DEPARTMENT OF
ENERGY, MINES AND RESOURCES
OTTAWA, CANADA

annual report 1969-70

Hon. J. J. Greene, Minister

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Cat. No. M1-5/1970

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Deep-sea offshore drilling rig.

New Directions

The objective of the Department of Energy, Mines and Resources (EMR) is to enhance the discovery, development and use of the country's mineral and energy resources and broaden our knowledge of Canada's landmass for the benefit of all Canadians. To attain this objective the department devises and fosters national policies based on research and data collection in the earth, mineral and metal sciences, and on social and economic analyses. This mandate specifies the need for capability in all phases of non-renewable resources management.

The challenge posed by such a mission in a country like Canada, which is so dependent for its present state of social and economic well-being on its mineral and energy resource industries, is central to national purposes, basic to federal-provincial relations and essential to our role in the international community.

As Canada entered into the new decade, the mineral industry was setting production records and providing more and more new wealth for Canada. But the nation was also confronted with a number of complex, if not

critical, issues in the mineral and energy economy, as for example: the orderly development of the resource base and the expansion of domestic and foreign markets; capital availability and issues relating to ownership and control; new tax policies; major programs requiring new policies in the Arctic frontier and offshore in the ocean frontiers; economic growth and the establishment of environmental quality standards; the need to integrate energy supply and demand patterns and to achieve reasonable energy costs, and the fostering of viable coal and uranium industries; the development of transportation arteries at realistic costs, and the stability of communities dependent on the resource industries for the well-being of their people and the future of their children.

These and other problems have brought into sharp focus the need to develop and implement coherent and effective mineral and energy policies and to improve Canada's technological and managerial competence in these fields.

The scientific and technical organization which EMR has built up over the years provides the capability to assess energy and mineral resource potential and improve the means to discover, develop and use it.

Already the nation's leader in earth sciences, the Department provides basic physical information about the earth, which contributes to man's understanding of his planet and includes integral environmental projects and studies. The scientific knowledge gained during the implementation of these programs is important to the work and planning of many federal departments and agencies, at all levels of government in Canada, as well as to a host of commercial and industrial organizations.

The Department's responsibilities have been sharpened by the transfer of some of its activities (notably astronomical and astrophysical research, and water resource programs) to other agencies — a restructuring that has given a new thrust to mineral, energy, earth and related socio-economic sciences.

ENERGY RESOURCES

Nowhere are the complexities of resource development better illustrated than in the field of energy.

It is clear that meaningful policies can no longer be developed for a single energy commodity, such as coal, gas, or electric power, without careful consideration, from the viewpoint of the whole national economy, of the impact of one energy source on another. Alternatives posed by present and projected technological advances require careful study, for their selection imposes subtle and wide-ranging effects. What are our existing and projected sources of energy? What proportion of these sources is economically recoverable with today's technology? With tomorrow's? To what extent does Canada have energy to spare for export? What systems should best be developed to transport it? What are the ecological implications? What policies should be developed to control foreign ownership of energy resources? Should the government itself be more active in resource development?

Part of the urgency of coming to grips with these problems stems from the phenomenal demand for Canadian energy. Domestic requirements are growing at an average annual rate in excess of four per cent and thus Canada's energy requirements will likely double over the period of the next 17 years. In addition to ensuring adequate energy supplies for the domestic market, there is considerable inducement to export energy because of favourable balance of payments effects, the incentive the larger market gives to earlier and rapid development of Canadian reserves and the stimulus to the development of the basic infrastructure of a regional economy.

One of EMR's most fundamental and pressing projects, therefore, is to complete an inventory of Canada's energy sources and a forecast of domestic needs. This will take into account 1) the supply, based on earth science data, and 2) the potential demand, based on the best forecasting technology and consumer market research.

At the same time EMR's energy specialists continue to monitor and assess current trends — regional, national and international — affecting any and every facet of the energy industries. This research emerges in the form of advice and policy recommendations leading to a fully coordinated approach to energy problems.

The task is not an easy one, for each sector of the energy economy has complex problems of its own. For instance, EMR specialists in electrical energy are concerned with various forms of power-system planning and the siting of generating and transmission facilities. A wide range of regional studies is undertaken in con-

junction with provinces, e.g., the feasibility study on the tides of the Bay of Fundy, the Power Market Study of the Upper Yukon River, and the Nelson River Power Development.

In the domain of oil and gas, Canada-U.S. relations are of prime importance. EMR's oil experts are assessing such matters as the U.S. quota system against Canadian oil exports, the ramifications of the Prudhoe Bay discovery, the problems of northern pipelines and marine transportation of oil and gas, and the ecological and pollution control problems associated with oil and gas development.

The economic implications and impact of oil and gas discoveries off the Atlantic Coast are high on the Department's priority list from a policy and administrative point of view. EMR is, in fact, both trustee and manager of the mineral resources off Canada's east and west coasts and in Hudson Bay and Strait. For more than a decade the Department has, through its resource management policies and its own work in submarine geology, played a key role in encouraging industry to explore for resources in the offshore. With over 600,000 square miles now under exploratory permit to a large number of oil companies and with the exploration activity rapidly increasing, a large responsibility is placed on the Department to set standards and enforce regulations which will ensure safe and pollution-free operations. In response to this increasing responsibility, EMR has established the Atlantic Geosciences Centre at Dartmouth, N.S., for the study of marine geology and geophysics on the continental shelves and in the deep ocean, and is providing office and laboratory facilities where cores and cuttings from offshore wells can be studied and stored. The facilities will serve as a base from which to evaluate and regulate activities concerning the exploitation of Canada's offshore mineral resources.

In the west, EMR has stayed with the coal industry through hard times and, in several ways, has contributed to the resurgence of the western coal industry. The Department is also studying the supply-demand picture affecting Ontario coal consumers and their dependency on imported coal and assessing technological improvements in coal mining, processing and transportation.

In the area of uranium and nuclear energy, there are many activities requiring immediate and in-depth attention. Indeed the strategic importance of uranium, the fact that Canada has large uranium reserves and a substantial government uranium stockpile, and the economic value of uranium both for export and domestic use are factors demanding the development of sound and flexible national policies and guidelines.

Canada's energy position is also being strengthened through geological investigations and fuels research.

Of some 500 continuing projects under way at the Geological Survey of Canada, a branch of the Department, a large number are directly, or indirectly, concerned with energy development. Many are conducted by the Institute of Sedimentary and Petroleum Geology in Calgary. The range of projects extends from field work in sedimentary basins of the Arctic to the development of new methods for petroleum prospecting, and includes many other field and laboratory investigations. In 1970 the Survey completed a study of the Mackenzie Delta and valley to provide geological information of importance to possible pipeline construction.

Meanwhile, advances in energy technology are being made at EMR's Fuels Research and Metals Reduction and Energy Centres which, in essence, are researching better ways of using and conserving Canada's reserves of coal, petroleum and natural gas. The Centres are currently giving special attention to combustion research with a view to the reduction of air pollution, the refining of low-grade oils, and the development of metallurgical coke from Canadian coal. Their work so far has done much to open up new markets for Western coal in Japan. They are currently studying the possibilities of using a water-slurry pipeline as a more economical way to move coal from strip mines in the Rockies to tidewater ports.

In the field of refining, fuels scientists are developing methods of converting the bitumen of the Athabasca tar sands to synthetic crude oil. These Canadian deposits contain some 600 billion barrels, one of the greatest sources of oil in the world. The challenge is to find processes that will permit the economic extraction and use of this tremendous potential and also that of other heavy oil deposits in Western Canada.

Drill jumbo in use, Sudbury nickel mine.

MINERAL RESOURCES

Departmental programs in reserves determination, mining, metallurgy and the processing of industrial minerals involve both policy formulation and scientific research in laboratory and field. In addition, factors, such as the strategies of foreign countries and multinational firms to obtain the maximum benefit from Canada's mineral base are proving a challenge of increasing importance. Thus the Department is focussing greater effort on policy formulation and programs to increase returns from exports and to improve the social-economic effects from mineral industry development throughout the nation.

EMR must ensure that the country's needs for mined products are met and it therefore monitors the performance of the industry with a weather eye on its economic health and the factors that affect it.

To identify and evaluate trends affecting the industry, EMR's resource economists study the entire spectrum of mineral industry activities from geologist to user: exploration and development, processing, transportation, marketing and consumption. The information provides a basis for decisions to be taken within the Department and contributes to the development of resource policies. Typical recent projects have involved such diverse matters as a cooperative study of minerals management undertaken with the Province of British Columbia: research leading towards a federal-provincial program for mineral development in Manitoba; special studies of concern to Newfoundland, New Brunswick, and Quebec in collaboration with the federal Department of Regional Economic Expansion, and cooperative planning for resource development in the north with the Department of Indian Affairs and Northern Development.

Other projects concerned the White Paper on Tax Reform and its impact on the industry, the potential benefits that might be derived from future mineral development in northwestern Canada if a new railway network were developed and other programs touching on some 60 mineral commodities.

EMR economists sit on numerous intergovernmental and international bodies concerned with mineral matters.

Highlighting developments in the industry in 1970 was

the changing pattern of trade in mineral products, with Japan emerging as a leading customer, especially of products from the West. Of all minerals imported by that country in 1969, one third of the potash, 50 per cent of the asbestos, 36 per cent of the molybdenum, one third of the lead and zinc concentrates, and 50 per cent of the nickel came from Canada. In addition, Japanese capital is participating in no less than 15 different copper development projects in the Canadian west. And the growing Japanese steel industry has been using Canadian iron ore for some years. Now strip mining of coking coal for these mills is becoming an important industry in Alberta and British Columbia. Shipments from the Pacific Coast could well be in the 30 million-ton-per-year range by 1975.

The federal government has recognized the importance of this new relationship. In December 1970, the Honourable J. J. Greene led a mission of government officials and mining industry representatives to Japan for talks at the level of the Japanese government and at senior business levels in Japan regarding the general trading and investment posture of Japan in the Canadian mineral industry and regarding a whole host of issues concerning the market performance of mineral commodities, Japanese demand and supply, further processing, Japanese investment in Canada and Canadian investment in the mineral processing industries in Japan, and other topics.

EMR's responsibilities in mineral development also extend into the laboratory and the field.

EMR's work in geology and geophysics provides a foundation for discovery and evaluation of Canada's mineral resource potential. Summer field parties were located in almost every province and every physiographic region of the country and in many locations of economic interest to the mining industry.

Other EMR geological programs deal with economic geology of mineral occurrences and some seek to improve the technology of prospecting and exploration. More of these programs are described in the body of this report.

Meanwhile, EMR scientists are working to improve the technology of mining, the processing of ores and minerals, and, through research in physical metallurgy, the development of new alloys and metal fabricating methods, ultimately broadening the market for Canadian metals.

Projects in mining technology, for instance, are producing answers to practical problems. For example: How can current methods of drilling, blasting, crushing and grinding be improved and made safer and less costly? How can the stability of a mine excavation or the sides of a quarry be determined? How can systems engineering be best applied to mining operations?

In answer to a need for greater government-industry cooperation, EMR set up a National Advisory Committee on the Mineral Industry to advise the government on a wide variety of issues affecting the industry. One of these is the maintenance of realistic environmental standards in the national interest.

Canada's mines and smelters use over a billion gallons of water a day, and produce 300 million tons of waste tailings a year. Much of this material is returned underground as fill. To date, a total of 130,000 acres of land have been used on which to store the remainder. Between now and 1975, a departmental survey shows that the mining and primary metallurgical industries plan to spend an estimated $500 million on environmental control.

In one environmental project, EMR researchers used a probe mounted on a helicopter to measure gas flows from the tall stacks now used to disperse sulphur dioxide. They hope, by studying the mechanism of sulphur dioxide dispersal, to establish optimum heights for such stacks. Other projects are aimed at the development of processes that avoid or prevent the production of sulphur dioxide. The extraction and processing aspects of mining pose many scientific and technological questions which EMR scientists are attempting to answer.

A good example of a successful commercial development resulting from recent departmental research is the Leigh oxygen probe. This instrument, developed by EMR's physical metallurgists, helps steel makers detect and measure unwanted oxygen in the molten metal. The project was carried on cooperatively by EMR, the Canadian steel-making industry, and Leigh Instruments Limited. The probe is now being marketed by the Canadian company to steel mills around the world.

WATER RESOURCES

Highlights of the Department's research and policy-making activities in water resources were the passing of the Canada Water Act to control water pollution and the successful completion of Hudson 70. The latter, the epic voyage of EMR's oceanographic ship around both North and South American continents, was a major navigational 'first'. Even more significant in the long term were the scientific results.

The 11-month, 41,000-nautical-mile expedition, resulted in the collection of a great mass of data on the Atlantic, Antarctic, Pacific and Arctic Oceans, contributing greatly to world oceanography and to the development of Canada's undersea resources.

Apparatus for thermal destruction of DDT, Fuels Research Centre, Mines Branch.

EARTH SCIENCES AND LAND-MASS MANAGEMENT

The Department continues to be responsible for carrying out the basic research programs and the technical surveys necessary for engineering and resource development purposes.

These include field and air surveys, topographic and other forms of mapping and geological and geophysical research. The programs are designed to further man's knowledge of the solid earth and thereby assist the nation in meeting its economic, social and other needs.

As the government agency for the preparation and production of maps (topographic, legal, electoral and other), EMR is providing data that is fundamental to national development and resource management. Maps at four miles to the inch now cover the entire country and those at one mile to the inch cover about 35 per cent. Annual sales of maps are nearing an all-time high of three million. Soon to be completed is the fourth edition of the *National Atlas of Canada.*

In earth physics, the Department undertakes research and field work in geomagnetism, seismology and gravity. Apart from their value to world science, these programs

are of considerable practical importance — for instance, to navigation by air and sea, to mineral exploration and even to the detection of nuclear explosions.

Geological surveys and research contribute to the land-mass management program mainly through the gathering of data on unconsolidated earth materials, land forms, rock structures and, in general, on the physical geography of Canada — information that is vital to a host of matters (e. g. rural and urban planning, efficient land use, structural engineering, environmental control and advice on both the use and misuse of terrain). Particularly significant is its value to northern development and the solution of terrain problems associated with it. One current area of activity relates to the terrain problems which might be encountered by pipelines along the Mackenzie Corridor.

Over the years EMR activities and facilities on Canada's polar continental shelf have paved the way for numerous developments in the Arctic and contributed to Canada's Arctic achievements. It goes without saying that adequate information about the Arctic and its environment is basic to the development of national and regional policies affecting it.

EMR carries out a multi-disciplined research effort covering the undersea continental shelf fringing the Arctic coast of Canada together with adjacent parts of the Arctic Ocean basin and the islands of the Canadian Archipelago. Scientists from other agencies also use EMR facilities for work in their own disciplines.

Looking to the future, EMR is moving rapidly into the field of space technology. The Department will soon have the means to obtain basic physical information about the country from instruments aboard orbiting satellites in NASA's Earth Resources Technology Satellite (ERTS) program.

A four-year agreement has been signed with NASA which will provide Canada with satellite photos and other data free of charge. At the same time Canada, under the leadership of EMR, is organizing a program of remote sensing by high altitude aircraft to supplement the satellite data with required detail.

Over 200 scientists from across the country have been involved in working groups for the past year studying how Canada can best develop a remote-sensing technology embracing both airborne and orbital sensing. Contracts for $200,000 worth of specialized sensors for the program have already been awarded to various Canadian organizations.

Measuring gravity at Arctic Ocean camp on polar ice.

The existing receiving station at Prince Albert in Saskatchewan will be used for reading out satellite data for all Canada with the exception of the Atlantic Seaboard. Data from the Atlantic Provinces will be received by a nearby U.S. station and the tapings sent to Canada for processing. All data collected will be sent to a Ground Data Handling Centre in Ottawa, where it will be corrected, reproduced and distributed to government agencies, universities and other organizations — an estimated 900 users in all. Capital cost for the station and data centre will be about $4.6 million.

The ERTS satellites can provide complete coverage of the world in 17 days. Photos show such variations as changes in snow and ice cover, changes in leaf cover in the forests, changes in water levels in lakes and rivers and even changes in surface temperature.

Canada is particularly anxious to obtain satellite photos in areas of critical interest such as the Beaufort Sea (ice cover), the Mackenzie River Delta (permafrost, possible damage to the environment from mineral exploration), the Mackenzie River valley (in anticipation of the proposed pipeline), the Prairies (crops), the Great Lakes (pollution), Hudson Bay (ice), the Gulf of St. Lawrence (oceanography) and the continental shelf on the Atlantic coast (ocean pollution).

ADMINISTRATION PROGRAMS

In the immediate future, the Department's success in carrying out its mandate may very well be determined by its success in coordinating and giving thrust to a number of diverse scientific and socio - economic programs. A prime concern, therefore, is to develop management structures necessary to make such an organization work effectively, with the agility to respond immediately to changing situations. Equally important is the need to provide the various departmental sectors with efficient support services (i.e. in planning, personnel, finance and administration, computer sciences and public relations and information). It should be added, however, that the Computer Sciences Centre is serving not only the needs of EMR but those of the Water Resources Branches of the Department of the Environment. The Department recently has signed a contract for rental of a large-scale CDC 6400 computer system with seven terminals located in various EMR buildings in Ottawa.

It is expected that EMR's central services and a number of other units of the Department will by 1973 be housed in a new high-rise building to be erected on the Booth Street site.

CONCLUSION

An essential activity of the Department of Energy, Mines and Resources is to build a foundation of knowledge and expertise for the development of sound policy recommendations. This is vital to the effective management of Canada's mineral and energy resources and to the solution of many complex and interrelated problems in this field.

How these resources are developed and used will have a profound impact on the national economy and the lives of Canadians.

Mines and Geosciences Sector

SURVEYS AND MAPPING BRANCH

The Surveys and Mapping Branch is responsible for providing the survey data, maps and aeronautical charts required by Canada for security, administrative purposes and the management of national resources.

Survey activities during the year included the operation of some 60 field parties that conducted surveys for geodetic and mapping control, for cadastral and boundary work and for field checks of mapping.

The Topographical Survey Directorate achieved a new record of output in producing 704 maps, comprising new and revised mapping. The status for mapping now available in Canada is: Maps at 1:25,000 (or 2½ inches to one mile) number 645 and cover urban and industrial areas; maps at 1:50,000 (or 1¼ inches to one mile) number 4,650 and cover 35 per cent of Canada's territory; and maps at 1:250,000 (or four miles to one inch) number 920 and cover all of Canada's territory. There are also maps at smaller scales covering all of Canada. All of these maps are being revised from time to time.

Map reproduction during the year included 2,118 different maps and charts, and involved a total of 38.5 million printing impressions.

The development of an Automated Cartography system in the Branch made encouraging progress. Hardware and software requirements are being resolved and considerable practical experience is being gained in the cartographic needs of the mapping program and the ways in which automated techniques can establish accuracy and quality in the maps to be produced.

The fourth edition of the *National Atlas of Canada* is being produced at a rate of approximately four sheets per month. At the end of the fiscal year 65 of the 128 sheets of maps, indexes or texts etc. were in various phases of production beyond the research stage.

In order to promote and sell maps the Branch was represented at nine major shows, and 1,523 people were conducted on tours of the Branch divisions. During 1969-70, map sales reached an all-time high of 2.7 million.

External assistance by the Branch in support of the Canadian International Development Agency continued in the form of consultant services for surveying projects in the West Indies and Africa, and also summer training courses for overseas students. On the broader international scene Branch personnel attended many international congresses, thus indicating Canada's interest and competence in the field of surveying and mapping.

The Mapping and Charting Establishment of National Defence made a modest but worthwhile contribution to various field surveys, map compilation and printing

when its resources permitted. The co-operation of all the provinces and the U.S. Geological Survey in many aspects of the Branch's work contributed to a progressive year.

The text of this report indicates the variety and scope of the Branch tasks necessary to fulfill the duties as the federal agency responsible for national control surveys and mapping, which in 1969-70 produced a record of expansion and accomplishment.

FIELD SURVEYS DIRECTORATE

Geodetic Survey

Thirty-two field parties established horizontal and vertical control to extend and densify the existing national control-survey framework and to provide control for the national mapping program. A number of special projects were also carried out, and the survey continued its investigational projects.

The extension and densification of the first-order horizontal control framework was carried out in the Yukon and Northwest Territories and in five provinces. In the Territories the aerodist program was continued, and the network extended north from Wrigley down the Mackenzie River to the Arctic coast north of Inuvik. This project covered an area of 98,800 square miles, established 42 new ground stations and provided mapping control for 377 map sheets (1:50,000) in this area of very high interest to the petroleum industry. In British Columbia and Alberta the spur network, which had been completed from Golden to Mica Dam in 1968, was extended north to connect with existing surveys west of Jasper, and the main east-west network was extended east from Golden to connect with existing surveys near Calgary. In southern Ontario the network, which had been completed from Chatham to Sarnia in 1968, was extended northeast to connect with existing surveys near Strathroy; a new network to cover the gap in control along the north shore of Lake Erie was completed from St. Thomas to Tillsonburg. In Quebec the co-operative densification program was continued and the network extended westward as far as Quebec City. In Nova Scotia a new network was established from Halifax north to Minas Basin, west to Annapolis Royal and thence southeast to connect with existing surveys near Liverpool. A scale-control party measured existing lines in Nova Scotia and New Brunswick to improve the scale of the existing networks.

First-order levelling was done in seven provinces. Re-levelling was carried out in the vicinity of the Bennett Dam in northern British Columbia in a continuation of the study of crustal movements in the area. In Saskatchewan a grid of level lines was established in the Watrous-Saskatoon area. The Trans-Canada level line was extended eastward from the Saskatchewan-Manitoba border and was completed to Sault Ste. Marie, Ontario, a distance of 1,260 miles. A Geodetic Survey — Manitoba Hydro project was carried out in the vicinity of Thompson, Manitoba, to provide vertical control information for studies related to the development of hydro-electric power. A winter party continued this work in February-March 1970. Levelling of high precision, using the metric system, was continued in the International Great Lakes Datum re-evaluation program. The line was extended eastward from Beauharnois to Levis, Quebec; this line also serves as part of the Trans-Canada level line. In the Churchill Falls area of Labrador a new line was run from Esker to Sail Lake. In Nova Scotia new lines were run along the Bay of Fundy coast, and a number of river gauges and Bay of Fundy tidal gauges were connected in the course of the work. A small party re-levelled ties to 18 water-gauge sites along the St. Lawrence Seaway between Cobourg, Ontario, and Quebec City, and checked the stability of 12 deep bench marks in the area between Pickering and Trenton, Ontario.

Five astronomic parties worked in the Northwest Territories and in the provinces of British Columbia, Saskatchewan, Ontario, Nova Scotia, and Newfoundland. Thirteen Laplace azimuth stations were established, two old Laplace stations were re-observed, ten plumb-line deflections determined and an orientation azimuth determined for the Magnetic Observatory at St. John's, Newfoundland.

The project which provides vertical control for the Western Cordillera gravity program of the Observatories Branch, and also provides control for 1:50,000 mapping, was continued. A Geodetic Survey party extended control through an area of 3,000 square miles in the Quesnel Lake area of British Columbia, and through an area of 8,000 square miles which lies east of the British Columbia - Alberta boundary between Lake Louise and Jasper. A party from the Mapping and Charting Establishment, Department of National Defence, established a small amount of ground control, verified and identified additional existing control in an area of approximately 14,000 square

miles in the vicinity of Bella Coola, on the British Columbia coast. This control is being used in conjunction with super-wide-angle photography which was flown simultaneously with Airborne Profile Recorder measurements to produce the vertical control and mapping control by photogrammetric methods.

Assistance to provincial and municipal authorities in establishing co-ordinate systems of control surveys was continued at a reduced level. In Ontario the co-operative Ontario Department of Highways — Geodetic Survey horizontal-control program was continued in the western part of the Niagara Peninsula and in the Windsor-Merlin area. Horizontal control networks were also established in Sarnia, Sarnia Township, Dover Township and in the northern part of Burlington. Vertical control grids were established in Sarnia, Chatham and Burlington, and in the eastern section of Montreal, Quebec.

Three parties were engaged in establishing control for 1:25,000 mapping at Three Rivers, St. Hilaire, St. Jerome and Valleyfield in Quebec, and at Cornwall, Pembroke, Blenheim and Georgetown in Ontario. During the late fall and early winter two parties started on a project to provide control for 1:25,000 mapping in the Ste. Scholastique, Quebec, area where the new international airport will be constructed. A helicopter-supported party established horizontal control for 1:50,000 mapping near Berens River, Manitoba; Mistassini Lake-Chibougamau, Quebec; and Goose Bay, Labrador. Control for 1:50,000 mapping was also established in the vicinity if Ivujivik, Quebec, at the western end of Hudson Strait.

A number of special operations included the positioning of a number of air-navigational aids for the Department of Transport, and the establishment of horizontal and vertical control for large-scale plans of several Indian reservations and for the new National Park at Long Beach, Vancouver Island; this latter work was requested by the Department of Indian Affairs and Northern Development. At the request of the Observatories Branch a second-order traverse from Yellowknife to Rae, N.W.T., established positions of a series of points approximately two kilometres apart along the Yellowknife-Rae highway. While this work was primarily to provide control for a seismological project of the Observatories Branch, it will also provide horizontal and vertical control for legal surveys and 1:50,000 mapping in the area. In Nova Scotia a survey team from the Royal Engineers of the British Army carried out two projects under the general direction of Surveys and Mapping Branch. The first project was to establish vertical and horizontal control for a photomapping test project in the Cornwallis area. The second project involved the establishment of a horizontal - control densification survey by trilateration, the measurement of distances only, in accordance with specifications of the Geodetic Survey. The first project was completed, but the trilateration survey was only about 80 per cent complete when the team returned to England.

Several advanced experimental and theoretical projects were carried out to keep the Surveys and Mapping Branch in the forefront on new techniques and instrumentation.

Legal Surveys

The Legal Surveys Division continued its statutory general management and technical control of all legal surveys in Indian Reserves, National Parks and the Territories. During the year, the City of Whitehorse and the immediate surrounding area was officially established as a Co-ordinated Survey Area. Hence the placement of all new official survey monuments shall involve surveyed connection to reference points prescribed for the purpose and description in terms of the system of co-ordinates prescribed for the Area.

Work on two major survey projects, the subdivisions of the Six Nations Indian Reserve in Ontario and the Caughnawaga Indian Reserve near Montreal, continued. Although the field work has been completed on the former, some 20 official plans still remain to be compiled. In addition to the 15 field staff parties that were engaged on legal surveys, 29 surveyors in private practice were engaged to undertake a number of projects required by federal government organizations administering the lands involved. One hundred surveys were made in Indian Reserves in all the provinces except New Brunswick and Newfoundland, 21 in National and Historic Parks, and 30 in the Territories.

Survey plans examined numbered 398, of which 152 were surveys required by administering organizations and 246 were surveys required by outside organizations or individuals. The Division issued 278 sets of technical instructions, and 372 airline distances were computed and supplied for official purposes. Documents recorded in the Canada Lands Surveys Record numbered 581,

and some 75,000 document copies and extracts, and astronomical field tables, were dispatched. It was decided to microfilm all the Canada Lands Surveys Records. About ten per cent of this task was completed.

The Board of Examiners for Dominion Land Surveyors met five times. A new edition, the eighteenth, of the *Regulations, Rules and Instructions* was published. Of the 32 candidates who sat at the 1970 annual examination at centres in Ottawa, Edmonton and Calgary, four passed the preliminaries, one the intermediate, and five the finals, the latter qualifying for the Dominion Land Surveyor commission.

Two federally appointed commissions, chaired by the Surveyor General of Canada Lands, were active this year with respect to the survey and maintenance of provincial boundaries.

The Manitoba-Saskatchewan Boundary Commission continued the resurvey of the southerly 240 miles of this boundary. This year's program included the monumentation of 167 miles of boundary surveyed in 1967 and 1968, with 139 concrete monuments. The survey and clearing of 26 miles was completed through the rough terrain and dense growth of the Duck Mountains. This latter section involved placement of 20 concrete monuments. In all, 193 miles of boundary were completed and the Commissioner personally inspected various parts of the work.

The British Columbia-Yukon and Northwest Territories Boundary Commission began a program of maintenance of this boundary. This included resurvey and recutting of 5½ miles at the Liard River and resurvey of 12 miles in the mountain region east of the Haines Road. This latter work was extremely difficult because of snow conditions at the higher altitudes. In addition, 41 miles of boundary vista were recut and 60 monuments inspected at road crossings along the boundary and 160 miles of vista were sprayed with herbicides from helicopters. A total of 220 miles of boundary were inspected and maintained.

International Boundary Commission

The International Boundary Commission under the authority of the Treaty of 1925, and the International Boundary Commission Act (Eliz. II, Ch. 31, 1960) is responsible for the effective definition and marking of the boundary between Canada and the United States. In discharging these responsibilities inspection and maintenance operations are carried out annually, and all works within 20 feet of Canada's international boundary are effectively regulated.

The Commissioner for Canada and the Commissioner for the United States make joint inspections of the conditions along the boundary, and of the work of the various field parties engaged on sections of the Quebec, Ontario and Manitoba international boundaries.

Three Canadian field parties completed maintenance operations on the Quebec-Maine, Ontario-Minnesota and British Columbia-Washington boundaries. Operations on the Quebec-Maine Highland boundary consisted of the treatment of 54 miles of 20-foot boundary vista to control growth, and the inspection of 1,319 boundary monuments of which 30 required surveys for accurate relocation. A second Canadian party continued resurvey operations on the Rainy River, Ontario-Minnesota boundary to re-establish reference monuments which became lost or disturbed by erosion and construction operations, and to improve the overall accuracy of the original boundary survey in that area. Twenty-seven reference monuments were re-established and accurately tied to primary geodetic control. The program of controlling growth along the 20-foot vista through British Columbia was continued during the field season. Herbicides were applied by helicopter to 51 miles of boundary vista in selected areas eastward from the Okanagan Valley.

The new and improved methods of maintaining right-of-way vistas, over the past decade, have vastly improved the effective definition and marking of Canada's international boundary.

TOPOGRAPHICAL SURVEY DIRECTORATE

Photogrammetry Division

This report covers the first full year of operation since the division underwent an internal reorganization in late 1968. The reorganization grouped the personnel into seven mapping teams and was primarily designed to increase productivity by delegating authority and upgrading the knowledge and skill of the staff. These objectives have been achieved, resulting in a substantial increase in production. The details of the year's production are as follows:

Production of Mapping 1969-70

Scale	*New Mapping*	*Revised Mapping*	*Total*
1:25,000	22	55	77
1:50,000	456	154	610
1:250,000	3	14	17
Total	481	223	704

During the last two years, the Division has succeeded in clearing a backlog of approximately 250 1:50,000 maps that had been compiled but lacked cadastral information and final inspection. The Division has now reached a production schedule of 15 months embracing the complete mapping cycle from project initiation to clearance to the Map Production Directorate.

Many of the existing older maps in the settled areas of the country are out of date and are of questionable use to the public. Increased emphasis has been placed on the revision of existing maps over the past three years. It is estimated that in the year 1970-71, revision will account for 50 per cent of the maps produced by the Division.

The Division's role as a consultant to other federal agencies in the field of photogrammetric mapping continued to increase.

The Division reviewed 1:50,000 compilations by the British Columbia Department of Lands, Forests and Water Resources prior to reproduction by the Map Production Directorate. Thirty of these maps were examined in the past year.

The Research and Engineering section has continued its development of new and improved mapping methods and adjustment procedures. Areas of particular emphasis include photomapping, a program to improve the method of obtaining ground elevations by radar altimetry, computer programming for the adjustment of large blocks of mapping, use of color photography in mapping, investigation of new photogrammetric instrumentation, aerodist photography and methods for improving the identification of field control.

Aerial Photography Division

The Branch reorganization in 1968 united the National Air Photo Library and the Air Photo Production Unit to form the Aerial Photography Division as part of the Topographical Survey Directorate. This change was made to co-ordinate the operations of the two units involved in the dissemination and reproduction of aerial photo products to government, industry and the public.

The National Air Photo Library continued to receive more queries on the availability of photography for specialized uses and an increased volume of orders for aerial photographs. Both operations showed an increase of 6 per cent over 1968-69, a figure which has been maintained for the past 12 years. The Branch Photo Library in Calgary has now been in operation for a year and is gradually building up a clientele who find the service very helpful. Orders from this office are expected to increase greatly in the next year.

A new system was installed in the Library which enables the staff to produce copies of the photo-coverage index maps within minutes. This improvement has expedited the provision of this item to customers; it also results in reducing the administrative load on the unit.

Under agreements, the Division stores the negatives of provincial photography for Newfoundland, Nova Scotia, Prince Edward Island, Manitoba and Saskatchewan. This photography is as readily available to the public as federally acquired photography, for the Library holds reference prints and maintains indexes.

The Air Photo Production Unit suffered from the loss of a number of key personnel due to resignations, resulting in a decline in production. A determined effort by the staff of this unit to meet the demand for aerial photographs kept the effect of this production loss to a minimum.

The Hostert color-film processor was acquired and put into operation, providing a continuous processor for aerial color film for the first time in Canada. This equipment accounted for a marked improvement in the quality of color aerial photography.

The Division continued to provide training for technicians from developing countries under the external aid program, with one trainee from Kenya and another from Guyana.

This year saw increased demand for aerial photographic services. All indications point to an annual increase in demand of approximately 10 per cent for the next five

years. Of interest is the marked increase in requests for aerial photographs from educational institutions and the increase in orders originating from the U.S.A. There have also been many new applications of aerial photography during the year, one of which has resulted in large orders for photographs from statisticians for use in the 1971 census of Canada.

MAP PRODUCTION DIRECTORATE

Cartography Division

The Division is responsible for the compilation of general maps, aeronautical chart bases, electoral maps, bilingual-district maps and the 1:125,000 series. It provides cartographic support in the reproduction of N.T.S. maps compiled by the Topographical Survey by scribing, type selection, type affixment and hill shading. Maps received from the Topographical Survey for reproduction numbered 704. These included 77 at the scale of 1:25,000, 610 at 1:50,000 and 17 at 1:250,000. Derived map compilations produced by the Division totalled 176; these included six general and special maps, 25 1:125,000-series maps, 26 aeronautical chart bases, nine IMW maps, 71 electoral, bilingual, departmental miscellaneous and 39 for other departments of government. Drafting production for the year totalled 786 completed jobs. These included 88 at 1:25,000, 537 at 1:50,000, seven at 1:125,000, 19 at 1:250,000, eight IMW, 37 aeronautical charts, 41 indexes and 49 miscellaneous drawings.

The status of the 1:50,000 National Topographic Series stands at 29.8 per cent published or 3,995 maps of a potential 13,200 for all of Canada. In the 1:250,000 series only three remain to be published of a total of 918, and in the 1:500,000 series only five of 219 have not yet been converted from the 8-mile scale.

Map Reproduction Division

Map printing during the past year included 930 topographical maps, 399 air charts, 39 general maps, 511 departmental projects and 239 maps and charts for other departments, for a total of 2,118 maps and charts printed.

The Operational Research Unit received 52 projects during the year while six were carried over from 1968. Of these 54 were completed, 39 accepted, eight rejected, seven abandoned and four still in progress. The Division acquired a new color offset press and other new equipment. The metal foundry type was declared obsolete during the year.

Aeronautical Charts Division

The Division continued to produce up-dated aeronautical charts and related flight-information publications. New radar-surveillance charts were developed to assist air traffic controllers in their work, special charts of the Joint Arctic Weather Stations are being produced as aids to radar approaches, the series of 69 1:1,000,000-scale aeronautical charts is being redesigned to a series of 19 charts in the interest of better service, and the first edition of a *Manual of Criteria for Instrument Approach Procedures* was produced. In addition, significant extensions were made to the following series: Radar Surveillance Charts, Air Traffic Controller Charts and Maritime Plotting Charts.

Toponymy Division

During the 1969-70 fiscal year, the Division, in support of the Canadian Permanent Committee on Geographical Names, investigated 28,235 names of which 5,399 were new decisions. Besides names for new and revised maps, geographic nomenclature for 235 other maps was checked and verified. The staff answered 332 inquiries, entailing a significant amount of investigation and research.

A new edition of the Saskatchewan volume of the *Gazetteer of Canada* series was produced in 1969. The second edition of the New Brunswick volume is being prepared for publication.

The field-research program in New Brunswick was completed in 1969 and a study of the origins of names in that province is being written.

The Map Library answered 1,290 inquiries, loaned 969 maps, atlases and gazetteers to internal agencies and others concerned with map production and cartographic research, and acquired 6,819 new maps, 22 atlases and five gazetteers.

Almost 3,000 visitors were taken on tours of the Library's display areas, which illustrate new maps and new cartographic techniques.

The Canadian Permanent Committee on Geographical Names met in Toronto in 1969. The Secretary

participated in a meeting of the ad hoc group of experts on the Standardization of Geographical Names in New York in March 1970, and was appointed chairman of the section on maritime and underseas features.

BRANCH FUNCTIONS

Map Distribution Office

Distribution of maps and air charts to civilian clients rose 20 per cent for the year to a total of over 2,600,000 maps. This increase is in part due to more attention to public relations. Over 1,500 students, teachers and officials toured the Branch, illustrated talks were given at local schools, and booths staffed by qualified personnel occupied prominent positions at nine regional and sportsman's shows, mostly in Ontario. A publicity film and various brochures were prepared to widen this coverage in future. The Branch supplies 282 approved map dealers throughout the country and an attempt is made to visit each outlet at least once every two years to ensure that good service is maintained. Constant liaison is maintained with many map libraries. Revenue from map sales did not keep pace with distribution but increased 12 per cent to $515,000.

Three members of the Mapping and Charting Establishment, DND, were attached to the Map Distribution Office to handle Canadian Forces requirements which eased somewhat to a total of 980,000 maps.

Geography Division

This small unit is responsible for production of material for the fourth edition of the National Atlas of Canada and various related thematic maps. The atlas will comprise 128 sheets being prepared simultaneously in English and French. Most of the map work is well in hand and the remaining text material should proceed rapidly.

Several thematic maps were revised and about 40 new ones printed, including *Census Divisions of Canada, Population Density and Radio and T.V. Coverage.*

Automated Cartography

The study of applying computer technology to the graphical work of the Branch began in 1967 and was directed in particular to the major problem facing it, that of production and the systematic revision of the thousands of 1:50,000 maps included in its program. It was also realized that the system must be versatile enough to cope with occasional urgent orders for maps and to produce a wide range of special maps from the stored digital data.

The study had advanced sufficiently by the beginning of 1969 to decide the procedures and to write the specifications for the equipment required to undertake the three phases of digitizing the source material, of processing the digitized data in a computer and of plotting the processed data on an automatic drawing table. Contracts were placed for the specified equipment and in March 1970 a cartographic digitizer and a computer were delivered.

INTERDEPARTMENTAL COMMITTEE ON AIR SURVEYS

During the year, the Interdepartmental Committee on Air Surveys monitored aerial photography contracts in all provinces and territories to meet requirements from 16 federal departments and agencies.

Because of abnormally poor weather conditions a large number of contracts were not completed which will seriously affect the planned mapping program of the Branch.

Methods to increase the photographic coverage required to carry out the mapping program for the orderly development of the country will be attempted during the coming year, one of which is the use of a jet aircraft with the mobility and speed to follow favourable weather patterns.

TECHNICAL AID SECTION

The Surveys and Mapping Branch continued to support the Canadian International Development Agency (C.I.D.A.) by providing consultant and inspection services for surveys and mapping projects in Trinidad and Tobago, Guyana, Tanzania, Kenya and Barbados. On-the-job training was provided for technicians in aerial photographic processing and photo-mechanics. The third Surveys and Mapping Summer Course was held from the period May 20 to August 8 and a total of 47 students from 22 different countries received

practical instruction in survey and associated subjects. The summer course has proven to be a most effective way of providing practical survey training.

Meetings of the National Advisory Committee on Control Surveys and Mapping were held in Ottawa in May and October, 1969, and showed progress on studies of survey administration in Canada and of monumentation. The 11th annual meeting of federal and provincial survey officers was held in Toronto in September.

The third and last volume of Men and Meridians was published culminating a seven-year task by author D. W. Thomson on 300 years of surveying and mapping in Canada.

GEOLOGICAL SURVEY OF CANADA

The Geological Survey of Canada maintains a capability in mapping, detection, interpretation, research, and advice in geological sciences, including mineralogy and paleontology, and in complementary aspects of geophysics, geochemistry, physical geography and other disciplines. It co-ordinates these to provide a national and regional inventory of formations of rocks and surficial materials, their structures, minerals, landforms, and conditions of stability, and to develop concepts and techniques to maintain the standard of the inventory and to increase its usefulness and effectiveness in the exploration of resources and in contending with the physical environment.

The scientific work of the Branch is carried out by five divisions, one of which is centred in Calgary, and by centralized support services. During the report period the Branch had 489 active projects, of which 221 had a field component. Although most field projects were directed by permanent staff members some were led by university professors and post-doctoral fellows. Some studies, such as those carried out on the Pacific Continental Margin, were carried out under contract as were aeromagnetic surveys and some airborne geophysics developmental work.

Scientists of the Geological Survey were invited to assist in the investigation of lunar material brought back by the Apollo 11 astronauts. The samples of moon rocks were exhibited at the Geological Survey in October 1969, and nearly 25,000 people, including H.R.H. Prince Philip and Governor-General and Mrs. Michener, visited the display. Subsequent investigations at the Geological Survey were made to determine chemical composition, mineralogy, petrology, electrical conductivity, magnetic properties, isotopic abundance and age.

INVENTORY ACTIVITIES

This major phase of the work of the Geological Survey has been concerned with the description and explanation of Canada's main geological provinces, their rocks, structures, and mineral resources, and their magnetic, electrical and geochemical attributes. It also includes a systematic analysis and description of the landforms and surficial deposits resulting mainly from the advance and withdrawal of the great ice sheets that covered so much of Canada in relatively recent geological times. All these activities provide basic geological data to forecast, discover and evaluate our mineral resources, to provide scientific knowledge on the origin and development of the earth's crust beneath Canada, to provide an understanding of the physical environment, and for support of the administration and policy formulation in mineral and energy resources.

The various types of geological mapping are in support of inventory activities and involved the deployment of more than 100 field parties, a top priority being given to completion of a broad reconnaissance coverage of the unmapped parts of the country at scales of 1:250,000, 1:500,000 and 1:1,000,000. At the present rate of work it is expected that this phase will be completed in the mid-1970s. During the summer of 1969 approximately 140,000 square miles of bedrock were mapped at these scales. Some of the major accomplishments in the field were completion of the mapping of Southampton Island at the north end of Hudson Bay together with 20,000 square miles in Labrador and northern Quebec; continuation of "Operation Norman", a three-year regional study of the lower Mackenzie River area combining bedrock mapping, stratigraphic studies and Quaternary research; "Operation Stewart" almost completed mapping at a

scale of 1:250,000 of a 20,000-square-mile block in Yukon and Northwest Territories. "Operation Smoky" continued mapping in the northern Rocky Mountains with major emphasis on structural style and stratigraphic framework; a long term, multi-discipline investigation of the Mackenzie Delta and Beaufort Sea continued to provide basic data for the interpretation of the sedimentary column and for the evaluation of the petroleum possibilities of the region and also as a contribution to the basic understanding of the world's major deltas and their associated sedimentary basins.

Field work in the Arctic Islands included a reconnaissance of eastern Devon and southern Ellesmere Islands and a study of the stratigraphic and biostratigraphic relationships of upper Paleozoic rocks on northern Ellesmere and Axel Heiberg Islands. Investigation of the regional structural framework of the northern Mackenzie Mountains, the Franklin Mountains and the Interior Plains was continued, and similar studies were made in the southern Foothills, the northern Rockies and in northern Yukon Territory.

In addition to these operations in northern and relatively inaccessible areas involving varying degrees of aircraft support there were a number of bedrock studies related to inventory activities in all parts of Canada. Primary reconnaissance as a preliminary to 1:250,000 mapping was completed in the Great Northern Peninsula of Newfoundland; Cambro-Ordovician platformal rocks, with their petroleum and base-metal potential were studied on each side of the Strait of Belle Isle. Studies that contribute to the understanding of the Precambrian Shield, and in the evaluation of its mineral resource potential and in the control of the physical environment were undertaken, such as petrological investigation of previously unmapped Keweenawan lavas on Michipicoten Island, Ontario, and of the Archean rocks of Manitoba. In the western Cordillera and along the Pacific margin mapping and specialized studies on structure, origin, and geological development relate to the mineral deposits of the region as a basis for mineral exploration. Under contract with the Department of Geology, University of British Columbia, the Geological Survey supported a submarine geology program.

Geophysical surveys made significant contributions to the inventory aspect of the work of the Geological Survey. Existing contracts under the Federal-Provincial aeromagnetic survey program added 90,000 square miles of mapping, mainly in south-central Baffin Island and northern Quebec; however, bad flying weather delayed completion of the northern contracts. The Skyvan project produced airborne geochemical maps (U, K, and Th) covering 400 square miles near Bancroft, Ontario and a cross-country profile from Ottawa to Yellowknife and return which identified all known uraniferous localities en route and indicated several others. Preliminary results have been released on open file pending publication. These flights more than demonstrated the usefulness of the project which has aroused considerable interest in industry. Seismic surveys, both hammer and conventional, were made in Ontario, in Lakes Erie, Huron and Ontario, and in the Gulf of St. Lawrence and Strait of Belle Isle. Of these, the marine seismic surveys were of particular interest to oil companies concerned with offshore leases.

Economic geologists of the Branch continued their comprehensive studies of all aspects of the geology of specific economic elements or geologically coherent groups of such elements. Major reports dealing with titanium and iron were published and a mineral resources map and several metallogenic studies are well advanced. A Canada-wide compilation on nickel was completed and research continued on the primary alteration zones in the Cobalt silver deposits.

Research in Quaternary geology and geomorphology is directed towards providing information to assist in the planning, management and conservation of mineral, land and water resources, and of the natural environment. At present most of the scientific capacity is devoted to making a Canada-wide terrain inventory. The scale of these studies varies from broad reconnaissance in the north to detailed projects in heavily populated southern areas.

In the Goose Bay region of Labrador the first aircraft-supported survey of earth materials to be undertaken in northern forest regions was carried out to meet the requirements of the Newfoundland Forest Inventory-Land Capability group of the Department of Mines, Agriculture and Resources. A survey in the Mackenzie Delta and valley was accomplished to meet an urgent need for terrain and foundation information for possible pipeline construction in the Mackenzie transportation corridor. As part of the departmental program on pollution in the Great Lakes, Survey geologists carried out offshore sampling for information on sediment distribution and the organic and inorganic geochemistry of lake-bottom materials.

DEVELOPMENT ACTIVITIES

In support of its inventory role, the Survey must devote some of its resources to improving the methods by which it acquires its data; and to the development of new concepts, instrumentation and in the establishment of physical, chemical and paleontologic standards.

In geophysics, the development phase of the high-resolution magnetometer system was completed. The instrumentation, developed by Geological Survey staff, was installed in a specially modified Queen Air aircraft. It is the most advanced system of its type in the world and is a significant contribution towards maintaining Canada's leadership in airborne geophysical surveying techniques.

The National Aeronautical Establishment North Star aircraft, carrying similar high-resolution aeromagnetic instrumentation developed by NAE and GSC staff, obtained 11,000 line miles of magnetic data from low-level traverses across the Labrador Sea. Preliminary interpretation of these data suggest that sea-floor spreading occurred in Baffin Bay and the Labrador Sea at the same time that the North Atlantic Ocean was formed by the separation of Europe and North America, a movement that probably started 100 million years ago.

Tests of electromagnetic methods (AFMAG) for rapid airborne reconnaissance have continued and are proving to be a useful aid to geological interpretation especially where outcrops are sparse. AFMAG surveys were flown in Manitoba, Saskatchewan and Nova Scotia mainly in areas where the geology was fairly well understood, and many of the results, published during the year, show good correlation between the airborne data and the geology of the terrain. Other developmental projects include ground AC resistivity equipment and a new type of magnetometer which makes use of the Overhauser effect.

Development of geochemical methods of prospecting has continued and the first full scale helicopter-supported survey to test new prospecting methods for uranium was carried out in northern Saskatchewan. The year also saw the first successful trails of geochemical exploration techniques in permafrost terrain in the Coppermine area of the Northwest Territories.

The field analytical techniques developed by the Branch for geochemical surveys could well have application in environmental control with the increasing public concern over inorganic pollutants such as mercury, arsenic, selenium and other materials; new testing methods for mercury are under development and a report on its role in the natural environment was prepared during the year.

The establishment of standards of time and stratigraphic sequence is necessary for proper correlation of geological events in different parts of the country and for a proper understanding of the geological history of a region. Dating of rocks is achieved by physical methods and paleontological methods. Physical dating involving isotope measurements was carried out on hundreds of samples and further refinement of the potassium/argon method will be possible with the 15-inch solid-source mass spectrometer completed during the year. Fossils continued to provide the most readily applied means of dating and correlating Phanerozoic rocks both in the field and in the laboratory where paleontological specialists of the Survey identified thousands of specimens collected in the field; they also sampled and studied fossils in well cores, especially from wells drilled in the northern territories. From all these data standards of chronology, and stratigraphic sequence for the Phanerozoic sedimentary rocks of many parts of Canada were developed. Significant faunas were described and illustrated in published reports and many additional specimens were documented and added to the Survey's collections as permanent reference standards.

Petroleum geologists of the Survey, in collaboration with Geoservices of Paris, brought to near-completion a test of a surface prospecting method for petroleum using traces of hydrocarbons in soils. A computer file on oil and gas data in western Canada has been compiled; this study involves contributions from both compiled; this study involves contributions from both government and industry and should be of value in planning future uses of our oil resources and in outlining future petroleum provinces.

Much of the work on fossils and on studies directly related to petroleum was carried out at the Survey's Institute of Sedimentary and Petroleum Geology in Calgary. The Institute is also responsible for the custody of drill cores, samples and other data resulting from exploration by industry in Yukon Territory and

Northwest Territories and for drill samples from western and northern Canada. During the year more than 2,000 persons used the core- and sample- examination facilities.

During the report period, work in geomathematics and data processing continued with the objective of developing and applying electronic techniques to the handling of geological data, of providing a consultative service to staff members and of carrying out mathematical research on the quantitative definition and interpretation of geological problems, especially on mineral probability.

Many Branch engineering-geology studies contributed directly to the optimum utilization of Canada's physical environment. During the year such work has included the evaluation of factors that influence the engineering behaviour of geological materials in areas such as the Welland Canal and at damsites in northwestern Ontario, investigations in environmental geology, studies of the processes of landscape change involving slope movement, erosion, and frost action, both by field and laboratory studies, and the development of mineral exploration techniques using the unconsolidated "drift" as a prospecting medium.

SUPPORT ACTIVITIES

Apart from essential administrative and pooled technical services, the support activities of the Survey provide the link between the scientific programs and the user public.

The scientific results of the Survey's research are published in a variety of ways designed to best meet the users' needs. During the report period three memoirs, two economic geology reports and 13 bulletins were released. These constitute the comprehensive, terminal report series. In addition, 77 papers, nine preliminary maps, 23 colored maps (including those used to illustrate some of the preceding items) and 395 aeromagnetic maps were published. Staff members also published 161 papers in scientific journals, gave 97 addresses to scientific meetings and delivered 76 university lectures. In all more than 500,000 items were distributed through the Ottawa, Calgary and Vancouver publications distribution offices. The Branch also distributed 9,350 of its popular rock and mineral sets.

Libraries in Ottawa and Calgary continued to provide an essential service to the Branch and to the public. Circulation figures show that 55,000 loans were made, including many on inter-library loan to other institutions; 22,000 new items were added to the libraries which form Canada's largest collection of literature on the earth sciences.

In 1966 the Survey initiated a project to develop and co-ordinate the preparation of an index to geological data as a pilot study for a National Index. This study was completed during the report period and the 15 books of indexes were prepared for publication. Staff members from this project have since become part of the Canadian Centre for Geoscience Data.

Staff members acted as advisors and consultants to other federal agencies and to provincial governments. At the request of the Canadian International Development Agency geologists were sent overseas to provide technical advice on assistance programs. Many representatives of mining and exploration companies consulted with members of the professional staff. The Survey was able to offer a modest service to the general public in the identification of mineral specimens, and the various booklets for mineral collectors continued to be best sellers.

The Geological Survey provides secretariat and funds for the National Advisory Committee on Research in the Geological Sciences of which the director of the Survey is permanent chairman. In 1969-70 a total of $275,240 was disbursed as grants-in-aid to Canadian universities. The National Advisory Committee also sponsored a conference on research in tectonics at the University of Manitoba and jointly sponsored with the Survey the publication of three volumes of proceedings of earlier symposia.

MINES BRANCH

The Mines Branch is a complex of laboratories and pilot plants designed to assist the Canadian mineral industry in the more efficient extraction and elaboration of mineral wealth of all types, and to improve and broaden the uses of metals and minerals. Particular emphasis is placed on the elimination of waste in mineral production, reduction of air pollution in industry, reduction of corrosion, mine safety, the discovery of new methods for working with low-grade or hard-to-process minerals and ores, and similar factors that will benefit the Canadian public and Canadian industry in its efforts to remain competitive in world markets.

The work is carried on in seven divisions, or centres: Physical Metallurgy, Fuels Research, Mining Research, Mineral Sciences, Extraction Metallurgy, Metals Reduction and Energy, Mineral Processing. There is a Technical Services Division which serves the other divisions by building or installing instruments and equipment, and a branch library.

The Physical Metallurgy Division concerns itself with the casting and solidification of metals, forming and fabrication, evaluation of engineering and other properties, experimentation with new alloys, and computerization of metallurgical processes. Division experts also dispense advice to Canadian industry and undertake tests and investigations on behalf of the latter.

The Fuels Research Centre seeks to find better ways for using and conserving Canada's fossil fuels—coal, petroleum, and natural gas. Special attention has lately been paid to combustion that will reduce air pollution. The refining of low-grade oils continues to receive considerable attention, as does the conversion of Canadian coals into metallurgical cokes.

The Mining Research Centre is concerned with rock breakage at mines by drilling, blasting, crushing and grinding, and stability of rock around mine excavations. It seeks to improve the design of open pit mines. Work is being carried out on the elimination of health hazards in mines and on more effective mine management.

In Mineral Sciences, the emphasis is in the scientific study of ore minerals, such as sulphides, the properties of complex minerals, standards for categorizing minerals, and analytical work for both the Mines Branch and for outside clients.

In the Extraction Metallurgy Division, research is carried out on pollution abatement in mine effluents, hydrometallurgy, and the causes and control of metal corrosion. Studies are also being carried out on the kinetics and thermodynamics of various important metallurgical reactions.

The staff of the Metals Reduction and Energy Centre studies the energy requirements of Canadian metals and minerals producers, transportation problems incidental thereto, carries out research on the application of energy to metallurgical processes and prevention of air pollution in metallurgy, and disseminates results by various organizational means.

In Mineral Processing, research is carried on in aid of mining, the production of ceramics and construction materials, and advice is given on various problems to private industry and the government. Aid to mining consists chiefly in finding better ways of concentrating ores.

Details of these and other activities will be found in the sections that follow.

PHYSICAL METALLURGY

The work of the Physical Metallurgy Division consists essentially of applied research and development related to the conservation, processing, properties and utilization of Canada's metals and the fabrication of products from these metals. It is designed to provide the maximum assistance possible to the Canadian economy in general, and to the metallurgical and resources industries in particular.

Research is based on an assessment of present and future requirements for continued technological growth, and in particular, on the necessity of filling gaps in the knowledge of metals science and technology. The comprehensive, interlocking metallurgical facilities available in the Physical Metallurgy Division enables a wide range of activities to be considered. Emphasis is on applied research and development that needs pilot-plant scale melting, casting, forming and fabricating facilities.

The Division also undertakes work to satisfy the needs of other government agencies, such as the Departments of National Defence, Public Works and Transport.

Work on metals and alloys processing and utilization is divided into five research-and-development activities and one consulting-and-investigations activity. The research-and-development activities are casting and solidification, forming and fabrication, engineering properties and service evaluation, alloy metallurgy, and techniques and equipment for research and development.

Casting and Solidification

Research on the direct quantitative determination of oxygen in molten metals by electromotive-force measurements has culminated in a successful commercial development known as the Leigh Oxygen Probe System for use in steel plants. This is an outstanding example of a successful mission-oriented research project initiated in this Division. It has been carried through successive stages of field trials and product development by the co-operative efforts of this Division, the Canadian steelmaking industry and Leigh Instruments Limited who are manufacturing and marketing the Leigh Oxygen Probe System on what is rapidly becoming a world-wide scale.

A ciné-radiographic installation using an X-ray intensification system has been used during the past year to study the flow of molten steel in moulds. This work is in its preliminary stages and is already providing significant information on the design of sprue and gating systems.

Forming and Fabrication

The compacting and sintering characteristics of various grades of nickel powders produced by Sherritt Gordon Mines Limited are being studied. Work has also been started on a study of the relationship between the characteristics of iron powders from various Canadian sources, and their compacting and sintering behaviour. The samples are representative of different methods used in iron-powder production in Canada. This work will enable fabrication processes to be adapted and modified to use these Canadian powders.

A study has been initiated on the effect of plate configuration on heat flow during welding. At present, fillet joints and double-vee butt joints are being studied. Data indicate that the simple assumptions used in the controlled thermo-severity test are not accurate, suggesting that some modifications may be necessary.

Engineering Properties and Service Evaluation

A study of the configuration of the fracture surfaces of both tensile and crack-notch toughness specimens has shown that the "shear lip" (slant fracture) configuration of these surfaces in not a result of shear, but is rather characterized by purely normal displacements and zero shear. This study has led to the hypothesis of a stress-distribution relationship that can account in quite a precise and invariant way for the form of the fracture even when plastic flow of several per cent preceded fracture. This relationship has been experimentally checked in the laboratory in a number of cases.

Studies of the environmental cracking of ultra-high-strength alloys have indicated that for HY 140 and 18 per cent nickel (250) maraging steels in sea-water service, cathodic protection of highly stressed members might be dangerous. Studies are also under way to determine the differences in the mechanism of stress-corrosion cracking and hydrogen-embrittlement cracking for maraging steels.

Alloy Metallurgy

Alloy-metallurgy research is in progress on a variety of steels and also on titanium, aluminum, magnesium, copper and zinc alloys.

In order to promote the use of Canadian molybdenum, the effect of molybdenum additions to austenitic chromium-nickel stainless steels is being evaluated. The effect of alloying elements on the corrosion behaviour of AISI Type 430 stainless steels is being studied. Low-carbon martensitic stainless maraging steel compositions employing beryllium as the age-hardening ingredient are being investigated.

Research has been initiated to investigate ways of improving the very low ductility of titanium alloys containing more than 7 per cent (in weight) of aluminum. The metallurgical factors affecting environmental cracking behaviour of titanium alloys in sea water are being evaluated.

The structure and properties of the heat-affected zone of welded joints in the Ti-6A1-2Nb-1Ta-1Mo alloy

are being studied. The use of the pulsed-arc welding process for the out-of-chamber welding of this alloy is also being evaluated.

Research on zinc-base aluminum alloys is continuing. The phenomenon of room-temperature ageing encountered in these alloys is being studied and the reasons are being sought for the superior impact strength of wrought zinc-aluminum alloys as compared with die-cast alloys of similar composition.

Techniques and Equipment for Research and Development

Considerable effort is being devoted to the establishment of computer programs for the correction of raw data produced by the electron microprobe analyzer. Uncorrected data may often lead to serious errors in interpretation. Facilities are also being developed to produce homogeneous standards of known composition that may be used to calibrate the electron microprobe analyzer.

Research has been initiated to develop new techniques and applications of the scanning electron microscope. Included in this project will be studies on image and contrast characteristics as a function of the material under examination, and the utilization of the generated outputs for quantitative metallographic purposes.

Consulting and Investigations

During the past year this Division has conducted 20 metallurgical investigations for as many Canadian manufacturing industries. It has also carried out 30 metallurgical investigations for 14 Government agencies. In addition to these investigations, this Division has supplied information and advice in response to 104 inquiries received from 84 Canadian manufacturing industries and 146 inquiries received from 28 Government agencies.

The metallurgical investigation of components from the HMCS *Kootenay* gear box was instrumental in identifying the cause of the fire which occurred aboard that ship.

A complete metallurgical investigation has been conducted on the cracked foil of the FHE 400 hydrofoil vessel. Reasons for the occurrence of this cracking have been clarified as a result of this investigation, and recommendations have been made to the Department of National Defence and its contractors, indicating how the recurrence of this type of failure might be avoided.

At the request of the St. Lawrence Seaway Authority, an investigation was undertaken to develop an appropriate welding procedure to rebuild by welding the worn surfaces of the tracks of a rolling lift bridge, on the Welland Canal. A welding procedure suitable for this application was developed.

Investigations have been carried out on the cold rolling of nickel plate for the Royal Canadian Mint, in order to provide a basis for the selection of rolling-mill equipment by the Mint.

Written examinations for the certification of industrial radiographers were conducted at 14 centres across Canada during this current year; 222 junior applicants and 95 senior applicants were certified. Applicants who undertook the practical tests at the Physical Metallurgy Division numbered 28.

Two ten-day courses in radiography were given to DND Quality Assurance Branch inspectors, and a four-day series of lectures on non-destructive testing and on welding and corrosion was given to 14 steamship-boiler inspectors from the Department of Transport.

FUELS RESEARCH

The Fuels Research Centre is the agency of the Federal Government concerned with the development of new engineering and scientific approaches to encourage the efficient utilization and conservation of Canada's coal, petroleum, and natural gas resources. These fossil fuels play a dominant role in Canada's economy and yet their use inevitably gives rise to some pollution of the environment. The Fuels Research Centre has shared the public interest in and concern for the efficient use and development of the fossil-fuel resources, particularly as such utilization influences the quality of the atmosphere. Public awareness of the seriousness of the pollution problems is now finding expression in terms of legislation the world over.

The enactment of legislation and the establishment of limits and penalties is one thing; but to overcome the technical difficulties to achieve these desired limits without suffering severe economic penalties is a much more complex problem. It is in this area that the

Fuels Research Centre has attempted to assist industry by finding practical solutions to some of the atmospheric pollution problems arising from combustion. This program will require continuous effort into the foreseeable future, as each advance in technology will be offset by two factors which tend to increase atmospheric pollution, the growth in population and the migration of people to the major centres in search of employment in industry.

To concentrate the research of the Fuels Research Centre on major national needs in a manner that would permit better financial support and control, the Centre's research was reorganized in October 1969 into three basic programs: air pollution and combustion research; the evaluation of the quality of Canadian fossil-fuel resources; and a program which includes the certification of electrical and diesel equipment for use in coal mines, and the associated research on combustion and ignition of gases and dusts.

During the year progress in all programs was impeded by the relocation of all facilities of the Centre to the new site near Bells Corners, Ontario, 12 miles from Ottawa. At the close of the calendar year, a considerable amount of reconstruction of the pilot plants remained to be completed. This included the 18-inch movable-wall test oven for the Metals Reduction Group, and all the large pilot plants of the petroleum-processing and high-pressure-hydrogenation groups. Every effort was made within the existing budget to complete as much of the construction as possible before the end of the fiscal year. This relocation, though expensive and time-consuming, will lead to improved operations.

Conceptually the program dealing with air pollution and combustion research may be divided into a) those projects concerned with the improvement of the combustion process and the elimination of pollutants after combustion by dispersion into the atmosphere, and b) those projects concerned with the elimination of sulphur from the fuel and the improvement of fuel quality before combustion.

In the first class the emphasis has been on a co-operative study o fthe dispersion of smoke plumes from the stacks of major thermal power plants in operative study of the dispersion of smoke plumes and Resource Management, and the meteorological service of the Department of Transport, which seeks to analyze in a quantitative manner the movement of air into and out of major urban centres. During the year the analytical instrumentation for use in helicopters was tested. The results were encouraging, so that further studies were planned for 1970 with superior range-finding equipment to define the position of the air samples with greater precision.

The Riley turbo furnace was reconstructed and combustion studies on lignite were completed to provide a basis for boiler design using this class of coal for the generation of thermal power.

The combustion research concerned with the way combustion pollutants spread through the air has been held up pending the assembly of the controlled-history furnace, and the acquisition of equipment.

Considerable effort was made to develop a satisfactory thermal method for the disposal of government stocks of DDT. Preliminary experiments indicate that a satisfactory combustion method of destruction can be developed by employing a blue-flame burner and a suitable system for scrubbing the hydrochloric acid from the combustion gases. A research report will be available shortly to enable the Department of Agriculture and others to build and operate similar equipment.

The elimination of sulphur from oils prior to combustion falls into two categories — the elimination of sulphur from residual oil obtained after the distillation of a normal crude oil, and the removal of sulphur from low-grade heavy crude oils such as the Athabasca bitument. With the development of increasingly stringent air-pollution regulations the markets available to both these types of oil will become more and more restricted. On the other hand the economy can only be sustained by an abundant supply of cheap energy from these sources. New technology has to be developed to eliminate sulphur from these fuels at reasonable cost. The core of the high-pressure hydrogenation research is directed to this objective.

Considerable progress was made during the year in understanding the advantages and limitations of the thermal hydrogenation of Athabasca bitumen. The refining conditions under which there was a slow accumulation of polymer in various parts of the hydrogenation system were outlined in a scientific paper presented in Edmonton. This information has been of

considerable interest to those in the industry concerned with the refining of this class of heavy crude oil and it will provide a basis for comparison with future catalytic experiments planned in the combined liquid-and-vapour-phase pilot plant.

The continuing tension in the Middle East together with shortages of natural gas and cheap sources of petroleum in the United States has spurred the interest in developing Arctic sources of petroleum as well as a review of North American fossil-fuel resources. The Fuels Research Centre is particularly concerned with the evaluation of the quality of the Canadian portion of these reserves and the development of improved techniques for obtaining sulphur-free petroleum from low-grade oil sands.

A directory of Canadian oil-analysis and reservoir data has been published. This directory includes most of the crude-oil analyses performed over the years at the Fuels Research Centre and is fairly representative of all significant Canadian oil fields. A project is now under way which will permit these data to be sorted mechanically by physical property.

Much of the pollution that arises from the combustion of low-grade petroleum is due to sulphur. The only method of effectively removing this element and producing a stable hydrocarbon is to remove the sulphur from the oil with hydrogen. At present little is known of the chemistry of the sulphur compounds that occur in the gas-oil distillation range. A project was therefore initiated early in the year to fractionate the sulphur-containing compounds by using gas chromatography. Significant advances were made.

The development of analytical capability is an important part of the research on petroleum, for the benefits are felt in a wide variety of problems extending from resource evaluation to the identification of oil in major marine oil spills such as that of the "Arrow".

One of the problems in the evaluation of western Canadian coking coals for export to the Japanese market is that the coke quality is underestimated by the method currently used and developed to assess the quality of Appalachian coals. Progress was made in rectifying this underestimation.

Another concern of western Canadian coking coal industry is the loss of coking properties that occurs through oxidation during mining, processing, transportation and storage. A study of the mechanism of the oxidation has tracked down the main chemical reaction causing this deterioration.

The demand on the Canadian Explosives Atmospheres Laboratory for the certification of electrical equipment used in mines and industrial areas where combustible gases are present increased substantially during the year. The demand for the certification of diesel engines for use in mines is also growing with the increased mining activity in western Canada.

The research conducted by the laboratory has involved the transmission of explosions through metal joints and cylindrical channels, as well as the investigation of spark incendivity. Recent work has demonstrated the hazard associated with the use of aluminum castings. Fine particles of aluminum in the joints greatly increase the chance of transmission of an explosion.

MINING RESEARCH

The Mining Research Centre during the past year continued to decentralize its staff by setting up a Western Office in Calgary (sharing space with the Institute of Sedimentary and Petroleum Geology). More staff is now located outside of Ottawa, at the Elliot Lake Laboratory and the Western Office, than in Ottawa at the Canadian Explosives Research Laboratory and the Rock Mechanics Laboratory. However, the actual work, which is done substantially in co-operation with mining companies, is spread throughout the country. The establishment of the Western Office will make it easier to work with the western coal, base-metals and potash mines.

The Centre operates on the project system, many individual projects being integrated with the work of individual companies and universities. Wherever possible, the prospect of an attractive payoff is used in the selection of projects. Those projects on which the potential benefit-cost ratio is particularly high receive maximum concentration of the budgetary resources.

Rock Breakage

The breaking of rock both at the mining face and subsequently in reducing the large blocks of ore to a fine size suitable for processing is a major part of mining. One objective of this research is to explore the mechanics of breakage, using forms of energy other

than explosives that may lead to radically new mining methods. This is a pioneering activity undertaken at the request of the Mining Association of Canada as a result of a survey showing that their members believe rock breakage is one of the most important areas in which research should be able to effect savings.

Besides helping to make current systems more efficient through the discovery of novel methods of drilling, blasting, crushing and grinding, it was also envisaged that conventional operations may be telescoped into some combined procedure quite unlike current practices. The work is being done primarily at the Elliot Lake Laboratory.

Blasting research is also being pursued to increase safety and to reduce the cost of drilling and blasting in industry, which accounts for the expenditure of approximately $100,000,000 per year in Canada. By the application of analytical techniques it should be possible to produce significant savings within a reasonable period of time. The resources of the Canadian Explosives Research Laboratory, the Rock Mechanics Laboratory and the Elliot Lake Laboratory, together with those of some private companies, are all being used for this work.

Ground Control

How to ensure stability of the rock around a mining excavation — that is, ground control — is an important aspect of mining. Solutions of the problem are being sought through analytical methods, which have been used in the design of building structures for over a hundred years. However, considerable research is necessary, both because of the great complexity of mining openings in Canada and because adoption of the large safety factors common in structural design might seriously impede economic extraction.

The work is done mainly through the Elliot Lake Laboratory with mining companies from Newfoundland to British Columbia. Control of the weak and friable roof rocks in both the eastern and western coal fields is being studied with various companies. Work is being done in the Saskatchewan potash mines and Ontario salt mines. In the former case, little experience exists in the world for mining such materials at the depths of these deposits. Studies have been made for the design of layouts for new mining methods in the uranium mines. Much information has been gathered from underground measurements in base-metal mines in both Quebec and Ontario on the stability of pillars. Design procedures have been evolved for support with rock bolts; work is proceeding to achieve the same objective for filling with waste mill tailings. Canada has one of the largest underground mining industries in the world, and such studies are extremely important to the Canadian economy.

As over 50 per cent of the ore produced in Canada comes from open pits, a substantial part of the research budget of the Centre is applied to open-pit mining. To produce the 200,000,000 tons of ore from these mines, typically 250,000,000 tons of waste rock must also be excavated from the slopes required for these pits, which can be as deep as 1,000 feet. The economic feasibility of any potential open pit is, therefore, largely dependent on the slope to which the walls must be cut. Scientifically determined optimum pit slopes would be worth much to industry. Individual mines, however, do not have adequate incentive to engage in the comprehensive program required for such a technological advance, and government enterprise is required.

Computer simulation of open-pit slopes is being used to examine the basic factors influencing the stability of slopes in rock. Under study are stress distributions in typical slopes subjected to varying tectonic stresses together with deformation patterns and their correlation with known modes of failure. In addition, optimization of excavations is being sought by changing slope angles as the mine gets deeper.

Environmental Control

Research is being conducted towards improving the environmental conditions in mining. Whereas the physiological effects are the concern of other research groups and ventilation design is done by mine staffs, the physics of measuring environmental conditions requires the more detailed study that is being undertaken in this program. At the present time, research on the standardization of methods for measuring dust and radiation hazards is being conducted in close co-operation with the Mine Accident Prevention Associations of Ontario and Quebec as well as with individual companies experiencing critical problems. Although conditions in Canadian mines are generally good, improvements must be made constantly in the working environment (e.g. air-conditioning, humidity control, noise suppression, and good lighting) to ensure

continuous interest on the part of technical personnel and labour in working in the mines. The work is being done primarily in the Elliot Lake Laboratory.

Mine Systems Engineering

Work has been started on systems analyses of various mining operations. Advances that are made by physical research on the various phases of operations (drilling and blasting, ground control, transportation, etc.) are being examined to determine their influences on mine economics. Computer programs are being developed for use by company staffs on mining properties.

With the high degree of complexity of current technology, we find that no organizations exist in the country with the personnel and facilities capable of assisting those with problems in many specialized areas. Consequently, calibration, testing and advisory services are provided when required by companies and agencies in the mineral and associated industries. This is consistent with the Mines Branch policy of orienting its research to fill gaps in technology of particular concern to the country. At present, most of the work is being performed at the Canadian Explosives Research Laboratory.

The general function of communication is being expanded by the development of an Information Centre involving both the Mines Branch Library and the Elliot Lake Laboratory whereby, through information officers and telex links, it is planned to provide industry and the universities with assistance in finding and obtaining the latest research information on any subject. At present, integration with private research is achieved either through joint projects or through liaison on subjects of mutual concern. The companies co-operating with the Mines Branch in research produce approximately 75 per cent of the Canadian mining output. Besides the conventional method of publishing significant results in journals, interim reports are written. Some of these are distributed exclusively through the Mining Association of Canada to interested companies, while others are used as research notes that are exchanged with laboratories both in Canada and abroad.

Canadian Advisory Committee on Rock Mechanics

In 1963, the Canadian Advisory Committee on Rock Mechanics was formed to stimulate greater interest in this base science for mining and to co-ordinate research. The membership has consisted primarily of representatives of industry and of the universities, with Mines Branch personnel providing the secretariat.

During the past year, one of the Committee's specialist panels completed a study of the requirements for improving design and construction practices of waste embankment. It is recommended that the Mines Branch have a code of practice compiled so that such disasters as Aberfan and the Crows Nest slide can be avoided in the future.

One of the principal ways in which the Mines Branch, with advice from the Committee, has been able to stimulate research is through its grants-in-aid which, starting with $10,000 in 1962, have grown to a cumulative total of $363,000 for mining research. The Committee also periodically examines and appraises the research of the Centre in rock mechanics.

MINERAL SCIENCES

Research in the mineral sciences has as its objective the provision of a sound, scientific base for the development of new technology in the extraction, processing and utilization of Canada's mineral resources. In working towards this objective, the Mineral Sciences Division employs a multi-disciplinary approach, utilizing the tools of chemistry, physics, crystallography and mineralogy in the planning and performance of research. The different research and development activities of the Division are broadly categorized into three core programs: the Sulphide Program, the Materials Research Program, and the Analytical Research and Services Program.

Sulphide Program

The Sulphide Program is designed to make use of new scientific concepts and techniques in the study of ore minerals (mainly base-metal sulphides which account for such a large portion of Canada's mineral production) with the purpose of tailoring practices used in the recovery of minerals and metals to the intrinsic characteristics of the ore minerals. Projects under this heading are classified into three sub-groupings: characterization of the minerals (relating the internal composition and structure of minerals to their bulk properties); studies of mineral assemblages, to improve the treatment processes used in beneficiation; and studies of the pro-

perties and phenomena that are associated with mineral surfaces, which are of particular importance in controlling the mineral separation process.

An essential part of this program has been the production of laboratory-grown crystals of mineral compositions. Success has been achieved in growing a number of sulphides of iron, nickel, and cobalt, as well as arsenides and sulfarsenides of these metals that have certain structural features of common interest to the program. Methods used in the growth of the crystals have been of three types — vapor-phase transport, using iodine and bromine; flux-melt techniques; and hydrothermal methods. Considerable data have been accumulated on the mechanisms and chemistry of crystal growth that will provide a sound basis for future progress. Copper sulphides were the subject of particular attention, leading to the discovery of a new variant of valleriite, a hydro-copper-iron sulphide, and to further progress on the characterization of talnakhite, a recently discovered copper-iron sulphide. Chemical bonding in minerals of the pyrite structural group was investigated by combining the results of micro-hardness and infrared determinations and applying thermodynamic considerations. The electrode behaviour of some semi-conducting sulphides was studied to explore the relationship between electrical properties of the minerals and their electro-chemical behaviour. Research was carried out to establish the nature and properties of metal complexes formed with sulphur-bonding chelating agents, in which it was necessary to synthesize the materials to be studied.

Studies of assemblages of ore minerals that are characteristic of Canada's economically important deposits are undertaken to provide basic mineralogical data, such as the identity of the mineral constituents, mineral compositions, and the distribution of constituents. This type of study is done primarily to examine and identify the important mineralogical features that influence exploitation and beneficiation of ores. Attention is given chiefly to mineral districts that have some special economic significance. Currently, for instance, work has just been completed on a detailed study of the Cobalt district where operators have had great difficulties in the past owing to the small size of orebodies and the mineralogical complexity of the ores. In the course of this work 13 operating mines were visited to collect samples and examine working faces; samples were collected from 46 other dormant properties to obtain as complete a picture as possible of the mineralogy of the Cobalt ores. New information and a better understanding of the nature of these silver ores has resulted in modifications to operating procedures in the recovery of silver and in day-to-day ore development. Two similar studies have been started during the past year; one in the Red Lake district of Ontario where significant base-metal deposits have recently been discovered, and the other in the disseminated copper deposits of the Highland Valley, British Columbia. A basic understanding is being sought of the electrochemical and surface properties of minerals in contact with aqueous electrolyte solutions, especially of the electrical double layer formed at the mineral/solution interface. This, in turn will clarify how these properties are influenced by physical or chemical treatments of the minerals or of the mineral/solution system. The double layer is being examined, for oxide as well as sulphide minerals, by various techniques including potentiometric titrations, Zeta potential measurements, electrophoretic measurements, and radiotracer methods. Research was begun into the possibility of altering mineral-surface properties by the use of high-intensity radiation to give either a higher flotation yield or greater flotation selectivity.

Materials Research Program

The concept of materials research is of rather recent origin. In brief, it is concerned with the relation between the structure and properties of materials, with factors which control the internal structure of solids, and with processes for altering the structure and properties of solids. Because of the tremendous number and variety of materials in existence it is necessarily a broad field of study. The Mineral Sciences Division is concerned only with a very small part of it, for which capabilities exist in the Division and which is related directly or indirectly to mineral processing and utilization.

Three activities constitute the Materials Research Program: phase-equilibrium studies on oxide systems, development of synthetic magnetic materials (ferrites), and a characterization program in co-operation with the Organization for Economic Co-operation and Development (OECD), an international co-operative project.

Work on phase equilibrium in oxide systems is of use in ceramics, cement manufacture, refractory brick production, and in other applications where the behaviour, or durability, of materials is critically dependent upon

composition and temperature ranges. With recently increased abilities to go to higher temperatures in phase-equilibrium studies, work was activated on the system $CaO-Al_2O_3-Fe_2O_3$, which involved reactions that take place in cement clinker production; and on the system $MgO-CaO-Fe_2O_3-SiO_2$ because of some unsolved problems involved in the performance of chrome-magnesite refractory bricks. New work was started on the system Sn-O because of the interest in tin oxide materials in electronic applications. Studies of three other systems were completed with the publication of results: Ti-O, $CaO-Ta_2O_5-SiO_2$, and $CaO-Nb_2O_5-TiO_2-SiO_2$.

Ferrites are used as magnetic materials for both the permanent and non-permanent types, which find their main application in the manufacture of television sets and computers. Use of these materials has greatly multiplied during the past few years, and projected trends indicate greatly increased markets for Canadian production. Past work of the Division has been concentrated on the hard ferrites, the permanent-magnet variety, with more recent attention being given to the soft ferrites. Canada has abundant resources for the production of both types and a large amount of assistance has been given industrial companies on various aspects of ferrite technology. Strontium is an important constituent of hard ferrites, and as a large body of celestite (strontium sulphate) is under development in Nova Scotia, research was undertaken to devise methods of extracting the strontium in a form suitable for the production of ferrite materials. Two methods were examined and successfully adapted at bench scale for this purpose.

The characterization program is a co-operative program jointly undertaken with about 60 other laboratories in different countries that are all participating in the Organization for Economic Co-operation and Development. The purpose is to examine and characterize very pure materials by a number of methods, e.g., spectroscopy, electronic behaviour, structural defects, etc.

Analytical Research and Services

The research of the Mines Branch requires the identification and measurement of a large number of chemical and physical factors, which is done in the Mineral Sciences Division. Most of this is done by chemical procedures, but a substantial amount of mineralogical examinations, X-ray analyses, magnetic and electrical measurements, and optical examinations are aslo made. As a result, an appreciable amount of work of the Division is devoted to developing new techniques and improving existing ones for use in the examination and measurement of mineral and material properties, including chemical analyses. The establishment of standard methods of analyses and the provision of standard reference materials are part of this general program.

The Mines Branch has a heavy commitment to supply standard reference materials for metals, minerals, and ores. These are used in Canadian laboratories particularly, and also by organizations throughout the world. Work leading towards the certification of standard platinum metal ores and concentrates has been just about completed, and new projects have been started on supplying standard reference materials for iron, radioactive ores, and six different sulphide ores from Canadian deposits, covering the important base metals.

Methods of chemical analyses are under continuing examination for ways of improving both accuracy and speed of analysis. Recent examples include the development of X-ray fluorescence methods for determination of tungsten and strontium in their ores, determination of fluorine and silicon in ores by neutron activation, installation of a new direct-reading vacuum spectrometer to obtain rapid and close compositional control of metal and alloy products made in the Physical Metallurgy Division, and an examination of some of the problems encountered in on-stream X-ray fluorescence analyses of ore slurries. Other applications of instrumentation to analytical procedures that have been made recently are: the use of Mössbauer spectroscopy to provide knowledge on the valence state of some atoms which has proved useful in slag chemistry, and the use of optical absorption for determining the nickel and iron content in a number of silicate materials.

Work in crystallography covers everything from simple identification of minerals by powder diffraction methods to the complete solution of crystal structures. A large part of the recent effort has gone into the modification and additions to the computer-controlled diffractometer system, which is now operating on a routine basis gathering data for use in the determination of the crystal structures. The system, with the aid of magnetic discs as back-up storage, is now able to exchange programs, and perform all operations of alignment and data col-

lection automatically. The data, which will shortly be gathered on magnetic tape, are then processed on a much larger computer, with the X-ray 67 program system. The programs for statistical phasing of crystal structure data have been written in this laboratory and are in general use in crystallographic laboratories throughout the world.

A feasibility study has been completed into the application of neutro activation analysis in the field of copper in drill core, and the determination of copper values for grade control in mining operations. Three neutron sources were used: californium 252, antimony 124/beryllium and a neutron generator. The neutron generator gave significantly better sensitivity than the other two neutron sources and could provide a rapid method for copper determinations.

EXTRACTION METALLURGY

In the Extraction Metallurgy Division, research and development were carried out on pollution abatement, on hydrometallurgical processes, and on causes and control of metal corrosion. Studies were also made of the kinetics and thermodynamics of various metallurgical reactions of importance in these fields. The results were made freely available to the Canadian mining and metallurgical industry in Mines Branch reports and published papers, through co-operative organizations such as the Canadian Mineral Processors, Canadian Mineral Analysts and the Canadian Uranium Producers' Metallurgical Committee, and through informal direct contacts.

In view of the concern over pollution such as might result from mining and metallurgical operations, increased effort was directed toward developing new and more effective pollution-control techniques and to promoting the efficiency of existing technology. Surveys of pertinent literature were made and circulated to the industry. Techniques for removal of undesirable metals from effluent solutions from base-metal operations, such as by absorption on activated carbon or ion-exchange resins, were investigated. In gold mining, the presence of even traces of cyanides in plant effluents is undesirable, and more effective analytical procedures were developed for the determination of small amounts of these compounds. The causes of arsine release during gold precipitation were also investigated.

As part of long-term studies to avoid sulphur-dioxide pollution of the atmosphere by pyrometallurgical plants treating sulphide-bearing ores, an alternative hydrometallurgical approach based on a chloridizing technique was studied. In this approach the sulphide sulphur is converted to hydrogen sulphide and then to elemental sulphur.

The conventional techniques for controlling sulphur-dioxide emission from electricity-generating plants using sulphur-bearing fuels by the injection of powdered limestone into the system are relatively inefficient both in sulphur-dioxide removal and in limestone utilization. To provide a basis for improving these techniques, the chemistry of the reactions between sulphur dioxide, oxygen and limestone was studied in detail to develop reaction criteria. Also a procedure for evaluating the effectiveness of different limestones for sulphur-dioxide absorption was worked out.

In the field of hydrometallurgy, naturally occurring bacterial leaching of uranium ore left underground in the Elliot Lake area stopes suggested the possibility of direct leaching of full stopes of freshly mined ore, thus substantially decreasing the amount of ore that must be brought to surface. To explore this possibility, column-leaching reactors were set up in the Mines Branch pilot plant in which run-of-mine uranium ore was contacted by percolation with bacterially active leaching solutions for extended periods. Preliminary results indicated that acceptable extraction of uranium can be obtained on both coarse and fine ore, and under suitable mining conditions the technique may well offer a more economic way of mining marginal uranium ore deposits.

In Canada there are a number of occurrences of copper and nickel sulphide ore that do not respond well to conventional concentration processes and are unsuitable for treatment by conventional ore-smelting technology, particularly in view of the current requirements for control of air and water pollution. As a way to overcome these difficulties, acid pressure-leaching was investigated, since with suitable conditions most of the sulphides can be converted to inert elemental sulphur. Acid pressure-leach investigations on a copper-nickel-iron sulphide material showed that pentlandite can be decomposed under moderate conditions to produce nickel in solution and elemental sulphur. However, further development work is required to obtain a satisfactory process for ores containing chalcopyrite.

The application of solvent extraction for the separation of nickel and cobalt in acid solutions was studied and a successful technique developed whereby a solution

with cobalt and nickel in the ratio of 1:3 was converted to a solution with a cobalt-to-nickel ratio of 500:1. Since this ratio is acceptable for a final product, the technique is being adopted in industry. In other work, a solvent extraction method was developed that could be used on alkaline solution systems for the separation of copper, nickel and cobalt, in place of the complex conventional processes now in use.

A long-term program has been carried out on the prevention of metal corrosion in mining and other industries. In the past year surveys were made to examine the common causes of corrosion in mining, and advice and background information in ways to avoid such damage have been provided to the industry. Corrosion is often the result of exposure to acidic industrial atmospheres, and improved chemical protection coatings for steels have been developed to prevent such attack.

Electroplating studies were continued and of particular interest has been the development of improved chromium plating baths with a low chromium-to-sulphate ratio. The improved bath composition, in which sodium hydroxide is added, permits good operation. These baths have a high plating rate and the coatings provide better protection for steel than those from conventional baths.

Parallel with the process research, studies were made of the kinetics and thermodynamics of related metallurgical reactions. Controlling factors in heap-leaching of copper minerals were investigated on a laboratory scale. The thermodynamic data of the cuprous oxide-cuprous sulphide system which is important in copper smelting were found to be unreliable, so studies were undertaken, utilizing an automated data-gathering system, to obtain experimental results that could be satisfactorily correlated. Another project has been devoted to the resolving of factors affecting the cementation of copper on aluminum sheet. Work was continued on the sulphation, oxidation and sintering of cobaltous oxide, in connection with its potential use as a catalyst for sulphur-dioxide removal.

In support of the various research activities in the Division, techniques used in the analysis of ores and metallurgical materials were modified and improved. A new Jarrell-Ash fully-compensated instrument was coupled with the atomic absorption-flame emission unit to make it more accurate for analyzing metal-bearing solutions. A program to improve methods for determining individual rare-earth elements by X-ray spectrometry was begun in order to assist the uranium mines in their efforts to recover these values from waste mill streams. More rapid procedures were developed for analyzing smelter slags to provide data for monitoring electric-furnace operations. Research to update on-stream analysis of xanthate residuals in cyanide flotation pulps was continued so that variations in liquor concentrations with reagent pick-up by the mineral surfaces can be related precisely.

Mineralogical studies were carried out in connection with the research of the Division. One study was made to examine the response of various uranium-ore minerals to acid-leach attack, by means of mounting previously studied polished mineral specimens in a percolation column in which bacterially active acid-leach solutions were flowing. The progress of the acid attack was followed by means of ore microscopy. A wide range of leaching rates for the ore minerals present was observed, with uranothorite being readily leached in seven days while brannerite was still highly refractory in an exposure of more than 100 days.

METALS REDUCTION AND ENERGY CENTRE

The Metals Reduction and Energy Centre was created on October 1, 1969, for the following purposes:

a) To conduct studies of the energy requirements of the Canadian metals and minerals industries.

b) To assess the related transportation problems in supplying these energy needs and in developing markets for metallurgical fuels and their products.

c) To perform both research and development work up to the pilot scale:

i) on the production of "further-processed" metal ores (particularly reduced iron ores) ferro-alloys, and other metal products;

ii) on the application of energy to metallurgical processes, including fossil-fuel carbonization or conversion and metal-ore reduction; and

iii) the abatement of air pollution arising from some metallurgical processes, especially those of the ferro-alloy industry.

d) To apply the results of these studies to obtain benefits for the Canadian economy through:

i) organization of co-operative formal government-industry groups, such as the Canadian Carbonization Research Association;

ii) organization of ad hoc technical committees, such as that formed to study special problems in the hydraulic transport of coals to be used for coking;

iii) consultation with industry, universities and government representatives; and

iv) the preparation of reports and papers not only to publish the results of research but also to identify opportunities and to offer solutions to problems associated with energy use in metallurgy and related industries.

Pyrometallurgical Pilot Plant

For several years a combination shaft-electric furnace (250 kVA) has been developed at the Mines Branch to obtain maximum productivity through the optimum use of various energy sources, including the hot reducing gases from the electric furnace and from gas burners. Extensive control data have been collected on magnetic tape through the "Datacom" link to the Control Systems Laboratory computer of the National Research Council. These data are now under analysis and a computer program for calculating the process-energy requirements is in preparation, first for the treatment of ilmenite ore, but also by generalization for processing iron-oxide pellets and other feed materials. This project is now being changed to investigate various factors of arc-furnace operation, such as slag composition, arc voltage and current, depth of slag, fume generation in the arc zone. The objective is to improve the economics of arc-furnace operation, to obtain better products and to minimize fume generation as a contribution to pollution abatement. For ferro-silicon furnaces, a study has been initiated on the pelletizing of furnace fumes to permit their recirculation. Increased emphasis will be placed on air-pollution aspects in the future.

Coking-Coal Program and Related Transportation Studies

Because of the present general shortage of good coking and combustion coals at prices acceptable to the large consumers, there is increasing world-wide interest in coals of western Canada. Hence, during recent months, testing in the Mines Branch technical-scale coke oven has been extended from coals for the Japanese markets to coals for South America, the United States and central Canada. A total of 132 tests, a new record, were made in the 500-pound pilot-scale movable-wall coke oven during the year, embracing studies of coal for the coal-exploration industry, coking-coal blends for the steel industry and research aimed at improving the coking process.

An extensive study has been initiated on the feasibility of transporting coking coals in water-slurry pipelines. New water-removal methods are under investigation in the Western Regional Laboratory (Edmonton — located in premises generously made available by the Research Council of Alberta) and the carbonization aspects of this project are under study at the new Coal Laboratory on the western outskirts of Ottawa, where a new 18-inch 800-pound-capacity movable-wall coke oven is now in operation, in addition to the 30-pound coke oven used for small-scale preliminary tests, and the 12-inch, 500-pound movable-wall coke oven which will soon be reconstructed. By year-end a solution to the problem of extracting coal from the water-slurry had been devised and a pilot plant was under construction. These testing facilities, operated with the co-operation of the Canadian Carbonization Research Association, grouping major steel and coking-coal companies, have been used in 1969-70 for the joint research program co-ordinated by its Technical Committee.

The Western Regional Laboratory has pursued its contributions to the improvement of coal and minerals beneficiation, mainly by means of compound-water cyclones. These units, invented, developed and manufactured in Canada, are gaining acceptance because of their efficiency and low cost. Also, special dewatering processes were developed during the past year to overcome the need for thermal methods of drying at coal-washery plants. A special design incorporating these new features was developed to control sulphur in Cape Breton coals and is now being considered by the Cape Breton Development Corporation.

To note other activities briefly, petrographic techniques have been evaluated for their usefulness in understanding western Canadian coking coals and are now used on a routine basis. In an effort to improve the transportability of coke, tests have indicated that coal,

crushed to coke-oven-feed size, may be used to fill the voids between the pieces of coke and later separated by screening at destination, and that oil can be absorbed into coke up to about 25 per cent of its weight. For coke-oven stamp-charging tests, a device for ram charging has been built for the 12-inch movable-wall coke oven which will allow oven tests at rigidly controlled bulk densities. Form-coking studies on a laboratory scale have been continued on five coals in bench-scale apparatus, and a prototype "spouting-bed" apparatus has been tested, as a preliminary step before considering the design of a "spouting-bed" furnace at the pilot scale. The oxygen-flask sulphur-analysis method has been improved for control use in coal or coke research and development work by using Arsenazo (III) as indicator. A new method has been developed for the removal of magnesium from artificial rutile. It is now being examined for patentability.

Energy studies on the economics of production, transportation, storage and utilization of Canadian coals have been continued, particularly as it now appears that the low-sulphur coals of western Canada may be needed for thermal power generation in Ontario as well as for coking, due to the rising demand for energy and the increasing need for air-pollution restrictions with the consequent need of coals of less than 1 per cent sulphur content.

MINERAL PROCESSING DIVISION

The Mineral Processing Division carried out basic and applied research in aid of the mining, ceramics and construction-materials industries and continued to supply expert advice to industry and other government departments.

Research to improve basic processes for concentrators of metal ores in the mining industry included development of new types of filter media, systematic study of cyclone operating parameters, and correlation of new methods of measuring ion concentration with the flotation behaviour of sulphides and oxides. The fundamental studies of the jigging process have resulted in development of a much simpler and more efficient method for concentration of ilmenite. Full-scale tests will be carried out by industry. Research to find a selective flotation process to separate talc from molybdenite in high-talc ores has continued with investigation of new talc depressants, the column flotation process and spherical agglomeration.

Applied research provided assistance to the mining and metallurgy industries in developing new mines, improvement in existing plants, and better utilization of resources. Preliminary investigations to provide metallurgical knowledge to industry on concentration of ore from new discoveries were conducted on 21 bulk samples covering the range of metals from gold to iron. Many of these were complex, e.g. silver-gold-lead-zinc-antimony; silver-lead-zinc-tungsten; and one of seven recoverable metals. Pilot-plant studies were made on several ores to confirm the feasibility of recommendations. Geographically, the sample origins ranged from Sable Island to Vancouver Island.

Assistance to the metallurgical industry included development of a process to recover and re-use chromite sands in a foundry operation. This process is now in operation. Assistance was provided to a Canadian producer in the development of a new method to process iron powder for use in powder metallurgy, and research continued on new methods of purifying iron mineral concentrates for preparation of iron powders.

Assistance was given to the ISO Committee on standardization of iron-ore testing procedures by conducting a statistical study of proposed screening methods.

Research in the industrial minerals field was directed to the solution of technological problems, conversion of waste materials, provision of technical advice and information. Activities in this field comprised projects for improved processing of Canadian industrial minerals, ceramics research, construction materials research, non-metallic minerals research and studies on the beneficiation and utilization of waste materials. Evaluations were carried out on a large number of industrial mineral samples supplied by industry, the public and other Government departments.

A long-range study of the floatability of non-metallic minerals has generated world-wide interest through departmental publications and scientific papers. Two patent applications, one on a biodegradable reagent for floating barite and celestite and the other for floating spodumene, were filed. Photometric sorting systems were devised for the concentration of uranium, limestone and lepidolite. New processes for spodumene, fluorite and celestite, and fluorite and barite, resulting from research in the Mines Branch, were transferred to pilot-plant recovery to determine their economic viability.

Evaluation of Canadian non-metallic minerals continued with work being carried out on sylvite-halite separations, gem stones from Baffin Island, rocks used for Eskimo carvings, marl, ultra-basic rocks, building stones from sandstone and white dolomite, scheelite, salt, barite, kyanite, clay, talc, magnesite, silica and lightweight aggregate raw materials. In a joint project with the Quebec Asbestos Mining Association, which carried out fibre-length and -distribution counts using the system developed at the Mines Branch, a statistical program was written from these results with assistance from the EMR Computer Science Centre. The magnetic susceptibility of chrysotile asbestos fibre was studied with the assistance of scientists from the Geological Survey of Canada.

Laboratory studies on by-product synthetic gypsum from plants in Alberta, Ontario and Quebec showed that a satisfactory gypsum wallboard could be processed from fertilizer plant residue. It was found that waste iron-oxide-precipitator dust from a steel plant could be used advantageously as a component in such clay products as facing brick and drain tile. Plans were made for establishing an inventory of mineral wastes in Canada so that priorities could be established on carrying out useful research on these materials.

The Construction Materials Section continued to lead the way in Canada in the establishment of rapid and accurate tests and standard methods for evaluating strength and durability properties of concrete and its ingredients. In co-operation with the University of Ottawa, a building supply company and a firm of consulting engineers from Ottawa, the Section studied means to determine potential strength of concrete in structures using the maturity concept and non-destructive methods. Data from a construction site in Ottawa were collected and analyses of the results are under way. Research in the development and modification of an accelerated test method for controlling the quality of cement during the production stage has been completed.

Research on the preparation, characterization and conversion of raw materials to ceramic products continued on such materials as alumina, zirconia, magnesite, clay and shale, kyanite and talc. Of particular interest was a study of a magnesite-talc deposit in Ontario which revealed that the ore was a potential source of 92 per cent refractory-grade magnesia and a high-quality talc. A long-term study of particle size and morphology of Canadian alumina continued with the aim of developing a material suitable for a substrate in the electronic industry. An improved method of measuring thermal diffusivity of ceramic materials, rock and minerals resulted from intensive laboratory research.

TECHNICAL SERVICES

The Technical Services Division has continued to provide engineering support to the various research centres and divisions in the Mines Branch. This support has been in the fields of mechanical engineering, electrical engineering and industrial instrumentation in order to provide the scientists and research workers with the type and quality of equipment that is necessary in their respective fields of research.

During the past year a considerable amount of both the mechanical and electrical effort of this Division has gone into designing and installing equipment at the Corkstown Road site. Existing equipment and apparatus moved from the Booth Street site, as well as newly acquired equipment had to be connected to the service facilities within the various buildings.

One of the major undertakings this year which called for close liaison between our electrical and mechanical sections as well as co-operation between our design staff and the research staff was the installation of the 18-inch coking oven which has a movable wall and can take an 800-pound charge. The oven was built by an outside contractor to drawings supplied by Bethlehem Steel Co., but a considerable number of instruments, such as temperature controllers and pressure recorders at various locations, had to be installed. As the natural working environment of a coking plant is normally very dirty, it was necessary to build a special room where all the control instrumentation could be installed. In addition to the oven proper a wide range of ancillary equipment such as levellers and pushers had to be designed and built so that the oven could be operated efficiently and in line with current industrial practice.

Another piece of equipment designed and built by the Division was a pulsating air-jig which was based on a small "bread-board" model used for feasibility studies. The enlarged version was designed to provide a variable number of pulses of air per minute as well as independent control over the volume of air required. This type of air-operated separator is of interest where

minerals require dry processing or where water is in short supply so that wet processing becomes impossible.

In conjunction with one of the research centres of the Branch, equipment is being designed and built for calibrating a coking oven while it is at operating temperature.

An experimental laboratory apparatus for measuring the magnetic susceptibility of small mineral specimens was developed and built for one of the research divisions. The apparatus allows small specimens of materials to be accurately located in a magnetic field which could be rotated around the specimen's vertical axis.

Apart from supplying the research divisions of the Branch with scientific apparatus and equipment, research and testing of mining drill rods and machinability studies were carried out for private companies. A major steel company requested the use of a specially designed lathe for machinability studies together with the services of our personnel.

Extended physical tests of mining drill rods to improve their fatigue life were undertaken for some private companies. Various types of steels were tested under both wet and dry conditions and the test specimens were subjected to different types of surface treatments that would impart compressive stresses to the specimen surfaces.

LIBRARY

The Mines Branch Library consists of the main library with a staff of three professional librarians and five clerks. There is a branch library in the Physical Metallurgy Division with a library clerk in charge, an active collection at the Mining Research Laboratories, Elliot Lake, with a clerk in charge, a collection at the Western Regional Laboratory in Edmonton with a technician in charge, and a collection at the Western Regional Office, Mining Research Centre, in Calgary with a technician in charge.

The library collection consists of 79,000 books and bound journals, and 12,000 documents and reports. Subscriptions to more than 900 journals are supplemented by publications acquired through exchange agreements with scientific and technical societies in all parts of the world. There are approximately 8,000 loans and photocopies provided each month on circulation, to both Mines Branch personnel and other libraries.

The Library's serials are publicized by means of the National Science Library's Union List of Scientific Serials in Canadian Libraries, and its books in the Union Catalogue of the National Library. In addition, our holdings are now announced in the Comprehensive List of Periodicals for Chemistry and Chemical Engineering by Chemical Abstracts Service, Columbus, Ohio.

There is no doubt that as time goes on more and more library tasks will be adapted for performance on computers. As a result, some of the Library's manual operations are now being redesigned so that data can be readily converted to machine-readable form when necessary.

OBSERVATORIES BRANCH

For approximately 70 years the Observatories Branch has been involved in two major disciplines, Astronomy and Geophysics. The astronomical work, originally involving only the astronomy of position, was begun for the measurement of time and to assist in the establishment of a geodetic survey. This work soon expanded to the study of the physics of stars and, as a corollary, the physical study of the only planet then available for direct observation — Earth. Astrophysical studies led to the establishment of the Dominion Astrophysical Observatory at Victoria in 1918, and of the Dominion Radio Astrophysical Observatory at Penticton in 1960. The geophysical work expanded into three separate Divisions — Gravity, Geomagnetism and Seismology.

On April 1, 1970 the Observatories Branch was dissolved with the transfer of astronomy to the National Research Council. The three geophysical divisions have been reorganized under the name Earth Physics Branch. One aspect of astronomy, positional astronomy, the original section for which the Observatory was founded,

remains behind. Physical methods of measuring time have become so accurate that we now know that the earth is a most imperfect clock; the vagaries of its rotation are related to conditions within the earth and it has now become a problem of geophysics.

ASTRONOMY DIVISION — OTTAWA

The Time Service, involving the time laboratory and the CHU transmitters, continued in operation throughout the year. Correct time is distributed to a number of users: Bell Canada, the R.C.M.P., the C.B.C. and a number of government laboratories. This service transferred to the Physics Division of the N.R.C. where it was combined with the Frequency Section with no interruption of service.

For many years the Division had attempted to perfect a Mirror Transit Telescope, a positional astronomy instrument of unique design. It was finally established that the instrument could not be made to meet the required degree of accuracy without transfer to a more remote site and extensive redesign. It was reluctantly decided to abandon the project; abandonment had been completed at the end of the fiscal year.

The remaining instruments of the positional astronomy groups, Photographic Zenith Telescopes at Ottawa and Priddis (near Calgary) and an experimental PZT at Ottawa have continued in operation throughout the year and, as mentioned above, will remain in the Earth Physics Branch.

Work in solar physics has continued. Observations with the solar magnetograph attached to the 80-foot horizontal telescope at the Dominion Observatory clearly indicated that the system was seriously hampered by poor seeing conditions at that site. Modifications were performed on the system to allow signal averaging methods to be used for overcoming the errors produced by rapid, random motions of the solar image. While the Solar Physics Section has transferred to N.R.C., this one telescope, with its associated laboratories, will be retained by the Section until current research projects are completed.

The major effort of the Solar Physics Section has been in the development of an optical solar patrol telescope (photo-heliograph) to be sited at Shirley Bay. The basic mechanical framework, constructed by Canadian Westinghouse Ltd., was delivered in September 1969. The completed telescope will provide high-resolution photographic records of solar active regions at time-lapse intervals as short as 0.1 second. Several optical systems for observing different portions of the solar atmosphere can be mounted at one time on an equatorially-mounted platform called a "spar". Mechanical construction was completed for the first of these systems — a photoelectric guider telescope for tracking the spar precisely on the centre of the sun. A digital data-acquisition and -control system was specified and ordered for monitoring and controlling the status of various environmental sensors and cameras on the telescope, and for recording the data on magnetic tape. The building for housing the telescope was substantially completed by the end of March 1970. Site testing adjacent to the building site continued through the summer of 1969 and provided further evidence of excellent seeing on favourable days.

METEOR PHYSICS

The Meteorite Observation and Recovery Project (MORP) progressed according to schedule during the year. Nine camera stations were constructed, completing the network of 12 stations covering the Canadian prairies. Cameras and electronic controls for all remaining stations were purchased for installation. One station was put into routine operation during the year, as a test station, and its performance fulfilled expectations by photographing a number of bright meteors. A computer program was written for the MORP program, which will take measures of meteor photographs and calculate the solar-system orbit and trace the dark flight trajectory to the ground.

The Meanook-Newbrook observatories continued their program of meteor spectroscopy until the end of 1969 when the equipment was prepared for moving to new sites near Ottawa.

DOMINION ASTROPHYSICAL OBSERVATORY — VICTORIA

On the occasion of the transfer of the D.A.O. to N.R.C. it is worth noting that since 1918 the Observatory has developed from a single telescope and a staff of seven to three research telescopes plus responsibility for work on Mount Kobau and a staff of 42 associated with the astrophysical division. The efficiency of the telescopes and their instrumentation continues to be improved with the result that for the coude spectograph of the 48-inch telescope with its dispersion of 2.4 A mm^{-1},

spectra are obtained in exposure times comparable with those required at the 200-inch Hale telescope. Accurate data reduction, which has always been a feature of the Observatory programs, has also been improved and digital and computer analysis methods are being worked out.

The 72-inch telescope was used for 1,148 hours on 193 nights during the year. The 48-inch telescope was used for 1,209 hours on 213 nights. This has been a good average year for observing, considering that the telescopes were out of operation for four nights for repairs, but it has been found that the average number of observing hours in recent years has been less than in the first years of the Observatory's operation.

A new optical shop was built under the supervision of the Department of Public Works from designs prepared at the Observatory and put into operation in January. The optical equipment bought for the Queen Elizabeth II telescope, with the exception of the large grinding machine stored at the University of British Columbia, is now in place. The principal task of the new shop will be the figuring of a new very-low-expansion 73-inch CER-VIT mirror blank to replace the 60-year-old plate-glass mirror of the main telescope. Great interest has been taken in the new shop by astronomical groups in Canada and throughout the world and many requests have been received to undertake precision optical finishing work for other observatories.

Twenty scientific papers were published by staff members during the year on topics such as the structure of the galaxy, binary stars, galactic clusters and loss of mass by hot supergiant stars, and the Observatory was represented at several international scientific meetings. Staff members have been invited to act as consultants on large-telescope and instrumental problems by the U.S.A., France, Germany, Italy, the United Kingdom and Australia. For example, Dr. E. H. Richardson spent five months in Texas at the 108-inch telescope in charge of the optics in a successful attempt to reflect a laser beam from the corner-cube reflectors placed on the moon by Neil Armstrong in July 1969; the moon's distance from the earth is now known to within a few inches.

Considerable improvements in the efficiency of the 72-inch and 48-inch telescopes were made during the year. New image slicers for the infrared and ultraviolet have been installed in the 48-inch and work has begun on an improved mirror-support system for the new 72-inch mirror. The process of automating the methods of measuring and processing the data obtained by the telescopes has proceeded rapidly and has contributed to a greatly increased output of scientific work. For instance, the 16-inch telescope on Mount Kobau was used very successfully with the Vidar Data Acquisition System to make over 3,600 observations of standard stars, members, clusters and associations, peculiar and reddened stars, etc.

The need for larger telescopes for the use of Canadian astronomers is very pressing and decisions are awaited from the Government in the very important question as to whether Canada participates in the 200-inch telescope to be built in Chile. The Science Council recommended this course in a report submitted to the Cabinet in September with the proviso that the 200-inch mirror be figured in Canada and that Canadians be responsible for 50 per cent of the work on the rest of the project. The design and optical teams drawn together to build the Queen Elizabeth II telescope are still available to work on any large telescope approved by the Government.

DOMINION RADIO ASTROPHYSICAL OBSERVATORY

The Observatory is concerned with studies of a wide range of astronomical bodies, mainly through investigations of their radio emissions. It operates three major instruments: a conventional 25-metre paraboloid used at frequencies from 110-2,000 MHz, and two large arrays operating at 10 MHz and 22 MHz. A new supersynthesis telescope, now under construction, will be used for both continuum and spectroscopic studies in the 1-2 GHz range.

The main research projects of the Observatory have been concerned with studies of the low-frequency emission from radio sources and the galaxy, the distribution and motion of galactic neutral hydrogen, the structure and temperature of galactic ionized hydrogen, the angular structure of quasars, and the intensity variations of pulsars.

The observations with the 10-MHz array have been terminated and the catalogue of 124 sources published. The three observers who have used the array have been collaborating in the production of a map of the con-

tinuum emission for much of the northern sky. This will be used mainly for studies of the distribution of the diffuse ionized hydrogen regions in the galaxy.

The 22-MHz survey of the sky visible from Penticton has been completed and the observations terminated. A list of flux densities for 200 radio sources has been published, and a complete analysis should yield another 400. The 10 MHz and 22 MHz observations have been compared with higher-frequency observations in a detailed study of the low-frequency radio spectra. Preliminary computer reduction of most of the sky survey observations has been completed. This project will produce a complete map of the northern sky which will be used for studies of the spectra and volume emissivity of the non-thermal continuum emission and of the nature and distribution of galactic ionized hydrogen.

The Observatory has continued as a member of the Canadian Long Baseline Interferometer Group. Observations during the year were made on quasars using the Algonquin Radio Observatory (46-metre paraboloid) and the Arecibo 1,000-foot bowl, and on pulsars using the Penticton-ARO baseline. A paper on source structure using most of the early observations was published this year.

Observations on the time variations of pulsar intensity continued. This work included simultaneous observations at the DRAO and the Nuffield Radio Astronomy Observatory at Jodrell Bank. Correlation studies of this type can yield information on motions in the interstellar medium. A program has been developed which is capable of on-line analysis for all pulsar periods using the PDP-9 computer at the DRAO. It has been used mainly for a survey for new pulsars at high declinations using the 25-metre paraboloid at a frequency of 400 MHz. An extensive effort to detect several pulsars with the 22-MHz array produced upper limits to their intensities at this frequency.

The 100-channel spectrometer was used for a number of hydrogen-line studies, principally by observers from the University of British Columbia.

The cosmic-ray facility of the University of Calgary has been expanded. Their new 22-MHz array and directional shower array were completed and made operational.

GRAVITY DIVISION

The primary responsibility of the Division is to produce a complete gravity map of Canada and to provide interpretation of the maps where this might be of scientific or commercial interest. The Bouguer Gravity Map of Canada, published in 1968, has many areas still incompletely surveyed. A major effort has thus been made in field surveys.

a) A party supported by two helicopters and one fixed-wing aircraft established 4,500 stations in the area between Great Slave Lake and the Mackenzie Delta. Anomalies of interest include a remarkable circular high of 120 mgal south of Darnley Bay.

b) Approximately 900 stations were observed on sea ice in the Beaufort Sea in conjunction with hydrographic surveys of the Polar Continental Shelf Project. The area covered extends north from Tuktoyaktuk to latitude 73°30′N and between longitudes 130°W and 135°W.

c) During 1969, 400 underwater gravity stations were added to previous surveys in Lake Ontario, Lake Erie and Lake Huron.

d) One and one-half crew months were spent linking together various previous bench-mark surveys in southern Ontario and western Quebec.

e) Preliminary airborne gravity tests using highly accurate electronic navigational equipment were carried out in the spring of 1970 in the vicinity of Alexandria, Ontario.

f) A Differential Omega Navigational System was evaluated in the Mackenzie Delta for positional accuracy, strength, stability and feasibility for helicopter in-flight use for the Polar Continental Shelf Project.

g) The detailed study of the gravity field of the Sudbury area was continued in 1969. A total of 652 new gravity stations were recorded, including 62 in and around Lake Wanapitei which was surveyed in March. The remaining regional and detailed stations were observed in the summer with the use of air, road and rail transportation. Altogether 2,300 gravity measurements are now available in this region.

It is important that gravity observations throughout Canada, and indeed throughout the world, be reduced to the same datum. The final adjustment of the National Gravity Net is now under way. During the past year

several field crews carried out direct connections between National Net stations throughout Canada to supplement earlier gravimeter work. The Canadian pendulum apparatus has now occupied sites in Ottawa, Winnipeg, Edmonton, Vancouver, Yellowknife, Resolute and Fairbanks. These measurements will provide scale control for the National Net adujstments. For operational reasons, the number of primary stations in the National Net has been reduced to 58. It is expected that the final adjustment will yield a uniform set of observed gravity values for the primaries and some 200 associated ex-centres.

Intercontinental and gravity ties and measurements on the world calibration lines carried out by Canadian observers since 1963 for the First Order World Gravity Net (FOWGN) have now been submitted to Professor Morelli of the Osservatorio Geofisico in Trieste and chairman of Special Study Group No. 6 of the International Association of Geodesy, who, for the past year, has directed the assembly of data from all participating countries into a homogeneous unit. Upon completion of this task each participating agency will receive a copy of the assembled data for analysis and adjustment.

Parallelling the collection and reduction of data is the interpretation of the anomalies shown by the finished maps. Major interpretations of gravity anomalies have been completed in several regions including the Province of Quebec; Queen Elizabeth Islands; Alexandria area, Ontario; Straits of Georgia and Juan de Fuca, British Columbia; Bancroft, Ontario; northwest Ontario; and in the Interior Plains of Canada. Theoretical studies of crustal loading in Canada and in Hawaii were completed during the year and investigations of new mathematical methods for interpretation continued during 1969.

Two programs of major research interest made progress during the year. Multidisciplinary geodetic and oceanographic studies in the vicinity of the North Pole, begun in 1967, and sponsored jointly by the Observatories Branch and the Polar Continental Shelf Project, were continued in the spring of 1969. Scientists from the Federal Government, from private industry and from universities were flown to a camp within 30 km of the North Pole. From April 8 to May 4 the party drifted some 60 km with the pack ice. Gravity observations in the vicinity of the North Pole and gravity traverses from the Lincoln Sea to the North Pole and across the Lomonosov Ridge were made. Both Omega radio navigation in differential mode and sunshots using a much improved atmospheric model for refraction corrections were used for positioning. Other studies included continuous wind-velocity measurements, ocean-current-velocity measurements ranging in depth from 0.5 m to 200 m, and the establishment of a number of salinity-temperature profiles to a depth of 500 m. A 120-m-long hydrostatic level was developed to measure the tilt of the fluid level of the ice-covered ocean. On May 1, 1969, a downward tilt of 4.3 microradians in the direction 198° of Greenwich was measured.

A second research project which concerns the loading and attraction effects of the ocean tide has been carried on co-operatively with the University of Durham in England during the past two years. A method has been developed for determining the theoretical regional and global effects of the ocean tide from worldwide co-tidal charts, assuming a Gutenberg-model earth. Theoretical effects have been determined for Britain and western Europe and are presently being determined for the Canadian east coast and for Ottawa. Also with the co-operation of Durham University, a new watertube tiltmeter has been developed and a prototype has been operating for several weeks in a mine near Durham. A second prototype is now under construction and, when finished, will be installed near Ottawa.

It is very important that reduced gravity data be readily available for regional studies, either by Observatory scientists or by university or commercial geologists. An IBM 360/65 disc retrieval system was installed some time ago and operated satisfactorily over the past year. It has been used extensively by the petroleum industry particularly those companies working in the Canadian Arctic. Several new features have been added.

Studies of proven or suspected meteorite craters have continued. They have been mainly concerned with sampling and laboratory investigations of material from the craters at Lake Mistastin, Labrador, Charlevoix, Quebec, and Brent, Ontario, for further analysis of shock metamorphism and crater structure.

GEOMAGNETISM DIVISION

The information on the direction and intensity of the earth's magnetic field shown on the magnetic charts of Canada, aeronautical and marine navigation charts, and

topographical maps, comes primarily from high-level airborne surveys carried out by the Division of Geomagnetism. The surveys are made in alternate years, because of the lower unit costs of a large-scale operation. No airborne survey was made in fiscal year 1969-70, but data from the early 1969 survey of British Columbia and the northeast Pacific Ocean was analyzed and prepared for publication. Several large-scale magnetic anomalies were discovered, most notably one parallel to the coast east of Vancouver Island, and a system of deep-seated anomalies 250 miles long and 120 miles broad in the Fort Nelson district of northeastern British Columbia. The explanation of these features will have important consequences to the understanding of the geological history and hence the distribution of the mineral deposits of western Canada.

Magnetic charts must be revised every five years because the geomagnetic field is constantly changing. To bring the data from earlier surveys up to date, measurements are made on the ground every few years at each of 100 carefully marked repeat stations, uniformly distributed over the country. During 1969, 26 such stations were occupied, in Newfoundland, Saskatchewan, Alberta, British Columbia and the Northwest Territories.

Variations in the direction and intensity of the geomagnetic field were recorded continuously at magnetic observatories in the following locations: Alert, Resolute, Baker Lake, and Mould Bay, all in the Northwest Territories; St. John's, Newfoundland; Poste de la Baleine, Quebec; Ottawa, Ontario; Churchill, Manitoba; Meanook, Alberta; and Victoria, British Columbia. In addition to the permanent observatories, unattended magnetic recording stations were operated in Manitoba at Lynn Lake, Thompson, The Pas, and Winnipeg, in a co-operative research project with the United States National Aeronautical and Space Administration involving the synchronous satellite ATS-5. Special magnetic recordings were made at four stations in the Atlantic Provinces during the solar eclipse of March 7, 1970, to study the magnetic variations due to the sudden decrease in the electrical conductivity of the ionosphere as the moon's shadow swept across it.

An investigation of the electrical conductivity and structure of the crust and upper mantle beneath Ellesmere Island was extended with the simultaneous recording of magnetic variations for five weeks at Meighen Island, Alert, and Cape Morris Jesup on the northern tip of Greenland. Twelve recording stations were occupied on a line between Prince Rupert, British Columbia, and Hinton, Alberta, in a similar study of deep crustal structure.

The Paleomagnetic Section completed a study of the magnetic properties of rocks dredged from the Mid-Atlantic Ridge, and proposed an explanation of the intense magnetic anomalies observed over the centre of the Ridge. Further information on the relative motions and rotations of continents was obtained in an investigation of Permian and Triassic rocks from the Dinaric Alps. Progress was made in deriving a magnetic chronology of the Paleozoic and late Precambrian.

SEISMOLOGY DIVISION

The standard network of seismic observatories equipped with short- and long-period seismographs continued as in the past, except for the enforced closure of the station at Coppermine, N.W.T. This followed the transfer of the meteorological ionosonde program at that site to elsewhere in the Arctic. The program of continuous instrumental updating and calibration continued on schedule, with a major field project at each of four high Arctic observatories. At one of these observatories, Alert on Ellesmere Island, additional specialized narrow-band, high-gain long- and short-period seismographs were introduced as part of a network evaluation leading to the better identification of underground nuclear explosions. Some improvements were initiated to make more Canadian abstracted seismograph data available for immediate epicentral determination by international agencies.

The local seismograph stations for more detailed study of Canadian seismicity continued unchanged, as did the extensive strong-motion network in western Canada: field parties routinely maintained and checked the latter network.

During the year, the new seismic zoning map for Canada described in earlier annual reports was officially accepted for the 1970 Revision of the National Building Code: the changes introduced in building and insurance practices resulted in an increase in the number of technical seismicity requests to the Division. A policy was adopted of making a small charge to recover direct additional computer usage costs, for cases where this was necessary to handle the requests.

The usual number of minor shocks were reported in both eastern and western Canada: one earthquake in the Laurentians in October was widely felt from Montreal to Ottawa and resulted in many public enquiries and expressions of concern and surprise. It is clear that despite every effort, the earthquake risk in Canada is poorly appreciated and understood by the general public. In order to help remedy this situation, a public relations leaflet describing this risk and some relevant work of the Division was drafted during the year.

Micro-earthquake field studies were undertaken to investigate further the extensive active earthquake sources discovered the previous year in the Coast Ranges near the northern British Columbia-Alaska border. This work is now being analyzed and prepared for publication as part of a continuing study to understand the tectonic fabric of western Canada, why earthquakes occur and why they occur in certain spatial patterns which are still only partially unravelled.

The techniques for the routine determination of the parameters of all significant Canadian earthquakes and their publication in an annul series were modified in an effort to make this important service available on a more current basis. However, the series, with our best efforts with the available manpower, remains about five years in arrears.

The first stage of a modernization of the short-period seismic array at Yellowknife was completed with an encouraging and positive assessment of the feasibility of radio telemetering and on-site computer control. Planning for the conversion is complete, and over a three-year period the medium aperture array will be completely converted to a radio telemetered system with computer control of the operating parameters, state of serviceability, etc. In addition, during the year under review, vault work was completed for installation of a third long-period element, when laboratory construction is complete: this will provide a minimum tripartite long-period array at Yellowknife with data available in a form suitable for digital machine processing. The analogue and digital data-processing laboratory in Ottawa was updated with the addition of oscilloscope read-out.

Considerable progress was made in research into the problem of the detection and identification of underground nuclear explosions: notable was the completion of experimental work on a study of the regional variability in the detection capability of the short-period array, further studies on identification at low yields using surface waves with emphasis on the data recorded in a format suitable for machine processing, and the development of an in-house system for determining the approximate epicentres of events anywhere in the world within one to two days, using abstracted data reported routinely to Ottawa from the Canadian network.

Research continued, with a number of publications, into the mechanism of earthquakes, the lateral variation in upper-mantle properties derived from surface-wave-dispersion studies, the structure of the deep interior of the earth and the derivation and understanding of the theoretical seismograms from nuclear explosions.

In July, the crustal group conducted a wide-angle reflection-refraction survey along a 100-km line near Yellowknife, N.W.T. The experiment was designed to test the effectiveness of a new technique in a structurally simple area, and to design ways of handling, processing and interpreting with digital means the nearly 1,000 seismograms of shots obtained with such techniques. In August, 20 large explosions were detonated using surplus naval ordnance in a lake in British Columbia. The project, code-named Edzoe, provided a repetitive source to 11 Canadian and U.S. university and government groups operating throughout western Canada to study the composition of the crust and upper mantle. Reduction of data obtained in earlier field projects continued and some theoretical studies were published.

The geothermal-studies group continued field measurements at widely scattered locations throughout Canada made available by commercial companies. In addition, further measurements were made in unusual Arctic lakes and some fiords. As a service to the oil-exploration industry, some deep-permafrost information was published, and plans were made to increase the number of measurements in permafrost regions. An interesting and unusual study in paleoclimatology was completed using heat-flow measurements made in northern Ontario, and an analysis of certain laboratory techniques completed and sent to press.

The level of visitors, contributions and papers sent to press and papers given at national and international meetings remained steady. The Division assisted the Committee of the Conference on Disarmament in Geneva on Comprehensive Test Ban Problems.

POLAR CONTINENTAL SHELF PROJECT

The Polar Continental Shelf Project is a continuing investigation of the continental shelf fringing the Arctic coast of Canada, together with adjacent parts of the Arctic Ocean basin, the islands of the Canadian Archipelago and the waters between them, and other areas that may be of special interest. The Project serves in part to facilitate Arctic researches and surveys of other units of the Department of Energy, Mines and Resources; in part it carries out, with its own personnel, work that is unique within the Department; it also serves as the vehicle through which the investigations of other government agencies are carried out in the Arctic Archipelago and the Arctic Ocean; and it provides facilities and support for approved university researches in the area.

The Project's field survey will eventually cover all the Canadian sector of the Arctic continental shelf of North America, those parts of the Arctic Ocean that are of interest to Canada and which can be reached with available logistics, and those parts of the archipelago and the mainland not studied by other agencies of the Department.

Field activities in 1969 were carried out from January to October. Studies continued till December and ranged from the lower Mackenzie River valley to the North Pole and northern Greenland. The main bases of operation were Tuktoyaktuk, Resolute and Alert.

In addition to the Department of Energy, Mines and Resources 22 other agencies were involved in or received assistance from the operations of the Polar Continental Shelf Project. Among them were 11 universities (four American and one Japanese), and Canadian government departments.

The 1970 program was to be, in the main, a continuation of that of 1969. The main emphasis was to be placed on the Beaufort Sea area.

The following is a summary of the work done in 1969, by major scientific field.

Climatology

Study was continued of the present behaviour of a small high Arctic icecap — the Meighen Island icecap — and its influence on and reaction to the local climate. Emphasis was laid on the energy exchange between the atmosphere and the earth's surface of known uniform physical properties.

Geology, Marine

In the Mackenzie River delta and inner Beaufort Sea, the study of the geology of the sediments, the processes of sedimentation, and the present and past organisms of the sea floor in an Arctic delta environment was continued.

Geology, Terrestrial

The study of the nature and distribution of permafrost in the Mackenzie River delta and the characteristics and mechanics of development of permafrost land forms was continued. Special attention was given to the development of pingoes and the occurrence of permafrost around lakes and the ocean shore. A shallow seismic survey of the thickness of permafrost and the structure of poorly consolidated sedimentary deposits of the Tuktoyaktuk peninsula was also undertaken. Another continuing study related to the recent geological history and the development of landforms in western and central Banks Island. To understand the stratigraphy of the economically promising area of the central Arctic Archipelago, a detailed study was carried out of the faunal variations in selected Paleozoic formations within the Franklinian geosyncline. Studies were also conducted in the stratigraphy and structure of the Mesozoic formation in the lower Mackenzie River valley. Mapping of vegetation types and study of peat deposits were carried out to determine the recent geological evolution of the western Arctic Islands.

Glaciology

The study of the mass balance and morphology of the thinnest and driest of North American Arctic glaciers — the Melville Island icecaps — was continued. Surveys were made of the accumulation, wastage and movement, and detailed aerial photography was carried out. Study was also continued of a small polar ice mass, the Meighen icecap. Experiments were made to determine the thermal and dynamic relationships of ice in a high Arctic environment. Further studies were carried out on the crystallography and internal structure of the ice mass to determine its history and climate during the recent geological past.

Geomagnetism

The project provided for measurements of the nature and variations of the earth's electromagnetic field along the edge of the Arctic Ocean basin on either side of a strong-conductivity anomaly. The anomaly was previously studied in the Alert-Robeson Channel area at the northeast edge of the Canadian Arctic Archipelago.

Gravity

Regional mapping of the gravity over the continental shelf and continental slope in the Beaufort Sea were carried out. The scale was 1:500,000. Mapping of the gravity over the lower Mackenzie River, valley and delta was completed. The scale was 1:250,000.

Heat Flow

Measurements were made of the flow of the geothermal heat from the earth's crust at selected Arctic locations.

Hydrography

A survey of the coastal area of Beaufort Sea was made for charting at a scale of 1:100,000. Continuous-profile soundings were made over parts of the submerged delta of the Mackenzie River, for evaluating potential sites for harbours for supertankers. Another survey was made over the continental shelf and continental slope between the Mackenzie River delta and Banks Island for charting at a scale of 1:500,000.

North Pole

A multi-discipline investigation — geodesy, gravity and oceanography — of a region near the North Pole and along the meridian 60° West was carried out.

Position Determination

Positions were determined of a number of selected points along the north coast of Greenland. As a result errors in the present maps were reduced. In the Beaufort Sea area evaluation was made of the signal strength and stability obtainable with the Omega navigation system in high latitudes and its accuracy compared with the Decca Lambda system.

Sea-Ice Studies

For the ninth successive year, a systematic aerial survey was carried out of the distribution, nature and movement of sea ice in the main channels of the Arctic Archipelago. Under the *Manhattan* project, the thickness, temperature profiles, salinity distribution and structure of the sea ice at selected locations were determined. These were along the route that the S. S. *Manhattan* proposed to take in late summer. A continuing study was under way of the stresses and strain relationships of the annual sea ice in Kugmallit Bay.

Miscellaneous

Support was also provided for 20 other studies, such as: a survey of the small mammals of the coastal Yukon and western Mackenzie district; biological and glaciological investigations in northern and eastern Devon islands; paleozoic paleontology and petrology in northern Banks Islands; geomorphological studies on Baffin Island; a continuing comprehensive biological and ethological investigation on Bathurst Island; archeological studies in the Mackenzie Delta region.

Mineral Development Sector

MINERAL RESOURCES BRANCH

The Mineral Resources Branch is responsible for resource-economic research, program development, and policy formulation in the field of non-renewable resources. The purpose is to contribute towards attainment of optimum economic and social benefits for the nation through effective mineral resource management in concert with Departmental objectives. The Branch continually seeks to identify and evaluate factors affecting mineral policy and mineral industry.

The Branch collaborates with other departments and agencies of government and with industry, and conducts research and field investigations into mineral problems, policies and programs on a commodity and industry basis, and in a regional, national and international context. The Branch continuously monitors trends, and integrates and analyzes data on a broad spectrum of mineral industry activities ranging from basic resources through exploration, development, processing, transportation, marketing and consumption. This information provides a basis for decision-making within the Department and within government on non-renewable resource policy, as well as the raw material for publications useful to those concerned with mineral economics.

The Branch is organized into three functional Divisions:

1) Research and Planning, 2) Minerals and Metals, and 3) Taxation and Legislation. Technical and administrative support groups are common to all Divisions. The Branch is changing towards a type of management organization that will facilitate interdisciplinary work.

Links with public agencies complement relationships with industries. Highlights that follow indicate the scope of Branch activities in the 1969-70 fiscal year.

Regional Development

Minerals administration practice in British Columbia was examined at the request of the British Columbia Department of Mines and Petroleum Resources. This co-operative study, begun late in 1968, was completed in the spring of 1970.

A federal-provincial program for mineral development in Manitoba was agreed upon and research initiated in the spring of 1970. The first phase consists in forecasting and evaluation of the economic mineral potential. The program will continue into 1972.

The Branch collaborated to an increasing extent with the Department of Regional Economic Expansion and with the provinces in furthering regional mineral development. Special studies pertaining to Newfoundland, New Brunswick and Quebec were undertaken in 1969-70.

Northern Development

A study, begun in 1968 and continuing in 1970, concerns the rail and road transportation needed for the development of northern British Columbia and the Yukon. The interdepartmental study, in collaboration with a private consulting firm, has meant a major involvement by the Branch in all phases of the project, with particular responsibility for assessing the economic mineral potential and how mineral development could contribute to development of the region. Methods developed with the consultant were successfully applied in full co-operation with private exploration managers. A report on the forecasting techniques used and the results obtained will be published in 1970.

The Branch continued to provide advice on mineral matters to the Department of Indian Affairs and Northern Development and to participate in interdepartmental activities concerned with northern economic development; one of these is road construction in the two territories.

Interdepartmental Commodity Committees

The Branch is represented on a number of interdepartmental commodity committees responsible for recommendations concerning mineral-commodity problems of industries, regions, or all of Canada. The data and research systems of the Branch contribute to decision-making as the need arises. Recent examples of governmental concern include: ensuring that an adequate supply of refined copper was available to the domestic fabricating industry during a period of world shortages and price disparities; and production-price problems of the Canadian potash industry.

Taxation

A study was begun of the implications for the mineral industry of the tax changes proposed in the White Paper on Tax Reform.

Analyses and recommendations were provided to the Department of National Revenue with respect to tax benefits under the Income Tax Act which are applicable to the mineral industry. Reports were prepared on 17 applications for three-year tax exemptions, and on two applications for the special oil-pipeline depreciation allowance.

Recommendations were made to the Department of Indian Affairs and Northern Development in the preparation of a proposed revised Yukon Minerals Act.

General Advisory and Consultative

As a result of continuing in-depth studies and analyses of all mineral commodities either produced in or of importance to Canada, the Branch provides information and advice on a broad scale to mineral-industry representatives and the general public through personal office interviews, correspondence, telephone and publications.

International Activities

The Branch represents the Department in intergovernmental organizations and international associations that embrace mineral-industry matters. Background studies are provided and recommendations on Canadian positions are made to Canadian government delegations on which Branch officers often serve.

The Branch represented the Department on the Canadian delegation to the International Lead and Zinc Study Group and attended the 13th Session in Geneva in October 1969. Contributions were made to the technical-economic studies and to the statistical needs of the study group. The Branch participated in matters concerning the Third International Tin Agreement, and towards the end of the year a Canadian team, including a Branch member, was prepared to commence negotiations for the Fourth International Tin Agreement to become effective on July 1, 1971, for a five-year period.

Mineral-industry data were supplied to OECD groups, including the Special Committee for Non-Ferrous Metals, and the European Nuclear Energy Agency. In conjunction with the latter group, of which Canada and the United States are members by virtue of their prominence in the nuclear-energy field, an officer of the Branch attended meetings and reviewed nuclear-energy facilities in a number of west European countries. A study of Canada's uranium production, reserves and short-term demand was presented to the meeting. The Branch also participated in meetings of the OECD Special Committee for Iron and Steel, the UNCTAD Special Committee on Tungsten, the UN ad hoc meeting on iron ore, and the UN's ECE Steel Committee. The Branch also co-ordinated a tour by the ECE Steel Committee of Canadian steel facilities, and worked with counterparts on a related tour of United States facilities.

The Branch has a continuing program of educational mineral filmstrips designed for use in high schools. The photographic library and mineral-resource records centre continued to be enlarged. The Branch contributed several sections on minerals to the Canada Yearbook, and prepared papers for presentation at international meetings and for publication in technical journals.

Foreign Aid

The Department, through the Branch co-ordinator, provided recommendations to the Canadian International Development Agency on 58 applications for technical training for foreign trainees. These programs were sponsored through the various regional plans of the Agency and through the United Nations. Practical training was arranged partly within the Department of Energy, Mines and Resources and also in private industry, provincial government departments, and university graduate schools. During the fiscal year ending March 31, 1970, 26 programs had been completed, and at the same date the arrival of 37 additional candidates was expected. Besides post-graduate training programs, five foreign undergraduates were assisted in finding summer employment, and 50 attended the Summer Survey School provided by the Department.

Through the foreign-aid services provided, four technical advisers to the Moroccan government were recruited in geochemistry, geophysics, petroleum geology and economic geology. Several observation tours of the Canadian mineral industry were arranged for foreign mineral specialists and metallurgists.

The Branch co-ordinated a mineral investigation in Niger for which a report was prepared to assist the Canadian International Development Agency with an evaluation of the phosphate resources of that country.

Consultation and advice on proposed bilateral capital assistance was provided to the Agency in respect to requests from the governments of Ethiopia, Guyana, Niger and Upper Volta. Comments were also prepared on several multilateral projects of the UNDP. The Branch provided the representation of the Department to the Interdepartmental Committee for Development Assistance within the UN.

Mineral Occurrence Index

The Branch maintains an index of Canadian mineral occurrences as part of its data base which is used in commodity studies and regional analysis. The data are also used by those interested in mining and mineral exploration in Canada. The index contains comprehensive summaries with provision for revision of location, geology, history of ownership, development, and results of development work, supplemented by map and literature references, on some 12,500 mineral occurrences. These summaries, each on individual cards, are arranged in conformity with areas of the National Topographic System.

Agreements for the exchange of mineral-occurrence information were in effect with the Nova Scotia Department of Mines, the Ontario Department of Mines, the British Columbia Department of Mines and Petroleum Resources, and with the Northern Economic Development Branch of the Department of Indian Affairs and Northern Development.

Priority was given during the year to indexing the mineral occurrences of Yukon and the Northwest Territories, and by the end of the review period about 80 per cent of the indexing for this area had been completed.

Roads to Resources

The Roads to Resources program was a national effort designed to provide access to areas potentially rich in natural resources. The administration of the agreements, which provided $7.5 million as the federal share of each province, was transferred to the Branch in October 1966.

Federal payments to March 31, 1970, at which time all payments under the program had been completed, amounted to a total for all provinces of $74,988,792.

The Emergency Gold Mining Assistance Act

The Act is administered in the Mineral Resources Branch under the direction of the Assistant Deputy Minister (Mineral Development).

Inspection engineers from the Branch conduct regular inspections of gold mines receiving assistance. They report upon all aspects of the mining operations which affect the assistance payable under the Act. In particular, they determine the proper classification of exploration and development expenditures, review the

allowance of costs which are in question and report on mining and milling practices and on the ore reserves of the mines.

The Audit Services Branch, Department of Supply and Services, examines interim applications for advance payments of assistance and carries out the final audit of the accounting records of each applicant.

The Act was passed originally in 1948 to extend the operating life of the gold mines and thereby to minimize economic and social hardships for the dependent communities due to mine closures.

By an amendment passed on November 28, 1967, the application of the Act was extended for three years to December 31, 1970.

The Minister of Energy, Mines and Resources, stated in the House of Commons on November 24, 1969, that an interdepartmental study group was examining the implications of the termination of the Act, and that a decision concerning renewal of the Act would be made after the report of the study group was received in the early summer of 1970.

An amendment to the Act in 1963 contained a restriction limiting eligibility for assistance in the case of lode gold mines commencing production after June 30, 1965, to those providing direct economic support to an existing mining community. A gold mine is deemed to provide such support if more than 50 per cent of the persons employed at the mine reside in the established mining communities listed in a schedule to the Act.

The number of lode gold mines receiving assistance under the Act has declined from 87 in 1948 to 33 in 1969, without, however, resulting in a decline of the total amount of money paid out annually in assistance. This is due to constantly rising costs of mining.

The amount of assistance payable to an operator depends on the amount by which the average cost of production exceeds $26.50 per ounce.

When calculated on the basis of all eligible ounces produced, the maximum assistance payable amounts to $10.27 per ounce.

The amounts paid to gold mine operators to March 31, 1970, for the years 1948 to 1969 inclusive totalled $275,152,190.84 on a production of 58,636,593.380 fine ounces of gold.

Figures for the calendar year 1969 were not yet complete at this writing, but the total was expected to come to between 14.5 and 15 million dollars.

Publications

The Branch published reports in the *Mineral Information Bulletin* series on iron ore, primary iron and steel, the economic character and change in the Canadian steel industry since 1945, mineral-resource development in the Atlantic Provinces, summary report on mineral-industry development in Manitoba to 1980, and also the regular preliminary annual review of the Canadian mineral industry. Also completed were four *Operators' Lists*, the 1967 *Canadian Minerals Yearbook,* and the nineteenth edition of the popular Map 900A *Principal Mineral Areas of Canada.* Work proceeded on world trade maps related to iron ore and potash and on reports concerning various other commodities, in a Canadian and international context.

EXPLOSIVES DIVISION

The high rate of fatal accidents in the explosives industry during the early 1900s emphasized the need for control over explosives, and the first Explosives Act was drafted and introduced into the House of Commons in 1911. The early recognition of the hazard and the willingness of the industry to accept controls have combined to make the explosives industry one of the safest in Canada.

The Explosives Act is primarily an act of public safety to control the manufacture, authorization, storage, sale, importation and transportation of explosives by road. Control is exercised by a system of licences and permits supported by inspections. All licences are issued from the Explosives Division office in Ottawa.

The volume of work at the head office increased notice-

ably during the year, partly due to acts of terrorism in the Province of Quebec. However, due to the streamlining of operations, the existing clerical staff was able to handle the increased work.

One of the prime responsibilities of the Explosives Division is concerned with the manufacture of explosives. The number of factories licensed under the Explosives Act continued to increase during the year and reached a total of 48 at the end of 1969. This increase was largely due to the continued expansion of explosives-manufacturing facilities at the place of use. A number of factories for the manufacture of slurry-type explosives, supported by bulk mix trucks and bulk pump trucks, have been located at many large open-pit mines. We expect this trend to continue in the future.

Members of the Division investigated several accidents during 1969. Although there were a number of quite serious accidents in the manufacture and transportation of explosives, none resulted in any fatalities.

In manufacture, four separate fires in smokeless powder presses at a plant at Valleyfield resulted in one serious injury. These incidents have led to a close study of the various aspects of this operation. There were four separate explosions while waste explosives were burned at various plants. There were no injuries, but these incidents resulted in a complete review of procedures for destroying waste explosives. Ten separate explosions during primer preparation at Valcartier resulted in five injuries. The frequency of these incidents causes concern, and has led to a review of these operations.

There were 11 accidents in the transportation of explosives, but none resulted in fire or explosion of the cargo. An engine fire of a bulk slurry truck was extinguished by the built-in fire extinguishing system required by the Division of these vehicles.

Members of the Explosives Division promote safety programs and regularly meet with members of the industry, federal and provincial government agencies and other groups involved with the handling of explosives. The Division also has available for distribution safety literature on the storage, handling and transportation of explosives.

A separate, more detailed report of the activities of the Explosives Division is published regularly.

Water Sector

MARINE SCIENCES BRANCH

The prime objective of the Marine Sciences Branch is to provide to public and private individuals and agencies of Canada technical information on those physical factors of the marine environment affecting the economy of Canada.

This requires the collection and interpretation of data describing the physical properties of the waters of the three oceans bordering on Canada. It requires, also, surveys of the geology and geophysics of the continental shelves over which Canada maintains jurisdiction and of the adjacent deeper portions of the Atlantic, Pacific and Arctic oceans.

The work of the Branch can be grouped into two main activities: hydrography and oceanography. In support of the two sciences the Branch operates a fleet of ships.

The Branch is organized along regional lines with offices in Dartmouth, Nova Scotia; in Victoria, British Columbia; and in Ottawa. The headquarters is situated in the Department of Energy, Mines and Resources complex in Ottawa.

During 1969-70 the Department's seagoing fleet travelled a total distance of 196,000 nautical miles. Changes in composition of the fleet included decommissioning of CSS *Acadia* on the East Coast after 56 years of service as a hydrographic vessel; and on the West Coast *Marabell,* a veteran of World War II, finished her long adventuresome career.

Another World War II vessel, *Radel* II, was acquired from the National Research Council and now is working on the Great Lakes; while MV *Martin Karlsen* and MV *Lac Erie* are serving on three-year charters.

CSS *Hudson* commenced her circumnavigation of the two Americas.

CSS *Parizeau* was converted from its role as a tidal survey vessel for temporary duties as a hydrographic vessel. Four 25-foot Bertram survey launches were acquired and fitted.

At the Canada Centre for Inland Waters three new craft were acquired, these being a 44-foot survey vessel of aluminum construction, a 34-foot steel launch, and a 40-foot pontoon craft.

HYDROGRAPHY

The Branch collects and publishes bathymetric data of Canada's navigable waters and of adjoining international waters essential to the safe, orderly and efficient conduct of commercial, recreational and defence shipping. This involves the preparation and publication of charts, pilots and tide and water-level almanacs.

The distribution of Canadian Hydrographic Service charts continued to increase at Ottawa and Victoria to an annual total of 318,400, representing a 3 per cent increase over the previous year.

The Service produced 279 new charts during the period. These comprised 34 standard navigation charts, 23 special charts, 12 charts in advance-print form, 76 new editions, 93 corrected reprints, 37 reprints and four supplementary prints.

Highlights among the new charts were :

a) Three offshore fisheries charts and a small-scale general chart of the Atlantic.

b) The first in a new series of metric charts of the entire Canadian Arctic.

c) The first in a projected series of small-scale bathymetric charts covering the continental shelf and the Great Lakes.

d) The prototype of a series of natural-resources charts at scale 1:250,000 showing bathymetric, magnetic and gravity information on the continental shelf.

e) Six charts showing Canada's territorial waters and fishing-zone limits, four on the Atlantic Coast and two on the Pacific Coast.

f) A chart of the surficial geology of the sea floor between Halifax and Sable Island. This chart was prepared in conjunction with the Geology Section of the Bedford Institute of Oceanography.

In August a new unit was established to investigate and develop the detailed charting of sea-floor topography and undertake physiographic studies with particular emphasis on the natural resource and bathymetric charting of the continental shelf.

The Sailing Directions section published a new edition of Volume 2 of the British Columbia Pilot and nine supplements to existing pilots.

Canada has continued to support the controversial charting of the deep parts of the world's oceans. The Canadian Hydrographic Service assumed responsibility for the maintenance of bathymetric plotting sheets in the western and eastern Arctic and along Labrador Coast which were formerly undertaken by the United States of America and the Federal Republic of Germany. A substantial amount of data on General Bathymetric Charts of the Oceans (GEBCO) was also exchanged with Great Britain, France and the Federal Republic of Germany during the year for inclusion in other plotting sheets for which these countries are responsible. The GEBCO Section also completed an extensive investigation and compilation of the nomenclature of the undersea features to be shown on new bathymetric charts of the Grand Banks of Newfoundland and Flemish Cap.

In addition to routine duties, the Nautical Geodesy Section provided a uniform control-data base for the St. Lawrence River surveys and the Ship Channel Division of the Department of Transport. The investigation and analysis of survey control in the Pacific Region was continued and the first phase, data conversion to computer cards and a check of the values, was completed.

Work continued on automating the cartographic processes of the Canadian Hydrographic Service. At the University of Saskatchewan research and development of the digitizer, general-purpose control computer and automatic drawing table are nearly complete. Most of the work during the past year concerned the analysis, design and development of the many control-computer programs and the testing of those programs through the basic system.

The Field Staff Training section conducted a six-week intermediate course at Ottawa for hydrographers from the three regions and a basic hydrography course was given to 13 new hydrographers. Participants in the basic course took their classroom training at Ottawa from October to the end of December and early in January sailed from Dartmouth, Nova Scotia, aboard CSS *Baffin* for a 2½-month training cruise in the Caribbean. For five weeks basic field training exercises were carried out in the Grenadines and the Bahamas. The results of these surveys will be sent to the British Admiralty for inclusion in its charts of the area.

The Service continued to provide guidance and advice on the technical problems in the formulation of a policy on national territorial waters.

The field surveys of the Canadian Hydrographic Service are managed through three regional offices situated in the Bedford Institute of Oceanography, at Dartmouth, Nova Scotia; in Ottawa; and in Victoria, British Columbia.

On the Atlantic Coast CSS *Baffin* completed the hydrographic and geophysical survey of the eastern part of

the Gulf of St. Lawrence and in October carried out a Lambda evaluation study to determine the accuracy of the Lambda system for the precise definition of undersea positions.

CSS *Kapuskasing* finished the survey of nearly the entire area between Funk and Fogo Islands off the northeast coast of Newfoundland; and CSS *Acadia* carried out two projects — a check survey of the critical area in the approaches to the Strait of Canso for deep-draft shipping and the survey of the sheltered but treacherous passage between the Fogo Islands and the mainland.

Revisory surveys along Nova Scotia's southwest coast, Passamaquoddy Bay and the Avon River to Hantsport were undertaken by CSS *Maxwell;* the headpond of the Mactaquac Dam on the Saint John River, the site of a new recreational area, was also surveyed.

Hydrographers also served aboard the CCGS *Sir John A. Macdonald* during her escort of the SS *Manhattan* through the Northwest Passage.

Projects designed to automate hydrographic surveys, improve navigational accuracy and assess accuracy standards were continued in 1969. Among these were the development of a digital echo sounder and the testing of satellite navigation equipment as well as the fitting out of a survey launch with data-logging equipment.

Field operations in inland waters continued to be essentially shore-based.

A party aboard the 37-foot survey launch *Verity* checked the charts between Kingston and Quebec City following a preliminary reconnaissance by helicopter.

Basic hydrographic surveying designed to meet the demands of recreational boating continued. The Lake of the Woods survey party worked the third year of a multi-year program and completed the central sections of this large island-studded lake. The Lake of Two Mountains survey began and the Rideau Lake system was surveyed between Kingston and Smiths Falls. Sounding control was established along the St. Lawrence River between Kingston and Brockville.

A Hydrodist-positioned examination was made of the navigation channel at Batiscan on the Lower St. Lawrence River and a survey to verify the positions and bearings of navigation ranges and to confirm the positions of the dredged or natural channels commenced at Montreal and progessed northeastward along the St. Lawrence Ship Channel.

To explore more efficient methods of collecting and processing field data a development-production survey of the Lower St. Lawrence River was initiated at Tadoussac. Sounding vehicles included eight launches, a sidewall air-cushion craft and auxiliary vessels. Automatic data-logging systems were evaluated and all survey data were teletyped to Ottawa for processing and analysis. The survey demonstrated that automated collecting and processing methods are feasible at the same time as providing useful information on the capabilities of hovercraft-type vessels.

The hydrographic unit of the Polar Continental Shelf Project moved from Mould Bay to Tuktoyaktuk in 1969 in order to begin work in the Beaufort Sea. From March to May 1969 soundings were taken through the ice using a helicopter platform. From early July to mid-September an SRN-6 Hovercraft supporting a strut transducer assembly was used to survey the waters near Herschel Island. Both operations employed a 6F Lambda Decca chain for positioning. The Beaufort Sea offshore survey was almost completed in March and April 1970.

Staff of the Canadian Hydrographic Service continued to support the scientific field activities of the Canada Centre for Inland Waters by establishing field control and operating two Decca Minifix positioning systems, maintaining echo-sounder and sonar equipment and managing the operation of the four ships and 12 launches used by the Centre.

On the West Coast activities continued to be primarily hydrographic, although significant ship and personnel support was supplied to West Coast oceanographic agencies.

CSS *Wm. J. Stewart* continued Minifix-controlled surveys westward in the Strait of Georgia and control was established for the continuation of these surveys northward in 1970. Surveys of Prince Rupert Harbour and of Venn Passage and approaches were completed.

CSS *Marabell* completed a survey of Comox Harbour as well as ranges at Helcken Island and a revisory

survey at Kelsey Bay. In the north, a survey of Port Simpson was made and the Meyers Passage survey was completed. A shore party also completed the survey of Fatty Basin in Barkley Sound for the Fisheries Research Board at Nanaimo.

A revisory survey party aboard the new launch CSL *Revisor* checked 27 charts and surveyed and sounded 14 ranges in the area covering the Strait of Georgia from Sidney to Johnstone Strait and Vancouver Harbour.

Surveys in the western Arctic continued from CSS *Richardson* and CCGS *Camsell*. *Richardson's* main project was the sounding of a 640-square-mile area north of Kugmallit Bay carried out in conjunction with the Polar Continental Shelf Project whose Decca Lambda chain was used for positioning. The approaches to Paulatuk were sounded and control was extended to the townsite. An investigation was made of Argo Bay. Additional soundings were taken between Cape Parry and Booth Islands and track soundings were run in Darnley Bay and east and north of Cape Parry. *Camsell* ran 1,200 miles of track soundings, mostly in Amundsen Gulf west of Victoria Island in Minto Inlet. Hydrographic work and sounding was undertaken at Sachs Harbour, Jesse Harbour, Coppermine, Expeditor Cove, Bay Chimo, Cambridge Bay, Simpson Strait, M'Clintock Bay, Gjoa Haven, Spence Bay and False Bay in Bellot Strait.

Current surveys aboard CSS *Parizeau* continued in the Strait of Georgia. Three additional cross-sections were observed together with four of the 1968 stations to fill in missing data. Cross-sections from the south end of Texada Island to Point Roberts have now been observed. A current survey using meters and drift poles was carried out off Roberts Bank in participation with personnel of the Pacific Oceanographic Group. Current surveys were made in Vancouver Harbour over the line of the proposed new tunnel crossing at First Narrows. At Victoria, two current meters were placed near the bottom on the proposed sewer outfall extension off Clover Point.

A mathematical model was developed for the Fraser River estuary and is being calibrated. It combines the contribution of tides and runoff and will be designed to provide accurate water-level predictions as an aid to navigation.

A test gauge station was established at Langara Island on the exposed northwest corner of the Queen Charlotte Islands. If this installation withstands the extreme weather and sea conditions it will be linked by radio to the mainland and will become an advanced warning station for tsunamis in the North Pacific.

An evaluation of the Motorola RPS Electronic Positioning System and an investigation of the use of colour and multi-spectra aerial photography and hydrography surveying were initiated.

OCEANOGRAPHY

The Branch provides assistance and expertise where and when required to a large spectrum of Canadian marine activities, which may benefit the economy and resource development, protect the environment or assist in national defence. The services range from the continual provision of tidal and water level data and the archiving and retrieval facility at the Canadian Oceanographic Data Centre in Ottawa, to specific requests and the concentrated effort required when the marine environment is threatened, as in the *Arrow* oil spill. The physical, geophysical, geological and chemical processes governing the marine environment are studied extensively by the research workers in the Branch. The major centres of oceanographic operations and research are situated at the Bedford Institute, Dartmouth, Nova Scotia; at Ottawa; and at Victoria, British Columbia.

The Tides and Water Level Service is probably the most widely used in the Branch, and there was a continuous and increasing demand for information during 1969-70. Data were supplied to many users within and outside the Department. The demand for chart-datum information showed a 70-per-cent increase over the previous year. The new format and bilingual editions of the Canadian Tide Tables have been well received.

The telemetry and announcing networks set up for the West Coast Tsunami Warning System in conjunction with the Department of Transport and Department of Public Works have been working extremely well. Continued instrument development of tsunami and tide gauges is being undertaken and documented.

The Canadian Oceanographic Data Centre offers an automatic processing service for physical and chemical oceanographic station data gathered by Canadian agen-

cies. It is responsible for archiving and the retrieval of these data to meet a variety of needs. In addition, the Centre publishes data reports and continually exchanges data with other national and world data centres. The Centre continued to provide a temporary processing service for Canadian limnological data pending the establishment of a Great Lakes Data Centre.

The data-development section has been largely involved in redefining and improving data handling, the results of which should become evident in 1970.

During the past year the wave-climate study was prepared for the 1970-71 field program by instrument tests and site surveys. An analysis system has been set up for the analogue wave data, the analogue-to-digital software being designed and constructed by a member of the group.

A great deal of emphasis during the past year has been given to organization and establishing a liaison with other federal departments, agencies and branches, and in some circumstances with non-federal agencies. Wave information has been obtained on a regular basis since April 1969 from the Strait of Georgia in a co-operative venture with the British Columbia Research Council. Close liaison has been maintained with the wave-climate study engineers in the Department of Public Works, especially with regard to data requirements. Maintenance of some installations has been undertaken, on contract, by the Telecommunications Branch, Department of Transport, Co-operation with the Division of Mechanical Engineering, National Research Council, led to an intercomparison study of an accelerometer buoy, wave staff and pressure cell in Lake Ontario.

The research group in Ottawa continued its emphasis on mathematical techniques. Tidal motion, wind evaluation and storm-surge problems are analyzed by these methods. Work is nearly complete on a study of the effects of tidal barriers and on how these effects vary critically with only small changes in the exact barrier location. Development is well under way of a wind-driven circulation model of the Bay of Fundy and the Gulf of Maine. It is expected that this work will be extended to include the Scotian Shelf. A steady wind-generated circulation model of the Gulf of St. Lawrence has already been completed and work started on a thermohaline circulation model. A comparison of the wind-driven circulations in Hudson Bay using two different techniques, geostrophic and balance equations, has been accomplished.

Each of the Great Lakes now has a completed wind-generated circulation model, and additional research is being carried out into two-layer and non-linear models. A dynamical storm-surge model for Lake Ontario and a short analytical study on the free oscillation in parabolic and similarly shaped lakes is under way.

A geophysical study of the Chandler wobble of the earth's axis and its relation to mean sea level is partially completed.

At the Bedford Institute the Marine Geology section made a trans-Atlantic cruise in CSS *Hudson* to Lisbon carrying out under way and station work on an 11,000-mile route, including the collection of planktonic foraminifera, deep-sea sediment cores, and drilling to gather rock samples at sea.

In the fall the most ambitious project ever undertaken by the Institute began with the departure of the CSS *Hudson* on the "HUDSON 70" cruise. During her circumnavigation of the Americas the vessel was to carry out multi-discipline studies of the Atlantic, Pacific and Arctic oceans. One outstanding success already accomplished was the first recording of the current structure in Drake Passage between South America and Antarctica.

A submersible was chartered in a joint program with the Biological Station, St. Andrews, N.B. The Atlantic Oceanographic Laboratory used the vessel as an observation platform and for the collection of bottom samples on the sea floor.

A program to map the surficial geology and near-surface structure and stratigraphy across the Scotian Shelf, by sampling and the examination of echo-sounder records, is continuing.

The organic geochemical studies are largely concentrated on an investigation of the role of humic acids in marine sediments. The inorganic geochemistry staff has been developing elemental analyses of fresh and salt water and layering silicates.

The Metrology section is carrying out the development of specialized oceanographic instrumentation. The main efforts of the section have included the successful use

of a rock-core drill driven by the water pressure at depth and the development of a towed "Batfish" which undulates between preset depths and carries instrumentation for the continuous measurement of temperature.

The Air-Sea Interaction research has continued to progress. The major aim of this group is the measurement of the stress of the wind on the sea surface and its equipment and instrumentation requirements are substantial. Good measurements of wind stress were obtained in 1969 before the stable platform suffered storm damage.

Autoanalyzer techniques were to be employed during the "HUDSON 70" cruise for the determination of nutrients especially along the north-south traverses in the Atlantic and Pacific oceans.

In addition to the "HUDSON 70" cruise the Ocean Circulation group continued work on the general circulation and time-dependent motions in the Atlantic and the St. Lawrence estuary. A theoretical study of thermal-convection problems in rotating media is under way.

During 1969 the Marine Geophysics group took part in the CSS *Baffin* Hydrographic-Geophysical survey of the Gulf of St. Lawrence, in a satellite-navigation-evaluation cruise and on a cruise to test the improvement of seismic instrumentation.

The Applied Oceanography section has concentrated its work on investigations in relatively confined waters, including the Strait of Canso, Halifax Harbour, St. Margaret's Bay and the Gulf of St. Lawrence. A study of Long Harbour, Newfoundland, was required as a result of phosphorus pollution.

In February and March 1970, the laboratory was asked for considerable assistance as a result of the grounding of the Arrow in Chedabucto Bay. The Director served as scientific co-ordinator of "Project Oil".

The Frozen Sea Research group in Victoria carried out two major field operations from Greely Fiord, Ellesmere Island, for periods of seven weeks and eight weeks respectively. A variety of measurements and tests were carried out to investigate the water and ice structures and secondary investigations into base operations in this environment were undertaken. The base complex and airstrip are now more or less complete.

Experiments on the freezing of fresh- and salt-water solutions have been carried out in cold rooms at Victoria. These involved measurement of temperature profiles across a growing ice/water interface to a relative accuracy of $\pm$ .001°C. The experiments are continuing and are directed towards an expansion in understanding the mechanism of solid/liquid phase change.

The West Coast staff continued the 1968 studies in physical and chemical oceanography and on pollution problems, the latter primarily associated with the discharges of sewage, pulp-mill effluents and wood solids into the marine environment. Most of the studies are carried out in co-operation with other government agencies and with universities.

Physical oceanographic studies in the Strait of Georgia consisted mainly of continuous current observations from moored buoys and drift observations of surface circulations in the Fraser River plume area. A one-dimensional numerical model of the Straits of Georgia and Juan de Fuca was completed and a report prepared.

Three cruises investigating the seasonal and annual variability of the waters up to 200 miles off the British Columbia coast were completed in 1969.

The weathership oceanographic program was expanded to two ships early in 1969. During the May-June cruise of the CCGS *Quadra,* a satellite navigation system, salinity-temperature-depth (STD) equipment, a STD digitizer and a data-acquisition system were all successfully operated. Considerable progress was made in the analyses of both present and past data. For the first time bottom currents have been measured at Ocean Station "Papa" using a free-fall current meter. A buoy program to include current measurements at several depths was begun in co-operation with the University of British Columbia.

Statistical analyses of sea-level data for Tofino, Tasu Sound, Prince Rupert and Bella Bella for May 1962-64 were undertaken. Daily seawater observations were continued at 17 stations, but the laboratory analysis of salinity of seawater samples was restricted to one station only, the remainder recording density by hydrometer.

Oceanographic observations from the drilling rig SEDCO 135F were continued until May 1969, when operations of the rig were suspended.

A numerical study of the effect of winds on flushing mechanisms in Departure Bay and a calculation of the propagation characteristics of tsunamis into all of the major inlets of British Columbia is being pursued.

POLICY AND PLANNING BRANCH

The Policy and Planning Branch advises on and recommends national policy and activities concerning water, air, and the national environment. It helps to co-ordinate federal, interdepartmental, federal-provincial and international activities in use and study of water and air, and advises on the socio-economic impact of such activities.

The Branch consists of three divisions and an administration unit. The library of the Water Sector is also attached to the Branch.

POLICY ADVISORY, CO-ORDINATION AND ADMINISTRATION DIVISION

The Division provides advisory services and the necessary interdepartmental co-ordination for policies and programs related to water and renewable resources. It also provides for federal-provincial consultation and negotiation on river-basin-planning agreements and for the subsequent administration of such agreements. During the year federal-provincial consultations were undertaken with respect to the Saint John River Basin in New Brunswick, the Qu'Appelle River Basin in Saskatchewan and the Okanagan River Basin in British Columbia.

In 1969-70 the Division reviewed, assessed and advised on federal water policies and activities as a basis for drafting new water legislation. In particular, it advised on the drafting of the Canada Water Act, which is designed to initiate and encourage federal and federal-provincial activities for the comprehensive planning, development and management of Canada's major water resources. The legislation places particular emphasis on co-operative federal-provincial programs for water-quality control and pollution abatement.

The Division was frequently called upon to explain federal water and renewable-resources policies and programs to special-interest groups. Also, recognizing the growing pollution of the natural environment and the intimate interrelationship of air, water and soil quality, the Division initiated studies of conflicts between environmental quality and economic growth, and of the various political, legal, and social factors that will have to be considered in the application of the Canada Water Act. Some preliminary work is being carried out by consultants.

The Division provides the secretariat for the Interdepartmental Committee on Resources which, in addition to ensuring a unified federal approach to the work of the Canadian Council of Resource Ministers (CCRM), maintains interdepartmental liaison and co-ordination on matters pertaining to renewable natural resources. The CCRM is composed of eleven Ministers — one from each province, together with the Minister of Energy, Mines and Resources representing the federal government. A co-ordinating committee provides advice and assistance to the Council; the federal representative on the committee is a member of this Division. Among the projects undertaken for this Council was the preparation of papers for and participation in a workshop seminar on water resources in the fall of 1969, the compilation of federal activities in pollution abatement and control, and participation in special advisory groups concerned with pollution, northern development and land use.

Preparations were begun for a major national conference proposed for 1973 on multiple use of resources and conflicts arising therefrom. The Division developed and presented the federal government's recommendations to the CCRM intergovernmental steering committee which was considering common approaches to pollution control by the various levels of government in Canada.

The Division provides the secretariat for the Interim Interdepartmental Committee on Water, which reviews and advises on all federal water policy and programs. The secretariat encourages development of co-ordinated federal approaches through analysis of issues and presentation of alternative solutions. Subcommittees developed proposals for regional water activities in the

Atlantic, Central, Western, Pacific and Northern areas of Canada. Ad hoc committees undertook special tasks, such as drafting a preliminary contingency plan for dealing with disaster pollution; investigating and reporting on water pollution by nutrient materials, particularly by phosphates originating from laundry detergents; and reviewing and assessing criteria by which water-quality standards might be established under authority of the proposed Canada Water Act.

The National Advisory Committee on Water Resources Research, established in 1967, consists of experts from federal and provincial agencies, universities and private industry. The Committee's secretariat is provided by the Division.

The Committee has two subcommittees, one on social sciences and one on natural sciences. Chaired by an official of the Department, the Committee has three functions: to advise the Minister on needs and priorities for water-resources research in Canada, to help co-ordinate such research, and to review and make recommendations on applications for grants in aid of water research and development dispensed by government. In 1969-70 these grants totalled $1,088,855. Development grants to universities totalled $540,000, for natural sciences research, $388,850, and for social sciences research, $160,055.

PLANNING DIVISION

This Division continues to prepare, in co-operation with the provinces, programs of joint comprehensive water-resource plans. It also draws up plans for federal programs for major river basins in Canada. In addition, in anticipation of the forthcoming Canada Water Act, work was under way to assess the organizational and operational requirements for the incorporation of water-quality management agencies and the selection and establishment of priorities for water-quality management areas. Within the joint comprehensive plans a number of water-resource-planning studies are being undertaken and co-ordinated with the federal departments, with provincial agencies, or through consultants. Such studies include the economic, sociological, financial and physical aspects of regional and national water planning. The Division has seven sections: Pacific, Western, Central, Atlantic, General Studies, Resource Data and Water Quality Management.

The Saskatchewan-Nelson Basin Study (SNBS) is a $5-million project shared by Canada with Alberta, Saskatchewan and Manitoba. The study commenced in October 1967 and will be completed by January 1972. Its primary purpose is to appraise the possible sources of additional water supply in the Saskatchewan and Nelson River Basins. The project will also include a preliminary investigation of the works, mainly reservoirs and diversions, required to develop and utilize the water resources of the basins.

During the year about 15 engineering studies were completed for the SNBS concerning water-supply feasibility and estimated cost of many combinations of storage and/or diversion works needed to provide a firm water supply at various selected points along the river system.

River-flow data are being collected and stored on magnetic tape for use in water studies for the SNBS. A number of computer programs have been developed and tested for simulating the operation of water and diversion projects in the basin. Investigations are continuing on operational criteria, constraints on reservoir operation and levels of withdrawal.

British Columbia and Canada are each contributing up to $18 million to the Fraser River Flood Control Program over a ten-year period, May 1968 to May 1978. Joint planning studies include: evaluation of flood-control benefits on the Serpentine-Nicomekl Rivers and on Indian reserves, socio-economic aspects of upstream storage or diversion in the Upper Fraser River Basin and a re-evaluation of overall flood control benefits in the Lower Fraser Valley. The officials are also considering alternative measures of flood control which may ultimately lead to multi-purpose reservoirs and river diversion in the headwaters. Eleven municipalities have made application for assistance in dyking or other projects under the Fraser River Flood Control Program, representing 18 separate projects. A further seven project applications are under review by the provincial government. Soil investigations for nine projects are in final stages of completion. The final design stage for bank protection, dykes and internal drainage has been reached for five projects. Construction is proceeding on two contracts valued at $1 million. Design criteria such as profile and frequency curves for various stations have been completed. Benefit-cost studies are under way for a number of marginal projects. The scope of upstream storage studies is currently under investigation.

The Canada-British Columbia Okanagan Basin Agreement was signed in October 1969, providing for a $2-million program in the Okanagan River Basin, shared jointly with the Province of British Columbia over a four-year period, October 1969 through October 1973. This program includes the preparation of a comprehensive development plan to the year 2020, including consideration of economic growth, water demand, water supply, ecology, aesthetic values, institutional and organizational structures, water re-use and a pilot project for advanced treatment of waste water. Project plans are in the process of being completed for over a hundred tasks including priority setting for the first year of activities.

The Qu'Appelle River Basin Agreement has been drafted and has received the approval of Canada, Saskatchewan and Manitoba. Formal execution of the agreement is expected early in 1970-71. The scope of this project concerns the preparation of a comprehensive development plan, including consideration of water demands, water supply, water quality, lake levels and flooding. The investigations include an economic base study, land use, water quality, hydrology and engineering studies. The $460,000 cost of the study will be shared jointly with the provinces of Saskatchewan and Manitoba over a two-year period, March 1970 through March 1972. Several ad hoc meetings have taken place prior to the setting-up of a study board and the appointment of a study director to discuss investigations and studies.

A task force has been set up for preparing a comprehensive framework plan for the development of water and related resources of the region embracing Lake Winnipeg, the Nelson River, the Saskatchewan River east of Cumberland Lake and the Churchill River Basin. It will also evaluate in greater detail proposals for regulation of Lake Winnipeg and diversion of water from the Churchill River into the Saskatchewan and Nelson Rivers. The task force report is expected to be submitted by June 1970.

An ad hoc task force has been formed to prepare background papers and briefing notes on the Great Lakes for future meetings between the federal, provincial and U.S. governments to discuss International Joint Commission report recommendations and common water-quality and pollution problems.

The Saint John River study of three-year duration will last from June 1970 through June 1973, at a cost of $775,000. The scope of this agreement with the Province of New Brunswick covers the preparation of an interim water-quality plan to be followed by a comprehensive planning program including consideration of water demand, water quality, water supply, ecological and aesthetic values, institutional, legal and administrative structures, and international implications. Background work undertaken this year includes the composition of a federal-provincial board and committee, preparation of the final draft agreement and designation of task teams to evaluate previous projects carried out by consultants.

Northeast New Brunswick Mine Water Quality

A proposal by the Federal Department of Fisheries and Forestry to set up a task force to investigate the pollution by mining wastes of northeastern salmon rivers in New Brunswick was under consideration by the Canada-New Brunswick Consultative Committee.

A review of provincial priorities and coastal and harbour pollution problems was initiated by the Canada-Nova Scotia Consultative Committee. A federal-provincial task force has been set up to report on water-resources problems and make recommendations for co-operative action.

Resource Data Section

This section is in the process of setting up a basis for the collection, categorization, storage and retrieval of information and data to help the water resource planning of the Division and Branch.

General Studies Section

Technical assistance and support is provided on a continuing basis to the regional units in the areas of economic analysis, new planning techniques development and other special assignments. A major program is under way to assess the National Water Use and Demand projections broken down by regional areas and by consumable and non-consumable use categories.

RESOURCES RESEARCH CENTRE

The Resources Research Centre conducts socio-economic research on the management of water and renewable resources and the protection of the environment.

The Centre comprises four sections: Economic Geo-

graphy, Resource Management and Special Studies in Ottawa, and the Great Lakes Section at the Canada Centre for Inland Waters (CCIW) at Burlington, Ontario. In addition to these sections, the Centre provides the secretariat for two geographical committees.

The Economic Geography section has experience in land-use planning, resource-use assessment, cartography and geographical aspects of regional urban and environmental problems.

The section's activities may be classified in three categories: 1) studies requested by other federal and by provincial government agencies, 2) studies requested by other divisions of Policy and Planning Branch, 3) studies initiated within the Centre.

Land-use maps of populated areas of eastern Canada (east of Manitoba) were completed for the Canada Land Inventory on behalf of ARDA early in 1970. The major portion of the study was begun in 1963 and finished by 1968, but completion of the entire project was not possible until air photos of Newfoundland were available. Other projects undertaken for the Canada Land Inventory were a land-use study of the Musquodoboit Valley, Nova Scotia, and the Prince Edward Island Development Plan.

Land maps of the Halifax-Dartmouth area were begun for use in urban planning by the Nova Scotia government.

Preparations were made for a study of the socio-economic implications of resource development in the Northwest Territories and the Yukon. This study will result in the establishment of land-use regulations.

Two projects related to river-basin planning were started. The first is evaluation of benefits to agriculture of proposed flood control on the Serpentine and Nicomekl Rivers in support of the Fraser River Flood Control Agreement with British Columbia. The second is a topographical relief map of the Okanagan River Basin showing its land relief, which is essential to water management.

A Great Lakes section was established about mid-year at the CCIW at Burlington, Ontario. Its responsibilities include:

(a) conducting social research focussing on the Great Lakes Basin, and

(b) providing advice to the CCIW on relating its natural-science research to the overall priorities of federal water policy.

Projects already begun include a water-use map of the Great Lakes, the economics of waste disposal, application of data to an economic model and a public perception and attitude survey designed to determine public awareness of pollution issues.

The Special Studies section concentrates its activities in two major areas:

(a) basic research to support the primary objective of the Centre in emphasizing the human aspects of resource and environmental issues, and

(b) research to provide a long-term perspective on future priorities for public resource programs.

The section is in the early stages of development.

The major current activity of this section is the pilot study on the Saint John River, which is one of Canada's contributions to the program of the NATO Committee on the Challenge of Modern Society. This three-year project is in the planning stage. Its primary objective is to develop and evaluate techniques of generating public participation in planning water-resource development, according to the economic and social needs of the affected population.

The Resource Management section is also in the initial stages of development. It is proposed that the staff of the section be a small but highly skilled group concerned with the application of social science on a foundation of natural science.

The Saint John River Simulation Model study was begun in February 1970. This study will include a set of engineering-economic models from which the optimum plan for water-quality management may be determined.

Planning has also begun for an international symposium to be held in 1972, during which mathematical models proposed for water-resource systems will be discussed.

In resource technology, studies are being developed in several fields. A study of air-photo interpretation and flooding has been started, and publication of a handbook for flood plain and water-resource planning is expected by mid-1971.

In addition to the above section, the Centre houses the Geographical Secretariat. The Secretariat administers the affairs of two committees:

(a) The National Advisory Committee on Geographical Research, and

(b) The Canadian National Committee of the International Geographical Union.

One of the Secretariat's major current responsibilities is the preparation and organization of the 22nd International Geographical Congress to be held in Montreal in 1972.

INLAND WATERS BRANCH

The Inland Waters Branch is the federal agency which provides services in natural sciences and engineering for optimum management of Canada's water resources. It produces scientific and engineering data, research results, and engineering studies, appraisals and advice.

One of the Branch's major objectives is the collection and dissemination of information on water quantity and quality throughout Canada. This is being achieved through networks of observational and sampling stations on Canadian rivers, lakes, aquifers, glaciers and snow courses. Emphasis is placed on making the collected data readily accessible in the most usable form.

Also of major importance is the Branch's responsibility for providing to the Government of Canada advice on technical aspects of managing interprovincial and international waters. This takes the form of technical studies in support of international and federal-provincial programs and agreements relating to fresh water.

To ensure that Canada's water resources are being used wisely for the benefit of present and future generations, new concepts have had to be developed and new knowledge of the behaviour and occurrence of water in the hydrologic cycle acquired. Standards and procedures for improved regulation and use of the country's fresh-water resources will have to be devised, and methods for predicting the response of lakes and rivers to pollution as a basis for economic pollution control must be developed. Liaison with other government agencies, universities and industries must be fostered both nationally and internationally for exchanging knowledge in the water field. These are the chief objectives of the Inland Waters Branch in its endeavour to provide the Government of Canada with the information essential for the development and application of an effective national water policy.

The Branch undertakes a major publication program to make its scientific and engineering data and studies available to the technical community. During the past year more than 100 scientific or technical brochures were published by the Branch and numerous papers were published in scientific journals.

CANADA CENTRE FOR INLAND WATERS

The Centre was established in 1967 at Burlington, Ontario, as a new federal institution for water research. The Department of Energy, Mines and Resources, mainly through its Inland Waters Branch but assisted by the Marine Sciences Branch and the Policy and Planning Branch, co-ordinates the activities at the Centre in collaboration with the Fisheries Research Board, the Department of National Health and Welfare, and the Association of Universities and Colleges of Canada.

The Centre is presently housed in a 25,000-square foot trailer complex, an assortment of temporary buildings, which provide housing for laboratories, stores, workshops, and library, and office space for administration, scientific and technical services. During the year, site development for the principal buildings were well advanced. Construction of the warehouse and workshop, the first permanent building, was begun in 1969. Construction of other buildings is expected to commence at brief intervals.

A number of important developments occurred during the year at the Centre. Volume 1 of the Report to the International Joint Commission on the Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River was released in October. Much of the Canadian survey work for that report was carried out by the staffs of the agencies associated with the Centre who collaborated with their colleagues of the Ontario Water Resources Commission, other federal agencies and United States representatives. Aside from recommending ways to control pollution, the report defines several problem areas which are under study in special research programs at the Centre.

At year's end, the federal government's contingency plan for dealing with major spills of oil and toxic material in waters of federal jurisdiction, co-ordinated by the Centre, was submitted to the Interdepartmental Committee on Water. The Committee approved the plan and recommended that it be submitted for Cabinet approval. A Socio-economic unit from the Policy and Planning Branch was established in November to undertake research in economics, sociology and geography complementary to existing research in natural science. A Public Relations and Information Services unit was established. An Environmental Quality Co-ordination unit was established in June to co-ordinate the results of research from the various disciplinary groups of the Centre and to channel those results into reports aimed at pollution abatement. A consultant's report on thermal inputs to the Great Lakes was released and further studies of the temperature and ecological effects of projected waste-heat discharges are under way. Work is under way to appraise potential environmental effects of "NTA", currently the most probable substitute for phosphates in detergents, and to study the distribution of mercury and other toxic materials in the sediments of Lakes St. Clair and Erie. At the annual Great Lakes Conference of the International Association for Great Lakes Research in Ann Arbor, Michigan, the 17 scientific papers presented by the Centre's staff formed the largest contribution from any research centre.

WATER SURVEY OF CANADA

The Water Survey of Canada conducts systematic surveys of stream-flow, water levels and sediment transport throughout Canada and publishes the results annually. In addition it carries out snow and glacier surveys. The Water Survey is also expanding its survey network to collect field data on behalf of other departmental agencies. During danger periods on a number of rivers subject to floods, a flood-warning service is maintained in co-operation with the provinces concerned. Although all of these activities are designed to meet the requirements of the federal government, an increasing portion of the total effort is aimed at satisfying needs of the provinces.

The Water Survey and its predecessors have collected and published basic streamflow and water-level data on a national basis for more than half a century, while the sediment survey has been in operation since 1961. These surveys are being expanded steadily and at present are conducted from 30 district and field offices extending across Canada. Planned expansion in 1970 will see a new district office established at Regina to serve the province of Saskatchewan and a new sub-office in the Atlantic provinces to better serve the province of New Brunswick. Two additional district offices in the north are to be established to provide closer liaison with agencies in the Northwest Territories and the Yukon Territory.

In 1964, the Quebec Department of Natural Resources assumed responsibility for the collection of hydrometric data for most rivers in Quebec; however, collection of data for a number of navigable and international streams in Quebec remains the responsibility of the Water Survey.

During the year under review some 50 stations were added to the Water Survey's gauging network, bringing to approximately 2,300 the total number of streamflow and water-level stations. Sediment data are gathered at 98 of these stations, an increase of 16 stations during the year. The above total also included 131 water-level stations operated in the field for the Tides and Water Levels section of the Marine Sciences Branch; most of these stations are located in the Great Lakes-St. Lawrence River system. The Water Survey also participates in the collection of hydrologic data for some 40 research watersheds established for the International Hydrological Decade.

During the year, hydrometric network planning, aimed at providing a sound basis for further expansion, was continued by engaging a consultant for planning the Prairie provinces, British Columbia and Northern Canada networks. By agreement with the Department of Indian Affairs and Northern Development (IAND), the Water Survey of Canada carries out the hydrometric

surveys in the Yukon and Northwest Territories; the Water Survey also collaborates with IAND in assessing the water resources in these areas.

Intensive sediment surveys on the lower Fraser River continued so as to provide data essential for the maintenance and improvement of the navigation channels in the river. Similar work on the south Saskatchewan River is under way to determine the effect of sediment deposition in Lake Diefenbaker and degradation in the river downstream from the dam. A terrestrial photogrammetric study to determine the extent of shoreline erosion of Lake Diefenbaker was also undertaken. A survey and study of reservoirs in Ontario was undertaken to determine the sedimentation regime and the extent of shoreline erosion. In applied research, the Water Survey helped develop new equipment and techniques for the measurement of sediment transport, particularly bed-load movement.

Automatic data processing was initiated in 1966 when two major projects were undertaken — the storing of historical hydrometric data on magnetic tape, and the developing of automated procedures for the computation of current data. Approximately 33,000 station-years of record, representing all historical daily-discharge data to 1968 inclusive, have been key-punched and converted to magnetic tape, and are available for computer processing. Special equipment for digitizing charts to develop automated streamflow computations has been installed and is now operational in all districts across Canada.

Engineers of the Water Survey of Canada are members of, or participate in, the activities of some 20 engineering boards, committees and special studies in connection with various aspects of national, international and interprovincial water problems. These responsibilities include major streamflow measurements on the interconnecting channels of the Great Lakes, on Northern Ontario rivers and on the Nelson River.

HYDROLOGIC SCIENCES DIVISION

The Hydrologic Sciences Division studies the physical processes governing the behaviour of water in the hydrologic cycle to improve methods of water management. In addition, it takes part in such research as the International Hydrological Decade and the International Field Year on the Great Lakes, and enters into joint research with universities, provincial authorities and other government departments and agencies in order to increase our understanding of the basic process of the hydrologic cycle, with particular emphasis on Canadian situations and applications.

The Division consists of three operational subdivisions — Glaciology, Groundwater and Water Science. The Division also provides administrative services required by the Secretariat of the Canadian National Committee of the International Hydrological Decade. Design specifications for a hydraulics laboratory to be located at the Canada Centre for Inland Waters to study the behaviour of moving water under environmental conditions are nearing completion, and construction is expected to start in 1971. Hydraulics staff will move to the Centre in mid-1970, and the Hydraulics Division will be established as a separate entity in April, 1971.

Glaciology Subdivision

Annual mass-balance measurements on Per Ardua Glacier (Ellesmere Island), Decase Glacier and the Barnes Ice Cap (Baffin Island), continued, and further support was given to glaciological work on the Devon Island Ice Cap.

Movement studies on the Barnes Ice Cap continued, and terrestrial photogrammetry was used experimentally in mass-balance studies on White Glacier, Axel Heiberg Island.

Theoretical work on the macro-scale climatology of the Arctic regions continued, with emphasis on moisture-flux distribution.

Work was begun on a new study of the distribution and rate of iceberg production from Canadian tidewater glaciers. Studies were intensified on hydrologic problems in Arctic Canada, with emphasis on the Mackenzie Delta.

Collection continued of annual mass-balance data for representative glacier basins in western Canada and the eastern Arctic, together with water-discharge measurements and meteorological observations. In addition, photogrammetric measurements were made at selected basins in order to determine glacier movement.

Parametric and statistical models of glacier melt were prepared for Peyto Glacier, Alberta, and a hydrologic

model is to be compiled for a more extensive basin. The model will be applied to melt water from ice and snow in the headwaters of the North Saskatchewan River, and should lead to more accurate forecasts of runoff from Alpine areas and glacierized basins.

Determination of the energy balance over the ice surface of Peyto Glacier will aid in the assessment of the components of ice and snow melt. A well-instrumented experimental plot was established at a site near Ottawa to study snow metamorphosis, snow melt and associated changes in soil moisture content and groundwater levels.

Development work and field testing of a 620-MHz radio echo-sounder for determining glacier thickness, continued in co-operation with the Water Science subdivision.

Preparation of a shaded relief map of Peyto Glacier, Alberta, continued in co-operation with the National Parks Branch, Department of Indian Affairs and Northern Development. The back of the map sheet will have an illustrated text containing historical, geological and other information of interest to tourists.

A glacier inventory of Axel Heiberg Island, N.W.T., has been completed. An index of over 12,000 glaciers on Baffin and Bylot islands has been prepared; these glaciers, plotted to a scale of 1:500,000 on 25 map sheets, will be published in an atlas. An inventory of glaciers in the Rocky Mountains and on Vancouver Island is being compiled; and a start has been made on survey of iceberg-producing glaciers in the Canadian Arctic.

The Science section published the first results of the X-ray topographical study of dislocations in ice, and further work is in progress. A postdoctoral fellow completed a two-year study of the effect of impurities on the mechanical properties of ice crystals.

A theoretical study of the possible future behaviour of Berendon Glacier, B.C., was completed and submitted for publication.

Groundwater Subdivision

The Maritime Research section which came into operation in 1969 already has made substantial progress. The section has undertaken to obtain information on seawater intrusion into coastal aquifers, to develop hydrochemical pumping-test techniques for coastal well fields and geophysical methods for studying groundwater flow in fractured rock. By the end of the current year, geophysical techniques had successfully located fresh and saline groundwater along the coasts of Prince Edward Island and New Brunswick. Moreover, new methods have been developed and are being tested to determine aquifer properties by hydrograph analysis, thermal logging and fracture analysis.

Computer-drawn maps showing various groundwater parameters in the Lake Ontario drainage basin have been produced by the groundwater-data-storage system (GOWN) from data for 60,000 wells supplied by the Ontario Water Resources Commission. These maps will be used during the International Field Year for the Great Lakes. Analysis of streamflow for 18 rivers flowing into Lake Ontario and estimation of groundwater flow into the lake have also been completed.

Other noteworthy items are the completion of runoff computation for 36 sub-basins of the Fraser River using parametric models, the use of microfaunal assemblages to determine past physical and chemical environments of prairie sloughs, and the development of a new technique to estimate regional evaporation. The inventory of Canadian freshwater lakes has been completed and published in atlas form. It is a first step in determining the quantity of water in storage in Canada.

Water Science Subdivision

The past year has seen the instigation and expansion of a large number of projects in the Water Science subdivision, which is responsible for providing the basic chemical and physical knowledge essential for the best utilization of Canadian water resources.

Studies of the physical properties of solutions are aimed primarily at determining the variation in parameters of pollutant solutions as a function of temperature, pressure and concentration.

Determinations of the mobility, degree of hydration, structure, conductivity and dielectric properties of solutions containing nitrates, phosphates, halides and heavy metal ions were carried out. The rate of reaeration through the surface of stagnant water bodies is being studied; and the effects of surfactants and pollutants on the reaeration rate are being evaluated. Molecular orbital calculations are also being used to aid in understanding the nature and hydration of dissolved gases and sulphurous compounds in water.

Toxic compounds in water are being studied with various techniques. These include X-ray crystallography of the crystalline compounds to elucidate their structures and the structures of products formed by their reaction with water, adsorption studies to show the rate and mechanism of their removal and co-ordination studies to show how such materials may form compounds in nature.

The Instrument Development section has continued to maintain and repair existing equipment as well as modify and design new equipment for the other subdivisions within the Hydrologic Sciences Division. A major project in this section is the development of a radio echo-sounder for locating and improving our understanding of the bottom profile of glaciers. This project requires the accumulation and handling of large amounts of data.

Future plans for the Water Science subdivision include the establishment of a Biosciences section to deal with the many aspects of water and its interactions with naturally occurring biota.

International Hydrological Decade Secretariat

The Secretariat's duties are guided by the 26-member Canadian National Committee which co-ordinates the country-wide scientific investigation and assessment of water resources under the International Hydrological Decade.

The Secretariat continued its active role in co-ordinating and reporting on the 185 active, ten deferred and 26 completed projects included in the Canadian program.

In addition to co-ordinating the program through the co-operation of various federal, provincial and university representatives, and organizing the annual meeting of the Canadian National Committee, the Secretariat organized, in co-operation with the University of Manitoba, an extensive hydrology seminar for Canadians; two workshop seminars — one on hydrologic mapping (resulting in a publication) and one on representative basin review; it met Canada's international IHD commitments through co-operation with UNESCO and the World Meteorological Organization, and provided assistance to federal, provincial and university agencies involved in holding seminars and workshops in hydrology. Detailed planning is under way for a CNC-sponsored international symposium on the role of snow and ice in hydrology, to be held at Banff in September 1972.

The Secretariat also published the annual progress report on Canadian IHD research projects and some preliminary surface water maps for the Hydrological Atlas of Canada.

GREAT LAKES DIVISION

The Great Lakes Division seeks to provide the knowledge and understanding of the chemical, physical and sedimentological behaviour of Canadian lakes needed for optimum management of the lakes. This task encompasses all Canadian lakes, but the emphasis at present is on the Laurentian Great Lakes because of their economic importance.

The Division conducts applied research and collects scientific data, and engages in limnological instrument design, development and evaluation, augmented by basic research. It encourages and promotes Great Lakes research in Canada and plays a leading role in co-ordinating research and data collection with its counterparts in the United States. Scientific support as well as administrative and technical services are provided to the various divisions and agencies at the Canada Centre for Inland Waters.

The Division's principal responsibilities are carried out by the Physical Limnology, Chemical Limnology and Limnogeology sections. However, aside from providing programmer services, the Computer and Data Services section maintains a computer terminal at the Centre and is testing shipboard computers. The Engineering Systems section provides engineering services to all sections and agencies at the Centre and to the scientists of the Association of Universities and Colleges of Canada participating in programs of the Centre. Personnel from the Technical Operations section are assigned to ships monitoring the Great Lakes and carry out all deck observations and routine meteorological observations.

Physical Limnology Section

The section conducts research into the hydrodynamic and the thermodynamic behaviour of lakes, undertakes studies of applied limnology and provides climatological and descriptive services in various aspects of physical limnology.

During the year, data collected during 1967 and 1968 in the Niagara River Plume studies were used to study circulation, thermal and diffusional characteristics of the Niagara River effluent. In air-lake-interaction

studies, special data collected during 1967 near Burlington and during 1968 near the mouth of the Niagara River were analyzed.

The 1969 MELON (Massive Effort in Lake Ontario) experiments were designed mainly to examine the structure and variability of water movements in the western end of Lake Ontario. The core of the experiments consisted of arrays of moored, self-recording current meters; but drogue tracking and dye-patch diffusion experiments were also employed. Airborne-remote-sensing techniques mainly in western Lake Ontario have also provided data which have been incorporated in the MELON program.

The preparation of an atlas of Great Lakes data continued. Summaries in map form of all available temperature and dissolved-oxygen data should be completed by the end of 1970.

The section collaborated with others at the Centre in the Fisheries Research Board's small-lakes-eutrophication program near Kenora, Ontario. In other areas, it has been involved in the design, development and testing of instruments and related equipment, in investigating, testing and evaluating models of hydraulically induced circulation, and has reviewed current methods of combatting oil pollution.

Chemical Limnology Section

The section is responsible for the planning and evaluation of the chemical monitor cruises on the Great Lakes. During the past year, a considerable part of the section's effort was diverted from purely laboratory studies to field studies, notably in co-operation with the MELON program.

Lake Ontario was monitored intensively during 1969, with cruises being scheduled every four weeks during the year while only one or two cruises were carried out on the other lakes.

During the year, personnel co-operated in a Lake Erie Time Study (LETS) to determine the extent and time duration of short-lived chemical and biological phenomena such as algal blooms in the lake's western basin. Rain samplers were installed at several stations on the Canadian shore of Lake Ontario to assess the contributions to the chemical budgets of the lake from atmospheric sources. Instruments were acquired to separate dissolved organic material extracted from lake water into individual compounds. Equipment was under test to determine the surface area of sediments, a property which reflects the ability of such deposits to absorb organic matter. Analyses of the interstitial water in sediment cores, sampled at uniform intervals at several stations in western Lake Ontario, revealed little variation in the chemical properties of the sediments over the summer. Studies of the geochemistry of brines were undertaken with a view to increasing our knowledge on the formation of sulphate-rich lake brines and prediction of the precipitation of sodium sulphate minerals. Micro-analytical methods for determination of molybdenum and vanadium in lake water have been developed and studies of these elements in lakes are in progress. The phosphorus cycle of Lake Ontario has been under study to determine the relative size and importance of, and seasonal changes in, the soluble organic phosphorus fraction in western Lake Ontario waters. Studies under way are concerned with the measurement of thermodynamic properties of aqueous mixed-salt solutions in the temperature range from the freezing point to 25°C. A program carried out on Lake Ontario during 1969 has led to the development of a technique for measuring the "rate of fall" and the "settlement rate" of organic particles in the water column. These and many other studies are adding to our understanding of the ecology and are revealing those areas requiring more effective water management practices.

Limnogeology Section

The section is undertaking two different though interrelated types of research on the bottom sediments and suspended particulate matter of major Canadian lakes. In one, inventory data are obtained which will permit categorizing and plotting of distribution maps and diagrams, to show, for example, what types of material are present in the lake sediments, how much material there is and where it occurs. The second line of research includes studies of the physical problems of erosion, transportation and deposition of sediments, the organic and inorganic chemical processes that took place within the sediment between the time of deposition and solidification, and the various geobiological inter-actions between the sediments and the biota. Of particular importance are exchanges of phosphates and other nutrients and micronutrients between the sediments and the overlying waters.

Major surveys consisted of: a sediment inventory along the north shore of Lake Ontario; collection of 560 bottom samples and cores in the heavily polluted

Niagara River mouth area and in relatively clean Georgian Bay - Bruce Peninsula region to provide valuable information for process studies on the spatial variations of physical, chemical, and biological parameters within the sediments; in the area of Lake Ontario between Hamilton and Toronto variations in the textural and mineralogical characteristics of sandy sediments were used as natural tracers to determine the net direction of transport and the origin of nearshore sand deposits; a number of different species of chironomids were taken from bottom samples from Lake Ontario in order to read them for morphological observations and identification at different stages in the life cycle (chironomid distribution is related to the degree of pollution of the sediments and can, it is hoped, be used as an indicator organism); detailed continuous profiling surveys were run over much of the western basin of Lake Erie, designed for shallow penetration to provide a better understanding of the complex stratigraphy of the unconsolidated deposits; a seven-week sediment cruise of Lake Huron was undertaken during which 7,000 nautical miles of line were surveyed and bottom samples were obtained at 196 stations for geochemical and sedimentological analysis.

In addition to these major projects, a team of divers undertook a preliminary evaluation of underwater sampling and survey operations using an underwater habitat located on the Bruce Peninsula. On Lake Winnipeg, a co-operative program was carried out with the Fisheries Research Board involving comparative tests using different bottom sampling and coring devices to determine the most efficient equipment for obtaining biological and geological materials.

Laboratories of the section have continued to process samples and to develop new methods for quantitative and qualitative geochemical and sedimentological analyses of sample material.

ENGINEERING DIVISION

The Division conducts field and office engineering investigations and makes recommendations on the development of water resources. It establishes ranges of engineering costs and prepares estimates of benefits for developments such as hydro-electric power plants and water-supply systems for domestic, industrial, irrigation or other uses. The Division provides technical advice to various federal and provincial departments and agencies; examines and reviews proposals for water conservation and control, including hydrology, hydraulic and structural design, and comparison of project benefits and costs; maintains continuing inspection and review of water-conservation and control projects to which Canada is contributing financially; undertakes negotiations with respect to federal participation in water projects and participates in federal-provincial and international boards, committees and task forces established for water-resource investigations, development, control and regulation.

To cope with its manifold tasks, the Division has four regional sections — Atlantic, Central, Western and Pacific — engaged in country-wide investigations and studies. Four support sections provide services in engineering hydrology, field investigations, project design and appraisal, and engineering systems to the regional components. Except where specifically noted, the Division's staff is located in Ottawa.

Engineering Hydrology

Engineering-hydrology studies carried out in the Division may be grouped into three broad categories: 1) those required in support of international, federal-provincial and federal programs pertaining to fresh water; 2) those which contribute to the general knowledge of Canadian water resources; and 3) those of a basic nature for the development of improved methods of hydrologic analysis. Examples of these three types of studies carried out during the year are as follows:

1) At the request of the Department of Transport a study of the Trent Canal system was undertaken. This study resulted in a set of tables for use in the day-to-day operation of the canal system between Hastings and Lake Ontario. These tables give all of the required relationships between flow, water level, gate openings, backwater, time of travel and changes in reservoir storage.

2) A brochure entitled High Water on Lake Winnipeg was issued for public information. This brochure gave a factual presentation of the factors causing high water on Lake Winnipeg, with particular reference to the maximum recorded level of 1966. The main purpose of the brochure was to correct some of the ill-informed opinions that had been voiced as to the cause of flooding on the lake.

3) Research was carried out on the analysis of floods, annual flows and monthly flows.

Field Investigations

The Division carried out the fourth year of field and office work investigations on the cost and engineering feasibility and of water-resources development in Northern Ontario. Field work was virtually completed, but preliminary design and costing of structures for alternative schemes are continuing and reports on water yield, power potential, cost and physical benefits for alternative development possibilities are under preparation.

Project Design and Appraisal

The Canada Water Conservation Assistance Act empowers the Government of Canada to provide financial assistance to the provinces in the construction of major works for the conservation and/or control of water. During the year the Division provided technical assistance in the design and appraisal of projects implemented under the Act. Activities were concentrated on conservation and flood-control works for the Metropolitan Toronto and Region Conservation Authority, Upper Thames River Conservation Authority and the Halton Region Conservation Authority in Ontario, and on projects in north and west Vancouver and in Alberni in British Columbia. In Manitoba, similar service with respect to construction of the Red River Floodway was provided under an ad hoc agreement. This major project was placed in operation during the year; however, several minor items are yet to be completed. Under a similar agreement, technical assistance was provided for the construction of flood-control dykes around several communities in the Red River Valley.

The final draft of the manual of standards and procedures for planning water-resources projects in Ontario was completed under the aegis of the Canada-Ontario Committee on Canada Water Conservation Assistance Act Programs and technical advice was provided on the assessments of discharge records to the Lake of the Woods Control Board.

The Division prepared up-to-date capital-cost estimates for the reconnaissance survey of hydro-electric potential in the Upper Yukon River Basin, and examined alternative schemes of development.

Engineering Systems

The Engineering Systems section was formed in July 1969. The main functions of the section are to develop mathematical modelling and computer applications for water engineering.

Work was completed during the fiscal year on a contract with the Saskatchewan-Nelson Basin Board to develop a mathematical model to produce synthesized flow sequences at 13 points in the Saskatchewan-Nelson Basin. The section also participated in studies by the International Great Lakes Levels Board and the International St. Lawrence River Board of Control.

Pacific Region

The Pacific Regional Office in Vancouver, British Columbia helps to carry out the ten-year federal-provincial Fraser River flood-control program which was authorized by Agreement in 1968. The regional engineer serves in alternate years as chairman and as vice-chairman of the Fraser River Joint Program Committee. Staff of the Division co-operated with provincial-government engineers and worked with consultants to develop design criteria and designs for dykes, pumping installations, river-bank stabilization and internal drainage works in the Lower Fraser Valley.

A section of the staff provided engineering support to the chairman of the Canadian section of the Columbia River Treaty Permanent Engineering Board. The regional engineer served the Canadian section as alternate member to the chairman and as secretary. The staff analyzed flood-control and power-operating data, prepared reports on implementation of the treaty and on operation of the treaty storages, and reviewed technical reports and operating programs prepared by the various agencies involved. The staff also continued to provide engineering support to the chairman of the Federal - Provincial Columbia River Advisory Subcommittee.

The regional staff participated in several other projects, including evaluation of the Upper Yukon River power-market potential.

Western Region

Excellent progress was made on the Saskatchewan-Nelson Basin study which is an examination of the water resources of the Saskatchewan-Nelson Basin, including potential additional supply by diversion or storage. The study is under the direction of the Saskatchewan-Nelson Basin Board, whose secretary is an officer of the Division. The staff also undertook

the preparation of a report on effects of southward diversions on the Athabasca-Mackenzie System.

The Prairie Provinces Water Board was reconstituted and an agreement apportioning the waters of the three prairie provinces was signed by Canada and the provinces of Alberta, Saskatchewan and Manitoba. An officer of the Division has been acting as *pro tem* secretary to the reconstituted Board pending establishment of a permanent secretariat.

The Division also provides the secretary and engineering support for the Canadian section, International Souris-Red Rivers Engineering Board.

Central Region

Through its Central Region section, the division provides advice on the regulation and control of waters of the Great Lakes - St. Lawrence system and carries out studies related to water management in the region. An office is maintained at Cornwall from which the regulation of Lake Ontario is supervised by Division members representing the International St. Lawrence River Board of Control under the aegis of the International Joint Commission. During the past year, the office staff contributed to studies of problems caused by low water levels on Lake St. Lawrence and of the problem of timing the installation of the ice-control structures in the International Rapids Reach.

The Division also provides technical advice to several other boards established by the Commission. As part of its responsibilities for regulating the outflows of Lake Superior, the International Lake Superior Board of Control made provision for the storage of additional water in the lake during the latter months of 1969, for release during the winter; this action was taken in connection with a test by the International Great Lakes Levels Board aimed at determining the feasibility of increasing maximum winter outflows.

Technical assistance was also provided by the Division to the Commission's American Falls International Board and its International Niagara Board of Control. As part of the investigation of the American Falls Board into possible measures to preserve and enhance the beauty of the American Falls, the Board temporarily dammed up the American Falls Channel during 1969 in order to permit intensive field surveys and geologic studies to be carried out "in the dry".

During the year, a high priority was given to studies for the International Great Lakes Levels Board of the Commission concerning the feasibility of further regulating any or all of the Great Lakes. Preliminary results have been obtained with regard to possible benefits from further regulation. The studies take into account the effects of varying lake levels and outflows on the various shore properties, navigation, and power production.

Atlantic Region

The Division provides technical advice with respect to the management of the water resources of the Atlantic provinces.

The study of the feasibility of building tidal-power plants in the Bay of Fundy was completed during the year. The Engineering Division provided technical and related support to the Atlantic Tidal Power Programming Board, which carried out the study under an agreement among the governments of Canada, Nova Scotia and New Brunswick. An officer of the Division acted as secretary to the Board and to the Board's Associated Engineering and Management Committee.

During the year the second phase of the study was completed. This work consisted of a refinement of the design and construction concepts for proposed structures, analyses of the possible power output and available markets as well as economic analyses of the power and energy products of such tidal power schemes.

WATER QUALITY DIVISION

The Water Quality Division collects, interprets and disseminates water-quality data for inland and coastal waters in Canada, conducts applied research in water and wastewater treatment and in analytical methodology, and provides analytical laboratory support for water-resources research and field investigations undertaken by the Department and by other government agencies, the provinces, universities, and private institutions.

The Division is divided into three subdivisions; 1) Resources and Surveys, 2) Water Pollution Research, and 3) Water Chemistry. Laboratories are maintained at Ottawa and Burlington, Ontario; Moncton, New Brunswick; and Calgary, Alberta.

Resources and Surveys Subdivision

The Resources and Surveys subdivision, which collects, interprets and disseminates water-quality data, continued to expand the monitoring and surveillance network across Canada to provide baseline water-quality data and measurement of pollution effects. Approximately 550 permanent sampling stations were in use during the year, an increase of 280 from the previous year. Emphasis continued to be placed on the establishing of sampling stations at gauging stations which are operated by the Water Survey of Canada, particularly in waters in which there is a strong federal-provincial interest. Sampling frequency varied from daily to monthly, depending on the accessibility of the stations and on the requirements of other studies of the sampled waters.

The expansion of the network in the Okanagan Valley is particularly noteworthy, as it illustrates one form of joint federal-provincial collaboration foreseen under the Canada Water Act. During the early planning of a Canada-British Columbia comprehensive study of the Okanagan Basin, the Division expanded the network of stations in the valley from four to 45, and began assembling water and wastewater quality data for the forthcoming study.

The Division also participated with other federal departments and provincial agencies in the planning and operation of a network of sampling stations in the Prairie provinces establishing the extent of mercury pollution in major waters in that area. The measurement of mercury concentrations at representative stations elsewhere across Canada was added to other routine analyses to provide data on this widespread contamination.

Collaboration continued with other government departments, provincial agencies and universities on research and experimental river basins throughout Canada, and the Department's work in the International Hydrological Decade, as did the water-quality study of the headwaters of the Saskatchewan River system, in support of the Eastern Slope watershed program.

The selection, acquisition and delivery of eight robot water-quality monitors for the Atlantic provinces was completed toward year-end. Plans were finalized for the location of seven monitors on the Saint John River and its tributaries in New Brunswick, with installation to be completed in 1970. The installation of the monitors represents a milestone in network development in Canada, making it possible to automatically measure and record stage, temperature, pH, turbidity, conductivity, chloride and dissolved oxygen at each station at hourly intervals, with all data telemetered to Moncton for reception and recording. The eighth monitor is to be located on the Petitcodiac River at Moncton. Each monitor is housed in a trailer providing not only mobility but also a field laboratory.

Monitoring of water quality in streams in the base-metal mining area of New Brunswick continued in support of pollution-control studies by the Department of Fisheries and Forestry and by the New Brunswick Water Authority.

Computer-based storage and retrieval of water-quality data received from the Division's laboratories and from other federal and provincial agencies became operative during the year with some trial computer print-out of data towards the end of the year. Development of automated printing of data in keeping with a wide range of data-user requirements will continue as water studies are expanded throughout Canada.

Water Pollution Research Subdivision

The study of the treatment and control of base-metal mining wastes continued as the principal laboratory and field activity of the subdvision. A pilot-scale oxidation lagoon was constructed at the Brunswick Mining and Smelting Company property in New Brunswick and was operated with modest success during the late summer. Laboratory research indicated that the development of cultures of the bacillus Thiobacillus Ferro-Oxidans in a controlled oxidation system could oxidize the sulphur compounds which give rise to the acidity in the waste systems following oxidation. The system having been stabilized, residual metals could then be precipitated with lime.

Plans were being made for a pilot-scale water-and-waste-treatment-research laboratory at the Canada Centre for Inland Waters at Burlington. Construction of the laboratory building was rescheduled with completion now planned for early 1971, rather than 1972. With this rescheduling, preliminary plans for experimental water-and-waste-treatment units to be assembled in modular fashion were set out, and a consultant was retained to undertake detailed planning and design in 1970-71. When completed, the pilot plant will provide facilities for applied research not

only on conventional water-and-waste-treatment equipment and systems available today, but also in innovative systems and methods of treatment that arise from basic research in other laboratories.

Water Chemistry Subdivision

The Division continued to develop and expand analytical services at the Ottawa, Moncton, Calgary and Burlington laboratories. Priority was given to research on automation of methods and on the acquisition of automated analytical equipment to meet the growing work load without unduly increasing staff.

Facilities at Moncton and Calgary were expanded to accommodate the rapidly growing work loads in the eastern and western regions. The unit at Burlington continued to provide shore- and ship-based analytical services.

A significant increase in activity in the Calgary laboratory came with the start of the joint Canada-British Columbia study of the Okanagan Basin. The laboratory established a mobile laboratory in the valley and began on-site sampling and analysis. Work load at the Calgary laboratory also increased with the regular shipment of samples from the Okanagan for detailed analyses.

The emergence of mercury pollution as a widespread problem across Canada pointed up the need for a rapid, sensitive, and reliable method of detecting and measuring this element in water. The Methods and Properties section of the Ottawa laboratory moved rapidly to develop such a method and, by year-end, both the Ottawa and Calgary laboratories were equipped and were detecting mercury concentrations as low as 0.05 micrograms per litre. The Calgary laboratory thereafter provided analyses of samples collected in a federal-provincial program on prairie region waters, while the Ottawa laboratory undertook analyses of samples from water in northern Ontario and in the Great Lakes-St. Lawrence River-Ottawa River waters which were subsequently found to be contaminated.

The Division continued its participation in the activities of the American Society for Testing and Materials, and maintained close liaison with the Federal Water Pollution Control Administration in the United States to keep abreast of new analytical procedures and the development of water-quality criteria and standards. The Division provided the chairman and staff for an interdepartmental working group on the development of water-quality criteria for Canada. The group hopes to include representatives from all provinces, universities and industry.

Energy Development Sector

The Energy Development Sector continued to pursue its broad responsibilities of providing the advice, co-ordination and guidance necessary to ensure the effective development and use of energy resources for the optimum benefit of Canada. Although the experts of the Sector work in separate groups, according to energy source, policy considerations relating to an individual energy source or form include all aspects of the complex interrelationship between individual energy sources.

One of the more important programs initiated during the 1969-70 fiscal year was the development of an extensive inventory of energy resources which will include not only quantitative data but also all relevant qualitative aspects. The Sector, in conjunction with other departments and agencies, strives to develop an accurate energy-demand forecast at the regional, national and international levels. The projected energy supply-demand picture includes availability of accurate and up-to-date status reports on the energy industries of Canada.

The Sector's Resource Administration Division continued its ever increasing role in resource management in our offshore areas and in federally-owned lands. Canada's submerged continental margin is probably the largest in the world. Some 950,000 square miles of the total 1.5 million square miles of submerged shelf, which is as large as 40 per cent of Canada's entire land area, are under the administrative control of the Resource Administration Division. At the end of the 1969-70 fiscal year the Division had issued exploration permits for almost 400 million acres and was administering the work obligations and exploration programs associated with those permits.

The Resource Administration Division has also participated in a major way in discussions with provinces concerning lines of demarcation between federal and provincial jurisdiction over the offshore areas and the sharing of revenue which may result from oil and gas production.

ELECTRICAL ENERGY

The Electrical section of the Energy Development Sector is primarily concerned with the production and transmission of electrical energy throughout Canada, and seeks to co-ordinate and encourage the best use of available energy resources. The Electrical section therefore has a special interest in power-system planning, including the various forms and the siting of generating and transmission facilities. Requisite consideration is given to the economic and environmental factors associated with the development and production of electric power.

The section's interests also include auxiliary systems such as power-system control, communication, fuel supply and storage, and extend to research programs and facilities pertaining to power generation and transmission, and the development and improvement of electrical equipment and prime movers.

Atlantic Provinces Power Development Act

The Energy Group continued its advisory role in connection with the administration and review of the Atlantic Provinces Power Development Act by the Department of Regional Economic Expansion. Studies carried on during the year resulted in the decision to

terminate the financing of power projects in the Atlantic provinces under the provision of the Act. The Energy Development Sector is continuing its technical advisory role in connection with power-system planning and consideration of assistance to power projects that are of major significance to the power systems of the Atlantic provinces.

Upper Yukon Power Market Study

In co-operation with the province of British Columbia, the British Columbia Hydro and Power Authority, the Department of Indian Affairs and Northern Development, and the Alaska Power Administration, the Energy Development Sector continued its study of the market potential for power that could be developed by diverting a portion of the Upper Yukon River waters to a generating station located on tidewater in northern British Columbia or southeast Alaska. This study is being undertaken because of the favourable influence such a station would have on the resource development of northern areas lying within economical distance of such a source. The study will be completed in the fiscal year 1970-71 and will be the basis of a decision concerning the merits of further engineering and economic feasibility studies.

Quebec — New Brunswick Intertie

Following the decision to grant federal government support to the New Brunswick Electric Power Commission's high-capacity direct-current interconnection with the Quebec Hydro system, the Energy Development Sector has maintained an active contact with the Department of Industry Trade and Commerce concerning research and development of the equipment required for this project.

Hydro Quebec Research Institute

Following a review that confirmed the national interest in the establishment in Canada of a high-voltage and high-power electrical research laboratory, the federal government decided to give financial assistance to the Hydro Quebec Institute of Research, in the form of a long-term repayable loan of $17,500,000 and annual grants of $325,000 for ten years. The Energy Development Sector, in conjunction with other federal departments having an interest in electrical-power research, drew up an agreement between the federal government, the Quebec government and Hydro Quebec to govern the provision of financial assistance to the Institute of Research.

To ensure the most effective use of this research facility for the ultimate benefit of the Canadian electrical utilities and the supporting electrical-manufacturing industry, the agreement provides for guidance of the Institute's programs by a federal-provincial review board and a technical advisory committee. These bodies represent the governments of Canada and Quebec, Hydro Quebec and, through the Canadian Electrical Association and Canadian Electrical Manufacturing Association, other electrical utilities, and electrical-manufacturing industries of Canada.

By year end, a draft agreement acceptable to Quebec and Hydro Quebec had been developed and submitted for formal federal approval.

Columbia River Development

The Assistant Deputy Minister (Energy Development) continued his chairmanship of the International Columbia River Treaty Permanent Engineering Board, and the federal chairmanship of the B.C. — Canada Columbia River Advisory Committee.

The Permanent Engineering Board is responsible for ensuring that the objectives of the Columbia River Treaty are achieved. Under the Treaty three Canadian storage projects were to be constructed. Two of them, namely the Duncan and Arrow, have already been completed well ahead of schedule and, as a result, have produced additional benefits for both the U.S. and Canada. Construction of the Mica Dam, the largest of the three Canadian projects, is proceeding on schedule for completion in 1973.

The B.C. — Canada Columbia River Advisory Committee assists the federal-provincial committee of ministers in the implementation of the Treaty by Canada. The Minister of Energy, Mines and Resources is the federal chairman of the ministerial committee.

Atlantic Tidal Power Investigations

The Energy Development Sector continued its participation in the study by the Atlantic Tidal Power Programming Board of Bay of Fundy tidal power. The Board completed its three-year study during the year and submitted its report to the governments of Canada, New Brunswick and Nova Scotia. The Board concluded that while the development of tidal power in the Bay of Fundy is technically feasible, such power would not be economically competitive with alternative forms of generation.

The study reported in detail on the three most attractive tidal power sites in the Bay of Fundy and noted that further study of these sites might be warranted should there be a substantial reduction in interest charged on loans or should advances in construction or generating technology promise substantial cost reductions.

The Energy Development Sector is maintaining its interest in tidal power, and watches any developments that might have a bearing on the practicability of tidal power in Canada.

Nelson River Power Development

The Assistant Deputy Minister (Energy Development) serves as chairman of the Federal-Provincial Nelson River Review Committee established in accordance with the Canada-Manitoba agreement signed in 1967. The agreement pertains to development of the Hydro Electric Potential of the Nelson River.

The Energy Sector has maintained an active interest in the high-voltage DC transmission system that is being constructed by the government of Canada from the Kettle generating station on the Nelson River to a terminus near Winnipeg, and other aspects of the current program for development of the Nelson River. While the Review Committee's main duties will not begin until the transmission system becomes operative in 1971-72, the members held one meeting during the year to review construction progress and planning.

Electric Power in Canada

Responsibility for preparation and publication of the annual publication Electric Power in Canada and tabulation of electrical power developments and transmission lines, was transferred from the Inland Waters Branch to the Energy Development Sector.

During the year a brochure summarizing achievements in the development of electrical power in Canada in 1969 was prepared, and material was assembled for the 1969 issue of Electric Power in Canada and for revision of the map supplements.

OIL AND GAS

Canada's oil and gas companies engage in resource development in western Canada, the far north and offshore on continental shelf areas, production, cross-country transportation, chiefly by means of a vast network of pipelines, petroleum refining at several centres across the country; and wide-ranging marketing.

The Energy Development Sector assesses the regional, national and international implications of trends in each sector of the industry and makes policy recommendations based on the results of its research.

Several departments and agencies of the federal government are directly interested in various phases of oil and gas industry activity. Consequently, the co-ordinating policy role of the Department of Energy, Mines and Resources involves interdepartmental liaison and consultation to ensure that the full resources of government are brought to bear on the complex policy issues associated with the supply and use of oil and gas.

Canada — U.S. Oil Relations

Oil and gas relations with the United States continue to be of prime importance as that country constitutes Canada's sole export market. The United States now imports almost as much oil and gas as is delivered to domestic markets from western Canada fields.

Following a study of the U.S. oil industry in 1969 by a Presidential Task Force, a system of quotas against Canadian oil was initiated early in 1970 and the implications of this action are being assessed. This assessment is proceeding in terms of world supply, as both Canada and the U.S. also rely on oil from overseas sources in addition to continental supplies.

Northern and Offshore Oil Development

The trend towards the development of Canada's oil and gas resources in the far north and offshore is of increasing significance. Following the discovery of oil at Prudhoe Bay on the north coast of Alaska in 1968, exploration activity in Canada's northern frontier areas accelerated. The Task Force on Northern Oil Development was then established by the federal government to assess the supply-and-demand implications of Arctic oil and gas development and the various proposals for transportation to major marketing centres.

The Task Force, chaired by the Deputy Minister of the Department, has been giving particular attention to transportation assessments as made by oil companies that sponsored the two voyages of the supertanker *Manhattan* and by companies concerned with plans for oil and gas pipelines from Prudhoe Bay and the Mac-

kenzie Delta across Canada to U.S. markets. Ecology and pollution control are being given careful study as well as transportation and marketing economics.

Northern exploration and the drilling off Canada's east coast are contributing much specific information concerning Canada's oil and gas potential. Supply and demand assessments and forecasts must have regard to developments in these far northern and offshore regions, as they are believed to hold about 60 per cent of Canada's total oil and gas resources.

Future Oil and Gas Requirements

Energy requirements in Canada are doubling every 15 years, and oil and gas will continue for many years to meet about three-quarters of these requirements. Domestic oil production is now equal to total domestic demand. This balance has been reached through growth in exports to the level of imports into eastern Canada, an area beyond the economic reach of western Canada crude.

To maintain and improve this supply-demand relationship requires not only major exploration and marketing efforts by industry but appropriate resource-development, transportation, marketing, and taxation policies on the part of government. Policy studies are therefore concerned with supply and demand relationships and also with the structure and operation of the oil and gas industry within the framework of broad national objectives relating to such matters as economic growth, employment, ownership and control, and the reduction of regional disparity.

Environmental Management

The increasing concern regarding pollution and the need for adequate environmental management has introduced a new dimension into cost/benefit analyses of oil and gas projects. All activities of the oil and gas industry ranging from exploration, through production, transportation, refining, and marketing create some pollution hazards for land, sea or air. Feasibility studies, and the policy recommendations arising from them, are therefore having regard to the costs of pollution prevention and control.

This new requirement must now be costed, and increasing attention is being given to research to ensure the development of secure and economic environmental control procedures. Included in the work of the Energy Development Group on this subject is its participation in a government-industry committee concerned with pipeline technology in northern terrains where ecological control is vital because of the unstable nature of permafrost and muskeg areas.

International Interests

International trends in the oil and gas industry are followed through participation in such organizations as the Oil Committee of the Organization for Economic Co-operation and Development (O.E.C.D.) and the World Petroleum Congress. International affiliations afford a means of appraising the impact of world petroleum resource developments and price trends on supply and demand within Canada.

COAL

A strong resurgence is taking place in the coal industry of western Canada to meet the rapidly growing demands of the export and home markets. This recovery was promoted since its early stages by joint federal-industrial programs including subvention aid, technical advice and mine-improvement loans. During the year, a number of coal companies completed their current programs of expansion and modernization to supply these markets. Several other companies are in the development stage.

Also during the year, the Canadian National and Canadian Pacific Railways inaugurated unit-train systems for the more efficient transportation of coal, and new coal-loading facilities were completed at the Port of Vancouver. As a result of these developments in western Canada, Canadian coal production is expected to increase from the 1969 level of approximately 10½ million tons to about 40 million tons by 1975 and to 60 million tons by 1980.

During the year, the coal consumers of central Canada, particularly in Ontario, began to experience a shortage of coal supply because of production problems at mines in the United States. Consequently, the steel-making and electric-utility industries as well as smaller consumers have been materially affected. Moreover, the increasingly strict civic regulations against the use of high-sulphur fuels have aggravated this position of short supply. In consequence, the Ontario consumer is showing greater interest in western Canada coals. The low sulphur content of these western coals, together with improved efficiencies at the mine and on the Canadian railways, give promise of substantial sales in Ontario and a lessening of the dependency on imported coal.

With respect to the tight situation in supply and demand for coal, the Energy Development Sector is maintaining a close liaison with central Canada consumers as well as with the coal producers of western Canada and the United States.

Transfer of the Staff of the Dominion Coal Board to the Energy Development Group

Legislation was passed during the year for dissolution of the Dominion Coal Board and for the transfer of its responsibilities to the Department of Energy, Mines and Resources. The transition of responsibilities has proceeded smoothly between the staff of the Dominion Coal Board and the Energy Development Sector, with the Board staff becoming the Coal Advisory section of the Sector.

Departmental Commitee on Coal

During the year, a departmental advisory committee on coal was established to co-ordinate and make best use of all existing knowledge and facilities within the Department. To make it even more effective, it is proposed to expand it to interdepartmental level by including representation from other interested departments. The first task of this committee was a reassessment of the measured coal reserves of western Canada; a report will be completed early in 1970-71. Additional assignments will include the determination of the quality of these coal reserves and their relative mineability, together with an investigation into existing and potential markets.

It is also proposed to make this committee a useful point of contact with the coal industry, including the consumers and transporters of coal. Toward this end, the industry is being encouraged to establish a fully representative industrial association to expedite a systematic exchange of views with Ottawa.

Coal Industry in the Maritimes

In the Maritime provinces, the coal industry continued to be phased down in accordance with joint federal-provincial programs for bringing coal production more in line with available markets and for introducing other industries.

The Canadian Conference on Coal

As part of its responsibility for co-ordinating energy-related matters, the Sector organizes and administers the annual Canadian Conference on Coal in co-ordination with the Coal Operators' Association of Canada and the Canadian Institute of Mining and Metallurgy. The Conference is a public forum for the exchange of ideas and the dissemination of knowledge related to coal resources and their orderly utilization.

The Phasing-Out of Coal Subventions

As a result of the improved economic situation in western Canada and of the alternative programs instituted for Nova Scotia and New Brunswick, federal subventions have been phased out and will be discontinued in 1970-71. In future, federal support will consist of research and development aimed at promoting long-term stability of the industry. This will include investigations into the problems of coal production, processing, transportation and utilization.

URANIUM AND NUCLEAR ENERGY

There are many activities associated with uranium and nuclear energy that require immediate and extensive attention by the federal government. The strategic importance of uranium, Canada's large uranium reserves, the economic significance of uranium domestically and as an export commodity and changing international developments, all require sound and flexible national policies and guidelines.

There are many federal departments and agencies that participate in a variety of studies and policy formulations concerning uranium and nuclear energy. The staff of the Energy Development Sector participates in the development and recommendation of policy on nuclear energy, uranium and associated matters. The Sector co-ordinated and conducted studies which led to announcement of a new export policy as outlined by the government on June 9, 1969. While maintaining Canada's policy with respect to nuclear safeguards, the policy reflects the increased world demand for uranium and requires examination and approval of export contracts on the basis of such factors as reserves, domestic needs, rate of exploration and price.

Foreign Ownership in the Canadian Uranium Industry

Because of factors mentioned above, the question of foreign ownership of uranium mines in Canada is an important element in the overall considerations of foreign ownership of our industries.

Subsequent to the Prime Minister's statement of March 2, 1970, on the government's position with regard to ownership in the Canadian uranium industry and the Honourable J. J. Greene's statement of March 19, 1970, outlining the criteria governing the proposed limitation of foreign ownership of uranium-producing enterprises in Canada, the Department was given the task of co-ordinating the preparation of regulatory measures required to implement this policy.

RESOURCE ADMINISTRATION DIVISION

The Resource Administration Division administers and manages the federal interests in mineral resources off Canada's east and west coasts and in Hudson Bay and Hudson Strait. The primary aim is to provide a uniform system of resource management that will, in a manner consistent with the public interest, encourage and maintain continuing and orderly investment in offshore mineral resource development and ensure that reserves discovered are as low in cost as possible. The Division also handles those federally-owned mineral rights in the provinces that become available for development.

In addition to the foregoing responsibilities, the Division develops and provides policy recommendations and advice in regard to matters related to the offshore; provides representation and expertise with respect to interdepartmental, federal-provincial and international offshore matters; provides co-ordination and liaison among numerous government and industrial agencies concerned with utilization of offshore areas; and provides expertise and advice to other governments and agencies concerning a wide variety of mineral-resource and related matters.

Offshore Mineral Resource Management

The total area of Canada's submerged continental margin is estimated to be in excess of 1.5 million square miles, about 40 per cent as large again as the total land area of Canada. Of this over 600,000 square miles lie off the east coast; 400,000 square miles lie in Hudson Bay and Hudson Strait; 50,000 square miles lie off the west coast; and some 500,000 square miles are in the high Arctic, in the Beaufort Sea and in the region of the Arctic Archipelago.

Preliminary investigations indicate that much of Canada's submerged continental margin is prospective for oil and gas. The Canadian Petroleum Association has recently estimated that the petroleum potential of Canada's east-coast shelf alone, including only areas to a water depth of 200 metres, amounts to some 25 billion barrels of oil and 150 trillion cubic feet of gas. Much lies beyond this; over 50 per cent of Canada's east-coast continental margin has water depths exceeding 200 metres. The potential for mineral resources other than oil and gas is also promising, although at present the mining industry lags considerably behind the petroleum industry in the offshore field.

Canada Oil and Gas Permits cover well over half of Canada's submerged continental margin. These offshore permits are issued and administered under the Canada Oil and Gas Regulations, promulgated pursuant to the Public Lands Grant Act of 1952. The Act gives statutory authority with respect to the offshore. Authority for dealing with offshore operational matters is also provided to a considerable extent by these regulations.

With the recent upsurge in offshore exploratory activity, particularly drilling, there is an urgent need for new and more comprehensive statutory authority to govern operational, production and conservation matters. This legislation would enable supervising authorities to continue evolving regulatory requirements and supervisory controls to keep pace with accelerating offshore activity and technology. In particular, it would enable the federal government to handle the new and complex situation that will arise upon the advent of commercial production.

A new bill to accomplish this with respect to oil and gas, Bill S-5, has been passed by the Senate and, at the end of this fiscal year, was before the House. The bill is designed to amend the Oil and Gas Production and Conservation Act, which became law last June, so that it will apply not only to the Canada Lands of the Yukon and Northwest Territories, but also to Canada Lands in the areas off Canada's sea-coasts. The amended Act will provide for more comprehensive statutory control over all offshore oil and gas activities, the safety of personnel and the prevention of waste and pollution. The Act's broad authority includes regulation of the exploration and drilling for, and the production, conservation, storage, transportation (pipelines), distribution, measurement, processing and other handling of offshore oil and gas.

In response to the upsurge in drilling activity off Canada's east coast, and in order to provide the

regulatory control embodied in the Act, the Division during the year began construction of a $126,000 regional office building on the site of the Bedford Institute in Dartmouth, Nova Scotia. This building will provide office space for a regional conservation engineer and his staff, who will be responsible for on-the-spot supervision and regulation of east-coast offshore drilling. The building will also include laboratory facilities for the processing, storage, curating, research and examination of cores and cuttings from east-coast offshore wells. Among the major considerations are the prevention of pollution, the safety of personnel and the conservation of mineral resources as well as the living resources of the sea.

At the end of the fiscal year, the Division was recruiting engineering and support personnel to staff the regional office, and sought to design and enforce comprehensive and up-to-date regulations for the offshore under the Oil and Gas Production and Conservation Act as amended.

Offshore Activity

During 1969, $22 million were spent by oil companies on offshore Canada Oil and Gas Permits administered by the Division, an increase of $4 million over that spent in the previous year. This brought the cumulative expenditures by companies engaged in oil and gas exploration in Canada's offshore areas to more than $80 million. During the year, the Division approved 38 separate offshore exploration programs and ensured that they were carried out in accordance with federal requirements.

Highlights of 1969 included:

1) completion of Shell Canada's exploratory drilling program off the west coast, with four additional exploratory wells drilled and abandoned for a total of 14 wells drilled during a two-year effort;

2) commencement of Shell Canada's exploratory drilling program on the Scotian Shelf off the east coast, with the abandonment of the first well with a significant show of gas, and the commencement of a second well; the semi-submersible rig used was to be joined by a second vessel in 1970 after construction in Halifax was completed;

3) drilling of the first well in Hudson Bay, about 125 miles offshore, and the drilling of a well farther to the northeast in the Hudson Strait region, on Akpatok Island in Ungava Bay;

4) announcement that a drilling program would be carried out in the summer of 1970 in the Gulf of St. Lawrence off Prince Edward Island.

Canada Oil and Gas Permits

A total of 371 Canada Oil and Gas Permits covering 23.2 million acres were issued during the fiscal year 1969-70 in offshore areas administered by the Division, as follows:

East Coast	247 permits	15,607,407 acres
West Coast	Nil	Nil
Hudson Bay-Hudson Strait	124 permits	7,563,822 acres

This brought the number of offshore Canada Oil and Gas Permits (except in the waters of the high Arctic) as of March 31, 1970, to 5,500 covering 389.3 million acres as follows:

East Coast	3,417 permits	259,021,252 acres
West Coast	251 permits	15,600,154 acres
Hudson Bay-Hudson Strait	1,832 permits	114,688,492 acres

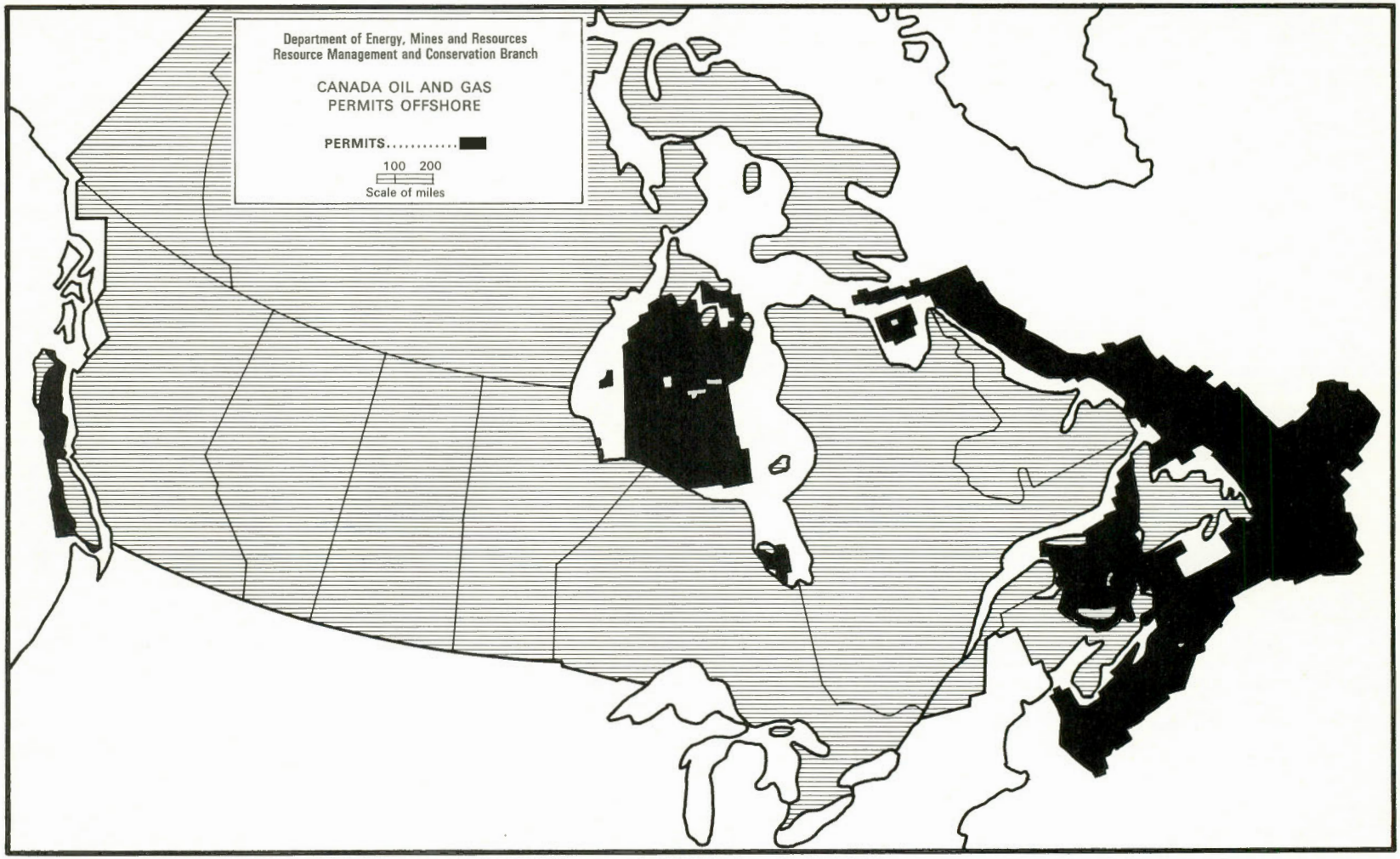
The total revenues received during the fiscal year 1969-70 from offshore permits, including permit fees, transfer fees, forfeitures, exploratory licences and maps amounted to $204,915.76, most of which was derived from permit fees.

Mineral Claims

Offshore mineral claims are issued for mineral rights other than oil and gas rights under the Canada Mining Regulations. A total of 165 offshore mineral claims were recorded during the past year in the Hudson Strait region. This brought the total number of mineral claims to 483, distributed as follows: east coast, 143; west coast, 108; Hudson Bay, 232. Total revenues received from the issuance of mineral claims and prospecting licences during the fiscal year 1969-70 amounted to $1,407.62.

Federally-Owned Mineral Rights in the Provinces

During the fiscal year 1969-70 nine oil and gas leases were issued. Four of these were in Alberta, three in Saskatchewan and two in Manitoba, bringing the total number of federal oil and gas leases in the provinces to 231. Of these 103 were issued in Alberta, 80 in Saskatchewan, 44 in Manitoba and four in Ontario.



The Resource Management and Conservation Branch is responsible for the management of the federal interests in the mineral resources of all Canada's offshore areas with the exception of the high Arctic. This responsibility includes the exercise of comprehensive statutory control over all exploratory and development work with such matters as, the prevention of pollution, the prevention of waste of resources, and the safety of personnel, being of primary importance.

To date, interest in offshore mineral resources has been confined primarily to the search for oil and gas, and in 1970 more than 130 companies held a total of 410 million acres under exploratory permit. The oil and gas industry has spent a total of $120 million, on the drilling of 46 wells and on numerous geophysical surveys, to explore this acreage. Offshore exploration activities are continuing to increase rapidly with expenditure of $55 million anticipated in 1971-1972.

In addition, two leases for minerals other than oil and gas are held in Ontario. On March 31, 1970, 68 oil and/or gas leases were productive as follows: 36 in Alberta, 22 in Saskatchewan, nine in Manitoba and one in Ontario.

The total revenues received during the fiscal year 1969-70 from oil and gas leases, including royalties, lease-sale bonuses, rentals, extension fees, lease fees and assignment fees, amounted to $280,754.42, most of which was derived from royalties.

Administration

The Administration program comprises the central Ministry supporting functions (Executive Offices, Finance and Administration, and Personnel and Organization) and the specialized services (Public Relations and Information Services, Computer Science Centre and Technical Field Support Services), maintained centrally to support other elements of the department.

A Monitoring Committee under the chairmanship of the senior assistant deputy minister was formed to stimulate and guide the implementation of the recommendations contained in the report of the Bureau of Management Consulting Services, as accepted by the department. Considerable progress was made, but another year is required to achieve the desired results.

A semi-official committee comprising senior branch administrative officers was formed to improve communications and understanding between headquarters and the operating units.

FINANCE AND ADMINISTRATION

The organization to meet the recommendations of the report of BMCS and the needs of the department was prepared and approved by requisite authority. The report recommended a shift in emphasis to that of planning and policy formulating at the departmental level and to the publishing of guidelines and procedures to enhance uniformity; this enables line officers to handle day-to-day administrative responsibilities to the greatest possible extent. It is anticipated that the reorganization will be completed during the next fiscal year.

The accounting system for Technical Field Support Services was revised and implemented. A new field equipment list was issued for the use of field officers.

The Departmental Secretariat co-ordinates and edits parliamentary returns, applies claims regulations to motor vehicle accidents and claims against the Crown, administers licences for patents for departmental employees under the Inventions Act, handles submissions to Treasury Board and memoranda to Cabinet, and edits and publishes procedural manuals. Four procedural manuals were issued during the year and five additional ones reached the draft and final discussion stage.

As a result of certain amendments to the Financial Administration Act, the Department assumed the responsibility for the pre-audit of accounts and claims, the preparation of financial accounting reports and other related services formerly provided by the Department of Supply and Services. The staff formerly employed in these areas of responsibility was transferred to the department on September 1, 1969. Certain procedural changes were necessary and these were instituted without any interruption in the service to the branches.

A 50 per cent increase in leases was noted; half were short-term leases, mainly for the water sector. There

was a constant demand for increased space, alterations and surveys, leading to either new leased accommodation or a new building.

In capital construction, the major completions involved the extension to the core laboratories in Calgary and the completion of the research plant at the Bedford Institute. A number of specialized installations in the Observatories Branch were completed, and design and construction work was carried out on the diesel test lab and rifle range at Corkstown Road.

PERSONNEL AND ORGANIZATION

At peak employment, the department had 6118 employees comprising executive, 29; scientific and professional, 1317; administrative and foreign service, 295; technical, 2431; administrative support, 1011, and operational, 1035.

Complete appraisal systems were developed and implemented for the Economics and Administrative Services groups. A Career Development Program for administrative officers was initiated.

Phase 1 of the Management Grid Development Program was provided to 109 officers from various branches. A supervisory development course was prepared and implemented. Educational leave was provided to 57 employees, ranging from zero to full pay, in work fields where it was difficult to recruit qualified staff. Some 170 departmental employees were enrolled in French language training.

The Cabinet freeze on continuing strength as of 31 July, 1969, required submissions for relief and review and approval by senior management of all staffing actions, on the basis of departmental priorities.

Recruitment was relatively successful for the specialized occupational groups required in the water and energy sectors. Some 900 students were employed during the summer for office, laboratory or field operations.

Most of the 42 collective agreements applicable to departmental employees were implemented during this period. Advice and assistance was provided to line management and staff officers on the implementation and interpretation of collective agreements and the resolution of grievances. Assistance was provided to Treasury Board on collective bargaining, especially where the department had a significant number of employees in the occupational group concerned.

A new disciplinary policy for ships' crews was developed and implemented. The departmental grievance procedure was revised.

The Deputy Minister introduced an official safety program. Departmental policy was established and a safety manual prepared and distributed. A departmental safety co-ordinator was appointed at headquarters as well as safety officers in most branches.

The work load involved in the classification of new positions and the reclassification of existing positions was heavy, partly because of a number or organizational changes. Training in job description writing and the classification of positions was provided to line management in most of the branches.

The conversion of positions from the old classes into the new occupational categories, groups and levels continued. The work was given high priority as it was required for collective bargaining. There was a significant backlog, mainly in the Scientific and Professional category and in the Engineering and Scientific Support group. The number of classification grievances was high.

The changeover from a punched card to a computer data system continued. The department assisted the Public Service Commission in developing a scientific vocabulary for data stream, especially in disciplines where the Department employed a significant number of professionals.

Advice and assistance was provided to line management concerning employees with alcoholic, health and work problems. Counselling was provided, as necessary, to the employees concerned.

COMPUTER SCIENCE CENTRE

The Computer Science Centre commenced the implementation of the recommendations of the Bureau of Management Consultants, as accepted by the department, to reorganize the Centre and to acquire a large-scale centralized computing facility. Most of the important staffing actions have been completed or are in the process of being completed.

Work was also commenced on the acquisition of new computing facilities. Following a period of intensive analysis of the present and projected work loads of the department, specifications of a computing facility capable of handling the required work load, were prepared and incorporated into an invitation to tender, which was issued April 15, 1970.

The Centre made a start on the development of a personnel data system and a system designed to assist in controlling an inventory of the equipment issued to the departmental field parties.

Of particular interest was the development of the computerized portion of a Water Quality Data System in co-operation with the Inland Waters Branch. The system provides the capability of editing, storing, manipulating and displaying information that describes the results of analyses of water samples from sampling stations across Canada.

PUBLIC RELATIONS AND INFORMATION SERVICES

The Public Relations and Information Services Branch provides support services to management that contribute to the attainment of the department's goals and the objectives of its programs.

The Branch comprises the Interpretive Writing, Media Relations, Graphic Arts, and Publishing Sections.

During the year, the Branch stationed a regional information officer at the Canada Centre for Inland Waters at Burlington, Ontario, and obtained a position for a similar officer at the Bedford Institute in Dartmouth, N.S.

The publicity highlight of the year was HUDSON 70, an 11-month, 41,000-mile oceanographic expedition around South and North America. The CSS *Hudson* left Dartmouth, N.S. in November 1969. Some 125 scientists from government laboratories and universities in Canada, United States and South America participated in the expedition, studying the Atlantic, Antarctic, Pacific and Arctic oceans.

Press kits on the expedition were prepared in English, French, Portugese and Spanish. Press conferences were held at Dartmouth, Nova Scotia, on the ship's departure, at Vancouver in June 1970, and at the termination of the expedition in Dartmouth in October 1970. With the co-operation of the Department of External Affairs, successful press conferences were held at the ship's ports of call in Rio de Janeiro, Buenos Aires, Punta Arenas, and Santiago. The expedition received extensive publicity in Canada and in the various ports of call in South America.

"Everybody's War", a Branch brochure on water pollution, proved so popular that a total of 75,000 English copies and 25,000 French copies had to be produced to meet the demand.

A start was made on the production of a series of six water pamphlets in response to requests for information on water pollution and water management.

Media Relations produced and distributed 81 press releases and 23 Minister's speeches in both official languages.

The Graphic Arts Section created and produced the designs for the various Branch publications and exhibits. Photographic assignments included press and publicity coverage of ministerial conferences, field projects and interdepartmental activities and still and movie photography of scientific projects. New earth science films were purchased and deposited in the EMR section of the National Science Film Library.

Fifty per cent of editorial man-hours was devoted to 12 large manuscripts during the year, of which the following were published: Transactions of the International Peat Congress, Mining and Groundwater Geophysics, Men and Meridians, Vol. 3, Proceedings of 5th International Conference on NDT, Combustion Handbook on Canadian Fuels, Vol. 1, Canadian Minerals Yearbook 1967 (French), Canadian Minerals Yearbook 1968 (English).

The following were edited but not brought to the publishing stage: translated parts of Geology and Economic Minerals of Canada (French), Geology and Economic Minerals of Canada, Prospecting in Canada, Canadian Minerals Yearbook 1968 (French), Canadian Minerals Yearbook 1969 (English), Men and Meridians, Vol. 1 (French).

Some 14,500 printed pages in all were edited, totalling 94 books of which 79 were published and 15 were in the process of editing. All books originated in branches of the department.