INLAND WATERS BRANCH
DEPARTMENT OF ENERGY, MINES AND RESOURCES

THE FEDERAL GROUNDWATER PROGRAM

Annual Project Catalogue 1968-1969

REPORT SERIES No. 3

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INLAND WATERS BRANCH
DEPARTMENT OF ENERGY, MINES AND RESOURCES
OTTAWA, CANADA, 1968

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STRUCTURE OF THE FEDERAL GROUNDWATER PROGRAM

1. Objectives and Program Development

With respect to Federal groundwater studies, the Hydrologic Sciences Division of the Inland Waters Branch has three main objectives:

- to develop new concepts in groundwater hydrology and to incorporate these concepts into hydrologic models,
- to develop new methods of evaluating and utilizing Canada's groundwater resources, and
- to develop computerized data storage systems for use by federal and provincial water resource agencies, universities and industrial concerns.

The responsibility to achieve these objectives rests with the Groundwater Subdivision, which is made up of four Sections arranged according to region and subject. In order to achieve the Divisional objectives, the Subdivision has developed a Groundwater Program which consists of 28 individual projects, each one being a set of plans or schedules projected for execution within a prescribed length of time.

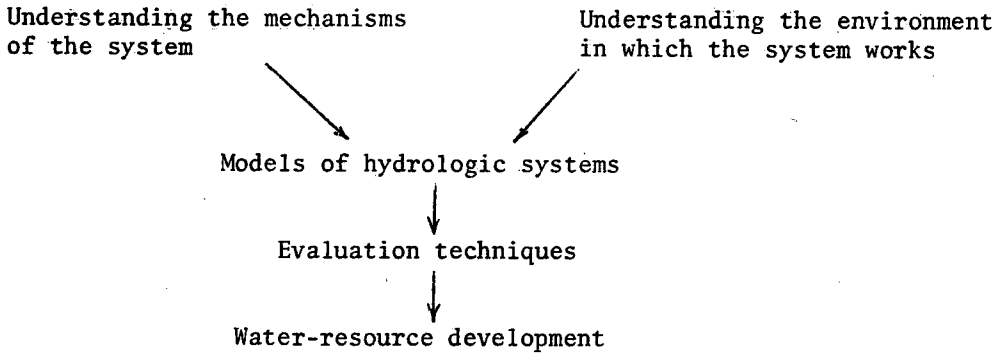
In order to be included in the program, projects must be suitable, feasible and acceptable, by which is meant that they must comply with legislative authority and branch policy, that the required competence must be within reach of the Subdivision , and that each project must be relevant to the Divisional objectives.

Projects can be initiated in a number of ways. Many of the current projects were initiated by the Groundwater Subdivision in response to perceived national or scientific needs, as witness the projects of the Maritime Research Section. Others were started because of Canada's commitment to international activities, such as the International Hydrological Decade. Strong support has been given to projects that originated from cooperative arrangements with provincial agencies, such as the International Field Year projects carried out in cooperation with the Ontario Water Resources Commission. And finally, some projects are initiated upon request from other Federal agencies, such as the development of large groundwater supplies for the Fisheries Research Board and the Queen Elizabeth observatory.

In order to ensure continued program efficiency, the Groundwater Subdivision follows the practice that has been instituted in the Hydrologic Sciences Division of estimating project effectiveness from weight and value assessments of 18 ranking factors. The calculated efficiency, expressed as a percentage of the ideal 100 percent level, is a measure of the probable significance of a given project in the dual context of Canadian need and scientific significance. Existing projects with relatively low effectiveness ratings will tend to be phased out; proposed projects will tend to be accepted or rejected in conformity with their ratings.

2. Program Content: Research, Applied Research, and Operations.

The Federal Groundwater Program has elements of theoretical research, applied research and operations. These terms require a brief explanation. As is the case with other natural sciences, research in hydrology tends to follow one of two paths, theoretical research or applied research. The first approach is used to investigate the mechanism of specific hydrologic processes, irrespective of environment. The second approach aims at solving specific problems related to man's desire to tap the resources of a certain environment. Although the approach in each case is different, the ultimate aim is the same — the development of evaluation techniques to ensure intelligent development of Canada's groundwater resources. The paths of the two approaches converge in the specific objective of developing models of hydrologic systems. The relation between both types of research and their ultimate objective can thus be shown as follows:



This diagram is consistent with the first two Divisional objectives and with the recommendation made by Bruce and Maasland 1)that "more effort should be concentrated on mathematical and model approaches to flow of water through porous media."

Apart from the two types of research the Federal Groundwater Program contains operational projects, which are those projects that are essentially pragmatic in nature.

Although each project contains elements of research, applied research, and operations, the Federal Groundwater Program has always emphasized its high research content, and as such it has acquired national and international recognition. However, in order to maintain its vitality, and in order to realize its national function more fully, the Groundwater Subdivision is preparing itself for an increase in the number of operational projects, where possible in cooperation with private consulting firms. Such projects are already included in the program of the Computer Research Section, whereas others will be initiated soon.

1) J.P. Bruce and D.E.L. Maasland 1968. Water Resources Research in Canada, Science Secretariat, Special Study No. 5, p.70.

It was explained in the 1967-1968 program write-up that any program designed to meet the Divisional objectives had to be based both on developments in Canada and developments in hydrology. This "two-master" concept has proved to be a useful guide, and following is a brief discussion of recent developments that are influencing or expected to influence the course of the groundwater program.

3. The influence of developments in Canada

3.1 URBANIZATION AND BASIN DEVELOPMENT

Although the Groundwater Program has no projects pertaining to basin management as such, substantial advances have been made towards developing models of the groundwater subsystem in natural drainage basins (projects GW 67-11 and GW 68-1). It is hoped that the proposed federal-provincial demonstration basins will give further impetus to this approach. Similarly, GOWN (GW 68-5) is expected to be of considerable value in evaluating the groundwater aspect of these basins.

In contrast, neither the anticipated quest for increased urban water supplies nor the mounting urgency of urban waste disposal problems has influenced the 1968-1969 program. Nevertheless, the need for hydrogeological guidelines for disposal site evaluation is as acute as ever, and a project along these lines will be started soon. Studies of salt-water intrusion will be discussed separately under section 3.6.

3.2 THE NEED FOR INVENTORIES

The National Canadian Committee for the Hydrological Decade has decided to sponsor a hydrological atlas of Canada. As certain sheets in this atlas will pertain to groundwater, the plans for a separate groundwater atlas have temporarily taken second place to the I.H.D. initiative.

With regard to inventory capability, GOWN is rapidly approaching the stage where the developed computer methodology will be of use to many provincial agencies. Several organizations have already expressed interest in GOWN and the system will soon reach the stage where periodic progress reports will be issued about its capabilities.

3.3 CONFLICTS IN WATER USE

In the Prairie region conflicts in water use between farmers and hunters are still in evidence. It has been decided by the Department of Indian Affairs and Northern Development that further Federal arrangements to protect prairie Wetlands have to consider the overall value of sloughs. To this end a National Committee on Wildlife Lands has been created, with a Subcommittee on Wetlands. This Subcommittee has requested a preliminary report on the hydrogeological value of Wetlands.

3.4 PERMAFROST HYDROLOGY

One project in permafrost hydrology was started during the past year (GW 67-3). However, the logistic problems proved to be formidable and the project may be terminated at the end of this summer. Consequently, the creation of a study group on permafrost hydrology has been temporarily postponed.

3.5 THE SASKATCHEWAN POTASH INDUSTRY

Thanks to the stimulating support of two major potash mines, the disposal study of potash waste (project GW 67-12) has made significant progress. It is hoped that the potash studies, together with the proposed urban waste-disposal studies, will form the nucleus for an advanced research program on groundwater pollution.

3.6 THE MARITIME RESEARCH PLAN

The Maritime Research Plan has been designed by the Groundwater Subdivision as a two-fold scheme for strengthening groundwater studies in the Maritime Provinces. In accordance with the recommendations by Bruce and Maasland (1968, P.70) the plan was conceived as a means to improve the scope of federal groundwater projects related to salt-water intrusion, flow through fractured rocks and the development of pump-test techniques to analyze these problems. The plan also seeks to stimulate additional provincial groundwater activity. The responsibility to execute the Plan rests with the Maritime Research Section, whose projects are described on pages 36 to 51.

4. The influence of developments in hydrology

4.1 DIRECTIONS IN HYDROLOGY

It was explained in the 1967-68 program write-up that both physical hydrology and parametric hydrology are being practiced in the Groundwater Subdivision. These approaches are not diverging, however, and it appears that the present dialogue between practitioners of either direction will produce reliable and useful models of groundwater runoff.

4.2 THE INTERNATIONAL HYDROLOGICAL DECADE

Three items under this heading deserve special attention: IHD Benchmark stations, IHD representative basins and the International Field Year on the Great Lakes.

Benchmark Stations. Some delays have occurred with the installation of benchmark stations and it will be considerable time before records will be available for analysis.

Representative basins. Significant progress has been made with regard to administering the various representative basins. The IHD Task Force, which has now been incorporated in the Computer Research Section, has taken on full responsibility for the following Canadian representative basins: Trapping Creek, B.C.; Good Spirit Lake, Sask.; and Oak River, Man. Details of the instrumentation of these basins can be found in the description of projects GW 67-1b, GW 67-2b and GW 67-19.

International Field Year on the Great Lakes. The Eastern Research Section, in cooperation with the Ontario Water Resources Commission and GOWN, is actively participating in this international endeavour. Projects pertaining to IFYGL are described under GW 68-2, GW 68-3, GW 68-4 and GW 68-5.

4.3 HYDROGEOLOGY AT CANADIAN UNIVERSITIES

Following last year's proposal to sponsor a limited number of hydrogeological thesis projects, a start has been made with one Ph.D. candidate from the University of Western Ontario. His thesis work is written up under project number GW 68-10, titled Salt-water intrusion, Shippegan, N.B.

5. Summary of progress since 1967-1968 program

The previous and following pages show that in the past year the Groundwater Subdivision has made significant progress towards:

. . . . . increased knowledge of unsaturated flow, flow in crystalline rocks, the role of reverse osmosis in deep fluid movement, the nature of barometric efficiency, and the relation between groundwater flow and heat flow,

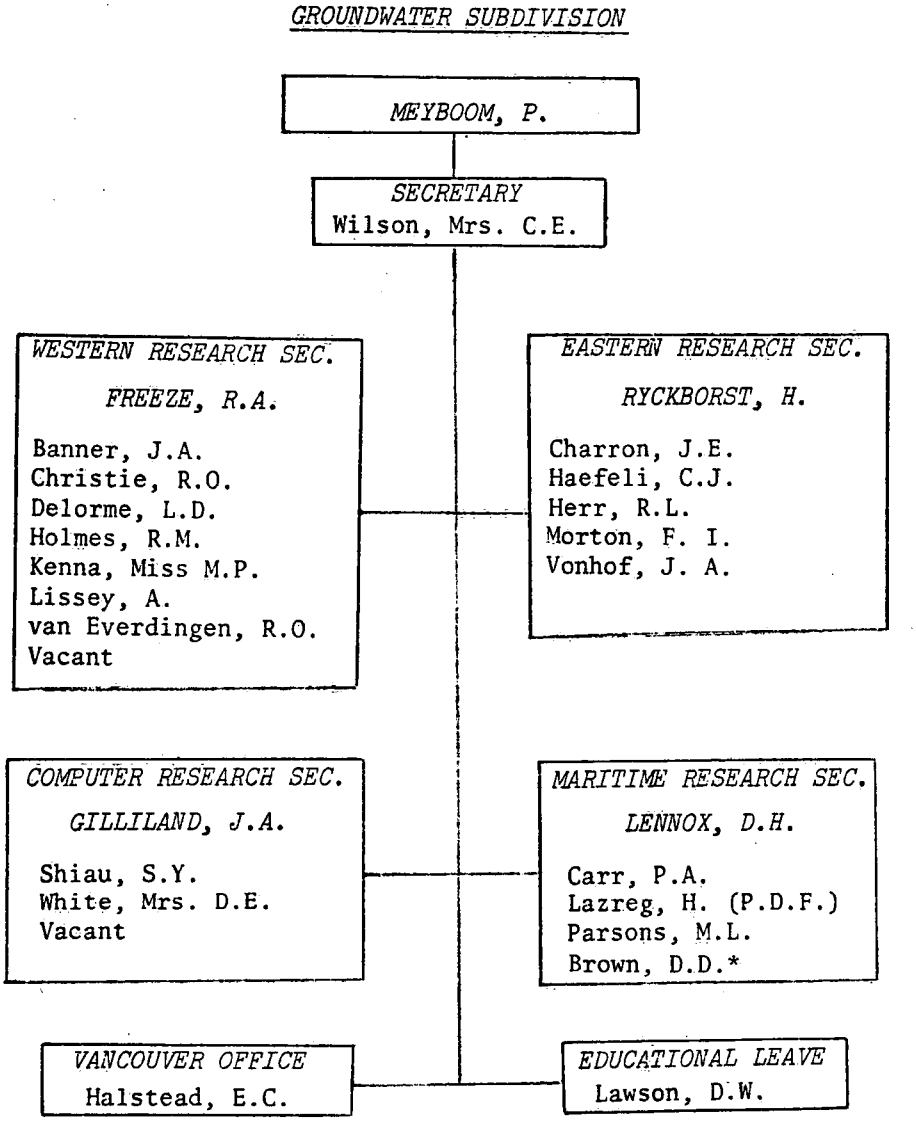
. . . . . the use and development of parametric and physically based models to analyse groundwater run-off in natural drainage basins,

. . . . . the use and development of computer techniques for solving complicated or time consuming hydrological problems,

. . . . . active and useful cooperation with provincial water resource agencies in Ontario, New Brunswick and Prince Edward Island

ORGANIZATION OF THE GROUNDWATER SUBDIVISION

1. Organization Chart



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

2. Definition of functions

The objectives of the Western Research Section, the Eastern Research Section and the Maritime Research Section are essentially the same. Each of these Sections tries to combine the concepts of environmental hydrology and theoretical hydrology in order to develop models and methods which will prove useful in the quantitative evaluation of Canada's groundwater resources. Yet, there are differences in the approach of each Section. The emphasis of the Western Research Section lies on the physico-chemical principles of fluid flow, the Eastern Research Section is particularly interested in the use of parametric models, whereas the Maritime Research Section has a strong mission towards developing a new methodology for the study of coastal aquifers.

The Computer Research Section is particularly concerned with the third Divisional objective. Consequently, the functions of the Section are strongly related to the development and use of GOWN as well as to the development of computer techniques to solve hydrological problems. In the future the Subdivision hopes to strengthen its structure with regard to research on groundwater pollution and operational problems in hydrogeological engineering.

Ottawa, December 12, 1968.

P. Meyboom, Head,
Groundwater Subdivision.

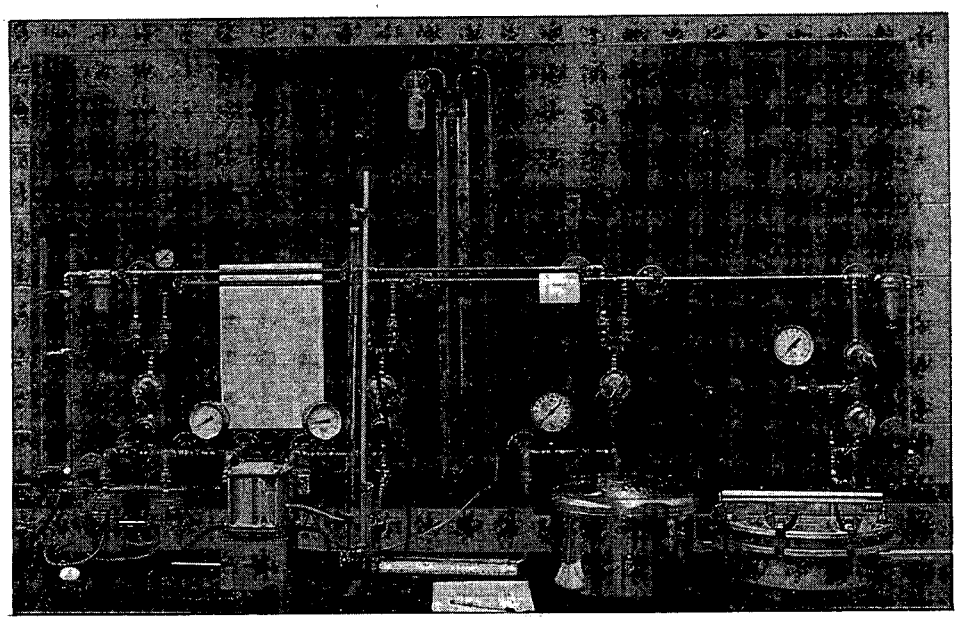


Figure 1 Soil-moisture extraction apparatus to determine the hydrologic properties of soils.

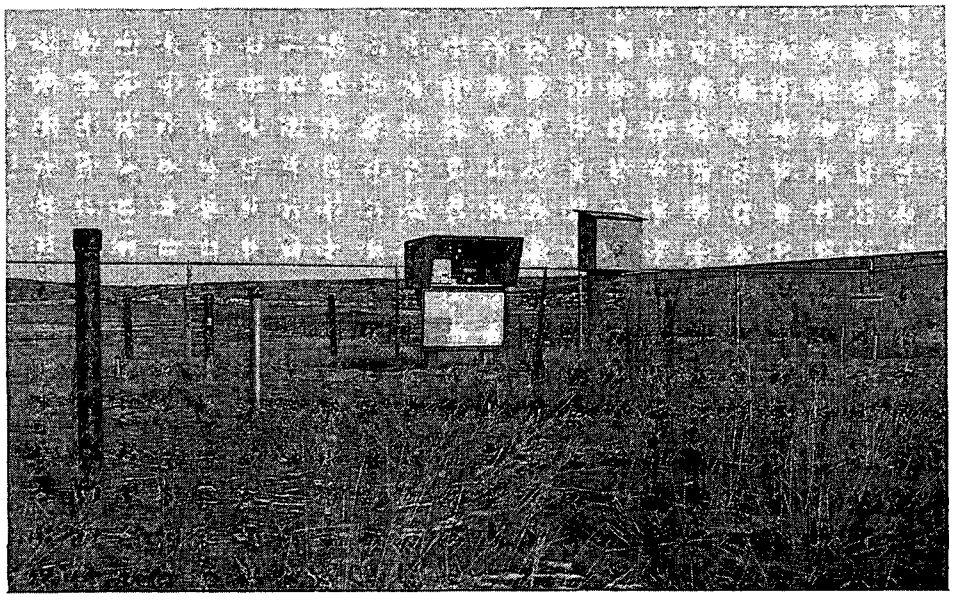


Figure 2 Experimental site at Calgary to verify theoretical values of unsaturated flow.

CATALOGUE OF CURRENT PROJECTS

1. Western Research Section

Project No. GW 67 - 1[a] R.A. Freeze

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., in press, The continuity between groundwater flow systems and flow in the unsaturated zone, Natl. Res. Council Canada, Proc. Hydrology Symposium No. 6: Soil Moisture, held in Saskatoon, Nov. 1967.

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, 154-173.

Freeze, R.A., The mechanism of natural groundwater recharge and discharge. 1. One-dimensional, vertical, unsteady, unsaturated flow above a recharging or discharging groundwater flow system. Submitted to Water Resources Research, Sept. 1968.

Freeze, R.A., Good Spirit Lake drainage basin, Saskatchewan: Progress report. Submitted to Inland Waters Branch for publication as Technical Bulletin, Oct. 1968.

2. Field

Permanent instrumentation in the Good Spirit Lake drainage basin includes:

1 streamgauge (operated by the Water Survey of Canada)
3 temperature-rainfall meteorological stations (operated by the Met. Branch of D.O.T.)
3 "recharge-discharge" sites, each with a piezometer nest, an observation well, a bank of soil moisture cells, and a raingauge.
4 isolated piezometer nests
1 isolated observation well recording the lake levels of Good Spirit Lake

This instrumentation has been measured once a week for 2-3 years (depending on site). Previous measurements have also been made of formation permeabilities, 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.

This project has now been turned over to Mr. Shin-Young Shiau of the Groundwater Subdivision, Ottawa as part of his duties as project coordinator of the Subdivision's IHD representative basins. He will supervise and interpret the continuing weekly measurement program carried out by the local basin manager, (see GW 67-1[b] page 58).

3. Office

The theoretical development satisfying the first objective has now been completed. The results are contained in the paper submitted to Water Resources Research.

4. Laboratory

The hydrologic properties of the soils in the Good Spirit basin have been determined in the soil moisture extraction laboratory, under the direction of J.A. Banner.

C. WORK IN PROGRESS:

1. Office

a) A discussion of laboratory and field results will form the nucleus of the second (and final) paper in the series: "The mechanism of natural groundwater recharge and discharge".

b) The possible application of Moire patterns in solving potential field problems in saturated and unsaturated flow is being investigated.

c) A joint project has been established with Prof. P.A. Witherspoon and Dr. I. Javendal of the University of California at Berkeley to study two-dimensional, transient, integrated saturated-unsaturated flow problems. The finite-element method, a powerful new numerical mathematical technique, will be used to illuminate the processes of artificial groundwater recharge, perched water tables, well hydraulics in unconfined aquifers, and natural systems.

2. Laboratory

a) A column experiment set up to simulate one-dimensional infiltration, and utilizing a tensiometer-transducer measurement system, is presently undergoing design adaptations. It is expected that results should be forthcoming in the near future.

b) An experimental plot has been established in a field adjacent to the building. Instrumentation now being installed includes a tipping bucket rain gauge and automatic recorder, a pair of atmometers, two neutron-probe access tubes, a bank of soil moisture cells, an observation well, a piezometer nest, and a heated recorder shelter.

c) The moisture extraction equipment is in continued use to determine the hydrologic properties of soils used in the column experiment, as well as those from the experimental plot, and Good Spirit basin.

Project No. GW 68 - 1 R.A. Freeze

BLUEPRINT FOR A HYDROLOGIC RESPONSE MODEL

A. OBJECTIVES:

1. To investigate the applicability of physically based hydrologic response models.

B. PREVIOUS WORK:

1. Publications

Freeze, R.A. and R.L. Harlan, Blueprint for a physically-based, digitally-simulated hydrologic response model. Submitted for presentation to the IASH Symposium on the Use of Analog and Digital Computers in Hydrology, Dec. 1968, Tucson, Arizona.

In this paper, a blueprint for the development of physically-based hydrologic response models is drawn up; a discussion of the level of sophistication which can be achieved with presently available methodology is presented; and the areas for necessary future research are pinpointed. The paper points out possible applications of the results of previous studies in the fields of regional groundwater flow and natural groundwater recharge to hydrologic response models.

Project No. GW 67 - 2[a] A. Lissey

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, p. 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

(i) Duration: May to September 1963-1967

(ii) Instrumentation:
4 Recording streamgauges (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.

2 record only daily precipitation. (all are operated by Met. Branch of Dept. of Transport).

79 piezometers arranged in 35 nests (read once a week from May 1965 to September 1967).

(iii) Other:

45 test holes drilled, sampled 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 streamgauges 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:

As of October 1, 1968 this project has been transferred to Mr. Shin-Young Shiau, of the Groundwater Subdivision, Inland Waters Branch, Ottawa.

Project No. GW 67 - 3 A. Lissey

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 capable of measuring and recording water level changes with an accuracy of $\pm$ 0.0001 feet was developed in the spring of 1968.

2. Field

In attempting to conduct water-level recession analyses on pingo lakes near Dawson, Y.T., in the summer of 1968, the following logistic problems were encountered:

(a) transportation: A Go-Anywhere-Vehicle purchased in anticipation of transportation problems proved to be inadequate for the terrain encountered hence few pingos were visited, and only instrumentation light enough for back packing was utilized on the one lake instrumented.

(b) instrumentation: The "Pingo Pinger", a device developed to measure and record very small water level changes, while it worked well in the laboratory, did not function effectively in the field due to the nightly occurrence of condensation in a vital switch. Hence water level recessions could not be recorded.

(c) drilling: A pack-sack diamond drill was utilized for drilling test holes. Mechanical problems with both drill and pump nullified the planned program.

Although field results were all negative the following conclusions about how work can be done effectively were reached:

(a) transportation: A moderately sized suitably equipped tracked vehicle capable of carrying a 1500 pound payload should be more effective in circumventing the transportation problem than the light GAV used this summer.

(b) instrumentation: Either a method for sealing switches or a different measuring principle must be developed before the "Pingo Pinger" can be used as a reliable field instrument.

(c) drilling: A drill larger than the pack-sack diamond drill used this summer is required before piezometers can be installed. Preferably this drill should be mounted on a tracked vehicle, have variable rotation speed, and be equipped to utilize either air, water or mud as the circulation fluid.

C. PRESENT WORK:

1. Laboratory

The Pingo Pinger is being modified to eliminate condensation problems.

2. Office

The aspects of different tracked vehicles are being investigated.

The aspects of various small air-water combination rotary drilling rigs are being investigated

D. FUTURE WORK:

1. Field

One more field season will be spent to conduct water recession analyses of pingo lakes. If further logistic problems appear to be too great the project will be temporarily suspended.

Project No. GW 67 - 4 R.O. van Everdingen

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 the 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 are being adapted for use on a UNIVAC 1108 in Calgary.

When the conversion is completed a write-up for publication can be considered.

Chemical analyses, pressure-test results and formation data for Manitoba wells have been coded and punched on IBM cards. Processing of these is expected to start soon.

Collection of pertinent references on the subject of formation water movement and chemistry was continued.

2. Field

a) The investigation of springs in the Rocky Mountains was extended to non-thermal springs. Field measurements included temperature, conductivity, pH and redox potential. Contents of H_2S, CO_2, O_2 were analyzed in the field. The application of geochemical thermodynamics to these spring waters is providing experience which will be valuable in dealing with formation waters in general.

b) Continued measurements in the Riverhurst area on Lake Diefenbaker confirm earlier observations on the influence of the surface reservoir on bedrock aquifers.

3. Laboratory

Initial tests with the "water-extractor-permeameter" setup revealed a number of shortcomings in the apparatus. A test with Bearpaw silty shale has given indications of possible osmotic effects taking place.

4. Publications

Van Everdingen, R.O., 1968, Studies of Formation Waters in Western Canada: Geochemistry and Hydrodynamics; Canadian Journal of Earth Sciences 5 (1968), p. 523-543.

Van Everdingen, R.O., 1968, Mobility of main ion species in reverse osmosis and the modification of subsurface brines; Canadian Journal of Earth Sciences 5 (1968), p. 1253-1261.

C. WORK IN PROGRESS:

1. Office

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.

2. Field

a) Regular bi-weekly measurements and sampling, and spot measurements and sampling during special events will be started at one of the Banff springs during the fall of 1968 and is expected to continue through 1969.

b) Measurements in Riverhurst (Lake Diefenbaker) will be continued through 1968 into spring 1969.

3. Laboratory

Improvement of the permeameter setup should enable determination of osmotic phenomena.

Project No. GW 67 - 5 R.M. Holmes

HYDRO-CLIMATOLOGY OF FOOTHILLS AND PRAIRIE

A. OBJECTIVE:

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., 1967, Airborne techniques in climatology and hydrology, 1. Oasis effect over prairie terrain: Submitted to "Atmosphere", Journal of Canadian Meteorological Society.

Holmes, R.M., 1967, Climate of the Cypress Hills, 1. Description of the site and problem. Submitted to "Atmosphere", Journal of Canadian Meteorological Society.

Holmes, R.M., 1967, Note on Low-Level airborne observations of temperature over Prairie Oases. Submitted to Monthly Weather Review.

Holmes, R.M. and K. Hage, 1967, Airborne Observations of three Chinook-Type situations in South Alberta. To be submitted to Jour. Appl. Meteorology.

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) hydro-thermograph 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. Field

a) During summer months each site is visited twice daily 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, with the help of R.O. Christie, to provide information on the layers of air immediately above the surface over a wide horizontal area. These data will 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.

2. 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.

3. 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. In succeeding seasons the surface observational work will continue with a program of data tabulation, reduction and computerization. It is envisaged that at least 5 years of data will be necessary to sample a suitable number of climatic variables. The airborne observations will continue to provide the observational continuum from the surface to the lower air layers. The past season produced data which show that this technique has significant application in climatology (see publications). The airborne method of measuring the energy budget of the surface as it affects the meso scale climate will be further developed. A critical re-evaluation of this project is planned for 1970-71 to determine if it is to continue, and on what basis.

Project No. GW 67 - 6 L.D. Delorme

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 laboratory of ponds, lakes, and streams.

2. To assess the relationship of the chemistry of pond, lake, and stream water to geology, botany, and climate.

3. To carry out a comprehensive systematic study of freshwater ostracodes of Canada.

4. To determine the paleohydrogeology of the interior plains by means of fossil ostracodes.

B. PREVIOUS WORK:

1. Publications

Delorme, L.D., 1967, Freshwater ostracode synonyms: Jour. Paleontology, v. 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., v. 4, no. 3, p. 433-447.

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

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

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

Delorme, L.D., (in press), The ostracode genera Cypriconcha and Megalocypris: Can. Jour. Zoology, v. 47.

2. 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 analysis 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.

3. Office

a) Computer Sciences of Canada (Calgary) have taken over the task of preparing programs from the Computer Science Division, Ottawa. They are still in the process of rewriting and de-bugging the programs.

b) Identification of ostracode species was done for the following people:

Dr. R.W. Klassen	-- Geological Survey of Canada, Dec. 12, 1967; 19 samples. Treherne, Manitoba.
Mr. C.R. Harington	-- National Museum of Canada, Dec. 15, 1967; 17 samples. Yukon.
Dr. R.S. Anderson	-- Canadian Wildlife Service, University of Calgary, April 1, 1968; 12 samples. Rocky Mountain Lakes.
Dr. C.H. Fernando	-- Department of Biology, University of Waterloo, June 15, 1968; 13 samples. Waterloo, Ontario.
Mr. C.L. McLay	-- Institute of Fisheries, Department of Zoology, University of British Columbia, September 9, 1968; 3 samples.
Dr. O.L. Hughes	-- Geological Survey of Canada, Sept. 11, 1968; 3 samples. Yukon.

C. IN PROGRESS:

1. Office

   a) Data collected during the 1968 field season are being prepared for computer processing.

   b) The catalogue of freshwater ostracode specific names is being continued and is nearing completion.

D. FUTURE WORK:

1. To sample Pleistocene and Holocene lacustrine sediments within the interior plains of Canada, to be completed by 1970.

2. To prepare systematic papers on Canadian Ostracoda.

3. To prepare ecological and paleoecological papers using freshwater ostracodes.

4. A student of the University of Waterloo who will study ostracode assemblages from southern Ontario, will spend several weeks in the Calgary office to become familiar with ostracode systematics and ecology.

Project No. GW 67 - 7 P. Meyboom

ASSINIBOINE RIVER DRAINAGE BASIN

A. OBJECTIVE:

1. To determine the manifestations of natural groundwater flow on the Canadian prairies, with particular reference to groundwater recharge.

B. PREVIOUS WORK:

This study started in 1962 and has resulted in a total of 14 papers on flow systems, phreatophytes, hydrochemistry and regional groundwater recharge. Reprints of most of these publications are available from the Calgary Groundwater Section (3303 - 33rd St., N.W., Calgary, Alberta). During the past year 2 contributions were made under the heading of this project:

Parry, J., 1968, Groundwater flow patterns of some prairie sloughs. Unpubl. M.Sc. Thesis, Department of Geology, University of Saskatchewan.

Sibul, U., 1968, Groundwater flow and hydrochemistry at the Morden Experimental Farm. Unpubl. M.Sc. Thesis, Department of Geology, University of Saskatchewan.

C. IN PROGRESS:

The research aspects of this project have been completed. The Sub-Committee in Wetlands of the National Committee on Wildlife Lands has requested a summary of the research findings in order to arrive at an overall assessment of the value of prairie wetlands. This submission is now being prepared.

D. FUTURE WORK:

The Assiniboine River drainage basin study will be completed with a final summary on the groundwater hydrology of prairie sloughs.

2. Maritime Research Section

Project No. GW 67 - 8 P. A. Carr

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, p. 109 - 111.

_____ (in press) Salt-water intrusion in Prince Edward Island. Can. J. Earth Sciences.

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

2. Field

a. installation of 45 piezometers and 10 open holes in 10 profiles to study groundwater flow in the upper 200 feet of bedrock.

b. collection of hydrographs from piezometers situated in the zone of diffusion.

c. determination of hydraulic conductivity from piezometer observations using the Hvorslev method.

2. Field (con't)

   d. determination of tidal and barometric efficiences from this network.

   e. completion by Mr. Chipping of the Georgetown study in which he ascertained the safe yield for the Georgetown well field in P. E. I.

C. WORK IN PROGRESS:

1. Publication

   In cooperation with Mr. G. van der Kamp, a report is being written describing a technique for determining regional values of hydraulic conductivity and specific storage from observed water-level fluctuations in wells influenced by tidal action. This technique is called, the tidal method, and involves determining true tidal efficiency and time lag from the well hydrograph.

2. Field

   Data from two continuous water level recorders and weekly water level readings from the remainder of the network are being collected.

D. FUTURE WORK:

1. A computer program will be written for the tidal method.

2. Refinement of the tidal method will be carried out by separating and individually analyzing the various tidal components.

Project No. GW 68 - 9

P. A. Carr and H. Gross

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. Two flights of IR imagery have been made: one in October, 1965, and the other in August, 1968.

   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:

More temperature measurements will be made of the lake in different seasons of the year to detect variation in temperature contrasts between surface waters and groundwater.

Project No. GW 68 -10

D.D. Brown

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 to the zone of diffusion near the centre of Taylor Island.

2. During August, 1967 and May to September, 1968:

   a. 42 test holes drilled, sampled and E-logged
   b. 28 piezometers installed in seven nests
   c. 6 wells pump-tested
   d. 14 groundwater level, 1 tidal and 2 precipitation gauges installed
   e. conductivities of bailer samples used to estimate salt content. Salt content of bailer samples was also determined directly by chloride titration.
   f. elevations with respect to mean tide datum determined for all open wells and piezometers
   g. 34 groundwater samples analyzed for pH, conductivity and all major anions and cations.

C. WORK IN PROGRESS:

1. Field

   Water level gauges read weekly.

2. Office

   Processing of pump test and water level records for digital modeling of well field in Taylor Island sandstone aquifer. This will form the basis of a Ph.D. Thesis study at the University of Western Ontario.

D. FUTURE WORK:

1. Monitoring of piezometers to determine rate of seawater inflow and freshwater outflow

2. Use of tidal efficiency and slug test data to obtain more permeability estimates for the sandstone aquifer.

Project No. GW 67 - 10 M. L. Parsons

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

   nil

2. Field

   a. Mapping of surficial sediments in an experimental area near Iroquois Falls.

   b. Installation of 46 piezometers at 20 different sites and completion of permeability tests on piezometers.

   c. Temperature logging of the deepest piezometer at each site, once during August, 1967 and once during March, 1968.

   d. Installation of a recording rain gauge in a typical "wetland" area.

   e. Installation of a weir in a small creek draining the "wetland". Current meter measurements of two adjacent small rivers to establish stage-discharge curves for 1966 and 1967, with the assistance of the Water Survey of Canada, North Bay Office.

   f. Installation in the "wetland" of five shallow observation wells equipped with Stevens' F recorders for spring to fall water level observations.

3. Office

   a. Analysis of piezometric and thermal data.

   b. Digital modelling of groundwater potential and temperature fields.

C. WORK IN PROGRESS:

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 at its annual meeting in November, 1968.

Parsons, M.L. Groundwater Movement and Subsurface Temperatures in a Glacial Complex, Cochrane District, Ontario. Ph.D. Thesis to be submitted to the University of Michigan. Following thesis submission, the results of this study will be published in a scientific journal.

Parsons, M.L. Preparation of a paper dealing with some observations of natural "wetland" drainage.

2. Field

a. Continuation of monthly piezometer readings by the Water Survey of Canada, North Bay Regional Office, to obtain a five-year record.

b. Continuation of precipitation, runoff and groundwater observations in the "wetland" by a local observer to obtain a five-year record.

3. Office

Preparation of hydrogeologic data for storage in GOWN.

D. FUTURE WORK:

Apart from continuing piezometer readings, this project will be terminated by April 1969.

Project No. GW 68 - 11

M. L. Parsons

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 steady 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:

nil

C. WORK IN PROGRESS:

1. Publications

   nil

2. Field

   nil

3. Laboratory

   Assembly of continuous logging quartz thermometer for borehole temperature measurement.

D. FUTURE WORK:

1. Field

   a. temperature logging of all existing piezometers and drill holes in New Brunswick and P. E. I.

   b. installation of a piezometer-profile in a typical Maritime Provinces coastal area to obtain hydrogeologic and thermal data to a depth of 500 feet.

2. Office

    1. Development of a digital model to simulate the regional hydrodynamics and thermal characteristics of a fresh-saline groundwater environment in a typical coastal area.

    2. Digital simulation of the effects of steady groundwater withdrawal on the natural regional hydrodynamics.

Project No. GW 68 - 12 H. Lazreg

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:

nil

C. WORK IN PROGRESS:

nil

D. FUTURE WORK:

1. Field

   Earth resistivity surveys in selected areas where seawater intrusion has or may become a problem and where there is ample information concerning the subsurface distribution of fresh, brackish and saline waters.

2. Office

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

Project No. GW 67-11 H. Ryckborst

PARAMETRIC HYDROLOGY OF A GLACIATED BASALT PLATEAU

A. OBJECTIVES:

To show the feasibility of system synthesis in the Fraser River forecast models. For this purpose an extended forecast of the water yield in twelve areas of the Bonaparte River basin in the Cariboo, B.C. will be given.

B. PREVIOUS WORK:

Field:

During the spring and summer of 1968 the following 34 instruments were installed in addition to the 31 operating recorders:

- 7 water level recorders along the rivers
- 9 groundwater level recorders
- 5 recording ground level rain gauges
- 5 DOT rain gauges
- 2 thermo-hygrographs
- 5 sandpoints were drilled
- 1 twelve arm wind tower

Meteorological data from the British Columbia Department of Lands, Forests and Water Resources were analyzed in an internal report by Dean A. Belton.

Laboratory:

The snow gauges were re-calibrated in the laboratory after winter use.

C. IN PROGRESS:

1. Publications (in preparation)
   a) Parametric hydrology of a glaciated basalt plateau (December 1968)

b) Rainfall distribution over a plateau

c) Comparison rainfall measurements at ground level, 30 cm and 150 cm above ground level.

d) Snowfall measurements in a rain gauge and on a snow pillow.

e) Rainfall and frequency of groundwater levels.

2. Field:

Installation of an Eppley recording radiometer.

The installation of a recording Troxler soil moisture probe.

Installation of hygristors and thermistors on the wind tower and in the soil under the tower.

The objective of the field work is to use Van Schaik's results from Lethbridge to explain the time lag of spring runoff after the snow melt. The results will be used to test F. I. Morton's regional evaporation model. The results will also indicate how the rain fall, and snowmelt, infiltration problem can be solved in a semi-arid area.

D. FUTURE WORK:

Data analysis, testing of computer programs and writing of publications. The heat flow equations with a sloping plane will be solved numerically. When the hydrologic model is operational, it will be used for the larger part of the Fraser River area.

Project No. GW 68-2 H. Ryckborst

PARAMETRIC HYDROLOGY OF THE
NORTHERN LAKE ONTARIO BASIN

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

A. OBJECTIVES:

As a contribution to the International Field Year on the Great Lakes, a forecast model will be tested in a complex river basin in the northern Lake Ontario area. The forecast model is based on the Fraser River system synthesis.

B. PREVIOUS WORK:

Mr. M. Oosterveld (University of Guelph) has written a report on a soil moisture in the Northern Lake Ontario basis (I.W.B. technical publications). All soil types in the basin are accounted for. The proposed soil moisture index is a modification of the "Ayers" soil moisture model, which will be tested in the forecast model.

C. PRESENT WORK:

Arrange for a joint project with a postdoctorate fellow.

D. FUTURE WORK:

Installation of ground level rain gauges, groundwater level recorders, snowfall recorders and river flow recorders.

Apply the results to the entire basin, including the U.S. side, and prepare the system for routine use.

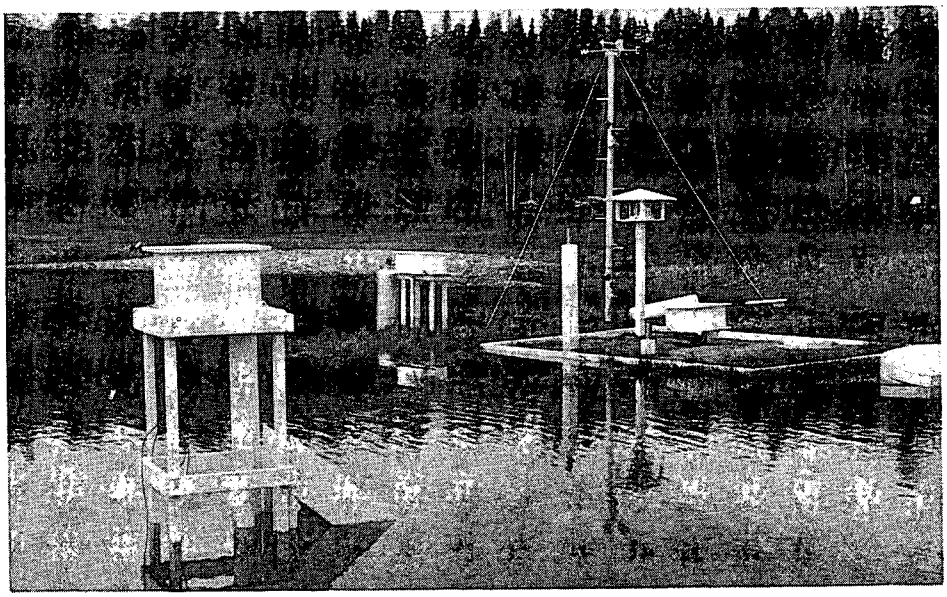


Figure 3 Observation well and hydrometeorological station in the Bonaparte basin to study bank storage and evaporation during spring flood.

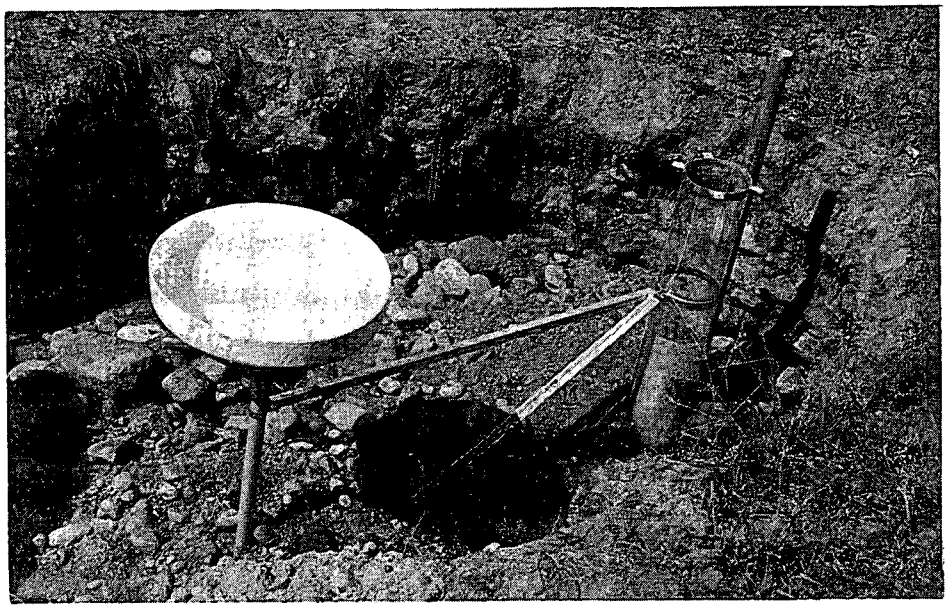


Figure 4 Installation of ground level rain gauge. The excavation will be filled up so that funnel rim is at ground surface.

3. Eastern Research Section

Project No. GW 68-3 Ch. Haefeli

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 our part of the IFYGL terrestrial water budget of Lake Ontario and its basin.

2a) Calculation of groundwater flow in a large basin using the Freeze FLOPAT 2-D method, rather than water-balance and representative basins.

b) Regional importance: Amount, storage and flow systems of groundwater in the Lake Ontario basin. Gauging of streams in watersheds where reservoirs and dams have been proposed (area of the Cataragin Region Conservation Authority).

B. PREVIOUS WORK:

1) This study started in April, 1968. No previous publications.

C. IN PROGRESS:

1) Field

a) Installation of 3 recording and 4 stream gauging stations in ungauged creeks between Belleville and Brockville; streamflow measurements.

b) Selection of 23 watersheds in the Lake Ontario drainage basin for hydrograph analysis.

c) Temporary installation of conductivity recorder at Collins Creek for baseflow study (Kingston area).

d) Preliminary telethermometric measurements along the shore in Collins Bay.

e) Preliminary IR-flights along the shore in the Kingston area through the Great Lakes Division, Burlington.

2) Office

a) Compilation of a geological map of the Lake Ontario basin using published and unpublished maps and documents. Construction of generalized geological cross sections.

b) Airphoto interpretation with particular regard to the geological structure and hydrogeological features (sinkbeds, resurgenes, flow pattern, stream channels).

c) Preliminary computation of the recession constant for three watersheds.

d) Analysis of the hydrogeological conditions in 23 watersheds situated around the Lake Ontario. Evaluation of: drainage pattern, slope, drainage density, flow frequency, baseflow recession, infiltration, transmissibility, storage, effect of soil, overburden, bedrock.

e) Application and development of various computer programs for hydrograph and groundwater flow analysis.

f) Evaluation of groundwater divides.

D. FUTURE WORK:

1) Field

a) Hammer seismic investigations between Trenton, Oshawa, Port Credit, Hamilton and St. Catherines in cooperation with the Geological Survey of Canada.

b) Determination of temperature anomalies along the shore of Lake Ontario (groundwater inflow) by means of telethermometric survey and IR-flights in cooperation with the Great Lakes Division, Burlington.

c) Drilling and testing of observation wells and piezometers to determine aquifer characteristics.

d) Tracer tests.

2) Office

a) Review and analysis of field data.

b) Evaluation of specific capacity, transmissibility, storage coefficient for the different geological formations using some 10,000 existing well data.

c) Construction of detailed hydrogeological cross sections close to the Lake Ontario shore. Quantitative determination of groundwater flow by using computer facilities.

d) Analysis of confined aquifers.

e) Publications.

Project No. GW 68 - 4

R.L. Herr

HYDROGEOLOGICAL MAPS OF THE LAKE ONTARIO BASIN
(A hydrogeological project for the International Field Year on the Great Lakes, IFYGL)

A. OBJECTIVES:

To develop computer methods for the construction of hydrogeological maps. This project is related to GW 68 - 5. The first specific sub-objective is to construct geological cross-sections through a given map area using water-well records.

B. PREVIOUS WORK:

Meetings have been held with officers of the United States Geological Survey and members of the Ontario Water Resources Commission to determine the phases to be covered by this international joint project.

C. WORK IN PROGRESS:

Water-well logs from the Lake Ontario basin which are stored by the Ontario Water Resources Commission in Toronto are being coded and digitized. This phase of the project is expected to be completed some time in 1969.

D. FUTURE WORK:

Construction of maps and cross-sections by means of special GOWN retrieval programs.

Project No. GW 67 - 12 J.A. Vonhof

THE EFFECT OF BRINE PONDS ON THE GROUNDWATER REGIME

A. OBJECTIVES:

1. To study the effect of brine disposal ponds near potash mines on the local groundwater regime.

2. To evaluate the long-term effects of the brine ponds on the surface water regime in the area.

3. To recommend possible alternative solutions to the brine disposal problem around potash mines based on the outcome of the above study.

B. GENERAL SETTING OF RESEARCH AREAS:

The research project is conducted in an area near the town of Esterhazy in southeastern Saskatchewan. Three potash mines are enclosed in the study area at present. Each mine is situated in a unique geologic and hydrologic environment.

1. International Minerals and Chemicals Corporation K1 Plant.
   Location: approximately 5 miles north of Esterhazy and 1.5 miles west of Cutarm Creek.
   Geologic setting: Plant and brine pond on low relief till plain. At a depth ranging from 20 to 50 feet stratified intertill deposits composed of sand and silt are present. Approximately 2 miles east of the plant the intertill deposit consists of 40-50 feet of water saturated sand which is used as a groundwater source by the town of Yarbo. A buried valley aquifer at the plant site is used as the source of their entire water supply. Daily production from this aquifer is approximately 1.5 million gallons (only potash mine using groundwater in Saskatchewan). Pleistocene deposits are underlain by Upper Cretaceous Shales.
   Hydrologic setting: Recharge area; buried valley drains towards northeast. As a result of pumping an artificial potential depression is created along the buried valley which most likely will limit the areal extent of any infiltrating brine.

2. International Minerals and Chemicals Corporation K2 Plant.
   Location: approximately 7 miles east of Esterhazy.
   Geologic setting: Plant and brine pond on till plain with moderate relief. At approximately 30-40 feet stratified intertill deposits. Pleistocene sediments are underlain by Upper Cretaceous shaly silt and sand beds.

Hydrologic setting: Recharge area for shallow groundwater flow. Discharge area for deep groundwater flow, + 10-20 feet of head. Head may be sufficient to limit brine infiltration.

3. Sylvite of Canada Limited.
   Location: approximately 25 miles southeast of Esterhazy and 1.5 miles south of the Qu'Appelle valley.
   Geologic setting: Plant on Welby sand plain, approximately 60-100 feet thick, which is a glacial outwash deposit outcropping in the Qu'Appelle valley.
   Hydrologic setting: Recharge area, gradient towards the Qu'Appelle valley.

C. PREVIOUS WORK:

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.

1968: A regional test drilling program was conducted during the summer of 1968 in the northern part of the area. Subsequent detailed shallow test drilling was done around the waste disposal basin near the K2 plant. Additional water samples were collected to define the groundwater chemistry in the area.

The data obtained from the test drilling program show:

a) on the bedrock surface the presence of a large basin partially flanked on each side by bedrock uplands with three outlets (?) or inlets (?) 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 silty and sandy beds in the Upper Cretaceous Shales immediately underlying the Pleistocene sediments on the southern flank of the basin near the K2 plant.

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

Preliminary work was started on the deposition of airborne salt emitted by the smoke stack from the K1 plant. This project was done with the assistance of the D.R.B. Suffield station.

D. IN PROGRESS:

Possibly three publications:

1. Geology and preliminary bedrock topography of the Esterhazy area (Technical Bulletin I.W.B.).

2. Fractured tills and their significance.

3. Groundwater chemistry as a mapping tool for buried valleys. Chemical analyses of water samples are not expected to be completed before the spring of 1969.

E. FUTURE WORK:

1969: Additional regional test drilling in the northern part of the area and sidehole sampling. Detailed stratigraphic information must be gathered to determine the relationship of the sediments in the outlets (?) to those in the basin. Detailed test drilling around the brine ponds. Installation of a number of observation wells. Regional test drilling in southern part of the area.

1970: Installation of observation wells and monitoring of groundwater flow model.

1971-1972 (?): Monitoring of model.

Over this period the following additional surveys are under consideration:
a) Surface Resistivity

b) Remote Sensing techniques such as infrared imagery.

A number of projects are under consideration and could run concurrently with the main research project:

1. Determine the effect of facies changes (geological) on the groundwater chemistry.

2. Determine the effect of brines on the permeability of a montmorillonitic till.

3. Study the effect of airborne salt on the hydrochemistry of shallow groundwater (in co-operation with D.R.B. Suffield Station).

On the latter project a start has been made.

Project No. GW 67-17

J. E. Charron

HYDROGEOLOGY OF THE NORTH NASHWAAKSIS BASIN, N.B.

A. OBJECTIVES:

To set up an IHD representative basin in New Brunswick which will function also as an outdoor hydrology laboratory for the University of New Brunswick.

B. PREVIOUS WORK:

Installation of 2 piezometer nests and a general hydrochemical survey.

C. IN PROGRESS:

Report completed and being edited.

D. FUTURE WORK:

Project completed.

Project No. GW 67-18 J. E. Charron

GROUNDWATER RESOURCES OF LAC DU BONNET AND SELKIRK AREAS, MANITOBA

A. OBJECTIVES:

To assess the groundwater potential.

B. PREVIOUS WORK:

1. Publications

Charron, J.E., 1966. Measuring and tracing groundwater movement with dye tracers in the Red River Valley, Man., Geol. Survey of Canada, Topical Report No. 111.

2. Field

A regional sampling program and well inventory was completed in 1965.

C. IN PROGRESS:

The final report on this study will be ready by September, 1969. It will constitute the last report in a series of 7 publications dealing with various aspects of groundwater supplies in southern Manitoba.

Project No. GW 68 - 7 J.E. Charron

A HYDROCHEMICAL STUDY OF RUSSELL COUNTY, ONTARIO

A. OBJECTIVES:

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

B. PREVIOUS WORK:

Four months field work completed.

C. PRESENT WORK:

Compiling and analysing data accumulated in view of publishing a report.

D. FUTURE WORK:

To extend this study into Prescott County in 1969.

Project No. GW 68-8 F. I. Morton

POTENTIAL EVAPORATION -- SIGNIFICANCE AND MEASUREMENT

A. OBJECTIVES:

1. To search for and, if necessary, to develop an evaporimeter for the precise and undistorted measurement of potential evaporation, i.e. the evaporation from a small moist surface with radiation absorption, vapour transfer and heat transfer characteristics similar to those of surrounding region.

2. To test the significance of potential evaporation as a manifestation of the evaporation from the surrounding region.

3. To develop an evaporimeter for the measurement of evaporation from snow.

4. To test both the potential and snow evaporimeters over a wide climatic range.

B. PREVIOUS WORK:

1. Publications

Morton, F. I., 1965, potential evaporation and river basin evaporation, Proc. ASCE, Vol. 91, No. HY6.

Morton, F. I., 1967, potential evaporation and river basin evaporation, closing discussion, Proc. ASCE, Vol. 93, No. HY4.

Morton, F. I., 1967, evaporation from large deep lakes, Water Res. Research, Vol. 3, No. 1.

Morton, F. I., 1968, evaporation and climate -- a study in cause and effect, Ph.D. Thesis, Trinity College, Dublin. Submitted to Inland Lakes Branch for publication in Scientific Series.

F. I. Morton

C. IN PROGRESS:

1. Publications -- Potential Evaporation as a Manifestation of Regional Evaporation, Journal of Hydrology.

2. Field -- To install evaporimeters and radiometers in the Lake Ontario basin.

3. Laboratory - Development of an evaporimeter

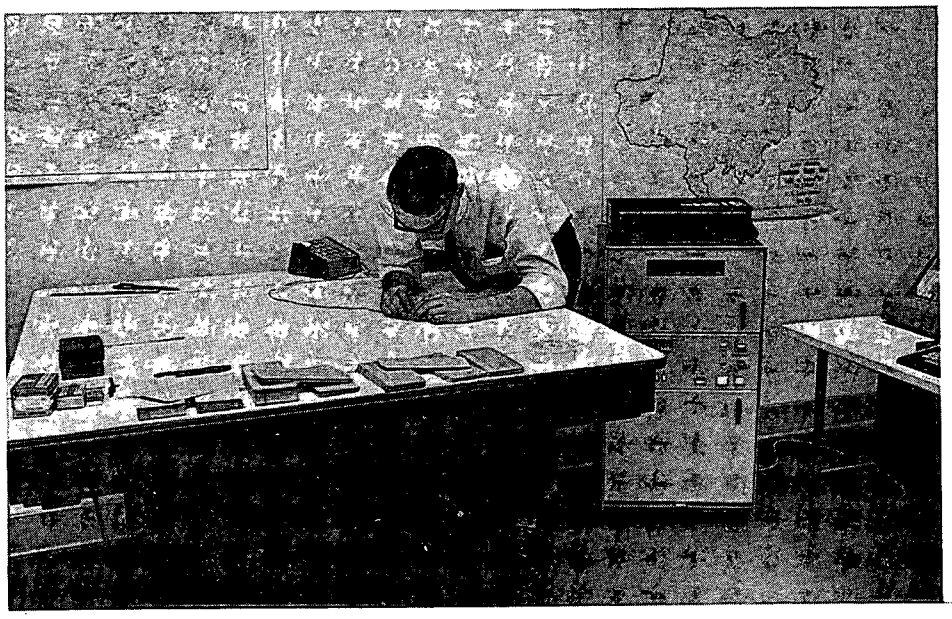


Figure 5 D-Mac Pencil Follower in use.

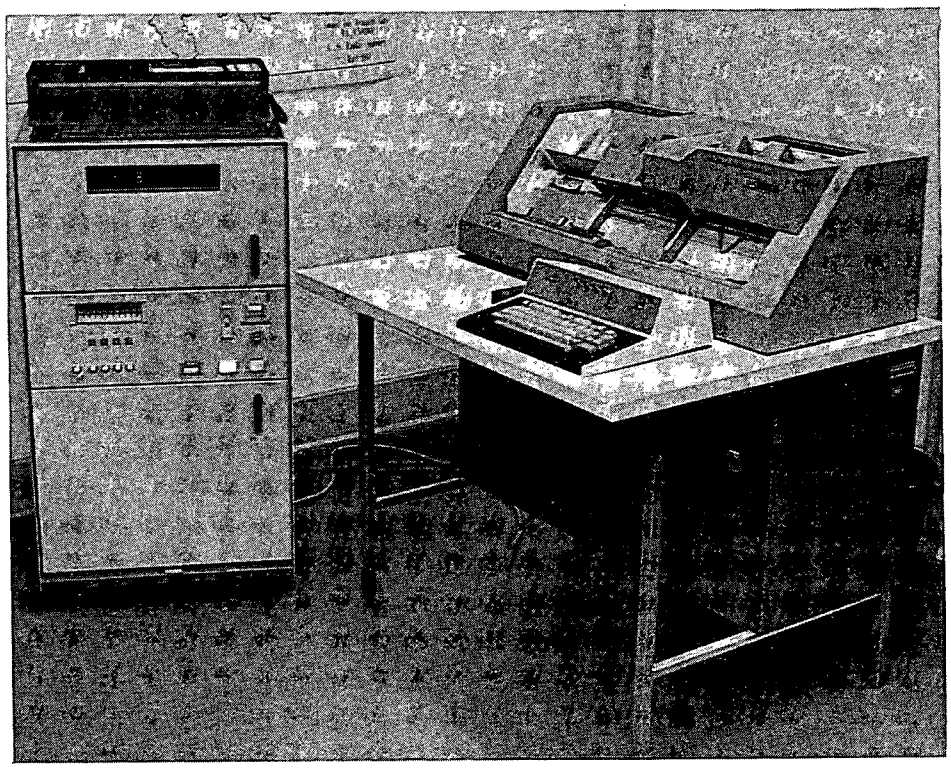


Figure 6 Console and 029 Keypunch connected to D-Mac Pencil Follower

Project No. GW 67 - 13 J. A. Gilliland

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. (in press). A Rigid Plate Model of the Barometric Effect. J. of Hydrology.

2. Field

Instrumentation installed in 1968 brings the total number of installations to 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 preliminary calculations carried out. These 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 (see Publication) and a physical model has been built to test the physical significance of various rigid plates.

C. WORK IN PROGRESS:

1. Further development of the rigid plate model is in progress using the physical model.

2. Analysis of the 1968 season field data is under way and will be published in 1969.

3. Analysis of P. E. I. hydrograph data has commenced. This project overlaps with 67-14.

D. FUTURE WORK:

The applicability of the rigid plate model and the detection of small fluctuations will be further investigated.

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

Project No. GW 67 - 14 J. A. Gilliland

NETWORK DESIGN

(This project and project 68-5 have replaced old project 67-14)

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 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.

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. A prototype of the variable time interval recorder is now being tested at Saskatoon.

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. Testing and evaluation of the prototype v.t.i. recorder continues under the direction of Professor A.R. Boyle.

D. FUTURE WORK:

1. Completion of all project phases mentioned above.

2. After successful testing of prototype v.t.i. recorder, four pilot models will be tested in various environments.

Project No. GW 68 - 5 J. A. Gilliland

"GOWN"

(This project and project 67-14 replace old project 67-14)

A. OBJECTIVES:

1. To establish 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. Specifically, to test the operation and utility of GOWN, in a cooperative project with the Ontario Water Resources Commission. Maps produced by GOWN will be compared with maps made by OWRC to evaluate the utility of GOWN.

B. PREVIOUS WORK:

1. Publications

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

Gilliland, J. A., 1968b. Manual on Groundwater Data Storage System. Internal Publication, IWB, now in 3rd edition.

Gilliland, J. A. and Treichel, A. (in press). GOWN -- A Computer Storage System for Groundwater Data. Can. J. Earth Sci.

2. Office

Programming of well log, well data and catalogue files completed and operation tested. Programs await a "production test".

Program for automatically calculating permeabilities from Hvorslev slug tests has been written.

A D-Mac Pencil Follower has been acquired and is being used for this project and project 68-6.

C. WORK IN PROGRESS:

1. Hydrograph file programming under way.

2. Development of "general purpose retrieval" program under way.

3. Development of two interpolation and contouring programs under way.

4. Digitizing locations of wells in Lake Ontario drainage basin and coding of well logs in progress in cooperation with OWRC for the IFYGL. Approximately 10,000 wells have been digitized to date. This part of the project is carried out jointly with project 68-4.

D. FUTURE WORK:

1. Programming of additional data files.

2. Development of display and retrieval procedures.

3. Production of various hydrogeological maps for the Lake Ontario drainage basin.

4. Coding of data from Saskatchewan is planned for the summer of 1969.

5. Program is continuous.

Project No. GW 68 - 6 J. A. Gilliland

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 I. H. D. (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. To date (17/10/68) the project is 75 percent completed. Lakes in Quebec were digitized by personnel of the Quebec Department of Natural Resources using the Inland Waters Branch pencil follower and copies of the results are sent to Quebec.

C. WORK IN PROGRESS:

Work continues PREVIOUS WORK above, using 1:500,000 aeronautical charts.

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. However, no plans exist for the Computer Research Section to carry out determination of depths or volumes.

The digitized lake outlines will eventually be stored in GOWN and will be used during retrievals.

Project No. GW 67 - 1[b] S.Y. Shiau

WATER BALANCE, GOOD SPIRIT LAKE BASIN, SASKATCHEWAN

A. OBJECTIVES:

To arrive at an annual or seasonal water balance of a parkland representative basin as part of Canada's program for the International Hydrological Decade. (For objectives of companion studies on groundwater recharge see project write-up GW 67 - 1[a] by R.A. Freeze).

B. PREVIOUS WORK:

1. Publications

R.A. Freeze has summarized the I.H.D. aspects of this study in a progress report called "Good Spirit Lake drainage basin, Saskatchewan". This report will be published as a Technical Bulletin by the Inland Waters Branch. The I.H.D. project will be carried on by S.Y. Shiau.

2. Field

Present instrumentation in the Good Spirit Lake Basin includes:

3 temperature-precipitation meteorological stations (operated by the Met. Branch of D.O.T.)
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 gauge.
4 isolated piezometer nests.

This instrumentation 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. Office

Proper computer procedures are being developed to store all hydrogeological and hydrometeorological data in GOWN.

2. 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 D.O.T.

   c. All other instrumentation is measured weekly by a local basin manager and processed by the Groundwater Subdivision in Ottawa.

D. FUTURE WORK:

1. Maintain instrumentation and continue field measurements.

2. Study of the rainfall-runoff relation and the snowmelt-runoff relation in the basin.

3. Improvement of the water balance studies.

4. Tritium study under the direction of Mr. A. Rutherford of the Saskatchewan Research Council.

5. Development of data storage and retrieval system and FORTRAN programming for various hydrologic problems of the basin - in cooperation with GOWN (Project 68 - 5).

Project No. GW 67 - 2[b] S.Y. Shiau

WATER BALANCE, OAK RIVER BASIN, MANITOBA

A. OBJECTIVES:

To arrive at an annual or seasonal water balance of a parkland representative basin as part of Canada's program for the International Hydrological Decade. (For objectives of companion study on the hydrogeology of Oak River basin see project write-up GW 67 - 2[a] by A. Lissey).

B. PREVIOUS WORK:

1. General

The hydrogeological aspects of this study started in 1963 by A. Lissey. (see: project write-up GW 67 - 2[a]) The I.H.D. aspects of this study were taken on by S.Y. Shiau during the summer of 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 the Met. Branch, D.O.T.)
- 2 precipitation stations (operated by the Met. Branch, D.O.T.)
- 77 piezometers arranged in 35 nests (read weekly from May, 1965 to September, 1967)

(B) Others

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

h. all piezometers surveyed into geodetic datum
i. 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 Met. Branch, D.O.T.
   c. All piezometers read monthly starting in September, 1967 by a local basin manager for processing by the Groundwater Subdivision at Ottawa.

2. Preliminary water balance studies of the basin.

D. FUTURE WORK:

1. Maintain instrumentation and continue field measurements.

2. Installation of observation wells to study the water table configuration in key areas of the Oak River basin.

3. Using the three-dimensional computer program developed by R.A. Freeze, together with field measurement, will

   a. estimate the groundwater component of the hydrologic balance,
   b. compare the surficial mapping of recharge and discharge areas completed by A. Lissey.

4. Study of the rainfall-runoff relation and the snowmelt-runoff relation of the basin.

5. Improvement of water balance studies.

6. Development of data storage and retrieval system and FORTRAN programming for various hydrologic problems of the basin -- in cooperation with GOWN (Project 68 - 5).

Project No. GW 67 - 19 S.Y. Shiau

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 and the Basin has been taken over by S.Y. Shiau in July 1968.

2. To arrive at an annual or seasonal water balance of a high-mountain representative basin as part of Canada's program for the International Hydrologic 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

The following instrumentation has been installed:

3 soil moisture stations (3-5 gypsum blocks at each station
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 hygrothermographs (with maximum, minimum and present temperature checks)
6 experimental evaporimeters (installed in pairs)
3 snow courses (10 points)
2 sunshine recorders
25 piezometers in 7 nests
13 water table wells

C. WORK IN PROGRESS:

1. Publication

Ecology of the Groundwater Flow Systems in the Okanagan Highland. To be written chiefly by Mr. W. Arlidge, B.C. Forest Service.

Chemistry of the Groundwater Flow Systems in the Okanagan Highland. To be written by D.W. Lawson.

2. 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 B.C. Department of Lands, Forests and Water Resources at Victoria.

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.

3. Preliminary water balance studies of the basin are being carried out by S.Y. Shiau.

D. FUTURE WORK:

1. Installation of a permanent hydrometric station at East Fork of Trapping Creek.

2. Maintain instrumentation and continue field measurements.

3. Laboratory calibration and field installation of 5 additional soil moisture stations using Soiltest MC-310A Standard cells.

4. Improvement of the water balance studies.

5. Development of data storage and retrieval system and FORTRAN programming for various hydrologic problems of the basin -- cooperation with GOWN (Project 68 - 5).

Project No. GW 67 - 15 E.C. Halstead

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:

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

The following instrumentation has been installed:

4 observation wells with Stevens Recorders
2 staff gauges, one on each creek
1 evaporation pan, rain gauge, anemometer
1 hygrothermograph
1 Fischer and Porter precipitation gauge
1 Bristol water thermograph
1 snow course

C. FUTURE WORK:

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. A final report on the drilling and successful development of a water-supply well is now being prepared.

Figure 7 Drill site (2) for production well on top of Mount Kobau, elevation 6,012 feet. Observation wells (1) are 275 and 300 feet distant from production well. Trace of major fault zone across mountain top indicated by black line. An earth dam constructed in 1932 created the storage reservoir shown as a lake in the centre of the photograph.

Project No. GW 67 - 16 E.C. Halstead

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 I.H.D. purposes.

B. PREVIOUS WORK:

Groundwater and well inventory, carried out in 1953 by Armstrong and Brown, followed by B.C. Water Resources rotary drilling program of eleven, 1,000-ft. 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 11 B.C. test holes. Sieve analyses of samples collected at 10-ft. intervals have been done. 250 water samples were collected and analyzed using a Hach chemical kit.

C. IN PROGRESS:

Analysis of data collected.

D. FUTURE:

Continuing observation program of piezometric levels, and periodic sampling programs.

Project No. GW 67 - 9

D. W. Lawson

PRINCIPLES OF GROUNDWATER POLLUTION

A. OBJECTIVES:

To gain an understanding of the movement and interaction of contaminated water which is injected into the natural groundwater flow pattern.

B. WORK IN PROGRESS:

Ph.D. program at the University of Guelph under the direction of Dr. D. E. Elrick.

A literature review of the theory of dispersion has been completed and an experiment involving dispersion in a non-uniform velocity field is presently being designed.

5. Summary of Current Research

The foregoing catalogue of research projects has been summarized in Table I

Table I Review of activities

Item	67-68	68-69
No. of active research projects in physical hydrology	14	19
No. of research projects in parametric hydrology	1	2
No. of major water-supply studies	2	1
No. of IHD representative basins	5	4
No. of data-processing projects	0	2
No. of papers published or accepted for publication	23	22
No. of sponsored Ph.D. thesis presented	-	2
No. of sponsored M.Sc. thesis presented	3	2

6. List of Projects

- by project number -

Project	Short Title	Investigator	Status*	Page
GW 67-1[a]	Natural groundwater recharge	R. A. Freeze	P	8
GW 67-1[b]	Water balance Good Spirit Lake	S. Y. Shiau	S	58
GW 67-2[a]	Hydrogeology Oak River basin	A. Lissey	C	12
GW 67-2[b]	Water balance Oak River Basin	S. Y. Shiau	S	60
GW 67-3	Permafrost geohydrology	A. Lissey	P	15
GW 67-4	Bedrock aquifers	R.O.Van Everdingen	P	17
GW 67-5	Hydroclimatology	R. M. Holmes	P	19
GW 67-6	Paleohydrogeology	L. D. Delorme	P	22
GW 67-7	Assiniboine basin	P. Meyboom	C	25
GW 67-8	Sea-water intrusion P.E.I.	P. A. Carr	P	26
GW 67-9	Groundwater pollution	D. W. Lawson	P	67
GW 67-10	Groundwater flow in the clay belt	M. L. Parsons	C	31
GW 67-11	Parametric Hydrology, basalt plateau	H. Ryckborst	P	36
GW 67-12	Brine ponds near Saskatchewan potash mines	A. Vonhof	P	43
GW 67-13	Groundwater hydrographs	J. A. Gilliland	P	51
GW 67-14	Network design	J. A. Gilliland	P	53
GW 67-15	Water balance Mt. Kobau Watershed	E. C. Halstead	C	65
GW 67-16	Nicomekl Serpentine Creek	E. C. Halstead	P	66
GW 67-17	North Nashwaaksis basin	J. E. Charron	C	46
GW 67-18	Lac du Bonnet	J. E. Charron	C	47
GW 67-19	Water balance Trapping Creek	S. Y. Shiau	S	62

6. LIST OF PROJECTS

- by project number -

Project	Short Title	Investigator	Status*	Page
GW 68-1	Hydrologic response model	R. A. Freeze	C	11
GW 68-2	Parametric hydrology Lake Ontario	H. Ryckborst	S	38
GW 68-3	Groundwater flow into Lake Ontario	Ch. Haefeli	S	39
GW 68-4	Hydrogeological maps Lake Ontario	R. L. Herr	S	42
GW 68-5	GOWN	J. A. Gilliland	P	55
GW 68-6	Inventory of Canadian lakes	J. A. Gilliland	P	57
GW 68-7	Hydrochemistry of Russell County	J. E. Charron	S	48
GW 68-8	Potential Evaporation	F. I. Morton	S	49
GW 68-9	Infrared anomalies	P. A. Carr	P	28
GW 68-10	Seawater intrusion, Shippegan, N.B.	D.D. Brown	S	29
GW 68-11	Groundwater flow and subsurface temperature	M.L. Parsons	S	33
GW 68-12	Geophysical methods	H. Lazreg	S	35

*S= Starting, P = Progressing, C = Completed or final stage.

List of Projects

- by Principal Investigator -

Principal Investigator	Short Title	Project
Brown, D. D.	Sea-water intrusion, Shippegan, N. B.	GW 68-10
Carr, P. A.	Sea-water intrusion, P. E. I.	GW 67-8
	Infrared anomalies	GW 68-9
Charron, J. E.	North Nashwaaksis basin	GW 67-17
	Lac du Bonnet	GW 67-18
	Hydrochemistry of Russell County	GW 68-7
Delorme, L. D.	Paleohydrogeology	GW 67-6
Everdingen,R.O. Van	Bedrock aquifers	GW 67-6
Freeze, R. A.	Natural groundwater recharge	GW 67-1[a]
	Hydrologic response model	GW 68-1
Gilliland, J. A.	Groundwater hydrographs	GW 67-13
	Network design	GW 67-14
	GOWN	GW 68-5
	Inventory of Canadian lakes	GW 68-6
Halstead, E. C.	Water balance Mt. Kobau Watershed	GW 67-15
	Nicomekl Serpentine Creek	GW 67-16
Haefeli, Ch.	Groundwater flow into Lake Ontario	GW 68-3
Herr, R. L.	Hydrogeological maps, Lake Ontario	GW 68-4
Holmes, R. M.	Hydroclimatology	GW 67-5
Lawson, D. W.	Groundwater pollution	GW 67-9
Lazreg, H.	Geophysical methods	GW 68-12
Lissey, A.	Hydrogeology Oak River basin	GW 67-2[a]
	Permafrost geohydrology	GW 67-3
Meyboom, P.	Assiniboine basin	GW 67-7
Morton, F.I.	Potential Evaporation	GW 68-8

List of Projects

- by Principal Investigator -

Principal Investigator	Short Title	Project
Parsons, M. L.	Groundwater flow in the clay belt	GW 67-10
	Groundwater flow and subsurface temperature	GW 68-11
Ryckborst, H.	Parametric hydrology, basalt plateau	GW 67-11
	Parametric hydrology, Lake Ontario	GW 68-2
Shiau, S.Y.	Water balance Good Spirit Lake	GW 67-1[b]
	Water balance Oak River basin	GW 67-2[b]
	Water balance Trapping Creek	GW 67-19
Vonhof, A.	Brine ponds near Saskatchewan potash mines	GW 67-12