



INLAND WATERS BRANCH

DEPARTMENT OF ENERGY, MINES AND RESOURCES

THE FEDERAL GROUNDWATER PROGRAM

Annual Project Catalogue 1969-70

REPORT SERIES No. 8

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**INLAND WATERS BRANCH
DEPARTMENT OF ENERGY, MINES AND RESOURCES
OTTAWA, CANADA, 1970**

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FEDERAL GROUNDWATER RESEARCH

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FEDERAL GROUNDWATER RESEARCH

1. Introduction

The B.N.A. Act of 1867 has given the Provinces proprietary rights over their water resources. In the case of groundwater, the Provincial rights are particularly stringent and most provinces have strong groundwater organizations. Consequently, groundwater inventory, evaluation and development are generally regarded as provincial matters.

The Canadian Council of Resource Ministers, in its handbook on the administration of water resources in Canada, has given an interpretation of the constitutional division of responsibilities which states that the lawful task of the Federal Government is to support the Provincial water-management agencies by providing financial and technical assistance, basic data and research. The Federal agency charged with conducting field and laboratory studies in hydrogeology in accordance with this interpretation is the Groundwater Subdivision of the Hydrologic Sciences Division, Inland Waters Branch.

The studies conducted by the Groundwater Subdivision comprise a number of projects which fit into two distinct categories - operational (GWO) or research (GW). This Project Catalogue lists all current projects of both types and provides information on objectives and progress.

Operational projects are initiated at the request of other Federal departments and are performed as a service for these departments in areas that are either under direct Federal jurisdiction (such as the national parks) or that are the sites of broadly based Federal research programs requiring some groundwater input. Some of these projects involve exploration and development of groundwater supplies and hence are only of short duration; those requiring an input of precise

groundwater data and expertise may demand Groundwater Subdivision commitment on a relatively long-term basis. Two examples of each kind are to be found in this catalogue.

Research projects originate closer to home within the Subdivision, Division or Branch. Related research projects with common objectives may be grouped together to form a program. A proposed new project may be seen either as the logical extension of an existing program or as the appropriate response to a new area of concern in groundwater hydrology. The bulk of the projects reported on in this catalogue fall into the research category.

Research is the salient activity of the Groundwater Subdivision. Operational projects represent an inter-department responsibility and they generally do not serve to advance research progress. It is important therefore, that this progress should not be unduly hampered by a necessity to commit manpower to operational projects. A partial solution to the problem is utilization of the private sector for field management of these projects. Consultants may also be used to advantage in research projects, not only for field management operations but also for such purposes as the development of new instrumentation. Utilization of the private sector is a policy with the Subdivision and it is anticipated that it will contribute to another benefit - the generation of a high degree of hydrogeologic competence in this sector.

2. The Research Framework

Of growing importance for Federal groundwater research are the judicious selection of new scientific programs and projects and the criteria used to determine their suitability for incorporation into Federal activities. These criteria define the boundaries or framework within which it is desirable that the Groundwater Subdivision

should operate as well as indicate generally how the research effort should be distributed within that framework.

Prominent among the existing criteria are the requirements that individual scientific projects should generally rate highly in terms of both national need and scientific significance. Further criteria have been provided by a recent restatement of the Inland Waters Branch objectives. Four Branch objectives have been defined, of which three apply to the Groundwater Subdivision. In order of priority, these three Branch objectives are:

1. Achievement, setting and maintenance of water quality standards appropriate to the nature, management and use of surface and groundwaters in Canada.
2. Determination of water quantities in rivers, lakes, aquifers and glaciers to the accuracy desired for planning and optimum water management.
3. Development, review, evaluation and recommendation of technical plans and procedures for implementing water resource management, conservation and development with respect to both quality and quantity.

Insofar as an existing or proposed groundwater research program or project satisfies Canadian needs, possesses scientific significance, and has a bearing on one of more Branch objectives, it can be judged with regard to its suitability for inclusion in Federal groundwater activities. This type of evaluation should play an important part in the future selection of new programs and projects and in the phasing out of older ones conceived in accordance with earlier criteria.

Just as the earlier criteria have been supplanted by those discussed above, so may the existing criteria be subject to change or modification. It is possible, for instance, that passage of the Canada Water Act will exert a profound effect on these criteria, an effect which may only become apparent in its entirety over a period of years. This possible effect should be an important consideration in the development of long-range plans for Federal research in hydrogeology.

3. Current Activities

The Groundwater Subdivision has developed three main research programs. These are:

1. The Maritime Research Program
consisting of research projects
GW 67-8, GW 68-10, GW 68-11,
GW 68-12 and GW 69-1.
2. GOWN and associated activities,
consisting of projects GW 67-1b,
GW 67-2b, GW 67-13, GW 67-14,
GW 67-19, GW 68-5 and GW 68-6.
3. Hydrologic Systems Analysis
consisting of projects GW 67-1a,
GW 67-11, GW 68-1, GW 68-2,
GW 68-3 and GW 69-2.

The 18 projects listed above are still active except for GW 67-1a and GW 68-1. Of the remaining ten active projects listed in this catalogue, four are concerned with various aspects of water quality. These are projects GW 67-6, GW 67-9, GW 67-12 and GW 68-7. Some of the four may eventually form the nucleus of a future program related to groundwater quality, as is discussed in a succeeding section.

Thus a great majority of active Groundwater Subdivision projects can be assigned to well-defined existing or possible future programs. A program may be

conducted in its entirety by just one of the Sub-division's four sections (e.g. the Maritime Research Program) or its projects may be shared by two or more sections. It is anticipated that there will be a growing tendency to form ad hoc research groups to undertake new programs, and that these groups will expand, contract and dissolve as programs get under way, mature and eventually meet their objectives. This could lead to some adjustments in the organizational structure of the Subdivision but should increase its overall flexibility.

The four existing sections are the Western, Maritime, Eastern and Computer Research Sections. A portion of the project catalogue is set aside for each and is prefaced in each case by a brief summary of the section's projects and progress.

4. Future Activities

The two previous issues of this annual report drew attention to the probable influence of current Canadian socio-economic trends on the development of the Subdivision's hydrogeologic program. Urbanization was singled out for particular mention because of the pressing needs it creates for large-scale integrated development and management of water resources and for the intelligent treatment and disposal of urban and industrial wastes. The growing requirement for an inventory of Canadian groundwater resources was also pointed out, as were the conflicts in water use arising in the Prairie region between farmers and hunters, and the particular water-supply and waste-disposal problems associated with development of Canada's northern permafrost regions and with the expansion of the Saskatchewan potash industry.

Although none of these problems is yet receiving the attention that is its due, two relevant projects have been initiated, and one of these (GW 67-12) is providing valuable data concerning the hydrogeologic effects of disposal of brines from potash mining into surface ponds.

The second, (GW 67-3), was an exploratory probe into permafrost geohydrology in which the major effort had to be diverted toward the solution of logistic and instrumental problems, so that progress in the study of hydrogeologic problems of the far north was unfortunately much less than had been hoped for. Although the departure of the principal investigator has forced the termination of this project, studies of groundwater in the Arctic regions will continue as part of a more comprehensive project in the Glaciology Subdivision of the Hydrologic Sciences Division. It is anticipated as well that a theoretical study of phase changes in the vicinity of the subsurface ice-water interface will become part of a new Groundwater Subdivision program on basin management. This proposed program is described in greater detail below. Close cooperation between the scientists engaged in the theoretical study and those making field observations of hydrogeologic phenomena in the far north is a firm objective and is essential to the ultimate success of any broadly based program in Arctic hydrology.

In outlining the Subdivision's current activities, it was suggested that a number of existing projects might eventually form the nucleus of a groundwater-quality program. In particular, it is anticipated that the potash-plant waste-disposal study may shortly be supplemented by an investigation into some selected aspect of the deep-well disposal problem. Growing concern is being expressed about the short and long-term effects of the increasing use of deep wells for the disposal of nondegradable liquid wastes, such as brines and phenols. Little is known about the subsurface movement of these wastes, their reactions with one another and the hydrogeologic environment, or the mechanical effects of the resulting steadily increasing fluid pressures within the formations utilized. A preliminary study is now being conducted to identify the most urgent research problems in this field, and to determine whether and in what way the Hydrologic Sciences Division can contribute to their solution.

A new program now under consideration and probably to be put into effect within the year is the Basin Management Program proposed by the Computer Research Section. As explained in the preamble to the portion of this catalogue describing the current projects of this section, many of these projects are either terminating or entering a period of routine housekeeping and data-collecting operations. The opportunity is presented to embark upon a well-planned cohesive program whose objectives satisfy the existing criteria of national need, scientific significance, and high priority in terms of the declared Branch objectives. The project structure of the proposed new Basin Management Program is now well defined; project and program objectives are under review to ensure individual and overall suitability for inclusion in Groundwater Subdivision activities. The basic theme of the program is the development of automated methods to provide, process and present the hydrologic data required by basin managers to enable them to make logical informed decisions concerning not only the storage, use and allocation of water resources but also those engineering or agricultural practices which might tend to influence the hydrologic regime. The program also aims at automation of the more routine decision-making processes to enable basin managers to concentrate on problems of a more critical and less stereotyped nature. Finally, as indicated in the earlier discussion relating to Arctic hydrology, it proposes an investigation into phase changes in the vicinity of the subsurface ice-water interface. This investigation will lead into a broader study of the interactions between groundwater and the hydrogeologic environment.

It can be inferred from the foregoing discussion that the proposed Basin Management Program would ideally encompass much more than is included in the relatively narrow confines of hydrogeology alone. Indeed, if it is to attain its objectives, it must be so. The initial projects will, however, be primarily hydrogeological in nature, making use of the expertise now available within

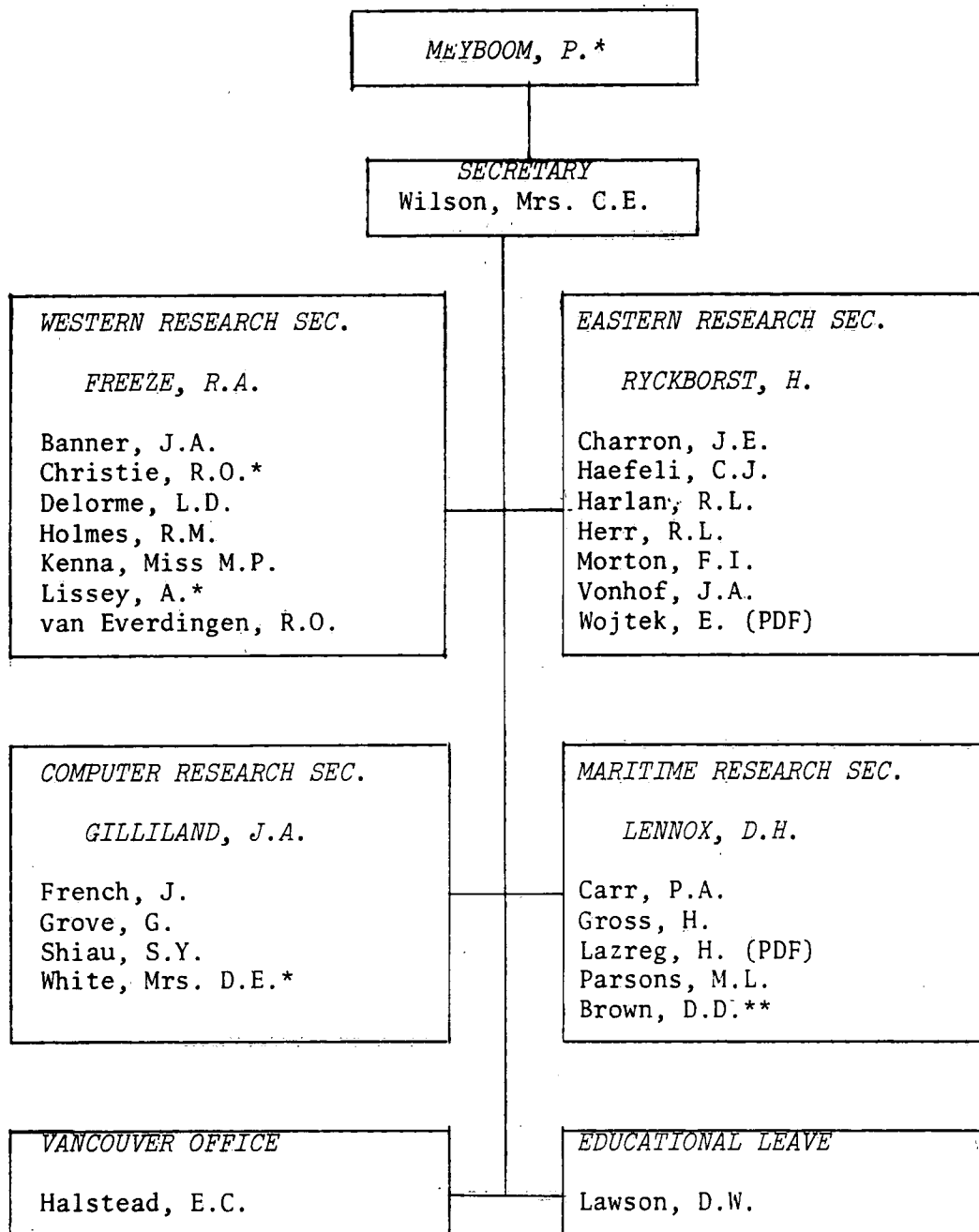
the Groundwater Subdivision. It is hoped that eventually other Federal specialist groups will participate directly or indirectly in this proposed program.

Ottawa, January 21, 1970.

A handwritten signature in cursive script, reading "D. H. Lennox". The signature is written in dark ink and is positioned above the typed name.

D. H. Lennox, A/Head,
Groundwater Subdivision.

5. ORGANIZATION CHART



**Ph.D. Candidate, University of Western Ontario, working under Mr. Lennox's direction.

*Has left Subdivision.

CATALOGUE OF CURRENT PROJECTS

Western Research Section

1. Western Research Section

The Western Research Section, unlike the other three sections in the Subdivision, is based in Calgary, Alberta, rather than in Ottawa. Most of its projects have either been completed or are now drawing to a close because of the departure of key personnel for other organizations. Since its inception as a section in 1965, its scientists have turned out an impressive total of 36 internal and external publications; more will be forthcoming during the final flurry of writing and publication accompanying the completion of a number of outstanding projects.

The activities of the Western Research Section have been more diversified than has been the case for the other three sections. A major project has been the study of groundwater recharge and flow through the unsaturated zone (GW 67-1a). The geohydrology of pingos has also been under investigation and a sensitive water-level detector has been developed for use in this study (GW 67-3). The chemistry and movement of formation waters in the Western Canada sedimentary basin are being investigated (GW 67-4) and useful data have been collected for springs in the Rocky Mountains as well as for deep formations in the plains area. An airborne platform has been used in southeastern Alberta to obtain an upward continuation of land-based measurements related to the energy budget at the ground-air interface (GW 67-5). The influence of chemical and physical environment on ostracode populations in prairie ponds, lake and sloughs has been intensively investigated (GW 67-6). One important objective of this last project is the determination of the paleo-hydrogeology of the interior plains by means of fossil ostracodes.

The Section has been responsible for two important innovations in Federal government hydrogeologic research. The first was the establishment of an experimental plot to provide field data for the investigations of the unsaturated zone (GW 67-1a). This plot has been transferred to and will be maintained by the Eastern Research Section; its successful use has stimulated the establishment of a similar plot at a site outside Ottawa. The second innovation was the establishment of a hydrogeological laboratory. Experiments conducted in this laboratory served to confirm or strengthen conclusions based on field results and theoretical studies: tensiometer-transducer column experiments were run in support of the unsaturated-zone studies (GW 67-1a) and permeability measurements were made in connection with the bedrock-aquifer formation-water studies (GW 67-4).

Natural Groundwater Recharge

A. OBJECTIVES:

1. To investigate the mechanism of groundwater recharge through the unsaturated zone.
2. To investigate the applicability of saturated-unsaturated flow pattern analysis in water resource studies which use the systems analysis approach.

B. PREVIOUS WORK:

1. Publications

Freeze, R. A., 1967. The continuity between groundwater flow systems and flow in the unsaturated zone. Natl. Res. Council Canada, Proc. Hydrology Symposium No. 6, pp 205 - 232.

Freeze, R. A., 1968. Quantitative interpretation of regional groundwater flow patterns as an aid to water balance studies. Intnatl. Assoc. Sci. Hydrology, Gen. Assembly of Bern, Publ. No. 78, pp 154 - 173.

Freeze, R. A., 1969. Hydrology of the Good Spirit Lake drainage basin, Saskatchewan: A preliminary analysis. Inland Waters Branch Technical Bulletin No. 14, 36 pp.

Freeze, R. A., 1969. The mechanism of natural groundwater recharge and discharge. 1. One-dimensional, vertical, unsteady, unsaturated flow above a recharging or discharging groundwater flow system. Water Resources Research, v. 5, pp 153 - 171.

Freeze, R. A. and J. A. Banner, in press. The mechanism of natural groundwater recharge and discharge. 2. Laboratory column experiments and field measurements. Water Resources Research.

Freeze, R. A. and J. A. Banner, in press. An instrumented experimental site for the investigation of soil moisture, frost and groundwater recharge, Calgary, Alberta. Inland Waters Branch Technical Bulletin.

2. This project is now complete.

Field instrumentation in the Good Spirit Lake IHD basin has been turned over to Mr. S. Y. Shiau of the Computer Research Section. He will supervise and interpret the continuing weekly measurement program carried out by the local basin manager. (see GW 67 - 1^b).

The experimental plot has been turned over to Dr. Harlan of the Eastern Research Section. He will supervise and interpret the continuing weekly measurement program carried out by Mr. J. A. Banner in Calgary (see GW 69 - 2). The moisture extraction equipment and tensiometer-transducer soil-column apparatus have also been transferred to Dr. R. L. Harlan.

Hydrogeology of the Oak River Basin, Manitoba

A. OBJECTIVES:

1. To determine whether the recharge and discharge ends of groundwater flow systems manifest themselves as mappable surface features.
2. To conduct a long-term hydrologic budget analysis of the basin (IHD representative basin).

B. PREVIOUS WORK:

1. Theses and Publications

Bostock, C. A., 1965. Groundwater Study, Rivers Area, Manitoba. Unpubl. M.Sc. thesis, Univ. of Sask.

Parry, J. P., 1966. Analysis of a Selected Artesian Aquifer in the Oak River basin, Manitoba. Unpubl. B.A. Sc. thesis, Univ. of Toronto.

Sharp, J. W. G., 1966. The Analysis of Pumping Test Data from artesian Aquifers. Unpubl. M.Sc. thesis, Univ. of Sask.

Korol, J. R., 1967. Permeability Determinations in the Oak River basin, Manitoba. Unpubl. B.Sc. thesis, Univ. of Sask.

Lissey, A., and Wyder, J. E., 1966. Interbasinal Groundwater Flow, Oak River, Manitoba. Geol. Survey Can., Paper 65-23.

Lissey, A., 1967. The use of Reducers to Increase the Sensitivity of Piezometers. Jour. Hydrology, V. 5, pp 197-205.

Lissey, A., 1968. Surficial Mapping of Groundwater Flow Systems with Application to the Oak River Basin, Manitoba. Unpubl. Ph.D. thesis, Univ. of Sask.

2. Field

- a. Duration - May to September 1963 - 1967.

b. Instrumentation:

- 4 recording stream gauges (1 operated by Manitoba Water Control and Conservation Branch and 3 operated by Water Survey of Canada).
- 8 meteorological stations (1 is a Class A weather station and includes tipping bucket and evaporation pan records; 5 record temperature and precipitation daily; and 2 record only daily precipitation). All are operated by Meteorological Branch, Department of Transport.
- 79 piezometers arranged in 35 nests (read once a week from May 1965 to September 1967).

c. Other:

- 45 test holes drilled, samples and E-logged (8 by GSC Pleistocene Section and 37 by Inland Waters).
- 32 piezometers (deepest one in nest) sampled and E-logged.
- 3 pumping tests conducted on town wells of Hamiota, Strathclair, and Oak River (in cooperation with Manitoba Water Control Board).
- 2 pumping tests on temporary wells.
- Slug tests and/or bailer tests on every piezometer.
- 65 detailed water analyses of groundwater from piezometers.
- 80 Hach kit analyses of surface waters.

All piezometers surveyed into geodetic datum.

C. PRESENT WORK:

1. Field

All meteorological stations recording daily measurements.
All stream gauges under continuous automatic recording.
All piezometers read once a month starting September, 1967 by a local basin manager.

2. Office

Objective No. 1 has been met. All results to date will be published in the following papers:

Lissey, A. (in preparation), Slough-focused Transient Groundwater Flow Patterns

Lissey, A. (in preparation), A Hydroecological Classification of Sloughs.

Lissey, A. (in preparation), Reconnaissance Mapping of Groundwater Flow Systems in the Oak River Basin, Manitoba.

D. FUTURE WORK:

A paper describing the Oak River basin study will be prepared for presentation at the 1970 meeting of the Geological Association of Canada in Winnipeg. Apart from the preparation of papers, this project is complete. Maintenance of instrumentation and collection of data became part of Project No. GW 67 - 2^b on October 1, 1968.

Permafrost Geohydrology

(a) Pingos, Yukon

A. OBJECTIVES:

1. Investigate the groundwater flow systems associated with the type of pingos occurring in the discontinuous permafrost region of the Yukon.
2. Investigate the modes of groundwater recharge and discharge in permafrost regions.

B. PREVIOUS WORK:

1. Laboratory

A device (Pingo Pinger) capable of measuring and recording water level changes with an accuracy of ± 0.0001 feet was developed in the spring of 1968. This instrument underwent considerable modification after the 1968 field season because of its failure to perform under field conditions.

2. Field

1968 - The attempt to conduct water-level recession analyses on pingo lakes near Dawson, Y. T. was marred by logistic and technical problems and no useful field data could be obtained. Movement in the area was restricted by lack of an adequate vehicle to transport personnel and equipment over difficult terrain and test drilling and water level measurements were unsuccessful because of mechanical problems. In particular, the "Pingo Pinger" failed to function effectively because of the nightly occurrence of condensation in a vital switch.

1969 - The 1969 field season was much more successful. The modified "Pingo Pinger", although still requiring further development work, operated well, making possible the measurement of lake level recessions in two pingo lakes. One of the pingos was completely surveyed and mapped. All the measurement sites on this pingo were precisely located. Access to the pingos was very satisfactory with a tracked vehicle which replaced the so-called go-anywhere-vehicle utilized in 1968.

C. PRESENT WORK:

1. Laboratory

The "Pingo Pinger" is undergoing further mechanical and electronic modification but has nevertheless demonstrated its value in measuring very small water level changes.

D. FUTURE WORK:

1. Office

The possible preparation of two papers is now under consideration. The first will describe field results and the second the equipment utilized.

Bedrock Aquifers of the Western Sedimentary Basin

A. OBJECTIVES:

1. To investigate properties and processes, leading to an explanation of the chemistry and movement of formation waters in the basin.
2. Assessment of the potential of the formation waters as an economic resource (in terms of both water and dissolved constituents).

B. PREVIOUS WORK:

1. Office

Computer programs for the processing of chemical and pressure data have been adapted for use on a UNIVAC 1108 in Calgary. Chemical analyses, pressure-test results and formation data for Manitoba wells have been coded and punched on IBM cards, and processing of these has been started. Collection of pertinent references on the subject of formation water movement and chemistry was continued.

2. Field

- a. The investigation of mineral and thermal springs in the Rocky Mountains was concluded with a detailed study of a group of acid iron-carrying springs in Kootenay National Park. Field measurements included temperature, conductivity, pH and redox potential. Contents of CO₂ and O₂ were analyzed in the field. The application of geochemical thermodynamics to these spring waters has provided experience which will be valuable in dealing with formation waters in general.
- b. One year of periodic (2-3 week interval) measurements and sampling of the Cave and Kidney Springs at Banff, Alberta, was completed in October 1969. Results of chemical analyses by the Water Quality laboratory in Calgary and of analyses for oxygen, hydrogen, sulfur and carbon isotopes by the Physics Department, University of Alberta in Edmonton, should become available in the near future. These are expected to provide clues to the origin of the water and of its mineral content.

- c. Piezometric measurements in the Riverhurst (Sask.) area, on Diefenbaker Lake, were continued during 1969.

3. Laboratory

- a. Some further tests of Bearpaw sand and shale with a large permeameter revealed development of measurable osmotic pressures for concentration differences between the solutions on either side of the sample of the order of 45,000 ppm.
- b. A series of simple tests was started on the acid, heavy-mineral carrying water from the Paint Pots springs in Kootenay National Park to determine whether a simple treatment might remove the "objectionable" properties of the water (low pH, high Fe, Zn and Pb content).

4. Publications

- van Everdingen, R.O., 1968. Diefenbaker Lake - Effects of bank erosion on storage capacity. Inland Waters Branch Technical Bulletin 10, 21 p.
- van Everdingen, R.O., 1969. The Ink Pots - a group of Karst springs in the Rocky Mountains near Banff, Alberta. Can. Jour. Earth Sciences, v. 6, pp 545-554.
- van Everdingen, R.O., 1969. Degree of saturation with respect to CaCO_3 , $\text{CaMg}(\text{CO}_3)_2$ and CaSO_4 for some thermal and mineral springs in the Southern Rocky Mountains, Alberta and British Columbia. Can. Jour. Earth Sciences, v. 6, no. 6, (in press).
- van Everdingen, R.O., 1968. Studies of formation waters in Western Canada: Geochemistry and hydrodynamics. Can. Jour. Earth Sciences v. 5, pp 523-543.
- van Everdingen, R.O., 1968. Mobility of main ion species in reverse osmosis and the modification of subsurface brines. Can. Jour. Earth Sciences, v. 5, pp 1253-1261.

C. WORK IN PROGRESS:

1. Office

- a. Coding of chemical analysis and pressure data from petroleum drilling in Saskatchewan and British Columbia is expected to get underway as soon as test runs on the Manitoba data (used as a large pilot sample) are completed.
- b. An extensively illustrated report is being prepared on the mineral and thermal springs studied in the past two years. Although it will contain all data available on these springs, it will be aimed at a mixed technical and non-technical audience. It is hoped a format can be found that would be suitable for distribution to visitors to the Rocky Mountain National Parks.

2. Field

- a. Piezometer measurements in the Riverhurst area, Sask., will be continued into 1970, because Diefenbaker Lake has not yet reached its full-supply level.
- b. It is anticipated that laboratory experiments on Paint Pots spring water will lead to a small-scale field treatment test either at the spring site, or at a site of mine-drainage pollution somewhere in Alberta.

3. Laboratory

- a. Experiments on the interaction between clay minerals (shales) and formation water will be continued, in cooperation with Dr. A.E. Foscolos of the Institute of Sedimentary and Petroleum Geology in Calgary.
- b. "Pollution abatement" tests on spring water from the Paint Pots will be continued and diversified.

Hydro-Climatology of Foothills and Prairie

A. OBJECTIVES:

To investigate the energy budget of the ground-air interface over an area of transition between prairie and foothills terrain, with particular reference to the hydrologic balance.

B. PREVIOUS WORK:

1. Publications

Holmes, R. M., 1969, Note on low level airborne observations of temperature near prairie oases. Monthly Weather Review, v. 97, pp 333-339.

Holmes, R. M., 1969. A study of the climate of the Cypress Hills. Weather, v. 24, pp 324-330.

Holmes, R. M., 1969. Oasis effects caused by the Cypress Hills. Proc. 3rd Conf. Forest Micro-climatology, Kananaskis, Alberta.

Holmes, R. M., 1969. Airborne measurements of thermal discontinuities in the lowest layers of atmosphere. Proc. 9th Conf. Ag. Met., Univ. Washington, Seattle.

Holmes, R. M., 1970. Airborne techniques in climatology; oasis effects above prairie surface features. Inland Waters Branch Technical Bulletin No. 19.

2. Field

- a. A transect of prairie to foothills (Cypress Hills) terrain has been instrumented with standard weather observing instruments to measure the climatic transition at the surface from one area to the other. These data are augmented by observations taken by the Departments of Transport and Agriculture at nearby Prairie sites. Observations taken at the various sites vary somewhat depending on the location but include maximum and minimum temperature, grass minimum (summer only), hygrothermograph trace, miles of wind, "A" pan evaporation (summer only), latent evaporation (summer only), wind speed and direction, soil temperature at 4" and 8", hours of sunshine (summer only), barometric pressure, rainfall, rainfall intensity, and dew point.

C. WORK IN PROGRESS:

1. Publications

Holmes, R. M., 1969. Effects of agriculture on the atmospheric boundary layer. Submitted to Agronomy Journal.

Holmes, R. M. and K. Hage, 1969. Airborne observations of three chinook type situations in south Alberta. In preparation.

2. Field

- a. During summer months each site is visited twice daily by a field crew, and observations are made. In the winter months, the sites are visited once a week and charts are changed on the hygrothermograph.
- b. A light aircraft is being instrumented to provide information on the layers of air immediately above the surface over a wide horizontal area. These data supplement the ground observations by providing an observational continuum from the surface sites to the air above. Further, concentrated measurements are taken over selected terrain to develop airborne methods of measuring the surface energy budget with particular regard to evapotranspiration. Measurements are taken at low level and will include observations of surface temperature (Infra-Red device) atmospheric moisture content, albedo, air temperature, altitude above ground, atmospheric pressure, and air turbulence. These measurements permit the calculation of evapotranspiration and the complete energy budget.
- c. During the summer of 1969 the sites were overflown by a National Aeronautical Establishment aircraft containing an airborne infrared (IR) scanner and cameras for false colour, IR, ekta chrome, and black and white photography. The results obtained with these different sensors are to be compared for the information they may yield on surface hydrology. Simultaneous air mass measurements were made with the instrumented light aircraft to determine the effects of air mass characteristics on the IR scanning.

3. Office

Climatic data are being abstracted from instrument charts and traces, and pertinent calculations are made. Tabulation and reduction of surface data takes place on a continuing basis with a view to developing quantitative relationships between terrain and climate.

4. Laboratory

The mobile laboratory is transported to the most convenient location for the work at the time (e.g. Elkwater, Suffield, Medicine Hat, Calgary, etc.) whether concerned with airborne or surface work. The laboratory is used full-time for the construction, repair, maintenance and calibration of instruments used in the airborne and surface measurements. Instruments are constructed which are not available commercially and which are within the capability of the personnel and equipment. Present efforts are directed toward maintenance and calibration of existing equipment and construction of air temperature and vapor pressure, and turbulence measuring devices for the surface and airborne phases.

D. FUTURE WORK:

The first three seasons were occupied largely in organization, obtaining equipment, and setting up of the present program. During the following seasons the surface observational work proceeded with a program of data tabulation, and reduction. It is envisaged that at least 5 years of data will be necessary to sample a suitable number of climatic variables at the surface sites. The airborne observations will continue to provide the observational continuum from the surface to the lower air layers. The past two seasons produced data which show that this technique has significant application in climatology and hydrology. The airborne method of measuring the energy budget near the surface as it affects the meso scale climate will be further developed. Completion of the complete instrument system including the turbulence sensors is planned. This system will then permit the measurement of the flux of heat and water from the surface through the atmospheric boundary layer. It is of value to note that the instrumentation thus far developed, functions properly and within specifications. These include, air temperature, air dew point temperature, albedo, surface IR temperature, and radar altitude. These are fast response sensors and are constructed to mate with fast response measurements of turbulence.

R. M. Holmes

A critical re-evaluation of the entire project is planned for 1970-71 to determine if it is to continue, and on what basis.

Paleohydrogeology of the Interior Plains of Canada

A. OBJECTIVES:

1. To determine tolerance limits of freshwater ostracodes to the chemical and physical parameters from the natural laboratories of ponds, lakes, and streams.
2. To assess the relationship of the chemistry of pond, lake, and stream water to geology, hydrology, botany, and climate.
3. To carry out a comprehensive systematic study of freshwater ostracodes of Canada.
4. To reconstruct the past history of ponds and lakes by means of water quality and quantity models.

B. PREVIOUS WORK:

1. Publications

Delorme, L. D., 1967. Freshwater ostracode synonyms:
Jour. Paleontology, vol. 41, no. 3, p. 792-794.

Klassen, R. W., Delorme, L. D., and Mott, R. J., 1967.
Geology and paleontology of Pleistocene deposits
in southwestern Manitoba: Can. Jour. Earth Sci.,
vol. 4, no. 3, p. 433-447.

Delorme, L. D., 1967. New freshwater Ostracoda from
Saskatchewan, Canada: Can. Jour. Zoology, vol. 45,
p. 357-363.

Delorme, L. D., 1967. Field key and methods of collecting
freshwater ostracodes in Canada: Can. Jour. Zoology,
vol. 45, p. 1275-1281.

Delorme, L. D., 1968. Pleistocene freshwater Ostracoda
from Yukon, Canada: Can. Jour. Zoology, vol. 46,
no. 5, p. 859-876.

Delorme, L. D., 1969. The ostracode genera Cypriconcha
and Megalocypris: Can. Jour. Zoology, vol. 47,
no. 3, p. 271-281.

- Delorme, L. D., and Donald, D., 1969. Torpidity of freshwater ostracodes. Can. Jour. Zoology, v. 47, no. 5, pp 997-999.
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- Delorme, L. D., 1969. Ostracodes as Quaternary paleoecological indicators. Can. Jour. Earth Sci., v. 6, no. 6.
- Delorme, L. D. Freshwater ostracodes of Canada, Part I. Subfamily Cypridinae. Can. Jour. Zoology, v. 48, no. 1. (in press)
- Delorme, L. D. Freshwater Ostracodes of Canada, Part II. Subfamilies Cypridopsinae, Herpetocypridinae, and family Cyclocyprididae. Can. Jour. Zoology, v. 48, no. 2. (in press)

Field

- a. 1966 - 768 samples were collected from 49,000 square miles in south central Alberta; 18,000 ostracode specimens were collected. Complete chemical analyses for major ions were made on the 768 surface water samples.
- b. 1967 - 1,650 samples were collected from 105,600 square miles in central and northern Alberta, North West Territories, and the western half of Saskatchewan; 42,000 ostracode specimens were collected. Chemical analyses for major ions were made on the 1,650 surface water samples.
- c. 1968 - 1,500 samples were collected from 96,000 square miles in eastern Saskatchewan, Manitoba, and southwestern Ontario; 37,500 ostracode specimens were collected. Chemical analyses for major ions were made on 1,500 water samples.
- d. 1969 - 75 samples were collected of which 24 were from the Kenora lakes on which the Fisheries Research of Canada, Freshwater Institute, Winnipeg are carrying out fertilization studies; 51 samples were collected on a 10-day cruise of Lake Winnipeg also in conjunction with the Freshwater Institute, Winnipeg. Chemical analyses for major ions were also made on these water samples.

- e. 24 cores were collected during the summer of 1969 using a Minuteman Mobile Drill modified to obtain a core. 360 feet of core were obtained producing 1589 samples.

3. Office

- a. Computer Sciences of Canada (Calgary) are in the process of completing programs which will be used in preparing paleoecological interpretations.
- b. Identification of ostracode species was done for the following people:

Dr. N. W. Rutter	Geological Survey of Canada, November 1, 1968; 9 samples. Peace River, Alberta.
Dr. P. F. Karrow	Department of Earth Science, University of Waterloo, November 14, 1968; 4 samples, Kincardine, Ontario.
Dr. W. O. Kupsch	Department of Geological Science, University of Saskatchewan, November 14, 1968; 1 sample, Saskatoon, Saskatchewan.
Dr. N. W. Rutter	Geological Survey of Canada, November 20, 1968; 1 sample, Calgary, Alberta.
Dr. E. A. Christiansen	Department of Geology, Saskatchewan Research Council, December 6, 1968; 12 samples, Saskatchewan.
Dr. P. F. Karrow	Department of Earth Science, University of Waterloo, December 9, 1968; 3 samples, Ontario.
Mr. L. Pettipas	Department of Archeology, University of Calgary, March 6, 1969; 5 samples, Swan River, Manitoba.

Dr. C. R. Harington	National Museum of Canada, April 2, 1969; paleoecological interpretation, Yukon.
Dr. O. L. Hughes	Geological Survey of Canada, March 6, 1969; 32 samples, Yukon.
Dr. R. W. Klassen	Geological Survey of Canada, April 14, 1969; 119 samples Assiniboine River Valley, Manitoba.

C. WORK IN PROGRESS:

1. Publications

Delorme, L. D. Freshwater Ostracodes of Canada, Part III.
Family Candonidae. Can. Jour. Zoology. (in preparation)

Delorme, L. D. Freshwater Ostracodes of Canada, Part IV.
Families Ilyocyprididae, Notodromadidae, Darwinulidae;
subfamily Neocytherideidinae. Can. Jour. Zoology. (in
preparation)

Delorme, L. D. Freshwater Ostracodes of Canada, Part V.
Family Limnocytheridae. Can. Jour. Zoology. (in
preparation)

2. Office

- a. Complete papers on systematics of freshwater ostracodes.
- b. Prepare paleoecological interpretations of cores
collected during 1969.

D. FUTURE WORK:

1. To core additional ponds and lakes in order to determine their
past histories by means of qualitative and quantitative models.

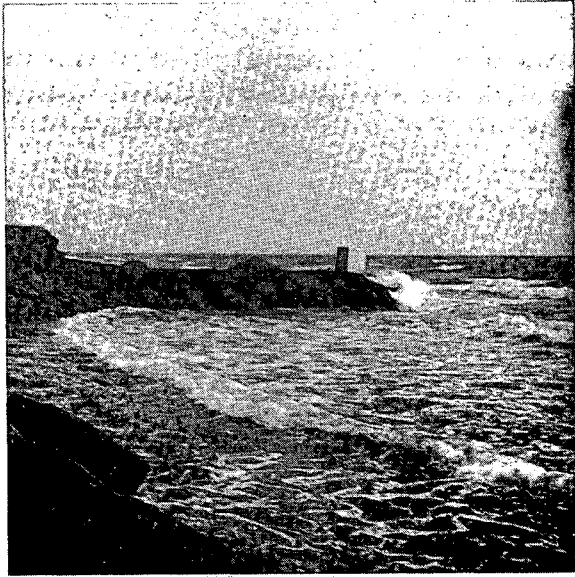


Figure 1. Measuring tidal effect on groundwater levels at Borden, P.E.I. (GW 67-8). This observation well and access ramp were constructed to examine tidally induced groundwater level fluctuations in the subsea portion of the aquifer.

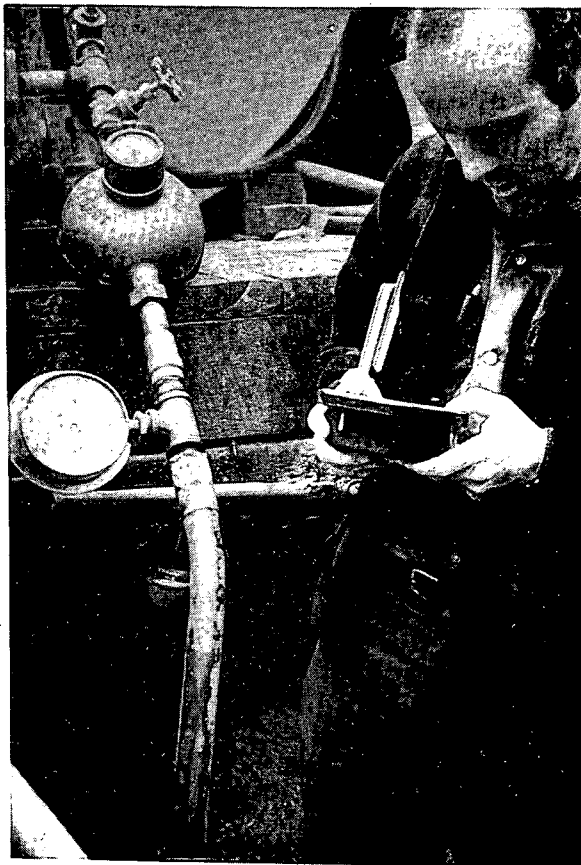


Figure 2. Injection testing to determine fracture-system parameters for an aquifer with a high percentage of fracture permeability (GW 68-11).

2. Maritime Research Section

The Maritime Research Section was created to carry out the Maritime Research Program. The first full-scale operational year for this section was completed during the autumn of 1969. It featured an investigation of tidal effects on groundwater levels (GW 67-8), a case-history study of salt-water intrusion at Shippegan, New Brunswick (GW 68-10), shallow geothermal logging and the observation and measurement of fracture systems in boreholes and at outcrops (GW 68-11), earth resistivity exploration (GW 68-12), and preliminary studies related to planned investigations of the effects of pump testing on the transition zone between fresh and salt waters in coastal aquifers (GW 69-1).

All these studies have a bearing on existing and potential salt-water intrusion problems in the Atlantic Provinces. The ultimate long-range objective of the program is to provide methodologies for (1) routine study and observation of saltwater intrusion and (2) design of well fields and, if necessary, engineering structures providing the most acceptable compromises between maximizing fresh-water production and minimizing salt-water intrusion while keeping capital and operating costs at acceptable levels.

Because this program is in its early stages, results for most projects are tentative and meaningful appraisals of progress are not in general possible. Exceptions can, however, be made in the cases of tidal effect analysis and earth resistivity exploration. Analysis of tidal groundwater level fluctuations are providing very useful information concerning hydrologic characteristics of coastal aquifers. Similarly, there is an excellent correlation between earth resistivity observations and the intrusion of salt water into these aquifers.

*Sea-Water Intrusion Study in the Pennsylvanian
and Permian Rocks of New Brunswick and Prince Edward Island*

A. OBJECTIVES:

1. To comprehend the relationship between seawater and fresh groundwater in the interbedded fractured sandstones and mudstones which characterize the bedrock hydrogeologic environment in the Maritime Provinces with the aim of establishing criteria necessary for the safe development of well fields near the sea.
2. To establish methods of determining regional aquifer parameters from the observation of groundwater levels fluctuating with the tides.

B. PREVIOUS WORK:

1. Publications

Carr, P. A., 1967. Salt-water Intrusion Studies in the Maritimes. Maritime Sediments, Vol. 3, No. 4, pp 109 - 111.

_____, 1969. Salt-water Intrusion in Prince Edward Island. Can. J. Earth Sci., Vol. 6, No. 1, pp 63 - 74.

Chipping, D. H., 1967. Groundwater Conditions Beneath Georgetown, Prince Edward Island. Student Research Report, Department of Geology, Stanford University, California.

Carr, P. A. and van der Kamp, G., 1969. Determining Aquifer Characteristics by the Tidal Method. Water Resources Research, Vol. 5, No. 5.

2. Field

- a. Installation of a line of 5 wells and a tidal gauge at Borden, P. E. I.
- b. Collection of 16 and 29 days of continuous records from this network.

C. WORK IN PROGRESS:

1. Office

Processing of these records and use of the computer to make a harmonic analysis of the various wave components. The attenuation and time lag of each wave will be used to test the tidal method for consistent results.

D. FUTURE WORK:

The aquifer diffusivity values determined by the tidal method will be used to see if the Rorabough method of calculating aquifer diffusivity from the rate of water-level decline on a well hydrograph can be applied to Prince Edward Island.

*Seawater Intrusion at Shippegan,
Taylor Island, New Brunswick*

A. OBJECTIVES:

1. To determine the influence on groundwater flow systems of salt-water intrusion induced by municipal and industrial pumping in the Shippegan area.
2. To predict rate and future extent of intrusion and to determine under what conditions the transition zone between fresh and salt water may stabilize.

B. PREVIOUS WORK:

1. Two wells drilled in 1967 by the New Brunswick Department of Natural Resources to determine depth of zone of diffusion near the centre of Taylor Island.
2. During August, 1967 and May to September, 1968 and 1969
 - a. 57 test holes drilled and logged
 - b. 54 piezometers installed in fourteen nests
 - c. 15 wells pump tested
 - d. 16 groundwater level, 1 tidal and 2 precipitation gauges installed
 - e. about 2,000 samples bailed from the salt-water intrusion wedge and titrated for chlorides
 - f. elevations obtained for all open wells and piezometers with respect to mean tide datum
 - g. 115 groundwater samples analyzed for all major ions
 - h. tidal efficiency and time lag determined on 54 piezometers and 30 open wells
 - i. piezometric heads measured weekly and flow net sections and plans prepared
 - j. slug tests conducted to determine permeability of claystone units

C. WORK IN PROGRESS:

1. Field

Piezometric heads read weekly to determine the aquifer response and safe yield of a new well field.

2. Office

- a. Analysis of tidal data to determine aquifer coefficients.
- b. Digital modeling of piezometric sections by finite-element and finite-difference methods to determine the annual recharge and discharge for the island.
- c. Application of the Pinder digital model to determine aquifer response to pumping at the new well field and safe yield of the well field.
- d. Study of mechanics of intrusion of seawater under the influence of a pumping coastal well field.

D. FUTURE WORK:

- 1. Project to be completed by June, 1970.

*Regional Groundwater Flow and
Subsurface Temperatures in a Maritime Province Coastal Environment*

A. OBJECTIVES:

1. To investigate the natural regional groundwater flow and heat transfer in fractured media in a Maritime Province coastal environment.
2. To assess the effect of groundwater withdrawal on the regional groundwater hydrodynamics, in particular on the fresh-saline groundwater transition zone.
3. To explore the application of geothermal measurements to the evaluation of groundwater flow.

B. PREVIOUS WORK:

1. Publications

nil

2. Field

- a. Measurement of fracture orientations in outcrops along 65 sample lines in eastern New Brunswick and 18 sample lines in P. E. I.
- b. Water injection testing in six existing observation wells in Prince Edward Island and eight existing observation wells at Shippegan, New Brunswick, totalling 1,500 feet of borehole.
- c. Temperature logging of 23 existing observation wells in the Eliot River area, P. E. I. and 17 observation wells at Shippegan, N. B.
- d. A four-day Field Seminar on fracture flow was held at Charlottetown, P. E. I. by members of the Maritime Research Section, with Dr. D. T. Snow, Colorado School of Mines, as seminar leader. Approximately 25 participants representing the Maritime Provinces, two groundwater consulting firms and the Hydrologic Sciences Division attended.

- e. Selection of a study site at Cap Pele, New Brunswick for detailed subsurface study of the fracture permeability and regional groundwater flow related to the fresh-salt water interface. This site will be used for detailed tidal efficiency studies being undertaken by Mr. G. van der Kamp.

3. Office

- a. Preparation of a computer program to calculate the permeability axes using field observations of fracture orientations and spacings and an estimate of fracture apertures from water injection test data.
- b. Attendance at a two-week course on Applied Reservoir Fluid Flow Simulation at Banff, Alberta in September, 1969.

C. WORK IN PROGRESS:

1. Publications

nil

2. Field

Drilling program to collect subsurface hydrogeological data at Cap Pele, New Brunswick. This program includes coring, electrologging, borehole photography, water injection testing, temperature logging and piezometer installation.

3. Office

- a. Processing of water injection test data and fracture data to calculate the permeability tensor.
- b. Development of a computer program to apply a variance analysis to the directional geometric properties of fracture systems.
- c. Analysis of borehole temperature logs.

D. FUTURE WORK:

1. Field

- a. Continued temperature logging of boreholes in the Cap Pele, Shippegan and Eliot River areas to monitor seasonal temperature variations and variations induced by groundwater withdrawal particularly in the Shippegan area.
- b. Study of groundwater hydrology in a fractured crystalline rock area where integranular permeability is negligible. Emphasis will be on determining the hydrologic properties of the fractured medium by hydraulic tests such as pump tests. A new field site is to be selected for this study which is to be conducted by a graduate student for a Ph.D. thesis.

2. Office

Numerical simulation of salt-water intrusion and subsurface thermal effects in a coastal environment.

*Geophysical Methods Applied to the
Study of Seawater Intrusion*

A. OBJECTIVES:

Evaluation of the application of geophysical methods in the characteristic hydrogeologic environment of the Maritime Provinces to:

1. the location of the interface or transition zone between fresh and saline waters in aquifers affected by seawater intrusion
2. the determination of horizontal and vertical variations in groundwater quality in the vicinity of the interface or transition zone
3. the observation of displacement, distortion or broadening of the interface or transition zone due to natural or man-made causes.

B. PREVIOUS WORK:

1. Delineation of the lateral intrusion zone, in Shippegan, Cap Pele, N.B.; and the Eliot River area, P. E. I. by surface electrical resistivity profiling.
2. Investigation of the vertical variation in conductivity of the geological formations by resistivity soundings in the above-mentioned areas.

C. WORK IN PROGRESS:

Interpretation of field results.

D. FUTURE WORK:

1. Field

Further earth resistivity surveys in selected areas where seawater intrusion has or may become a problem and where the methods developed to date can be tested. Preliminary studies of the induced polarization technique as a supplement to the resistivity method in determining depth to the freshwater-seawater interface.

2. Office

Literature survey of application of earth resistivity method in particular and of ground and airborne geophysical techniques in general.

Development of computer methods for the final stages in the analysis of resistivity field data.

Pumping Experiments with Coastal Wells

A. OBJECTIVES:

1. For typical coastal aquifers, to examine the effects of pumping from wells completed in the vicinity of the transition zone between fresh and salt waters.
2. To evaluate the possibility of using special techniques (such as 'doublet wells' producing from both the fresh-water zone and the underlying saltwater zone) to maximize long-term freshwater production while avoiding 'upconing' or other harmful effects due to excessive modification of the pre-existing distribution of fresh, brackish and salt waters.
3. To develop field methods for the accurate observation of the movement of hydrochemical boundaries due to pumping from the vicinity of the transition zone.

B. WORK IN PROGRESS:

A test drilling program is being conducted near Rice Point on the south coast of Prince Edward Island to obtain an accurate picture of the subsurface distribution of fresh, brackish and salt waters. This water quality information is required for the intelligent design of pump test experiments.

C. FUTURE WORK:

1. Field

Completion of the 1969 test drilling program. Further test drilling and some pump testing in 1970.

2. Office

Analyses of hydrologic, geologic and hydrochemical data from 1969 test drilling program. Design of 1970 drilling and testing program.



Figure 3 (above). Two river level recorders for the testing of intake pipe devices.



Figure 4. The B.C. hydraulic snow gauge is a large closed butyl-rubber tube filled with antifreeze. An open manometer (thin tube at left) records snow load pressure on the shield.

3. Eastern Research Section

The research field of the Eastern Research Section comprises groundwater inflow and outflow, groundwater chemistry, and evaporation from the groundwater reservoir. The ultimate research objective is the synthesis of groundwater hydrology, soil physics and surface-water hydrology.

Two projects are concerned with parametric hydrology - one for a glaciated basalt plateau in British Columbia (GW 67-11) and one for the Northern Lake Ontario basin (GW 68-2). The latter study is a contribution to the International Field Year on the Great Lakes (IFYGL), as are an investigation of groundwater flow into Lake Ontario (GW 68-3) and the development of computer methods to construct geologic maps and cross sections for the Lake Ontario basin (GW 68-4). This last project will take advantage of data retrieval programs developed for GOWN (computerized data storage, processing and retrieval system) originated by the Computer Research Section - Project GW 68-5).

Other projects of the Eastern Research Section include a study of the relation between potential and regional evaporation (GW 68-8), an investigation of the mechanisms of snowmelt infiltration and associated groundwater recharge (GW 69-2), a study of the relations between groundwater chemistry and groundwater movement in the interstream area between the Ottawa and St. Lawrence Rivers (GW 68-7), and an evaluation of the effects on groundwater and surface-water regimes of surface disposal of waste brines from potash mining (GW 67-12).

Anomalous streamflow data collected during the parametric hydrology studies indicated that the conventional gauge well intake device used to obtain stream water levels gave inaccurate results. This observation led to the development of an improved intake device by the National Research Council. The parametric hydrology studies also led to the development of a model for simulation of daily runoff from daily rainfall and this model was applied successfully to 36 sub-basins within the Fraser River basin.

The Lake Ontario IFYGL studies established that the groundwater divide between the Lake Ontario and Lake Simcoe basins may be accurately taken to coincide with the topographic divide. Analysis of available streamflow data indicated that baseflow characteristics for this area can be predicted from a knowledge of topography, river channel morphology, soil type and geology. Infrared scanning and seismic results for shoreline areas pinpointed areas of groundwater inflow and provided estimates of bedrock depths, respectively. The well inventory for the Lake Ontario basin continued but is still far from completion.

Other highlights included the development of a widely applicable formula to estimate regional evaporation from climatological observations and the identification of the Alfred bog as the major groundwater discharge area for Russell and Prescott counties in eastern Ontario. Results from many of the section's projects suggest that physically based models of complete hydrologic systems should be possible before 1974.

Parametric Hydrology of a Glaciated Basalt Plateau

A. OBJECTIVES:

To show the feasibility of linear system synthesis in the Fraser River forecast models. For this purpose a forecast of the daily flows of 38 large drainage areas in the Fraser River catchment (200,000 sq. kilometers) will be given for the water year, April 1, 1970 - March 31, 1971.

B. PREVIOUS WORK:

1. Field

During the spring and summer of 1969 the following 23 instruments were installed in addition to the 65 operating recorders:

1. shortwave Eppley sensor and integrating analog AC recorder (Texas Instruments)
2. twelve thermistors were installed on a 12-arm wind-tower and the signals are recorded on a 24 channel AC Texas recorder
3. a hygristor was installed and the signal is recorded on the 24-channel Texas analog AC recorder. The recorders are installed in an insulated shelter
4. a 3-arm windtower was installed for wind profile measurements
5. 7 groundwater level sandpoints were installed
6. a barometer was installed.

One-hundred trees were cut to analyze the tree ring widths. The snowgauges were re-calibrated.

C. WORK IN PROGRESS:

1. Publications

- a. Comparison of rainfall measurements at ground level, 30 cm and 150 cm above ground level.
- b. Cross correlation of tree rings from the Cariboo, British Columbia.
- c. The simulation of daily runoff of 38 catchments in the Fraser River basin.
- d. A soil moisture model for the Lake Ontario basin.

2. Field

- a. installation of a downward pointed Eppley radiometer and an analog recorder.
- b. installation of soil moisture cells.
- c. installation of three anemometers.

D. FUTURE WORK

1. Peak flow and low runoff design discharges for the British Columbia plateau areas.
2. A linear rainfall model over a plateau.
3. Snowfall measurements in a ground level raingauge and on the B. C. hydraulic snow gauge.
4. The monoclinic wave runoff routing model in the Fraser River system.
5. A parametric snowmelt and rainfall infiltration model to the groundwater table.
6. Frequency of high and low groundwater tables in the British Columbia plateau areas.
7. The forecast of daily runoff of 38 catchments in the Fraser River basin from April 1, 1970 - March 31, 1970.

Parametric Hydrology of the Northern Lake Ontario Basin

A hydrogeological project for the International
Field Year on the Great Lakes - IFYGL

A. OBJECTIVES:

To simulate daily runoff from daily rainfall for 63 watersheds on both the Canadian and American sides of the Lake Ontario basin for 1095 daily intervals (3-year period).

B. PREVIOUS WORK:

1. Publications

Oosterveld, M., 1969. A soil moisture index on the Lake Ontario basin. Unpubl. M.Sc. thesis, University of Guelph.

A parametric rainfall infiltration model has been developed by Mr. M. Oosterveld (University of Guelph) on contract with the Groundwater Subdivision. It makes it possible to compute the daily soil moisture changes in millimeters over the basin.

C. WORK IN PROGRESS:

1. To test the Oosterveld algorithm (Ayers' model) on data from the Sleepers River area, Vermont, U. S. A.
2. To test Surkan's (IBM) routing model for runoff simulation for application in the Lake Ontario basin.

D. FUTURE WORK:

To proceed with testing of models for forecasting runoff on a daily time interval basis and to predict in advance a year's sequence of runoffs for all tributaries to Lake Ontario.

These predictions will be based on a simulation of rainfall events throughout the year derived from a statistical analysis of existing rainfall data.

Groundwater Flow into Lake Ontario

A hydrogeological project for the
International Field Year on the
Great Lakes (IFYGL)

A. OBJECTIVES:

1. To determine the groundwater flow into the Canadian side of Lake Ontario. The study is a part of the IFYGL terrestrial water budget of Lake Ontario and its basin.
2. Regional importance: amount, storage and flow systems of groundwater in the Lake Ontario basin.

B. PREVIOUS WORK:

1. Field

- a. Instrumentation for baseflow analysis - installation and maintenance of 3 stream gauging stations (in cooperation with the Water Survey of Canada), 4 groundwater level recorders, 2 conductivity recorders.
- b. Use of tracers to evaluate travel time in relation to discharge and slope for stream baseflow study.
- c. Selection of some 20 suitable watersheds for baseflow analysis.
- d. Temperature survey along the shore of Lake Ontario to spot and verify major groundwater outlets (buried channels). The investigations were carried out by boat and by airplane (infrared) in cooperation with the National Research Council and the Canada Centre for Inland Waters, Burlington.
- e. Drilling and testing of 7 deep exploration holes to delineate and determine hydrogeological conditions in buried bedrock channels in the Toronto area.
- f. Seismic survey along the shore of Lake Ontario from Trenton to Scarborough (approximately 80 miles) to determine drift depth and bedrock surface (in cooperation with the Geological Survey of Canada).
- g. Survey of existing wells in the area between Toronto and Lake Simcoe to locate the groundwater divide between the Lake Simcoe and Lake Ontario basins.

2. Office

- a. Compilation of a geological map of the Lake Ontario basin using published and unpublished documents.
- b. Airphoto interpretations with particular regard to geological structures and hydrogeological features.
- c. Application and development of computer program for stream hydrograph analysis.
- d. Analysis of hydrogeological conditions in some 20 watersheds situated around Lake Ontario. Evaluation of: baseflow recession, transmissibility, storage, infiltration, drainage pattern and density, effects of soil, overburden and bedrock on groundwater flow.

C. WORK IN PROGRESS:

- a. Review and analysis of field data.
- b. Construction of geological cross sections along the shoreline.
- c. Evaluation of hydrogeological parameters of the overburden and of the different bedrock formations using some 10,000 existing well data.
- d. Publications (final titles may be different)
 1. Groundwater Flow between Lake Simcoe and Toronto.
 2. Concentrations of Groundwater Inflow along the Shore of Lake Ontario.
 3. The Groundwater Inflow into Lake Ontario.
 4. Baseflow Analysis.

D. FUTURE WORK:

- a. Investigation of hydrogeological conditions in the Hamilton area (Dundas Valley).
- b. Groundwater velocity measurements by means of tracers.
- c. Project should be terminated by Fall, 1970.

Hydrogeological Maps of the Lake Ontario Basin

A hydrogeological project for the International
Field Year on the Great Lakes - IFYGL

A. OBJECTIVES:

1. To develop computer methods for the construction of hydrogeological maps.
2. To develop a computerized method for correlating computer-constructed geological cross-sections.

B. PREVIOUS WORK:

1. Computerized method developed for construction of geological cross-sections.
2. Plotting routine developed for checking digitized values with actual plotted values.

C. WORK IN PROGRESS:

1. Water well locations from the Lake Ontario Basin which are stored by the Ontario Water Resources Commission in Toronto are being digitized and should be completed by the end of 1969.
2. Water well data are being coded and should be completed during 1970.

D. FUTURE WORK:

1. Construction of maps and cross-sections by means of special GOWN retrieval programs.
2. Computerized comparison and verification of the maps produced.

*The Effect of Waste Disposal Basins
on the Groundwater Regime*

The research project is being carried out around International Minerals and Chemical Corporation (Canada) Ltd., K-2 (potash) mine in the vicinity of the town of Esterhazy in southeastern Saskatchewan with full cooperation of the company. Large volumes of waste, both solid and liquid, are generated as a result of mining and processing of potash ore. These wastes are stored in natural depressions and/or constructed pond areas near the plant.

A. OBJECTIVES:

1. To study the effect of the waste disposal basin on the local groundwater regime.
2. To determine if and when remedial measures must be taken to limit the spread of subsurface pollution.
3. To evaluate the long-term effects of the waste disposal basin on the surface water resources in the area.
4. To recommend possible alternative solutions to the waste disposal problem around potash mines based on the outcome of the above study.

B. PREVIOUS WORK:

1. 1967 - Fieldwork during the summer of 1967 consisted primarily of a farm well inventory, collecting of water samples for chemical analysis, map compilation and augering.
2. 1968 - A test drilling program was conducted during the summer to determine the regional geological setting of the area. Additional water samples were collected to better define the groundwater chemistry of the area.
3. 1969 - A test drilling and sidehole sampling program to obtain detailed stratigraphic information in the vicinity of the disposal basin near I.M.C.C. K-2 mine was completed during the summer of 1969. An additional test drilling program will be carried out during the winter of 1969 - 1970 to supplement the first drilling program and to finish the detailed geological investigation phase of the study.

The data obtained from the regional and detailed test drilling programs show:

- a. On the bedrock surface (Riding Mountain Formation of Upper Cretaceous age) the presence of a large basin partially flanked on each side by bedrock uplands with three outlets at different elevations.
- b. A large aquifer system in the basin covering an area of approximately 1,000 square miles.
- c. The presence of a large recharge area, connected with the aquifer system, approximately 10 miles north of Esterhazy. Only the southern limit of this recharge area has been reasonably well defined. A typical geological section shows 5 - 10 feet of oxidized sandy and silty till (Battleford Formation) overlying 100 - 150 feet of sand. The water table is approximately 50 feet below surface.
- d. The presence of badland topography on the bedrock surface in the vicinity of I.M.C.C. K-2 mine.
- e. The presence of silty and sandy beds in the Riding Mountain Formation immediately underlying the Pleistocene sediments on the southern flank of the basin near the K-2 mine.

Detailed stratigraphic work has been done on the Pleistocene sediments. A number of excellent exposures of fractured tills were found, and fracture patterns and fracture densities were measured. The significance of the fractures is that they constitute highly permeable paths in an otherwise poorly permeable sediment.

C. WORK IN PROGRESS:

Data analysis.

D. FUTURE WORK:

1. 1970 - Installation of observation wells and monitoring of groundwater flow model. Theoretical study of flow in fractured till.
2. 1971 - 1972 - Monitoring of model. Construction of an analog or computer model of the waste disposal basin.

Over this period a number of publications are expected to be finished.

Additional surveys under consideration for this period are:

- a. Surface resistivity.
- b. Remote sensing using techniques such as infrared imagery.
- c. Determination of the effect of brines on the permeability of a montmorillonitic till.
- d. Study of the effect of airborne salt on the hydrochemistry of the shallow groundwater in selected areas.

*A Hydrochemical Study of
Russell and Prescott Counties, Ontario*

A. OBJECTIVES:

To investigate groundwater chemistry in Russell and Prescott Counties with the specific objective to determine the direction of groundwater flow in the interstream area of the Ottawa and St. Lawrence Rivers.

B. PREVIOUS WORK:

Nine months of field work in the two Counties has been completed. A report on Russell County has been submitted for editing.

C. WORK IN PROGRESS:

Analyzing data accumulated in the Prescott county.

D. FUTURE WORK:

To extend this study into Glengarry County in 1970.

*Potential Evaporation --
Significance and Measurement*

A. OBJECTIVES:

1. To test the significance of potential evaporation as a manifestation of the evaporation from the surrounding region.
2. To relate the potential evaporation to climatologic and evaporimeter observations.
3. To relate evaporation from a large region to climatologic or evaporimeter observations.
4. To relate catchment runoff to climatologic and/or evaporimeter observations.

B. PREVIOUS WORK:

1. Publications

- Morton, F. I. (1965). Potential evaporation and river basin evaporation. J. Hydraul. Div., Proc. Am. Soc. Civil Engrs., Vol. 91, No. HY6.
- Morton, F. I. (1967). Closure to potential evaporation and river basin evaporation. J. Hydraul. Div., Proc. Am. Soc. Civil Engrs., Vol. 93, No. HY4.
- Morton, F. I. (1967). Evaporation from large deep lakes. Water Res. Research, Vol. 3, No. 1.
- Morton, F. I. (1969). Evaporation and climate, a study in cause and effect. Scientific Series 4, Inland Waters Branch, Department of Energy, Mines and Resources.
- Morton, F. I. (1969). Potential evaporation as a manifestation of regional evaporation. Water Res. Research, Vol. 5, No. 6.

2. Office

- a. Formulation of model which permits the regional evaporation to be estimated by its effects on climatologic or evaporimeter observations.

- b. Test of the model over a wide range of climatic and geologic conditions.

C. WORK IN PROGRESS:

1. Preparation of paper "Catchment evaporation as manifested in climatologic observations" which describes formulation of the model and the comparison of model predictions with the differences between precipitation and runoff observations for twenty catchments in Canada and Ireland.

D. FUTURE WORK:

1. Assess various types of evaporimeters with regard to their capability to provide accurate and undistorted estimates of potential evaporation.
2. Investigate seasonal variations in catchment storage by means of a water balance based on model estimates of evaporation with the object of establishing a general relationship between precipitation and runoff.
3. Install instruments in the Perch Lake Research basin with the object of improving the model by a detailed investigation of sublimation from snow and of testing any such improvement against a catchment water balance.

*Snowmelt Infiltration
and Associated Groundwater Recharge*

A. OBJECTIVES:

1. To determine the mechanisms of snowmelt infiltration and associated groundwater recharge.
2. To investigate the applicability of a physically-based, snowmelt infiltration-groundwater recharge model in hydrologic systems analysis.

B. PREVIOUS WORK:

1. An experimental site on the Central Experimental Forest near Ottawa was selected in the spring of 1969 for cooperative investigations by the Groundwater and Glaciology Subdivision of snowmelt and associated groundwater recharge.
2. Groundwater instrumentation installed during the summer of 1969 includes:
 - 1 water-table observation well
 - 4 piezometers

C. WORK IN PROGRESS:

1. Office
 - a. Work on the development of a theoretically-based digital simulation model of the snowmelt-infiltration-groundwater recharge processes is in progress.
 - b. Instrumentation for the experimental verification of the theoretically-based simulation model is being designed. It is anticipated that the instrumentation and data acquisition system will be operational by late Fall, 1969.
2. Laboratory
 - a. Investigations in conjunction with R. A. Freeze and J. A. Banner of the Western Research Section are in progress to assess the use and interpretation of electrical-resistance, soil-moisture data for a freeze-thaw environment.

3. Field

- a. Instrumentation of the experimental site near Ottawa for the monitoring of the soil-temperature, soil-water, and groundwater regimes during snowmelt is in progress.

D. FUTURE WORK:

1. Office

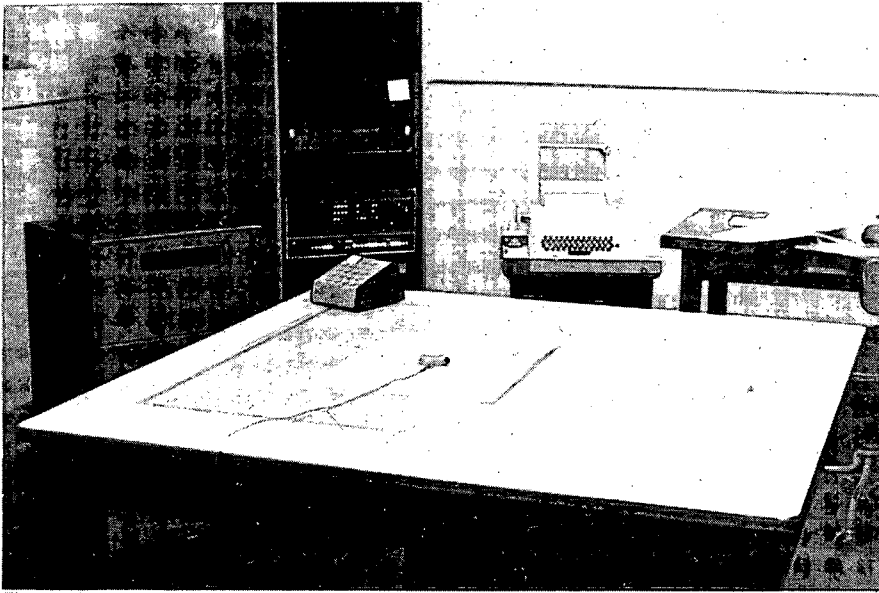
- a. Verification of snowmelt infiltration-groundwater recharge model and the testing of the applicability of the model in hydrologic systems analysis.
- b. Evaluation of the consequence of error in the estimation of controlling hydrologic parameters on the accuracy of simulation.

2. Laboratory

- a. Evaluation and calibration of instrumentation.
- b. Determination of transmission and moisture retention of soils from experimental site.

3. Field

- a. Continuation of monitoring of the soil-temperature, soil-water, and groundwater regimes during snowmelt on the Central Experimental Forest study site.



*Figure 5. Computer
Research Section data
acquisition system.*

4. Computer Research Section

The Computer Research Section is responsible for the program made up of GOWN and associated activities. GOWN (GW 68-5) is an evolving general purpose computerized hydrogeologic data storage, processing and retrieval system. Computer processing of hydrologic data is also an essential feature of groundwater hydrograph analysis (GW 67-13) and the Canadian lake inventory (GW 68-6). Other activities associated with GOWN include the establishment of design criteria for observation well networks and groundwater monitoring instruments (GW 67-14) and the collection of hydrologic data for a group of representative IHD (International Hydrological Decade) basins (GW 67-1b, GW 67-2b, GW67-19).

There were a number of significant developments during the past year. The acquisition of a PDP/8I computer system on line to a pencil follower now expedites the handling of large amounts of data. The GOWN well log, well data and catalogue files have been tested and are now operational; retrieval programs are under development and hydrogeologic maps of the Lake Ontario drainage basin will be produced by GOWN in 1970. A 10-minute movie based on a recent scientific paper by a member of the section was produced to investigate the possible improvement in scientific communication using this medium. Copies of this film will be available to universities and scientific organizations for viewing and appraisal. Finally, the compilation of selected data on Canadian freshwater lakes with areas greater than 100 square kilometers was completed and a published atlas should be available in 1970.

A number of Computer Research Section projects are nearing termination and others are entering a period in which routine house-keeping or data-collecting operations will predominate. Thus the section will shortly be in a position to embark on a new program. A proposed new program is outlined briefly elsewhere in this report.

Computer Research on Groundwater Hydrographs

A. OBJECTIVES:

1. To determine the applicability of techniques from communication theory to hydrograph analysis.
2. To utilize large quantities of computer-compatible hydrograph data to detect small periodic fluctuations in groundwater hydrographs.
3. To study the phenomenon of water table fluctuations in response to changes in barometric pressure.

B. PREVIOUS WORK:

1. Publications

Gilliland, J. A., 1969. A Rigid Plate Model of the Barometric Effect. J. of Hydrology, Vol. 7, pp. 233-245.

2. Field

Total number of installations is 13 water-table wells, 36 piezometers, 2 barographs, 5 nests of soil moisture cells, 1 hygrothermograph, 2 recording rain gauges, 1 recording temperature gauge, and approximately 50 plastic rain gauges. In addition the 6 wells in Prince Edward Island (project 67-14) are being used for correlation studies.

3. Laboratory and Office

Computer programs have been developed to derive various correlation functions from hydrograph data. Hydrograph and barograph data have been digitized, and calculations carried out. These results will be published in 1970. They indicate that small fluctuations can be detected using communication theory techniques. A conceptual model of the effect of changes in barometric pressure on water levels in wells in unconfined aquifers has been developed.

C. WORK IN PROGRESS:

1. Analysis of P. E. I. hydrograph data is in progress and will be published in 1970. This project overlaps with GW 67-14.

D. FUTURE WORK:

The use of correlation functions in hydrogeologic network design will be investigated.

Project will terminate in 1970.

Network Design

A. OBJECTIVES:

1. To establish design criteria for networks of groundwater observation wells, measuring natural water levels and monitoring changes in groundwater storage, with particular reference to optimum well spacing.
2. To establish design criteria for observation wells and monitoring instruments.
3. To develop a recorder working on the variable time interval (v.t.i.) principle (see Gilliland 1968a, in Publications for project 68-5).

B. PREVIOUS WORK:

1. Publications

Gilliland, J. A., 1967. Observation Well Program.
Inland Waters Branch Paper 67-1.

Gilliland, J. A., 1969. Groundwater Instrumentation
and Observation Techniques. Proc. Hydrology
Symposium 7.

2. Field

Various types of analog and digital recorders have been installed at Swift Current and Good Spirit Lake, Saskatchewan; Ottawa, Ontario; and Prince Edward Island. Four wells of various designs have been installed at Delta, Manitoba, together with an experimental transducer-recorder system and some meteorological instruments. The data from P. E. I. will be analysed in project 67-13. Data from other installations await evaluation.

3. Office

A pilot study has been completed to investigate the pattern of meteorological variation across Canada insofar as it affects groundwater network design.

C. WORK IN PROGRESS:

1. A full-scale study of the areal variability of meteorologic phenomena has been 75 percent completed.
2. Enough data are now on hand to evaluate commercially available recorders and instruments.
3. Four prototype v.t.i. recorders have been delivered and are undergoing testing, ten more are on order.

D. FUTURE WORK:

1. Completion of all project phases mentioned above is scheduled for 1970.

GOWN - Operation and Maintenance

A. OBJECTIVES:

1. To operate and maintain a general purpose hydrogeologic data storage and retrieval system for all types of hydrogeologic data for the use of the Inland Waters Branch and other agencies..
2. To produce automatically, maps and sections displaying hydrogeological information.

B. PREVIOUS WORK:

1. Publications

Gilliland, J. A., 1968^a. Digitizing, Storing and Recovering Groundwater Hydrographs. Jour. of Hydrology, Vol. 6, pp. 143 - 167.

Gilliland, J. A., and A. Treichel, 1968. GOWN - A Computer Storage System for Groundwater Data. Can. Jour. Earth Sci., Vol. 5, pp. 1518 - 1524.

Grove, G. and J. A. Gilliland, 1969. Manual on Groundwater Data Storage System. Internal Publication, IWB, 4th ed.

2. Office

- a. Programming of well log, well data and catalogue files completed and operation tested. Programs have been production tested.
- b. A PDP-8/I digital computer interfaced with a D-Mac Pencil Follower is being used to process data for this project.

C. WORK IN PROGRESS:

1. Digitizing locations of wells in Lake Ontario drainage basin and coding of well logs in progress in cooperation with Ontario Water Resources Commission for the International Field Year on the Great Lakes. This part of the project is carried out jointly with project GW 68 - 4 and is 80% complete.

2. Development of programs for contouring and drawing sections (work done by Computer Science Division).

D. FUTURE WORK:

1. Production of various hydrogeological maps for the Lake Ontario drainage basin.
2. Maps and sections displaying various hydrogeological parameters will be produced on a routine basis.
3. Digitizing, coding and storage of data as required.
4. Project is continuing.

Inventory of Canadian Lakes

A. OBJECTIVES:

1. To produce an inventory of Canadian fresh-water lakes larger than 100 square kilometers for hydrologic purposes, for the IHD (this differs from the CLI lake survey, which is intended to assess the suitability of lakes for sport fishing, recreation, etc.).

B. PREVIOUS WORK:

Two programs have been written to compute the total area, water surface area, center, maximum dimension and direction of maximum dimension for small lakes and large lakes (small lakes are those whose outline is represented by less than 750 points) The input to these programs is cards produced by the D-Mac pencil follower. The output is obtained as tables, cards and plots. Lakes in Quebec were digitized by personnel of the Quebec Department of Natural Resources in cooperation with the Inland Waters Branch.

C. WORK IN PROGRESS:

Work continues PREVIOUS WORK above, using 1:500,000 aeronautical charts. A program has been developed to determine the volume of lakes from test soundings and is being tested for validity.

D. FUTURE WORK:

The completed inventory will be published as an atlas containing lists and maps of the lakes with provision for adding information on depths and volumes. The Computer Research Section will determine volumes of those lakes for which soundings are available on charts. The area information will be published by March, 1970. Project will terminate July, 1970.

*Water Balance, Good Spirit Lake Basin
Saskatchewan*

A. OBJECTIVES:

To arrive at an annual water balance of a parkland representative basin as part of Canada's program for the International Hydrological Decade.

B. PREVIOUS WORK:

1. Publications

Freeze, R. A., 1969. Hydrology of the Good Spirit Lake Drainage Basin, Saskatchewan. Inland Waters Branch Technical Bulletin No. 14.

2. Field

Present instrumentation in the Good Spirit Lake Basin includes:

- 3 temperature-precipitation meteorological stations
(operated by the Meteorological Branch, Department of Transport)
- 1 stream gauge (operated by the Water Survey of Canada)
- 1 isolated observation well measuring lake levels
- 3 recharge-discharge sites, each with a piezometer nest, an observation well, a bank of soil moisture cells and switchbox and rain gauges
- 4 isolated piezometer nests
- 7 Carborandum block evaporimeters measuring (daily) evaporating power during the growing season

This instrumentation (except for evaporimeters) has been measured weekly. Previous measurements have also been made of formation permeability, surface sand depth (by hammer seismograph) and water table profiles. Samples have been collected for chemical analysis from the lake, sloughs, streams, groundwater and geological formations. A random slough survey was carried out in the summer of 1966.

C. WORK IN PROGRESS:

1. Field

- a. Hydrometric data on the Spirit Creek are being collected and processed by the Winnipeg Regional Office of the Water Survey of Canada.
- b. Meteorological data are being collected and processed by the Met. Branch of DOT.
- c. All other instrumentation is measured weekly by a local basin manager and processed by the Groundwater Subdivision in Ottawa.

2. Office

- a. Evaluation of the area distribution of the evaporating power and calculation of the basin-wide evapotranspiration loss.
- b. Improvement of the water balance study.

D. FUTURE WORK:

- 1. Maintain instrumentation and continue field measurements.
- 2. Tritium study under the direction of Mr. A. Rutherford of the Saskatchewan Research Council.
- 3. Scientific aspects of this project will terminate in 1970, field measurements will continue until at least the end of the IHD.

Water Balance, Oak River Basin, Manitoba

A. OBJECTIVES:

To arrive at an annual water balance of a parkland representative basin as part of Canada's program for the International Hydrological Decade.

B. PREVIOUS WORK:

1. General

The Hydrogeological aspects of this study started in 1963 by A. Lissey. The results were summarized in his Ph.D. Thesis "Surficial Mapping of Groundwater Flow Systems with Application to the Oak River Basin, Manitoba", 1968.

2. Field

a. Instrumentation

Present instrumentation in the Oak River Basin includes:

- 4 recording stream gauges (operated by the Water Survey of Canada)
- 1 Class A weather station (operated by the Meteorological Branch of the Department of Transport)
- 5 temperature and precipitation stations (operated by Met. Branch, DOT)
- 2 precipitation stations (operated by the Met. Branch, DOT)
- 77 piezometers arranged in 35 nests (read weekly from May, 1965 to September, 1967)
- 11 Carborundum block evaporimeters (daily measurement, growing season)

b. Others

- 45 test holes drilled, sampled and E-logged (8 by Geological Survey of Canada Pleistocene Section and 37 by Inland Waters Branch)
- 32 piezometers (deepest one in nest sampled and E-logged)
- 3 pumping tests conducted on town wells of Hamiota, Strathclair, and Oak River (in cooperation with Manitoba Control Board)
- 2 pumping tests on temporary wells
- Slug test and/or bailer tests on every piezometer

65 detailed water analyses of groundwater from piezo-
meters
80 Hach kit analyses of surface waters
all piezometers surveyed into geodetic datum
slough survey in the Oak River Basin performed

C. WORK IN PROGRESS:

1. Data Collecting and Data Processing

- a. Continuing collection and processing of hydrometric data by the Water Survey of Canada
- b. Continuing collection and processing of meteorological data by Meteorological Branch, DOT
- c. All piezometers read monthly starting in September, 1967 by a local basin manager for processing by the Groundwater Subdivision at Ottawa.

2. Office

- a. Flow pattern analysis together with field measurement to:
 - (i) estimate the groundwater component of the water balance
 - (ii) compare the surficial mapping of recharge and discharge areas completed by A. Lissey
- b. Evaluation of the area distribution of the evaporating power and calculation of the basin-wide evapotranspiration loss.

D. FUTURE WORK:

1. Maintain instrumentation and continue field measurements.
2. Improvement of water balance studies
3. Scientific aspects of this project will terminate in 1970, field measurements will continue until at least the end of the International Hydrological Decade.

Water Balance, Trapping Creek Basin, B. C.

A. OBJECTIVES:

1. The original objective of Trapping Creek basin was to study the groundwater flow systems in an area of high relief underlain by crystalline bedrock. This aspect of the project was completed by D. W. Lawson in 1968.
2. To arrive at an annual water balance of a high-mountain representative basin as part of Canada's program for the International Hydrological Decade.

B. PREVIOUS WORK:

1. Publications

Lawson, D. W., 1967. A Groundwater Investigation of the Trapping Creek Basin. Unpubl. M.Sc. Thesis, Univ. of Guelph, Guelph, Ontario.

Lawson, D. W., 1968. Groundwater Flow System in the Crystalline Rocks of the Okanagan Highlands, British Columbia. Can. J. Earth Sciences, v. 5, pp 813-824.

2. Field and Laboratory

a. The following instrumentation has been installed:

- 5 soil moisture stations
- 1 permanent stream gauge (at mouth of basin)
- 3 temporary stream gauges (on 3 major sub-basins)
- 1 Fischer-Porter precipitation recorder
- 2 Sacramento Storage precipitation gauges
- 3 integrating anemometers (11.4 ft.)
- 3 Lambrecht-type hypothermographs (with maximum, minimum and present temperature checks)
- 30 evaporation stations (Carborundum block evaporation meter)
- 3 snow courses (10 points)
- 2 sunshine recorders
- 25 piezometers in 7 nests
- 12 water table wells

b. Laboratory calibration of soil moisture cells.

C. WORK IN PROGRESS:

1. Data Collecting and Data Processing

- a. Hydrometric data on the main stream are collected and processed by the Vancouver regional office of the Water Survey of Canada.
- b. Snow course data are collected and processed by the Department of Lands, Forests and Water Resources at Victoria, B. C.
- c. Sunshine data are collected and processed by the Regional Climate Data Centre, Gonzales Observatory at Victoria.
- d. All other data are collected by a local basin manager.
- e. Arrangements have been made for the following meteorological data to be processed by the B. C. Forest Service: temperature, relative humidity, precipitation, snowpack, wind and evaporation.
- f. Fischer-Porter precipitation data are to be processed by the Meteorological Branch of the Department of Transport in Toronto.
- g. Soil moisture data, hydrometric data on the tributary streams and piezometer and observation well data are to be processed by the Groundwater Subdivision in Ottawa.

2. Office

- a. Evaluation of the resistance coefficient vs stage relationship for the 3 tributaries of Trapping Creek to estimate the discharge using the available stage records.
- b. Variation of the evaporating power due to the change of topographic condition and calculation of the evapotranspiration loss.
- c. Flow pattern analysis to estimate the groundwater component of the water balance.
- d. Field density estimation by Volumeasure test.

D. FUTURE WORK:

1. Maintain instrumentation and continue field measurements.
2. Improvement of water balance studies.
3. Scientific aspects of this project will terminate in 1970, field measurements will continue until at least the end of the IHD.

Other Research Projects

5. Other Research Projects

Three Groundwater Subdivision projects were initiated and have been conducted by scientists based elsewhere than in Ottawa or Calgary and not attached to any of the four research sections. Two others are the responsibility of members of the Maritime Research Section, but were originally undertaken before the formation of the section and do not form part of the Maritime Research Program. For convenience, all five are reported on in this portion of the project catalogue.

One of these projects (GW 67-9) is a laboratory study of hydrodynamic dispersion in non-uniform flow fields using electrical conductivity observations to detect the movement of solutes through water-filled permeable media enclosed between parallel plates. The findings will have application to studies of tracer movement, salt-water intrusion and waste disposal. An investigation of groundwater flow in a glacial complex in the Clay Belt of Northern Ontario (GW 67-10) has been completed except for publication of two papers, one on the inferred natural movement of groundwater and one on the influence of this movement on shallow subsurface temperatures. The results from this study have prompted the continuation of temperature studies as part of the Maritime Research Plan (GW 67-10). Two projects reported on in this section are water balance studies. One of these (GW 67-15) is now complete except for the long-term collection of hydrologic data. This project led to the location of a groundwater supply for the Queen Elizabeth Observatory. The last of the five projects reported on here (GW 68-9) was an investigation of the relation between an anomaly observed on infrared (IR) imagery and a zone of groundwater inflow into the Lake of Two Mountains. Repeated IR flights have established the reproducibility of the anomaly and strongly support its connection with discharge into the lake from a known buried valley.

Principles of Groundwater Pollution

A. OBJECTIVES:

1. To gain an understanding of the theory of physio-chemical transport phenomena in porous media.
2. To develop mathematical models of physio-chemical transport phenomena.
3. To demonstrate the employment of these models in studies of waste disposal, salt-water intrusion, tracer movement, etc.

B. PREVIOUS WORK:

1. Publications

Elrick, D. E. and D. W. Lawson, 1969. Tracer Techniques in Hydrology, National Research Council, Proc. Hydrology Symposium No. 7: Instrumentation and Observation Techniques, Victoria, pp 155 - 187.

2. Office

- a. An introduction to the theory of physio-chemical transport phenomena is contained in the above-mentioned paper by Elrick and Lawson.
- b. A preliminary literature review of hydrodynamic dispersion (theory, mathematical modeling, experimentation) has been completed. Hydrodynamic dispersion - the continuous change in the volume occupied by a given mass of solute due to convection and molecular diffusion.
- c. Laboratory equipment for determining hydrodynamic dispersion coefficients has been designed.
- d. Laboratory equipment for studying dispersion in non-uniform flow fields has been designed.

3. Laboratory

- a. A new technique has been developed for determining solute concentrations in parallel-late sand models and is described in a paper by Bachmat and Lawson (see below).
- b. The equipment for determining dispersion coefficients has been constructed.

C. WORK IN PROGRESS: (Ph.D. Program at University of Guelph)

1. Publications

Bachmat, Y. and D. W. Lawson. Being edited for outside publication. "A New Electrical Conductivity Method for Determining Concentrations in Parallel Plate Models".

2. Office

- a. The literature review of hydrodynamic dispersion continues to be improved.
- b. An experiment involving dispersion in a non-uniform flow field is being planned. The objective of this experiment is to test the prevailing theory of hydrodynamic dispersion.

3. Laboratory

The equipment for determining dispersion coefficients is being developed (tested and modified accordingly). The determination of the hydrodynamic dispersion coefficients for the selected porous medium is a necessary prerequisite to the non-uniform flow experiment.

D. FUTURE WORK:

As dictated by the results of the WORK IN PROGRESS and OBJECTIVES 1, 2 and 3.

*Groundwater Flow in the Clay Belt
of Northern Ontario*

A. OBJECTIVES:

1. A quantitative evaluation of groundwater flow as influenced by various geologic and topographic features characteristic of the Clay Belt.
2. Determination of the influence of groundwater movement on subsurface temperatures in the study area.

B. PREVIOUS WORK:

1. Publications

Parsons, M. L. and H. N. Pollack. Piezometric and Thermal Studies of Groundwater Flow in a Glacial Complex. Paper presented to the Geological Society of America Annual Meeting, November, 1968, Mexico City.

Parsons, M. L., 1969. Groundwater Movement and Subsurface Temperatures in a Glacial Complex, Cochrane District, Ontario. Ph.D. Thesis, University of Michigan, Ann Arbor.

2. Field

Field work complete. Refer to 1968-69 project catalogue.

3. Office

- a. Analysis of piezometric and thermal data is complete.
- b. Numerical modelling of groundwater potential and temperature fields is complete.

C. WORK IN PROGRESS:

1. Publications

Parsons, M. L. Groundwater Movement in a Glacial Complex, Cochrane District, Ontario. Paper submitted to the Can. Jour. Earth Sci.

Parsons, M. L. The Groundwater Thermal Regime in a Glacial Complex. Paper submitted to Water Resources Research.

2. Field

nil

3. Office

Compilation and interpretation of stream discharge, precipitation and water level data collected from a typical clay belt bog.

D. FUTURE WORK:

nil

*Water Balance of Mt. Kobau Watershed,
Southern Okanagan, British Columbia*

A. OBJECTIVES:

To determine the water balance of Mt. Kobau watershed, in particular Testalinden Creek and Richter Creek, as related to the water supply for Queen Elizabeth Observatory.

B. PREVIOUS WORK:

1. Publications

Halstead, E. C., 1965. Water Supply Queen Elizabeth Observatory, Mt. Kobau, B. C. Geol. Survey of Canada. Topical Report No. 101.

Halstead, E. C., 1969. Groundwater Investigation, Mt. Kobau, British Columbia. Inland Waters Branch Technical Bulletin No. 17.

2. Field

The following instrumentation has been installed:

3 observation wells measured weekly with electric tape
1 observation well with Stevens Recorder
1 staff gauge at Richter Creek
1 evaporation pan, rain gauge, anemometer
1 hygrothermograph
1 Fischer-Porter precipitation gauge
1 Bristol water thermograph
1 snow course
1 stilling well and A-35 recorder on Testalinden Creek

C. WORK IN PROGRESS:

The Mt. Kobau activity has been reduced to the collection of data from existing installations. These records are being forwarded to the Vancouver Groundwater office.

D. FUTURE WORK:

Continuous collection of records from installations.

*Nicomekl-Serpentine Basin Study,
Fraser Lowland, B. C.*

A. OBJECTIVES:

1. To analyze the hydrologic regime in a thick sequence of unconsolidated surficial deposits constituting a valley fill.
2. To arrive at a decennial water budget for IHD purposes.

B. PREVIOUS WORK:

Groundwater and well inventory, carried out in 1953 by Armstrong and Brown, folled by B. C. Water Resources rotary drilling program of eleven 1,000-foot test holes, and a quantitative study of aquifers. In 1966 another test hole was put down to a depth of 987 feet for correlation purposes with the eleven B. C. test holes. Sieve analyses of samples collected at 10-foot intervals have been done. Two hundred and fifty water samples were collected and analyzed using a Hach chemical kit. A 795 foot test hole was drilled in the upland area.

C. WORK IN PROGRESS:

Analysis of data collected. Continuous collection of records from piezometers and observation wells.

D. FUTURE WORK:

Continuing observation program of piezometric levels, and periodic sampling programs. Hydrochemical mapping of ground-water types; pH, temperature and conductivity readings of each well drilled since 1955.

*Investigation of Infrared Anomalies in
the Lake of Two Mountains, Quebec*

A. OBJECTIVES:

1. To determine whether observed anomalies on infrared (IR) imagery taken over the Lake of Two Mountains are related to the discharge of groundwater into the lake through buried valleys lying below lake level.
2. To assess the IR scanner as a tool for prospecting for groundwater.

B. PREVIOUS WORK:

1. Field

- a. Three flights of IR imagery have been made: one in October, 1965, one in August, 1968 and the other in October, 1969. The 1965 flight was conducted by another agency. Later examination of the 1965 results led to the initiation of this project.
- b. Preliminary temperature measurements have been made on the lake.
- c. A sparker seismic survey has been made on the lake and three boreholes were drilled in the buried valleys by a consulting company.

C. WORK IN PROGRESS:

1. Office

The results of the sparker and drilling programs are being assessed and correlated with earlier results from a seismic survey on land (G.S.C. paper 61-20) as well as with the IR data.

D. FUTURE WORK:

Writing of a report and termination of the project in 1970.

Operational Projects

6. Operational Projects

Two operational projects involved water-supply problems. The first (GWO 69-1) was for a suitable groundwater supply for a proposed golf course on National Capital Commission property. This study was handled by a consultant and is now complete. The second (GWO 69-4) is to satisfy an estimated 2 million gallon per day requirement for the new Montreal International Airport. This study will also be handled by a consultant and is just getting under way.

An investigation of the mechanisms of groundwater inflow into a lake in the Kenora area (GWO 69-2) is a contribution to a eutrophication study by the Fisheries Research Board. This project has been allocated to Dr. J. A. Cherry of the University of Manitoba. The fourth operational project (GWO 69-3) is a study of the groundwater regime in the Central Research Forest of the Federal Forest Management Institute, and was undertaken at the request of the Forest Manager.

Project No. GWO 69-1

*Groundwater Assessment
Bell's Corner, Ontario*

A. OBJECTIVES:

To determine the feasibility of obtaining a suitable groundwater supply for a proposed golf course at the National Capital Commission property near Bell's Corner, Ontario.

B. NATURE OF REQUEST:

Written request by the Chairman of the National Capital Commission to the Department of Energy, Mines and Resources.

C. ORGANIZATION OR PROJECT:

On February 3, 1969, tenders were requested from several qualified consulting firms. Following selection of a successful bidder, and awarding of a contract, the Groundwater Sub-division received a complete report on the feasibility study by March 30, 1969. The report gave an excellent summary of the regional hydrogeology and of several aquifer tests conducted on wells near the NCC property and concluded that a suitable groundwater supply could be developed at this site. A copy of the report was forwarded to the National Capital Commission on April 23, 1969.

D. PRESENT STATUS OF PROJECT:

Completed.

Kenora Lakes Study, Fisheries Research Board

A. OBJECTIVES:

1. To provide a detailed understanding of the mechanisms of groundwater inflow into "Lake 239" which is one of the lakes in the Kenora area selected for eutrophication studies by the Fisheries Research Board.
2. To provide a network of groundwater observation wells and piezometers to determine the quantity and chemical composition of the groundwater inflow.

B. NATURE OF REQUEST:

Written request by the Director of the Federal Freshwater Institute in Winnipeg to the Inland Waters Branch.

C. ORGANIZATION OF PROJECT:

Because of its location and interdisciplinary interest, the direct supervision of this project has been allocated to Dr. J. A. Cherry, Associate Professor of Hydrogeology, University of Manitoba. He will be integrating the groundwater aspects of the study into the overall evaluation of the hydrologic budget of the watershed being conducted by Dr. R. W. Newbury, Associate Professor of Civil Engineering, University of Manitoba. Some of the groundwater data may be suitable for use by graduate students as thesis material. Progress reports and a comprehensive final report will be submitted by Professor Cherry to the Groundwater Subdivision.

The Groundwater Subdivision provides funds and administrative arrangements for drilling contracts, field instruments and other services that are required.

The project is part of a large assistance program by the Inland Waters Branch coordinated by Dr. R. K. Lane.

D. PRESENT STATUS OF PROJECT:

During the summer of 1969 the following contracts were completed:

- a. a drilling program to determine the depth of bedrock in the research drainage basin

- b. a hammer-seismic program to obtain detailed information on the depth to bedrock at certain locations (this project was carried out in conjunction with the Geophysics Division of the Geological Survey of Canada).
- c. the preparation of a detailed topographic map with 5-foot contour interval from existing air photos.

E. FUTURE WORK:

1. Design and installation of a groundwater observation network.
2. Collection and interpretation of data (1970).
3. Preparation of final report on the groundwater balance and groundwater chemistry of the research lakes.

Expected date of final report - June 1971.

*Groundwater Regime
Central Research Forest*

A. OBJECTIVES:

To determine the direction of groundwater movement, and the magnitude of the annual water-table fluctuation throughout the Central Research Forest of the Federal Forest Management Institute.

B. NATURE OF REQUEST:

Verbal request by the Manager of the Central Research Forest to the Groundwater Subdivision.

C. ORGANIZATION OF PROJECT:

This project is carried out under the direction of Mr. R. L. Herr of the Groundwater Subdivision in view of his interest in computerized data retrieval systems.

D. PRESENT STATUS OF PROJECT:

During the summer of 1969 a drilling program was carried out at the Central Research Forest to determine the regional hydrogeology and to install seven piezometer nests, each one consisting of three or four piezometers. The drilling program was conducted in close cooperation with Dr. M. Bik of the Geological Survey of Canada. One of the piezometer sites will be part of the Groundwater Glaciology experimental plot described in Dr. Harlan's write-up on research project GW 69-2.

E. FUTURE WORK:

- Installation of pressure transducers and recording equipment to measure fluctuations in fluid potential (Fall, 1969).
- Design of computer program to calculate changes in groundwater storage during selected periods.
- Occasional synoptic water-table measurements on water-table wells installed by Mr. Herr and those installed previously by Dr. Bik (ongoing).
- Organization of bi-annual groundwater reports to the Manager of the Central Research Forest (ongoing).

Project No. GWO 69 - 4

Groundwater Assessment, New Montreal Airport

A. OBJECTIVES:

1. To determine whether the water supply for the new Montreal International Airport (an estimated 2 million gallons daily) can be obtained from aquifers underlying airport land.
2. To design a well field for efficient economical extraction of this supply.

B. NATURE OF REQUEST:

Verbal and subsequent written requests from the Construction Branch, Department of Transport.

C. ORGANIZATION OF PROJECT:

Exploration and development phases will be carried out by consultants; the Groundwater Subdivision will provide periodic appraisals of consultants' proposals and reports.

D. PRESENT STATUS OF PROJECT:

An initial proposal is under consideration.

7. Project Index

A. By Project Number

<u>Project</u>	<u>Short Title</u>	<u>Status</u> [*]	<u>Page this catalogue (or last catalogue giving detailed information)</u>
GW 67-1 ^a	Natural groundwater recharge	C	14
GW 67-1 ^b	Water balance Good Spirit Lake	P	75
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