

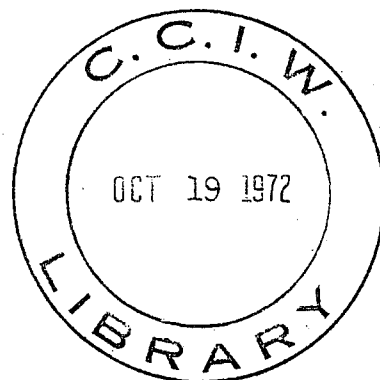
CANADA Inland Waters Directorate.
Report Series

23



Directorate
INLAND WATERS BRANCH

DEPARTMENT OF THE ENVIRONMENT



Research Projects in Glaciology, 1972

REPORT SERIES NO.23

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Research Projects in Glaciology, 1972

INLAND WATERS DIRECTORATE
DEPARTMENT OF THE ENVIRONMENT
OTTAWA, CANADA, 1972

FOREWORD

This report contains two parts, 1) A general review of the organization and objectives of the glaciological program within the Water Resources Branch and 2) A catalogue of current projects with pertinent data on objectives, work in progress, etc.

O.H. Løken
Chief,
Glaciology Division.

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RESEARCH PROJECTS IN GLACIOLOGY

INTRODUCTION

Three annual catalogues of glaciological projects sponsored by the Federal Government have been published during the last four years. This is the fourth report in this series and it is similar in scope to the last report which dealt with the projects in the Inland Waters Branch. It comprises the glaciology projects in the Water Resources Branch, Inland Waters Directorate, Department of the Environment. I wish to emphasize that the projects sponsored by the Department of Energy, Mines and Resources, the Department of National Defence, the National Research Council, and by other Branches of the Department of the Environment are not included.

Glaciology and the Department of the Environment

Last year's report covered the glaciological studies in the Inland Waters Branch, Department of the Environment. Internal reorganization within the Department resulted in the establishment of the Water Management Service which incorporates the Inland Waters Directorate. The Inland Waters Directorate comprises Water Resources Branch (WRB), Water Quality Branch (WQB), and Water Planning and Management Branch (WPMB).

The Glaciology Division, which consists of the former Glaciology Subdivision and some additional units is part of the Water Resources Branch. Figure 1 shows a simplified organization chart which relates the Division to other parts of the Department. In broad terms it can be said that the Water Resources Branch consists of the former Water Survey of Canada (WSC) and the Glaciology and Groundwater Subdivisions. In contrast to the WSC, the two subdivisions have a strong research orientation and the new structure thus represents a closer coordination of operational and research oriented activities in the water quantity field.

In accordance with the Canada Water Act, the Federal Government has responsibility for "the management of the water resources of Canada including research and planning and implementation of programs

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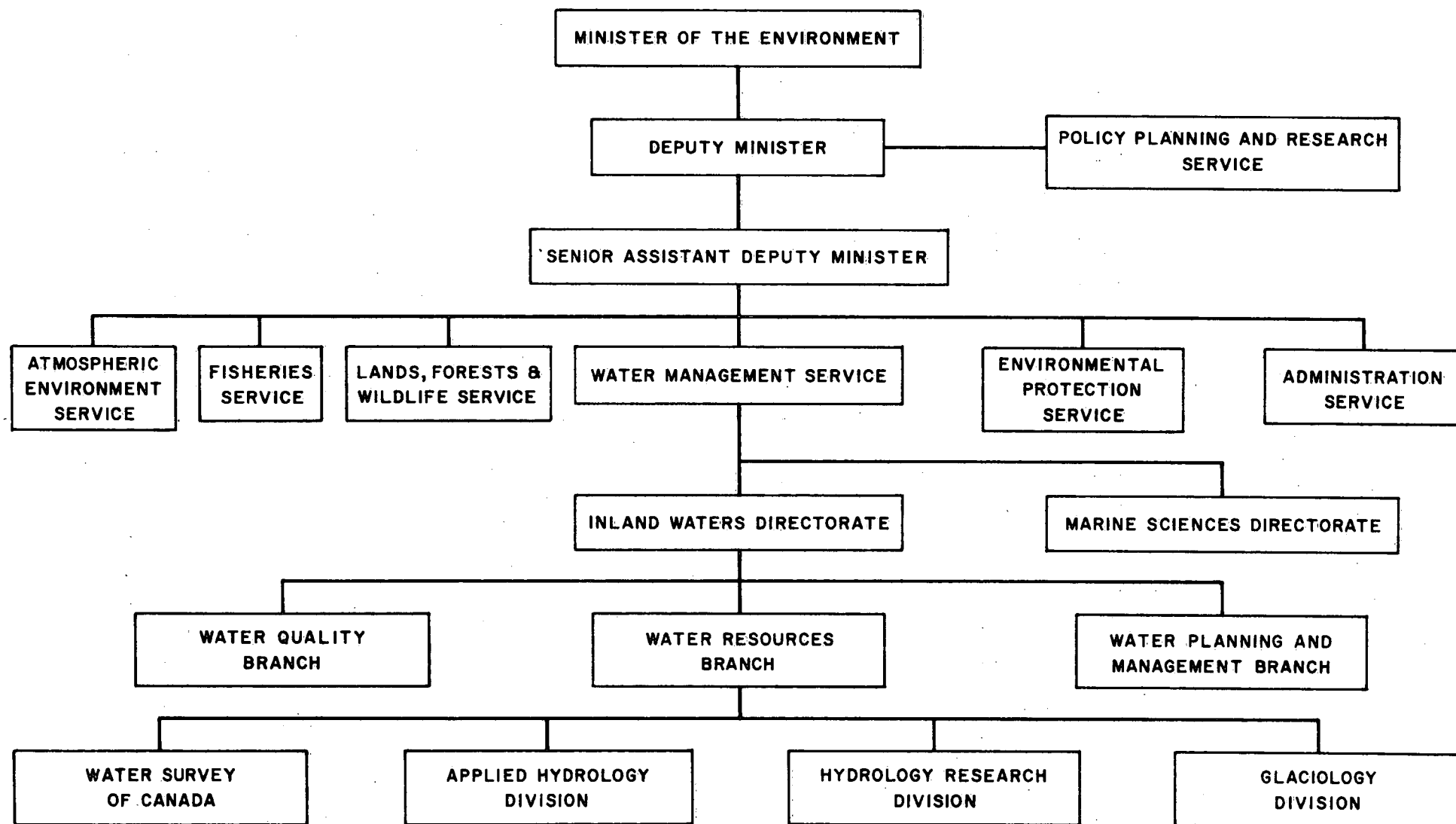


FIGURE 1

relating to the conservation, development and utilization of water resources". At the federal level, the Water Resources Branch provides the technical and scientific information on water quality, which is required by the government in order to discharge its responsibility according to this Act. In a country with a cold climate such as Canada's, this technical and scientific competence naturally encompasses studies in glaciology.

While the major thrust in glaciology lies within the Water Resources Branch, similar and closely related studies are undertaken also by other agencies, e.g., the Water Planning and Management Branch and the Canada Centre for Inland Waters (CCIW), both parts of the Inland Waters Directorate. At CCIW, ice studies will soon develop in the Hydraulics Division, where test facilities will be available in the near future. The Marine Sciences Directorate has the Frozen Sea Research Group which is a major federal agency in sea-ice research.

Outside the Water Management Service, the Ice Division in the Atmospheric Environment Service is responsible for the ice information services for marine and inland waters. Its program is essentially directed towards operational needs, but research is also carried out.

The Glaciology Division

The Division has recently been reorganized into six sections, in contrast to the previous four - Arctic, Cordillera, Glacier Inventory and Ice Science. The reorganization reflects 1) the recognition of the need, after more than four years, to modify the organization in view of the considerable changes in program thrusts; and 2) the addition of new programs and responsibilities.

Figure 2 shows the current organization and the following is a brief review of the functions of the sections.

Arctic Hydrology Section: This section crystallized in connection with the Mackenzie Valley Pipeline Studies sponsored by the Federal Government. Its prime objectives are the studies of 1) river-ice problems connected with possible construction of a pipeline and 2) geomorphological, dendrochronological

GLACIOLOGY DIVISION

Løken, O.H.
Chief

Lytle, D.L.
Secretary

PERENNIAL
SNOW AND ICE

Ommanney, C.S.L., (Head)
Arnold, K.C.
Beck, T.H.M.
Bellaar Spruyt, T.
Christian, D.M.
Clarkson, J.
Fogarasi, S.F.
Holdsworth, G.
Mokievsky-Zubok, O.
Stanley, A.D.
Strome, M.M.

REMOTE SENSING
AND INSTRUMENTATION

Kruus, J., (Head)
Burgess, E.H.
Christie, R.O.
Fish, D.T.
Gross, H.
Maxin, T.W.
Terroux, A.C.D.
Van Duren, J.

ALPINE AND
SNOW HYDROLOGY

Derikx, A.L., (Head)
Loijens, H.S.

I.A. Reid,
Water Survey of Canada

ARCTIC HYDROLOGY

MacKay, D.K., (Head)
Henoch, W.E.S.
Thakur, T. (Postdoctorate Fellow)
Anderson, J.C. (Term appointment)
Anderson, R.J. (Term appointment)
Arsenault, L.E. (Term appointment)
Boakes, M. (Term appointment)
Helpman, E. (Term appointment)
Lindeier, F. (Term appointment)
Sellars, D. (Term appointment)
Swami, K. (Term appointment)

ICE SCIENCE

Jones, S.J., (Head)
Barnett, G.A.
Chen, E.C.
Gilra, N. (Postdoctorate Fellow)

FLOATING ICE

Ramseier, R.O., (Head)
Dickins, D.F.
Weaver, R.

RADIO-ECHO
SOUNDING PROJECT

Goodman, R.H.

Figure 2

and other evidence that can shed light on the hydrologic characteristics of the basin on a long-term basis beyond the period of actual records. While the current emphasis is primarily on the Mackenzie River Basin, the problems in that area are seen in a context of arctic hydrology in general.

Perennial Snow and Ice Section: The glaciers are the focus of attention in this section, and the principle program components are the Glacier Inventory and the Glacier Mass Balance started as part of the Canadian International Hydrological Decade program. The studies of ice deformation and of the calving processes associated with the formation of icebergs are also carried out within this group.

Alpine and Snow Hydrology Section: The snow cover is a major source of runoff in all parts of Canada, particularly in the mountainous regions of Western Canada where snowfall is especially heavy. Processes within the snow cover and in the ground immediately beneath it are of great importance and they are studied in a field-laboratory near Ottawa. These studies contribute to our understanding of the snow cover, the ecological and environmental impact of which is more and more appreciated.

Floating Ice Section: The establishment of this section recognizes the great significance of floating ice and the need for more specific information of its characteristics in terms of formation, physical properties, and behaviour. Emphasis is on the study of ice on freshwater bodies, but some work is done on sea ice since the similarities between fresh and salt water ice are more striking than the differences. The distinction between the two becomes even more indistinct in estuaries.

Ice Science Section: Most glaciological studies include field operations, but detailed studies of the fundamental properties of ice are best carried out in controlled laboratory situations, and this section concentrates on such projects.

Remote Sensing and Instrumentation Section: This section was originally organized in response to the recognized need for technical expertise so that the great variety of instruments used by today's scientists might be serviced and when necessary adapted to extreme cold and harsh conditions. One of the major instrument needs, in a large country like Canada, is for instrumentation suited for isolated remote

locations, hence the broadening of the terms of reference to include remote sensing. The application to hydrology of remote sensing data from airborne and satellite born sensors is an important part of the function of this section.

Radio-Echo Sounding Project: The unique character and requirements of this development are such that it has been retained as a separate unit.

Recent Changes in Research Activities

Any research organization must be flexible and ready to respond to new needs that become apparent as a result of changing priorities and new knowledge. The new projects which have been added reflect both these developments; it is partly a redefinition or change in emphasis within existing projects and partly an addition of completely new projects. The list also reflects an increasing emphasis on contract research which is done by outside groups, thus greatly expanding the range of talent which can actively contribute to our program.

Project G-70-1 - Mackenzie Valley Studies is an example of change in emphasis as it has been greatly expanded after being incorporated under the environmental aspect of the Mackenzie Valley Pipeline Studies of the Federal Government. This expansion has been possible due to the availability of extra funds.

The specifics of the new projects are presented in the catalogue section of this report, but the highlights are given below:

- Iceberg Project, Leffert Glacier (G-72-1) -
is a detailed study of the calving-process and has been separated from G-70-2 as a separate entity.
- Bibliography of Canadian Glaciers (G-72-2) -
was started in order to make available a computerized retrieval system for information about current and past glacier studies in Canada.
- Glaciation Limits, Equilibrium Lines (G-72-3)
- is an extension into the Canadian Arctic

of similar studies done in Western Canada. This type of study is currently being extended to the circumpolar region. The project is done on contract.

- St. Elias Mountain Inventory (G-72-4) - is also carried out on contract. The initiation of this project is most timely as the major part of this area is included in the recently established Kluane National Park, Y.T.
- Aging of Oils on Ice and Snow (G-72-5) - is closely related to the other laboratory studies of oil properties and behaviour in cold environments. The new emphasis stems from the Division's recent participation in a U.S. Coast Guard oil-spill test in Alaska.
- Precipitation Climate, British Columbia (G-72-6) - is a long awaited addition to the glacier mass balance studies in the same area; this study forms an 'up-stream' element of these investigations.
- Mackenzie Basin Morphometry (G-72-7) - is an expansion of what was previously a part of the Mackenzie Valley studies.
- Hydrology of Glacierized Basin (G-72-8) - represents an application to other basins of the results of pilot studies originally done on Peyto Glacier.
- Hydrologic Information from Satellites (G-72-9) and Retransmission of Hydrologic Data (G-72-10) - are closely related and their objective is to investigate potential applications of satellite technology to hydrology. The imminent launch of the Earth Resources Satellite (ERTS) has prompted the initiation of the first of these projects.
- Instrumentation Shop (G-72-11) - was transferred to the Division as part of the recent reorganization.
- Radio Echo Sounding Projects (G-72-12) - represents an updating of an existing project, (G-68-3).

- Growth Mechanisms, River and Lake Ice (G-72-13) and Mechanical Properties, River and Lake Ice (G-72-14) - are closely related to previous projects (G-69-5 and 6) which have now been given sharper focus. Project G-72-13 is part of the Ministry of Transport study of possible extension of the navigation season on the St. Lawrence Seaway, and the project G-72-14 has been changed so that it reflects a specific field program which has been initiated near Kingston, Ontario.
- Sea Ice Ground Truth (G-72-15) - is a project related to remote sensing and at the same time it is an important element of Canada's participation in AIDJEX (Arctic Ice Dynamics Joint Experiment): it is a major study of ice dynamics off Canada's third coast.
- Hydrologic Reconnaissance, Mackinson Inlet (G-72-16) - was initiated so that information might be collected about the hydrologic conditions along a potential pipeline route from the Sverdrup Basin on western Ellesmere and adjacent islands to a possible port site on Mackinson Inlet.
- Hydrology, d'Iberville Basin (G-72-17) - is intimately related to the previous project, as it focuses a freshwater inflow and its influence on the sea-ice regime in a high arctic fiord such as Mackinson Inlet. Carried out on request from the Marine Sciences Directorate, the project emphasizes the close connection between land discharge and the oceanographic conditions in the marine waters into which it flows.

Achievements

The benefits from research projects are often realized only a long time after the research was completed, when the new knowledge resolves sudden problems. It is, therefore, difficult to evaluate our achievements and emphasis must be on the concrete aspects of what has been accomplished.

Our achievements are presented first and foremost in the scientific reports and papers, and

the maps which we have published. These are listed in the following section. Last summer facilities at 562 Booth Street were completed for laboratory studies. We now have four coldrooms, one of which can be cooled to -30°C . With the additional equipment, the range of experiments has been greatly increased. Another concrete achievement is the purchase of a Wild RC-10 aerial camera which is used for research-oriented, special photography in the Canadian Arctic. Excellent cooperation with the Polar Continental Shelf Project, which provides the aircraft, has made this project a very successful venture.

During the preceding years staff members have been called upon to participate in a great variety of committees, working groups, seminars, etc. The objectives of these groups have ranged from providing advice and guidance on technical and scientific matters, organization of scientific conferences to participation in bargaining teams established under the labour relation legislation presently in force. Some of these committees and working groups are national in scope, but many are international in character. This contribution to national and international progress will continue.

June, 1972

O.H. Løken

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- 1971 Glaciology and ice thickness measurements. Potential use for remote sensing. In: Ice Reconnaissance and Glaciology, Report No. 7, Department of Energy, Mines and Resources, Ottawa, Ontario, pp. 30-31.

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- 1971 C.D. Walcott's panoramas of Western Canada. Glacier Inventory Note, No. 5, Inland Waters Branch, Department of the Environment, Ottawa, Ontario, 7 pp.
- 1971 Glacier surveys by district personnel of the Water Survey of Canada, 1. The Victoria Glacier. Glacier Inventory Note, No. 5, Inland Waters Branch, Department of the Environment, Ottawa, Ontario, 18 pp.
- Ramseier, R.O.
- 1971 Formation of primary ice layers. Proceedings of the International Association of Hydraulics Research, Symposium on Ice and its Action on Hydraulic Structures, Reykjavik, Iceland, September, 1971, pp. 311-318.
- 1971 Oil pollution in ice infested waters. Proceedings of the International Symposium on Identification and Measurement of Environmental Pollutants, Ottawa, Ontario, June, 1971, pp. 271-276.
- 378 Oil spill at Deception Bay - Hudson Strait (Preliminary Report). Arctic Circular, Vol. 21, No. 1, pp. 22-27.

Van de Wall Bake, G.W.

- 1971 Stream flow characteristics of the Mistaya River Basin. Internal Report, Inland Waters Branch, Department of the Environment, Ottawa, Ontario, 67 pp.

MAPS

The following index maps for the Glacier Inventory have been published since May 1971. (All at the scale 1:500,000).

2.0	Devon Island	IWB 1146
2.1	Grinnell Peninsula	IWB 1144

2.2	Colin Archer Peninsula	IWB 1145
2.3	South West Devon Island	IWB 1138
2.4	Maxwell Bay	IWB 1136
2.5	Bear Bay	IWB 1140
2.6	Devon Ice Cap - South West	IWB 1143
2.7	Devon Ice Cap - North	IWB 1141
2.8	Devon Ice Cap - South East	IWB 1142
8.8.1	Vancouver Island - South	IWB 1137
8.8.2	Vancouver Island - North	IWB 1139

Catalogue of Projects

Project G-67-1

MASS AND WATER BALANCE MEASUREMENTS
AT PLACE GLACIER

PRINCIPAL INVESTIGATOR: O. Mokievsky-Zubok.

COOPERATING AGENCY: Water Survey of Canada.

OBJECTIVES: Place Glacier is one of five glacier basins in a transect across the Canadian Cordillera selected for long-term investigations to determine the role of glaciers in the hydrologic cycle by:

1. Measuring annual accumulation and ablation
2. Recording meltwater discharge and meteorological data
3. Relating glacier variations to recent climatic trends.

The glacier is one of a worldwide network of glacier basins selected for detailed mass, water and energy balance measurements under the International Hydrological Decade (IHD) program.

LOCATION: Coast Mountains (50° 18' N, 122° 48' W) 120 km north of Vancouver, B.C.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Ground control for compiling a topographic map (scale 1:10,000) was established from 1965 aerial photographs. Glaciological, hydrological and climatological observations have been made each summer since 1965.
2. References: Østrem, G., 1966. Mass balance studies on glaciers in Western Canada. Geographical Bulletin, Vol. 8, No. 1, pp. 81-107.
3. Mokievsky-Zubok, O., 1972. Sentinel Glacier, B.C., Mass balance and its measurements, 1966-1971. M.A. Thesis, Carleton University, 121 pp.
4. Inland Waters Branch, 1967. Relief map of Place Glacier, 1:10,000.

WORK IN PROGRESS: Period of field work May-September annually.

1. Determination of winter balance in late May and continuous measurement of ablation throughout the summer at more than 40 locations on the glacier surface. These locations are surveyed annually to determine surface movement.
2. Determination of daily discharge of meltwater stream by continuous monitoring of stage during the summer period.
3. Maintenance of meteorological records consistent with recommendations by the IHD Committee on mass, water and energy balance studies.

Instrumentation installed at 1,850 m a.s.l.: Automatic precipitation gauge and long-term recorders for temperature, relative humidity, wind run and direction.

The gauging station has been constructed by the Water Survey of Canada to record stream discharge throughout the year.

FUTURE WORK: Continuation of glaciological, hydrological and meteorological observations throughout the decade.

Project G-67-2

DISCHARGE COMPONENTS OF A MELTWATER STREAM FROM
DRAINAGE BASIN OF SENTINEL GLACIER

PRINCIPAL INVESTIGATOR: O. Mokievsky-Zubok.

COOPERATING AGENCY: Water Survey of Canada.

OBJECTIVES: Sentinel Glacier is one of five glacier basins in a transect across the Canadian Cordillera selected for long-term investigations to determine the role of glaciers in the hydrologic cycle by:

1. Evaluating existing techniques of measuring changes in glacier volume and by establishing criteria for direct comparison of these methods - surface measurement of stakes, terrestrial photogrammetry and hydrologic methods.
2. Developing a method of identifying the glacier meltwater component in a stream which includes runoff from unglacierized areas.
3. Relating glacier variations to recent climatic trends. The glacier belongs to the worldwide network of glacier basins selected for detailed mass, water and energy balance measurements under the IHD program.

LOCATION: Coast Mountains (49° 50' N, 122° 55' W) 70 km north of Vancouver, B.C.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Stereoscopic terrestrial photographic surveys for mapping part of the glacier were carried out in 1964, 1966 and 1968 by the Water Survey of Canada (see Project G-67-16).

Ground control for compiling a map of the whole glacier (scale 1:10,000) was established from 1965 aerial photography. Standard glaciological measurements of mass balance and hydrological and meteorological observations were obtained each summer in 1966, 1967 and 1968.

2. References: Mokievsky-Zubok, O., 1972. Sentinel Glacier, B.C., Mass balance and its measurements, 1966-1971. M.A. Thesis, Carleton University, 121 pp.

WORK IN PROGRESS:

1. Surface measurements along longitudinal and transverse profiles to establish the winter balance in late May, and measurements at 33 locations on the glacier's surface to obtain summer balance and ablation.
2. Meltwater discharge measured within the main meltwater channel using a Stevens A-35 stage recorder located at 1,500 m a.s.l. The rating curve is re-established each year.
3. Meteorological observations are taken for the periods May-October. Instrumentation installed at 1,540 m a.s.l. includes:

*Thermohygrograph	Solarimeter
*Totalizing Anemometer	MSC Precipitation Gauge
Sunshine Recorder	

Seven precipitation gauges have been located throughout the basin and a thermohygrograph set at 1,900 m a.s.l.

*The first two instruments have been replaced by long-term recorders.

4. Terrestrial photogrammetry of the ablation area was repeated during August 1970 by the Water Survey of Canada.

FUTURE WORK:

1. Continuation of all glaciological, hydrological and meteorological observations.
2. Study of hydrology and sediment transport of the meltwater stream.

Project G-67-3

MASS AND WATER BALANCE MEASUREMENTS
AT WOOLSEY GLACIER

PRINCIPAL INVESTIGATOR: A.D. Stanley.

COOPERATING AGENCY: Water Survey of Canada.

OBJECTIVES: Woolsey Glacier is one of five glacier basins in a transect across the Canadian Cordillera selected for long-term investigations to determine the role of glaciers in the hydrologic cycle by:

1. Measuring accumulation and ablation.
2. Recording meltwater discharge and meteorological data.
3. Relating glacier variations to recent climatic trends.

The glacier belongs to the worldwide network of glacier basins selected for detailed mass, water and energy balance measurements under the IHD program.

LOCATION: Selkirk Mountains (50° 00' N, 118° 13' W) 15 km northeast of Revelstoke, B.C.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Ground control for compiling a topographic map (scale 1:10,000) was established from 1965 aerial photography. Glaciological, hydrological and climatological observations have been made each summer since 1965.

2. References: Østrem, G., 1966. Mass balance studies on glaciers in Western Canada, 1965. Geographical Bulletin, Vol. 8, No. 1, pp. 81-107.

Inland Waters Branch, 1968. Coloured Relief Map of Woolsey Glacier, 1:10,000.

Stanley, A.D., 1971. Combined balance studies of selected glacier basins in Canada. In: Glaciers, Proceedings of

Workshop Seminar, Vancouver, B.C., 1970, Canadian National Committee for the International Hydrological Decade, pp. 5-10.

WORK IN PROGRESS:

1. Measurement of winter balance in mid-May and continuous study of ablation throughout the summer at more than 37 locations on the glacier surface.
2. Determination of daily discharge of the meltwater stream at the lake outflow during the period June-October using a Stevens A-35 recorder.
3. Maintenance of meteorological records June-October. Instrumentation installed at 1,990 m a.s.l. includes an automatic precipitation gauge and long-term recorders for temperature and relative humidity.

FUTURE WORK: Continuation of mass balance and water balance measurements until the end of the decade.

Project G-67-4

MASS AND WATER BALANCE MEASUREMENTS
AT PEYTO GLACIER

PRINCIPAL INVESTIGATOR: A.D. Stanley.

COOPERATING AGENCY: Water Survey of Canada.

OBJECTIVES: Peyto Glacier is one of five glacier basins in a transect across the Canadian Cordillera selected for long-term investigations to determine the role of glaciers in the hydrologic cycle by:

1. Measuring accumulation and ablation.
2. Recording meltwater discharge and meteorological data.

The glacier belongs to the worldwide network of glacier basins selected for detailed mass, water and energy balance measurements under the IHD program.

LOCATION: Rocky Mountains (51° 40' N, 116° 34' W) 45 km northwest of Lake Louise, Alberta.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Preparation of a base map (scale 1:10,000) from aerial photographs taken in August 1966. Standard surface measurements of glacier mass balance have been obtained each summer since 1965 and measurement of stream discharge since 1966. Meteorological observations were obtained during summer months.
2. References: Østrem, G., 1966. Mass balance studies on glaciers in Western Canada, 1965. Geographical Bulletin, Vol. 8, No. 1, pp. 81-107.

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Goodison, B., 1971. The relation between ablation and global radiation over Peyto Glacier, Alberta. In: Glaciers, Proceedings of Workshop Seminar, Vancouver, B.C., 1970. Canadian National Committee for the International Hydrological Decade, pp. 39-42.

Stanley, A.D., 1971. Combined balance studies of selected glacier basins in Canada. In: Glaciers, Proceedings of Workshop Seminar, Vancouver, B.C., 1970, Canadian National Committee for the International Hydrological Decade, pp. 5-10.

Young, G., 1971. Mass balance measurements related to surface geometry on Peyto Glacier, Alberta. In: Glaciers, Proceedings of Workshop Seminar, Vancouver, B.C., 1970. Canadian National Committee for the International Hydrological Decade, pp. 11-20.

Goodison, B., 1972. The distribution of global radiation over Peyto Glacier, Alberta, Part 1 of final report. Inland Waters Directorate, Department of the Environment, Ottawa, Scientific Report (in press).

Goodison, B., 1972. A statistical analysis of climate and runoff events for Peyto Glacier, Alberta, Part 2 of final report. Inland Waters Directorate, Department of the Environment, Ottawa, Scientific Report, (in press).

WORK IN PROGRESS:

1. Determination of winter balance in late May and continuous measurement of summer balance and ablation throughout the summer at more than 38 locations on the glacier surface. These locations are surveyed annually to determine surface movement.
2. Determination of meltwater discharge by continuous monitoring of stage and measurements of flow using a fluorometric technique.
3. Maintenance of meteorological records consistent with recommendations of the IHD Committee on mass, water and energy balance studies. Instrumentation installed each summer at 1,900 m a.s.l. includes: sunshine recorder, solarimeter, rain gauge and long-term recorders for temperature, relative humidity, wind run and direction.

Other instruments include seven precipitation gauges throughout the basin and a Stevens A-35 recorder in the meltwater channel. Thermographs were installed in the basin.

4. During the summer, 1971, a detailed study of the energy balance at stake 40 was completed by S. Munro, University of Toronto. This will be used to evaluate energy balance models based upon physical parameters of the basin.

FUTURE WORK: Continuation of all glaciological, hydrological and meteorological observations and calculation of mass and water balance for the duration of the decade.

Project G-67-5

MASS AND WATER BALANCE MEASUREMENTS
AT RAM RIVER GLACIER

PRINCIPAL INVESTIGATOR: A.D. Stanley.

COOPERATING AGENCY: Water Survey of Canada.

OBJECTIVES: Ram River Glacier is one of five glacier basins in a transect across the Canadian Cordillera selected for long-term investigations to determine the role of glaciers in the hydrologic cycle by:

1. Measuring accumulation and ablation.
2. Recording meltwater discharge and meteorological data.

The glacier belongs to the worldwide network of glacier basins selected for detailed mass, water and energy balance measurements under the IHD program.

LOCATION: Rocky Mountain (51° 51' N, 116° 12' W) 45 km north of Lake Louise, Alta.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Ground control for compiling a topographic map (scale 1:10,000) was established from 1965 aerial photography. Glaciological, hydrological and climatological observations have been made each summer since 1965.
2. References: Inland Waters Branch, 1967. Coloured Relief Map of Ram Glacier, 1:10,000.

Østrem, G., 1966. Mass balance studies on glaciers in Western Canada, 1965. Geographical Bulletin, Vol. 8, No. 1, pp. 81-107.

Stanley, A.D., 1971. Combined balance studies of selected glacier basins in Canada. In: Glaciers, Proceedings of Workshop Seminar, Vancouver, B.C., 1970, Canadian National Committee for the International Hydrological Decade, pp. 5 - 10.

WORK IN PROGRESS:

1. Determination of winter balance in late May and continuous measurement of ablation throughout the summer at more than 20 locations on the glacier surface. These locations are surveyed annually to determine surface movement.
2. Determination of the discharge of the meltwater stream for period June-late September using a Stevens A-35 recorder.
3. Maintenance of meteorological records for period June-late September. Instrumentation installed at 2,550 m a.s.l. includes an automatic precipitation gauge and long-term recorders for temperature, relative humidity, wind run and direction.

FUTURE WORK: Continuation of all glaciological, hydrological and meteorological observations during the decade.

Project G-67-6

GLACIOLOGICAL INVESTIGATIONS IN THE AREA
OF BERENDON GLACIER

PRINCIPAL INVESTIGATOR: A.D. Stanley.

COOPERATING AGENCY: Granduc Operating Company Ltd.

OBJECTIVES: The Berendon Glacier was selected for long-term investigations to complement existing IHD programs to determine the role of glaciers in the hydrologic cycle. Incorporated in the overall program are a number of specific objectives:

1. Evaluation of an existing theory that predicts the behaviour of glaciers from the simple parameters of mass balance, surface movement and ice depth data.
2. Determination of a simple model that will require only a minimum of annual observations to predict changes in surface velocity and terminus position that may be hazardous to large-scale mining operation.
3. To contribute to the existing IHD network of glacier studies. Berendon Glacier forms part of the N-S chain of glacier basins that extends from Alaska to South America.

LOCATION: Coast Mountains (56° 15' N, 130° 10' W) 35 km north of Stewart, B.C.

PREVIOUS WORK ON THIS PROJECT:

1. Field: In 1956-1957, an expedition to the Salmon Glacier area to make seismic, gravimetric, glaciological and photogrammetric studies was undertaken by the National Research Council and the University of Toronto. Since 1960, the Granduc Mining Company has been active in the area and since 1965, under the supervision of Dr. W.H. Mathews of the University of British Columbia, some velocity data has become available for the Berendon, North Leduc and Frank Mackie glaciers.

Studies by the Cordillera Section begin in late 1967 and include surface measurements of the mass balance, daily discharge measurements of the stream below the lake and meteorological observations from late May to early October.

2. References: Derikx, A.L. and Loijen, H., 1971. Model of runoff from glaciers. In: Runoff from Snow and Ice, Symposium No. 8, National Research Council Associate Committee on Geodesy and Geophysics, Subcommittee on Hydrology, Quebec City, May 1971, pp. 153 - 199.

Fisher, D.A. and Jones, S.J., 1971. The possible future behaviour of Berendon Glacier, Canada - A further study. Journal of Glaciology, Vol. 10, No. 58, pp. 85 - 92.

WORK IN PROGRESS:

1. Standard glaciological surface measurements are being made to determine the winter accumulation in mid-May and observations of ablation throughout the summer at more than 40 locations.
2. To survey each location for glacier movement, a series of five permanent stations were established about the glacier in 1967, and others have been added in later years.
3. A stream gauge was installed in August 1967 and rating curves and stage records obtained.
4. Meteorological parameters were obtained during the summer at one main site near the glacier terminus. Instruments installed at 630 m a.s.l. now include: sunshine recorder, actinograph, automatic precipitation gauge, and long-term recorders of temperature, relative humidity, wind run and direction.

FUTURE WORK:

1. Continuation of glaciological, hydrological and meteorological program during the decade.
2. Measurement of glacier depths for selected longitudinal and transverse profiles using a radio-echo sounder.

Project G-67-7

GLACIER SURGES

PRINCIPAL INVESTIGATOR: A.D. Stanley.

COOPERATING AGENCIES: Surveys and Mapping Branch; Polar Continental Shelf Project; Icefield Ranges Research Project, (Arctic Institute of North America and American Geographical Society).

OBJECTIVES: To obtain information on glacier surges from maps, air photos, description of surges, etc. to evaluate existing theories as to their causes.

LOCATION: Ottawa, and Steele and Fox glaciers, Icefield Ranges, Yukon.

PREVIOUS WORK ON THIS PROJECT:

1. Field: An extensive photographic record of Steele Glacier is available due to the effort of Dr. W. Wood, Icefield Ranges Research Project, Working Group on Steele Glacier and others who have worked in the area since the 1920's.

In the summers of 1967 and 1968, the Glaciology Subdivision measured the meltwater discharge of the glacier basin. 'Fox' Glacier is considered to be in a pre-surge condition.
2. Office: Participation in the Working Group established to coordinate map requirements.
3. References: Faber, T. 'Fox' Glacier basin, Yukon Territory, Canada. Results of the 1968 hydrological field work. Paper presented at the Symposium on Hydrology of Glaciers, Cambridge, England, (in press).

Stanley, A.D., 1969. Observations of the surge of Steele Glacier, Yukon Territory, Canada. Canadian Journal of Earth Sciences, Vol. 6, pp. 819-830.

WORK IN PROGRESS: No progress during 1971.

FUTURE WORK:

1. In cooperation with other groups - to obtain further information on the final stages of the surge - including aerial photographs and surface measurements.
2. Measurement of ice depths along the longitudinal profile, using a radio-echo sounding unit.
3. Measurement of the stream discharge from the 'Fox' Glacier basin during the 'anticipated' surge.

Project G-67-8

PEYTO GLACIER AREA MAP

PRINCIPAL INVESTIGATOR: W.E.S. Henocho.

COOPERATING AGENCIES: Surveys and Mapping Branch; National and Historic Parks Branch, (Department of Indian Affairs and Northern Development).

OBJECTIVES: To prepare a detailed multicoloured map of the Peyto Glacier area (scale 1:10,000) with marginal notes about the local environment to:

1. Determine the feasibility of using sophisticated cartographic techniques to portray a glacier in an Alpine environment.
2. Promote more extensive use of maps among the general public and to provide information for park visitors.

LOCATION: Peyto Glacier (51° 40' N, 116° 34' W) in the Rocky Mountains 45 km northwest of Lake Louise, Alberta.

PREVIOUS WORK ON THIS PROJECT: Peyto Glacier has been shown on all topographic maps compiled at scales of 50,000 and smaller by the Surveys and Mapping Branch. The 'Water Resources' group compiled maps of the terminal area for a number of years between 1945 and 1960, and in 1966 aerial photographs were obtained so that the Surveys and Mapping Branch could compile a detailed map of the area (scale 1:10,000).

Reference: Henocho, W.E.S., 1970. Peyto Glacier Map 1:10,000; Sedgwick, J.K. and Henocho, W.E.S. Interpretive notes and map. English and French Edition, 1970. (Preliminary edition.)

WORK IN PROGRESS: Map with bedrock portrayed is now being prepared by a draftsman of the Inland Waters Branch, at the facilities of the Topographical Survey of Switzerland. A final map will be prepared in cooperation with the Surveys and Mapping Branch, Energy, Mines and Resources.

Project G-67-11

BARNES ICE CAP STUDIES

PRINCIPAL INVESTIGATOR: G. Holdsworth.

COOPERATING AGENCIES: Surveys and Mapping Branch, Geodetic Survey,
University of Minnesota.

OBJECTIVES: Measurements will be continued on the Barnes Ice Cap as part of a long-term (10 year) survey begun in 1962 by Løken (1965, 1966 and 1967). Local investigations at and near the margins of the ice cap will be made to study the mode of flow of the marginal ice and the processes occurring there. Later, deeper information will be obtained by drilling. A second-order survey of pole arrays, extending from the summit of the south dome to the NE margin of the south lobe, will be remeasured yearly up until at least 1974 for purposes of establishing the flow regime and net balance of the region of greatest accumulation.

LOCATION: Baffin Island, N.W.T. (73° W, 70° N).

PREVIOUS WORK ON THIS PROJECT:

1. Field: The first glaciological investigations of the Barnes Ice Cap were made by the Arctic Institute Expedition in 1950 (Baird, 1950). In 1962, studies of mass balance, glacier meteorology, the hydrology of a meltwater stream and terminal moraines were started on the northern part of the ice cap. Up to 1969 the program was an expansion of the original program to cover the whole ice cap and to give increased emphasis to glaciological aspects. In 1970 and 1971 measurements of strain rate and velocity were made on the south dome. Ice depths were determined with the 30 MHz echo sounder by S.J. Jones at accurately known points.
2. References: Anonymous, 1967. Hydrology of the Lewis Glacier. Geographical Bulletin, Vol. 9, No. 3, pp. 232-261.

Baird, P.D., 1950. Baffin Island Expedition 1950, a preliminary report. Arctic, Vol. 3, No. 3, pp. 131-149.

Løken, O.H., 1965, 1966 and 1967. Field Reports, North-Central Baffin Island. Geographical Branch, (Mim).

Løken, O.H., and Andrews, J.T., 1966. Glaciology and chronology of fluctuations of the ice margin at the south end of the Barnes Ice Cap, Baffin Island, N.W.T. Geographical Bulletin, Vol. 8, No. 4, pp. 341-349.

Løken, O.H., and Sagar, R.B., 1968. Mass balance observations on the Barnes Ice Cap, Baffin Island, Canada. International Association of Scientific Hydrology Publication No. 79, pp. 282-291.

Løken, O.H., 1969. Evidence of surges on the Barnes Ice Cap, Baffin Island. Canadian Journal of Earth Sciences, Vol. 6, No. 4, pp. 899-901.

Holdsworth, G. and McLaren, P., 1971. Proglacial lake studies, Generator Lake, Baffin Island, N.W.T. Arctic Circular, Vol. 21, No. 3, pp. 164-175.

WORK IN PROGRESS:

1. An assessment of mass balance for the ice cap up to 1969 is being made. Local mass balance and flow regime data for 1970 and 1971 will be prepared.
2. Ice depth measurements have been made (Jones, S.J., 1970) by radio-echo sounder for the survey network from the South Dome to the margin and results are available.
3. Surface movement and surface strain rate are being measured on the southern part of the ice cap. (next resurvey 1973 or 1974). Near the margin, surface deformation is related to the character of the ice margin. Factors controlling the type of margin and hence the marginal mode of flow are being studied. Two localities are undergoing detailed study; one is the margin which flows into Generator Lake; the other is a land-based margin with and without shear moraine development. The latter is being studied by Professor R. LeB. Hooke, University of Minnesota.
4. Temperatures profiles to 10 m and 20 m depth in the ice cap (divide and margins have been measured) (1970, 1971). These are being analyzed by R. Hooke.

FUTURE WORK:

1. R. Hooke plans to complete his marginal studies of shear moraines by deformations and structured measurements (summer 1972).
2. Drilling through the south dome area is planned for summer 1973 or 1974 and associated core and borehole investigations would start when the holes are completed. (R. Hooke, University of Minnesota). A deep self-drilling remote probe for measuring basal temperatures could be ready by 1974 or 1975. (either Barnes Ice Cap or Ellesmere Island or both).
3. Additional ice depths and experiments dealing with the attenuation of signal with depth and position using the 30 MHz radio echo-sounder (S. Jones, 1973 or 1974).
4. 30 m temperatures are to be studied in additional drill holes. (Holdsworth or Hooke, 1973, 1974).
5. Accumulation of data (temperature, deformation and depth) to enable a generalized flow law to be determined for the ice cap, and a more precise net balance to be established for a part of the south dome.

Project G-67-13

DECADE GLACIER STUDIES

PRINCIPAL INVESTIGATOR: A.D. Stanley.

COOPERATING AGENCY: None.

OBJECTIVES: To study the mass, water and energy balance of a small well defined glacier basin in an Arctic environment, in order to determine the role of glaciers in the hydrologic cycle by:

1. Measuring accumulation and ablation;
2. Recording meltwater discharge and meteorological data;
3. Relating glacier variations to recent climatic trends;
4. Comparing glacier runoff to the regime of an adjacent unglaciated basin.

The glacier belongs to the worldwide network of glacier basins selected for detailed mass, water and energy balance measurements under the International Hydrological Decade program.

LOCATION: Central Baffin Island (69° 38' N, 69° 48' W), 70 km southwest of Clyde River, N.W.T.

PREVIOUS WORK DONE:

1. Field: Winter accumulation measurements in May-June of each year since 1965. Summer discharge of meltwater stream measured each year since 1965. During summer of 1965, 1966, 1967, 1968, 1969 and 1970, meteorological records were kept at 960 m a.s.l.
 - concurrent discharge records of the two rivers were taken;
 - stakes have been surveyed for movement studies and three profiles were leveled across the glacier to determine changes in surface elevation;
 - extent, amount and profiles of aufeis formations of two basins.

2. References: Løken, O.H., 1965, 1966, 1967. Field Reports, North-Central Baffin Island. Geographical Branch, (Mim.).

Østrem, G., Bridge, C.S. and Rannie, W.F., 1967. Glacio-hydrology, discharge and sediment transport in the Decade Glacier area, Baffin Island, N.W.T., Geografiska Annaler, Vol. 49, pp. 268-282.

Surveys and Mapping Branch, E.M.R., 1965. Decade Glacier Base Map, 1:10,000.

WORK IN PROGRESS:

1. Continuation of data reduction for all glaciological, hydrological and meteorological observations.
2. Investigation of the use of special forms and surfaces as markers in the stratigraphic column of a glacier, to trace the areal extent and annual variation of mass balance.
3. Study of the lake, permafrost, groundwater and aufeis system of two river basins.

FUTURE WORK:

1. Continuation of spring and fall surveys.
2. Installation of long-term meteorological recorders for all year operation.

Project G-67-14

PER ARDUA GLACIER STUDIES

PRINCIPAL INVESTIGATOR: A.D. Stanley.

COOPERATING AGENCY: Defence Research Board.

OBJECTIVES: To investigate the mass and energy balance of a small, well-defined glacier in a high-Arctic environment and study the role of glaciers in the hydrologic cycle by:

1. Measurement of mass balance.
2. Relating glacier variations to recent climatic trends.

The mass balance data are related to surface movement determined each year by terrestrial photogrammetry.

LOCATION: At head of Tanquary Fiord, Ellesmere Island (76° 35' W, 81° 32' N) 240 km northeast of Eureka, N.W.T.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Glacier was originally selected by Geophysics Section, Defence Research Board and field work was started in 1964, then taken over by the Glaciology Subdivision in 1968 as an International Hydrological Decade project.
2. Reference: Hattersley-Smith, G., 1967. Operation Tanquary preliminary report, 1964. Defence Research Board, Directorate of Physical Research, Geophysics Section, Hazen 25, 50 pp.

WORK IN PROGRESS: Continuation of mass balance, movement and stratigraphic studies.

FUTURE WORK:

1. Installation of instrumentation for summer discharge measurements.

2. Installation of long period recording equipment.
3. Investigation of detailed studies of snow and firn metamorphosis in a high-Arctic environment.
4. Measurement of glacier thickness.

Project G-67-15

GLACIER INVENTORY

PRINCIPAL INVESTIGATOR: C.S.L. Ommanney.

COOPERATING AGENCY: None.

OBJECTIVES:

1. To prepare an inventory of perennial ice and snow masses on and beneath the land surfaces as part of the Canadian IHD program.
2. To develop computer programs for the storage, analysis and reduction of inventory data.
3. To investigate on the basis of the collected data the factors that influence the geographical distribution and types of ice masses and the role of perennial ice in the Canadian water balance.

LOCATION: Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT:

1. Office: Two pilot studies were completed for the UNESCO Guide to the Inventory of Perennial Ice and Snow Masses. Glacier inventories of Axel Heiberg Island and Vancouver Island have been completed. All glaciers on Baffin, Bylot and Devon islands have been indexed. Inventory work maps for all glaciers between Waterton Lakes and the Columbia Icefield have been prepared as well as for part of the Columbia River headwaters.

A computer program for obtaining totals, averages, weighted averages and histograms from the basic inventory data has been developed.

2. References: Müller, F., Ommanney, C.S.L., and Stanley, A.D., 1967. Three Pilot Studies for the IHD World Inventory of Glaciers. Paper presented at the International Association of Scientific Hydrology General Assembly, Bern, 1967.

Ommanney, C.S.L., 1968. An assessment of the ice masses of Axel Heiberg Island, N.W.T.: a study in glacier inventory, M.Sc. thesis, McGill University, 183 pp.

Ommanney, C.S.L., Goodman, R.H. and Müller, F., 1969. Computer analysis of a glacier inventory of Axel Heiberg Island: Canadian Arctic Archipelago. International Association of Scientific Hydrology Bulletin, Vol. 14, No. 1, pp. 19-28.

Ommanney, C.S.L., 1969. The ice masses of Axel Heiberg Island, Canadian Arctic Archipelago: a study in glacier inventory. Axel Heiberg Island Research Reports, Glaciology, No. 3, McGill University, Montreal, 105 pp.

Ommanney, C.S.L., 1969. Glacier Inventory of Canada: Axel Heiberg Island, N.W.T. Inland Waters Branch Technical Bulletin No. 37, Department of Energy, Mines and Resources, Ottawa, 97 pp.

Ommanney, C.S.L., 1970. A pilot study for an inventory of the glaciers of the high Arctic. Glacier inventory of Steacie Ice Cap area (70° N, 90° W), Axel Heiberg Island, N.W.T. In: Perennial Ice and Snow Masses, UNESCO/IASH Technical Papers in Hydrology No. 1, A.2486, pp. 25-35. (I.W.B. Reprint Series No. 102).

Ommanney, C.S.L., 1970. A national inventory of glaciers. Park News, October, pp. 15-20 (I.W.B. Reprint Series No. 93).

Stanley, A.D., 1970. Inventory of glaciers in the Waputik Mountains; a pilot study for an inventory of the glaciers in the Rocky Mountains. In: Perennial Ice and Snow Masses, UNESCO/IASH Technical Papers in Hydrology No. 1, A.2486, pp. 36-46.

Ommanney, C.S.L., 1971. The Canadian Glacier Inventory. In: Glaciers Proceedings of Workshop Seminar, 1970, Vancouver, B.C., Canadian National Committee for the International Hydrological Decade, pp. 23-30.

Müller F. and Ommanney, C.S.L., 1971. The contribution of glacier ice to the world water balance; (a Status Report on the World Glacier Inventory). Symposium on the World Water Balance. Reading, 1970, Vol. 3. International Association of Scientific Hydrology, Publication No. 94, pp. 6-20 (I.W.B. Reprint Series No. 102).

Ommanney, C.S.L., Clarkson, J. and Strome, M.M., 1971. Information booklet for the inventory of Canadian glaciers.

Glacier Inventory Note 4, Inland Waters Branch, Department of Energy, Mines and Resources, Ottawa, 68 pp.

Ommanney, C.S.L., 1971. A program to identify and measure all the glaciers in Canada. Arctic Circular, Vol. 22, No. 2, pp. 90-97.

WORK IN PROGRESS:

1. Inventory work maps for glaciers in the headwaters of the Columbia and Kootenay rivers systems are being prepared.
2. Using a D-Mac pencil follower interfaced with a PDP 8/I computer, location, length, area and elevation data on all glaciers in the Nelson River system is being digitized from the work maps.
3. A report on the glacier inventory of Vancouver Island is being prepared.
4. Modifications are still being made to the computer program for the analysis of inventory data.

FUTURE WORK:

1. Short-term: To complete the glacier inventory of all glacierized areas in Canada mapped at a scale of 1:50,000 or better.

To compile data sheets for the remaining glaciers in Canada showing orientation, location and existing photo coverage, in conjunction with Projects G-69-1 and G-69-2.

Further testing and modifications to existing computer programs.

2. Long-term: Completion of all glacier inventory measurements for the remaining glacierized areas.

Publication of detailed glacier inventory reports in line with approved international standards.

Refinement of computer programs for detailed analysis of data, the drawing of trend surfaces and for map printouts of glaciological data.

To extend the inventory to include ground ice.

Project G-67-16

DETERMINATION OF ICE ABLATION BY
TERRESTRIAL PHOTOGRAMMETRY

PRINCIPAL INVESTIGATOR: K.C. Arnold.

COOPERATING AGENCY: McGill University, Polar Continental Shelf
Project, Department of Energy, Mines and Resources.

OBJECTIVES: To measure ice ablation by photogrammetric methods which
have an accuracy of approximately \pm 10 cm in order to:

1. Examine criteria by which ablation stakes should be distributed over a surface with respect to parameters that influence ablation, with special reference to albedo.
2. Develop an economic data gathering system.
3. Examine some criteria by which benchmark glaciers may be selected, with special reference to those in Arctic Canada.

LOCATION: White Glacier, Axel Heiberg Island (79° 28' N, 90° 45' W), N.W.T.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Terrestrial photography of Peyto Glacier, Alberta, in 1966, 1967 and 1968.

Terrestrial photography of Per Ardua Glacier, Ellesmere Island, 1964, (Faig, University of New Brunswick), 1966, (September), 1967, (June and September), and 1968, (close of season).

Meighen Ice Cap, aerial photography, 1960, repeated in 1971.

2. References: Arnold, K.C., 1966. The glaciological maps of Meighen Island, N.W.T. Canadian Journal of Earth Sciences, Vol. 3, No. 6, pp. 903-908.

Arnold, K.C., 1968. Determination of changes of surface height, 1957-1967, of the Gilman Glacier, Northern Ellesmere Island, Canada. M.Sc. thesis, McGill University, 74 pp.

WORK IN PROGRESS:

1. Terrestrial photogrammetry is presently used, but other techniques of remote sensing, e.g., aerial photography, may be used later.
2. A detailed field program to test the technique has been developed and was carried out on White Glacier, Axel Heiberg during 1969 and 1970 ablation seasons. The lower part of the glacier, below 500 m, was photographed three times in conjunction with standard ablation measurements on stakes and ice velocity data obtained by members of the Axel Heiberg Expedition. The relatively smaller mass flux typical of Arctic glaciers, should make this a critical test case. The photogrammetric data has been plotted, and computer programmes are being developed to make this technique readily usable in other Arctic areas.

FUTURE WORK:

1. Extension of the methods developed to the accumulation areas of glaciers and ice caps, where stereo-perception is more difficult.
2. Alternative methods of data collection in the accumulation areas of glaciers will be examined.
3. Adaption of the techniques developed to include air photogrammetry.

Project G-67-17

DEFECTS IN ICE CRYSTALS

PRINCIPAL INVESTIGATOR: S.J. Jones.

COOPERATING AGENCIES: None.

OBJECTIVES:

1. Short-term: To determine the density of dislocations and their velocity under stress in pure and impure ice.
2. Long-term: By studying the distribution of defects, in particular dislocations in ice crystals, it is hoped to understand:
 - a) The nature of the flow of ice under stress.
 - b) The underlying reason for the effect that impurities have on the flow of ice (see G-68-1).
 - c) The role of dislocations in the formation of ice.

LOCATION: Ice Science Laboratory, 562 Booth Street, Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT: The first results of this work have been published:

Jones, S.J., 1970. X-ray topographic evidence for prismatic dislocation in ice. Journal of Applied Physics, Vol. 41, No. 6, pp. 2738-2739.

Jones, S.J. and Gilra, N.K., 1972. Increase of dislocation density in ice by dissolved hydrogen fluoride. Applied Physics Letters, Vol. 20, No. 8, pp. 319-320.

WORK IN PROGRESS: Equipment is being designed that will enable the samples to be stressed while on the X-ray apparatus. The effect of dissolved hydrogen fluoride has been investigated (see publication above), and preliminary results on the effect of stress have been obtained.

FUTURE WORK:

1. The collection of results will continue to improve the quality of the topographs. Topographs will then be taken before and after stressing the crystal.
2. The effect of impurities on the dislocation velocity will be examined in conjunction with G-68-1.
3. Natural ice will be examined to see what information can be obtained about its history from a study of the topographs.

Project G-67-18

COMPUTER APPLICATIONS TO GLACIER FLOW:
BERENDON GLACIER, B.C.

PRINCIPAL INVESTIGATOR: S.J. Jones.

COOPERATING AGENCY: None.

OBJECTIVES: To repeat some earlier calculations using much better data collected by the Subdivision in order to see what effect this would have on the predicted behaviour of Berendon Glacier.

LOCATION: Berendon Glacier, B.C. (lat. $56^{\circ} 15' N$, long. $130^{\circ} 05' W$).

PREVIOUS WORK ON THIS PROJECT:

1. References: Fisher, D.A. and Jones, S.J. 1971. The possible future behaviour of Berendon Glacier, British Columbia - a further study. Journal of Glaciology, Vol. 10, No. 58, pp. 85-92.

Untersteiner, N. and Nye, J.F., (1968). Computations of the possible future behaviour of Berendon Glacier, Canada. Journal of Glaciology, Vol. 7, No. 50, pp. 205-213.

WORK IN PROGRESS: None.

FUTURE WORK: It is anticipated that the calculations will be repeated in about 1974 when another four years data will be available.

Project G-67-19

DRAINAGE BENEATH THE SALMON GLACIER-HYDROLOGIC STUDIES
SUMMIT LAKE

PRINCIPAL INVESTIGATOR: D. Fisher.

COOPERATING AGENCY: U.S. Water Resources Group, Alaska.

PUBLICATION: Fisher, D.A. Subglacial leakage of Summit Lake, British Columbia; by dye determination. Union Géodésique et Géophysique Internationale. Association Internationale d'Hydrologie Scientifique. Commission de neiges et Glaces. Symposium on the hydrology of glaciers, Cambridge, 7-13 September, 1969, organized by the Glaciological Society, (in press).

Project Completed

Project G-68-1

MECHANICAL PROPERTIES OF ICE CONTAINING IMPURITIES

PRINCIPAL INVESTIGATOR: S.J. Jones.

COOPERATING AGENCY: None.

OBJECTIVES: To study the effects that impurities have on the mechanical properties of single crystal ice and the practical importance of this to natural conditions.

LOCATION: Ice Science Laboratory, 562 Booth Street, Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT:

1. Laboratory: A study of the effect of HF, NH₃, and NH₄F on the mechanical properties of ice has been made by Glen and Jones (see publications below).
2. References: Glen, J.W., and Jones, S.J., 1967. The deformation of ice single crystals at low temperatures. In: Physics of Snow and Ice, International Conference on Low Temperature Science, Hokkaido University, Japan, 1966, Vol. 1, Part 1, pp. 267-275.

Jones, S.J., 1967. Softening of ice crystals by dissolved fluoride ions. Physics Letters, Vol. 25 A, No. 5, pp. 366-367.

Jones, S.J., and Glen, J.W., 1968. The mechanical properties of single crystals of ice at low temperatures. I.U.G.G. General Assembly, Bern, 1967. International Association of Scientific Hydrology, Publication No. 79, pp. 326-340.

Jones, S.J., and Glen, J.W., 1969. The effect of dissolved impurities on the mechanical properties of ice crystals. Philosophical Magazine, Vol. 19, No. 157, pp. 13-24.

Nakamura, T. and Jones, S.J., 1970. Softening effect of dissolved hydrogen chloride in ice crystals. Scripta Metallurgica, Vol. 4, pp. 123-126.

WORK IN PROGRESS: A report summarizing the work done by a Post-doctoral Fellow, (Dr. T. Nakamura) is being prepared.

FUTURE WORK: None planned for 1972-73.

Project G-68-2

FLUCTUATIONS OF GLACIERS IN THE ROCKY MOUNTAINS

PRINCIPAL INVESTIGATOR: W.E.S. Hensch.

COOPERATING AGENCY: None.

OBJECTIVES: To study secular glacier fluctuations in selected areas of the Rocky Mountains and examine glacier fluctuations, correlation with climatic parameters, river discharge and dendrochronological records.

LOCATION: The Rocky Mountains.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Over the last 20 years, several studies have been completed in the Rocky Mountains including studies of mass balance measurements on glaciers, direct observations of water discharge, a series of geomorphological studies of glacier fluctuations and dendrochronological investigations of glacier retreat. These studies have been undertaken in a number of disciplines and all have some bearing on the hydrology of the area.

2. References: Hensch, W.E.S., 1970. Estimate of glacier secular volumetric change and its contribution to the discharge in the Upper North Saskatchewan River Basin. Journal of Hydrology, Vol. 12, pp. 136-151.

Hensch, W.E.S. and Parker, M.L., 1971. The use of Engelmann Spruce latewood density for dendrochronological purposes. Canadian Journal of Forest Research, Vol. 1, pp. 90-98.

Hensch, W.E.S. Glacier variations. In: Guidebook for the International Symposium on the Role of Snow and Ice in Hydrology, (I.H.D. 1965-74), (in press).

WORK IN PROGRESS: Study of glacier secular fluctuations and the state of contemporary glacier activities will be examined in selected areas peripheral to the major ice masses in the Canadian Cordillera.

FUTURE WORK:

1. Tree ring and glaciological data analysis applied to water resources research.
2. Wood samples collected above the recent elevation of treeline are indicative of the past warmer climate. Several wood samples were collected above treeline in the Peyto Glacier area. They are being analyzed for dendrochronological records. One of these samples dated by C_{14} method yielded the date 2790 ± 170 G.S.C. A number of wood samples collected in the Canadian Cordillera were C_{14} dated and described by several researchers in: Radiocarbon dates No. I to IX, G.S.C. The implication of these dates as to the climatic changes and glacier fluctuations are being examined.
3. Photographic survey of glacier termini in Glacier Lake area, Rugged Range, Mackenzie Mountains, N.W.T. Glacier fluctuations dated by tree ring analysis.

Project G-68-3

RADIO-ECHO SOUNDING PROJECT (RESP)

PRINCIPAL INVESTIGATORS: R.H. Goodman and T. Beck.

Project replaced by G-72-12

Project G-68-4

HYDROLOGY OF GLACIERIZED BASINS

PRINCIPAL INVESTIGATOR: L. Derikx.

Project replaced by G-72-8

Project G-69-1

GLACIER ATLAS OF CANADA

PRINCIPAL INVESTIGATOR: C.S.L. Ommanney.

COOPERATING AGENCY: Surveys and Mapping Branch, Department of Energy, Mines and Resources.

OBJECTIVES: To compile and publish index maps showing the location and identification of every glacier in Canada, as part of the national IHD program for an inventory of perennial ice and snow masses.

LOCATION: Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT: Glacier index maps of Axel Heiberg, Devon, Baffin and Bylot Islands and for the Nelson River drainage area and Vancouver Island have been completed.

WORK IN PROGRESS: All completed maps are being printed. Maps of Ellesmere Island and part of the Columbia River Basin are being compiled.

FUTURE WORK: In conjunction with Project G-67-15, index maps of all glaciers in Canada will be compiled and printed at a scale of 1:500,000 on 11" x 15" sheets. Maps issued individually when completed, will be bound into the inventory reports (Project G-67-15) and, at the termination of the project, will be presented as a Glacier Atlas of Canada.

Project G-69-2

GLACIOLOGICAL ARCHIVE

PRINCIPAL INVESTIGATOR: C.S.L. Ommanney.

COOPERATING AGENCY: American Geographical Society, World Data Centre
A: Glaciology, Seattle.

OBJECTIVES: To develop a glaciological archive, referenced to the glacier index numbers (Project G-69-1), for filing all available information on individual ice masses in Canada in the form of data sheets, maps, photographs, published and unpublished literature.

LOCATION: Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT:

1. Office:

- a) Collection of glacier photographs as an extension of the glacier inventory conducted for the I.G.Y.
- b) Indexing and transferring to stable-base film of photographic records of the International Boundary Commission surveys along the B.C. - Alaska border.
- c) Identification and indexing of early photographs of Baffin, Bylot, Devon and Axel Heiberg islands, obtained during the I.G.Y. in conjunction with Project G-69-1.
- d) Listing of Canadian glacier information in the Royal Geographical Society and the Scott Polar Research Institute.
- e) Identification of glacier photographs held by the Department of Travel Industry in Victoria, British Columbia.

2. References: Ommanney, C.S.L. 1970. Photographs and manuscripts held by the Scott Polar Research Institute, Cambridge, England. Glacier Inventory Note 1, Inland Waters Branch, Department of Energy, Mines and Resources, Ottawa, 8 pp.

Ommanney, C.S.L., 1970. Photographs of glaciers in Western Canada held by the Royal Geographical Society, Kensington

Gore, London. Glacier Inventory Note 2, Inland Waters Branch, Department of Energy, Mines and Resources, Ottawa, 11 pp.

Ommanney, C.S.L., 1971. Photographs of glaciers in British Columbia held by the Film and Photographic Branch, Department of Travel Industry, British Columbia. Glacier Inventory Note 3, Inland Waters Branch, Department of Energy, Mines and Resources, Ottawa, 7 pp.

Ommanney, C.S.L., 1971. C.D. Walcott's panoramas of Western Canada. Glacier Inventory Note 5, Inland Waters Branch, Department of Energy, Mines and Resources, Ottawa, 7 pp.

WORK IN PROGRESS:

1. Continuation of identification, copying and filing of International Boundary Commission photographs of Canadian glaciers in cooperation with Dr. W. O. Field, A.G.S.
2. Development of a cross-referenced file system for identification of all International Boundary Commission photo survey points, in cooperation with Dr. W. O. Field, A.G.S.
3. Identification and indexing of early photographs of Ellesmere Island.

FUTURE WORK:

1. Identification and indexing of all glacier information obtained from Federal, Provincial, Municipal and private sources as well as any obtained from extra Canadian sources.
2. Observation of glaciers with long-term historical records and of those glaciers 'typical' of certain areas as determined from data collected for Project G-67-15.

Project G-69-3

GLACIER MELTWATER CONTRIBUTION TO THE FLOW OF THE
NORTH SASKATCHEWAN RIVER

PRINCIPAL INVESTIGATORS: H.S. Loijens.

COOPERATING AGENCY: None.

OBJECTIVES: To develop a parametric hydrologic model for the quantitative assessment of the glacier meltwater contribution to the flow of the North Saskatchewan River at Saskatchewan Crossing.

LOCATION: North Saskatchewan River headwaters (52° 45' N, 117° 40' W) Banff National Park, Alberta.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Streamflow data from Mistaya River (No. 05DA-7) and North Saskatchewan River (No. 05DA-6) since 1950 (mainly from May - November). Streamflow, mass balance and meteorological observations from Peyto Glacier since 1965 (Project G-67-4).

Snow courses were established in the Mistaya River Basin in 1969 on the east side of the river, maintained in 1970 and three new courses laid out on the west side. Since 1969 three temperature/relative humidity recording stations have been maintained. Additional observations during the summer of 1970 of wind run, precipitation, sunshine and global shortwave radiation. Streamflow, precipitation and glacier ice sampling for tritium analysis. Stream gauging station established in May 1970 in three creeks (Rampart, North Saskatchewan just below glacier and Nigel Creek).

A detailed hydrometric program was carried out in the Mistaya Basin in 1971. Hydrometeorological stations established earlier have been maintained and some added to obtain a better aerial coverage.

2. References: Derikx, A.L. and Loijens, H., 1971. Model of runoff from glaciers. In: Runoff from Snow and Ice,

Symposium No. 8, National Research Council Associate Committee on Geodesy and Geophysics, Subcommittee on Hydrology, Quebec City, May 1971, Vol. 1, pp. 153-199.

Loijens, H.S., 1971. Assessment of glacier melt contribution and stream flow hydrograph synthesis in the North Saskatchewan headwaters, Alberta. Internal Report, Inland Waters Branch, Department of the Environment, Ottawa, 37 pp.

Van de Wall Bake, G.W., 1971. Stream flow characteristics of the Mistaya River basin. Internal Report, Inland Waters Branch, Department of the Environment, Ottawa, 67 pp.

WORK IN PROGRESS:

1. Evaluation of hydrometric data collected in 1971 to assess glacier melt contribution and waterbalance in the Mistaya basin.
2. Stream flow routing Mistaya River.
3. Conceptual basin runoff model is being tested on Marmot Creek research basin data.
4. Snow distribution in the Mistaya Basin.

FUTURE WORK:

1. Collection of field data will be terminated at the end of the 1972 field season.
2. Integration of conceptual basin runoff model, glacier runoff simulation model (project G-68-4) and streamflow routing model into one mathematical computer model for the continuous simulation of streamflow in the Mistaya Basin.
3. Application model to entire North Saskatchewan headwaters and other glacierized drainage basins.
4. Remote sensing techniques to measure snow accumulation.

Project G-69-4

GLACIER CLIMATE RELATIONSHIP ON THE
DEVON ISLAND ICE CAP

PRINCIPAL INVESTIGATOR: O. H. Løken - work done under contract with
A.I.N.A.

COOPERATING AGENCIES: Arctic Institute of North America, McGill
University and Polar Continental Shelf Project.

OBJECTIVES: To study the relationship between glacier variations
and meso-scale synoptic weather patterns over the area.
Particular emphasis is given to the contrasts between the
southeast and northwest sides of the ice cap.

Project temporarily suspended

Project G-69-5

GROWTH MECHANISMS OF RIVER AND LAKE ICE

PRINCIPAL INVESTIGATOR: R.O. Ramseier.

Project replaced by G-72-13

Project G-69-6

MECHANICAL PROPERTIES OF RIVER AND LAKE ICE

PRINCIPAL INVESTIGATOR: R. O. Ramseier.

Project replaced by G-72-14

Project G-69-7

MECHANICAL PROPERTIES OF POLYCRYSTALLINE ICE

PRINCIPAL INVESTIGATORS: S.J. Jones and G. Barnett.

Project combined with G-72-14

Project G-69-8

MASS AND ENERGY TRANSFER IN A SHALLOW SNOWPACK

PRINCIPAL INVESTIGATOR: L. Derikx.

COOPERATING AGENCY: None.

OBJECTIVES:

1. To determine the mechanisms of mass and energy transfer in a shallow snowpack during the period of snow accumulation.
2. To determine the mechanisms of moisture flux in terms of mass transfer properties of the snowpack during the period of snow ablation.
3. To synthesize the results of these studies into mathematical physically-based models and investigate the applicability in hydrologic systems analysis.

LOCATION: Mer Bleue, near Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT:

1. An experimental site at Mer Bleue (Central Experimental Forest) near Ottawa was selected in the spring of 1969 for cooperative investigations of snow melt and associated groundwater recharge by the Glaciology and Groundwater subdivisions (R. Harlan, Project GW-69-2).

2. Instrumentation installed by Glaciology Subdivision:

Mass in and output - standard Canadian snow gauge with Nipher shield

- Fisher and Porter recording precipitation gauge with Alter windshield
- MSC - tipping bucket rain gauge*
- 12-foot snow pillow (Bollay Associates)*
- 6-foot snow pillow (Bollay Associates)*
- snow boards and snow density measuring equipment
- net loss plastic pans
- recording snow melt lysimeter

Energy in and
output

- Thornthwaite wind profile register system*
- Cambridge thermoelectric dew point profile system*
- ventilated air temperature profile system*
- 3 Kipp and Zonen pyranometers*
- 2 C.S.I.R.O. net-allwave radiometers*

Energy and mass
balance

- Troxler two probe gamma density gauge
- snow capacitor (model Howorka and Amback)
- 3 snow temperature thermistor profiles*

* These instruments are connected to a central data acquisition system, located in a heated trailer on the measuring site.

WORK IN PROGRESS:

1. Development of physically-based digital simulation models.
2. Processing and analysis of data.
3. Preparation of paper on energy balance and mass balance aspects of a shallow snowpack.

FUTURE WORK:

1. Continuation, refinement and extension of scientific data collection.
2. Refinement and extension of models.

Project G-69-11

INVESTIGATION OF SURFACE INSTABILITIES ON GLACIERS

PRINCIPAL INVESTIGATOR: G. Holdsworth.

Project terminated.

MACKENZIE VALLEY STUDIES

PRINCIPAL INVESTIGATOR: D.K. MacKay.

COOPERATING AGENCY: University of British Columbia (Dr. J.R. MacKay),
Geological Survey of Canada, Water Survey of Canada.

OBJECTIVES:

To conduct hydrologic - geomorphic studies in the Mackenzie Basin aimed at providing:

1. Information against which the environmental impact of a possible Mackenzie Pipeline can be assessed,
2. Improved knowledge about one of Canada's largest river basins, by investigating:
 - a) Water budget of a tundra-taiga transitional basin, Boot Creek, N.W.T.
 - b) Water budget of a tundra basin, Peter Lake, N.W.T.
 - c) Katabatic winds at Paulatuk, N.W.T.
 - d) The significance of cryostatic pressure caused during freeze-back of the active layer (in conjunction with Dr. J.R. Mackay).
 - e) Effects of snow cover on ground temperatures (in conjunction with Dr. J.R. Mackay).
 - f) Ice shove and jamming on the Mackenzie River.
 - g) Seasonal distribution of flow in the Delta.
 - h) Hydrologic characteristics and water balance study of the Mackenzie basin.
 - i) Physiography of rivers tributary to the Mackenzie River and Mackenzie Bay.
 - j) Twisty Creek elementary watershed study.
 - k) Distribution of aufeis.

LOCATION: Mackenzie Delta region, N.W.T.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Cryostatic pressure - transducers and thermistor cables installed in 1967 and read on weekly basis since then.

Katabatic winds - anemometer installed at two locations near Paulatuk in 1968. Initially only totalizing anemometers were used but since August 1969, instruments recording both run and direction of wind have been used.

Water budget, Boot Creek - discharge measurements began in 1967 but discontinued in 1968. More comprehensive program began in July 1970.

Water budget, Peter Lake - bathymetry of lake and basin reconnaissance completed in summer 1970. Water budget measurements continuing.

Snow cover and ground temperatures - thermistor cables and snow depth markers installed on Garry and Ellice islands, Paulatuk, and near Peter Lake. Measurements on Garry and Ellice when possible, Paulatuk on weekly basis since October 1969, and weekly at Peter Lake from December 1970.

Ice shove on Mackenzie - field work in various past years on trips down river.

2. References: MacKay, D.K. and MacKay, J.R., 1972. Break-up and ice jamming on the Mackenzie River, N.W.T., Canada. 22nd International Geographical Congress, Montreal, August, 1972, Monograph, (in press).

MacKay, J.R. and MacKay, D.K., 1972. Ground temperatures at Garry Island, N.W.T. 22nd International Geographical Congress, Montreal, August 1972, Monograph, (in press).

Neill, C.R., 1972. Aerial reconnaissance and study recommendations for rivers in the Mackenzie Basin, N.W.T. Report to Hydrologic Sciences Division, Department of the Environment, 27 pp. and appendices.

WORK IN PROGRESS: Continuation of measurements and evaluation of results.

FUTURE WORK: Phasing out of some projects and introduction of new ones as progress warrants.

Project G-70-2

ICEBERG PRODUCTION SURVEY IN ARCTIC CANADA

PRINCIPAL INVESTIGATORS: C.S.L. Ommanney and K.C. Arnold.

COOPERATING AGENCIES: Polar Continental Shelf Project, and Department of National Defence.

OBJECTIVES: To study the distribution of tidal glaciers in Arctic Canada, the present rate and volume of iceberg production and variations in the last 25-30 years.

PREVIOUS WORK ON THIS PROJECT:

1. Office: Identification of calving glaciers on Baffin, Bylot, Devon and Axel Heiberg Islands.
2. Field: Photography of glaciers on Ellesmere Island and Devon Island in the summers of 1970 and 1971.
3. References: Løken, O.H., Ommanney, C.S.L., Holdsworth, G. and Arnold, K.C., 1971. Iceberg studies in the Glaciology Subdivision. In: Proceedings of the Canadian Seminar on Icebergs, Halifax, December 1970, pp. 128-134.

WORK IN PROGRESS:

1. Identification of calving glaciers on Coburg and Ellesmere Islands.
2. Continuation of aerial photography of selected glaciers in eastern Ellesmere Island.

FUTURE WORK:

1. Completion of calving glacier inventory based on 1960 aerial photography.
2. Continuation of aerial photo survey.

3. Estimation of present glacier velocities, rates of ice discharge and significant changes in iceberg production based on the continuing photography.
4. Time-lapse mapping of selected glaciers to determine fluctuations.

Project G-70-3

OIL POLLUTION IN ICE INFESTED WATERS

PRINCIPAL INVESTIGATOR: R.O. Ramseier.

COOPERATING AGENCY: United States Coast Guard.

OBJECTIVES: To study the interaction between oils and ice to develop effective containment and clean-up techniques which will be applicable to an ice-infested environment.

LOCATION: Laboratory, Ottawa, and various field locations.

PREVIOUS WORK ON THIS PROJECT:

References: Ramseier, R.O., 1971. Preliminary report of oil spill at Deception Bay, Hudson Strait. Arctic Circular, Vol. 21. No. 1. pp. 22-27.

Ramseier, R.O. 1971. Oil pollution in ice infested waters. Proceedings of the International Symposium on Identification and Measurement of Environmental Pollutants, Ottawa, June 1971, pp. 271-276.

Ramseier, R.O., 1972. An overview of potential oil pollution in the High Arctic. United States Glaciological Panel, United States Academy of Sciences, Tucson, Arizona, November 1971, (in press).

WORK IN PROGRESS: Preparation of film on oil pollution in ice-infested waters.

FUTURE WORK: Testing of oil behaviour in a series of pools located in the vicinity of Ottawa in conjunction with the remote sensing program. Forecasting of oil pollution in ice infested waters.

Project G-70-4

EXTREME SUMMER STORM CONDITION IN THE TRIBUTARY HEADWATERS
OF THE LOWER MACKENZIE, N.W.T.

PRINCIPAL INVESTIGATORS: D.K. MacKay, S. Fogarasi and M. Spitzer.

COOPERATING AGENCY: Water Survey of Canada.

OBJECTIVES: To document and analyze an extreme meteorological event which occurred in the headwaters region of the Arctic Red, Ramparts and Mountain tributaries of the Mackenzie in July 1970 and to describe and discuss the hydrologic and geomorphic manifestations of this event.

LOCATION: Lower Mackenzie Region, N.W.T.

PREVIOUS WORK ON THIS PROJECT: Nil.

WORK IN PROGRESS: Collection and analysis of pertinent meteorological and hydrological data. Field work involving sectioning of trees levelled by floodwaters, mapping of changes in fluvial geomorphology and possible determination of flood heights completed. Work on manuscript continuing.

Project G-70-5

REGIONAL HYDROLOGIC CHARACTERISTICS OF MACKENZIE RIVER BASIN

PRINCIPAL INVESTIGATOR: T. Thakur.

COOPERATING AGENCY: None.

OBJECTIVES:

1. To study the hydrologic characteristics of the Mackenzie River Basin.
2. To mathematically formulate the seasonal runoff variations of the rivers in the region.
3. To construct a mathematical model of periodic water levels for the Mackenzie River.

LOCATION: Mackenzie River Basin.

PREVIOUS WORK ON THIS PROJECT:

References: Mackay, D.K., 1967. Discharge of the Liard and Mackenzie Rivers. Geographical Bulletin, Vol. 9, No. 1, pp. 11-19.

Water Survey of Canada, Calgary, 1970. Study of probability and frequency of Mackenzie River water levels. Water Survey of Canada, Inland Waters Branch, Department of Energy, Mines and Resources, 100 pp.

Thakur, T., 1972. A study of the geomorphic and hydrologic characteristics of the Mackenzie River Basin. Internal Report, Inland Waters Branch, Department of the Environment, Ottawa, 9 pp.

Jasper, J.N., 1972. Morphometric properties and runoff of several large western Mackenzie River headwater tributaries, B. Sc. Thesis, McMaster University, Hamilton, 147 pp.

WORK IN PROGRESS: Evaluation and analysis of Published Hydrologic Data. Testing of the preliminary seasonal discharge model on available data.

FUTURE WORK: Further refinement of the discharge model. Development of the water level model. Writing of report.

Project G-70-6

MATHEMATICAL STUDIES OF MACKENZIE DELTA PROCESSES

PRINCIPAL INVESTIGATOR: T. Thakur.

COOPERATING AGENCY: None.

OBJECTIVES:

1. To describe and explain the morphology and processes of the delta.
2. To describe and explain the quantitative properties of the delta dammed networks.

LOCATION: Mackenzie Delta, N.W.T.

PREVIOUS WORK ON THIS PROJECT:

References: Mackay, J.R., 1963. The Mackenzie Delta.
Geographical Branch Memoir No. 8, 202 pp.

The District of Mackenzie Maps of the Department of Mines and Technical Surveys.

WORK IN PROGRESS: The theoretical and mathematical analysis is being carried out.

FUTURE WORK: The study is continuing and a report on delta processes will be presented at the National Research Council Hydrology Symposium No. 9, by T. Thakur and D.K. MacKay.

Project G-70-7

BAFFIN ISLAND CLIMATOLOGY

PRINCIPAL INVESTIGATORS: S. Fogarasi and M. Boakes.

OBJECTIVES: To develop a physical model that will relate the mass balance parameters of local glaciers to the short-term atmospheric water balance components; to calculate atmospheric water balance of selected weather conditions in the 1968 summer when heavy precipitation is observed over the Baffin Island region by:

1. calculating the precipitation pattern, and
2. applying streamline analysis for the calculation of moisture flux divergence.

LOCATION: Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT:

1. Office: Statistical studies of the distribution and flux of atmospheric moisture have been made for the period 1961-1965.

Computer processing of moisture flux divergence over selected areas for the period 1961-1965.

Computerized Arctic weather type classification for the 1968 summer season.

Horizontal velocity divergence, total vertical velocity, and precipitation patterns have been calculated for selected weather conditions over the Canadian Archipelago in the 1968 summer.

2. References: Barry, R.G., 1966. Meteorological aspects of the glacial history of Labrador-Ungava with special reference to atmospheric vapour transport. Geographical Bulletin, Vol. 8, No. 4, pp. 319-340.

Barry, R.G., 1967. Seasonal location of the Arctic front over North America. Geographical Bulletin, Vol. 9, No. 2, pp. 79-95.

Barry, R.G. and Fogarasi, S., 1968. Climatological studies of Baffin Island, N.W.T., Inland Waters Branch, Technical Bulletin No. 13, 106 pp.

Barry, R.G., 1968. Meteorological field program, preliminary report-1967. In: Field Report, North-Central Baffin Island 1967, Inland Waters Branch, Report Series No. 2, pp. 103-135.

Fogarasi, S., 1971. Weather systems and precipitation characteristics over the Arctic Archipelago in the summer of 1968. M.Sc. Thesis, McGill University, 169 pp.

Barry, R.G., 1972. Further climatological studies of Baffin Island, N.W.T. Inland Waters Directorate, Department of the Environment, Ottawa, Technical Bulletin. No. 65, (in press).

WORK IN PROGRESS:

1. Atmospheric water balance components, precipitation and evaporation is being estimated over inaccessible areas along a grid point network and the preparation of the report.
2. Synoptic climatology of the head of Inugsuin Fiord is being investigated.
3. Examination of the effect of cloudiness and incoming global radiation on the stream discharge at the head of Inugsuim Fiord, N.W.T., in the summer of 1968.

FUTURE WORK: The physical model of water balance and precipitation calculation will be applied to:

1. the periods of selected weather types,
2. a period when mass balance observations are made in order to study the glacier climate relationship.

Project G-71-1

DIFFUSION IN ICE

PRINCIPAL INVESTIGATORS: G. Barnett and S.J. Jones (Supervisor).

COOPERATING AGENCY: None.

OBJECTIVES: To study the rate of diffusion and solubility of various substances in ice.

LOCATION: Ice Science Laboratory, 562 Booth Street, Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT: No previous work has been done by our Section on diffusion. In the literature, the diffusion of tritium (H^3) and oxygen (O^{18}) has been studied, both in pure and impure ice. Diffusion of HF has been studied with conflicting results. No other impurities have been studied. A rather crude apparatus was assembled and preliminary measurements of the diffusion of He have been obtained. These show a very high rate of diffusion ($\approx 10^{-6} \text{ cm}^2 \text{ sec}^{-1}$) compared to the self-diffusion ($\approx 10^{-11} \text{ cm}^2 \text{ sec}^{-1}$).

WORK IN PROGRESS: None. Recent publications in the literature may make the experiment unnecessary. Also, the higher priority of other projects has not left any time for this work.

FUTURE WORK: When other work is completed this project will be reactivated.

Project G-71-2

SPREADING COEFFICIENTS OF OILS ON ICE AND SNOW SURFACES

PRINCIPAL INVESTIGATOR: E. C. Chen.

COOPERATING AGENCY: None.

OBJECTIVES: To obtain information on the mechanism of oils spreading on ice and snow surfaces so that an assessment of the effect of oil spillages on these surfaces can be made.

LOCATION: Laboratory, Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT: The spreading coefficients as well as contact angles of arctic diesel (pour point: -40°C) and Lambton crude oil (pour point: -37°C) on smooth polycrystalline ice surface were determined at temperatures between -20°C and 0°C .

Field: Participation in the U.S. Coast Guard Arctic Winter Oil Spill Test, January 1972.

Reference: Chen, E.C. Report on the U.S. Coast Guard Arctic oil spill test. Internal Report, Inland Waters Branch, Department of the Environment, Ottawa, 25 pp.

WORK IN PROGRESS: Determination of the rate of spreading of arctic diesel and different types of crude oil on ice surfaces as a function of temperature and surface roughness.

FUTURE WORK: Studies will be made on the spreading of oils on snow surfaces.

Project G-71-3

OIL/WATER EMULSION STUDIES

PRINCIPAL INVESTIGATOR: E.C. Chen.

COOPERATING AGENCY: None.

OBJECTIVES: To study the nature and stability of oil/water emulsions at low temperatures in order to understand their significance for combating oil pollution in a cold environment.

LOCATION: Laboratory, Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT: Methods for the preparation of a reproducible oil-in-water emulsion, technique of sampling and analysis of the emulsion stability were tested.

WORK IN PROGRESS: Investigation on the properties and stability of arctic diesel/water emulsion as a function of temperature.

FUTURE WORK: Properties and stability of various types of crude oil/water emulsion will be studied.

Project G-71-4

VAPOUR-LIQUID EQUILIBRIA OF HYDROCARBON OILS-ICE/SNOW SYSTEM

PRINCIPAL INVESTIGATORS: E.C. Chen & S.D. Chang.

Project discontinued.

Project G-71-5

REGIONAL MASS BALANCE MEASUREMENTS IN THE
QUEEN ELIZABETH ISLANDS BY USING AERIAL PHOTOGRAMMETRY

PRINCIPAL INVESTIGATOR: K. C. Arnold.

COOPERATING AGENCY: Polar Continental Shelf Project, Department
of Energy, Mines and Resources.

OBJECTIVES: To extend the limited number of mass balance measurements that have been made in the conventional manner by ground parties to a larger number of locations. Regional and altitudinal variations in mass balance will be determined, and the concept of representative glaciers will be tested. At first dynamically uncomplicated ice masses will be chosen for study, so that height changes can be easily related to mass balance changes. Air photography will be taken from low altitude at the end of each budget year at all sites, and at the onset on the melt season at a limited number of sites.

LOCATION: Queen Elizabeth Islands.

PREVIOUS WORK ON THIS PROJECT: 1971. The flying programme was begun. Five areas in Axel Heiberg Island were photographed at the start of the melt season, but early snowfalls and aircraft unserviceability prevented air photography at the end of the ablation season.

WORK IN PROGRESS: Further air photography, and setting up ground survey control.

FUTURE WORK: The number of sites will be extended by five to ten each year over a period of five years.

Project G-71-6

APPRAISAL OF LONG TERM METEOROLOGICAL RECORDERS

PRINCIPAL INVESTIGATORS: A.D. Terroux, J. Kruus.

COOPERATING AGENCY: Atmospheric Environment Service, Atomic Energy of Canada Ltd.

OBJECTIVES: Obtain, modify or develop a long term meteorological recorder capable of operating unattended under winter conditions in the Arctic and Cordillera.

LOCATION: Main tests in Resolute, N.W.T.

PREVIOUS WORK ON THIS PROJECT: In 1969 all known manufactures of meteorological recorders were contacted and instrument specifications appraised. Of the 30 manufacturers approached - Ott, Plessey, Epsylon Leach and Braincon have developed models that include some of the features required.

Two Ott instruments were purchased and power systems designed to operate at low temperatures. A wind generator was supplied by Lubing and a thermo-generator using a radio-active source was designed under contract by Atomic Energy of Canada Ltd. One Ott Station together with power unit and wind generator was installed at Churchill weather station for one year to compare performance with standard meteorological instruments. The system is now operating at Arctic Mountain House, N.W.T.

WORK IN PROGRESS: Modification of the system in Resolute and analysis of data from operation. During 1971 one station, using a nuclear power supply, was installed at the weather station in Resolute Bay in order to test all components of the system. In the first six months of operation, there were some insulation difficulties.

FUTURE WORK: Tests will be continued on the Ott recorders until they are completely functional under the specified conditions.

Project G-71-7

APPLICATIONS OF REMOTE SENSING TECHNIQUES TO GLACIOLOGY

PRINCIPAL INVESTIGATORS: A.D. Terroux & A.D. Stanley.

COOPERATING AGENCY: U.S. Geological Survey (Dr. M.F. Meier).

OBJECTIVES: To determine area of application of ERTS imagery to the study of snow and ice. The initial program will establish the resolution and accuracy for

- (1) Distribution of snow over large areas.
- (2) Assessment of snow depletion during the spring runoff.
- (3) Variation of glacier mass balance based on snow line levels at the end of the summer.

LOCATION: Western Cordillera between 46°N and 64°N.

PREVIOUS WORK ON THIS PROJECT: Examination of existing Federal and Provincial photography from the Canadian Cordillera.

WORK IN PROGRESS: In 1972 - June 1 and June 10 requested high level flight by CF100 aircraft to obtain imagery along an E-W transect across southern British Columbia and Alberta. Snow line information will be compared with ground truth data from selected glacier basins.

- Infra-red photography was flown at 15,000 feet using a WILD RC 10 aerial camera in September. Analysis is proceeding.

FUTURE WORK: Interpretation of CF100 imagery, and of ERTS imagery when it becomes available in 1973.

South-north flight by U-2 aircraft along the Coast mountains in early June and mid-August to obtain high level imagery.

Comparison of ground data from selected glacier basins with snow line data from high level imagery to determine resolution and accuracy.

Project G-72-1

ICEBERG PROJECT: LEFFERT GLACIER, S.E. ELLESMERE ISLAND

PRINCIPAL INVESTIGATOR: G. Holdsworth.

COOPERATING AGENCIES: Polar Continental Shelf Project, Marine Sciences Branch and the Department of Transport, National Research Council.

OBJECTIVES: To determine discharge rates of selected tide-water glaciers on the S.E. Ellesmere Island coastline and to understand the glaciological/oceanographic processes influencing iceberg calving.

This involves:

1. Estimating glacier velocities, rates of ice discharge and significant changes in iceberg production along the southeast Ellesmere Coastline, by establishing a continuous survey of calving glaciers (aerial photogrammetry).
2. Determination of flow regime and marginal deformation as well as calving rates, on a selected glacier.
3. Investigating processes of calving on a selected outlet glacier.
4. (a) field investigations (Leffert Glacier).
(b) laboratory (model) studies.

LOCATION: Ottawa, Ontario and Ellesmere Island - Leffert Glacier, Lat. 78° 40' N Longitude 75° W.

PREVIOUS WORK ON THIS PROJECT: Department of Transport, 1967, Publications on ice conditions in Canada. Meteorological Branch, Department of Transport, DS No. 6-67, Toronto, Ontario, 5 pp.

WORK IN PROGRESS:

1. An aerial reconnaissance of calving glaciers on southeast Ellesmere Island was made in the summer of 1971 (K. Arnold).

2. A suitable site for a base camp adjacent to Leffert Glacier was selected (August 1971) on the basis of a field reconnaissance and aerial photographs.
3. Theoretical models for floating and semi-floating ice tongues are being considered.

FUTURE WORK:

1. Photography and re-photography of calving termini to establish present snout positions. Map production at various scales.
2. Photogrammetric determination of glacier velocities.
3. Field program: (1972)
 - Establishment of tide-level gauges; oceanographic investigations.
 - Geophysical, glaciological, topographic and hydrographic surveys.
4. Laboratory Work:
 1. Studies of bending of ice (model beams, plates).
 2. Determination of ice properties and structure (field samples, cores).

Project G-72-2

BIBLIOGRAPHY OF CANADIAN GLACIERS

PRINCIPAL INVESTIGATOR: C.S.L. Ommanney.

COOPERATING AGENCIES: Department of Energy, Mines and Resources.

OBJECTIVES: To produce a computerized reference system to all bibliographic material on Canadian glaciers.

LOCATION: Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT: None

WORK IN PROGRESS: An initial input of 100 references with key words has been made to the RAID program of EMR.

FUTURE WORK:

1. The approximately 2,500 references to work on glaciers in Canada so far identified will be coded for input to RAID.
2. A thesaurus of the key words used will be prepared.
3. The photographic records will be coded for input so that photographic and literature references for individual glaciers can be retrieved together.

Project G-72-3

GLACIATION LIMITS AND EQUILIBRIUM LINE ELEVATIONS
IN THE CANADIAN HIGH ARCTIC

PRINCIPAL INVESTIGATOR: C.S.L. Ommanney - work done on contract by J.T. Andrews, Institute of Arctic and Alpine Research, Boulder, Colorado.

COOPERATING AGENCIES: University of Colorado, INSTAAR.

OBJECTIVES: To map the glaciation limits and equilibrium lines between latitudes 74° and 84° N and between longitudes 60° and 120°W; this is to provide: -

- a) a fundamental measure of the present state of glacierization
- b) unique information on the sensitivity of the region to climatic change
- c) a measure of the relationship of the present glaciation limit to the contemporary climate
- d) an integrated, regional, climatic picture to supplement that obtained from existing weather stations.

LOCATION: Ottawa, Ontario and INSTAAR, Boulder, Colorado.

PREVIOUS WORK ON THIS PROJECT: Andrews, J.T. and Miller, G.H., 1972. Quaternary history of northern Cumberland Peninsula, Baffin Island, N.W.T., Canada: Part IV: maps of the present glaciation limits and lowest equilibrium line altitude for north and south Baffin Island. Arctic and Alpine Research, Vol. 4, No. 1, pp. 45-59.

WORK IN PROGRESS: Rough mapping of northern Ellesmere Island has been completed and revealed a very steep gradient between eastern Ellesmere Island and northwestern Greenland.

FUTURE WORK: Detailed mapping will continue and will include the Torngat Mountains, Labrador, as well as the High Arctic. Analysis of climatological and radio-sounde data will be carried out to aid in the interpretation of the resulting patterns.

Project G-72-4

IRRP GLACIER INVENTORY PROGRAMME, ST. ELIAS MOUNTAINS

PRINCIPAL INVESTIGATOR: C.S.L. Ommanney - work done on contract through the Arctic Institute of North America by R.H. Ragle and S.G. Collins.

COOPERATING AGENCIES: Arctic Institute of North America and American Geographical Society.

OBJECTIVES: To carry out an inventory of glaciers in the St. Elias Mountains in accordance with International and Canadian Specifications.

LOCATIONS: Ottawa, Ontario, Montreal, Quebec, New York, N.Y., Washington, D.C. and St. Elias Mountains.

PREVIOUS WORK ON THIS PROJECT: A pilot study of the Steele Creek basin was completed in March, 1972 as a feasibility study for the St. Elias inventory.

WORK IN PROGRESS: Inventory studies are being continued in the Donjek and White River basins of the Yukon River Drainage region.

FUTURE WORK:

1. The inventory will be expanded to include the Alsek River basin but restricted to the Canadian St. Elias Mountains.
2. Bibliographic and photographic source materials for all areas inventoried will be identified.

Project G-72-5

AGING OF OILS ON ICE AND SNOW

PRINCIPAL INVESTIGATOR: E.C. Chen.

COOPERATING AGENCY: Water Science Subdivision.

OBJECTIVES: To obtain information on the changes in physical properties of oils caused by aging on ice or snow as basic inputs to the research of oil pollution in the Arctic.

LOCATION: Laboratory, Ottawa.

PREVIOUS WORK ON THIS PROJECT: The changes in surface tension of petroleum crudes as a result of initial aging were determined.

Reference: Chen, E.C. and Guarnaschelli, C. Changes in surface tension during the initial aging of some petroleum crudes. Journal of Petroleum Technology, (in prep).

WORK IN PROGRESS: Development of correlations to relate the changes in surface tension of oil with aging processes, such as evaporation and dissolution.

FUTURE WORK: The study is continuing.

Project G-72-6

PRECIPITATION-CLIMATE AT SOME OF THE
BRITISH COLUMBIAN GLACIERS

PRINCIPAL INVESTIGATOR: S. Fogarasi.

COOPERATING AGENCY: None.

OBJECTIVES: To design a model for the estimation of instantaneous and long-term mean precipitation patterns at selected drainage basins in British Columbia by:

- a) relating large, and meso-scale orographic weather parameters to known precipitation values,
- b) with the help of weighting factors derived for various weather types expressed in terms of cloud patterns.

LOCATION: Ottawa, Ontario.

WORK IN PROGRESS:

1. Collection of ESSA 8 Satellite pictures.
2. Review of pertinent literature.

Project G-72-7

MORPHOMETRIC ANALYSIS OF MACKENZIE DRAINAGE BASIN NETWORKS

PRINCIPAL INVESTIGATOR: T. Thakur.

COOPERATING AGENCY: None.

OBJECTIVES:

1. To study complete Mackenzie Basin morphometry including all factors of drainage network and topography from the available maps and records.
2. To interpret hydrologic and geomorphic characteristics of the region from the collected morphometric data.

LOCATION: Mackenzie River Basin.

PREVIOUS WORK ON THIS PROJECT: The study involves collection, analysis, compilation and interpretation of existing maps, aerial photographs and other pertinent records. Maps with scales of 1:50,000 and 1:250,000 are available.

WORK IN PROGRESS: Mackenzie Region is divided into drainage basins following the procedures adopted by the Water Survey of Canada. Each basin is further subdivided into smaller units in order to facilitate data collection. Several morphometric parameters and constants related to the following basin features are measured.

1. Strahler's stream order system.
2. Total length of stream of each order.
3. Drainage area.
4. Basin perimeter.
5. Channel length.
6. Length of dominant drainage line.
7. Sub-basin land cover.
8. Basin area drained by stream of each order.
9. Area of land cover.
10. Basin slope.

FUTURE WORK: Map study is being continued. Attempts are being made to establish mathematical correlation between morphometric

parameters of different basins and its hydrologic significance. Various measures of basin morphometry and climate are combined for assessing peak discharge and other hydrologic characteristics of the basins in the region.

Project G-72-8

HYDROLOGY OF GLACIERIZED BASINS

PRINCIPAL INVESTIGATOR: L. Derikx.

COOPERATING AGENCY: None.

OBJECTIVES:

1. To study in detail the energy and mass transfer processes at the atmospheric-glacier interface in different scales, both in time and in space.
2. To synthesize the results of the energy and mass transfer studies in a flexible and adequate mathematical model to simulate the runoff from glacierized basins in the Canadian Cordillera.
3. To develop a statistical model for aerial extension of hydroglaciological information to ungauged glaciers.

LOCATION: Ottawa, Ontario, on the basis of field data from several glaciers.

PREVIOUS WORK ON THIS PROJECT:

1. Field: Standard glaciohydrological and meteorological data since 1965. Detailed heat balance and associated melt measurements at Peyto Glacier in 1970 and 1971. Preliminary measurements of aerial variability of temperature, relative humidity, run of wind, global radiation and precipitation at Peyto Glacier in 1970.
2. Office: A runoff simulation model for daily streamflow has been developed and tested on Berendon Glacier and Peyto Glacier. The model has been applied to fifty-three glaciers and perennial snow patches in the Mistaya Valley, headwaters of North Saskatchewan River, (part of project G-69-3). The hydrological response of the exposed ice region has been determined: the response of the snow covered region and the firn area has been estimated by an optimization procedure.

3. References: Derikx, L., 1969. Glacier discharge simulation by groundwater analogue. Presented at the Symposium on the Hydrology of Glaciers, IASH, Cambridge, England, (in press).

Goodison, B., The distribution of global radiation over Peyto Glacier, Alberta. Part 1 of the Final Report, Inland Waters Directorate, Department of the Environment, Scientific Report, (in press).

Derikx, A.L. and Loijens, H., 1971. Model of runoff from glaciers. In: Runoff from Snow and Ice, Symposium No. 8, National Research Council Associate Committee on Geodesy and Geophysics, Subcommittee on Hydrology, Quebec City, May 1971, Vol. 1, pp. 153-199.

Derikx, A.L., 1971. The heat balance and associated runoff from an experimental site on the glacier tongue. Presented at the Symposium on Snow and Ice in Mountainous Regions, IASH, XV General Assembly, Moscow, USSR.

Derikx, A.L. Hydrological characteristics for Peyto Glacier. To be published in Guidebook for Symposia on the Role of Snow and Ice in Hydrology, September 1972, Banff, Alberta.

WORK IN PROGRESS: Processing, analysis of micrometeorological data and a study of the theoretical aspects of latent and sensible heat transfer across the air/ice interface. These studies are part of a Ph.D. thesis of Scott Munro, McMaster University, Hamilton, Ontario.

Development of a model which relates glaciohydrological and meteorological observations to location of the glacier, topography of the basin and physical characteristics of the glacier surface.

A paper on mass and energy transfer in a glacier snowpack is in preparation.

FUTURE WORK:

1. Field: no fieldwork is anticipated in the near future.
2. Office: refinement of mass and energy transfer calculations. Modelling of temperature, wind and humidity fields in glacierized basins. Extension of models to ungauged glaciers.

Project G-72-9

EXTRACTION OF HYDROLOGIC INFORMATION FROM
ERTS SATELLITES IMAGERY

PRINCIPAL INVESTIGATOR: J. Kruus.

COOPERATING AGENCY: Canada Centre for Remote Sensing.

OBJECTIVES: To conduct research into methods which may be used to extract information from images received from the Earth Resource Technology Satellites. To attempt an evaluation of the costs and benefits of obtaining this information by means of polar-orbiting satellites as compared to other means.

LOCATION: Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT: Elementary photointerpretation work has been done in identifying groundwater inflows to rivers and lakes. Experience has been gained in obtaining and interpreting infra-red (IR) imagery.

WORK IN PROGRESS: Completion of reports pertaining to IR imagery. Parallel interpretation studies will be carried out by other federal agencies.

FUTURE WORK: The soliciting of research proposals from interested organizations, universities, research institutes, and consultants. Evaluation of proposal and funding of accepted proposals. In order that the Division benefit maximally, a large portion of the work shall be done in Ottawa.

Project G-72-10

RETRANSMISSION OF HYDROLOGIC DATA

PRINCIPAL INVESTIGATOR: J. Kruus.

COOPERATING AGENCIES: Atmospheric Environment Service, Water Survey and Water Quality Division.

OBJECTIVES: To gain experience with the operation of a data retransmission system based on the ERTS polar orbiting satellites. In conjunction with the Atmospheric Environment Service, the Water Survey and the Water Quality Divisions, to evaluate the advantage of short-time data acquisition from a site with both hydrologic and water quality instruments.

LOCATION: Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT: A request to NASA has been submitted. Cooperating agencies have been named as co-investigators.

WORK IN PROGRESS: Procurement and design of sensor system and transmitting platform.

FUTURE WORK: Installation of sensor system interfaced to transmitter and evaluation of system performance.

Project G-72-11

OPERATION OF INSTRUMENTATION SHOP

PRINCIPLE INVESTIGATOR: J. Kruus (Officer in charge).

COOPERATING AGENCY: None.

OBJECTIVES: To provide engineering advice and assistance for field and laboratory investigations.

Project G-72-12

USE OF RADIO-ECHO SOUNDING TECHNIQUE FOR THE STUDY
OF TEMPERATE GLACIERS.

PRINCIPAL INVESTIGATOR: R.H. Goodman.

COOPERATING AGENCY: None.

OBJECTIVES: To study the propagation of meter length waves of
electromagnetic radiation in a temperate glacier.

To determine the characteristic of intraglacial layers.

To map the bottom of a typical temperate glacier.

To develop techniques of interpretation and computer processing
of radio echograms.

LOCATION: Athabaska Glacier.

PREVIOUS WORK ON THIS PROJECT: System has been developed and tested.
Two papers in press.

References: Robin, G. de Q., and others., 1969. Interpretation
of radio echo soundings in Polar Ice Sheets. Philosophical
Transactions Series A, Vol. 265, pp. 437-505.

Rudakov, V.N. and Luchinov, V.S., 1969. Radio sounding of glacier
in homogeneities. Soviet Physics-Technical Physics, Vol. 14,
No. 6, pp. 751-755.

Goodman, R.H., 1970. A data collection system for glacier
studies. Proceedings Ninth Annual Hydrographic Conference,
Ottawa, Ontario. January 1970, pp. 69-78.

Goodman, R.H., 1970. Radio-echo sounding on temperate glaciers:
a Canadian view. In: Gudmandsen, P. (editor), International
meeting on Radioglaciology, Lyngby, Denmark, 1970, pp. 135-146.

Løken, O.H. and Goodman, R.H., 1971. Glaciology and ice thickness
measurements. Potential use for remote sensing. In: Ice
Reconnaissance and Glaciology, Report No. 7, Department of Energy,
Mines and Resources, Ottawa, pp. 30-31.

WORK IN PROGRESS: System is being rebuilt for field operation.

FUTURE WORK: Study of surging glaciers and jökulhaups.

Project G-72-13

GROWTH MECHANISMS OF RIVER AND LAKE ICE
(INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES)

PRINCIPAL INVESTIGATOR: R.O. Ramseier.

COOPERATING AGENCIES: Canadian Centre for Remote Sensing, Energy, Mines and Resources; Canadian Forces Airborne Sensing Unit, Department of National Defence; Manned Spacecraft Centre, Houston, National Aeronautics and Space Administration; Department of Transportation and Communication, Ontario and Marine Sciences Institute, Finland.

OBJECTIVES: To advance the knowledge of the growth and mechanical properties of river and lake ice in such a way as to predict the physical and mechanical properties of floating ice by the use of standard meteorological and hydrodynamic parameters and remote sensing techniques.

LOCATION: Ottawa, Lake Ontario and Finland.

PREVIOUS WORK ON THIS PROJECT:

References: Ramseier, R.O., 1968. The origin of preferred orientation in columnar ice. Journal of Crystal Growth, Vol. 4, pp. 621-624.

Michel, B. and Ramseier, R.O., 1969. Classification of river and lake ice based on its genesis, structure and texture. Universit! Laval, Section M!canique des Glaces, Report S-15, 54 pp.

Michel, B. and Ramseier, R.O., 1969. Crystallographic analysis and theoretical flexural strength of river ice. Universit! Laval, Section M!canique des Glaces, Report T-6, 17 pp.

Michel, B. and Ramseier, R.O., 1969. Structural and textural analysis of river ice, St. Lawrence Seaway, Montreal. Universit! Laval, Section M!canique des Glaces, Report T-9, 18 pp.

Michel, B. and Ramseier, R.O., 1970. Structural and textural characteristics of river ice based on meteorological parameters. Universit! Laval, Section M!canique des Glaces, Report, T-13, 60 pp.

Michel, B. and Ramseier, R.O., 1970. Classification of river and lake ice. Canadian Geotechnical Journal Vol. 8, No. 36, pp. 36-45.

Ramseier, R.O., 1971. Formation of primary ice layers. Proceedings of the International Association of Hydraulic Research, Symposium on Ice and its Action on Hydraulic Structures, Reykjavik, Iceland, September, 1971, pp. 311-318.

Project G-72-14

ICE INFORMATION AND MECHANICAL PROPERTIES OF
RIVER AND LAKE ICE
(EXTENSION OF THE NAVIGATION SEASON,
ST. LAWRENCE SEAWAY)

PRINCIPAL INVESTIGATOR: R.O. Ramseier.

COOPERATING AGENCIES: Operations Branch, St. Lawrence Seaway Authority; Canadian Marine Transportation Administration, Department of Transport; Department of Transportation and Communication, Ontario; Canadian Remote Sensing Centre, Energy, Mines and Resources and Queen's University.

OBJECTIVES: To study the influence of macroscopic defects and impurities on the ductile behaviour of laboratory and naturally grown river and lake ice and to determine the relationship between small- and large-scale tests of ice in the ductile-brittle range.

To determine forces created by ships navigating in ice covered rivers.

To study the mechanism of pressure ridge formation in Lake Erie and to test remote ice thickness measuring devices in fresh water and sea ice.

LOCATION: Laboratory, Ottawa and Queen's University, St. Lawrence River, St. Clair River, Lake Erie and Lake St. Clair.

PREVIOUS WORK ON THIS PROJECT:

References: Ramseier, R.O., 1970. Mechanical behaviour of ice at high temperatures. Bulletin of American Physical Society Vol. 15, p. 812.

Ramseier, R.O. Mechanical properties of snow ice. Proceedings of Port and Ocean Engineering Under Arctic Conditions, Technical University of Norway, (in press).

Ramseier, R.O. and Dickins, D.F., 1972. A new approach to field and laboratory tests of tensile, compressive and flexural strength of polycrystalline, fresh water ice. In: Proceedings, Ice Symposium of International Association of Hydraulic Research, Leningrad, September 1972, (in press).

WORK IN PROGRESS: The first phase of laboratory testing has been completed and the results are being written up. A review of published results from other investigations and field tests have been started in preparation for large-scale outdoor tests. Analysis of the large, in situ, beam test of the 1971-72 winter season is underway.

FUTURE WORK: Laboratory tests are contemplated to determine the effect of subboundaries and grain boundaries on creep mechanisms and to gain insight into the microscopic aspect of creep deformations. Field investigations are planned to determine the statistical behaviour of major flaws on the mechanical properties. The effect of impurities will also be investigated.

Field tests will be set up to determine the forces transmitted through the ice, by passing ships, onto shore structures and embankments; and the frictional forces on ships travelling through ice debris-filled channels.

To measure the sites of pressure ridges forming on Lake Erie and under hanging dams on the St. Lawrence River.

Project G-72-15

SEA ICE GROUND TRUTH
(ARCTIC ICE DYNAMICS JOINT EXPERIMENT)

PRINCIPAL INVESTIGATOR: R.O. Ramseier.

COOPERATING AGENCIES: National Aeronautics and Space Administration, Houston, Texas; Goddard, Washington; Microwave Division, Aerojet-General, El Monte, California; United States Geological Survey, Tacoma, Washington and Communications Research Centre, Department of Communication, Ottawa.

OBJECTIVES: To obtain data on the vertical and horizontal variations of various physical properties of first year and second year sea ice and to correlate the findings with the brightness temperatures from passive microwave radiometry obtained by Aerojet-General on the ground and by NASA in the CV 990 during the seven low and high level flights taken.

LOCATION: Laboratory, Ottawa, Arctic Ocean

PREVIOUS WORK ON THIS PROJECT:

References: Adey, A.W., 1971. Theory and field tests of a microwave radiometer for determining sea ice thickness. Proceedings of the Advisory Group on Aerospace Research and Development, Document CP-90-71, Air Force Academy, Colorado Springs, Colorado, pp. 8.1-8.10.

Edgerton, A.T., Stogryn, A., Williams, D.P. and Poe, G., 1971. A study of the microwave emission characteristics of sea ice. Aerojet-General Corporation, El Monte, California, Technical Report 1741R-1, 82 pp.

WORK IN PROGRESS: Analysis of the field data collected during AIDJEX 1972.

FUTURE WORK: Additional field tests during AIDJEX 1973 and the main AIDJEX year 1974-75.

Project G-72-16

HYDROLOGIC RECONNAISSANCE - MACKINSON INLET AREA,
ELLESMERE ISLAND, N.W.T.

PRINCIPAL INVESTIGATOR: O.H. Løken - work done under contract with
McMaster University - Professor S.B. McCann.

COOPERATING AGENCIES: Polar Continental Shelf Project.

OBJECTIVES: To carry out a hydrological reconnaissance in the area
near the head of Mackinson Inlet and northward to the head of
Bay Fiord, Ellesmere Island, with particular emphasis on ice
problems and hydrologic problems which may arise in connection
with possible pipeline and/or marine terminal construction in
this area.

LOCATION: Ellesmere Island, N.W.T.

WORK IN PROGRESS:

1. Drainage basins are outlined on the basis of map and air
photo interpretation.
2. Key problem areas are being identified for detailed field
checks during July, 1972.

Project G-72-17

HYDROLOGY OF D'IBERVILLE BASIN, N.W.T.

PRINCIPAL INVESTIGATOR: L. Derikx.

COOPERATING AGENCY: Marine Sciences Directorate, Frozen Sea Research Group.

OBJECTIVES: To determine the average monthly inflows of fresh water into d'Iberville Fiord.

LOCATION: d'Iberville Fiord (80° 35' N., 79° 00' W), Ellesmere Island, N.W.T.

PREVIOUS WORK: None

WORK IN PROGRESS: Inventory of glaciers.

FUTURE WORK: Survey of literature, including publications of meteorological and glaciological data in Eastern Archipelago. Development of a "square grid" energy and mass balance model.

GLACIER MAPPING

PRINCIPAL INVESTIGATORS: I.A. Reid

COOPERATING AGENCY: None

OBJECTIVES: To determine volumetric and linear changes of seven glaciers on the basis of biennially detailed topographic mapping. The following glaciers are investigated: Sentinel, Sphinx, Bugaboo, Kokanee and Nadahini in British Columbia, and the Athabasca and Saskatchewan glaciers in Alberta.

LOCATION: Ottawa, Ontario.

PREVIOUS WORK ON THIS PROJECT:

1. Field: A terrestrial photogrammetric survey of the glaciers in British Columbia was made in 1964, 1966, 1968, 1970 of the Athabasca Glacier in 1959, 1962, 1965, 1967, 1968, 1969 and 1971 and of the Saskatchewan Glacier in 1965, 1967, 1969 and 1971.
2. References: Campbell, P.I., Reid, I.A. and Shastal, J., 1969. Glacier surveys in Alberta. Inland Waters Branch, Department of Energy, Mines and Resources, Report Series No. 4, 15 pp.

Campbell, P.I., Reid, I.A. and Shastal, J., 1969. Glacier surveys in British Columbia. Inland Waters Branch, Department of Energy, Mines and Resources, Ottawa, Report Series No. 5, 17pp.

Reid, I.A. and Shastal, J., 1970. Glacier surveys in British Columbia. Inland Waters Branch, Dept. of Energy, Mines and Resources, Report Series No. 10, 26 pp.

<u>Map</u>	<u>Scale</u>	<u>Contour Interval</u>
Bugaboo (1968)	1:2,500	10 metres
Sentinel Glacier (1968)	1:2,500	5 metres
Sphinx Glacier (1968)	1:5,000	10 metres
Nadahini Glacier (1968)	1:5,000	5 metres
Kokanee Glacier (1968)	1:2,500	5 metres
Saskatchewan Glacier (1969)	1:10,000	10 metres
Athabasca Glacier (1969)	1:10,000	10 metres

WORK IN PROGRESS:

1. Terrestrial photogrammetric surveys of the Bugaboo, Kokanee, Sentinel, Sphinx and Nadahini glaciers.
2. Ice discharge movement of the Saskatchewan Glacier.

FUTURE WORK: The mapping projects of the seven glaciers are expected continue until the mid-1970's.

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