys moved roughly east or southeast at speeds of two to six miles per day. Around January 26, when the three buoys still attached to drogues were near 132°W longitude, they all turned north, moving in that direction for about 16 days. During this period they covered a distance of 20 to 50 miles. On February 13 they again turned east to southeast. The only buoy which still retained its drogue into March showed an increasingly southerly trend, finishing up moving due south between March 6 and March 17 when it lost its drogue. After losing their drogues all of the buoys went ashore, mostly on the inner coast of Queen Charlotte Sound and Hecate Strait. One even penetrated as far as Prince Rupert. Analysis of weather data and the data from sensors on the buoys is continuing. (Garrett)

XBT Accuracy

During a cruise in August 1975 expendable bathythermograms (~XBTs) were routinely taken when leaving STD stations. A comparison of the resulting profiles, as reported in a Pacific Marine Science Report by Wayne Wood, showed that for the approximately 50 remaining after eliminating all traces containing obvious imperfections and restricting comparisons to regions without large gradients and away from the surface, the mean temperature difference between the XBT and STD was about 0.01°C and standard deviation of the temperature differences was about 0.10°C. A study of the differences in the apparent depths of isotherms as reported by the two instruments indicated that a large fraction of the relative variability of the XBT was associated with variations in the fall speed. (Garrett)

Line P Oceanographic Structure

A computer contouring program has been used to produce vertical sections of temperature and salinity along Line P as obtained from STD measurements begun in late 1968. Many of these plots show the presence of eddy-like temperature structures in the upper few hundred metres of the water column. These features are seen as strong horizontal temperature gradients which are often over 2°C in less than 150km. During the June 1969 cruises for example, four such fronts were observed in association with a system of alternating 'cold' and 'warm' cores having vertical extents of over 400 metres. Although there is generally an absence of appreciable horizontal structure in the water west of the mid-point of Line P, cores of warm or cold

water do sometimes appear. Few salinity fronts have occurred, however, and large changes in the isohalines are generally confined to the coastal regime. Updating of the Line P data is underway. (Thomson)

Lead Patterns in the Arctic Sea Ice

Satellite imagery of the Arctic Ocean commonly reveals the presence of mesoscale rectilinear leads that form a criss-cross pattern within the sea ice. These have now been explained as failure structures initiated by pressure gradients within the ice pack.

In analogy with semi-brittle fracturing found in rock mechanics, the leads form at well-defined angles depending upon the type of medium, the time rate of strain and/or the magnitude of the confining pressure at right angles to the applied stress. A three day sequence of NOAA satellite images showing the development of a lead at an acute angle to the axis of maximum compressive strain has been used to support this concept. (Thomson, with Marko)

Johnstone Strait Oceanography

As a follow-up to a tidal current investigation performed in 1973 by the Hydrographic Service, current meter moorings were deployed between April and June, 1976 at two along-channel locations 10km apart in the western basin of Johnstone Strait. A preliminary analysis of the 1976 data supports a conclusion drawn from the earlier measurements that there is a semi-diurnal internal tide generated at the shallow sill in this basin. Over 250 STD and hydrocasts were also obtained on the two cruises with detailed observations of temperature, salinity and dissolved oxygen between Cape Mudge and Alert Bay. In addition, four 25-hour time-series stations were occupied in the western basin of Johnstone Strait; STDs were taken every hour and hydrocasts every four hours. Two pressure gauges and one anemometer were also deployed midway between Alert Bay and Kelsey Bay. Further cruises are planned for 1977. (Thomson, with Huggett)

Pacific Yachting Series

The oceanographic series begun in 1974 in Pacific Yachting magazine (circulation ~ 20,000) was continued with articles on tsunamis, wind-wave generation, and currents during the 1976 Swiftsure Yacht Race. (Thomson)

Longshore Currents in the Strait of Georgia

Three current meter moorings and one thermistor chain mooring were maintained off the Iona Jetty of the Fraser River delta from May to July 1976. Winds were simultaneously measured at the end of the jetty. The purpose of this experiment was to determine if internal waves could generate longshore currents along the edge of Sturgeon Bank, and if so, to correlate the strength and duration of this current with the characteristic scales of the internal wave motions. As with last year's attempt, numerous problems were associated with the need to change the tape on the thermistor data logger every three days.

Bringing this data into usable form has been time consuming and no results are yet available. In contrast to last year, however, there was no ship-related damage as private boaters and commercial companies responded favorably to special notices directed their way. The loss of data in 1975 through damage and malfunctioning meters, in fact, provided little useful or reliable information. (Thomson with Huggett)

A Re-Examination of Vorticity Transfer Theory

The vorticity transfer theory of Taylor (1915, 1932) and the momentum transfer of Prandtl (1925, 1942) have been re-examined. In particular, we demonstrate that a diffusion-type equation for momentum also conserves vorticity whereas a diffusion-type equation for vorticity does not necessarily conserve momentum. A two-dimensional diffusing wake has been used to illustrate this point. On the basis of our analysis, therefore, Taylor's vorticity transfer theory is fundamentally incorrect. According to the referee, "This is an interesting paper, which drives a stake through the heart of a theory which is already nailed quite firmly in its coffin". (Thomson, with Stewart)

Oceanography of North Pacific Ocean

An examination of surface current velocity data for the North Pacific obtained from two independent sources by the use of the dead-reckoning method suggests that a narrow, weak, westward-flowing countercurrent is present in the latitudinal belt between 48 and 51°N, especially during the winter. The direction of the current is generally opposite to that of the winds in the region. Oceanographic survey data collected in the past do not have sufficient density, particularly along the meridians, to delineate this flow. Only two sets of observations; from the summers of 1958 and 1959, indicate the presence of a westward-flowing baroclinic transport with sufficient continuity that they could be interpreted as being associated with the countercurrent. From available evidence, the current appears to have a breadth of roughly 100km, a surface speed as high as 10cm/s, and transport as large as five Sverdrups (relative to 1000 decibar surface). It apparently occurs more often on the eastern than on the western side of the ocean.

The westward flow may originate initially in the offshore transport of water lying off the coast of British Columbia or may result from the return flow of the portion of the Subarctic Current. The latitudinal belt of the countercurrent coincides with the region of a local meridional minimum in the cyclonic wind-stress curl for the winter months. As a consequence, the existence of the countercurrent has been shown to be consistent with the westward zonal transport obtained from the application of the simple, steady state, Sverdrup-type flow.

The 22-year means of zonal transport computed for the belt, 48-51°N, indicate the presence of the westward flow for December and January and suggest such a flow for February through April as well. Values obtained for individual years show this for other months also. This

has been particularly true since 1963, when there was a sudden change in the behavior of the computed zonal transport. While the mean annual calculated zonal transport was eastward prior to 1963, it has since attained a westward component so it is now either westward or weakly eastward. This change in 1963 may be associated with the change in the behavior of the climate over the North Pacific Ocean. (Tabata)

Short-Time Response of the Upper Ocean

A strategy has been developed for obtaining proper data sets to evaluate the short-period response of the upper layer of the North Pacific Ocean west of 170°W over a four-month period in 1977. These data sets will then be used in a model to assess the relative importance of the various processes responsible for the upper layer structure. In particular, daily meteorological information that includes short-wave radiation and back radiation will be fed into the model over a 2.5° grid scale. This information will be supplemented with bi-weekly air expendable bathythermograph (AXBT) data to a depth of 300 metres from a 5° x 10° area centered around 165°W, 40°N, supplied by the scientific team of the Anomaly Dynamic Study Group of the NORPAX program. (Miyake)

Heat Budget of the Upper Ocean of Station Papa

The structure of the upper layer of the ocean is determined by air-sea interactions, by turbulent mixing processes, and by horizontal advection. Ten years of time-series data from meteorological and bathythermograph observations at Station P have been analyzed to assess the validity of various transfer coefficients.

It has been found that the coefficient of evaporation must be 60 percent higher to produce the difference between cooling in the ocean and the latent heat transfer observed in air. Since it has been difficult to account for the total heat content at Station P, extensive work on the upper ocean heat budget is still needed. (Miyake)

FROZEN SEA RESEARCH GROUP

E.L. Lewis - Head

J.W. Butcher - Computing Services	R.G. Perkin
R.A. Cooke - Survey Electronics	D.L. Richards
A.W. Koppel	+ E.E. Richards
+ J.M. McNeill	R.B. Sudar
A.E. Moody	D.R. Topham
S.W. Moorhouse	E.R. Walker
* P.E. Oswald	* P.E. Greisman - Postdoctoral Fellow

+ Joined in 1976
* Left in 1976

During February, 1976, an oceanographic survey was conducted in the Greely Fiord area (80.2°N) which culminated in a tracked vehicle journey from our base on d'Iberville Fiord to Eureka. The vehicles and sledges used were then shipped to Rea Point in a C130 aircraft to take part in current meter installations in Byam and Austin Channels mentioned below. The survey itself started near the snout of the glacier in d'Iberville Fiord, where CTD profiles show the effect of the melting ice foot, and extended over more than 200km showing the change in water structure in passing from an isolated fiord through to a channel having properties typical of the arctic archipelago as a whole. In d'Iberville Fiord ablation rates of the submerged portions of icebergs were determined by measuring the change in flotation level that had occurred since they froze into the sea-ice cover. An experiment was designed to show the horizontal extent of convective exchanges taking place in the skeletal layer of sea ice at the growing ice/water interface. These exchanges are the origin of the salt required for the downward mixing processes below the sea sheet which are of major importance in understanding water movement in an ice covered sea. Two linear arrays of thermistors at 3cm intervals were deployed at right angles just below the growing ice, and the ice/water interface advanced to encapsulate each thermistor. The expected temperature pulses associated with convection appeared on each thermistor record, but without any discernable correlation between records. This indicates that convection in the skeletal layer has a very small lateral extent. In addition, photographs of dye plumes seeping through the sea ice into the underlying water were made in an attempt to gain further understanding of the process.

During March/April, 1976, current meters were laid across Byam and Austin Channels between Melville Island and Bathurst Island at about 75.5°N. The meters were placed near the sea bed to acquire information on forces likely to act on bottom structures such as pipeline crossings, and just below the ice/water interface to estimate the potential for pollutant transport. Hourly readings taken by the bottom current meters were transmitted sonically to a hydrophone at the surface which was in turn connected to a telemetering radio transmitter. Data from the surface current meters was also transmitted, and a receiver station on Byam Martin Island recorded both

these readings and those from the lower instruments on incremental digital cassette tape. The surface units were removed at the end of July, 1976, before breakup of the ice sheet when it was found that about 65 percent of the possible data was available at the receiver station. The major weakness in the transmission system was the sonic link. A contract has been let to improve its reliability both by the design of a new hydrophone and alterations to the data transmission system within the existing current meter (Aanderaa). The bottom current meters will be picked up in February, 1977, by navigating to the same position using our range-range system. The current meters require a directional reference other than the horizontal component of the earth's magnetic field and the entire engineering design has been described by Lewis (1975). Data from these field trips has been published. Planning the deployment depended heavily upon interpretation of LANDSAT imagery to give some ideas of annual variability in ice cover and breakup patterns associated with polynias, often the results of strong local currents. These studies continue.

A major project has been a study of the definition of salinity and its calculation from conductivity measurements. The problem is very complex and has arisen because the precision and accuracy of modern measurement resolves changes in the conductivity-salinity-density relationship met with as the result of variations in the ionic composition of seawater or different authors' data reduction formulae. Very significant errors can occur in a comparison of data from one cruise to that from another made by a different institute using different instruments and different equations. Presently, internationally accepted definitions and relationships do not extend to the temperature range of greatest importance for in situ readings and do not allow the easy comparison of a local water mass, with its particular chemical composition, to that used in providing the definition. A study of the problem and a recommendation on a new definition of salinity has been published.

Arising from the Beaufort Sea Project, further study has been made of atmospheric pollution arising from burnoff of an arctic oil spill; additional work on the albedo change associated with the surface contamination of the snow/ice surface by oil has also been carried out.

The rupture of ice sheets by gas accumulated at the ice/water interface as an accompaniment to an oilwell blowout has been studied. The results are very sensitive to the physical constants assumed for the ice sheet but a 1.5m thick ice sheet, having an ice/water interface relief equivalent to the capture of 10cm thickness of gas at that location would rupture at a gas bubble diameter of order 100-200 meters. Further work on the analysis of data from the oilwell blowout simulation conducted in water of depth 65m in Patricia Bay in January, 1975, is being carried out. This has shown that the similarity solution normally applicable to buoyant jets may not be used for a 'bubbler' system of this magnitude.

As a result of the need to plan the recovery of the bottom current meters from beneath the sea ice, a study has been made of mooring systems to predict the depression and horizontal movement suffered by

our sub-surface floats marking the current meter locations when they are dragged by local currents acting on the mooring line. It was found that the commonly used equations did not express the drag components on the line properly and a new expression has been derived that introduces a small, but often significant, correction to the cable profile as previously predicted.

We have extended our experiments into the stability and reliability of the CMI ultrasonic current meters preparatory to an attempt to measure correlation coefficients in the turbulent structure of waters convecting beneath growing sea ice. The intention is to use two separated heads, each giving both X and Y components of velocity and record their output simultaneously. The separation would then be varied, and the resulting correlation, or lack of it, noted. As a necessary adjunct, the interfacing of this equipment to a small computer has been studied for an interactive experiment allowing immediate adjustment to parameters in terms of observations made. Numerous minor modifications to our arctic current meter system have been made to improve reliability as a result of this year's experience.

Considerable effort has been expended to build a sensor chain which, through simultaneous measurement of temperature and conductivity, will yield salinity. Experiments so far have been confined to the laboratory but are encouraging, and the first field tests are anticipated early in 1977.

REMOTE SENSING SECTION

J.F.R. Gower - Head

J.S. Wallace

B. Oliver - NRC Postdoctoral

R.A. Neville - NRC Postdoctoral Fellow

Fellow

During 1976 the Remote Sensing Section was involved in satellite oceanography (infrared sea surface temperature and radar wave height measurements), airborne observations of coastal B.C. waters using the MIDAS Marine Inertial Data Acquisition System, a detailed water color analysis using the 256 channel spectrometer and imagery and photography in support of other programs.

Satellite Oceanography

The usefulness of infrared sea surface temperature measurements has been demonstrated in many parts of the world as well as by our own analysis of NOAA VHRR data for the B.C. coastal waters. We have encouraged the construction of a permanent west coast satellite receiving station in Vancouver and are developing a minicomputer image enhancement facility to process the data to our own requirements.

An application of visible satellite data was dramatically demonstrated by a frame from the temporary station operated for a month in April/May 1976 in Vancouver. This showed vortex streaks developing in the atmosphere behind the Aleutian Islands in a way that could be used to test fluid mechanical theories of interest to oceanography.

GEOS-3 radar altimeter data continued to arrive during the year, but in small volume and with numerous complications that are hampering U.S. and Canadian analysis projects. It appears that waveheights should be measured to .5 metres along the satellite track, and future satellite systems, such as SEASAT, where a set of three satellites will give fuller ocean coverage, should considerably improve reporting of ocean wave conditions and could also be used in weather forecasting. Since sea surface elevation is also measured, a project to analyse ocean tide heights is also planned.

Planning for prototype SEASAT A project continues with J.F.R. Gower on the NASA team for the synthetic aperture radar experiment and on the Canadian Committee for SEASAT A participation.

Airborne Oceanography

The MIDAS system has now been developed to the stage where aircraft track recovery is accurate to better than 10 metres at all times and the positions of targets and ocean features sighted by the operator can be measured to the same accuracy. The system has been used to map surface currents in Haro Strait using floating targets deployed by launches. Interactions of water bodies at tide lines can be followed by recording both tide line and target positions. The system has also been used in an ocean dumping exercise off Point Grey and to follow the development of the Fraser River plume. Instruments have now been added to record the wind velocity at the aircraft's flying height. This is to be used to support tests of drift models for oil spills in Juan de Fuca Strait.

An examination of the effects of different vertical distributions of chlorophyll on water color and fluorescence line height was carried out in Saanich Inlet using the 256 channel spectrometer. Previous measurements here and elsewhere show that chlorophyll concentrations can be estimated and mapped from the air, but that data tends to show only concentrations near the surface. Since layers of high chlorophyll concentration are often present at various depths, the resulting maps can be misleading. Preliminary analysis shows that it should be possible to deduce information on the vertical distribution of chlorophyll from an aircraft using both color and fluorescence data from the spectroscopy.

The spectrometer was also used in Ottawa for water color measurements by the Canada Centre for Remote Sensing and for measurements of soil spectra by the Geological Survey of Canada.

Imagery and Photography in Support of Other Programs

To support the program of current measurements in Haro Strait being carried out by the Coastal Oceanography Section, surface current measurements were made with the MIDAS system (described above), three thermal scanning flights were arranged over the area and oblique photographs of a small but critical area off San Juan Island were recorded at ten minute intervals during daylight hours continuously for two and a half months.

The thermal scanning flights were made by Intera Environmental Consultants using a Cessna 206 aircraft flying at an altitude of 16,000 feet. The imagery showed fronts between water bodies of different temperatures, with evidence of upwelling, and of surface stratification as revealed by ship wakes. Such imagery can be recorded day or night, but cloud free conditions are required.

The oblique photography was taken by an unattended super-8 time lapse camera attached to a tree near the top of Mt. Dallas on San Juan Island. Fronts associated with the incoming tide pass close to the foot of the mountain and could be seen on the film on 57 days out of 73. Front velocities could be deduced on 24 occasions and timing was accurate to about ten minutes.

ARCTIC MARINE SCIENCE

A.R. Milne - Head

R.H. Herlinveaus

B.D. Smiley

The Beaufort Sea Project was an arctic marine environmental assessment program financed jointly by the Federal Government and 18 member companies of the Arctic Petroleum Operators Association. While field studies ended in September 1975, there remain seven technical reports outstanding of a total 46 technical reports expected. Six overview reports, designed for the interested layman, are in various editorial stages. So far, about 15,000 copies of technical reports have been mailed.

During 1976 field and laboratory studies focussed on the Canadian Arctic Archipelago and to a lesser extent on the Beaufort Sea. These studies were mainly marine environmental research related to petroleum development and possible oil spills and their effects.

The main arctic study in 1976, funded by the Department of Indian and Northern Affairs, related to the possibility of oil spills from tankers, marine pipelines or underwater oilwell blowouts in the vicinity of recent oil strikes on Cameron Island by Panarctic Oils Ltd. Ice movements in Byam and Austin Channels were tracked using radar during August and September; concurrent satellite imagery and surface wind measurements provide supplemental information on general ice drifts in the region. The radar showed a consistent eastward ice drift across the north end of Byam Martin Island. The radar analysis is being carried out by Seakem Oceanography Ltd. under contract.

The porosity of multi-year sea ice was investigated from early to late summer in a study designed to throw some light on the permeability of old sea ice to oil trapped beneath it. Three sets of data, obtained under various freezing and thawing conditions, showed that the porosity of the surface layer increased with thawing while the ice in contact with the sea became more porous as the ice warmed to sea temperature at the end of summer. This study was funded by the Environmental Protection Service.

In October, an environmental review of the proposed marine drilling by Norlands Petroleum Ltd. in Lancaster Sound was initiated with funding support by DINA. The review is to be completed by August, 1977 and will consider the possible impact of a deep-water oilwell blowout on the biota of Lancaster Sound.

In connection with the environmental review and the study carried out in Byam and Austin Channels, two complementary studies are underway. The first consists of a review of the Oceanography of the Arctic Archipelago using all available data. The aim is to understand the surface, sub-surface and ice movements in the channels of the Archipelago by tracing water masses and wherever possible inferring geostrophic currents. The second study is of ice movement patterns as they relate to oil-spill trajectories, primarily in the Sverdrup Islands and Parry Channel. Landsat and NOAA satellite imagery provides sequential observations of ice floes and ice edges.

In the Beaufort Sea, wave-rider buoys were deployed in a cooperative study with Imperial Oil, Canadian Marine Drilling Ltd. and DFE's Marine Environmental Data Services. Locations of interest were off Kugmallit Bay, Pullen Island, Garry Island, Warren Point and from a CanMar drillship.

In winter, from November 1975 to late March 1976, a camp was occupied in the shear zone of the southern Beaufort Sea from which oceanographic, meteorological and ice movement observations were carried out. Ice reconnaissance using aircraft extended to July 1976. The work was performed under contract by Norcor Engineering and Research Ltd. of Yellowknife with joint funding from EPS.

The Polar Continental Project provided extensive logistic support during the 1976 field season.

OCEAN MIXING SECTION

P.W. Nasmyth - Head

A.E. Gargett
G.W. Chase

R.C. Teichrob

Development of an instrumentation system for microstructure/turbulence measurement from Pisces IV has been carried through to the point where successful performance has been proven. In order to achieve a sufficiently stable 'flight path' it was necessary to design a set of stabilizing fins as was reported last year. Extensive experience in over 50 dives with the fins installed has proven completely satisfactory performance.

An interim system of sensors and a data recording package have been developed, installed and tested in Pisces IV for measurement of:

- i) three components of fluctuating turbulent velocities with a spatial resolution of 0.5cm in the longitudinal component and 3-5cm in the cross components,

- ii) temperature with a spatial resolution of a few millimeters,
- iii) conductivity with a spatial resolution of a few centimeters.

Auxilliary instrumentation measures depth, mean forward motion, vibration and submarine motions in pitch and roll, and mean water velocity past the sensor array.

A final series of trials for the year was carried out in November in four parts:

- i) in the deep quiet waters of Bute Inlet to establish noise levels for all components of the system,
- ii) in an area of strong turbulence south of Cape Mudge which has been extensively studied with earlier ship-towed equipment, to compare system performance with previous results,
- iii) in the area of the Fraser River plume to investigate the boundary layer between the river water on the surface and Strait of Georgia water beneath, and
- iv) 1-5 metres above the bottom in Malaspina Strait to investigate the feasibility of operating in the bottom boundary layer.

While these trials were of an exploratory nature to define the capabilities of the system and develop operating procedures, a considerable amount of good data was obtained and analysis will proceed during 1977.

A data analysis scheme was devised and tested for obtaining information on the vertical gradients of temperature and salinity from a horizontal measurement. Taking advantage of the fact that internal waves are continually raising and lowering constant density surfaces in the ocean, a T/S plot of the time series of horizontal data indicates whether the local temperature and salinity gradients have the same or opposite signs. Addition of the sign of the difference between two temperature measurements spaced 1m in the vertical then completes the determination of the signs of the gradients. An idea of the strength of the local density gradient may also be obtained from the slope of the curve in the T/S plane. Such information will be essential to proper understanding of high frequency velocity and temperature measurements taken at the same time during towed body operations in 1973.

A complete set of programs was put together for the analysis of data obtained with CAMEL, a profiling microstructure instrument belonging to Dr. T. Osborn of IOUBC, during a joint microstructure experiment with Woods Hole Oceanographic Institution in the fall of 1975. Processed data for each of 26 profiles include digital chart records, with signals displayed as functions of pressure rather than time, estimates of dissipation rate, calculated from the output of the Osborn shear probe, as a function of pressure, and plots of temperature and temperature difference on scales agreed upon for inter-comparison. Completion of this processing within a year has been a major effort. The data will be analysed during the coming year.

Another important project has been the development of display programming for use during operations with Pisces IV. It is necessary to check signals during the first part of any operation, when instruments are being mounted and debugged. It is also desirable to be able to display signals in scientific units and with changeable gains during any operation, both as a continuing check that instruments are operating properly and as an aid to planning further investigation. To these ends, we have developed very flexible display programs, allowing choice between volts or scientific units, and choice of gain and off-set.

OCEAN ECOLOGY LABORATORY

R.O. Brinkhurst - Head

M.J. Austin

P. Chapman - Graduate student, UVic

G. Gardner - Postdoctoral Fellow

W. Carolsfeld - summer student

The mandate of the laboratory is to carry out bio-oceanographic studies in support of the Departmental and Institute objectives, and especially to act as a catalyst between the governmental and academic biological constituency and the physical and chemical scientists of the Institute. The Laboratory Head transferred from the Atlantic Region of FMS in January 1976, and so this year has been one of policy discussion and acquisition of base-line equipment, library needs and such mundane issues as a place to work pending the completion of the new Patricia Bay facility.

An obvious need in the Region is for a time-series of oceanographic and biological information along the Canadian shelf to provide background for studies of ocean climate, environmental disturbances such as a build-up of hydrocarbons or CO₂ level changes in the atmosphere (studied by Ocean Chemistry) and for fisheries managers seeking anomalies that can be related to survival of young fish at sea. The combination of severe weather and lack of adequate platforms has made the shelf difficult of access, and this remains our major problem. A ship-of-opportunity program is being investigated as the only feasible method of operation.

Dr. D. Mackas will bring to the laboratory in 1977 his expertise on studies based on the seawater intake of vessels and Dr. G. Gardner has studied regional zooplankton communities, which brings us a good balance, especially as they come from the two major academic Institutes of Oceanography in Canada. As our biologist, M. Austin, came to us from CEPEX, we are in a good position to be in touch with several major schools of thought in plankton biology.

While planning for plankton studies continues, benthic studies are under way. Contracts have been let for studies on the effect of dredge spoil rich in wood wastes in Alberni Inlet, for the identification of other collections of benthic samples, and for a first look at the benthos of Saanich Inlet. These are part of a long-term aim to examine the oxygen budget of inlets and the value of benthic associations as indicators of natural and man-made stresses. This

bio-indicator concept has proved itself in the well-established area of sludge-worm biology.

During the year, Carolsfeld studied the fauna of the major urban drainage system reaching Victoria Harbour, and Chapman and Carolsfeld are using Westwater Institute samples of oligochaeta from the lower Fraser River to examine distribution in relation to pollution and the salt wedge. The laboratory continues to advise and educate biologists in the method of naming sludge worms, and a significant collection from Tasmania has proved especially interesting.

OCEAN ENGINEERING DIVISION

W.N. English - Chief of Division

COMPUTING SERVICES SECTION

K. Teng - Head

R.E. Johns	* R.G. Hlady - Management Services
D.B. Smith	J.S. Page - Ocean Chemistry
J.W. Butcher - FSRG	P.J. Richards - Numerical Modelling
A.N. Douglas - Tidal & Current	E. Wong - Offshore Oceanography
R. Dykes - Management Services	A.L. Woollard - Tidal & Current
M.G. Foreman - Numerical Modelling	

* Left during 1976

Departmental Computer

1976 saw the establishment of a large Regional Computing Centre for the Department in the Institute facilities at Patricia Bay. The Univac 1106, purchased from Bell Northern Research, will serve the needs of the Institute of Ocean Sciences as well as other Department of Fisheries and the Environment units in the Pacific Region. The system includes a main memory of 131K 36-bit words, approximately 47 million words of secondary drum storage, six magnetic tape units, three card-reader/line-printer combinations (one installed at Fisheries Operations in Vancouver), and some communications hardware. The operating system supports concurrent local batch, remote batch, and demand (time-sharing) processing and the software includes all the standard languages and many application packages.

Education of DFE personnel commenced in March with courses by Univac on the job control language. A resident systems analyst was assigned to DFE by Univac to assist with training and to eventually implement and support the operating system and associated software. Some users started conversion of programs to the Univac by utilizing an external service bureau (Digitech in Calgary) over the summer.

Although the Univac 1106 computer was delivered to the Patricia Bay site on May 31, building construction problems delayed completion of

the installations until the end of September. The Univac was accepted as ready for use on October 12. Following an intensive course and a number of seminars, most on-site users began conversion of programs and data files in earnest during December.

Intermittent problems with Hydro power have been the major difficulty with the system. The Univac computer is particularly sensitive to short-duration transient voltage fluctuations, which result in a CPU halt and the loss of all active runs. Although system restart is quite easy, a solution to this nuisance will be sought in 1977.

Other Developments

The computerized Financial Accounting and Reporting System was converted from a service bureau to an in-house mini-computer (HP 2100) by March. The Datapoint terminal, for off-line entry and editing of financial transactions, became operational in August. It is now possible to have a daily up-to-date picture of the financial status of the region and all collators.

Implementation of an Inventory Management System was nearly complete by the end of 1976. The system features interactive and batch entry of inventory data, and uses System 2000 for updating and maintaining the data base.

The Fortran HAAPS software was implemented and successfully used on Hydrography's PDP-8 computers during field operations. This is an improved system of routines for editing, processing, and plotting hydrographic data. It features reduced execution time and better algorithms to handle unusual conditions in the data than previous HAAPS programs. At year's end the Fortran HAAPS routines were being modified to handle data collected by the new PHAS microcomputer-based hydrographic data acquisition systems, which record on 3M cartridge drives.

Other mini-computer developments include: first use of Coastal Zone Oceanography's HP21MX processing system in the field; improved software and hardware (with assistance of Survey Electronics) for the translation of Aanderaa current meter tapes; provision of updated disc operating system software for the three disc-based HP 2100 series computers; improvements, extensions, and complete documentation for the Hp context editor.

Additional hardware acquired during 1976 includes: a large Tektronix graphical display terminal for Patricia Bay, allowing the small Tektronix to be connected to the Federal Building HP 2100; a new Versatec printer/plotter for the Patricia Bay HP 2116; four HP 2640 terminals to provide access to the Univac 1106 from Patricia Bay, the Pacific Forest Research Centre, and Fisheries Operations in Vancouver; four TI Silent 700 series terminals for access to the Univac computer.

Installation of the Univac 1106 increased the responsibilities of the senior Computing Services staff. K. Teng assumed the role of Centre Manager for the Departmental computer, R. Johns became Supervisor of Systems and Operations and D. Smith became Supervisor of Mini-Computer Systems.

THE LIBRARY

Sharon Thomson - Librarian

The year 1976 was one of expansion in the responsibilities of the Library, while the difficulties inherent in our separated locations were still very evident.

Material of interest mainly to chemists is housed in the Ocean Chemistry Division, from whence it is retrieved for borrowers in other sections. The same conditions apply to items located with Frozen Sea Research Group. One half of a trailer at Patricia Bay serves as a repository for journals used by the clientele working on the site and it must seem to the office staff there that we will wear the things out transporting them from place to place and back again.

Two new groups were added to our library clientele in 1976 - an Ocean Ecology Group and an Arctic Marine Group. It was immediately apparent their needs for biological, ecological and arctic subject matter were not going to be met from a collection focussed on physics and chemistry. We quickly embarked on a buying program to supply these groups with the core materials in their specialties. The needs of 20 biologists are really not greater in terms of core material than the library requirements of one biologist. What is called in college library circles 'an opening day collection' is exactly what we must achieve for each of these groups - and at once!

We have added on-line literature searches to our services and the response of the users so far has been one of delight. We expect this service, which only started December 15, to be more widely used now that the 'bugs' are out and more people are aware that it is available.

Our losses from the collection are large and replacements will have to be made good once we are moved to the Institute. At that time we will be able to give proper care to the collection and to start a better circulation control system. These things are now much closer to reality since we have been advised that we may be moving as soon as August of 1977.

Persons and companies who have contracts with us expect support from our Library since we have the only oceanographic collection in the area. If their requests result in a direct expense to the Library we check with the contractor supervisor to be certain the request is a valid part of the contract.

No annual Library report would be complete without a remark or two on money. Libraries are very expensive and it must seem to the administration that they are insatiable in their demands for funds. However, as the cost of our paid subscriptions averages \$100 per year and the cost of the types of monographs we buy approaches \$25 per volume it is readily apparent that \$25,000 per year will not adequately support a research collection which is growing and must continue to grow rapidly to be of real use to its patrons.

SHIP FACILITIES

E.N. Geldart - Regional Marine Superintendent

F.S. Green, Assistant Marine
Superintendent (Deck)

D. Marr, Assistant Marine
Superintendent (Engineering)

The Institute of Ocean Sciences, Patricia Bay, operated three government vessels, Parizeau, Vector and Richardson. MV Pandora II, a mothership for the submersible Pisces IV, is on long-term charter to IOS as is MV Radium Express on the Mackenzie River. The survey vessel Wm.J.Stewart was laid up during the year because of limitations in man-year allocations. The Institute operates 30 launches, of which one is configured especially for oceanography, and assorted power boats.

CSS Parizeau, CSS Vector, MV Pandora II and Pisces IV were in the West Coast ship pool of the Pacific Sub-Committee on Oceanography. Principal characteristics of these vessels are given below.

CSS PARIZEAU

Master - A.G. Chamberlain

Chief Engineer - R. Parkinson

Length overall - 64.3 m
Beam - 12 m
Draft - 4.8 m
Shaft hp - 3400
Speed - 15 kts
Range - 12,000 n.m.
Displacement
tonnage - 1929.2 tons metric

Total complement - 51
Capabilities - tidal and current
survey
oceanography
Construction - 1967 Burrard Dry
Dock Ltd., Vancouver, B.C.

CSS VECTOR

Master - J.C. Marston

Chief Engineer - J. Peet

Length overall - 39.6 m
Beam - 9.4 m
Draft - 3.3 m
Shaft hp - 700
Speed - 11 kts
Range - 3,500 n.m.
Displacement
tonnage - 505 tons metric

Total complement - 27
Capabilities - oceanography (physical, chemical, geological, biological)
Construction - 1967, Yarrows Ltd.,
Victoria, B.C.

MV PANDORA II

Master - R. Jones	Chief Engineer - C. Tuck
Length overall - 59 m	Total complement - 29
Beam - 11.5 m	Capabilities - oceanography (physical, chemical, geological, biological)
Draft - 5 m	Construction - 1974, Bel Aire Shipyards Ltd., North Vancouver, B.C.
Shaft hp - 5600	
Speed - 11 kts	
Range - 10,000 n.m.	
Displacement tonnage - 1300 tons metric	

PISCES IV

Operations Officer - G. Meek	Chief Pilot - I. Sanderson
Length overall - 6.6 m	Total complement - 7 (3 operations, 4 support staff)
Height - 3.9 m	Capabilities - oceanography (physical, chemical, geological, biological, ecological & hydrographic examinations)
Breadth - 3.3 m	Construction - 1972, International Hydrodynamics Co.Ltd., North Vancouver, B.C.
Speed - 1 ¹ / ₂ kts	
Range - 6 n.m.	
Displacement tonnage - 10 tons metric	
Depth cap. - 2000 m	

PERMANENT STAFF 1976

DIRECTOR GENERAL

Stewart, R.W.; B.Sc., M.Sc., (Queen's), Ph.D. (Cantab), FRSC, FRS,
D.Sc. (McGill), LL.D. (Dalhousie).

DEPUTY DIRECTOR GENERAL

English, W.M.; B.A. (Brit.Col.), Ph.D. (California)

MANAGEMENT SERVICES DIVISION

Todd, N.A.; B.S. (Glasgow), M.A. (Carleton) - Chief of Division

Aanhout, D.L.v.	Lohrmann, B.A.; B.Sc., M.Sc. (Guelph)
Aavik, J.F.	McKenzie, S.D.
Coldwell, J.H.	* Mackenzie, R.M.D.
Craton, M.I.K.	Martyn, B.T.
Crouch, R.W.	* Moulson, S.A.
Curtis, J.N.	* Oswald, P.E.
Doyle, D.A.	Parsons, J.E.
Drysdale, A.E.	Peirson, E.
* Egan, L.L.	Reinstein, H.G.
Firth, C.	Sabourin, J.T.
Foote, S.B.	* Smith, D.C.
Galibois, S.	Smith, G.R.; B.A.Sc.(ME) (Brit.Col.), P.Eng.
* Gravel, J.N.	Thomas, C.D.
Hall, E.J.	Thomson, L.S.C.; B.A. (Saskatchewan), B.L.S. (Brit.Col.)
Hogg, W.	Van Dusen, T.S.
Jensen, S.M.	Wakefield, L.M.
Kwiatkowski, B.S.	

* Left during 1976

COMPUTING SERVICES

Butcher, J.W.; B.Sc.(Victoria), M.Sc.(Toronto)	Page, J.S.; B.Sc. (Brit.Col.)
Douglas, A.N.; B.Sc.(Victoria)	Richards, P.J.; B.Sc. (Brit.Col.)
Foreman, M.G.; B.Sc. (Queen's), M.Sc.(Victoria)	Smith, D.B.; B.Sc. (Victoria)
Johns, R.E.; B.Sc. (Victoria), M.Sc. (Brit.Col.)	Teng, K.; B.A.Sc., M.A. (Brit. Col.)
	Woollard, A.L.; B.Sc.(Victoria)

HYDROGRAPHIC DIVISION

Bolton, M. - Regional Hydrographer

Ages, A.B.; B.A.Sc., M.A.Sc. (Brit.Col.), P.Eng.	Ma, A.C.; B.Sc. (Victoria)
Bell, R.D.	May, R.I.D.; Dip.BCIT
Bennett, K.M.	Milner, P.R.; Dip.BCIT
Brown, R.E.	Mortimer, A.R.; Master, F.G.
Browning, P.C.	Muse, R.A.; Trade Cert.CAF
Carracedo, C.	Nast, C.J.
Chan, G.L.	Nielson, G.C.
Chivas, J.W.; Master, F.G.	O'Connor, A.D.; Master, H.T. (U.K.), 350 T
Clark, D.J.	Osbourne, M.
Coldham, F.A.	Patton, M.M.
* Coldwell, J.H.	Philp, A.R.
Cooke, R.A.	Pickell, L.M.
Coulter, E.M.	Pierce, R.A.
Curran, T.A.; B.A.Sc. (EE) (Brit.Col.), P.Eng.	* Plume, T.C.
Czotter, K.L.; Dip.BCIT	Popejoy, R.D.
D'Aoust, A.J.	Preece, M.L.; Dip.BCIT
Dobrosch, L.W.	Prussner, L.E.; Dip.BCIT
Earl, E.L.P.	Rapatz, W.J.; B.Sc. (Victoria)
Eaton, G.H.; Dip.BCIT	Raymond, A.R.; Dip. Algonquin College
Farmer, M.	Richardson, G.E.
Fisher, D.L.	Ryan, C.F.; Dip.RRE (England)
* Fujino, N.S.; Dip.BCIT	Sandilands, R.W.; Lt.RN (Retd.)
Galloway, J.L.; B.A.Sc. (EE), M.A.Sc. (EE) (Brit.Col.), P.Eng.	Shoenrank, R.U.; B.Sc. (Victoria)
Gregson, D.J.; Dip.BCIT	Smithers, F.R.
Harris, W.J.	Soutar, T.J.; Dip.BCIT
Hermiston, F.V.	Stephenson, F.E.; B.Sc. (Victoria)
Hinds, E.W.; Dip.BCIT	Tamasi, C.R.; Dip.BCIT
Hohl, H.E.	Taylor, M.S.
Holman, I.R.	Taylor, W.R.; Dip.RCC
Huggett, W.S.; Master, F.G.	Thompson, L.G.
Johnson, R.W.	* Walker, K.H.
Josephson, K.G.	Wanamaker, J.G.; Dip.BCIT
Korhonen, R.K.	Watt, B.M.
Kynoch, B.D.	Watt, J.W.; B.A.Sc. (EE) (Brit. Col.), P.Eng.
Larkin, J.G.; B.Sc. (P.E.I.)	Wigen, S.O.; B.A.Sc. (BritCol.), P.Eng.
* Lee, H.R.L.	Wills, R.; Master, F.G.
* Life, J.H.	Wood, D.J.; Dip.BCIT
Loshiavo, R.; Dip.BCIT	Woods, M.V.; Dip.BCIT
Lusk, B.M.; 350 T	Woodward, M.J.; B.Sc. (Victoria), M.Sc. (Toronto)
Lyon, A.G.	

* Left during 1976

OCEAN PHYSICS DIVISION

Nasmyth, P.W.; B.A.Sc., M.A., Ph.D. (Brit.Col.) - Chief of Division

Austin, H.J.; B.Sc. (Brit.Col.)
Bell, W.H.; B.A.Sc. (Brit.Col.),
M.Sc. (Hawaii), P.Eng.
Bigham, R.H.
Brinkhurst, R.O.; D.Sc. (London)
Chase, G.W.; Dip.BCIT
Crean, P.B.; B.Sc. (Dublin),
M.A.Sc. (Toronto), Ph.D.
(Liverpool)
de Jong, C.
Farmer, D.M.; B.Com., M.Sc. (McGill),
Ph.D. (Brit.Col.)
Garrett, J.F.; B.A. (Harvard),
Ph.D. (Brit.Col.)
Giovando, L.F.; B.A., M.A., Ph.D.
(Brit.Col.)
Gower, J.F.R.; B.A., M.A., Ph.D.
(Cantab)
Herlinveaux, R.H.
Kamitakahara, G.R.; B.Sc. (Toronto)
Koppel, A.W.
Kimber, P.M.
Kuwahara, L.S.C.; B.Sc. (Brit.Col.)
Lake, R.A.; B.Sc. (Brit.Col.),
M.Sc. (Washington)
Lewis, E.L.; B.Sc., M.Sc., Ph.D.
(London)
Love, J.
McNeill, J.M.
Meikle, J.H.
Milne, A.R.; B.A.Sc. (Toronto),
M.Sc. (McGill)
Minkley, B.G.; Dip.BCIT
Miyaki, M.; B.S. (EE) (Drexel), M.S.,
Ph.D. (Washington)
Moody, A.E.
Moorhouse, S.W.
Perkin, R.G.; B.A.Sc., M.Sc.
(Brit.Col.)
Henry, R.F.; B.Sc. (Edinburgh),
Ph.D. (Cantab)
Richards, D.L.
Sieberg, D.G.; Dip.VVI
Smiley, B.D.; B.Sc., M.Sc.,
(Alberta)
Spearing, L.A.F.; B.Sc. (Brit.
Col.)
Stickland, J.A.
Stucchi, D.J.; B.A.Sc. (York),
M.Sc. (Dalhousie)
Sudar, R.B.; B.A.Sc. (Toronto)
Tabata, S.; B.A., M.A. (Brit.
Col.), D.Sc. (Tokyo)
Teichrob, R.C.; Dip.BCIT
Thomson, R.E.; B.Sc., Ph.D.
(Brit.Col.)
Walker, E.R.; B.Sc. (Manitoba),
M.A. (Toronto), Ph.D. (McGill)
Wallace, J.S.

OCEAN CHEMISTRY DIVISION

Wong, C.S.; B.Sc., M.Sc. (Hong Kong), Ph.D. (Scripps), Dip.Mar.Sc.
(UNESCO), MCIC, FRIC - Chief of Division

Bellegay, R.D.; Dip.NAIT, Ass.Deg.in Oceanography (Shoreline Community
College, Seattle)
Cretney, W.J.; B.Sc., Ph.D. (Brit.Col.)
Jackson, C.M.; B.Sc. (Victoria)
Johnson, W.K.; Dip.BCIT
Macdonald, R.W.; B.Sc., Ph.D. (Dalhousie)
McLaughlin, F.; B.Sc. (Victoria)
Munro, P.; B.Sc. (Queen's)
Paton, D.; B.Sc. (Brit.Col.)
Thompson, J.A.J.; B.Sc. (McMaster), Ph.D. (Alberta)

SHIP DIVISION

Geldart, E.N.	1st Class Marine Engineer, Fellow Institute of Marine Engineers; Regional Marine Superintendent
Green, F.S.	Master Mariner; Assistant Marine Superintendent (Deck)
Marr, D.	1st Class Marine Engineer, Fellow Institute of Marine Engineers; Assistant Marine Superintendent (Engineering)
Keene, R.W.	Master, F.G. (X); Relief Master
Henderson, J.D.	Engineer 2nd Class Steam; Depot Supervisor
Chan, C.C.	Engineer 1st Class Motor; Relief Engineer

CSS PARIZEAU

Chamberlain, A.G.	Master, F.G.; Master
Fisher, E.G.	Master, F.G.; 1st Officer
Christie, J.N.	Radio Certificate; W/O
Clarke, L.E.	Supply Officer
Parkinson, R.	Engineer 1st Class Combined; Chief Engineer
Kyle, R.G.	Engineer 2nd Class Motor; Senior Engineer
Orr-Hood, J.	Engineer 4th Class Motor; 2nd Engineer

CSS WM.J.STEWART

Sjoholm, K.J.	Master, F.G.; Master
Easson, R.J.	Master, F.G.; 1st Officer
Palmer, S.	Supply Officer
Gibson, R.B.	Engineer 3rd Class Steam; Senior Engineer
Conway, A.	Engineer 4th Class Combined; 2nd Engineer

CSS VECTOR

Marston, J.C.	Master, F.G.; Master
Bishop, S.O.	Mate H.T.; 1st Officer
Purdon, D.	Mate H.T.; 2nd Officer
Peet, J.	Engineer 3rd Class Motor; Chief Engineer
Pearson, R.	Engineer 3rd Class Motor; 1st Engineer
Knoblauch, I.	Engineer 4th Class Motor; 2nd Engineer

CSS RICHARDSON

Wheeler, M.G.	Master, 350 T; Master
Henderson, J.N.	Engineer 4th Class Motor; Chief Engineer

MV RADIUM EXPRESS

O'Sullivan, J.	Master
Butler, W.	Chief Engineer

MV PANDORA II (Charter)

Jones, R.	Master
Tuck, C.	Chief Engineer

PISCES IV

Meek, G.R.	Operations Officer
Sanderson, I.	Chief Pilot
Chambers, F.	Pilot
Taylor, R.H.	Pilot
Jacobson, R.	Pilot
Gaudreault, J.	Pilot
Grant, D.	Pilot

SCIENCE RELATED CONTRACTS AWARDED IN 1976

PACIFIC CONTRACTS

1.	Identification of ecological indicators of ocean mixing in Haro Strait. <i>Dobrocky Seatech, Victoria, B.C.</i>	\$ 8,988
2.	Sampling of marine benthic fauna in Saanich Inlet. <i>Beak Consultants, Vancouver, B.C.</i>	9,985
3.	Identification of benthic samples. <i>Envirocon Ltd., Vancouver, B.C.</i>	1,309
4.	Sample analysis to investigate distribution of benthos in relation to ocean dumping. <i>P. Chapman, Victoria, B.C.</i>	3,240
5.	Sample analysis to investigate distribution of benthos in relation to ocean dumping. <i>W. Carolsfeld, Victoria, B.C.</i>	5,760
6.	Digestion in sludge worms. <i>N. Kaushik, Guelph, Ont.</i>	6,500
7.	Analysis of lighthouse oceanographic data. <i>I. Webster, West Vancouver, B.C.</i>	3,440
8.	Analysis of lighthouse oceanographic data phase III. <i>Associated Engineering Services Ltd., Vancouver, B.C.</i>	16,064
9.	Placing and recovery of an experimental instrument mooring. <i>Dobrocky Seatech Ltd., Victoria, B.C.</i>	4,500
10.	Experimental mooring of current meters to test cable fairing. <i>Dobrocky Seatech Ltd., Victoria, B.C.</i>	8,500
11.	Feasibility and design study for a profiling current meter platform. <i>Canadian Thin Films Ltd., North Vancouver, B.C.</i>	8,000
12.	Updating computer system software to achieve compatibility of context editor at the Institute of Ocean Sciences. <i>Apocalypse Enterprises Inc., Victoria, B.C.</i>	2,136
13.	Provision of computer operations services for Dept. of Environment, Pacific Region computing centre. <i>Ronor Management Ltd., Ganges, B.C.</i>	32,702

14.	Development of a computer program for ocean mixing. <i>Apocalypse Enterprises Inc., Victoria, B.C.</i>	\$17,976
15.	Development of computer programs for hydraulic research. <i>Apocalypse Enterprises Inc., Victoria, B.C.</i>	17,789
16.	Development of computer programs for remote sensing. <i>Apocalypse Enterprises Inc., Victoria, B.C.</i>	11,960
17.	Provision of field support for geological surveys in the Fraser River and Georgia Strait. <i>Dobrocky Seatech Ltd., Victoria, B.C.</i>	21,288
18.	Study of the Squamish estuary by means of aerial photography to assess the effect of port construction. <i>Pacific Survey Corp., Vancouver, B.C.</i>	746
19.	Water properties sampling and measurement program aboard CCGS Vancouver at Ocean Station P. <i>Seakem Oceanography Ltd., Victoria, B.C.</i>	47,825
20.	Evaluation of water samples for analysis of trace metals and hydrocarbons in seawater. <i>Seakem Oceanography Ltd., Victoria, B.C.</i>	10,673
21.	Field support for chemical oceanography and sampling in Georgia Strait. <i>Dobrocky Seatech Ltd., Victoria, B.C.</i>	10,500
22.	Assistance in organizing and participation in the CEPEX field experiments. <i>Thalassic Data Ltd., Vancouver, B.C.</i>	6,027
23.	Oceanic water properties sampling and measurements aboard CCGS Quadra and chemical analysis of seawater in shore laboratories. <i>Seakem Oceanography Ltd., Victoria, B.C.</i>	63,972
24.	Deployment of CEPEX bags. <i>Case Existological Laboratories Ltd., Victoria, B.C.</i>	2,250
25.	Development of techniques for extraction of lead in tuna fish and mercury extraction method for marine sediments. <i>J. Alix, Victoria, B.C.</i>	1,659
26.	Development of analytical techniques for measurement of concentrations of natural and anthropogenic hydrocarbons in seawater, marine organisms and marine sediments. <i>P. Christensen, Victoria, B.C.</i>	4,500

27.	Analysis of ocean chemistry plankton samples from the CEPEX CO ₂ project. <i>J. Chang, Port Hardy, B.C.</i>	\$ 3,000
28.	Service to coat all lead diving weights with epoxy paint for CEPEX bag deployment. <i>Case Existological Laboratories Ltd., Victoria, B.C.</i>	1,000
29.	Physical oceanography of Haro Strait. <i>Dobrocky Seatech Ltd., Victoria, B.C.</i>	72,000
30.	Examination of the movements of oceanic fronts in Haro Strait. <i>S. Yee, Sidney, B.C.</i>	2,700
31.	Data survey and recommendations for an oceanographic study of Haro Strait. <i>Associated Engineering Services Ltd., Vancouver, B.C.</i>	7,096
32.	Computer sorting of hydrographic data. <i>Apocalypse Enterprises Inc., Victoria, B.C.</i>	443
33.	Revision of Canadian Hydrographic Service charts and the supply of information for B.C. Sailing Directions. <i>I. Campbell, Sidney, B.C.</i>	2,000
34.	Study of the feasibility of using photogrammetric techniques to obtain data necessary to generate hydrographic charts. (Aerial Hydrography project). <i>S.E. Masry, Fredricton, N.B.</i>	16,800
35.	Development of computer programs for field hydrography. <i>Apocalypse Enterprises Inc., Victoria, B.C.</i>	4,875
36.	Specialized revision of hydrographic charts. <i>Case Existological Laboratories Ltd., Victoria, B.C.</i>	32,619
37.	Contouring of computer-sorted hydrographic data. <i>Dataplotting Services Ltd., Don Mills, Ont.</i>	500
38.	Oceanographic water properties sampling and measurements aboard CCGS Quadra. <i>Seakem Oceanography Ltd., Victoria, B.C.</i>	3,877
39.	Biological and oceanographic research support. <i>University of Victoria, Victoria, B.C.</i>	8,000
40.	Oceanographic support to the Institute of Ocean Sciences. <i>Dobrocky Seatech Ltd., Victoria, B.C.</i>	33,000

41.	Research study on shelf wave propagation along the B.C. coast. <i>L.A. Mysak, Vancouver, B.C.</i>	\$ 5,000
42.	Cooperative research on fiord dynamics for ocean sciences. <i>University of B.C., Vancouver, B.C.</i>	17,204
43.	Development of improved airfoil probes for oceanographic measurements. <i>University of B.C., Vancouver, B.C.</i>	5,000
44.	Feasibility study of deploying drifting buoys from islands during the First Global Experiment - part of the Global Atmospheric Research Program (GARP). <i>Beak Consultants Ltd., Vancouver, B.C.</i>	8,000
45.	Study of chlorophyll concentrations in seawater. <i>R.A. Neville, Sidney, B.C.</i>	12,900
46.	Numerical modelling of the movement of the Fraser River discharge in the southern Strait of Georgia. <i>University of B.C., Vancouver, B.C.</i>	3,075
47.	Preparation of zooplankton species reference collection. <i>University of B.C., Vancouver, B.C.</i>	325
48.	Analysis of oceanographic data from weather ship cruises. <i>G.C. Jewsbury, Victoria, B.C.</i>	3,150
49.	Analysis of Patricia Bay sediment samples. <i>Chemex Ltd., North Vancouver, B.C.</i>	484
50.	Preparation of oceanographic data in digital form for the Fraser River plume. <i>University of B.C., Vancouver, B.C.</i>	1,012
51.	Airborne thermal scanning of Haro Strait. <i>Intra Environmental Consultants Ltd., Calgary, Alta.</i>	2,155

ARCTIC CONTRACTS

52.	Installation and recovery of wave-rider buoys in the southern Beaufort Sea. <i>Seakem Oceanography Ltd., Victoria, B.C.</i>	2,410
53.	Study on sea-ice distribution and sea-ice-air interaction. <i>G. Bugden, Victoria, B.C.</i>	350
54.	Study of Beluga and Bowhead whales in the southern Beaufort Sea. <i>F.F. Slaney and Co., Ltd., Vancouver, B.C.</i> (Funded by Beaufort Sea Project)	9,000

55.	Overview study and report related to the fate of oil in sea ice. <i>A.L. Watson, Victoria, B.C.</i> (Funded by Beaufort Sea Project)	\$ 9,875
56.	Analysis of oceanographic field data from the Canadian Arctic Archipelago. <i>D. Fissel, Victoria, B.C.</i> (Funded by EPS)	15,350
57.	Radar tracking of ice in Byam Martin area. <i>Seakem Oceanography Ltd., Victoria, B.C.</i> (Funded by DINA)	20,762
58.	Assembling and analysis of arctic oceanographic data. <i>G.R. Wilton, Victoria, B.C.</i> (Funded by DINA)	19,880
59.	Satellite image analysis and ice forecast evaluation pertaining to the Canadian Arctic Archipelago. <i>J.R. Marko, Victoria, B.C.</i> (Funded by DINA)	22,000
60.	Overflight studies of spring breakup of transition zone ice in the Beaufort Sea. <i>NORCOR Engineering and Research Ltd., Yellowknife, N.W.T.</i>	23,952
61.	Field studies in the seasonal and permanent polar ice pack of the Beaufort Sea. <i>NORCOR Engineering and Research Ltd., Yellowknife, N.W.T.</i>	84,913
62.	Development of a scientific oilspill response plan for the Beaufort Sea. <i>LGL Ltd., Edmonton, Alta.</i> (Funded jointly by DINA and OAS)	19,630
63.	Preparation of a selective annotated bibliography of the biology of Lancaster Sound and vicinity. <i>LGL Ltd., Edmonton, Alta.</i> (Funded by DINA)	13,374
64.	Analysis and dating of Beaufort Sea surface sediment samples by lead-210 method. <i>Thalassic Data Ltd., Vancouver, B.C.</i> (Funded by Beaufort Sea Project)	4,800
65.	Modification and testing of Beaufort Sea meteorological model. <i>Atmospheric Dynamics Corp., Elsmire, Ont.</i>	2,975

OCEAN DUMPING STUDIES

66.	Study of the effects of dumping dredge spoils containing wood debris on the benthic community in Alberni Inlet. <i>Dobrocky Seatech Ltd., Victoria, B.C.</i>	\$32,130
67.	Toxicity of leachates from dredge spoils containing wood wastes. <i>EVS Consultants Ltd., Coquitlam, B.C.</i>	8,147
68.	Chemical and physical analysis of samples containing wood debris. <i>Econotech Services Ltd., New Westminster, B.C.</i>	11,070
69.	Ocean dumping training manual. <i>Valerie Bradshaw, Vancouver, B.C.</i>	4,500
70.	Evaluation of additional data from Point Grey dump site. <i>Seakem Oceanography Ltd., Victoria, B.C.</i>	2,357
71.	Mercury mobilization from resuspended dredge spoils. <i>Seakem Oceanography Ltd., Victoria, B.C.</i>	21,514
72.	Collection of sediment samples at Mamquam Channel. <i>Chemex Labs Ltd., North Vancouver, B.C.</i>	4,762
73.	Heavy metals in marine benthic organisms at the Point Grey dump site. <i>Cantest Ltd., Vancouver, B.C.</i>	2,038
74.	Biotransformation of inorganic mercury to organo-mercurials in Mamquam Channel sediments. <i>Willis Cunliffe Tait & Co., Ltd., Victoria, B.C.</i>	8,900
75.	Design of a benthic corer for Pisces IV. <i>Canadian Aircraft Products, Richmond, B.C.</i>	5,500
76.	Investigation of coring techniques for areas with extensive wood debris. <i>B.H. Levelton & Associates, Ltd., Victoria, B.C.</i>	8,000
77.	Core samples from Mamquam Channel. <i>B.C. Research, Vancouver, B.C.</i>	1,650
78.	Establishment of a tentative oxygen budget for Alberni Inlet. <i>Seakem Oceanography Ltd., Victoria, B.C.</i>	2,000

UNSOLICITED PROPOSALS

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| 79. | Improvement of high speed acoustic telemetry links on present current meter systems.
<i>Caulfield-Liron Consultants. Edmonton, Alta.</i>
(Funded by DSS) | \$123,500 |
| 80. | The evaluation of a multi-beam sonar as a new hydrographic survey system.
<i>McElhanney Offshore Surveying and Engineering Ltd., Vancouver, B.C.</i>
(Funded by DSS) | 104,420 |

