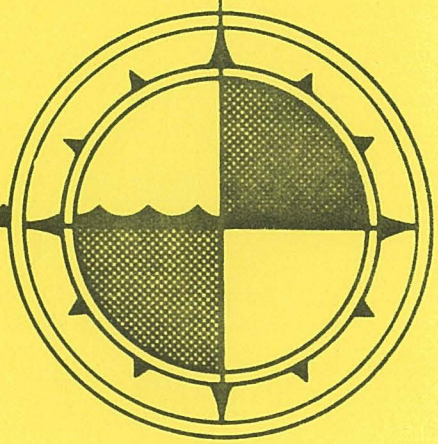
INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY

ANNUAL REPORT – 1976



INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY
Victoria, B.C.

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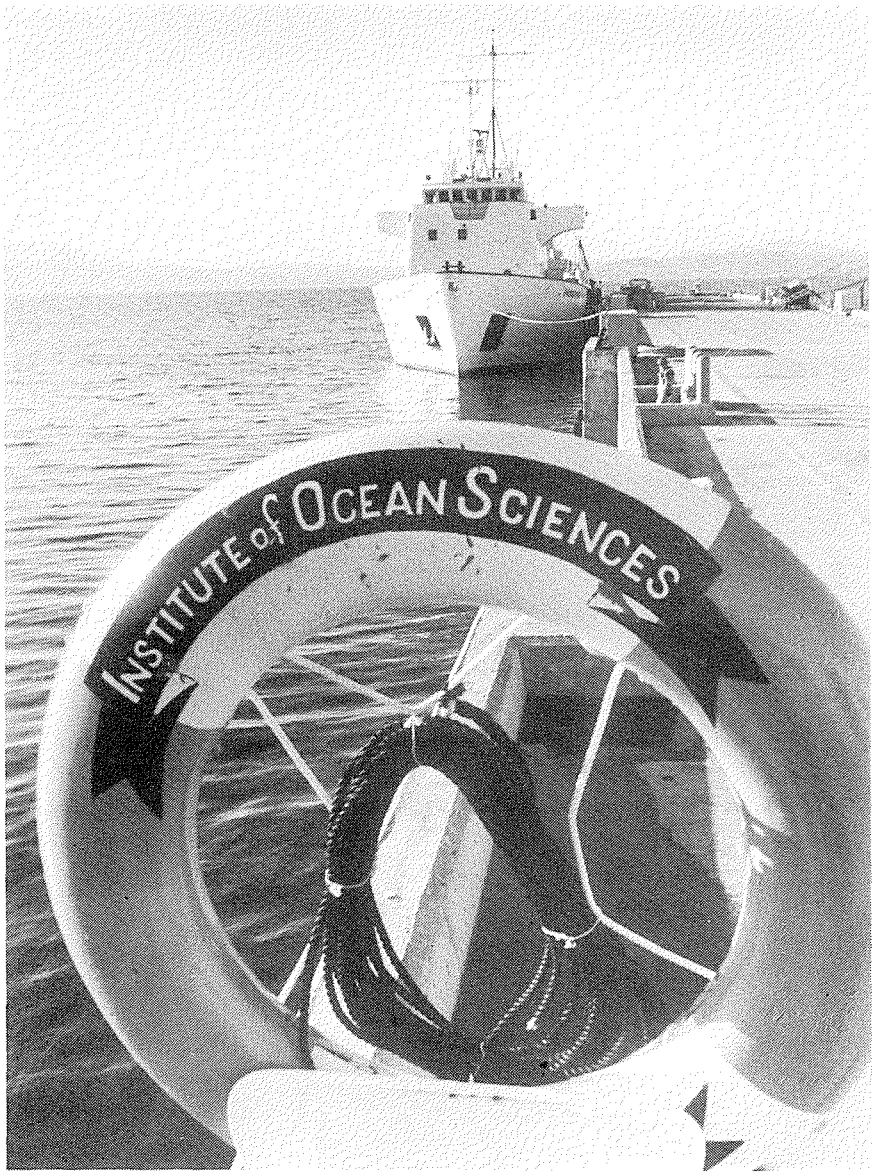
ANNUAL REPORT 1976



VICTORIA, B.C.

APRIL, 1977

INTRODUCTION

As is the case for all years, 1976 saw its successes and its disappointments, its appointmemnts and retirements. Perhaps most notable of the successes is the progress in the construction of our new Institute at Patricia Bay. The dock area and the depot building surrounding the old hangar have now been completed and are occupied permanently by stores and personnel of Ship Division, and temporarily by other groups awaiting completion of the main building.

Because of accurate judgment of the probability of labour disputes in the construction industry during 1976, and fairly accurate judgment of the intensity and duration of these disputes, it has proved possible to keep quite closely to planned construction and cash-flow schedules. Although we have suffered some cost over-runs, these are very minor compared with those of some other construction projects in the country.

It is anticipated that a major section of the new building housing Ocean Physics and, later, a substantial portion of Hydrography, will be occupied in May, 1977. As the building comes off paper and takes form as glass and concrete and carpets, it continues to give the impression that it will be an attractive and effective place in which to work. The site is of course magnificent - even inspirational. We must trust that, after the first blush, not too much time will be spent admiring the view. My personal experience from other places where I have worked leads me to believe that this will not in fact be a problem.

The major disappointment of the year was the failure of CSS Parizeau to get into the Beaufort Sea. In her attempt to round Point Barrow and the north coast of Alaska, she encountered heavy multi-year ice which impeded her progress for many days and eventually caused such damage to both propellors that the summer's operation had to be abandoned. In the end she was brought back to Victoria by the Canadian Forces tug St. Anthony, which performed this long tow with great efficiency. The loss of the year's hydrographic work in the western Arctic was a severe blow, following as it did two years when hydrographic studies of the area were deliberately forsaken in favour of the oceanographic program of the Beaufort Sea Project.

The Hydrographic Division responded quickly and efficiently to this extended loss of our major ship. Although they were unable to attempt any work in the Amundsen Gulf, which was Parizeau's destination, shore-based launch operations were rapidly expanded and a substantial quantity of valuable hydrographic work was performed in British Columbia coastal waters.

Although not perhaps in the category of a disappointment, since we were never led to expect better, the increasingly tight restrictions on man-years and on money, together with increasing demands for our services, continue to keep our operations under the greatest of strain.

Although some things have been improved by increased efficiency, and we confidently expect further efficiencies when we move together into our new Institute, the level of service and support available to our professionals is unquestionably decreasing.

Of retirements, none compares in impact and significance with that of Dr. W. N. English, Deputy Director-General. Dr. English has a wealth of experience gained in a variety of posts in the Canadian Federal Government. He knew how the system worked, and he got things done. Those of us who worked with him learned a lot from him and we will continue to get things done. The organization of the Institute of Ocean Sciences has always been designed to suit the people here, rather than the other way round. The post of deputy director-general was established to accomodate Dr. English's abilities. With his retirement the post will not be filled. His duities will be covered by a re-distribution of responsibilities amongst other members of the staff.

Almost of the nature of a retirement has been the decision not to reactivate the William J. Stewart for the field season of 1976. The continuing squeeze on financial and man-year resources made it impossible for us to return her to service. She is a fine old ship, attractive to the eye and comfortable to sail in. It hurts to see her idle, but we could do no other. The cost of support of all kinds has increased markedly in the past few years and the most effective use of resources appears to be to hold or even increase our professional staff while accepting a decrease in support.

Some notable acquisitions and appointments have taken place. The decentralization policy in the Hydrographic Service has led to an increase in our local chart production capability, at the expense of that in Ottawa. We have been able to make a start on our long-planned Ocean Ecology Laboratory although, under conditions of restraint, it may be many years before it achieves the size that the importance of the work warrants. Two people from the Pacific Environment Institute were transferred to us, adding strength to our chemistry effort. We have expanded our large-scale air-sea interaction program, and in particular our attempts to develop an understanding of the influence of the ocean on weather and climate. In the same move we have very much tightened our relationship with U.S. groups working on the same problem, particularly in the NORPAX program.

Readers familiar with our annual reports may find the following pages somewhat more philosophical in their tone than is customary. This is a spin-off from an examination of Departmental programs which is being undertaken within the framework of a "Zero A-Base Review". I have considered it useful that some of the material prepared for this review should be included in the 1976 Annual Report.

R. W. Stewart

HYDROGRAPHIC DIVISION

M. Bolton - Regional Hydrographer

The primary objective of the Hydrographic Division of the Institute of Ocean Sciences is to provide accurate and timely bathymetric and navigational information. This information, published in the form of nautical charts, tide tables and Sailing Directions, is made available to various users, including commercial shipping, fishermen, and recreational boaters. Pertinent data are provided for other federal government agencies, engineering and consulting firms, universities, environmental groups and the general public. The Division is operationally responsible for integrated geophysical-hydrographic surveys of the continental slope and margin.

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 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 radio navigation 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.

FIELD HYDROGRAPHY SECTION

R. Wills - Regional Field Superintendent

F.A. Coldham
K.C. Czotter
G.H. Eaton
*N.S. Fujino
J.B. Larkin
B.M. Lusk
R.I.D. May
P.R. Milner
A.R. Mortimer
A.D. O'Connor
R.A. Pierce
R.D. Popejoy
M.L. Preece
L.E. Prussner
A.R. Raymond
G.E. Richardson
R.U. Schoenrank
C.R. Tamasi
*K.H. Waller
J.G. Wanamaker
D.J. Woods
M.V. Woods

*Left during 1976.

R.W. Sandilands - i/c Sailing Directions
J.W. Chivas
L.M. Wakefield

J.B. Larkin - i/c Hydrographic Development
+A.D. O'Connor
+G.H. Eaton
+A.R. Raymond
A.J. D'Aoust (at CCRS Ottawa)

+Rotational staff on Hydrographic Development

This Section is responsible for all hydrographic field operations in the Pacific Region (British Columbia, Athabasca-Mackenzie Waterway, Western Arctic) and includes Hydrographic Development and Sailing Directions.

The CSS William J. Stewart was not available to the Hydrographic Service in 1976 with the result that increased use was made of shore-based launch parties, operating in southern British Columbia waters. Hydrographic surveys of Nanoose Bay, Ucluelet Harbour, Nanaimo Harbour, Becher Bay, Malaspina Inlet and Saanich Inlet were completed. Further work was done in Barkley Sound, including Pipestem and Effingham Inlets. A survey of Sabine Channel in the Strait of Georgia was 80 per cent completed. Control and photo-identification work was carried out in the Vancouver Harbour area in connection with plots to be prepared for 1977 surveys. A minor large-scale survey was completed at Victoria to augment earlier Victoria Harbour and Trial Islands surveys.

The CSS Parizeau, with B.M. Lusk as hydrographer-in-charge, continued hydrographic and geophysical surveys northward along the continental margin of Vancouver Island, closing the gap between 1975 work and 1973 surveys of Queen Charlotte Sound. In July Gebco lines were run en route to the western Arctic but the ship suffered ice damage off

Point Barrow and was unable to reach the survey area.

Revisory work, employing mainly the launch Revisor, with A.R. Mortimer as hydrographer-in-charge, covered the Vancouver Island coastline and adjacent mainland coastlines as far north as Rivers Inlet. A field contract was let for the first time to undertake chart revision work, and to update Sailing Directions, on the mainland coast north of Queen Charlotte Sound. This proved to be a most successful and economical operation and a considerable amount of useful information was obtained.

On the Athabasca-Mackenzie Waterway the main task of the charter vessel Radium Express, with M.V. Woods as hydrographer-in-charge, was a survey of the navigation channel through Eskimo Lakes from Liverpool Bay to Hans Bay, the proposed site of a new natural gas plant. Gulf Oil Limited provided considerable support and assistance on this project. The survey of Mackenzie Bay was completed and new surveys were conducted in Kittigazuit Bay, at Hay River, and from mile 90 to mile 140, chart 6407.

Preparations are underway for the calibration of the Loran-C positioning system mentioned earlier. Reconnaissance trips were made to the transmitter sites at Williams Lake and George, Washington. Mr. A.R. Mortimer is in charge of this project.

Sailing Directions

The tenth edition of B.C. Sailing Directions, (South Portion), Volume 1, was received from the printers in December. Revision of the B.C. Sailing Directions (North Portion), Volume II, and Small Craft Guide, Volume II, is in hand for 1977 publication.

The third edition of Small Craft Guide, Volume I, is expected in January 1977. The limits of this publication have been extended to include Port Alberni to Sooke and Nanaimo to Campbell River. In conjunction with Small Craft Guide, Volume II, coverage for small craft is now extended to the southern waters where the majority of recreational boating takes place in British Columbia.

Compilation of a gazetteer of local place names containing approximately 2,000 local and superseded names has been compiled for limited distribution for Canadian Hydrographic Service and Air Sea Rescue use. Canadian Coast Guard authorities report that this cross index of local to official place names has been of great value in rescue incidents where the vessel in distress has identified its position only by reference to a name in local use. A cooperative program with the Canadian Coast Guard cutters on coastal patrol was initiated which resulted in the receipt of valuable data for revision purposes.

Hydrographic Development

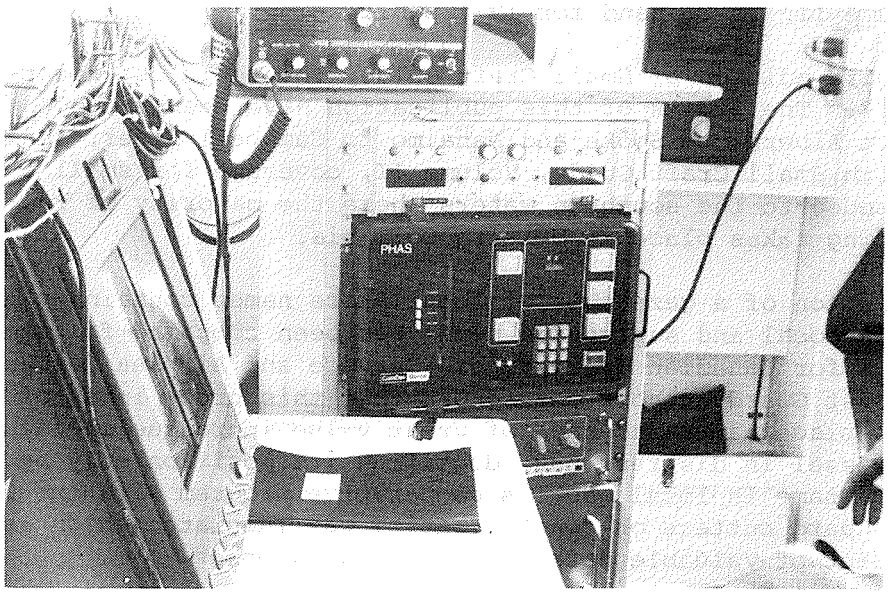
The Aerial Hydrography Project on shallow water surveying continued at Canada Centre for Remote Sensing. Final flight tests are anticipated by the fall of 1977.

Four Portable Hydrographic Acquisition Systems (PHAS) units were delivered, and preliminary testing was carried out in the northern portion of Saanich Inlet. Units were sent to the other Regions for evaluation, and the system was used on local surveys done after CSS Parizeau returned from the Arctic. PHAS will be fully operational for the coming field season.

Specifications were prepared for a suitable winch, tow cable and attachments for using side-scan sonar from CSS Richardson. After thorough evaluation, the system is now in routine operation and has proved extremely useful. Since it is on a small but seaworthy vessel, it is available at short notice without disrupting the schedule of the larger ships.

Investigations were conducted into wind-powered battery charging sources to relieve logistic support of microwave positioning transponders at remote sites. The performance of an unsolicited proposal contract to demonstrate BOSUN sonar sounding techniques in Juan de Fuca Strait was monitored.

Support was provided to various groups, including positioning for scientists monitoring ocean dumping sites in the Strait of Georgia; positioning and control for MOT personnel altering sector lights at Kootenay Lake; and completion of the field training portion of the 1975/76 Hydrography I course for Pacific Region candidates.



The new Portable Hydrographic Acquisition System (PHAS) was installed in the launch Jaeger for field trials in Saanich Inlet.

TIDAL AND CURRENT SURVEY SECTION

S.O. Wigen - Regional Tidal Superintendent
W.J. Rapatz - Acting Regional Tidal Superintendent

A.B. Ages - i/c Hydraulic Research
A.L. Woollard (Computing Services)
W.S. Huggett - i/c Current Surveys
A.N. Douglas (Computing Services)
W.J. Harris
J.J. Manson
F.V. Hermiston
M.J. Woodward
F.E. Stephenson - i/c Tidal Survey
R.E. Brown
C.C. Carracedo
D.E. Hilder
A.C. Ma
*L.E. Ponse
A.J. Smedley
*W. Tario

*Left in 1976

As an integral part of the Canadian Hydrographic Service, the Tidal and Current Survey Section provides the mariner with tidal and current information essential for safe navigation. It also provides data for and interacts with the coastal zone, offshore and Arctic oceanographic sections, in various oceanographic studies.

The Hydraulic Research Unit further improved its numerical models of the Fraser River estuary, the approaches to Vancouver Harbour and Burrard Inlet. The models provide navigational information and also information on water levels and on the diffusion of pollutants in the lower reaches of the Fraser River. A field program on the behaviour of the 'salt wedge' in the main arm of the Fraser was carried out in cooperation with the Water Survey of Canada and the Department of Public Works. Further development of oil spill tracking methods was carried out.

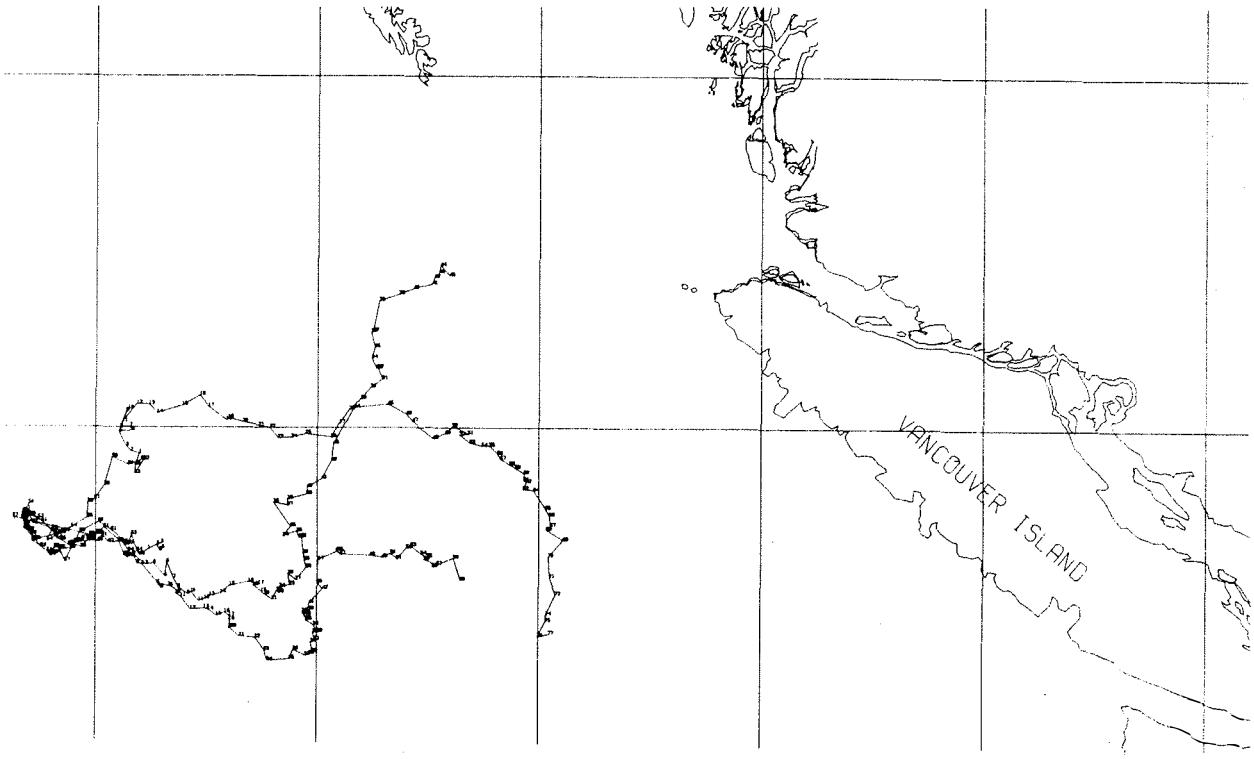
Three major tidal and current surveys were carried out, in Haro Strait, Johnstone Strait and the approaches to the Fraser River, the latter two being a continuation of previous surveys. Oceanographic personnel participated in the surveys and many temperature and salinity profiles as well as current meter records were obtained. The data will be used in the definition of tidal streams and currents in the interest of safe navigation, as well as for studies of oceanographic processes as discussed in the oceanographic part of this report.

Tidal and current survey operations were carried out in the Mackenzie River and in the Western Arctic. These surveys provided datums for hydrographic charting in the Eskimo Lakes and Mackenzie Delta, field information for storm surge and tidal prediction in the Beaufort Sea, and 205 days of current information for ice movement prediction in the vicinity of Herschel Island. The demand for tidal information in the Western Arctic is increasing, and dual air/water pressure gauges were installed at Tuktoyaktuk, Cape Parry and Cambridge Bay which it is hoped will provide a continuous year-long record of tidal level at the three locations. As part of a modest continuing study of tidal processes in the north-east Pacific, the submersible Pisces IV was used to look for tide gauges installed for us by USA agencies on Bowie Seamount and Cobb Seamount. The Bowie search was

successful and an invaluable 416 days of open ocean tidal data was recovered. The extreme tidal range over this seamount was 4.0 meters, four times what was expected.

All instrumentation for the temporary and tsunami-warning tide gauge stations was maintained, overhauled, repaired and distributed from the Section's workshop. The field data from 23 stations (permanent, temporary and tsunami-warning) and from 25 gauges operated by field hydrographic parties, was processed, yielding over 300 months of tidal data.

A very considerable effort has been devoted to the reading, editing and compiling in improved format of data tapes and other current and tidal records. This has made available new information for the three volumes of Tide and Current Tables for which the Institute is responsible and which have now all been updated.



Mean daily positions of satellite tracked drifting buoys launched Dec. 13, 1975. One mark corresponds to each day. The buoys are attached to drogues suspended at a depth of 20 metres. Their mean direction of motion changes several times during the period, indicating changes in current patterns. Although most of the buoys lost their drogues through a weakness in design, the most easterly retained its drogue for 95 days.

CHART CONSTRUCTION SECTION

F.R. Smithers - Regional Chart Superintendent

R. Bell
K. Bennett
P. Browning
*P. Buckley
G. Chan
D. Clark
E. Coulter
D. Dobson
E. Earl
M. Farmer
D.L. Fisher
M. Hohl
K. Holman
R. Johnson
K. Josephson
R. Korhonen
B. Kynoch
A. Lyon
C. Nast
G. Neilson
M. Patton
*K. Peterson
L. Pickell
R. Pierce
A. Philp
*T. Plume
M. Taylor
L. Thompson
*J. Underwood
*J. Unti
*K. Vaino
B. Watt
*V. Young
*W. Young

*Left in 1976

During 1976 the Chart Construction Section moved towards establishing a total package for the production of nautical charts in the Region. With the exception of 10 metric format charts of the Gulf Islands now being produced in Ottawa, all compilation, drafting, printing, correction and distribution of Pacific Coast, Western Arctic and Athabasca-Mackenzie Waterway charts is done locally. Hydrographic headquarters in Ottawa retains quality control and approval for release of charts.

This development has been possible through a transfer of man-years and personnel from headquarters. Nine positions were reallocated, with an additional three to be transferred over the next two years. Understandably some growing pains were experienced during the transition. Problems with contract chart printing centred around colour densities as some inconsistencies in the tone of buffs and blues were experienced. These appear to be resolved, while the cooperation and service from the printer continue to be first rate.

During the summer the processing of both new editions and reprints lagged behind the demand for charts and several 'out-of-stock' situations developed. The critical factors were old or damaged reproduction material, which had to be rescribed, and the relative inexperience of some of the staff. Neither factor should apply in 1977.

The following statistics give some indication of the work accomplished:

*New editions	9	Charts distributed	158,567
*Reprints	32	Publications distributed	64,096
*New charts	2	Dealers inspected	40
Notices to Mariners	115	Dealers established	23
Chart patches	23	Dealers withdrawn	18
Chart corrections	1,300,065	**MAREPS processed	324

*Includes compilation, drafting and printing.
**MAREP - Marine Reporting System established in cooperation with Canadian Power Squadrons.

Because of manpower limitations and the heavy workload, the Section temporarily discontinued the provision of graphic arts services in the Institute. The same constraints precluded participation in displays or

SURVEY ELECTRONICS SECTION

J.V. Watt - Head

W.R. Taylor - Head, Technical Support
R.A. Cooke (with Frozen Sea Research)
L.W. Dorosh
D.G. Gregson
E.W. Hinds
R. Loschiavo
R.A. Muse
M. Osborne
C.F. Ryan
T.J. Soutar (with Ocean Chemistry)

T.A. Curran - Electronics Engineering
J.L. Galloway - Electronics Engineering

The Section provides electronics engineering and technical support for survey, research and ship operations in the Region. The demand for these services continues to grow each year as the amount and sophistication of electronic equipment in use increases. The resources of the Section were severely strained in 1976, and it was only possible to provide technical support, at a minimal level, to major cruises. Planned maintenance has been drastically reduced, with an inevitable future increase in down time, and the technical back-up to the electronics engineering effort has been well below optimum. Despite these difficulties substantial progress has been made in up-grading the electronic systems used for regional survey and research.

Engineering Support

A significant amount of engineering effort went to supporting Field Hydrography following the delivery of the new Portable Hydrographic Acquisition System (PHAS), which is based on a micro-processor and is lighter, more compact and more reliable than earlier systems. The support involved acceptance tests, field trials, test equipment, interfacing and software.

Paper studies were carried out on echogram optimization, contouring, automatic plotting and depth digitization, to meet regional needs. A project on the recovery of valuable Arctic data from a very poor quality tide gauge recording resulted in the development and construction of a highly refined reader for Aanderaa tapes. Some minor projects in support of oceanographic programs were the development and construction of a computer to multi-channel strip chart recorder interface, a camera timer and an engineering study of data returns from a drift buoy experiment.

Technical Support

1976 field activities included provision of technical support aboard both charter and government ships, and ashore, at a variety of sites, in support of a number of shore-based hydrographic survey parties. In addition the group successfully modified and set up a Mini-fix chain in the Rho-Rho mode and performed the modifications necessary to operate, for the first time, an Innerspace 408 digitizer in a programming mode. Other significant actifities included a study of radio communication problems from Victoria to Point Barrow; development of plans for more effective mobile electronics support for shore-based field parties and preparation for the 1977 Loran-C calibration operation. New field equipment such as the PHAS acquisition system, an EPC graphic recorder, a 5 km, ±1 meter accuracy, Trisponder system, new microprocessor based Omega and Loran-C positioning system receivers and an Innerspace 412 depth digitizer have added spice to the maintenance and installation diet during 1976.

J. Love, D. Smith and T. Curran with Aanderaa tape translation system. Data, recorded in coded form in submerged instruments, is read from recovered tapes and translated into computer compatible format for processing.

OCEANOGRAPHIC DIVISIONS

The oceanographic activities of the Institute are in three ocean areas: coastal, deep sea and Arctic. The paragraphs which follow discuss the factors which have shaped the Institute's program in these areas.

The present day reasons for studying the ocean are to describe ocean systems, - physical, chemical and biological, and to define ocean processes and reactions in order to understand and evaluate the effects, direct and indirect, of the ocean on human activities and the impact of human activities on ocean systems. One might include scientific curiosity, and this has, indeed, been a significant reason for much of the oceanographic research which has been done in the past. In these times of economic restraint and limited resources, however, very little oceanography is done out of curiosity alone. There are too many pressing, practical problems demanding attention, - problems associated with the extraction of ocean resources, - renewable and non-renewable, the effects of coastal engineering developments on the marine environment and on fisheries and wildlife habitats, deliberate dumping and/or accidental spillage of pollutants, navigation, transportation, recreation, and a host of other human activities which interact with or are affected by the ocean directly or in secondary ways.

Coastal Oceanography

It is in the coastal area where the most varied and most intensive interactions between man and the sea take place, and it is in this area that a very large proportion of the available effort is expended on investigations of immediate practical importance. Industrial developments and engineering activities involving coastline modification are in conflict with fisheries interests. Domestic and industrial wastes entering coastal waters through sewer or river systems interact with local ecosystems and may affect human health through direct recreational contact with the water or through the food chain. Underwater cables and pipelines may pose a threat to marine life in case of leaks or breakage, and their positioning and design must take into account bottom material and configuration and the stresses imposed by water currents.

In case of accidental spillage of potentially dangerous or noxious materials - particularly oil, and particularly in populated areas or areas of special ecological concern - it is necessary to understand surface current patterns and the effect of local winds on surface drift in order that the movement of spilled material can be predicted and countermeasures planned for maximum effectiveness, and it may be necessary to have a knowledge of deep currents and mixing and diffusion processes in order to assess the potential hazards from dissolved or suspended materials. It is

necessary also to recognize and understand natural trends or changes in the marine environment. Not only may these themselves affect biological productivity and/or the harvesting of fisheries resources, but failure to account for natural changes can lead to complete misinterpretation of observations in terms of the influence of man.

Recognizing the importance of and limitations in supply of coastal ocean resources, and recognizing existing and potential conflicts between the many diverse users of coastal waters it has become necessary to establish management procedures and controls to reconcile and arbitrate amongst the multiple demands on the ocean system, to take account of continuing increase in human population in coastal areas, and to allow continuing industrial expansion without unacceptable degradation of the marine environment or its resources. To, firstly, recognize and define real or potential problems in any of the subject areas referred to and, secondly, attempt to find solutions or acceptable compromises, it is necessary to understand water currents and circulation patterns, mixing and diffusion processes, temperature variations, water mass origin and distribution, chemical baselines, the pathways and fate of pollutants and aspects of local ecosystems at lower trophic levels. It is to gain knowledge of these and related subjects that our Coastal Oceanography program is designed.

Limitations in available resources place severe restrictions on the scope of programs which can be undertaken. Areas for work are selected according to national and regional priorities, modified according to shifting pressures of the moment, although flexibility is limited by the inherent nature and variability of the ocean. It may take one to three years to develop a reasonable understanding of a particular area, and longer to define long term trends on which future planning should be based. To some degree economic or political pressures which may shift with shorter time scales must be resisted if we are to make efficient use of the limited resources available.

The most cost-effective use of public funds in coastal oceanography necessitates a balance between seeking longer term scientific goals that have general application in coastal waters and a task-force like attack on specific urgent problems. Longer term programs permit the development of a sound physical understanding of processes likely to be encountered in specific locations and also lead to the development of strong scientific capability among the individuals involved. Urgent practical problems are then much more effectively tackled by making use of this scientific expertise which has been allowed to develop with longer term projects.

Deep Sea Oceanography

Most major institutions carrying out oceanography regard deep sea oceanography as the centre of their operations. However, the oceanic area for which the Institute of Ocean Sciences is responsible is so large, and the resources available to it are so limited, that this is not the case for

IOS. Most of the effort of the Institute is concentrated on coastal waters. Nevertheless, a significant offshore effort is maintained. Resources employed are kept to a minimum by using situations of opportunity and by cooperating with American groups working in our geographic area. An appreciable amount of effort is employed in seeking ways of obtaining data more cost-effective than the dispatching of expensive well equipped research ships into the open Pacific.

The outstanding situation of opportunity on the west coast is the existence of the weatherships "Vancouver" and "Quadra" operating out of Esquimalt to Station "P" at Latitude 50°N Longitude 145°W. The primary mission of these ships is meteorological. Substantial oceanographic programs can be mounted from them for minimal additional cost. A great deal of our deep sea oceanography is built around this opportunity.

Deep sea oceanography is carried out at IOS for the following motivations:

1. Generalized oceanic pollution: The northeast Pacific contains the oldest water in the world in the sense of the water which was least recently in contact with the surface. It is also the water of the northern hemisphere which is least subject to the direct influence of man, and therefore a very important baseline area in considering the general health of the ocean. Since the world's oceans are connected and water circulates more or less freely among all oceans, materials such as radioactive wastes, petroleum hydrocarbons and PCBs introduced into the ocean at any point on the globe may eventually affect Canadian ability to use ocean resources such as fish. The topics requiring investigation are oceanic circulation, oceanic mixing and the chemistry of potential pollutants which could increase or decrease concentrations and availability. It is also important to determine as well as possible the present condition of the ocean so as to be able to detect deterioration or amelioration. It is important to recognize that if the ocean as a whole becomes polluted in some subtle but biologically important way, the volume involved is so great that remedial action may be difficult to the point of being impossible.

2. Climate: Several of the theories purporting to account for climatic fluctuations give a prominent role to variations in temperature of the northest Pacific. Canada, as a northern country, is very vulnerable to the effects of climatic fluctuations and it is important that the Canadian government scientists be able to offer the best possible advice on the probable evolution of climate and the possibility of predicting climate change.

   Most of the solar energy reaching the earth is absorbed in the oceans as heat since the oceans cover 75% of the earth's surface and since the atmosphere is practically transparent. Horizontal differences in the ocean surface temperature associated with varying insolation between polar and tropical regions but modified

by the ocean circulation lead to horizontal temperature differences in the overlying atmosphere, leading in turn to atmospheric circulations. However the winds associated with the atmospheric circulation control the oceanic circulation and hence in turn the availability of heat to drive the atmospheric circulation. The ocean also acts as a reservoir or buffer for other substances which can potentially affect the atmospheric circulation and hence the climate, such as carbon dioxide and water. Variations in the ocean can lead to changes in the atmospheric circulation, affecting the weather and climate.

Because of its geographical situation, the Canadian economy is sensitive to climate trends in the areas of energy production and consumption, agriculture, forestry, and all occupations involving work outdoors. It is thus important to have the earliest possible information and advice on possible climate variations so as to permit effective planning. Important problem areas are ocean response to atmospheric inputs, atmospheric circulation response to oceanic conditions, chemical storage of carbon dioxide, and historical climatology.

One major Institute activity is the maintenance of the oceanographic time series at Ocean Weather Station "P". It is impossible to detect variations or trends in climate without long records. The series of observations from Station "P" was begun in 1954, and is one of the two or three longest systematic series of mid ocean observations available. A comparatively recent addition to this series is the measurement of the carbon dioxide content of the air and water. The air measurement clearly show the steady increase hitherto only seen from land stations, and provides conclusive evidence that the phenomenon is global and that the ocean is not able to absorb carbon dioxide rapidly enough to lead to reduced fluctuations over the sea. The sampling is presently carried out by commercial concerns under contract, leading to a significant increase of the oceanographic capabilities of the private sector.

3. Interaction of deep sea and coastal waters: It has become evident that a great many of the things observed in coastal waters, which influence such coastal phenomena as the flushing of pollutants and the environment of fish, are very strongly determined by events occurring in the deep sea. These coastal phenomena will never be understood or made predictable without a deeper understanding of what is occurring in the deep ocean.

   Generally speaking coastal waters are a mixture of offshore ocean water with water from coastal rivers. To some extent the properties and behaviour of coastal waters are controlled by local influences, meteorological or otherwise, but variations in the offshore waters making up the largest part of the mixture cannot be neglected. Neither can dynamic influences originating in the deep ocean. (The tides are the most obvious of these influences, but there are a

host of other, more subtle, types of waves which propagate into inshore waters and greatly complicate our attempts to understand what goes on in these waters). This is particularly true in more open areas, such as the water of the continental shelf, or Queen Charlotte Sound, Hecate Strait and Dixon Entrance. Thus in order to obtain the understanding of coastal processes necessary for fisheries management and pollution control it is necessary to have an understanding of the variability of adjacent offshore waters. In addition to the problem of observing and describing the character and behaviour of the offshore waters, a special problem area exists because the effects of rapid changes in depth, as over the continental slope, radically alter the possible dynamics and lead to much greater variability along the coast than would otherwise be possible.

Arctic Oceanography

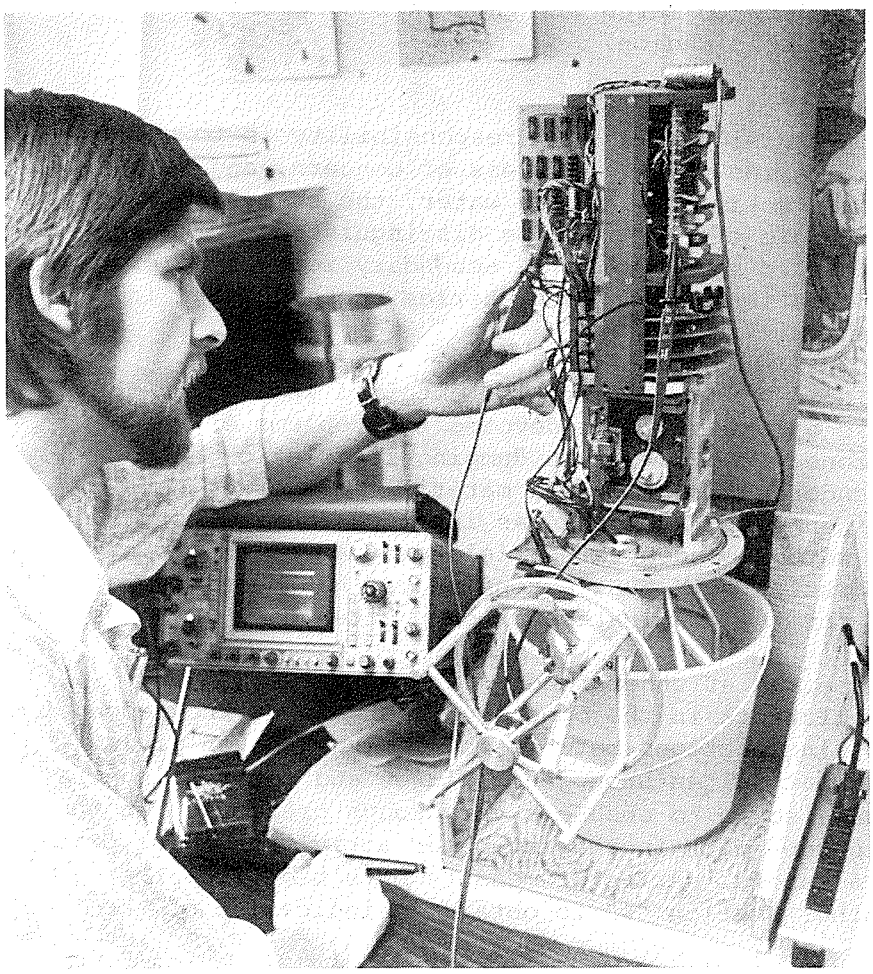
Petroleum and natural gas offshore exploration is taking place in the Beaufort Sea and the Sverdrup Basin. Drilling could take place in Lancaster Sound, on the Baffin Island Shelf, Davis Strait and Cumberland Sound in a few years' time. The waters supporting these activities will form the barriers as well as the routes through which the energy yielded by the sea bottom will reach markets to the south. These waters can also become the recipients of tailings from mines and form the pathways and boundaries for spilled oil. The seasonally and geographically variable sea-ice forms part of the boundary separating the waters from the atmosphere and has as much to do with defining the locations of high biological productivity as does the presence of nutrients in the water itself.

The oceanography of Arctic waters is a key element in the overall management of human activities in the Canadian high Arctic. Water transports nutrients which are needed to nourish biota at the base of the food chain. Water also transports pollutants such as heavy metals and toxic chemicals and emulsified and dissolved hydrocarbons. Sea-ice can herd floating oil, and surface currents spread oil. Water and ice thus importantly influence the destination of pollutants and their concentrations which must be known to assess possible damage to wildlife. In the design of offshore drilling systems, currents in the water column determine marine riser stresses; also should a sub-sea blowout occur, these currents will determine the distribution of oil at the surface. Water movements through the islands of the archipelago permit persistent polynyas or open water areas to exist. Their importance biologically and their role in possibly concentrating oil pollution is unknown.

Investigations in Arctic oceanography relate directly to legislative responsibilities in accordance with the Arctic Waters Pollution Prevention Act and the Ocean Dumping Control Regulations. It is in defining operating conditions and assessing the consequences of non-compliance or

accidents that the main difficulties exist relating to the adequacy of oceanographic information. Even though the industry must take a large responsibility for environmental observations, the regulatory function of Government requires that Government officials have both knowledge and expertise relevant to Arctic oceanography. This region takes the major responsibility for determining physical oceanographic conditions in relation to drilling permits in the Arctic.

Historically, Arctic oceanography, with few exceptions, has been conducted on an opportunity basis with a resulting emphasis on locations accessible by ice breaker and on measurement spanning short time intervals. These features have imposed such limitations on measurements that they have yielded little information other than informed guesses on water mass movements and their variability relative to atmospheric driving forces. We have reached the stage of knowing where and what to measure next in the process of developing a working hypothesis of water movement -- at least in the archipelago. However, the required measurements have not yet been taken. Until they have, and have been analysed, our information will remain rudimentary.



Acoustic current meter, used by Coastal Zone Oceanography Section, undergoing laboratory testing.

OCEAN CHEMISTRY DIVISION

C.S. Wong - Chief of Division
W.J. Cretney - Head, Marine Hydrocarbons
R.W. Macdonald - Head, Chemical Oceanography

R.D. Bellegay - Station P coordinator
C.M. Jackson
W.K. Johnson
F.A. McLaughlin
P.S. Munro - CEPEX coordinator
J.S. Page (Computing Services)
D.W. Paton
J.A.J. Thompson - Heavy metals pollution

P.A. Christensen (NRC Postdoctoral Fellow)
K. Kremling (Visiting Scientist, Institut für Meereskunde, University of Kiel, F.R.G.)
E. Matsumoto (NRC Postdoctoral Fellow, from Geological Survey of Japan)
J. Piuze (NRC Postdoctoral Fellow to March 31, then on secondment from Fisheries Management, Quebec Region)

The Ocean Chemistry Division's primary responsibility is to understand the chemical state of marine waters in areas of concern, and to assess the chemical effects of human activities on the water, the suspended matter and the bottom sediments. These effects must be distinguished from large natural and often non-systematic variations. A secondary role is to provide chemical oceanographic information useful in fisheries research, and in the study of water transport and mixing.

Analysis has continued of the information obtained in 1975 in the Beaufort Sea. Considerable effort has been devoted to problems of the British Columbia coastal zone. The new ocean dumping legislation has drawn attention to the need to understand how dumped materials disperse, settle and interact with the environment. Response has included chemical studies of ocean dumping problems with a concentrated field program at the Point Grey dumpsite. In collaboration with EPS, extensive use has been made of the submersible Pisces IV for the examination of dump sites.

Another program is aimed at understanding the distribution and variability of chemical pollutants in the open ocean, acquiring knowledge of the major transport paths, interactions between the living and non-living reservoirs, estimating the natural anthropogenic fluxes and determining the relevant chemical reactions, so as to enable a very rough prediction on the capability of the ocean to cope with increasing human activities. The principal effort in 1976 was a careful series of measurements made from the weatherships at Ocean Weather Station "P" to obtain an indication of the

variability of pollutant concentrations and also to test new techniques of chemical analysis. Due to the fact that extremely small concentrations of many pollutants may affect marine resources or their utilization, some effort has to be devoted to development of methods to detect reliably minute concentrations of pollutants in sea water or in marine organisms.

Marine Carbon Budget

(Wong, Bellegay, Munro, Jackson, Page)

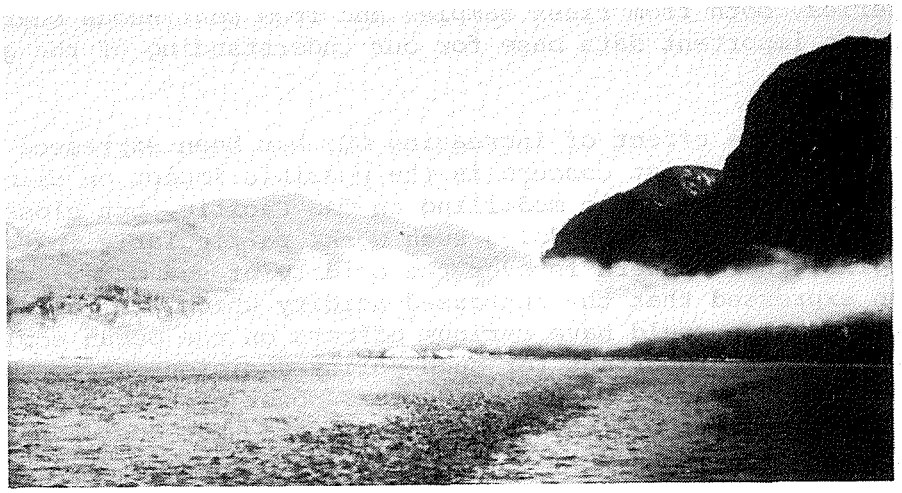
Efforts to document the increase in background atmospheric CO_2 over the ocean are now in their eighth year at Ocean Weather Station "P" (50°N, 145°W). Weekly air samples were collected on the weatherships CCGS "Quadra" and CCGS "Vancouver" and analyzed in our infrared CO_2 laboratory, which also performed air CO_2 analysis and reference gas calibrations for other Canadian CO_2 stations, at Sable Island in the Atlantic and at Alert in the Canadian Arctic, manned by the Atmospheric Environment Service. Continuous air CO_2 records by infrared analysis on the weatherships were started in April 1976, and the time series, both from flask samples and from continuous chart recording, form an important data base for our understanding of the global carbon budget.

Concern over the effect of increasing CO_2 has been expressed from two points of view. The first concern is the possible impact on climate. No work is being done on climatic modelling in OAS Pacific, but close contact is maintained with groups doing such work, particularly in the United States. The other concern is over the acidity of sea water, where fears have been expressed that the increased acidity which will accompany increased carbon dioxide could have serious effects on the ocean ecology. These questions are very important for such policy decisions as to whether our future energy needs should be met by nuclear power or by burning fossil fuels. (The former has its own environmental dangers, but does not add to the CO_2 tension in the atmosphere).

The atmospheric CO_2 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 ocean or the biosphere. These absorption processes are very complex and are poorly known at present. Carbonate chemistry of the surface mixed layer, global oceanic circulation and marine organic carbon cycle have to be considered. Thus, at Station "P", times series are also studied for carbonate chemistry, partial pressure of CO_2, carbon isotope ratio and radiocarbon in the surface waters and the marine atmosphere.

The effect of the marine biosphere on the CO_2 cycle is being studied using a ¼ scale CEE[1] enclosing 60,000 litres 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 CO_2 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. Water samples were analyzed for phosphate, nitrate, silicate, chlorophyll, carbon productivity, plankton biomass, pH at 25°C, alkalinity, total CO_2, carbon isotope ratios, particulate organic carbon, dissolved organic carbon, temperature, salinity and detritus carbon. 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 pH 7.2.

The preliminary results this year indicated that in experiments where nutrients were injected the low pH bags showed a time lag of one to two days in both the increase of photosynthetic activity and the increase in the biomass of plankton (indicated by the Chlorophyll-a content in seawater). This result is similar to what was observed in 1975 in a bag adjusted to a pH of 7.6. The low pH seems thus to have some effect, but apparently not a catastrophic one.



Chlorine cloud released into the atmosphere through an accident in the FMC plant at Squamish

Marine Hydrocarbons

(Cretney, Christensen, Macdonald, Wong, 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 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 both on the baseline levels of hydrocarbons in the Southern Beaufort Sea, and the distribution of tar and other particulate pollutants along the Beaufort Sea coast and offshore islands.

[1] "Controlled Ecosystem Enclosure"; see discussion of CEPEX which follows.

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 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 hydrocarbons in fish suggest marginal presence of petroleum hydrocarbons in the tissues. The 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. 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.

A new 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. This 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.

The concept of 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 that the source of much of this material was inland, transported by the Mackenzie River.

To meet the stringent requirements of obtaining samples which are not contaminated in the taking, 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

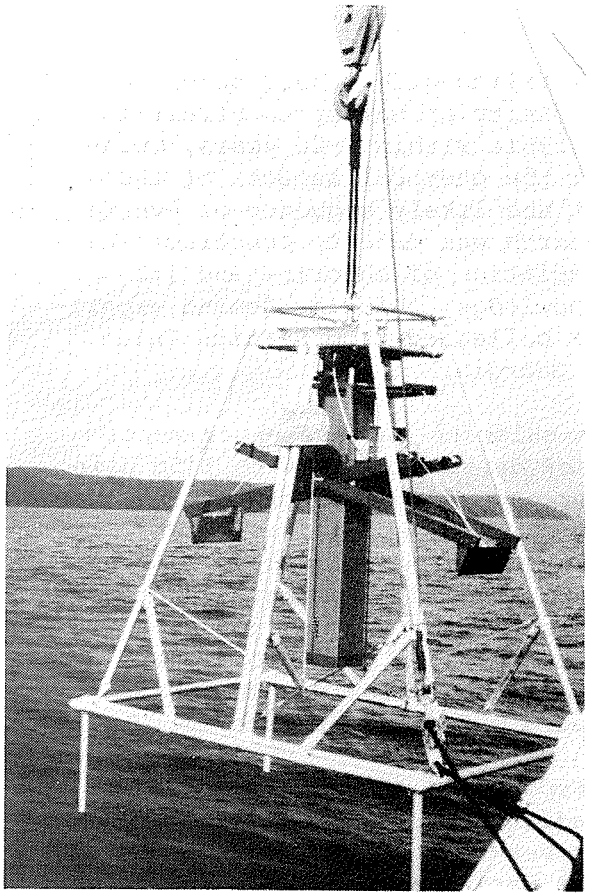
(Wong, Kremling, Piuze, Matsumoto, Macdonald, Johnson)

The main objective of this program 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. For seawater, the key problem is the reliability of the sampling and analysis of trace metals at the sub-parts per billion level. There is also the problem of trace metal detection and chemical species identification in a complex biological matrix, and of the assessment of physiological significance at such low metal levels. For marine sediments, the mobilization and fluxes of metals are the important factors for understanding the behavior and pathways of metal contaminants in ocean management problems.

The ubiquitous presence of lead aerosols in the air has caused serious unreliability in lead determinations. Thus, the study of the levels of lead in the environment requires extreme care in every step of sample collection, handling, work-up and analysis to ensure that the sample is not contaminated during or after collection. Using very special techniques, the levels of lead and other heavy metals in the Strait of Georgia have been measured in connection with the ocean dumping project. Preliminary results indicate much lower values for dissolved metal concentrations than previously obtained. Lead levels, by flameless atomic absorption, were 0.03-0.7 µg/kg. Lead by mass spectrometry was 0.04-0.27. Other metal levels determined were cadmium, 0.0l-0.07 µg/kg; copper, 0.1-1.4; zinc 0.3-3.3; mercury 0.0-0.07.

In response to an urgent concern regarding mercury levels in the north, Ocean Chemistry conducted a crash program to analyze the plankton, fish and surface sediment samples collected during the 1975 Beaufort Sea cruise, and accelerated the processing of shipboard data on seawater mercury levels. The seawater and surface sediment in the southern Beaufort Sea were found to have values of mercury lower than any reported in the literature, 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.

The dumping ground off Point Grey near the estuary of the Fraser River is the largest dumpsite in Canada for disposal of dredge spoils from river channels and from building construction and excavation. The behaviour and dispersion of dumped material was studied by sampling of seawater for trace metals, suspended matter and other characteristics following controlled dumps. 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 relative 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 release of metals from dumped material.



Sediment collection by the Soutar-Bruland undisturbed box coring device in the Strait of Georgia

To explore the possibility of a chemical screening test for potential dump material, a laboratory study was made on the release of absorption of trace metals (lead, copper, zinc, cadmium and mercury) from a dredge spoil sample, when placed in seawater at a suspended matter concentration similar to natural conditions. Lead and mercury showed a fourfold increase before dropping back to initial concentrations later. A more comprehensive study of the release of mercury from resuspended sediment 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 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, frozen immediately after collection, were x-rayed for template reference and sub-sampled for trace metal analysis and lead-210 dating. Preliminary results indicated a sharp discontinuity in lead-210 dates when ocean dumping took place. The same technique was also applied to Beaufort Sea samples to assess the sedimentation rates in near-shore areas.

Chemical Oceanography and Pollution Chemistry

(Macdonald, Wong, Bellegay, Jackson, Munro, McLaughlin, Thompson, Paton)

Long-term trends of chemical parameters at Ocean Weather Station "P" (50°N, 145°W) were monitored as a continuing effort of the Division. Newston-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 CO_2, surface alkalinity, total CO_2 and surface radiocarbon were taken. Continuous shipboard infrared measurements of marine air CO_2 and pCO_2 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 weathership program also included collection of tritium samples and measurements of mercury and dissolved aromatic hydrocarbons 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 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, 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 using 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 as well as white flakes of hydrates was 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 gaseous explosion caused by localized superheating of liquid chlorine is not expected to be a problem at the anticipated water temperature.

The Controlled Ecosystem Pollution Experiment (CEPEX) is an international cooperative program, involving Canadian, American, British, Japanese and West German scientists. It was set up 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 experiments performed on the carbon dioxide cycle, on cadmium and on lead, using a 1/4-scale CEE (Controlled Ecosystem Enclosure) with about 60,000 litres of seawater, and an experiment on low-molecular weight hydrocarbons utilizing the full-scale CEE.

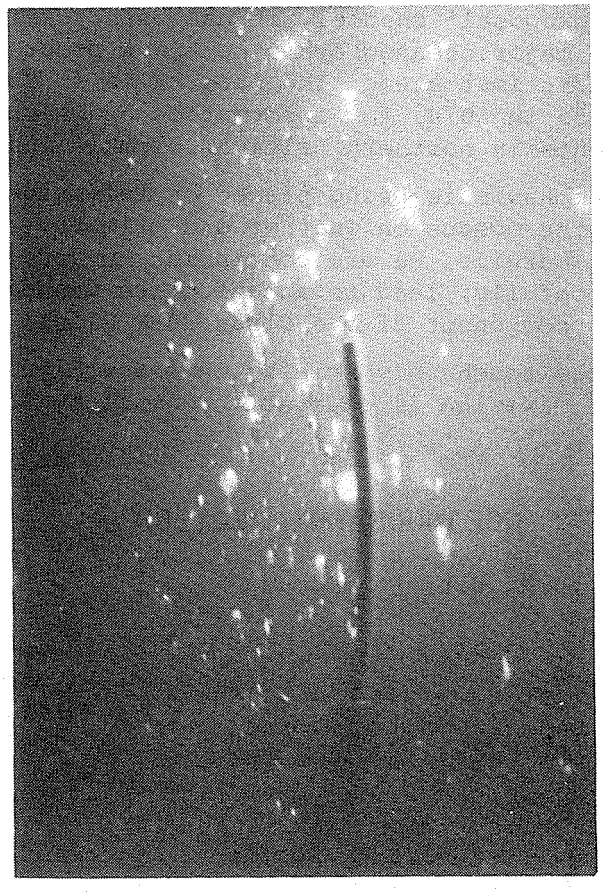
Results from 1975 had shown the insignificance of the removal of cadmium by organic matter and the association of low cadmium content in particulates with high productivity. In 1976, a second cadmium experiment was conducted using two 1/4-scale CEEs, one as control, one spiked with about 1 μg of cadmium per litre. Work is in progress on chemical analysis of samples of dissolved cadmium, particulate cadmium and detritus material.

An experiment on lead was carried out in 1976 using three 1/4-CEEs, with one as a control, one spiked with lead-210 and lead-206, and one with tetraethyl lead. Preliminary results showed that lead decreased by about 50% of its concentration in seawater during the 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.

During the period of CEE experiments by Dr. R. Lee of Skidway Institute, August 16-30, measurements of low-molecular-weight hydrocarbons were made in a full-scale control 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 following artificial fertilization. This experiment shows that these hydrocarbons are produced naturally in the ocean - a fact of considerable importance in the interpretation of pollution-related observations.

Dr. J.A.J. Thompson and Mr. D.W. Paton transferred to the Division from the Pacific Environment Institute in July and have been setting up facilities for 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 also being studied.



Liquid chlorine released from Pisces IV to observe behaviour of liquified gas. Chlorine bubbles can be seen rising and hydrate particles sinking.

OCEAN PHYSICS DIVISION

P.W. Nasmyth - Chief of Division

The Ocean Physics Division has continued to operate through 1976 at approximately the same funding level and with the same allocation of permanent staff as in 1975. Without any significant increase in internal resources it has nevertheless been possible to mount a substantial post-Beaufort Sea program with funds contributed by the Environmental Protection Service and the Department of Indian and Northern Affairs, and the logistic support of industry involved in northern activity.

It has also been possible to increase our level of activity on the British Columbia coast through contracts with the private sector. Over a period of years a substantial capability in the ocean sciences has been developed in local industry, but the extent to which this capability can be utilized is limited, of course, by the availability of funds for contracting. However, with support from the Department of Supply and Services through their 'unsolicited proposal' channel, it has been possible to undertake detailed planning of a major oceanographic contract program to begin in 1977 in the Camano Sound/Kitimat area. The program is in response to increasing demands, predicted in 1974, for information on which to base environmental impact assessments in northern British Columbia coastal waters.

A modestly increased emphasis is being placed on investigations relating to the influence of the oceans on weather and climate. Jointly with the Atmospheric Environment Service, we are continuing to develop techniques and hardware which will, hopefully, lead to an effective Canadian contribution to the 'drifting buoy' component of the First GARP Global Experiment.

The preceding paragraphs touch only briefly on a few highlights and trends. The program of the Division is covered in detail by Section in the following pages.

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)

The work of the Offshore Oceanography Section is primarily motivated by the need to establish offshore water-quality baselines, to understand the oceans' role in climate, and to determine the influence of the offshore regime on the coastal regime. In pursuit of answers to these complex oceanic problems, the Ocean Station P monitoring program has been continued and studies of ocean current patterns off the British Columbia coast have been initiated using satellite tracked surface drogues and ship-drift reports. Oceanographic data collected between Station P and the coast is also being analyzed for long period changes in water properties

and for the occurrence of 'events' that could be correlated with short term climatic variations.

Despite its name, work by members of the Section is frequently carried out in coastal water. Usually, but not always, this work is associated with offshore influences. For example in 1976 detailed investigations were begun of currents and water properties within the northern sector of the inside passage between Vancouver Island and the Mainland. These will help provide an understanding of the physical interaction between coastal and deep sea oceanic regions.

Ocean Going Field Research

The oceanographic time series program at Ocean Weather Station P (50°N, 145°W) has been continued into its 21st year with contracts to Seakem Oceanography Ltd. (Victoria) and Chemex Laboratories Ltd. (Vancouver) to carry out observations during the four patrols of the CCGS Vancouver.

In conjunction with the Tidal and Current Section, current meter moorings were maintained at two closely spaced locations in Johnstone Strait. A preliminary investigation of the data supports past evidence of a highly amplified bottom flow at the eastern end of the Strait. During two cruises with the CCS Vector over 250 STD and Hydro casts were obtained between the Strait of Georgia and Queen Charlotte Strait in order to provide detailed sections of the water properties in this poorly studied region of the coast. (Thomson, Huggett)

Two cruises to the Strait of Georgia using the CCS Vector were made to investigate the possibility, suggested by earlier theoretical work, that longshore currents were being generated along the Fraser River Delta by breaking internal waves. The records from three current meter moorings in this region will also assist in our understanding of sediment and pollution dispersal by currents off the mouth of the Fraser River. (Thomson, Huggett)

Data Analysis and Theoretical Research

Satellite imagery of the western Arctic Ocean has been used to demonstrate that the large scale (100 km) criss-cross lead patterns in the ice cover are analogous to semi-brittle fracture patterns found in rock mechanics. This concept marks an appreciable departure from present theories about lead formation in the Arctic ice cover. (Thomson, Marko)

The Vorticity Transfer Theory proposed by G.I. Taylor early in this century has been shown to be fundamentally incorrect. This result establishes certain limitations on theories of ocean circulation. (Thomson, Stewart)

Analysis of surface current velocity data for the North Pacific obtained from U.S. and Japanese pilot charts has revealed the presence of a westward flowing countercurrent between 48°-51°N latitude. Although the current appears to be especially strong during winter months, attaining speeds of 10 cm/s in a confined latitudinal belt 100 kilometers wide, it appears that its presence has not previously been remarked upon. (Tabata)

Ten years of time-series data from meteorological and bathythermograph observations at Ocean Station P have been analyzed in order to determine values for various transfer coefficients at the air-sea boundary. In some cases, appreciable variation from accepted values has been found. These coefficients are essential parameters in the modelling - both of the ocean and of the atmosphere. (Miyake)

The paths of five locally built drifting buoys, launched near Station P, were tracked by the Nimbus-6 satellite in early 1976. All buoys were carried toward the coast. Those that retained their drogues also moved with large north-south excursions that had periods of around two weeks with speeds of two to six miles per day. (Garrett)

An assessment has been made of the usefulness of satellite imagery in the study of Oceanography along the Pacific Coast. Particular attention has been given to the use of infrared imagery to detect cold upwelling regions adjacent to the coast. (Tabata, Gower)

The quality of oceanographic data collected during the Weather Ship program is presently being assessed. Results of this study will be important to international use of this data and for determining procedures for up-grading its quality.

Support Programs

As part of Canada's contribution to the First GARP Global Experiment (FGGE) in the southern Pacific in 1979, supportive research was directed toward the design of instrumentation for the measurement of barometric pressure and sea surface temperatures from drifting buoys. Under contract, Beak Consultants Ltd. (Vancouver) completed a feasibility study of deploying drifting buoys from volunteer ships. Tests were conducted by the Section on the possible use of commercial pressure transducers in the buoys. The stability and accuracy of these sensors appears to be adequate for long term operations in the Southern Hemisphere experiment. (Garrett)

Hermes Electronics (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 and make them highly suitable for the FGGE. (Garrett)

A comparison of the accuracy of Expendable Bathythermographs (XBT's) and the temperature records from STD's has shown that the two instruments have a mean difference of 0.01°C and a standard deviation of 0.10°C. Much of this difference was attributed to variations in the fall speeds of the XBT probes. (Garrett)

An onboard data-logging system developed by the Section in 1976 for rapid collection and dissemination of STD data has proved extremely useful in field operations. Our ability and efficiency in getting such information into directly useful form has also been appreciably enhanced.

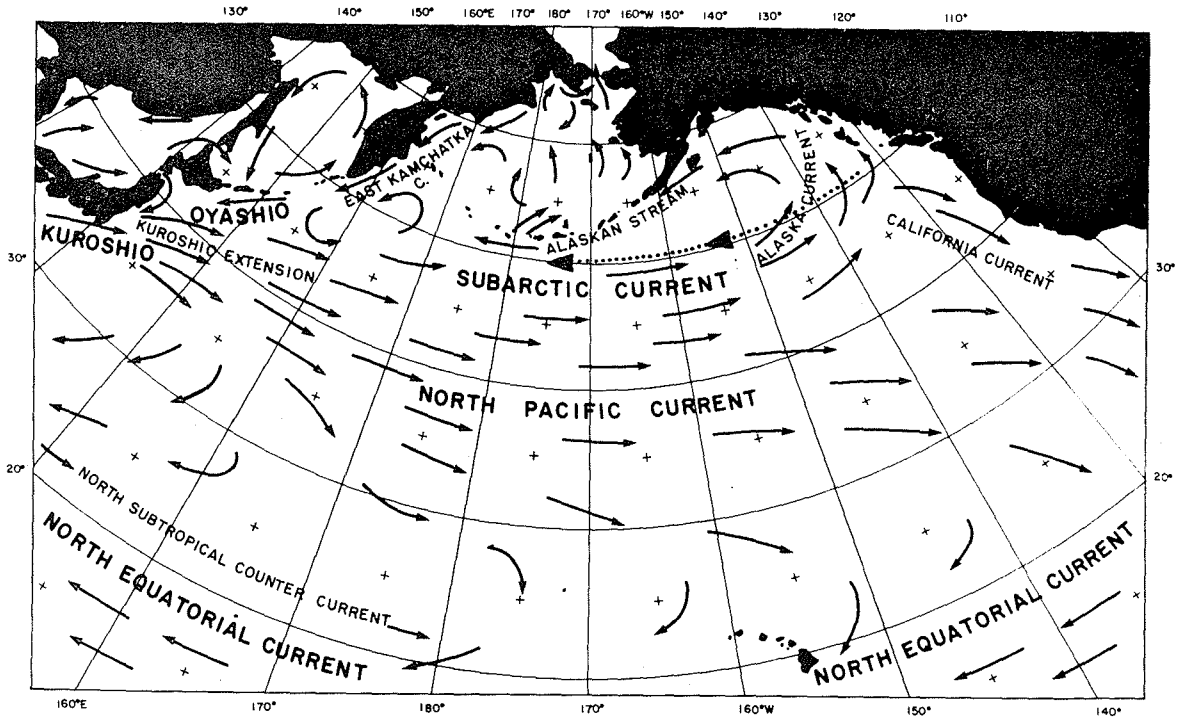


Chart showing the distribution of major surface currents of the North Pacific Ocean. The dotted line indicates the location of the recently postulated countercurrent.

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

Field Studies

In cooperation with the Tidal and Current Section, the Section undertook a current-meter observation program in Haro Strait in July and August. The 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 occuring within each tidal cycle. Fronts travelling

through the strait produced visible surface effects which were recorded by camera from San Juan Island.

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.

As part of a program designed to examine the mechanisms involved in fjord circulation the Section conducted a pilot study in Knight Inlet 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 tide with the sill. A rapid deepening of the fresher surface layer accompanied by large amplitude internal waves of about ten minute period occurred about three hours into the flood tide at our anchor station located a few kilometers up-inlet of the sill.

Analysis and Interpretation

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. Magnetic particles from mine tailings in the water interfered with observations of both current speed and conductivity, causing 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, U.B.C.

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 contemporary developments in dumping technology.

The 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 examine critically 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 summarizing results of studies conducted under the auspices of the Beaufort Sea Project.

Analysis of data collected during the Babine Lake project continued, with emphasis on mechanisms involved in the generation of internal surges.

Technical Development

Investigation of some practical mooring problems associated with drag due to fast currents was carried out by numerical simulation. In addition, trial moorings were undertaken in an area of swift currents in order to provide data for comparison with the model and to check out alternative procedures. 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.

Effort was spent in developing our CTD profiling capability so as to permit (1) preliminary data processing facility by mini-computer during field operations and (2) portability of the system to allow its use on a variety of vessels. Work was begun on the development of a profiling current meter.

ARCTIC MARINE SCIENCE

A.R. Milne - Head

R.H. Herlinveaux B.D. Smiley

The main thrust of the Arctic Marine Science program has been devoted to environmental investigations related to offshore petroleum development. These studies had two major subdivisions, one being on threats to the environment likely to be caused by offshore petroleum development, and the other to threats from the environment to offshore drilling systems. To a lesser extent we were engaged in baseline studies, which are studies of the current state of the Arctic environment. It is anticipated that in the future most work will be related to environmental assessment. As such, it is likely that we will be engaged in joint programs with other agencies, either in the context of spearheading the programs themselves, or conducting joint programs of mutual interest.

The majority of the funds (approximately 80%) obtained during the fiscal year 1976-77 were expended on contracts. It is anticipated that 80% of new funds allotted to Arctic Marine Science would again be expended on contracts.

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. The management of the entire project, including editing of all reports, was the responsibility of the Arctic Marine Science Group. 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 distributed.

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 porosity of sea-ice, which influences the rate at which an oil spill under the ice would rise to the surface, was measured at three locations in the Arctic Archipelago between July and September 1976. The picture was taken in Barrow Strait in September.

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 surface layer increased with thawing and the ice in contact with the sea also became more porous as the ice warmed to sea temperature at the end of summer. This study was funded by the Environmental Protection Service of the Department of Fisheries and the Environment.

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 field data from the Arctic Archipelago using all available sources. The aim is to understand the surface, subsurface 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 wave study with Imperial Oil, Canadian Marine Drilling Ltd. and DFE's Marine Environmental Data Services. Locations of buoys were off Kugmallit Bay, Pullen Island, Garry Island, Warren Point and from a CanMar drillship.

In winter, from November 1975 to late March 1976, an ice-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 carried under our supervision by Norcor Engineering and Research Ltd. of Yellowknife.

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

FROZEN SEA RESEARCH GROUP

E.L. Lewis - Head

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

+Joined in 1976
*Left in 1976

The Frozen Sea Research Group was established in 1964 to study oceanographic problems unique to ice covered waters and their research efforts have been concentrated in the Canadian Arctic. Much of their expertize in the scientific understanding of oceanographic processes in Arctic waters is now being directly applied to the problems associated with the exploration and exploitation of petroleum resources in the far north. The projects undertaken in 1976 are summarized below.

Water Movement in Channels of the Arctic Archipelago

Current meters were laid across Byam and Austin Channels between Melville and Bathurst Islands at a latitude of about 75°N. The meters were placed in the top and bottom boundary layers with a view of obtaining information on the potential for the movement of oil beneath the sea ice and the forces likely to act on a pipeline crossing planned at that location. Density profiles were also obtained. The movement of pollutants from a hypothetical oil well blowout in the Arctic Islands is at present largely unknown and studies of this type are an essential part of predicting the environmental consequences of such an event.

An overall survey of the oceanography of the Arctic Islands has been undertaken to provide a background for industrial developments. An attempt is being made to model one aspect of the Archipelago based upon a review of meteorological data, water structure variability, long term water level variations, and the magnitude of water level runoff from the land.

Circulation in Arctic Fjords

These continuing studies have been centred at Cambridge Bay, Victoria Island and d'Iberville Fjord, Ellesmere Island, with the 1976 field trip being to d'Iberville Fjord. The operation culminated in an oceanographic section running 200 kilometers approximately from the glacier at the head of d'Iberville Fjord out over the sill, down Greely Fjord into Eureka Sound and so to Eureka itself. These studies of circulation are essential to understand and predict the extent of pollution possible from depositing mine tailings into the ocean at these latitudes. During 1976 advice was provided in connection with Nanisivik Mines, Strathcona Sound, and the proposed Arvik Mine on Little Cornwallis Island.

As the ice cover prevents wind mixing, and run off from the land is restricted to a few months of every year, Arctic Fjords are a simpler circulatory system than fjords at more temperate latitudes. Results from studies on Arctic fjords may thus be used to elucidate problems arising due to coastal pollution in southern Canada, for example, on the British Columbia coast.

As the sea ice grows salt is rejected into the underlying water column producing vertical convective motion immediately below the growing interface. The dynamics of this process are of great interest in regard to the lodgement and dispersal of oil deposited at the ice/water interface by an offshore oil well blowout as well as in terms of the fundamental physics of the atmosphere/ocean energy exchange and its effect on world climate. Studies on this convective system were continued during 1976 and will carry on into the next fiscal year. Although the process is being studied in fjords it is of importance under any sea ice cover.

Direct Environmental Effects of an Offshore Oil Well Blowout

Studies have been pursued on changes of the ice surface albedo due to contamination by crude oil, the atmospheric pollution to be anticipated from burn-off of a blowout, and the rupture of a sea ice sheet due to the accumulation of gas at the ice/water interface. Gas (methane) invariably accompanies an oil flow and if retained in the relief at the ice/water interface in sufficient quantity, will eventually cause the sheet to crack thus providing a path for oil to reach the upper surface. An analysis of this problem has been accepted for publication in the open literature. A detailed analysis of the results obtained from the simulated blowout carried out in Patricia Bay during 1975 using compressed air is now available and supplements the preliminary study given in Beaufort Sea Report #33.

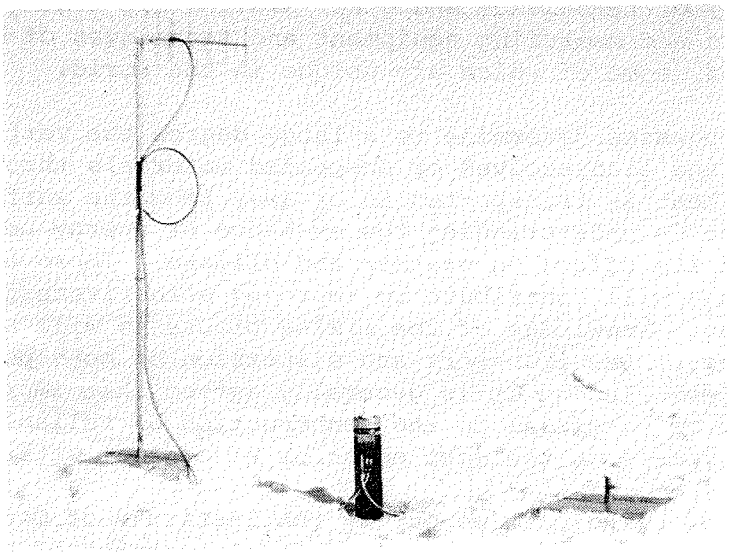
Instrumentation

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 subsurface 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 be-

neath growing sea ice. 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.



Telemetering equipment installed in the sea ice for data relay to a remote recording station. The central vertical black tube forms a float, extending through the ice sheet, which contains the radio transmitter as well as internal recording gear for under ice water movement. A hydrophone hanging beneath the float receives sonic pulses which are coded data on water movement near the sea bed and information on both top and bottom currents goes to a recorder on land via the UHF antenna on the left of the picture.

Definition of Salinity

A study has been made of the definition of salinity and its calculation from conductivity measurements. The problem is 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.

OCEAN MIXING SECTION

P.W. Nasmyth - Head

A.E. Gargett
G.W. Chase
R.C. Teichrob

For over 20 years a modest program has been in progress on the West Coast of Canada to investigate the characteristics, occurrence and distribution and intensity, of turbulence and other small scale mixing processes in the ocean. Sensors and measuring equipment and techniques of data analysis have been developed, some of which are unique in the world.

The mixing processes determine to a large degree the vertical transport of heat or energy and of dissolved or suspended materials through the ocean. The rate at which heat is transported to or away from the surface layer is of major importance in understanding the exchange of energy between the ocean and atmosphere and its effect on weather and climate. Improved knowledge of the air-sea exchange will contribute to improved effectiveness and range of weather forecasting. Knowledge of the mixing processes will also contribute to an understanding of the transport and dispersion of both pollutants and nutrients in the sea. Indeed it is generally agreed that improved understanding of mixing is essential to the construction of reliable three dimensional predictive models of the deep ocean or of coastal waters.

The project now being carried out by the Institute of Ocean Sciences was originally undertaken and developed by the Department of National Defence. In earlier stages, sensors were towed from a surface ship. When the deep submersible Pisces IV was acquired by the Department of Fisheries and the Environment in 1974, the development of new instrumentation was undertaken to make measurements from Pisces, with greater flexibility of operation and greater depth capability than the towed system.

Measurement System Development and Use

In 1976 the new system has been carried through to the point where successful performance has been achieved. In order to get a stable 'flight path' it was necessary to design a set of stabilizing fins. Extensive experience in over 50 dives with the fins installed has proved completely satisfactory.

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 0.5 cm in the longitudinal component and 3-5 cm in the cross components,
ii) temperature with a spatial resolution of a few millimeters,
iii) conductivity with a spatial resolution of a few centimeters.

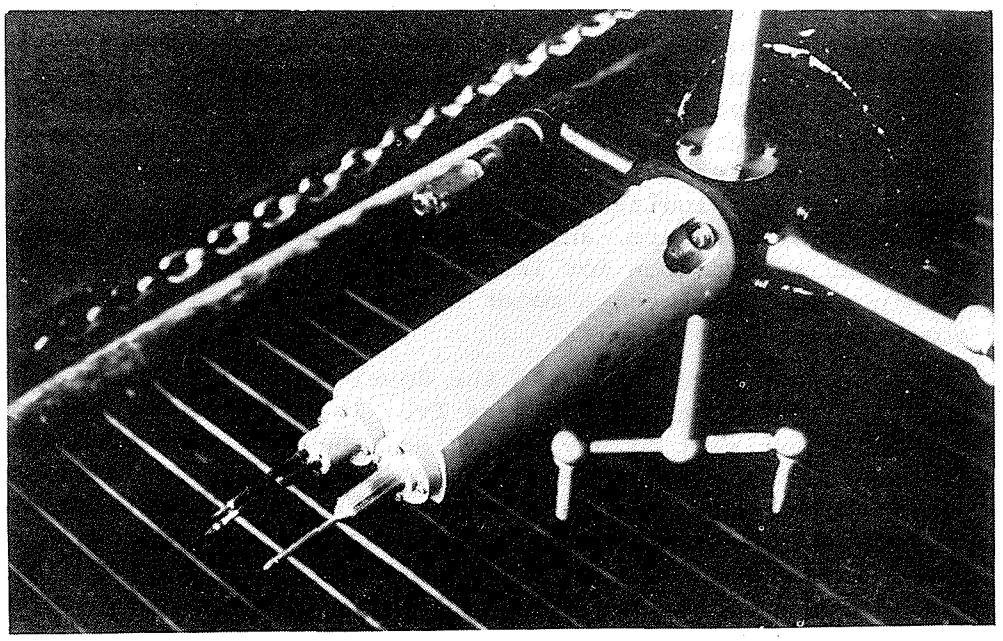
Auxilliary instrumentation measures depth, mean forward motion, vibration and submarine motions in pitch and roll, and mean water velocity past the sensor array.

Two sea operations, totalling approximately 45 days at sea, were

carried out during the year, primarily to test the performance of components of the system in various modes of operation. Most recently a 5-week series of trials of the total system was carried out in November/December 1976 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.



The main grouping of sensors mounted on a special framework in front of the submersible Pisces IV for measurement of ocean turbulence and microstructure. Three high resolution probes mounted at the extreme forward end of the structure appear at lower left in the picture. The two close together at the left use very small platinum films to measure water temperature and the longitudinal component of velocity. The third uses a piezoelectric element to measure the two cross components of velocity. The sensor in the upper centre measures electrical conductivity and temperature, from which density is calculated. An acoustic current meter (bottom right) and two others to the right and on top, of which only the mounting stems can be seen, measure three orthogonal components of mean water velocity past the sensor array.

Analysis of Data

A data analysis scheme was devised and tested in 1976 for obtaining information on the vertical gradients of temperature and salinity from a purely horizontal measurement, taking advantage of the fact that internal waves continually raise and lower constant density surfaces in the ocean. A temperature versus salinity (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 1 m in the vertical then completes the determination of the signs of the gradients. A measure of the strength of the local density gradient may 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 which were taken at the same time during towed body operations in 1973. Analysis is continuing, but this work has already demonstrated that 'double diffusion' phenomena, depending on the difference in diffusion rates between heat and salt, may be important even in the North Pacific. Conventional wisdom, based on less detailed observations, has been of the opposite opinion.

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 the rates of dissipation of turbulent energy 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 intercomparison. 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 physical units, and choice of gain and off-set.

REMOTE SENSING SECTION

J.F.R. Gower - Head

J.S. Wallace
R.A. Neville - NRC Postdoctoral Fellow
B. Oliver - NRC Postdoctoral Fellow

In 1971 the Remote Sensing Section was established in the Pacific Region to take Marine Sciences' (now Ocean and Aquatic Sciences) responsibility for development of remote sensing techniques for oceanography and for evaluation of techniques originating elsewhere.

Imagery from satellites has become a powerful tool for observation of ice characteristics distribution and motion in the Arctic and gives promise of becoming comparably useful for determination of sea-surface temperature, surface currents and wave height, synoptically over large areas of ocean. Photography, infrared imagery and spectrometric examination of sea-surface radiation from aircraft also offer large area coverage which would be impossible to duplicate by measurement from the surface and prohibitively expensive. Certain other techniques such as photographic time series taken by a camera suspended by balloon, and precise optical tracking of drifting targets on the sea surface using an aircraft equipped with a modified inertial navigation system have also been exploited by the Section.

The Remote Sensing Section has no operational program of its own; it develops techniques and assists other sections or agencies. During 1976 the Section was involved in satellite oceanography (infrared sea-surface temperature and radar wave height measurements), airborne observations of coastal B.C. waters using the Marine Inertial Data Acquisition System (MIDAS), a detailed water-color analysis using the 256 channel spectrometer, and imagery and photography in support of various programs.

Satellite Oceanography

The usefulness of infrared sea surface temperature patterns 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 requirements.

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 wave-heights should be measurable to within 0.5 metres along the satellite track, and future satellite systems, such as SEASAT, 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 the prototype SEASAT A project continues with J.R.F.Gower on the NASA team for the synthetic aperature 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

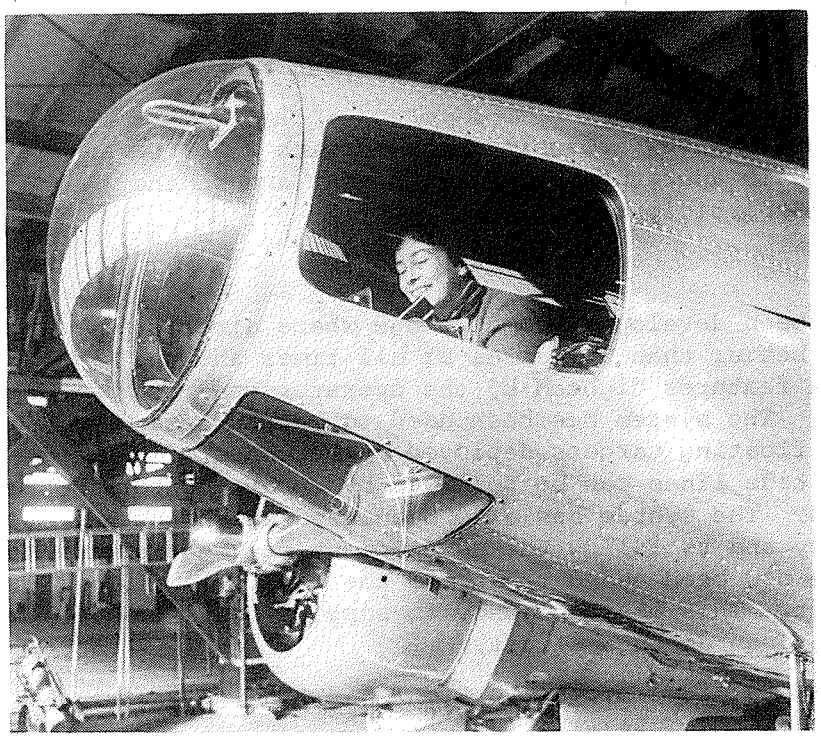
chlorophyll on water color and fluorescence line height was carried out in Saanich Inlet using the 256 channel spectrometer. Previous measurements here and elsewhere show that chlorophyll concentrations can be estimated and mapped from the air, but that data tends to show only concentrations near the 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 of 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.

Three thermal scanning flights over Haro Strait were made by Intera Environmental Consultants Ltd. (Vancouver) 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.

Oblique photography in Haro Strait 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.

The last two projects were done for the Coastal Zone Oceanography Section of the Institute.



Beach 18 aircraft belonging to B.C. Government is used by Remote Sensing Section for tracking surface targets in support of oceanographic programs measuring surface currents and tracking oil spills. It is also used for developing and testing instruments for measuring water color.

NUMERICAL MODELLING SECTION

R.W. Stewart - Head

P.B. Crean
P.J. Richards - Computing Services
R.F. Henry
M.G. Foreman - Computing Services

The Section is involved in the development and application of numerical models for simulation of currents and surface levels in areas of high priority study. Numerical models form a species of theory, and share with other kinds of theory two characteristics: (1) The better the theory, the fewer the observations required to describe any situation. Properly employed, theory can be cost-effective for this reason alone. (2) Theory permits prediction. For example a successful model, once developed, may then be run on the computer under any desired set of conditions to determine currents and levels over the area for any period of time, - information which could be obtained only with great difficulty and expense by other means. An appropriate model may also be used to predict the movement of, for example, an oil spill under any combination of wind and tide.

Georgia Strait Modelling

A sophisticated two-dimensional tidal model of the Strait of Georgia/ Strait of Juan de Fuca system, considered to be one of the most successful of its kind in the world, has been under development for several years and is still being refined. During 1976 an extended run (30 days) was carried out on the Strait of Georgia model, simulating measured and predicted values with gratifying precision. Analysis of the resulting data 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 used to drive a finer scale model (2 km mesh size) for more detailed coverage of Juan de Fuca Strait, the southern Strait of Georgia and the region of the San Juan and Gulf Islands. This is the region of most concern with respect to tanker traffic in southern coastal areas.

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. No realistic pollution or ecological model of this area will be possible until the Fraser plume is incorporated. (Crean)

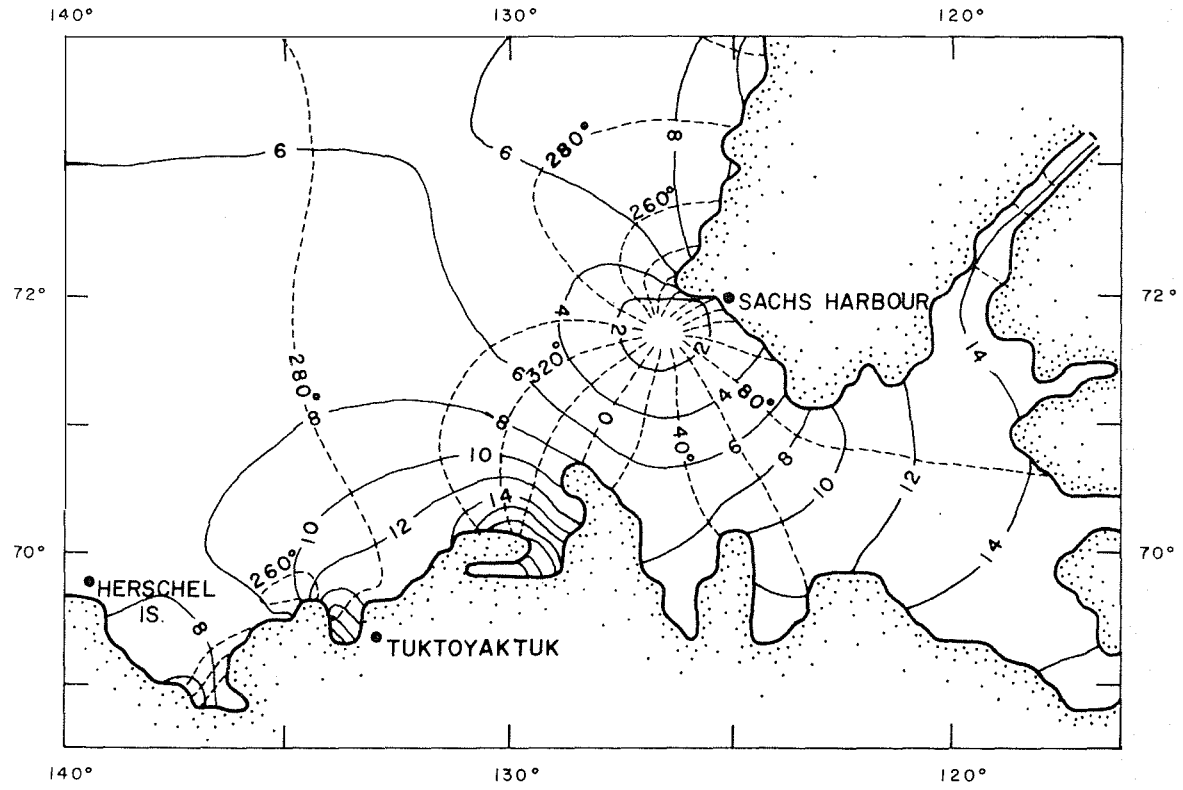
Simulation of Tides and Storm Surges

Tidal and storm surge models of the southern Beaufort Sea and Amundsen

Gulf have been developed as part of the Beaufort Sea Project. These models have served to confirm that wind stress on open water is the dominant cause of surges and that the shallow coastal shelf is the area where surges are generated. Outflow from the Mackenzie River has been shown to increase surge heights in the southern part of Mackenzie Bay. A small area surge model is designed for incorporation into an operational air and sea forecasting system to be run by the Atmospheric Environment Service in support of drilling operations in the Beaufort Sea, and of clean-up operations in the event of an oil spill.

A barotropic model has been 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 charts for the semi-diurnal constituents of Amundsen Gulf and the waters off Banks Island.

Preliminary study and data preparation has been undertaken towards the development of a barotropic tidal model of Queen Charlotte Sound, in anticipation of increasing demand for environmental impact studies in the Prince Rupert - Kitimat area. (Henry)



Cotidal chart for lunar semi-diurnal (M_2) tide in the southern Beaufort Sea, based on a simulation by means of a numerical model. The chart agrees satisfactorily with field observations where available. Full lines are amplitude contours of surface elevation (cm). Co-phase lines are shown dashed; the tide reaches the same state (eg. high tide) simultaneously at all locations on a given co-phase line.

OCEAN ECOLOGY LABORATORY

R.O. Brinkhurst - Head

M.J. Austin
G. Gardner - Postdoctoral Fellow
P. Chapman - Graduate student, UVic
W. Carolsfeld - Summer student

In the course of discussions during 1974 and 1975 on the organization of the Fisheries and Marine Service, it became clear that a gap in programs had developed over the years. The study of non-commercial organisms, even those used as food for commercial fish and those which were important indicators of the health of the ecology, was being seriously neglected. It was agreed that the effort in this area would be increased and that the work should be carried out by OAS rather than by Fisheries Management.

These decisions were closely in line with proposals made in 1971 for the range of expertise which should be incorporated in the proposed Institute of Ocean Sciences. Accordingly, the nucleus of an Ocean Ecology Laboratory was established within the Institute early in 1976.

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 Fisheries and Marine Service in January 1976, 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 Institute of Ocean Sciences 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 CO_2 level changes in the atmosphere, 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 the major problem. A ship-of-opportunity program is being investigated as a feasible method by which the large amount of data needed for a time-series may be collected in a cost-effective way.

While the planning for plankton studies in continental shelf and inshore waters continues, benthic (bottom) studies are underway. 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 fresh water sludge-worm biology.

During the year, Carolsfeld studied the fauna of the major urban drainage system reaching Victoria Harbour, and Chapman and Carolsfeld used 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 biologists on the taxonomy of 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
D.B. Smith
J.W. Butcher - FSRG
A.N. Douglas - Tidal & Current
R. Dykes - Management Services
M.G. Foreman - Numerical Modelling
*R.G. Hlady - Management Services
J.S. Page - Ocean Chemistry
P.J. Richards - Numerical Modelling
E. Wong - Offshore Oceanography
A.L. Woollard - Tidal & Current

*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 micro-computer-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.

MANAGEMENT SERVICES DIVISION

N.A. Todd - Chief of Management Services

Institute of Ocean Sciences

The last two annual reports have talked about audible and visible evidence that the new facilities at Patricia Bay were becoming a reality. During 1976 the whole Institute has taken shape, and a considerable part of it has been completed and put into use.

The wharf became fully operational early in the year. The ships began to use Patricia Bay as their home base when the new workshop-warehouse or depot building was turned over from the contractors in mid-June. At that time all of Ship Division moved to Pat Bay from Harbour Road. The new warehouse and central stores have rapidly taken on the appearance of all such spaces with shelves stacked with equipment.

The UNIVAC 1106 computer has been temporarily accommodated in the depot building. Providing power, air conditioning and other mechanical services for this regional computing centre has been a project in itself. The quality of the electrical power is perhaps the largest problem which hopefully will be finally resolved when the computer is moved to its permanent location in the main building.

The main building is well advanced. The basic steelwork and concrete work are all completed and the job of filling in the spaces is well underway. The project did suffer from a loss of three months through labour stoppages. This loss may, from our point of view, have been more apparent than real because the rate of construction progress was outrunning the allotted cash flow for the year.

The main complex will be finished sequentially. The first section is expected to be occupied in May 1977 by Ocean Physics. Next year's report should be able to start with a statement that all our staff are housed in their new quarters.

Administration

The administrative services carried on their function in the best traditions of the silent service. The computerized financial system has proved itself to be a reliable, economical and powerful management tool. Daily print-outs for allotment, commitment and expenditure controls are obtained.

Good progress has been made with the Computerized Materiel Management or inventory system. This has been developed in close cooperation with Computing Services and is designed to give a detailed yet flexible system serving our internal needs and those of the auditors.

Continuing man-year constraints are a problem here as elsewhere. The Section takes satisfaction in knowing that our administrative overhead stands up very well in comparison with other organization.

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 DIVISION

E.N. Geldart - Regional Marine Superintendent

F.S. Green - Assistant Marine Superintendent (deck)
D. Marr - Assistant Marine Superintendent (engineering)
G.R. Meek - Submersible Operations Manager

The Pacific Region Ship Division provided ship, submersible, launch and depot support for the 1976 hydrographic and scientific programs and for several federal departments and universities.

CSS PARIZEAU (64.3 m. overall, 1929 metric tons)

Master: A.G. Chamberlain Chief Engineer: R. Parkinson

Following annual drydocking and refit at Yarrows Ltd., Victoria, B.C. CSS Parizeau was employed in support of various scientific and hydrographic programs: P.E.I. ecology; I.O.U.B.C. biology, botany; D.R.E.P. ocean acoustics, towex; O. & A.S. ocean chemistry, coastal oceanography. She was converted to hydrographic configuration and sailed from Victoria for the Western Arctic, July 5, 1976, meeting the icebreaker CCGS J.E. Bernier at Icy Cape, July 15, 1976. The two vessels battled very heavy ice, reaching a position just north and east of Point Barrow. At this point Parizeau, due to severe damage to her propellors and rudder, had to cancel her hydrographic program and proceed south under tow of J.E. Bernier, to safe anchorage at Teller, Alaska. The CFAV sea-going tug St. Anthony towed Parizeau from Teller, Alaska to Yarrows Shipyard, Esquimalt, B.C. for repairs which proved difficult and time-consuming. The vessel returned to service on November 15, 1976.

CSS WM. J. STEWART (65 m., 1720 tonnes)

Master: K.J. Sjoholm Chief Engineer: J.D. Henderson

The Wm. J. Stewart was not commissioned in 1976, because of severe manpower restrictions. The ship was towed to the new Institute wharf at Patricia Bay in June, where she accommodates the Ship Division offices.

CSS VECTOR (39.6 m., 505 tonnes)

Master: J.C. Marston Chief Engineer: J. Peat

The CSS Vector's annual drydocking and refit was carried out at Yarrows Ltd. During the year she carried out the following programs without interruption: S.F.U., biology; I.O.U.B.C. biology, physics; U.Vic, biology; E.M. & R. geology; P.E.I. ecology, biology; E.P.S. biology; O. & A.S. tides and currents, ocean chemistry.

CSS RICHARDSON (19.8 m., 76 tonnes)

Master: M.G. Wheeler Chief Engineer: I.N. Henderson

The CSS Richardson's drydocking and refit was carried out at Sterling Shipyard, Vancouver, B.C. Following refit she was used in full support of the following programs: O. & A.S. hydrography and side scan sonar.

C.F.A.V. LAYMORE (53.6 m., 645 tonnes) Dept. of National Defence

Master: M.J. Dyer Chief Engineer: H.R. Doherty

From January 1 to February 15, 1976 Laymore was used on the following programs: I.O.U.B.C. biology; P.E.I. biology; D.R.E.P. ocean acoustics. The Laymore was taken out of service and decommissioned February 15, 1976.

M/V RADIUM EXPRESS (22.2 m., 100 tonnes) on charter

Master: J.P. O'Sullivan Chief Engineer: W. Riggs

The hydrographers reported a successful survey season with the Radium Express, covering the Mackenzie River from Hay River to the Mackenzie Delta and the Eskimo Lakes.

M/V PANDORA II (58.2 m., 2,200 tonnes) on charter

Master: R. Jones Chief Engineer: C. Tuck

The Pandora II's area of operations for the year 1976 was along the B.C. Coast, and with Pisces IV she was employed in the following programs: E.P.S. biology; D.R.E.P. underwater cable inspection, ocean acoustics; U. Vic. biology; E.M. & R. geology; D.N.D. Voodoo Aircraft search; P.B.S. biology; O. & A.S. tides and currents, ocean physics, diver training and certification.

PISCES IV (6.1 m., 12 tonnes)

Operations Officer: G.R. Meek Chief Pilot: I. Sanderson

Pisces IV, the deep-dive submersible, underwent annual refit and was employed in various scientific programs with Pandora II. She was also employed in a search for a missing Voodoo aircraft. The aircraft was not located.

C.S.L. REVISOR (11 m., 10 tonnes)

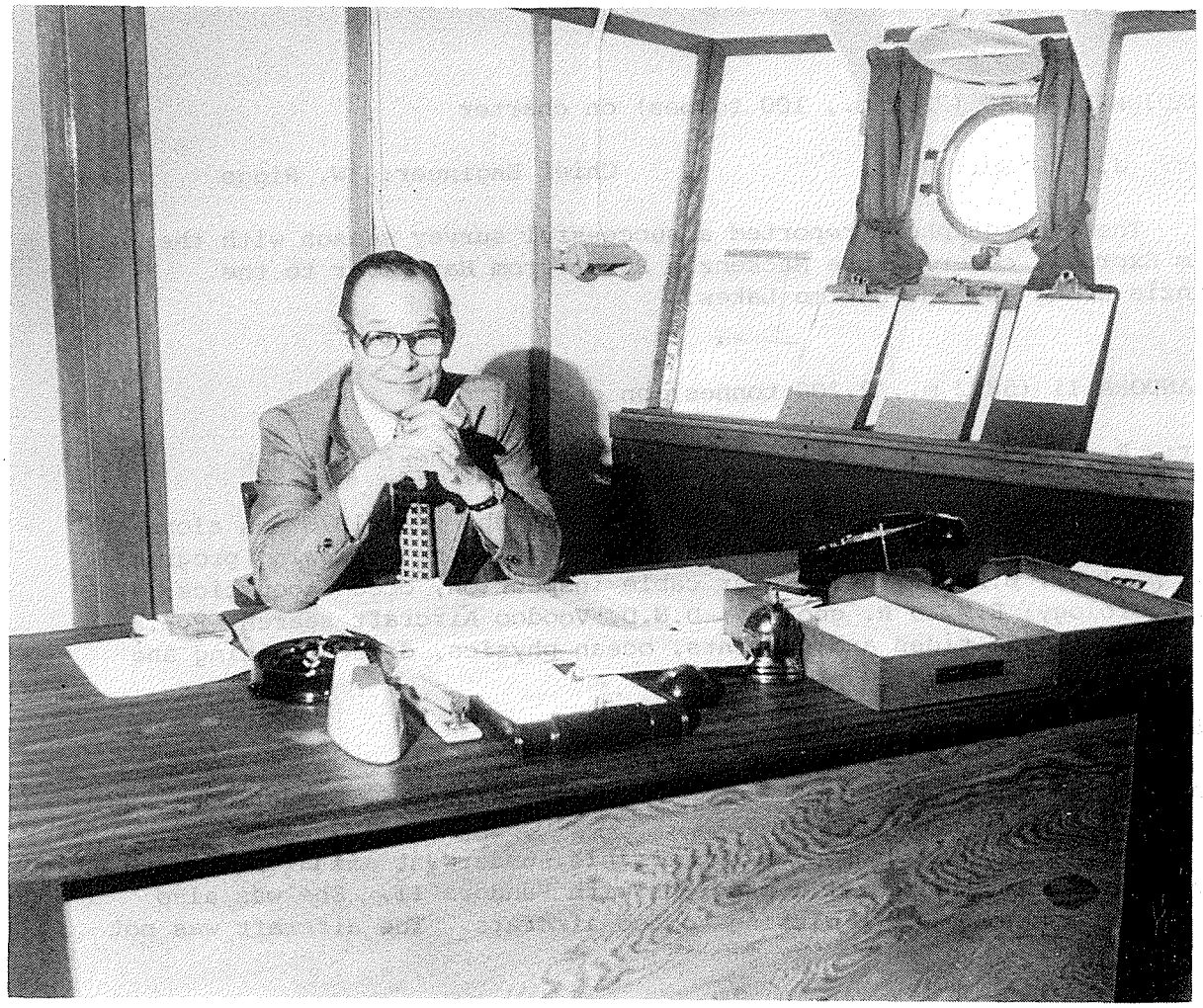
The launch Revisor was actively engaged in revisory surveys in various locations along the B.C. south coast.

LAUNCHES

Survey launches were fully employed by shore-based hydrographic survey parties working in the Gulf of Georgia and Ucluelet areas.

DEPOT

The depot workshops facility continued its full support to all Institute groups. The depot was moved from Harbour Road, Victoria, B.C. to the new workshops facility at I.O.S. Patricia Bay in June, 1976. This move was completed in one working week and support services were carried on without interruption.



E.N. Geldart, Regional Marine Superintendent, in his temporary office on board CSS Wm. J. Stewart

SCIENCE CONTRACTING

G.R. Smith - Industrial Liaison Officer

In 1976-77 the value of science-related contracts to industry for the Institute exceeded $1 million. This is 10 times the expenditure in 1972 when a contracting-out policy was implemented and is a 45 per cent increase over 1975-76. Contracting scientific activities has involved learning for both government scientists and industry. The response of Institute staff has been very encouraging. They have recognized the value of technical support from the private sector, and as a result industry is increasingly involved in Institute field projects. More than half of the science-related contracts are funded directly from the budgets of individual Sections.

The results of the efforts by the Institute, over the past few years, to implement federal government policy by developing commercial oceanographic services in Western Canada, are beginning to show. Industry has improved its capability in both field work and data analysis. An indication of success is that a number of companies now employ full-time oceanographers, and a market for oceanographic services is developing within the private sector. Oceanography should soon be a fully viable commercial activity on the Pacific Coast of Canada, with resulting benefit to the regional economy as well as an enhanced ability to deal with marine pollution and other environmental problems.

SCIENCE RELATED CONTRACTS AWARDED IN 1976

Ocean Dumping Program

To provide a basis for the regulation of ocean dumping on the Pacific coast.

		Total Amount
1.	Study of the effects of dumping dredge spoils containing wood debris on the benthic community in Alberni Inlet. Dobrockey Seatech Ltd.,Victoria,B.C.	$ 32,130
2.	Toxicity of leachates from dredge spoils containing wood wastes. EVS Consultants Ltd.,Coquitlam,B.C.	8,147
3.	Chemical and physical analysis of samples containing wood debris. Econotech Services Ltd.,New Westminster, B.C.	11,070
4.	Ocean Dumping Training manual. Valerie Bradshaw, Vancouver, B.C.	4,500
5.	Evaluation of additional data from Point Grey dumpsite. Seakem Oceanography Ltd., Victoria, B.C.	2,357
6.	Mercury mobilization from resuspended dredge spoils. Seakem Oceanography Ltd., Victoria, B.C.	21,514
7.	Collection of sediment samples at Mamquam Channel. Chemex Labs.Ltd., North Vancouver, B.C.	4,762
8.	Heavy metals in marine benthic organisms at the Point Grey dumpsite. Cantest Ltd., Vancouver, B.C.	2,038

9.	Biotransformation of inorganic mercury to organo-mercurials in Mamquam Channel sediments. Willis Cunliffe Tait & Co.Ltd., Victoria, B.C.	8,900
10.	Design of a benthic corer for Pisces IV. Canadian Aircraft Products, Richmond, B.C.	5,500
11.	Investigation of coring techniques for areas with extensive wood debris. B.H. Levelton & Associates Ltd., Victoria, B.C.	8,000
12.	Core samples from Mamquam Channel. B.C. Research, Vancouver, B.C.	1,650
13.	Establishment of a tentative oxygen budget for Alberni Inlet. Seakem Oceanography Ltd., Victoria, B.C.	2,000

Pacific Coast Program

To contribute to a basis for meeting Institute responsibilities in Pacific marine waters.

14.	Identification of ecological indicators of ocean mixing in Haro Strait. Dobrocky Seatech Ltd., Victoria, B.C.	8,988
15.	Baseline sampling of marine benthic fauna in Saanich Inlet. Beak Consultants, Ltd., Vancouver, B.C.	9,985
16.	Identification of benthic samples. Envirocon Ltd., Vancouver, B.C.	1,309
17.	Sample analysis to investigate distribution of benthos in relation to ocean dumping. P.Chapman, Victoria, B.C.	3,240
18.	Sample analysis to investigate distribution of benthos in relation to ocean dumping. W.Carolsfeld, Victoria, B.C.	5,760
19.	Digestion in pollution-indicating sludge worms. N.Kaushik, Guelph, Ont.	6,500
20.	Analysis of lighthouse oceanographic data. I.Webster, West Vancouver, B.C.	3,440
21.	Analysis of lighthouse oceanographic data Phase III. Associated Engineering Services Ltd., Vancouver,B.C.	16,064
22.	Placing and recovery of an experimental instrument mooring. Dobrocky Seatech Ltd., Victoria, B.C.	4,500
23.	Experimental mooring of current meters to test cable fairing. Dobrocky Seatech Ltd., Victoria, B.C.	8,500
24.	Feasibility and design study for a profiling current meter platform. Canadian Thin Films Ltd.,N.Vancouver, B.C.	8,000
25.	Updating computer system software to achieve compatibility of context editor at the Institute of Ocean Sciences.	2,136

26.	Provision of computer operations services for Dept. of Environment, Pacific Region Computing Centre. Ronor Management Ltd., Ganges, B.C.	32,702
27.	Development of a computer program for Ocean Mixing. Apocalypse Enterprises Inc., Victoria, B.C.	17,976
28.	Development of computer programs for hydraulic research. Apocalypse Enterprises Inc., Victoria,B.C.	17,789
29.	Development of computer program for Remote Sensing. Apocalypse Enterprises Inc., Victoria, B.C.	11,960
30.	Provision of field support for geological surveys in the Fraser River and Georgia Strait. Dobrocky Seatech Ltd., Victoria, B.C.	21,288
31.	Study of the Squamish estuary by means of aerial photography to assess the effect of port construction. Pacific Survey Corp., Vancouver, B.C.	746
32.	Water properties sampling and measurement program aboard CCGS Vancouver and Ocean Station P. Seakem Oceanography Ltd., Victoria, B.C.	47,825
33.	Evaluation of water samplers for analysis of trace metals and hydrocarbons in sea water. Seakem Oceanography Ltd., Victoria, B.C.	10,673
34.	Field support for chemical oceanography and sampling in Georgia Strait. Dobrocky Seatech Ltd., Victoria, B.C.	10,500
35.	Assistance in organizing and participation in the CEPEX field experiments. Thalassic Data Ltd., Vancouver,B.C.	6,027
36.	Oceanic water properties sampling and measurements aboard CCGS Quadra and chemical analysis of sea water in shore laboratories. Seakem Oceanography Ltd., Victoria, B.C.	63,972
37.	Deployment of CEPEX bags. Case Existological Laboratories Ltd., Victoria, B.C.	2,250
38.	Development of techniques for extraction of lead in tuna fish and mercury extraction method for marine sediments. J.Alix, Victoria, B.C.	1,659
39.	Development of analytical techniques for measurement of concentration of natural and anthropogenic hydrocarbons in seawater, marine organisms and marine sediments. Dr.P.Christensen, Victoria, B.C.	4,500
40.	Analysis of Ocean Chemistry plankton samples from the CEPEX CO_2 project. J.Chang, Port Hardy, B.C.	3,000
41.	Service to coat all lead diving weights with epoxy paint for CEPEX bag deployment. Case Existological Laboratories Ltd., Victoria, B.C.	1,000
42.	Physical oceanography of Haro Strait. Dobrocky Seatech Ltd., Victoria, B.C.	72,000

43.	Examination of the movements of oceanic fronts in Haro Strait. S.Yee, Sidney, B.C.	2,700
44.	Data survey and recommendations for an oceanographic study of Haro Strait. Associated Engineering Services Ltd., Vancouver, B.C.	7,096
45.	Computer sorting of hydrographic data. Apocalypse Enterprises Inc., Victoria, B.C.	443
46.	Revision of Canadian Hydrographic Service charts and the supply of information for B.C. Sailing Directions. I.Campbell, Sidney, B.C.	2,000
47.	Study of the feasibility of using photogrammetric techniques to obtain data necessary to generate hydrographic charts. (Aerial Hydrography Project) Dr. S.E. Masry, Fredricton, N.B.	16,800
48.	Development of computer programs for field hydrography. Apocalypse Enterprises Inc., Victoria, B.C.	4,875
49.	Specialized revision of hydrographic charts. Case Existological Laboratories Ltd., Victoria, B.C.	32,619
50.	Contouring of computer-sorted hydrographic data. Dataplotting Services Ltd., Don Mills, Ont.	500
51.	Oceanographic water properties sampling and measurements aboard CCGS Quadra. Seakem Oceanography Ltd., Victoria, B.C.	3,877
52.	Biological and oceanographic research support. University of Victoria, Victoria, B.C.	8,000
53.	Oceanographic support to the Institute of Ocean Sciences. Dobrocky Seatech Ltd., Victoria, B.C.	33,000
54.	Research study on shelf wave propagation along the B.C. coast. L.A.Mysak, Vancouver, B.C.	5,000
55.	Cooperative research on fjord dynamics. University of B.C., Vancouver, B.C.	17,204
56.	Development of improved airfoil probes for oceanographic measurements. University of B.C., Vancouver, B.C.	5,000
57.	Feasibility study of deploying drifting buoys from islands during the First Global Experiment - part of the Global Atmospheric Research Program (GARP). Beak Consultants Ltd., Vancouver, B.C.	8,000
58.	Study of chlorophyll concentrations in seawater. R.A. Neville, Sidney, B.C.	12,900
59.	Numerical modelling of the movement of the Fraser River discharge in the southern Strait of Georgia. University of B.C., Vancouver, B.C.	3,075
60.	Preparation of zooplankton species reference collection. University of B.C., Vancouver, B.C.	325

61. Analysis of oceanographic data from weathership cruises. G.C.Jewsbury, Victoria, B.C. 3,150

62. Analysis of Patricia Bay sediment samples. Chemex Ltd., N.Vancouver, B.C. 484

63. Preparation of oceanographic data in digital form for the Fraser River plume. University of B.C., Vancouver, B.C. 1,012

64. Airborne thermal scanning of Haro Strait. Intera Environmental Consultants Ltd., Calgary, Alta. 2,155

Arctic Program

To contribute to a basis for meeting Institute responsibilities in Arctic marine waters.

65. Installation and recovery of wave rider buoys in the southern Beaufort Sea. Seakem Oceanography Ltd., Victoria, B.C. 2,410

66. Study on sea-ice distribution and sea-ice-air interaction. G.Bugden, Victoria, B.C. 350

67. Study of beluga and bowhead whales in the southern Beaufort Sea. F.F. Slaney and Co.Ltd., Vancouver, B.C. Funded by Beaufort Sea Project. 9,000

68. Overview study and report related to the fate of oil in sea ice. A.L. Watson, Victoria, B.C. Funded by Beaufort Sea Project. 9,875

69. Analysis of oceanographic field data from Canadian Arctic Archipelago. D.Fissel, Victoria, B.C. Funded by Environmental Protection Service. 15,350

70. Radar tracking of ice in Byam Martin area. Seakem Oceanography Ltd., Victoria, B.C. Funded by DINA. 20,762

71. Assembling and analysis of Arctic oceanographic data. G.R. Wilton, Victoria, B.C. Funded by DINA. 19,880

72. Satellite image analysis and ice forecast evaluation pertaining to the Canadian Arctic Archipelago. J.R. Marko, Victoria, B.C. Funded by DINA. 22,000

73. Overflight studies of spring breakup of transition zone ice in the Beaufort Sea. NORCOR Engineering and Research Ltd., Yellowknife, NWT. 23,952

74. Field studies in the seasonal and permanent polar ice pack of the Beaufort Sea. NORCOR Engineering and Research Ltd., Yellowknife, NWT. 84,913

75. Development of a scientific oilspill response plan for the Beaufort Sea. LGL Ltd., Edmonton, Alberta. Funded jointly by DINA and OAS. 19,630

76. Preparation of a selective annotated bibliography of the biology of Lancaster Sound and vicinity. LGL Ltd., Edmonton, Alberta. Funded by DINA. 13,374

77. Analysis and dating of Beaufort Sea surface sediment samples by lead-210 method. Thalassic Data Ltd., Vancouver, B.C. 4,800

78. Modification and testing of Beaufort Sea meteorological model. Atmospheric Dynamics Corp., Elmira, Ont. 2,975

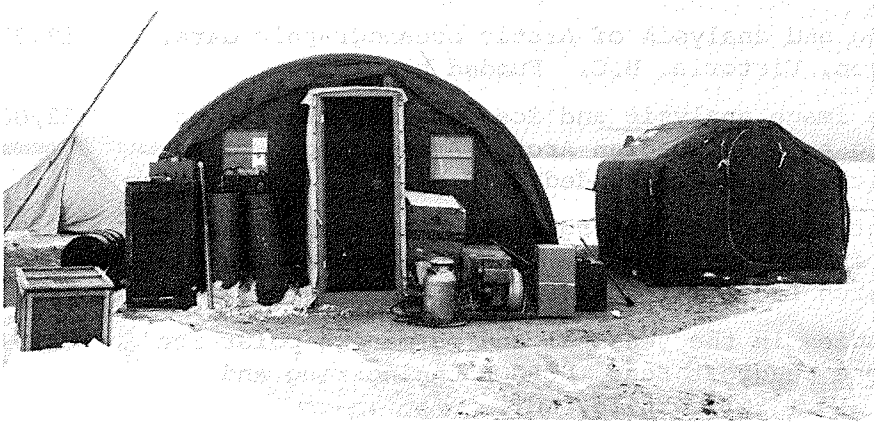
Unsolicited Proposals

Contracts supervised by the Institute for the Department of Supply and Services.

79. Improvement of high speed acoustic telemetry link on present current meter systems. Caulfield-Liron Consultants, Edmonton, Alberta. Funded by DSS. 123,500

80. The evaluation of a multi-beam sonor as a new hydrographic survey system. McElhanney Offshore Surveying and Engineering Ltd., Vancouver, B.C. Funded by DSS. 104,420

TOTAL 1,164,263



Camp on Byam Martin Island was used for field studies in August and September by Arctic Marine Science group measuring surface currents by tracking ice floes with radar.

TASK FORCE, COMMITTEE AND SIMILAR ACTIVITIES

R.W. Stewart

Joint Organizing Committee (JOC) of the Global Atmospheric Research Program (GARP)

Canadian National Scientific Committee for GARP

Scientific Committee on Oceanic Research (SCOR) - member executive committee

SCOR - IAMAP - IAPSO Working Group on Air-Sea Interaction Research (COSPAR) - Canadian delegate

Sea Use Council (Canada-USA) - vice-chairman

Regional Board, Pacific Region (DOE)

Regional Board, Pacific Region, Executive Committee

Regional Board, Western and Northern (DOE)

National Research Council of Canada - GARP Grants Advisory Committee

Physical Oceanographic Commission (IAPSO) - president

Beaufort Sea Steering Committee - chairman

Arctic Environmental Steering Committee

Arctic Waters Oil and Gas Advisory Committee

Royal Society of Canada Interdisciplinary Selection Committee

W.N. English

Advisory Board on Marine Technology, B.C. Research Council

Pacific Sub-Committee on Oceanography

Regional Board, Pacific Region (DOE) - alternate

Pacific Region Board Working Group on Abatement of Pollution from DOE Ships - chairman

Regional Board, Pacific Region, Estuary Working Group

Sea Use Council (Canada-USA) - alternate

Military Colleges Advisory Board

Regional Ocean Dumping Advisory Committee

FMS Study Team on Future Direction of FRB - chairman

Federal-Provincial (B.C.) Fisheries Committee

HYDROGRAPHIC DIVISION

Ages, A.B.
- Environmental Emergency Working Group, Victoria Zone
- Coastal Water Pollution Group, Committee on the Challenges of Modern Society, NATO
- Technical Committee (DOE), Annacis Island Sewage Treatment

Bolton, M.
- Canadian Institute of Surveying - Councillor-at-Large
- DOE Kitimat Oil Pipeline Working Group
- DOE Mackenzie Basin Committee
- Hydrographic Committee CIS - chairman
- National Cartographic Appraisal Board
- National Hydrographic Survey Officers' Appraisal Board
- National Hydrographic Training Committee
- New Research/Survey Vessel Users Design Committee - chairman
- Pacific Sub-Committee on Oceanography of CCO - alternate
- Research Ship Scheduling Committee
- Joint DOE/DEMR Guiding Committee of Offshore Surveys

Curran, T.A.
- Electronics Advisory Committee, Camosun College

Huggett, W.S.
- New Research/Survey Vessel Users Design Committee
- Environmental Emergency Working Group, Victoria Zone

O'Connor, A.D.
- Canadian Institute of Surveying, Victoria Branch - chairman

Rapatz, W.J.
- B.C. Civil Defense Tsunami Committee
- Ocean Dumping Act - inspector
- Canadian Hydrographers Association - national president

Sandilands, R.W.
- Hydrographic Technical Committee, Canadian Institute of Surveying
- The Canadian Surveyor - associate editor (hydrography)
- Canadian Hydrographic Association - associate editor
- Survey Technology Advisory Committee, Camosun College
- Workshop Group on Offshore Surveys for Mineral Resource Development
- Board of Trustees, Maritime Museum of B.C. - chairman
- International Hydrographic Technical Conference Committee (1979)-member

Smithers, F.R.
- Public Information Group, DOE Pacific
- Regional Committee on Interagency Routing of Navigational Information

Watt, J.V.
- Aerial Hydrography Project Sub-Committee of Oceanography Working Group of CACRS
- Electronics Advisory Committee, Camosun College

Wills, R.
- Regional Hydrographic Survey Officers' Appraisal Board - chairman
- Regional Committee on Interagency Routing of Navigational Information
- Survey Technology Advisory Committee, BCIT
- Regional Board, Pacific Region, Estuary Working Group

OCEAN CHEMISTRY DIVISION

Cretney, W.J.
- Ph.D. Dissertation Committee - D.R. Green at UBC
- Working Group on Laboratory Waste Disposal, Pacific Region
- Laboratory Safety Committee, Ocean Chemistry - chairman

Wong, C.S.
- Advisory Committee - Chemistry, CEPEX
- Ocean Dumping Technical Committee, Pacific Region
- Ph.D. Dissertation Committee - D.R. Green at UBC

OCEAN PHYSICS DIVISION

Brinkhurst, R.O.
- Honorary Professor, University of Victoria, Department of Biology
- Thesis Committees, University of Victoria
- Canadian Society of Zoologists, Science Policy Committee - chairman
- Biological Council of Canada
- Science Subvention Program Review Committee, Fisheries and Marine Service
- Ocean Dumping Technical Committee

Farmer, D.M.
- Babine Lake Steering Committee
- RODAC Technical Subcommittee
- Canadian Meteorological Society, Oceanographic Division - chairman

Garrett, J.F.
- International Council of Scientific Unions Committee on Space Research (COSPAR), Committee for Use of Satellites for Oceanography
- Canadian National Committee for Scientific Committee on Oceanic Research
- GARP Committee for Drifting Buoys

Giovando, L.F.
- Joint Working Committee Lower Fraser River Environmental Monitoring
- B.C. Coastal Zone Resource Subcommittee

Gower, J.F.R.
- Canadian Advisory Committee on Remote Sensing, Working Group on Oceanography - chairman
- National Research Council Associate Committee on Space Research
- NASA SEASAT Synthetic Aperture Radar Experiment Team - associate member
- DOE Committee on Remote Sensing

Lewis, E.L.
- UNESCO/SCOR/IAPSO/ICES Joint Panel of Experts on Oceanographic Tables and Standards (SCOR W.G.10)
- SCOR/IAPSO Working Group 51 - "Evaluation of CTD Data"
- Panel on Ice - Arctic Oceanography Subcommittee, Canadian Committee on Oceanography
- Marine Science Communications - Editorial Advisory Board

Milne, A.R.
- Beaufort Sea Project - manager
- Arctic Islands Pipeline Program - board member
- Arctic Region Ocean Dumping Committee
- SEASAT Working Group on Ice
- Task Force on Energy-Related Baseline Studies

Miyake, M.
- Canadian GARP Coordinating Committee
- Canadian GARP Scientific Committee
- NCAR Aircraft Facility Evaluation Committee
- Executive Committee Mixed Layer Experiment, U.S. Office of Naval Research
- Committee for Long-Range Transport of Air Pollutants

Nasmyth, P.W.
- IGOSS Group of Experts on Technical Systems Design and Development and Service Requirements - chairman

Tabata, S.
- Ocean Climatic Panel of Working Group 34 of the Scientific Committee on Oceanic Research (SCOR)

Thomson, R.E.
- British Columbia Coordinating Climate Committee
- Initial Environmental Assessment Study Group on the proposed Burrard floating drydock and ship repair facility

OCEAN ENGINEERING

Teng, K.
- West Coast Electronic Data Processing Coordinating Committee, DOE
- Canadian Information Processing Society, Victoria Section - program chairman
- Organizing Committee for CIPS/ACM Northwest 78 Regional Conference - co-chairman

Johns, R.E.
- West Coast Electronic Data Processing Coordinating Committee, DOE
- Univac Scientific Exchange - installation representative

SHIP DIVISION

Geldart, E.N.
- Pacific Regional Resource/Survey Vessel Committee - secretary

Institute of Ocean Sciences, Patricia Bay, 1975 Annual Report.

PACIFIC MARINE SCIENCE REPORTS

PMSR 76-1 Twaites, B.L., K.A. Coates, C. de Jong	Oceanographic observations at Ocean Station P (50°N,145°W) volume 64, 10 January-19 February 1975.
PMSR 76-2 de Jong, C.	Oceanographic observations at Ocean Station P (50°N,145°W) volume 65, 14 February-2 April 1975.
PMSR 76-3 Smyth, T.A., G.W. Arminini, C. de Jong	Oceanographic observations at Ocean Station P (50°N,145°W) volume 66, 28 March-14 May 1975.
PMSR 76-4 Brinkhurst, R.O.	Aquatic Oligochaeta recorded from Canada and the St.Lawrence Great Lakes.
PMSR 76-5 Ages, Alard and Anne Woollard	The tides in the Fraser Estuary.
PMSR 76-6 Fissel, D.B. and W.S. Huggett	Observations of currents, bottom pressures and densities through a cross-section of Juan de Fuca Strait.
PMSR 76-7 Bell, W.H., D.M. Farmer, G.R. Kamitakahara	A field translation system for Aanderaa data tapes.
PMSR 76-8 Landry, L.P.	Radar tracking of drift drogues in Pendrell Sound and Port Mellon June and September 1974.
PMSR 76-9 Stickland, J.A., R.H. Bigham	Techniques for mooring oceanographic instruments from small vessels.
PMSR 76-10 Stucchi, D., D.M. Farmer	Deep water exchange in Rupert-Holberg Inlet.
PMSR 76-11 Webster, Ian, D.M.Farmer	Analysis of salinity and temperature records taken at three lighthouse stations on the B.C. coast.

PMSR 76-12 Lewis, E.L.	Oil in sea ice.
PMSR 76-13	Oceanographic observations at Ocean Station P (50°N,145°W) volume 67, 9 May-26 June 1975.
PMSR 76-14	Oceanographic observations at Ocean Station P (50°N,145°W) volume 68, 20 June-17 September 1975.
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PMSR 76-20 Frozen Sea Research Group	Oceanographic data report d'Iberville Fiord, Greely Fiord, Eureka Sound Ellesmere Island, N.W.T. March 1976.
PMSR 76-21 Walker, E.R.	Salinity in physical oceanography.
PMSR 76-22 Bell, W.H.	The exchange of deep water in Alberni Inlet.
PMSR 76-23	Oceanographic observations at Ocean Station P (50°N,145°W) volume 71, 9 January - 18 February 1976.
PMSR 76-24	Oceanographic observations at Ocean Station P (50°N,145°W) volume 72, 13 February-12 May 1976.

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Oceanographic observations at Ocean Station P (50°N,145°W) volume 73, 1 May-23 June 1976.

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PMSR 76-27

Herlinveaux, R.H., B.R. de Lange Boom, G.R. Wilton — Water movements in the Beaufort Sea: summer 1974, spring and summer 1975.

PMSR 76-28

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PMSR-76-29

Gargett, A.E. — A method of examining the vertical background of ocean microstructure data obtained from horizontal lines.

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Farmer, D.M.; The influence of wind on the surface layer of a stratified inlet: Part II - Analysis. *Journal of physical oceanography, 6(6)*.

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Macdonald, R.W.; The distribution of low-molecular-weight hydrocarbons in the southern Beaufort Sea. *Environmental science and technology, 10*.

* Marko, J.; Satellite observations of the Beaufort Sea ice cover. *Beaufort Sea Project technical report no.34*.

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Tabata, S.; The general circulation of the Pacific Ocean and a brief account of the oceanographic structure of the North Pacific Ocean. Part I - Circulation and volume transports. *Atmosphere, 13(4)*.

Tabata, S.; The general circulation of the Pacific Ocean and a brief account of the oceanographic structure of the North Pacific Ocean. Part II - Thermal regime and influence on the climate. *Atmosphere, 41(1)*.

Tabata, S.; Evidence of a westward-flowing 'Subarctic Countercurrent' in the North Pacific Ocean. *Journal of the Fisheries Board of Canada, 33(10)*.

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Thomson, R.E.; Tidal waves (Tsunamis). *Pacific yachting, 11(4)*.

Thomson, R.E.; Winds, waves and whitecaps. *Pacific yachting, 11(6)*.

Thomson, R.E.; Tidal currents and the 1976 Swiftsure. *Pacific yachting, 12(5)*.

Thomson, R.E.; Where did the big waves come from? *Pacific yachting, 12(6).*

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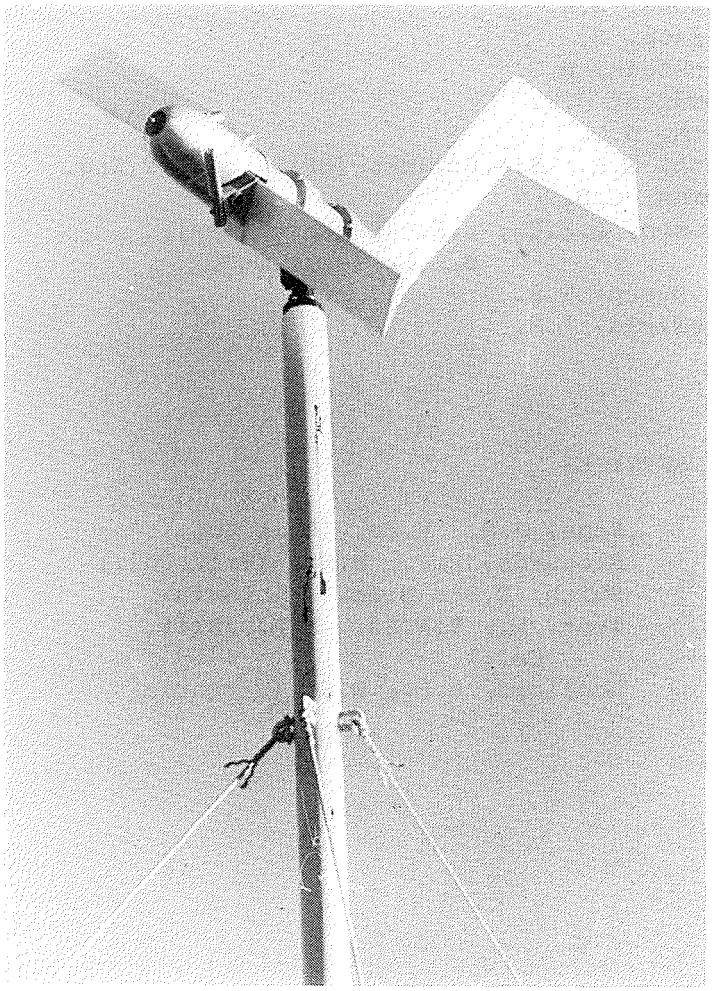
Wong, C.S., D.R. Green and W.J. Cretney; Distribution and source of tar on the Pacific Ocean. *Marine pollution bulletin, 7.*

Wong, C.S. and R.W. Macdonald; Chemical studies on ocean dumping. *Proceedings of the Workshop on Ocean Dumping Investigations, May 10-11, 1976, Vancouver, B.C.*

* Wong, C.S., D. Macdonald and W.J. Cretney; Tar and particulate pollutants on the Beaufort Sea coast. *Beaufort Sea Project technical report no.13.*

* Wong, C.S., W.J. Cretney, J. Piuze, P. Christensen and P.G. Berrang; Clean laboratory methods to achieve contaminant-free processing and determination of ultra-trace samples in marine environmental studies. *Methods and standrads for environmental measurement, Proceedings of 8th Materials Research Symposium, National Bureau of Standards, Gaithersburg, Maryland, September 20-24, 1976.*



Windmill being tested for possible use as a wind-powered battery charging source for transponders on hydrographic surveys at remote sites.

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

* Left during 1976

COMPUTING SERVICES

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

* 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

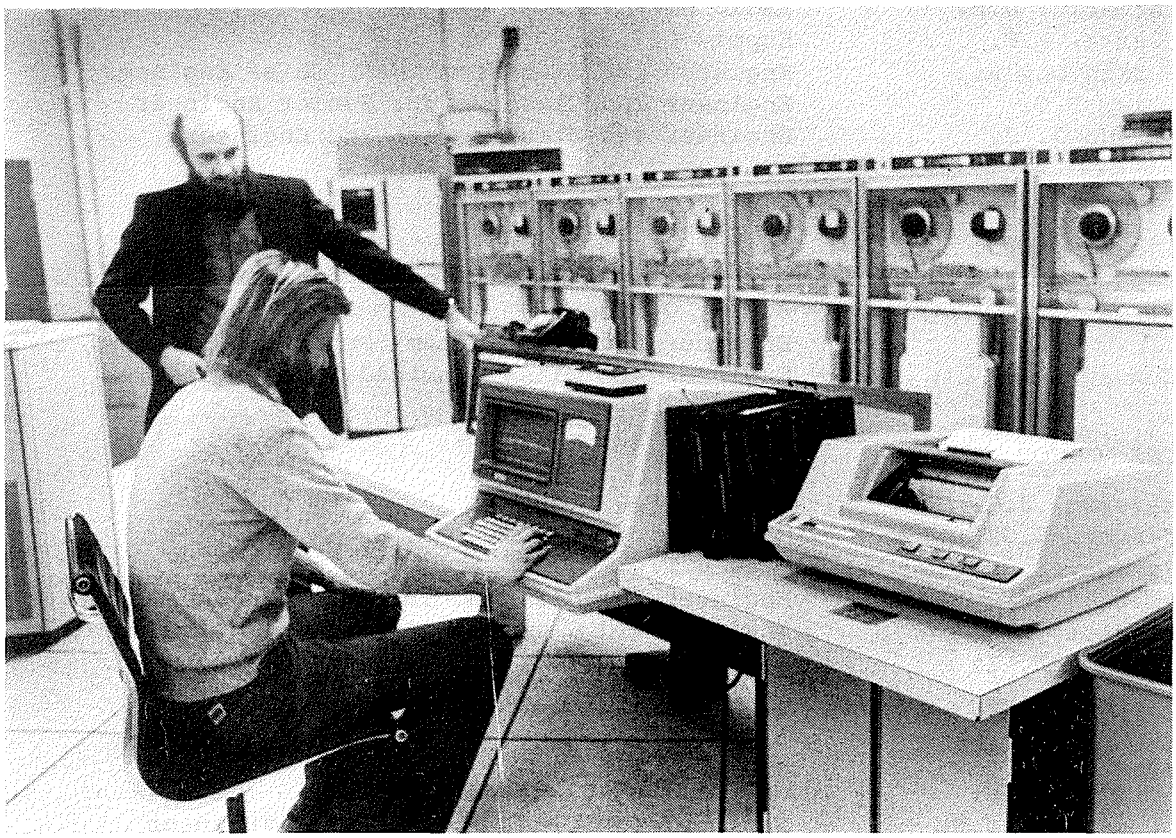
O'Sullivan, J.	Master
Butler, W.	Chief Engineer

MV PANDORA II (Charter)

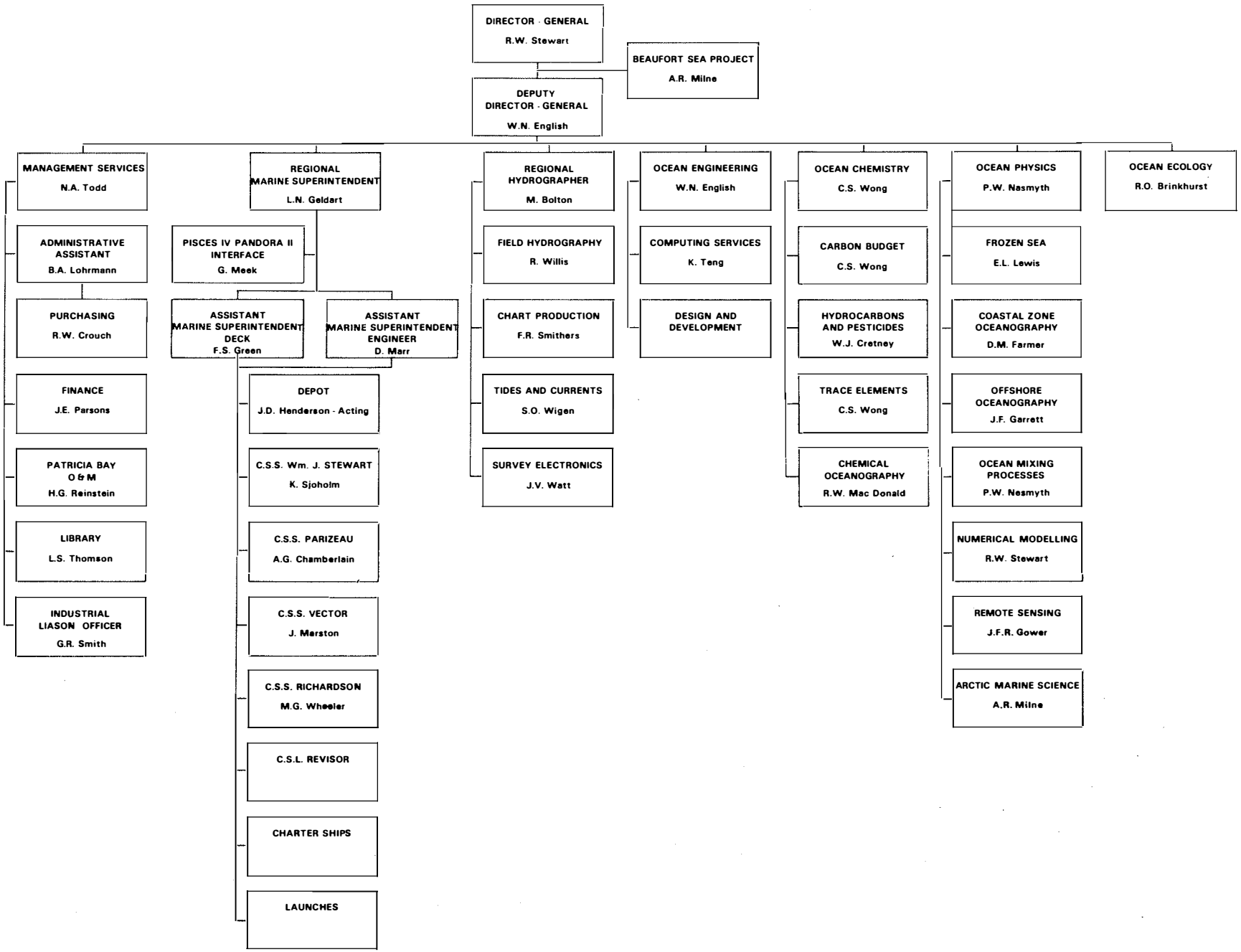
Jones, R.	Master
Tuck, C.	Chief Engineer

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



Regional Computing Centre for DFE was installed at Patricia Bay during 1976.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BEAUFORT SEA PROJECT
A.R. Milne
DEPUTY DIRECTOR - GENERAL
W.N. English
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N.A. Todd
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ASSISTANT MARINE SUPERINTENDENT DECK
F.S. Green
ASSISTANT MARINE SUPERINTENDENT ENGINEER
D. Marr
DEPOT
J.D. Henderson - Acting
C.S.S. Wm. J. STEWART
K. Sjoholm
C.S.S. PARIZEAU
A.G. Chamberlain
C.S.S. VECTOR
J. Marston
C.S.S. RICHARDSON
M.G. Wheeler
C.S.L. REVISOR
CHARTER SHIPS
LAUNCHES
REGIONAL HYDROGRAPHER
M. Bolton
FIELD HYDROGRAPHY
R. Willis
CHART PRODUCTION
F.R. Smithers
TIDES AND CURRENTS
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SURVEY ELECTRONICS
J.V. Watt
OCEAN ENGINEERING
W.N. English
COMPUTING SERVICES
K. Teng
DESIGN AND DEVELOPMENT
OCEAN CHEMISTRY
C.S. Wong
CARBON BUDGET
C.S. Wong
HYDROCARBONS AND PESTICIDES
W.J. Cretney
TRACE ELEMENTS
C.S. Wong
CHEMICAL OCEANOGRAPHY
R.W. Mac Donald
OCEAN PHYSICS
P.W. Nasmyth
FROZEN SEA
E.L. Lewis
COASTAL ZONE OCEANOGRAPHY
D.M. Farmer
OFFSHORE OCEANOGRAPHY
J.F. Garrett
OCEAN MIXING PROCESSES
P.W. Nesmyth
NUMERICAL MODELLING
R.W. Stewart
REMOTE SENSING
J.F.R. Gower
ARCTIC MARINE SCIENCE
A.R. Milne
OCEAN ECOLOGY
R.O. Brinkhurst