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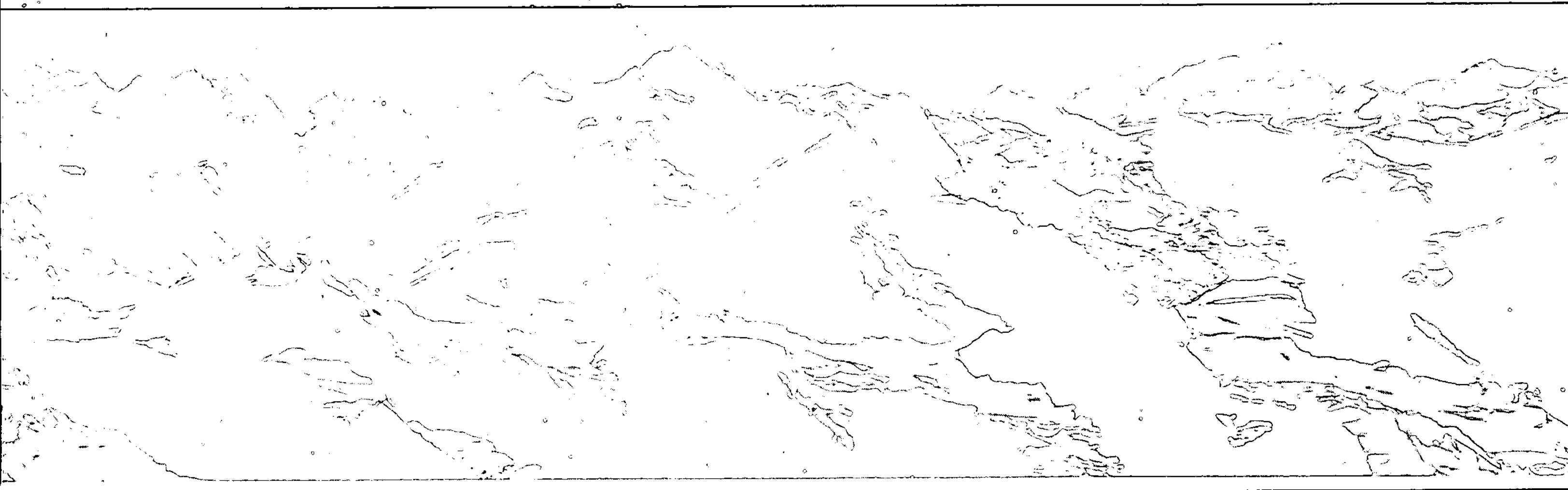
# Hydrology Research Division

## Annual Progress Reports and Short Research Notes 1975-76





**REPORT SERIES NO. 45**

*INLAND WATERS DIRECTORATE,*
*WATER RESOURCES BRANCH,*
*OTTAWA, CANADA, 1976.*

Environment Canada
Environnement Canada

# Hydrology Research Division

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**REPORT SERIES NO. 45**

***INLAND WATERS DIRECTORATE, WATER RESOURCES BRANCH, OTTAWA, CANADA, 1976.***

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# Hydrology Research Division

## Annual Progress Reports and Short Research Notes 1975-76

INTRODUCTION

The Hydrology Research Division is one of two research arms of the Water Resources Branch, Inland Waters Directorate, Environment Canada. Its activities fall into two distinct categories: (1) hydrogeologic research and (2) research into other aspects of the hydrologic cycle in general. In both of these categories, selection of research projects or programs is guided by two broad objectives:

1. To develop hydrologic techniques and methodologies for water resource management.

2. To identify operational areas in the water resource field where there are needs for research and to implement appropriate research projects and programs.

At the present time the Hydrology Research Division has seven main research programs comprising some 34 individual projects. The programs include: (1) the Maritime Research Program to investigate salt water intrusion into coastal aquifers and flow through fractured media; (2) the Subsurface Contamination Research Program to investigate the infiltration of fluid contaminants into the subsurface and their movement through the ground; (3) the Northern Hydrogeology Program to gather information on the ground water-permafrost system of northern Canada and to improve our understanding of its response to environmental disturbances; (4) the GOWN program to develop an operational computerized system for the storage, processing and retrieval of ground water data; (5) the Urban Hydrogeology Program to investigate the interrelationships between hydrogeology and human activities in an urbanizing region; (6) the Hydrogeology of Major Excavations and Impoundments to study the effects on hydrogeologic regimes of such activities as open-pit mining and mine dewatering and (7) the Interface Hydrology Program to develop, investigate and improve hydrologic simulation and forecast models.

This publication contains a series of brief papers and reports on various aspects of these research programs. In some cases, they report generally on progress made during a period of a year to a year and a half terminating in late 1975 or early 1976; in others, detailed results are given for some selected aspect of the study.

This publication is the latest in a series presenting somewhat similar information on research progress. The format for the last two members of the series has been modified somewhat from an earlier tabular type of presentation and is, we hope, more readable and informative.

The preceding publications in the series were as follows:

The Federal Research Program in Hydrogeology.
1967-68, 60 p.

The Federal Groundwater Program.
Annual Project Catalogue 1968-69.
IWB Rept. Series 3, 82p.

* The Federal Groundwater Program.
Annual Project Catalogue 1969-70.
IWB Rept. Series 8, 108p.

* The Federal Groundwater Program.
Annual Project Catalogue 1970-71.
IWB Rept. Series 13, 113p.

Research Program. Hydrology Research Division. Project Catalogue 1971-73.
IWD Rept. Series 31, 145p.

Research Program. Hydrology Research Division. Summaries of Progress and Short Research Reports. IWD Rept. Series 42, 120 p.

Limited numbers of some of these earlier publications are still available.

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* Out of print

# THE EFFECT OF WASTE DISPOSAL BASINS ON THE GROUND WATER REGIME

Project No. GW 67-12

J.A. Vonhof*

*Annual Progress Report*

The bulk of the field activity in this long-term study was terminated at the end of 1975, although monitoring of ground water levels and some sampling of ground waters for chemical properties will be continued through part of 1976. By the end of the calendar year, however, the field installations will either have been closed down or transferred to some other organization interested in continued monitoring.

The field site is on the property of the International Minerals and Chemical Corporation $K_2$ Mine near Esterhazy, Saskatchewan. The original objectives of the study were (1) to evaluate long-term effects of brine storage in surface ponds on the ground water regime, (2) to determine if and when remedial measures must be taken to limit the spread of subsurface pollution, and (3) to recommend possible alternative long-term solutions to waste disposal problems of the potash industry.

The evidence gathered during the study has indicated that there is little or no immediate danger of ground water pollution from the Esterhazy brine ponds. Thus the original objectives are no longer particularly pertinent. The study has instead furnished a wealth of data on local hydrogeological conditions and the responses of a relatively dense network of observation wells to a variety of natural driving forces (barometric pressure changes, earth tides, etc.) and to depletion of the aquifer by pumping. It has also served as a field site for the examination of changes in the chemical properties of ground water samples as a result of removal from their natural environment and handling and storage prior to analysis. The examination of these and other specialized aspects of the study have been assigned to a number of scientists, consultants, etc. with expertise appropriate to the particular problems. The principal investigator will continue with the preparation of a report concentrating on geology, hydrogeology and certain aspects of the hydrogeochemistry.

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* Hydrology Research Division, Calgary

# THE EFFECT OF WASTE DISPOSAL BASINS ON THE GROUND WATER REGIME

Project No. GW 67-12

J.A. Vonhof[1]

## *Electric Analogue Model of a Waste Disposal Lagoon*

by D. Randal Bourne[2]

This study reports the results of an investigation of the potential pollution hazard of the waste disposal lagoon at the International Minerals and Chemical Corp. (Canada) Ltd., $K_2$ potash mine and processing plant nine miles east of Esterhazy, Saskatchewan.

The most important elements in assessing the potential pollution hazard of a waste lagoon are the direction of the brine movement through the geological formations and the travel time for the brine to travel from their source to a potable aquifer or stream. Determination of these elements requires an understanding of the geologic model and the hydrogeologic parameter distributions - hydraulic conductivity (K), compressibility of the aquifer ($\alpha$), and porosity (n).

The geological model has been defined by Vonhof (1971). A major buried valley containing highly permeable fluvial deposits underlies an average of 40 feet of till beneath the waste lagoon. This buried valley extends toward the surface waters of Cutarm Creek, about 7,000 feet away, and acts as a conduit for the brine.

An electric analog model of the hydrogeological environment has been used to analyse the situation. The model has been calibrated against the existing steady state ground water flow system and has been used in a transient mode to assess some proposed remedial measures designed to prevent the brine from migrating as far as Cutarm Creek.

The results of this study will appear as an M.Sc. thesis at the University of British Columbia. The expected completion date of the project is April 1976.

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1 Hydrology Research Division, Calgary
2 Graduate Student, University of British Columbia

REFERENCE

Vonhof, J.A., 1975. Waste disposal problems near potash mines in Saskatchewan. XV Cong. Int. Union Geodesy and Geophysics. Proc. Moscow Symp. Ground Water Pollution. IAHS Publ. No. 103, p. 191-215.

# HYDROGEOLOGICAL MAPS OF THE LAKE ONTARIO BASIN

Project No. GW 68-4

R. L. Herr*

*Annual Progress Report*

The principal objective of this project has been to develop computer methods for the construction of hydrogeological maps. Overburden isopach and bedrock structure contour maps prepared for the following sub basins of the Lake Ontario Basin:

1. Duffin Creek
2. Oakville Creek
3. Wilmot Creek

have been compared with hand-drawn maps prepared by the staff of the Ontario Ministry of the Environment in Toronto. A report on the results of the comparison is being written.

No further work is anticipated at this time, although other automatic contour methods may possibly be evaluated as they are developed.

* Hydrology Research Division, Ottawa

# GOWN - OPERATION AND MAINTENANCE

Project No. GW 68-5

G. Grove*

*Annual Progress Report*

## METRIC CONVERSION - GENERAL

Investigation into the conversion to the metric system of hydrogeologic parameters in general and the GOWN system in particular has revealed some major problems. One of these problems is the lack of a standardized set of units in both Canada and the U.S. for recording hydrogeologic parameters. With the conversion to the metric system the opportunity exists for establishing a standardized set of units for recording these parameters.

Recommendations on the application of the International System of Units (SI - Systême International ) to individual fields of interest have been published by the Canadian Standards Association. In its Metric Practice Guide the Association recommends that all physical quantities be derived from seven arbitrarily defined base units.

In hydrogeology the implementation of the metric system will involve the conversion of several physical quantities particular to this area of hydrology. As well it will also involve consideration of other physical quantities - such as discharge, water level, water temperature and velocity - which are of importance in other fields of hydrology. As some of the other sectors of hydrology are more advanced in conversion to the metric system, the possibility of adopting the units proposed by these other sectors of hydrology should be considered for these common parameters. The standards proposed by the other sectors of hydrology for recording water levels and water temperatures would seem acceptable to hydrogeologists. However, the units of cubic metres per second and metres per second proposed by the other sectors for measuring water discharge and water velocity will pose some problems. Although the recommendations of the Canadian Standards Association have been followed in deriving these units, the magnitude of the numbers which normally result from the use of these units in the field of hydrogeology would be awkward to use. For example, one imperial gallon per minute converts to $75.8 \times 10^{-6}$ $m^3$/sec. The selection of an acceptable set of metric units for expressing ground water parameters is complicated by the conflicting

* Hydrology Research Division, Ottawa

requirements 1) of adhering to the standards for metric practice 2) of maintaining some compatibility of units for the same physical quantities in the various sectors of hydrology and 3) of developing a practical set of field units which can be easily used by the practicing hydrogeologist.

Because of its commitment to complete conversion to the SI system by January 1, 1978, the Hydrology Research Division has been giving consideration to the question of standard units in hydrogeology. We have prepared for our own use a proposed set of standard units which, in our opinion, seems to provide a reasonable compromise among the conflicting requirements listed above. The rationale which has led us to proposing them follows:

## 1. PARAMETERS INVOLVING TIME

It is recommended that seconds be retained as the basic unit for the measurement of time for all hydrogeologic parameters which are a function of time. This suggestion follows the recommended practice for metric units, is compatible with other sectors of hydrology and eliminates the awkward conversion required to change measurements recorded in a mixed system of time units to some common time base.

## 2. MULTIPLES AND SUBMULTIPLES OF BASIC UNITS

Multiples and submultiples (e.g. centimetres) of the basic units may be used for the description of quantities which cannot be conveniently described by using the basic units. If multiples or submultiples are required, the Canadian Standards Association recommends that the prefixes used should represent 10 raised to powers that are multiples of ± 3. Some measurements may require use of the basic unit with prefixes to indicate multiplication or division by powers that are multiples of three. The diameter of a 4-inch well might be conveniently expressed as 100 mm (or .10 m); a natural ground water velocity of 1 foot per day as 3.5 μm/s; and a transmissivity of 1000 imperial gallons per day per foot as 172 $mm^2/s$. The prefixes used in the case of hydraulic conductivity would vary over a wide range of materials and conductivity values: a gravel bed could have a conductivity that is conveniently expressed in millimetres per second; the corresponding units for sands and silts would be micrometres per second (μm/s) and nanometres per second (nm/s).

For the processing of data by computer one basic unit of measurement must be adopted. The choice of basic units which would require the resulting values to be expressed in scientific notation should be avoided if possible. Introduction of the power of 10 can be awkward for storage and handling of data by computer. However, given the limitation that one basic unit must be used the introduction of the power of 10 cannot be avoided for data items which have a wide range of values. Therefore to store transmissivity and hydraulic conductivity the basic units of $m^2/sec$ and m/sec will be used and the appropriate power of 10 which would normally be indicated by a prefix will be stored as well.

## 3. VOLUMETRIC MEASUREMENTS

In the measurement of volumes or volume discharge rates the hydrogeologist is commonly faced with a choice of $m^3$, $dm^3$, $cm^3$ and $mm^3$. Although the other sectors of hydrology have selected the cubic metre as the volumetric measure, we were anxious to have some alternative volume unit that would allow for a more simple expression of the typical numbers resulting in hydrogeology.

The litre is a volumetric measure that is much more suitable for general hydrogeological work than either the $m^3$ or the $mm^3$. Unfortunately the litre was originally defined as the volume of a kilogram of pure water at specified temperature and pressure. Hence, although it is almost the same as a cubic decimetre, there is some slight difference between the two units (until 1964, 1 litre equalled 1.000 028 $dm^3$ by definition). For this reason, the litre is not recommended as a volumetric unit for high precision measurements. Hydrogeologic measurements, however, do not approach this degree of precision and the litre can be retained in hydrogeology as both a standard volumetric unit and as the equivalent of the cubic decimetre.

## SUMMARY

A listing of some of the physical quantities of concern to hydrogeologists is presented in the following table. The dimensional structure of these quantities and the proposed metric units which will be used in the GOWN system where necessary are included in the table.

| | Physical quantity | Dimensional structure | Proposed unit |
|---|---|---|---|
| 1) | ground water level | L | m |
| 2) | lithologic interval/well depth | L | m |
| 3) | casing/bore hole diameter | L | mm |
| 4) | ground water temperature | | °C |
| 5) | pumping rate/artesian flow rate | $L^3/T$ | l/s |
| 6) | transmissivity | $L^2/T$ | $m^2/s$ |
| 7) | hydraulic conductivity | L/T | m/s |
| 8) | specific capacity | $L^2/T$ | $m^2/s$ |
| 9) | ground water velocity | L/T | m/s |
| 10) | leakage coefficient | $^1/T$ | $^1/s$ |

The only departure from the recommended SI practice that is suggested for hydrogeology is the adoption of the litre ($\approx 1\ dm^3$) as the standard volumetric unit. This is convenient for field practice and furthermore avoids awkward numerical expressions. Thus, a pumping rate of 100 imperial gallons per minute, for example, equals 7.6 l/s. The only options in recommended SI practice for this example would be $7.6 \times 10^{-3}\ m^3/s$ or $7.6 \times 10^6\ mm^3/s$.

## GOWN CONVERSION TO METRIC

During the summer of 1975 work continued on the conversion of the GOWN system to metric units. The development and preliminary testing of the programs to convert the appropriate fields from British to metric units on the existing master files was completed. Some changes, such as the revision of the reasonable limits which are used for checking the validity of data, were also made on copies of the programs for the current system. However, before proceeding with production testing and implementation the units to be used for some of the data fields must be agreed upon so that data formats and conversion factors can be finalized in the programs.

One of the other complex aspects of the conversion process will be the transition period required for users to adapt to the new system of units. Initially it was thought that pre-edit programs for the well data and well log files could be designed to scan the data. Based upon probable ranges of data and other edit checks, those data items which are known to be coded in British units could be converted to metric units and those data items which are suspected of being coded in British units would be flagged by a warning message but no conversion would be performed. However, it was found that very few reliable conversions of data could be performed by these pre-edit programs because there is so much overlap of the probable ranges of data values between the two systems of units. It has now been decided to simply set up a flag field on the GOWN cards to designate the system of units being used (M in col. 76 for metric units) and to use the pre-edit programs to convert the data when necessary to one consistent system of units.

# A HYDROCHEMICAL STUDY IN THE INTERSTREAM AREA OF THE OTTAWA AND ST. LAWRENCE RIVERS

Project No. GW 68-7

J.E. Charron*

*Annual Progress Report*

The objective of this project is, through hydrochemistry, to determine the direction of ground water flow in the interstream area between the Ottawa and St. Lawrence Rivers. The study area includes Russell, Prescott, Glengarry and Stormont Counties in Ontario as well as the relatively smaller interstream area located in Quebec. After five field seasons the field work was completed in September of 1973. The field work consisted in gathering data on over 10,000 water wells and sampling 440 of these wells as representative wells. One report on the Russell County, Ontario portion of the study area has now been published.

Since October 1, 1973 the work on this project has consisted in programming and analyzing computerized hydrochemical contour maps and comparing them with the hand-drawn maps of the same area that had been drawn over the past five years. The results are more encouraging than had been initially anticipated. The computerized and hand-drawn contours are compatible in delineating the direction of ground water flow. Besides, from the ground water viewpoint, the computerized contour maps are more accurate and bring out more details locally and regionally than do the hand-drawn maps. Furthermore this work makes possible for the first time a comparison between the chemical and the piezometric head approaches to ground water flow. Again the two methods are compatible. However it would seem that the chemical approach gives much more detail using the same number of control points than does the piezometric approach.

The results from this computer analysis and the general conclusions concerning ground water flow systems in the interstream area are presented in a comprehensive report which has now been approved for publication.

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* Hydrology Research Division, Ottawa

REFERENCE

Charron, J.E., 1974. A study of ground water flow in Russell County, Ontario. IWD Sci. Series 40, 26 pages.

# POTENTIAL EVAPORATION - SIGNIFICANCE AND MEASUREMENT

Project No. GW 68-8

F.I. Morton*

*Annual Progress Report*

The main objective of the project has been the formulation of a model for estimating the areal evaporation, i.e. the evaporation and transpiration from a large area, by its effects on the temperature and humidity of the overpassing air as reflected in the potential evaporation. Details of a model developed during 1973-74 and a test of the results against precipitation less runoff data for 118 river basins in Canada, Ireland and the southern United States have been published (Morton 1975a, 1975b). In 1975 the model was improved by taking into account the effects of changes in surface temperature on long wave radiation and the test was extended to include 2 river basins in the highlands of Kenya (Morton 1976). Other investigations have indicated that further conceptual improvements to the advection energy term may be possible.

Model estimates of areal evaporation have been added to river runoff to evaluate the well known underestimates of precipitation in northern Canada. The study indicates that the deficiencies in the precipitation can be estimated from the ratio of published end-of-month snow depths to published snowfall. The model has also been modified so that it can be used to estimate the evaporation from shallow lakes (Morton 1975c).

A Bowen ratio system for providing field estimates of evapotranspiration was operated at the Mer Bleue experimental site near Ottawa during July and August of 1975. A computer program made it quite easy to process the results. However, two problems in the system decreased the scientific value of the observations. These were interference in the integrating circuits from the Hurst motor and the inadequacy of the wick system to supply sufficient moisture during hot dry afternoons. It is believed that these problems have been solved and that the system will operate satisfactorily during the next field season.

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* Hydrology Research Division, Ottawa

REFERENCES


Morton, F.I., 1975a. Potential evaporation - significance and measurement, in Research Program, Hydrology Research Division, Summaries of Progress and Short Research Reports, IWD Report Series No. 42, p. 9-12.

Morton, F.I., 1975b. Estimating evaporation and transpiration from climatological observations. Journal of Applied Meteorology, Vol. 14, No. 4, 488-497.

Morton, F.I., 1975c. Estimating lake evaporation from climatological observations, in Hydrologic Studies on a Small Basin on the Canadian Shield, Atomic Energy of Canada Limited, p. 459-469.

Morton, F.I., 1976. Climatological estimates of evapotranspiration. Journal of Hydraulic Division, American Society of Civil Engineers, Vol. 102, No. HY3, 275-291.

HYDROGEOLOGY, FRASER VALLEY

Project No. GW 71-1

E.C. Halstead*

*Annual Progress Report*

The objective of this project is to evaluate the source, movement and distribution of ground water in the lower Fraser Valley. Throughout the year considerable attention was given to the collection of records from drilling contractors, visits to well drilling operations and the collection of water samples.

The records of materials penetrated during drilling are correlated to produce fence diagrams showing the geological framework through which the ground water is recharged, transmitted and discharged. Revision and drafting of fence diagrams is being completed to show the hydrology of ten townships in the central part of the Fraser Valley south of Fraser River and bounded by the International Boundary. This area is to include the municipalities of Surrey, Langley and Matsqui.

The possible definition of local, intermediate and regional flow systems is based primarily on the hydrochemistry, total dissolved solids (TDS) and host materials (geology). Preliminary interpretations of over 450 chemical analyses collected in the field area south of Fraser River outline the main chemical composition of the flow systems located in the Pleistocene and Holocene deposits. Two significant generalizations can be made from the interpretation of these data plotted on Piper diagrams.

(1) Ground water flow systems within the complex distribution of surficial deposits can be defined by observing salient changes of the hydrochemistry as the water flows from recharge areas, penetrates into deeper confined aquifers, and then in places becomes integrated into broader regional flow systems. As flow progresses through permeable sands and gravels, the chemistry changes from a low-TDS (50-200 mg/l) calcium-magnesium-bicarbonate water to a high-TDS (700-3000 mg/l) sodium-bicarbonate water. Migration of ground water from recharge areas through marine silty clays takes on a different

* Hydrology Research Division, Vancouver

character. Here the low-TDS calcium-magnesium-bicarbonate water rapidly changes to a high-TDS (1000-1500 mg/l) sodium-chloride or sodium-bicarbonate-chloride water without the transition to a predominantly sodium-bicarbonate water as was previously suspected.

(2) Hydrochemical maps of the lower Fraser Valley have been compiled showing the different water qualities found in the study area. The map commonly shows the localization of high TDS in the lowland areas whereas the upland areas have more palatable water. Maps have also been compiled plotting isovalues for all the constituents and properties analysed.

Areas have been identified where nitrate concentrations are reaching levels at or beyond recommended limits. The areas of significant nitrate accumulations are underlain by sand and gravel up to 100 feet thick at or near the surface and constituting free water table aquifers. A number of stations in these areas are monitored at regular 6-week intervals to assess the rate of change in nitrate concentrations. Fourteen wells, one spring and five creeks are sampled. In the wells seasonal trends are evident with concentrations being greater just prior to annual recharge by winter precipitation. In 24 months one well improved from a concentration of 226 ppm to 34 due to removal of a stockpile of poultry manure. Two wells in areas of concentrated agriculture practices have shown a significant increase in nitrates presumably due to heavy fertilizer applications. All the streams sampled receive ground water discharge. In three the nitrate concentration remains less than 5 ppm whereas in the other two nitrate concentrations have increased to as much as 15 ppm. This is possibly because of contamination from septic systems since the sources of these latter two streams pass through more densely populated urban developments.

Routine sampling of ground water supplies in an area north of the Fraser River in the lower Fraser Valley has isolated a problem of excessive fluorides. Two wells in this area are developing water from fractures within interbedded Eocene sandstones, siltstones, shale and coal. Local outcrops of Eocene basalts and silicic igneous rocks show some hydrologic continuity with the sedimentary rocks. A recent pump test on one of the high fluoride wells tended to confirm this continuity. Preliminary sampling procedures within the general region show the chemistry to be somewhat ideal for high fluorides in that the ground water has a high pH, low total dissolved solids and very low calcium. Investigations are continuing in an attempt to outline the geometric profile of this aquifer, local ground water flow patterns, and the extent of fluorosis (bone disease) and mottling of teeth experienced by users of this water.

It is also of interest to note that the ground water chemistry changes very little at a specific point in the flow system of a confined aquifer. Five samples were collected in 1956 and forwarded to the Industrial Waters Section, Dept. of Mines and Technical Surveys, Ottawa. The same 5 wells were sampled recently and the analyses were carried out by the Water Quality Branch, IWD, Pacific & Yukon Region. The 1956 samples had a total transit plus shelf time that was at most 21 days. The 1975 samples were fully tested within 24 hours. The constituents and properties analysed in 1975 are practically identical to those reported in 1956.

# WATER BALANCE, IHD REPRESENTATIVE BASINS

Project No. GW 71-4

S.Y. Shiau*

*Annual Progress Report*

Three basins (Trapping Creek, Good Spirit Lake, Oak River) are included in this project. The data collection and field measurements programs for these three basins were all completed on or before the end of August 1975. This project will be concluded by the submission of the final summary reports for each of the three basins.

The principal objective of this project is to test and utilize a generalized hydrologic model for the evaluation of basin hydrologic response, the simulation of streamflow, and the assessment of annual and monthly water balance. For the Trapping Creek basin where the frozen soil conditions are absent or negligible because of the deep mountain snowpack, the objective has been achieved and the results summarized (Shiau, 1975).

For the two Prairie basins (Good Spirit Lake in east-central Saskatchewan and Oak River basin in west-central Manitoba), the frozen and/or partially frozen soil conditions due to the generally shallow snow cover make quantitative evaluation most difficult during the spring melt periods. Preliminary results show that for some years the simulated and observed hydrographs compared reasonably well while for other years the observed peaks are much higher than the simulated ones. Initial assessment gives the following explanations of these year to year variations.

(1) If soil is frozen at a low moisture content (following a hot summer and a dry autumn) and the soil temperature at time of major melt is near or above freezing, simulation will generally be successful because, in this case, only a small fraction of the pores are filled with ice, and these are thawed rapidly with the downward movement of melt water. The soil mantle then acts in a normal unfrozen condition.

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* Hydrology Research Division, Ottawa

(2) If soil is frozen at a low moisture content, but the soil temperature at time of major melt is well below freezing, simulation fails because water entering the soil is frozen in the pores and movement is inhibited.

(3) If soil is frozen at a high moisture content, and the soil temperature at time of major melt is near or above freezing, some of the melt water is able to penetrate the soil and thus transfer heat to melt the ice-filled pores. Progressively, as the soil warms and the pores melt, the soil mantle will return to the unfrozen condition. The simulated hydrograph exhibits a time lag with the peak(s) more or less flattened in comparison to the observed hydrograph.

(4) If soil is frozen when saturated, or if an impervious ice layer develops on the surface during the melting period, the major fraction of the basin will act as an impervious area for variable lengths of time. Without proper accounting for this additional impervious area due to the frozen soil and/or ice layer, the simulation completely fails to generate the peak(s) flow and instead generates too much baseflow at later stages.

Checking with the available soil moisture and soil temperature data indicates that the above assessments can be used as an aid to predict the type of flow regime to be expected during the major melt periods. However, this prediction would only be qualitative in nature. The problem is further complicated by the freeze and thaw cycles experienced in the Prairie region.

Additional information such as soil temperature, and infiltration rates for frozen and partially frozen soils is required in order that flows generated under frozen soil conditions can be simulated with reasonable confidence.

REFERENCE

Shiau, S.Y., 1975. Evaluation of watershed hydrological response by application of a generalized hydrologic model. Proc. Tokyo Symp., Int. Assn. Hydrol. Sci.,Publ. No. 117, p. 87-98.

# WELL FIELD DESIGN IN A COASTAL ENVIRONMENT

Project No. GW 71-5

A. Vandenberg*

*Annual Progress Report*

This project has been completed with the preparation of a mathematical model and computer program to simulate the movement of a salt water intrusion front during pumping from a well field in a coastal aquifer. The model uses a standard finite-difference technique for the calculation of the time-dependent piezometric surface; from the piezometric surface, the gradients and velocities of a set of moving particles located on the fresh water - salt water boundary are determined. These gradient and velocity values are then used to establish the new positions of the moving particles after the passage of a selected finite time element. The model is limited at present to horizontal and isotropic aquifers; these however may be inhomogeneous. It is furthermore based on the assumption that no vertical stratification of salt and fresh water occurs or, in other words, that the density contrast can be neglected. The model has been shown to perform well by comparison with analytical solutions for the case where a single pumping well is located near an infinite linear recharge boundary.

The basic mathematical model and computer program have been extended to include the simulation of leaky aquifers and to provide the option to use variable dimensions of the elementary rectangles of the finite-difference grid.

Furthermore, a set of basic criteria for the position and pumping rate of a single well in a coastal aquifer have been developed. These relate the extent of the intrusion, and the time taken for the intrusion to advance to the well, to the magnitude of the piezometric gradient in the aquifer under nonpumping conditions.

The results of the project have been documented in the following publications:

Vandenberg, A., 1971. Movement of salt water intrusion front induced by pumping. Unpublished progress report, 11 pages.

Vandenberg, A., 1972. Nomogram for the construction of flow nets near singular boundary points. Jour. Hydrology, Vol. 16, No. 4, 301-306.

Vandenberg, A., 1974. A digital simulation of horizontal salt water encroachment induced by fresh water pumping. IWD Sci. Series 41, 27 pages.

* Hydrology Research Division, Ottawa

Vandenberg, A., 1974. Program SOPH - simulation of time-variant piezometric surface in a confined aquifer subjected to pumping. IWD Misc. Series, 56 pages.

Vandenberg, A., 1974. Program FLONET, flownet contouring for well fields near a recharge boundary. IWD Misc. Series, 21 pages.

Vandenberg, A., 1975. Simultaneous pumping of fresh and salt water from a coastal aquifer. Jour. Hydrology, Vol. 24, No. 1/2, 37-43.

Vandenberg, A., 1975. Program FRONT, a two-dimensional simulation of a moving intrusion front in a thin, horizontal, confined aquifer. IWD Misc. Series (in press).

Vandenberg, A., 1975. Program TEBES - transmissivity, leakage factor and storativity from a least squares fit of residual drawdown. IWD Misc. Series (in press).

Vandenberg, A., 1975. Determining aquifer coefficients from residual drawdown data. Water Resources Research (in press).

Vandenberg, A., 1976. Program ESOPH - an extended version of Program SOPH. IWD, Water Resources Branch, Ottawa, (in press).

# DEEP-WELL DISPOSAL, SOUTHWESTERN ONTARIO

Project No. HR 72-1

A. Vandenberg*

*Annual Progress Report*

In view of the potential hazards of waste disposal in the relatively shallow Dundee Formation and Detroit River Group of southwestern Ontario a joint federal-provincial study of the disposal operations in Lambton County, Ontario, was undertaken to (1) develop techniques for studying and monitoring the movement of wastes underground and, (2) to document a Canadian case history of the deep-well disposal practice.

This study consisted of three parts:

(1) The construction of a finite element model of liquid waste movement in a nonhomogeneous ground water system, and its application to some hydrogeologic situations in the disposal zone in Lambton County. The construction of the model was successfully completed as an M.Sc. thesis (Smith, 1973), but its application was hampered by the lack of adequate data on the hydrogeological characteristics of the disposal zone.

(2) A critical analysis of records of oil and gas wells on file at the Ontario Ministry of Natural Resources, and of water-well records on file at the Ontario Ministry of the Environment. As a result a number of piezometric maps of the disposal zone were prepared. These piezometric maps, however, which all purported to represent the same piezometric surface, were very inconsistent, except for some broad regional features which persisted on all maps. Thus, the conclusion was reached that the piezometric data was not of such quality that a detailed description of the movement and spread of the waste could be made. Some of the reasons for errors in the piezometric data are: (1) incomplete recovery of the piezometric head at the time the measurement was taken, (2) the effect of open-hole measurement, and (3) the effect of well-field development in progress. This aspect of the study is reported on by Vandenberg et al. (in press).

(3) A study of the motion and chemistry (quality) of ground water in the overburden and the upper part of the bedrock; these zones are the source of potable water for domestic and farm use in Lambton County, and as such accidental breakthroughs from the disposal formations is one of the prime public concerns. This aspect of the study is also reported in Vandenberg et al. (in press).

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During the 1972 field season 102 water samples were collected from water wells and springs, analysed for the major ions, divided in types based on Schoeller's work, and mapped. This geochemical map shows a distinct zonation which fits the pattern of ground water motion as established from the water level data for this shallow aquifer. Nevertheless, there are a number of exceptional samples which have a relative high chloride or high sulphate content (or both) in comparison with the samples which are normal for the area. Some of the anomalies could be simply the result of a different type of bedrock formation at shallow depth and not shown on the most recent geological map. However, they might conceivably be indications of formation water from the disposal zone being pushed up through abandoned oil wells or along surfaces of higher permeability associated with geological structures. Thus, although the presence in the shallow aquifer of the waste itself has not been demonstrated, waste disposal operations may yet be responsible for a deterioration in the quality of the water in this aquifer.

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# EFFECTS OF MODEL HETEROGENEITY ON THE MODELLING PROCESS

Project No. HR 73-1

V. Klemes*

*Annual Progress Report*

The project has been concerned with the effects of heterogeneity of models used for the representation of hydrologic time series. The past work included an analysis of the effects of nonlinearity (Klemes, 1973a) and nonstationarity (Klemes, 1974). The general conclusion has been that an analysis of a historical series itself, even if the series is a relatively long one, cannot reveal with certainty whether the series is a realization of a nonstationary or nonlinear process since usually a stationary and linear model can be devised that can generate sample series similar to the observed historical record. However, the distributions of parameters of such a linear model can significantly differ from those derived from the "correct" (nonlinear, nonstationary) model. Hence the confidence limits derived from a distribution pertaining to a model fitted to a historical series with the desire to formally preserve some of its characteristics may not adequately characterize the variability of the studied process. This leads to a postulate that the type of the model be chosen on the basis of the type of the physical mechanism underlying the analyzed time series. It has been shown that one of the plausible physical mechanisms underlying most hydrological processes is the routing process through a cascade of semi-infinite nonlinear reservoirs. A special case of the latter is a cascade of discrete linear reservoirs. The output from such a cascade can be described as an autoregressive, a moving average, or an autoregressive-moving average process. The output properties for this linear cascade have been derived in a paper by Klemes and Boruvka (1975). An analytical description of the output from a cascade of nonlinear reservoirs has been found mathematically very complicated and is not being pursued for the time being (the results for one nonlinear reservoir are given in Klemes, 1973a, and some results for 2 nonlinear reservoirs in Klemes, 1973b).

The problem of model heterogeneity is now seen in a rather different perspective than it was when the project started, especially as it relates to stochastic models of hydrological time series. The real issue seems to be the identification of the range of heterogeneous models of a given broad category as well as the range of their parameters compatible within chosen confidence limits with a given historical series. One of such model categories is, for instance, the group of the above mentioned models reduceable to a cascade of linear reservoirs.

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The final stage of the present project will address this problem. The specific objective will be to delineate, for a number of confidence limits, the range of linear models compatible with historical series of annual runoff.

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# APPLICATION OF RUNOFF FORECASTING TO STORAGE RESERVOIR OPERATION

Project No. HR 73-2

V. Klemes*

*Annual Progress Report*

The scope of this project has been broadened to include, besides the effect of forecasting, also the effect of utilizing a given amount of information for the development of an optimum operation policy of a reservoir. A study investigating the interrelationship between a given amount of hydrologic information (e.g. an estimate of the mean flow based on a historic record of varying length), the size of the reservoir, and the present worth of benefits resulting from reservoir operation was carried out and the results presented at the XVIth Congress of the International Association of Hydraulic Research (Klemes 1975).

The study is now being expanded with the aim of finding quantitative measures for the amount of information (or of the lack of it, i.e. of the uncertainty), both hydrological and economical, utilized in the development of the optimum operation policy.

A "byproduct" of the study has been a finding (supported by a mathematical proof) that the optimum policy for a multipurpose reservoir with a convex objective function is to maintain such rates of outflow that will best average out the fluctuations of reservoir inflow within the constraints of the given reservoir storage capacity. This finding adds weight to the real-time inflow forecasting as a tool for reservoir optimization. The results on this problem are being summarized in a separate paper.

The final aim of the project is to evaluate the effect of heterogeneity of inflow models by comparing the benefits from reservoir operation under the optimal policies compatible with the various models. Such an evaluation may serve as a guide for judging the practical importance of incremental information, that is the desirability of expanding the flow forecasting efforts both in terms of developing more sophisticated models and expanding the observation networks.

REFERENCE

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GROUND WATER CHEMISTRY - FLUCTUATIONS AND ANALYTICAL PROBLEMS

Project No. HR 73-5

J.A. Vonhof[1] and C.C. Davison[2]

*Annual Progress Report*

This study investigated the hydrogeochemistry of an aquifer system located underlying and in the vicinity of a brine disposal lagoon approximately 14 km east of Esterhazy, Saskatchewan. The disposal lagoon overlies an extensive buried valley aquifer. Approximately 30 m of glacial till separate the disposal lagoon from the aquifer unit. Geophysical and hydrogeological evidence suggest that the glacial till is extensively fractured in the study area.

During this investigation, the background hydrogeochemistry of the aquifer unit exhibited significant spatial variation. Dilute Ca - $HCO_3$ type water characterized the shallow portion of the aquifer. There was a trend toward more concentrated Na - $SO_4$ type water with depth in the aquifer and with increasing distance along the ground water flow path. This spatial chemical trend can be explained equally well by two different hypotheses:
1) the continuous chemical evolution of the ground water in transit along the flow path by various aqueous solution - aquifer matrix chemical reactions;
2) the mixing of chemically distinct ground waters within the aquifer unit.

Ground water samples were collected daily throughout the summer of 1973 from two flowing wells in the aquifer. Triplicate chemical analyses of these samples revealed significant temporal chemical variations. The ground water in the shallow portion of the aquifer responded chemically to a major spring storm recharge event whereas the ground water in the deep portion of the aquifer had no detectable chemical response to this spring recharge event. The ground water in the deep portion of the aquifer indicated a chemical response to a midsummer hydrostatic event (unrelated to precipitation or barometric variations), whereas no similar chemical response was detected in the shallow ground water of the aquifer.

Unpreserved ground water samples can exhibit chemical alteration during storage prior to chemical analysis. The pH of $CO_2$ - enriched ground water samples can increase (up to 1.0 pH unit) during storage as a result of $CO_2$ losses to the atmosphere. This can result in extreme supersaturation of the water samples with respect to carbonate mineral phases and precipitation losses of these minerals would be expected in unpreserved samples. Significant amounts of Ca (up to 50 per cent of the total Ca) were observed to precipitate

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from such samples stored for a period of 3 months at ambient temperatures. Mg precipitation losses were insignificant in these samples.

Significant random analytical uncertainties can occur in the chemical analyses of ground water samples (due to analytical technique and/or operator-related variations). These uncertainties should be assessed in all hydrogeochemical investigations to avoid the risk of data misinterpretation. Analytical uncertainties can obliterate temporal chemical variations in periodically collected ground water samples. Analytical uncertainties can also result in significant uncertainties in subsequent mineral equilibria calculations for ground water samples.

Details of this hydrogeochemical study are included in the M.Sc. thesis of C.C. Davison.

NORTHERN GROUND WATER AND ENGINEERING PROBLEMS RELATED TO GROUND WATER FLOW

Project No. HR 74-2

R. O. van Everdingen*

*Ground Water Level and Ground-Temperature Observations, Norman Wells, N.W.T.*

by R.O. van Everdingen and J.A. Banner*

Early in 1973 an instrumented section was established near Norman Wells, N.W.T., by Ottawa staff of the Hydrology Research Division, as part of Project No. GW 71-3 - Hydrogeology, Mackenzie Valley. The purpose was to determine hydrodynamic gradients and seasonal fluctuations in head in the ground water flow system presumably existing below the permafrost, and to gather data on the effects of surface disturbance on the permafrost and the thermal regime (Harlan, 1975). Some additional instrumentation was installed during June of 1974 (van Everdingen and Banner, 1975). Temperature measurements and recording of pressures were discontinued and the instrumentation was removed on September 16, 1975.

A report on the results of this project is being prepared for the Environmental - Social Program, Northern Pipelines, under which this project was initially funded.

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# NORTHERN GROUND WATER AND ENGINEERING PROBLEMS RELATED TO GROUND WATER FLOW

Project No. HR 74-2

R.O. van Everdingen*

## *Field Observations of Ground Water Recharge and Discharge, District of Mackenzie, N. W. T.*

Fieldwork for this project during 1975 was concentrated in the area between Willowlake River (NTS 95J) and Hanna River (NTS 96E). Ground water discharge phenomena investigated included springs, features resembling open-system pingos, and an icing area. Ground water recharge was observed in a number of sinkhole areas.

Warm saline springs at Roche-qui-trempe-à-l'eau (950) and hot springs on the Redstone River in the Backbone Ranges (95N) were sampled in detail. Detailed testing and sampling in the mixed-source spring area near the mouth of Willowlake River (95J) revealed the presence of an additional, considerably more saline source of spring water. Investigation of the Old Fort Island spring area (95J) led to the discovery of a number of spring outlets below the low-water level of the Mackenzie River in September. A spring source for the significant icing area at mile 407 on the Mackenzie Highway Training Section was located and sampled.

A group of sulfurous springs located a short distance south of Hanna River and west of the Norman Range (96E), which was first tested and sampled during 1973, was revisited twice during 1975 for detailed testing and sampling. Local alteration of limestone into gypsum was observed near some of the main spring outlets. The alteration presumably results from high $H_2S$ concentrations in the spring water. Samples were collected for further study.

A number of features resembling open-system pingos were discovered at a spring site on the east side of Bear Rock, NW of Fort Norman (96C). Level and transit surveys of the pingo-like features were made on July 2 and on September 11, 1975. Springs in the main spring area and on the south and west side of Bear Rock were tested and sampled for chemical analysis. Pingo-like features were also observed at a spring site northeast of Turton Lake (96E).

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Field measurements at the various spring sites included water temperature, electrical conductivity, pH and redox potential, as well as contents of dissolved oxygen and $H_2S$. Discharge rates were determined in a few cases. Water samples were collected for conventional inorganic chemical analysis, and also for study of $^{18}O$, D, T, $^{14}C$ and $^{34}S$ isotopes. Samples of spring water precipitates and evaporates were collected for both mineral and isotope analysis. Formation rock samples were collected for isotope analysis for correlation purposes.

Ground water recharge was observed in a number of small and large sinkholes in the Norman Wells (96E) and Mahony Lake (96F) map areas. Recharge water was sampled at a small sinkhole on Mount Richard, and in two major sinkhole areas 25 and 40 km north of Mahony Lake.

The study of $^{18}O$, D, T and $^{14}C$ isotope concentrations in the samples collected during 1975 is carried out by F.A. Michel at the University of Waterloo as part of his work towards a Master's Degree. The work on sulfur isotopes is a joint undertaking with Dr. H.R. Krouse of the Physics Department, University of Calgary.

Detailed reporting on the results of the various studies depends on completion of laboratory analyses and on the possible need for further investigation in the field.

# NORTHERN GROUND WATER AND ENGINEERING PROBLEMS RELATED TO GROUND WATER FLOW

Project No. HR 74-2

R.O. van Everdingen*

## *Frost Detectors and Freezing Detectors*

by R.O. van Everdingen and J.A. Banner*

A simple and accurate method for determining the rate and depth of penetration of freezing and thawing in soils is desirable for both observational and research purposes in areas of seasonal and perennial frost.

Frost tubes for visual determination of the depth of the 0°C isotherm in freezing and thawing soils were described by Rickard and Brown (1972) and by Mackay (1973). A disadvantage of these devices is that automated or remote readings are impossible. A second, and perhaps more important, disadvantage is the fact that freezing of the soil around the frost tube may be considerably delayed (compared to freezing of the liquid in the tube) by depression of the initial freezing point of the soil/water system. A similar error occurs when thermocouples or thermistors are used in the study of soil freezing; a temperature below 0°C does not necessarily mean that the ground is frozen (i.e., containing at least some ice).

The abrupt increase in electrical resistance of a soil/water system upon freezing and the corresponding abrupt decrease upon thawing provides a better indirect method for detection of actual freezing (ice formation) than either temperature measurements or visual frost tube observations (Sartz, 1967).

Experiments with and testing of various types of frost and freezing detectors were initiated in Calgary in the fall of 1972. At that time a probe (Type I) using stainless steel plate electrodes spaced at 6 cm intervals along an acrylic bar, which also contained a number of thermistors for temperature measurement, was installed in the experimental site near the I.S.P.G. (Institute of Sedimentary and Petroleum Geology) building. A special AC Wheatstone bridge with phase-sensitive detector and automatic gain control was developed to enable resistance measurements between electrodes without interference from power lines or polarization.

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A second type of freezing detector (Type II), using 1/2-inch (nominal) galvanized pipe couplings as electrodes, and plastic nipples of various lengths as insulators was constructed in 1973. One of these was installed in a test site on 16th Avenue N., just west of Blackfoot Trail on November 2, 1973, together with a Type I detector. Both were removed on May 16, 1974. The Type I detector was installed near Norman Wells, N.W.T. on June 29, 1974, and retrieved on September 16, 1975. Three other freezing detectors of Type II were installed at the Frost Effects Test Facility of Canadian Arctic Gas in Calgary on February 26, 1974. They are expected to be maintained as long as the test facility stays in operation.

In order to enable detection of frost (temperature below 0°C) with electrical probes, a closed-system type frost detector (III) was constructed from 1/2-inch (nominal) PVC pipe, using pieces of 1/8-inch stainless steel tubing placed radially through the plastic pipe as electrodes. The probe was sealed and insulated externally by wraps of self-vulcanizing rubber tape. Internal filling consisted of small styrofoam balls and tap water with one gram per litre of table salt added.

Type IV combines the frost detection capability of Type III with freezing detection through the use of stainless steel hose clamps, fastened around the outside of a Type III probe, as electrodes. Probes of Type III and IV were installed in the experimental site on September 18, 1974; Type III was installed in a 1-1/2-inch (nominal) ABS access tube from which it can be removed; Type IV was installed directly in the ground.

During the summer of 1975 it became apparent that the internal portions of the Type III and IV probes were not performing properly. Consequently their styrofoam and salt solution filling was replaced by tap water on October 2, 1975.

In addition to the electrical resistance type detectors, two frost detectors of the visual type were installed in the experimental site on September 19, 1974. Both contained fluorescein solution, mixed with glass beads in one, and mixed with small styrofoam balls in the other. Problems were encountered in both cases with detection of the color change from green to pale yellow which occurs when the solution freezes. Consequently both of the visual frost detectors were modified and reinstalled on October 15, 1975. One now contains a 0.1% fluorescein solution and white sand in a 3/8-inch ID (1/2-inch OD) nylon tube; the other contains a 0.01% solution of bromthymol blue indicator with 1 g/l sodium bicarbonate and styrofoam balls in a clear acrylic tube of the same size. Both are installed in the ground in 1/2-inch (nominal) PVC pipe access tubes.

Measurements of electrical resistance of the electrical detectors and readings of frost depth by the visual detectors are taken weekly throughout the year. A more detailed report on construction, operation and measurement results for the various types will be prepared after the 1976 spring thaw.

To enable automatic recording of the electrical frost and freezing detectors, a digital data recording system is presently being developed. It will include four main functions: a scanner to individually select up to 1000 electrodes; a signal conditioner to measure and digitize the inter-electrode resistances; a paper tape punch to record the measurements; and a control circuit to automatically start, cycle and stop the recording system at selected intervals. By the selection of suitable signal conditioners, it will also be capable of digitally recording other measurements which can be made electrically.

## REFERENCES


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# GOWN - DOCUMENTATION

Project No. HR 74-3

G. Grove*

*Annual Progress Report*

Draft copies of the program documentation for the following programs have been completed:

(1) well log card-to-tape

(2) well log edit

(3) well log update

(4) well data card-to-tape

(5) well data edit

These manuals are being edited and prepared for publication. It is planned to publish the manuals in a loose-leaf form. Selected pages can then be updated periodically as required.

Future effort will be concentrated on the documentation for the well data update program, the development of operation manuals for the data storage system and the revision of the user's manual.

Specific improvements effected in the system include:

1. WELL-DATA CARD-TO-TAPE Program

   - Creates a reject-type record if master record is erroneous i.e. invalid field or year missing.

   - If day is missing, middle of the month (day 15) is used to compute minutes.

   - If month and day is missing, zero minutes are used.

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## 2. WELL-DATA EDIT Program

- Variable definitions were reorganized according to type and listed alphabetically.
- Message variables were reorganized and expanded.
- 'TYPE-2' comments were deleted while '**FATAL**' was added.
- Accepts reject records (erroneous master records).
- Checks to see if fields in reject-type records are within their proper limits.
- Checks to see if location is present on reject-type records.
- Checking of ERROR-CODE '01' or '02' was moved to eliminate unnecessary testing.
- Testing of record-type paragraph was streamlined.
- Check to see if location is within a proper range was added (and easily changeable).
- Checks on certain fields to see if a value was present and numeric were improved. First leading spaces were replaced by zeros, then checked to see if numeric and lastly tested for zero. This was done to improve logic efficiency.
- Tests were incorporated that would ensure no overlapping of depth fields.
- A general clean-up of programming style was done.

GOWN - RETRIEVAL

Project No. HR 74-4

L. Crichton*

*Annual Progress Report*

Because the person responsible for this project resigned early in 1975 and the Division was not able to restaff the position for a considerable period of time, no progress can be reported for this project.

Work is now under way again on the development of the detailed specifications for the programs in the redesigned system. It will continue during the next fiscal year with possible complete implementation by September of 1977.

* Hydrology Research Division, Ottawa

# GENERALIZED HYDROLOGIC MODEL FOR STREAMFLOW SIMULATION

Project No. HR 74-5

S.Y. Shiau*

*Annual Progress Report*

Testing of the model (Shiau, 1975a, 1975b) in the Prairie region indicates that the noncontributing area concept has to be incorporated into the model for the effective simulation of flow. The noncontributing area is defined here as that portion of the basin area from which the surface runoff and interflow do not contribute to the flow at the downstream gauging site. It has been recognized that the noncontributing area of a particular basin is dynamic in nature, varying primarily with soil moisture conditions. To this effect, the parameter PBNC is introduced into the model. PBNC is continuously monitored in the program by the equation:

PBNC = PBNCMN + (1.0-PBNCMN) (1.0-TWIDX)

where

PBNCMN = the minimum noncontributing area expressed as a decimal fraction of the total basin area. PBNCMN is generally discernible from the topographic map.

TWIDX = Tension water index
= Square root of the ratio of tension water content to tension water capacity
= SQRT [(UZTWC + LZTWC)/(UZTWM + LZTWM)]

Surface runoff and interflow generated from the noncontributing area are recycled as moisture input to the system in the subsequent computation step. For mountainous basins such as Trapping Creek where the noncontributing area stays relatively constant or is insignificant, the dynamic nature of PBNC is inactivated by setting TWIDX = 1.0 and initiating PBNCMN = C (i.e. = constant). In the Prairie region, the effective drainage area varies significantly with time. In other words, the noncontributing area increases as the season progresses and the soil mantle becomes drier, as is manifested by the disappearance of flowing water in intermittent streams. Inclusion of the parameter PBNC gives

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an effective representation of the noncontributing area concept which plays an important role in runoff generation.

For basins with shallow snow cover, such as those in the Prairie region, flow simulation is further complicated by the frozen soil conditions which prevail during the winter and spring melt periods. The infiltration capacity of the frozen soil is one of the main factors affecting the flow regime. The year to year variations in infiltration capacity for the same type of soil make the simulation of flow much more difficult. These variations are due mainly to the soil being frozen at different moisture contents and to the varying degrees of soil temperature at times of moisture input from snow melt and/or rain.

The current version of the model, which does not take into account the frozen soil conditions, may be applied for qualitative assessment of the flow regime during the spring melt periods as described under Project No. GW 71-4. Such assessments, although qualitative do give some insight into the year to year variations of the basin response and can be used as an aid to predict the type of flow regime to be expected if the soil moisture and soil temperature data are available.

The effect of frozen soil on runoff generation is a very complex problem. Further research and experiment are required to determine the infiltration capacity of various types of soils frozen at different moisture contents with varying degrees of soil temperature at time of moisture input. The results obtained from such research and experiment can then be utilized for the modification of the model so that flows generated under frozen soil conditions can be simulated with reasonable confidence.

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# HYDROGEOLOGY OF THE NATIONAL CAPITAL REGION

Project No. HR 74-6

R.L. Herr*

*Annual Progress Report*

A ground water well inventory was undertaken during the months of July and August in the area west and north of the Gatineau Park. This survey covered NTS map areas 31F9 E&W, 31F8 E&W north of the Ottawa River, and parts of 31G12 W west of the Gatineau River. These map areas represent approximately one-third of the National Capital Region in the province of Quebec.

The survey involved visiting rural property owners and cottagers to obtain information regarding their water wells, and their water usage. The survey also involved visits to the Agriculture representatives in Shawville and Buckingham, P.Q. From the regional office of the Department of Agriculture in Buckingham we were able to photocopy the well logs of water wells drilled by the department for individual farmers. These records contained good geology and yield information but were lacking in adequate location information. It was therefore necessary to invest some time in matching our inventory sheet with well records.

The field data are now being compiled in the office and the well locations digitized.

* Hydrology Research Division, Ottawa

# HYDROGEOLOGICAL APPLICATIONS OF ERTS IMAGERY IN THE PRECAMBRIAN SHIELD

Project No. HR 74-7

J.E. Charron*

*Annual Progress Report*

The principal investigator has already conducted studies on correlation of ERTS imagery with the hydrogeology of two other areas in Canada - the Winnipeg area of Manitoba and the interstream area of Ottawa and St. Lawrence Rivers, between Ottawa and Montreal. He has had extensive field experience in these two areas.

Two ERTS images, E-1044-15170 and E-1440-15154, in false colour composites of spectral bands 4, 5, 6 and 5, 6, 7 respectively, illustrate a host of lineaments in the Precambrian bedrock. These ERTS lineament features are the object of this study. Initially, the main lineaments were mapped for orientation, density, distribution and pattern. It then became apparent that some could also be seen on the topographic maps. Therefore a second map was made making use of both imagery and maps. The topographic sheets at 1:125,000 showing the relief in three dimensions were found to be the most useful. It was believed that some of these linear features could have hydrogeological significance and might be useful in locating ground water bearing zones in the Canadian Shield. Thus, in the summer of 1975, field studies were begun in a Precambrian area northeast of Ottawa. The area was chosen for its accessibility and numerous lineament features. It extends in the south from Masson to St. André-Est along the Ottawa River and in the north from Mont-Laurier to the Parc Provincial du Mont Tremblant. For the first summer the field work was limited to an area approximately 25 miles in radius from Lac des Plages.

As usual aerial photographs and the available geological maps were used. A well inventory of the 600 square mile area was also carried out. At the same time, as many lineament features as were visible on the ground and on the aerial photographs were checked out and mapped. The most useful tool was the mapping of joints and fractures in the bedrock. Where possible, the strike and dip of the main joint systems and fractures as seen on the bedrock outcrops were recorded. Finally, the specific conductance of a large number

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of streams, lakes, springs and wells was recorded throughout the summer. These latter data have not yet been analyzed.

A few things stand out in connection with this field work. The pattern of one set of lineaments (north-south) is parallel to the foliation of the bedrock; while the (east-west) direction of a second set of major lineaments was attributed to geological structures such as faults or major joint systems. The north-south foliation lineaments appear as a long string of lakes on the ERTS imagery while the east-west structural lineaments appear as long wide valleys on the ground. It became apparent later on in the summer that the lineaments represented regional foliation or structure. Furthermore, the regional strike of these lineaments was compatible with the local strike of foliation or structure as observed on the local bedrock outcrops. On the ground lineaments were revealed in a variety of physiographic features, including series of long narrow lakes, rivers, bedrock contacts, joint systems or just plain faults.

If the geological part of the work concerning lineaments was very interesting, the hydrogeology of the area was a disappointment. The well inventory shows that most wells are dug wells. Very few drilled wells were encountered. The dug wells are dug in the overburden in the valleys. One of the biggest surprises was to discover that the overburden in the valleys consists mostly of sand and gravel or gravelly till. Consequently, many springs exist because each local valley has steep lateral walls producing a relatively steep local hydraulic gradient.

Thus far it has not been possible to relate the lineaments to ground water. This, however, does not mean that the relationship does not exist.

# GEOPHYSICAL SURVEY
# STRAIT OF CANSO AREA, N.S.

Project No. HR 74-8

H.M. Elliott*

*Annual Progress Report*

In the fall of 1974 a short program of shallow geoelectrical soundings of Schlumberger and Wenner types was performed on or close to sites where the Nova Scotia Department of the Environment had drill hole control of the geology. The results of this survey were sufficiently interesting that a longer program of nineteen deeper soundings, exclusively of the Schlumberger type and including time-domain induced polarization readings, was undertaken in July and August of 1975. With hopes of improving the geological control in the study area, four deep holes that the provincial department had kept open were logged by the Hydrology Research Division's geophysical bore hole logger. As a favour to the provincial department three wells on Cape Breton Island itself were also bore hole logged.

The 1975 soundings have been interpreted and computer verified. An interesting side light is the reduction in the average number of computer runs per sounding necessary to obtain an acceptable, theoretically feasible model. This is taken as an indication of growing competence in the interpretation of geoelectrical soundings.

Many of the induced polarization readings, while taken in the same manner as in previous years, show an excessive degree of scatter expressed in the calculated L/M ratio. This has limited their overall usability, especially for AB/2 electrode spacings larger than about 50 metres. It is supposed that these faulty readings are the result of some form of inductive and/or capacitive coupling between the cable reels or lines laid out on the ground. Steps will be taken in any new surveys to define clearly the source of erroneous signals and to minimize their effects.

A number of geoelectric sections have been constructed using the interpreted soundings, including geology logs from test wells wherever possible.

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*Hydrology Research Division, Ottawa

While the analysis is not yet far enough advanced to draw general conclusions, in one case there is an interesting observation to be derived from comparing two soundings (N.S. 75-10 and N.S. 75-16). N.S. 75-10 was performed on the road allowance of Nova Scotia Highway 105 while N.S. 75-16 was performed in a field about 700 metres northeast of N.S. 75-10. The curve shapes are very similar except for one obvious disparity; initial resistivities for 75-16 are very high leading to an interpreted first-layer resistivity of 2610 ohm-metres and a second-layer resistivity of 65 ohm-metres whereas initial resistivities for 75-10 are very low giving an interpreted first-layer resistivity of 32 ohm-metres and a second-layer resistivity of 80 ohm-metres. Thereafter the curve shapes are nearly superimposable. The difference between 65 ohm-metres and 80 ohm-metres is small and falls within the range of values one could reasonably expect to derive for a silty clay layer. The very high resistivity first-layer of N.S. 75-16 is a dry silty till but, while the surficial material at the site of N.S. 75-10 also appears to be silty, gravelly till, it shows a very low resistivity. This anomalously low level of resistivity is most probably due to contamination of the ground with salt used during the winter months to clear the highway of ice.

GEOPHYSICAL STUDIES IN THE
FREDERICTON-OROMOCTO AREA

Project No. HR 74-9

Haig G. Tejirian*

*Annual Progress Report*

This study has been conducted for the Hydrology Research Division under contract. Its objectives were: (1) to investigate the extent, origin and significance of inland saline waters in the Fredericton-Oromocto area of New Brunswick and (2) to delineate the dip and structure of the resistant basement and the hydrostratigraphy of the overlying Carboniferous rocks.

Field studies began in the summer of 1974 and were continued during the following summer. The core of the study was the application of the vertical electrical sounding earth resistivity technique: 22 of these soundings were made in 1974 and 36 in 1975. The resistivity soundings were supplemented in 1974 by 55 gravity stations and the collection of a number of saline water samples; in 1975 further information was provided by a test drilling program. The lithologic data, geophysical well logs, aquifer test data and chemical analyses of ground waters from the program were expected to aid substantially in the interpretation of the vertical electrical soundings.

The study was originally intended to form the nucleus of a Ph.D thesis at the Department of Geology, University of New Brunswick. It now appears that this objective cannot be realized. A report of more limited scope is to be prepared by the principal investigator during 1976. It is expected that the report will contain at least a preliminary evaluation of the sounding curves and their dependence on local hydrostratigraphy and basement structure.

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* Department of Geology, University of New Brunswick

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## STOCHASTIC ANALYSIS OF SUBSURFACE FLOW

Project No. HR 74-10

R.A. Freeze*

*Annual Progress Report*

Three numerical mathematical models have been developed for transient flow in saturated heterogeneous systems. In all 3 models, the heterogeneity of the system has been introduced by an assumption that the hydraulic conductivity, compressibility, and porosity of the porous medium are random variables with specified probability distributions. Probabilistic interpretations have been made on the basis of Monte Carlo simulations of deterministic solutions carried out for the three above mentioned parameters represented by values taken from known representative populations.

The following are the three models investigated:

(1) One-dimensional transient consolidation with the parameters specified from a 3-variate normal distribution without spatial structure (Freeze, 1975).

(2) One-dimensional transient consolidation with the parameters specified from a 3-variate normal distribution with spatial autocorrelation and spatial trend.

(3) Two-dimensional transient radial flow to a well with the parameters specified from a 3-variate normal distribution.

Work has also been started on a model involving unsaturated flow. However, this work will not be completed during the contract period.

Besides the paper cited in the reference, the results pertaining to model 1 were presented at two symposia. Papers on models 2 and 3 are in the process of finalization.

* University of British Columbia, Vancouver, B.C.

REFERENCE

Freeze, R.A., 1975. A stochastic-conceptual analysis of one-dimensional ground water flow in nonuniform homogeneous media. Water Resources Research, Vol. 11, No. 5, 725-741.

# WATER MIGRATION IN FREEZING SOIL COLUMNS

Project No. HR 74-11

P.J. Williams*

*Annual Progress Report*

This investigation involves two successive contracts with Carleton University. The first, awarded in 1974-75, was concerned principally with the construction of a laboratory apparatus to observe and measure the one-dimensional migration of water in freezing soil columns. A secondary objective was to provide documentation to demonstrate that a truly one-dimensional fluid and heat flux had been achieved with the experimental apparatus and to provide a set of measured data for one specific soil type used in the development of the apparatus. The second contract, awarded during 1975-76, is intended to provide similar data for a variety of other soil types.

The scientific and technical objectives for the study were threefold: (1) to investigate methods for determining water movement in frozen soil (particularly permafrost) due to temperature and other gradients, (2) to carry out determinations of such movements and to compare these with theoretical calculations based on the theoretical studies of Harlan (1971, 1973a, 1973b), and (3) to consider such water movements in relation to temperature gradients and other soil conditions relevant to "cold" pipelines.

The first stage of the investigation has been completed. The apparatus is operational and was used to measure the pertinent hydrologic and thermal properties of an Oneida clay soil. Properties measured included hydraulic and thermal conductivities of the unfrozen soil column, volumetric heat capacity, dry bulk density, and the variation in volumetric moisture content along the length of the column when subjected to a temperature gradient in which temperature varied from about -3° C at one end of the column to a variable temperature ranging from 2 to 8° C at the other. Frozen thermal conductivity (also a required parameter) was calculated.

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* Department of Geography, Carleton University

The report describing the apparatus used and the first preliminary results is given by Williams (1975b).

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Project No. HR 75-1

R.E. Jackson

## *Hydrogeochemical Processes Affecting the Migration of Radiocontaminants in a Shallow Ground Water Flow System at Chalk River*

by R.E. Jackson[1] and K. Inch[2]

## INTRODUCTION

Approximately twenty years ago two experimental subsurface disposals of medium-level, radioactive liquid waste were conducted in one of the waste-management areas at the Atomic Energy of Canada Ltd.'s (AECL) Chalk River Nuclear Laboratories (CRNL). Since that time the wastes have chromatographically separated into $^{90}Sr$ and $^{137}Cs$ plumes which are migrating through a ground water flow system at characteristic velocities much less than the velocity of the transporting ground water. This paper constitutes a progress report of the work done by the authors in cooperation with W.F. Merritt of CRNL and J.F. Pickens of the University of Waterloo during 1975 (Merritt et al., 1975) to determine the nature of the hydrogeochemical processes affecting the mobility of radiocontaminants at CRNL.

## RADIOCONTAMINANT MIGRATION

In 1954 about 70 $m^3$ of medium-level, liquid radioactive waste containing about 60 curies (Ci) of $^{90}Sr$ and 70 Ci of $^{137}Cs$ was released into a pit lined with lime and dolomite. An experimental disposal in 1955 contained 300 Ci of $^{90}Sr$ and 250 Ci of $^{137}Cs$, however no attempt was made to neutralize it with lime or dolomite as in the previous disposal. Because the 1954 wastes have moved farther, due to the initial high ionic content of the liquid and the relatively high hydraulic gradients near A disposal area, we shall be concerned mainly with the $^{90}Sr$ and $^{137}Cs$ plumes from this disposal (see Fig. 75.1.1).

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[1] Hydrology Research Division, Ottawa

[2] Hydrology Research Division, Chalk River

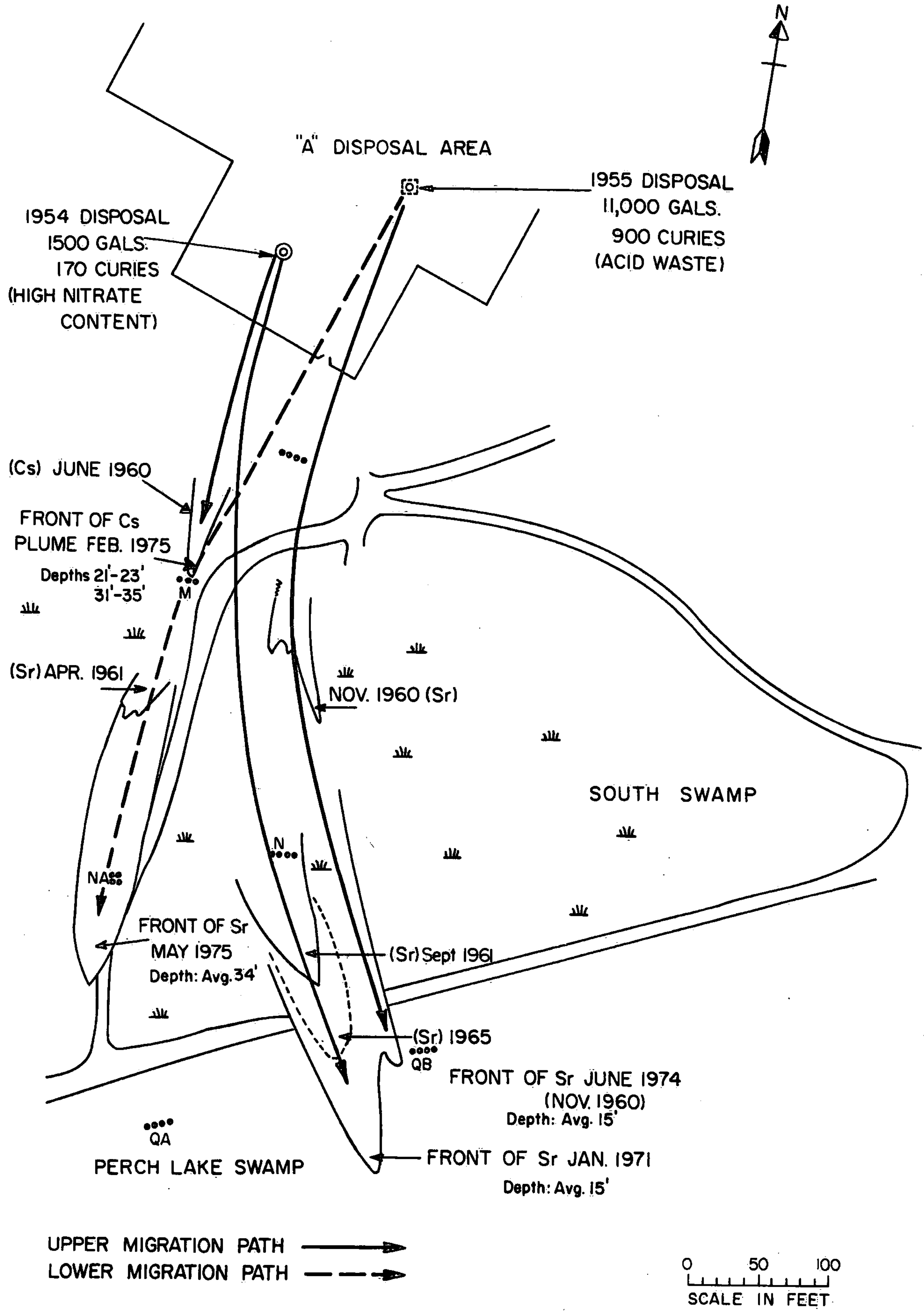


*Figure 75.1.1. Migration patterns of radioactive wastes.*

The migration of radiocontaminants in ground water flow systems when modified by attenuation due to ion-exchange processes may be described by the retardation equation:

$$V_r = \frac{V_{gw}}{1 + \frac{\rho_b Q}{n\, C_o} f'}$$

where $V_r$ = radionuclide velocity
$V_{gw}$ = ground water velocity
$\rho_b$ = bulk density
$n$ = porosity
$Q$ = cation-exchange capacity
$C_o$ = total competing cation concentration
$f'$ = selectivity quotient

Since all of these variables with the exception of the selectivity quotient have been measured we can solve the retardation equation for f'. The values of f' given in Table 75.1.1 are derived assuming $\rho_b$ = 1.69 g/cm$^3$, n = 0.38 and Q = 1.0 meq/100 g. $C_o$ is set equal to the potassium ion concentration (i.e. ($K^+$) in the case of $^{137}Cs$ and ($Ca^{2+}$) in the case of $^{90}Sr$). The f' values obtained by radiochemical analysis are f' ($^{137}Cs$) = 5.1 and f' ($^{90}Sr$) = 1.5.

An interesting observation which we have made is that the determination of f' through the analysis of the migration of the front of the contaminant plume will yield a low estimate when compared to that by radiochemical analysis. This is because the radionuclide velocity is calculated from the migration rate of the fastest radionuclide ions, whereas the ground water velocity is a mean value. As time progresses (see Table 75.1.1) even lower f' values are observed when front-to-front calculations are used.

## SEDIMENTARY MINERALOGY

The hydrostratigraphy of a section of the ground water flow system downstream from the waste-management area is shown in Fig. 75.1.2. The flow system may be seen to be composed predominantly of fine-grained sands with silt and clay lenses occurring within the sand units. Because the ground water geochemistry is intimately related to the sedimentary mineralogy we have conducted some preliminary estimates of mineral abundances in these sands. Fig. 75.1.3 shows the estimated mineral abundances in the Upper Sands at piezometer nest 0. It seems that the major minerals are evenly distributed with depth although there

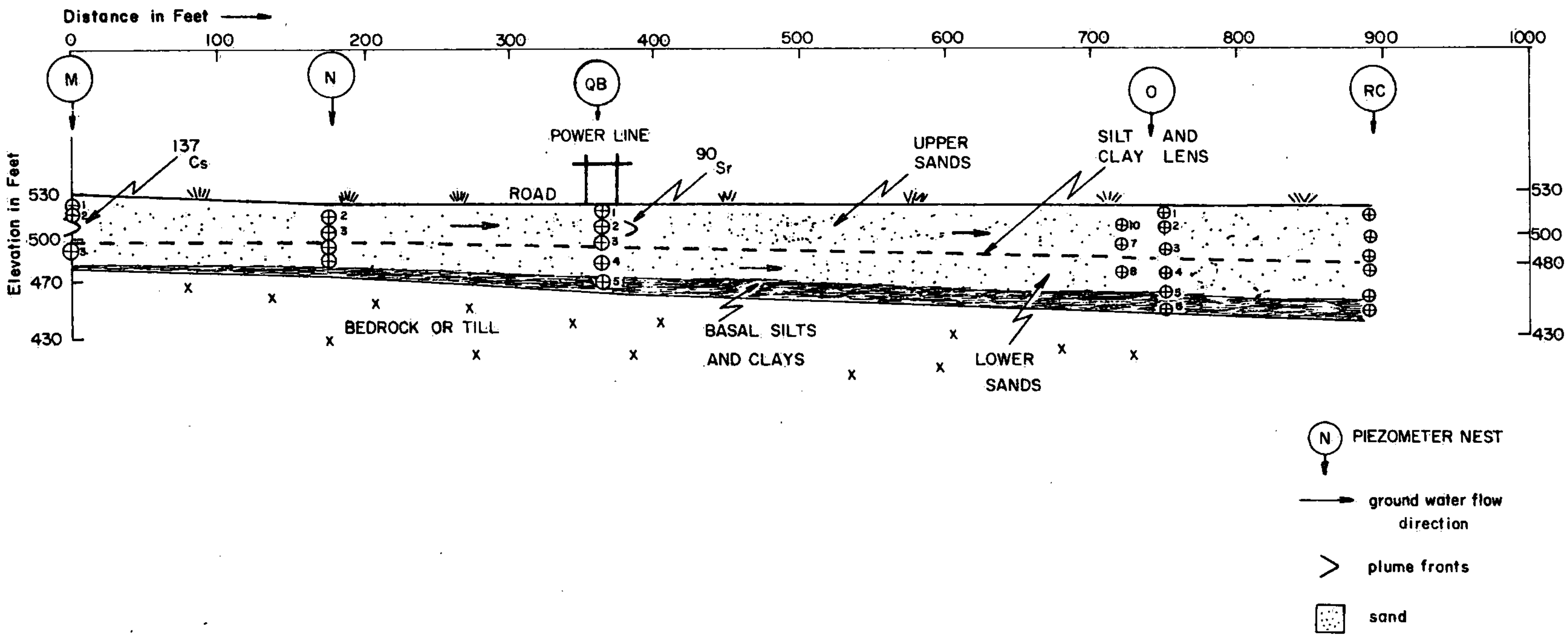


*Figure 75.1.2. Hydrostratigraphic cross section through the South and Perch Lake Swamps.*

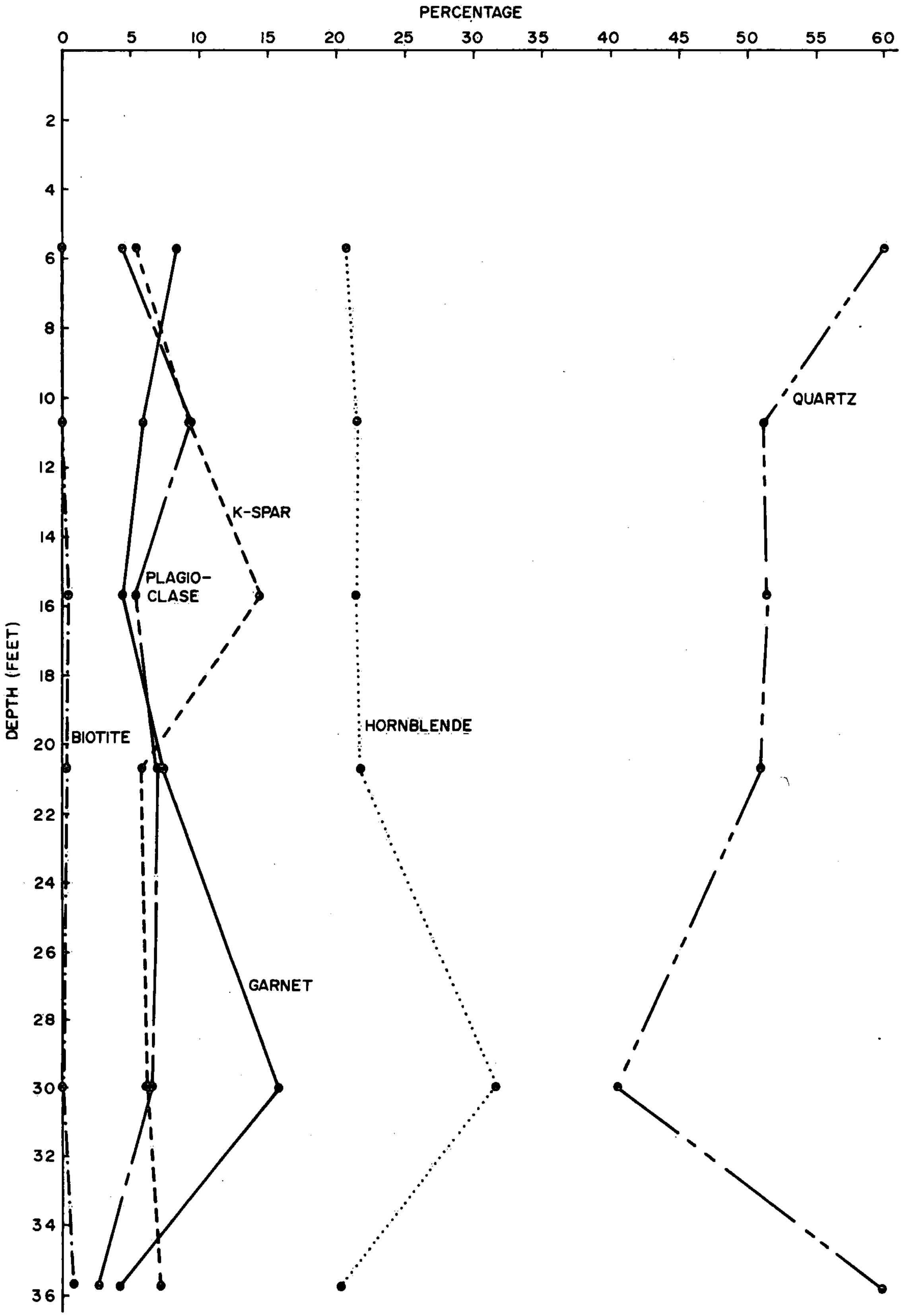


*Figure 75.1.3. Mineralogy of the sand fraction of the Upper Sands unit at 0 piezometer nest.*

is some enrichment in the heavy minerals at 30 feet (9 m) which may be due to the washing operation during drilling or it may be a true washed sand. Fig. 75.1.4 summarizes in histogram form the estimated mineral abundances of the fine-sand fraction in the Upper Sands, till and weathered bedrock in the Lower Perch Lake basin at CRNL. The staining of the plagioclase suggested that it was mostly of the albite variety.

While the sand mineralogy is important in the evolution of the ground water geochemistry it is the clay mineralogy which is important in the adsorption and retardation of radiocontaminants. Fig. 75.1.5 shows an x-ray diffractogram of clay colloids taken from a clay lens at the 36-foot (11-m) depth level at nest 0. The clay minerals present are predominantly illite and chlorite with minor amounts of hornblende, plagioclase and K-felspar. Table 75.1.2 shows the results of a semiquantitative analysis of this diffractogram.

## GROUND WATER GEOCHEMISTRY

Since the methods of sampling, preserving and analyzing ground waters at CRNL are discussed in a separate progress report, we shall confine this section to (1) a review of the possible mechanisms of radiocontaminant retardation and (2) a discussion of the data collected during the summer of 1975.

As the data in Table 75.1.1 show, the velocity of $^{137}Cs$ is only 0.3% that of the ground water whereas the velocity of $^{90}Sr$ is approximately 3.0% of the ground water. We can attribute this retardation of the radiocontaminants to either their adsorption from solution or their precipitation from solution. To gain some understanding of which of the processes might be operating we must consider the nature of the ground water quality. Table 75.1.3 lists the observed and determined values for various ions and aqueous parameters which are of interest in this study.

Because of the solubility of the alkali metals it is not conceivable that $^{137}Cs$ could be precipitated from solution in such a dilute geochemical environment as the Lower Perch Lake basin, therefore its retardation must be due to adsorption from solution. However it is conceivable that $^{90}Sr$ might be precipitated from solution either directly as $SrCO_3$ or indirectly by isomorphous substitution or coprecipitation with $CaCO_3$ or $BaSO_4$ in which case the $Sr^{2+}$ ion would replace $Ba^{2+}$ or $Ca^{2+}$. To determine the state of saturation of the ground waters of the Lower Perch Lake basin with respect to $SrCO_3$, $CaCO_3$ and $BaSO_4$ a saturation index for each mineral was computed. The index for $SrCO_3$ is defined by

$$S.I. = \log (IAP/K_{eq})$$

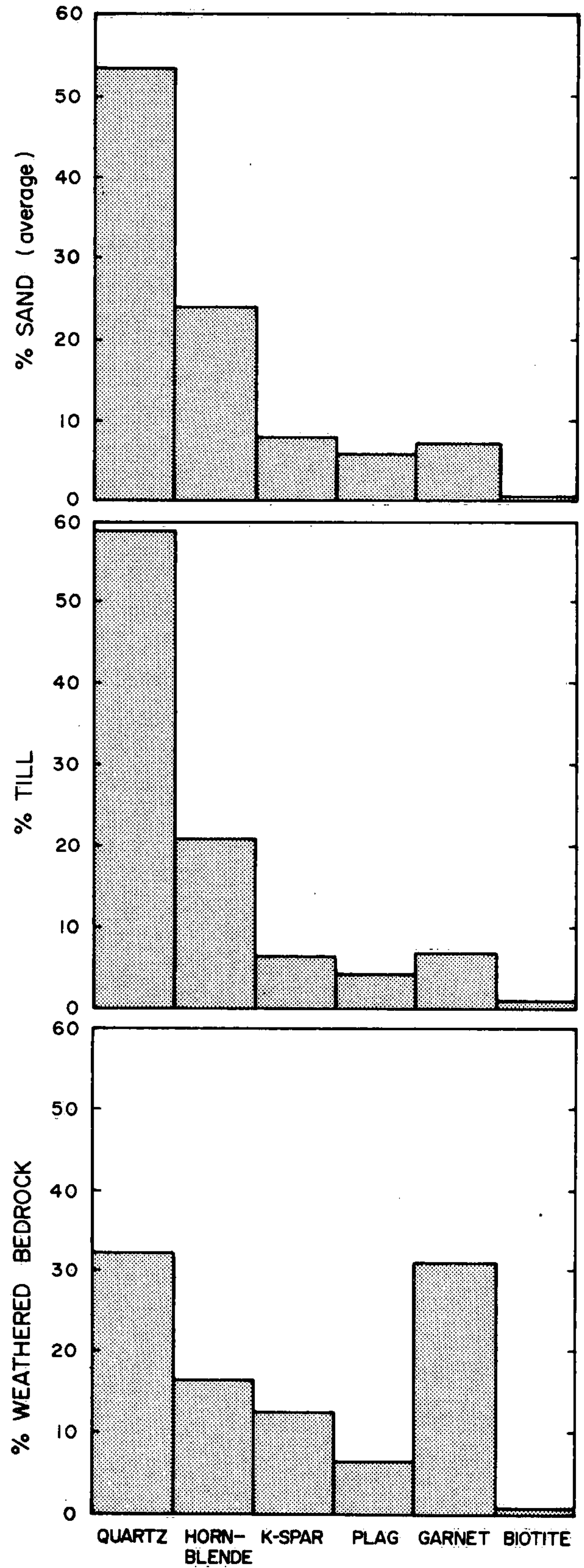


*Figure 75.1.4. Mineralogy of the sand fraction of various local geological materials in histogram form.*

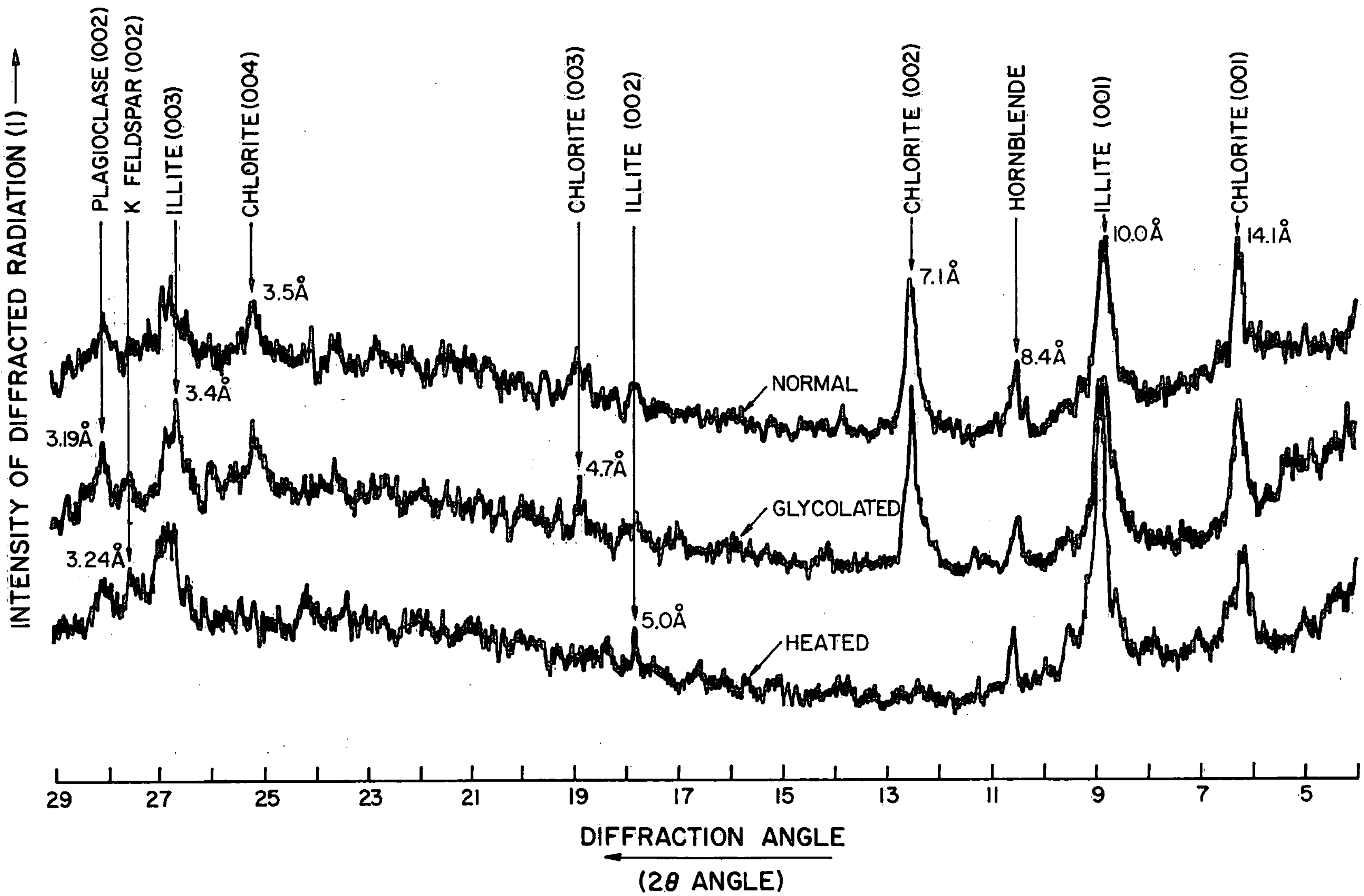


*Figure 75.1.5. X-ray diffractogram of a clay band from the silt and clay lens at 0 piezometer nest.*

where IAP = ion activity product of [$Sr^{2+}$] and [$CO_3{}^{2-}$]

and $K_{eq}$ = solubility product of $SrCO_3$.

When SI < 0.0 the ground water is undersaturated with respect to $SrCO_3$ whereas when SI > 0.0 it is supersaturated. Table 75.1.4 shows that the 02 and 03 ground waters are undersaturated with respect to all three minerals and therefore retardation by precipitation is not a plausible explanation for $^{90}Sr$ retardation.

Therefore both $^{137}Cs$ and $^{90}Sr$ must be retarded in their subsurface migration by being adsorbed from solution. The question which next arises is "by what?" Three colloidal materials are probably the controlling mechanisms in this adsorption although their relative importance is not yet understood. First, there are the clay minerals, in particular illite and chlorite, which have been observed by x-ray diffraction methods (see Fig. 75.1.5). It is probable that the great affinity of illite for the cesium ion is the cause of its relatively slow migration vis-à-vis $^{90}Sr$. Second, there exist in the Chalk River sands significant amounts of sedimentary organic matter (approximately ½% by weight) which may have a considerable cation-exchange capacity. Interpretation of the results of Ophel et al. (1971) suggests that a direct correlation exists between the exchangeable $^{90}Sr$ adsorbed to the sandy bottom sediments of Perch Lake and the amount of organic matter in these sediments. Finally we must consider the possibility that $^{90}Sr$ might be adsorbed to or coprecipitated with hydrous ferric oxide (e.g. FeOOH, $Fe(OH)_3$). Following what Whittemore and Langmuir (1975) have written we note that the CRNL ground waters are saturated with a dubiously stable siderite (S.I. = 0.35 for piezometer 02) in equilibrium with amorphous hydrous ferric oxide (pQ (02) = 36.9).

During the summer of 1975 fifteen more piezometers were sampled along the path of the waste plumes (see Figs. 75.1.1 and 75.1.2) in order to determine the principal hydrogeochemical controls on the migration of the radionuclides. These data are recorded in Table 75.1.5 and are presently being analyzed with the use of a computer program which was written to compute the geochemical equilibria between species (Truesdell and Jones, 1974).

An interesting feature of these data is that they confirm the observation of other hydrogeologists that there is a steady decline in the redox potential (Eh) from ground water recharge to discharge. The redox potential in the recharge area is over +400 mv as is witnessed in piezometer M2 (see Fig. 75.1.2), however, by the time the ground water has reached piezometer nest 0, the potential is approximately +150 mv. The cause of this drop is probably the reduction of the oxidized species in the ground water flow system (e.g. $O_2$, $NO_3$, $Fe(OH)_3$, etc.) during the oxidation of reduced sedimentary organic matter.

## CONCLUSIONS

The mechanism of radiocontaminant retardation in the Chalk River sands is probably due to the adsorption of the radiocontaminants from solution. However as yet the relative importance of clay minerals, organic matter and hydrous ferric oxide in adsorbing $^{137}Cs$ and $^{90}Sr$ from solution is unknown. This matter, together with the study of the ground water geochemistry, is the subject of our present research.

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TABLE 75.1.1 Variation in f' for $^{90}Sr$ and $^{137}Cs$ when calculated by the retardation equation and front-to-front plume mapping.

| Radionuclide | Survey Date | $V_r$ (ft/day) | $V_{gw}$ (ft/day) | $C_o$ (meq/litre) | f' (0) |
|---|---|---|---|---|---|
| $^{90}Sr$ | 1965 | 0.046 | 1.54 | 0.0009 | 0.66 |
| $^{90}Sr$ | 1971 | 0.048 | 1.54 | 0.0009 | 0.63 |
| $^{90}Sr$ | 1974 | 0.059 | 1.54 | 0.0009 | 0.51 |
| $^{137}Cs$ | 1975 | 0.0045 | 1.67 | 0.0001 | 0.84 |

TABLE 75.1.2 Semiquantitative analysis of the x-ray diffractogram by peak-height ratios.

| Clay Mineral | % |
|---|---|
| Illite | 42 |
| Chlorite | 30 |
| Hornblende | 18 |
| Plagioclase | 10 |

TABLE 75.1.3 Ground water geochemistry in the area of the leading edge of the $^{90}Sr$ plume (1974 data).

| Piezometer | 02 | 03 |
|---|---|---|
| $Na^+$ | 11.9 mg/l | 10.5 mg/l |
| $K^+$ | 3.6 | 4.5 |
| $Mg^{2+}$ | 5.8 | 12.7 |
| $Ca^{2+}$ | 16.8 | 19.4 |
| $Sr^{2+}$ | 0.14 | 0.13 |
| $Mn^{2+}$ | 0.19 | 0.30 |
| $Fe^{2+}$ | 5.6 | 2.5 |
| $HCO_3^-$ | 56.1 | 72.4 |
| $SO_4^{2-}$ | 13.4 | 18.4 |
| $Cl^-$ | 38.5 | 37.5 |
| Ion Balance Error | -3.4% | +1.1% |
| Si | 7.9 mg/l | 6.7 mg/l |
| DOC | 3.8 mg/l | 2.0 mg/l |
| Temperature | 7°C | 7°C |
| pH | 6.5 | 7.0 |
| Eh | +133 mv | +135 mv |
| Specific Conductance | 298 μmho | 274 μmho |
| Ionic Strength | 0.003 | 0.004 |
| $P_{CO_2}$ | $10^{-1.78}$ | $10^{-2.23}$ |

TABLE 75.1.4 Saturation indices for $SrCO_3$, $CaCO_3$ and $BaSO_4$ for ground waters 02 and 03.

| Mineral | Piezometer | S.I. |
|---|---|---|
| $SrCO_3$ | 02 | -3.4 |
| | 03 | -2.8 |
| $CaCO_3$ | 02 | -2.2 |
| | 03 | -1.5 |
| $BaSO_4$ | 02 | -1.2* |
| | 03 | -1.1* |

* Barium concentration assumed = 0.010 mg/l

TABLE 75.1.5 Ground water geochemical data from the 1975 field season.

| PIEZO-METER | pH | Eh (mv) | $HCO_3^-$ | $SO_4^{2-}$ | $Cl^-$ | $F^-$ | $Fe^{2+}$ | $Mg^{2+}$ | $Mn^{2+}$ | $K^+$ | $Sr^{2+}$ | $Ca^{2+}$ | $Na^+$ | ION BALANCE ERROR | T(°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 07 | 6.89 | +167 | 62.8 | 18.0 | 28.0 | .230 | 1.14 | 8.93 | .138 | 3.01 | .096 | 14.4 | 11.8 | 2.5 | 7 |
| 08 | 6.93 | +142 | 51.5 | 15.6 | 20.2 | .116 | 5.02 | 5.75 | .051 | 2.55 | .053 | 10.1 | 11.9 | 0.0 | 7 |
| 010 | 6.81 | +141 | 66.0 | 9.6 | 23.8 | .186 | 2.81 | 4.02 | .133 | 2.00 | .109 | 13.9 | 11.2 | 8.2 | 7 |
| QB2 | 6.48 | +280 | 36.4 | 19.0 | 39.8 | .145 | 2.13 | 5.92 | .128 | 2.13 | .088 | 15.6 | 12.3 | 5.9 | 7 |
| QB3 | 6.90 | +158 | 68.0 | 16.6 | 42.0 | .220 | .73 | 11.3 | .153 | 7.19 | .094 | 15.6 | 11.4 | 2.9 | 7 |
| QB4 | 6.70 | +189 | 45.4 | 17.2 | 28.0 | .098 | 1.33 | 9.12 | .145 | 3.29 | .058 | 9.7 | 10.6 | 2.3 | 7 |
| QB5 | 7.52 | + 86 | 71.0 | 17.2 | 14.0 | .206 | .54 | 6.79 | .204 | 4.22 | .065 | 17.3 | 5.6 | 3.1 | 7 |
| QA1 | 5.92 | +156 | 34.2 | 23.0 | 12.3 | .073 | 16.9 | .84 | .043 | 6.16 | .023 | 1.8 | 4.9 | 7.1 | 7 |
| QA2 | 6.10 | +146 | 31.2 | 13.8 | 23.0 | .069 | 4.76 | 1.54 | .102 | 2.08 | .056 | 9.4 | 8.3 | 8.0 | 7 |
| QA3 | 8.30 | + 94 | 91.8 | 14.4 | 21.8 | .381 | .16 | 3.29 | .235 | 1.56 | .075 | 22.3 | 6.8 | 0.0 | 7 |
| QA4 | 8.30 | + 98 | 90.9 | 7.6 | 21.3 | .532 | .08 | 4.47 | .136 | 1.28 | .103 | 28.2 | 5.1 | 5.8 | 7 |
| NA2 | 6.37 | +185 | 29.4 | 21.4 | 125.0 | .052 | 57.0 | 11.0 | .16 | 2.05 | .168 | 27.5 | 33.1 | 13.2 | 7.5 |
| NA3 | 8.00 | + 66 | 116.5 | 12.4 | 35.4 | .356 | .22 | 5.05 | .09 | 2.43 | .131 | 33.2 | 14.7 | 6.6 | 8 |
| M2 | 6.01 | +434 | 27.7 | 15.2 | 10.9 | .056 | .06 | 1.30 | .04 | 1.92 | .049 | 12.8 | 4.2 | 4.5 | 10 |
| M3 | 6.22 | +217 | 27.7 | 19.4 | 100.0 | .062 | .00 | 12.5 | .00 | 3.33 | .142 | 20.5 | 34.1 | 0.8 | 9 |

Project No. HR 75-1

R.E. Jackson

# *Development of Methods for Sampling, Preserving and Analysing Dissolved Chemical Species and Other Aqueous Parameters in Ground Waters*

by R.E. Jackson[1] and K. Inch[2]

## INTRODUCTION

This short paper constitutes a progress report of the work carried out by the authors at the Chalk River Nuclear Laboratories, 200 kilometres northwest of Ottawa, concerning the measurement of dissolved solids and other aqueous parameters in the ground waters of the "A" waste-management area.

This problem of measurement may involve as many as three steps - (1) field sampling, (2) field or laboratory preservation and (3) field or laboratory analysis. Fig. 75.1.6 shows the sequential routine of steps which we undertake in our analysis of the Chalk River ground waters. In this report we shall consider each step.

## FIELD METHODS

The sampling points at Chalk River (see Fig. 75.1.7) are 1-inch (2.54-cm) inside diameter PVC piezometers with 2-foot (61-cm) long screens made by cutting slots in the PVC with a hacksaw and by binding them with fibreglass tape. Prior to sampling, the piezometers are drained or flushed by the use of Tygon tubing connected to a 2-litre Erlenmeyer flask which is evacuated with either a hand pump or a portable peristaltic pump run by a 12 volt D.C. battery or a small portable generator.

While the piezometer is being flushed, combination pH electrodes are calibrated using two buffer solutions which span the range of the expected pHs and which have been brought to the ground water temperature (Barnes, 1964). (Together with the specific electrical conductance the

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[1]Hydrology Research Division, Ottawa

[2]Hydrology Research Division, Chalk River

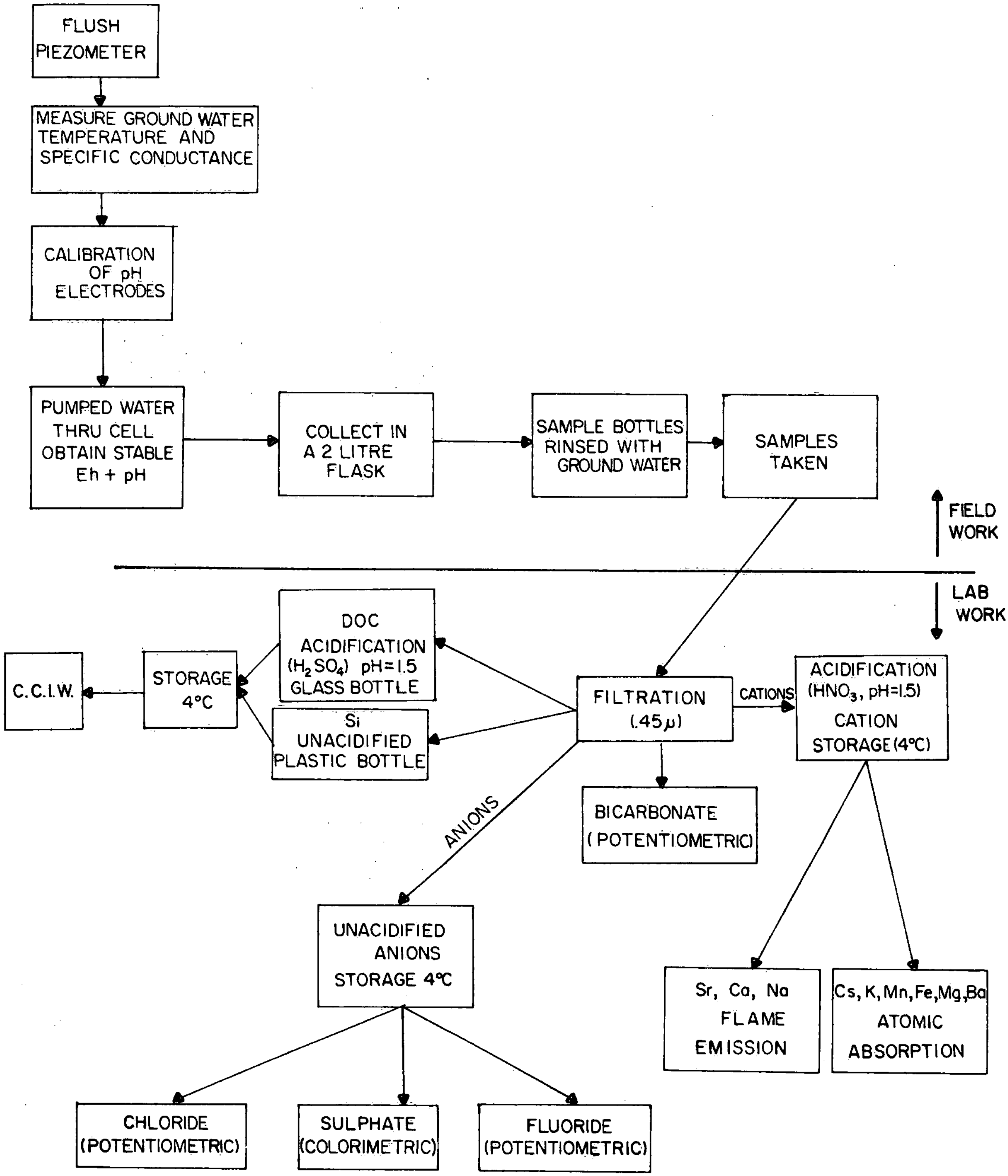


*Figure 75.1.6. A flow chart of sampling, preservation and analysis procedures conducted on all samples.*

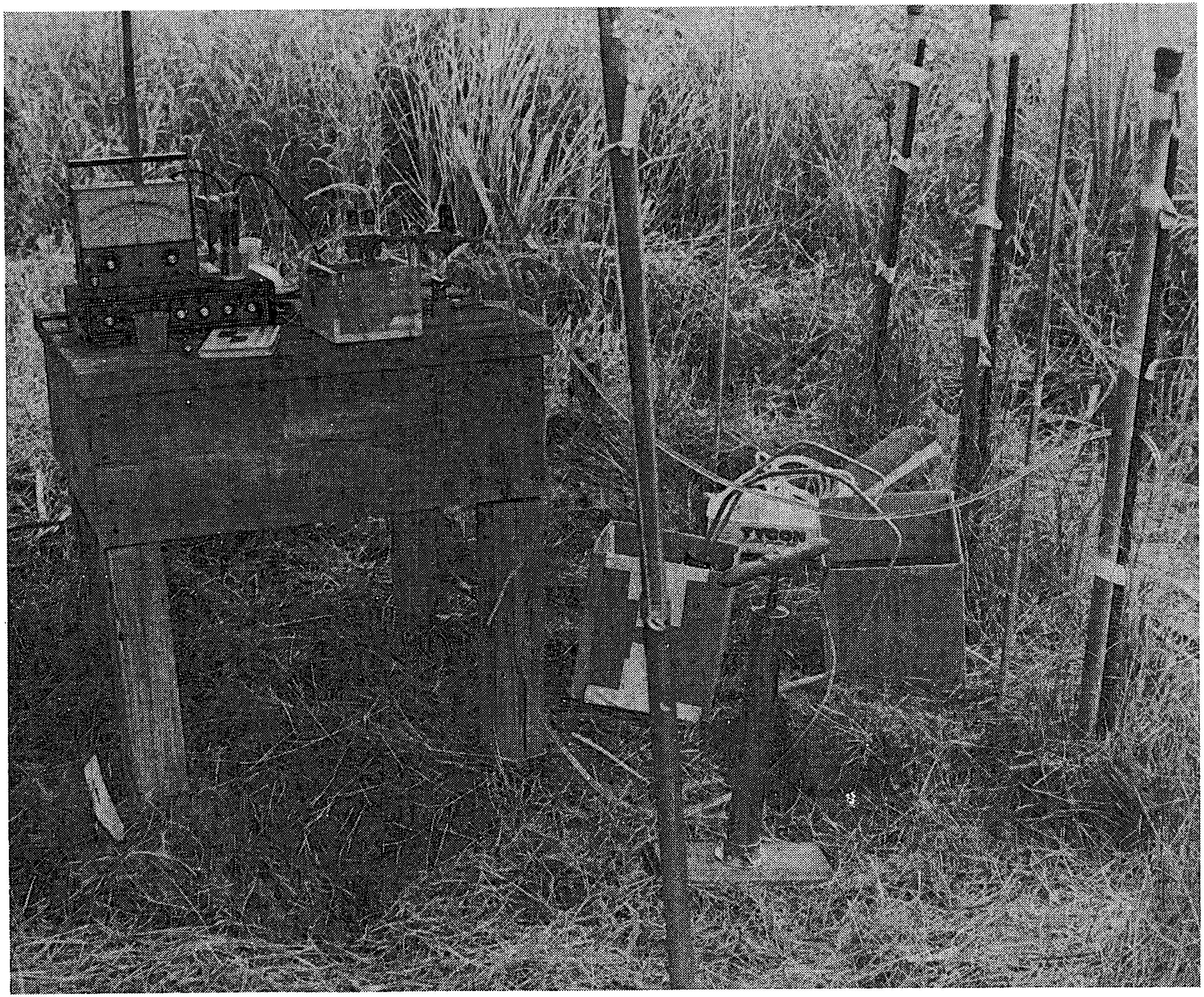


*Figure 75.1.7. Hydrogeochemical apparatus in use at a piezometer nest.*

ground water temperature is measured with a downhole temperature probe (e.g. YSI SCT meter)). The pH electrodes are connected to an electrode switch (Orion 601) which is in turn connected to a pH meter (Orion 407A). In this manner (see Fig. 75.1.8) several electrodes may be used with the same pH meter without continual insertion and detachment of the electrode jacks upon the occasion of the use of each electrode.

After the piezometer is thoroughly flushed the ground water is then passed through an airtight sampling cell and then into the Erlenmeyer for collection. The purpose of the cell is to provide an environment in which the pH may be measured without loss of carbon dioxide and in which the Eh and sulfide may be measured without entry of oxygen. The cell is made by reaming out a 250 ml chamber from an 8 cm plexiglass rod (see Fig. 75.1.9). The cell has inlet and outlet ports which are controlled by stainless steel ball valves and two stainless steel, vacuum sealing fittings inserted in the lid of the cell in which the electrodes are fitted. The cell is fitted into an ice bath (see Fig. 75.1.10) which allows the storage of the buffers and demineralized rinse water at approximately the temperature of the ground water. It also serves to keep the cell water cool.

After a stable pH reading has been obtained (10-60 minutes) one of the pH electrodes is removed from the cell, checked against the buffer solutions and then replaced in the cell by a combination redox potential (Eh) electrode. This electrode is cleaned before use by immersion in 10% $HNO_3$ and is then checked in Zobell's solution as to its accuracy (Langmuir, 1971). At 25°C the electrode should read +0.185 v in the Zobell solution relative to the saturated calomel electrode. Readings more than ±5 millivolts different imply electrode poisoning (Langmuir, 1971). Eh readings are then taken with water flowing through the cell until the same steady minimum electrode potential is observed at which time the ball valves on the cell are closed and the Eh is read. Failure to interrupt flow during the final Eh measurement will result in an erroneous streaming potential of .010 to .030 volts (Langmuir and Whittemore, 1971). The time required to reach a steady potential for Eh measurements is commonly one to two hours because it is necessary to flush the extraneous oxygen from the tubing and the cell and because the ground waters are poorly poised, that is they contain only minor amounts of electroactive species. This two-hour measurement period has been experienced not only at Chalk River but also in the Atlantic Coastal Plain (Back and Barnes, 1961) and the Lincolnshire Limestone in the U.K. (Edmunds, 1973). A steady Eh reading has been defined as one in which there is no more than 0.002 v change in 5 minutes (Edmunds, 1973) or less than 0.005 v change in 20 minutes (Langmuir and Whittemore, 1971).

While the pH and Eh are being measured, ground water is collected in the Erlenmeyer, the first portions of which are used to rinse out the sample bottles which have already been rinsed with 10% $HNO_3$. Ground water is then poured into a 4.5 litre polyethylene container, a 250 ml polyethylene bottle for silicon analysis, and a 200 ml glass bottle for dissolved organic carbon analysis, and temporarily stored in an ice-filled cold chest prior to transportation back to the laboratory.

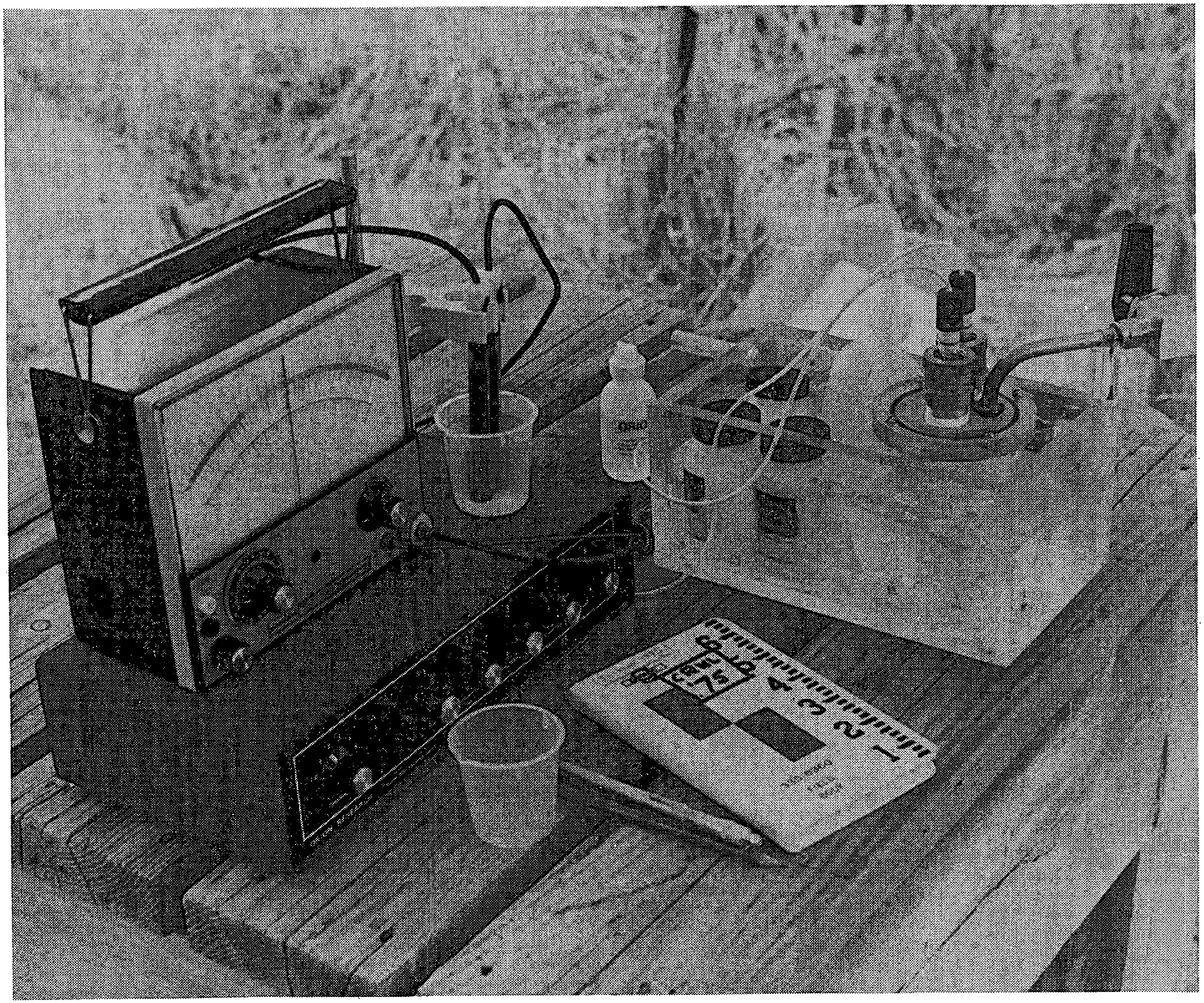

*Figure 75.1.8. pH/Eh/volt-meter resting on an electrode switch and connected to two pH electrodes inserted into the air-tight flow cell.*

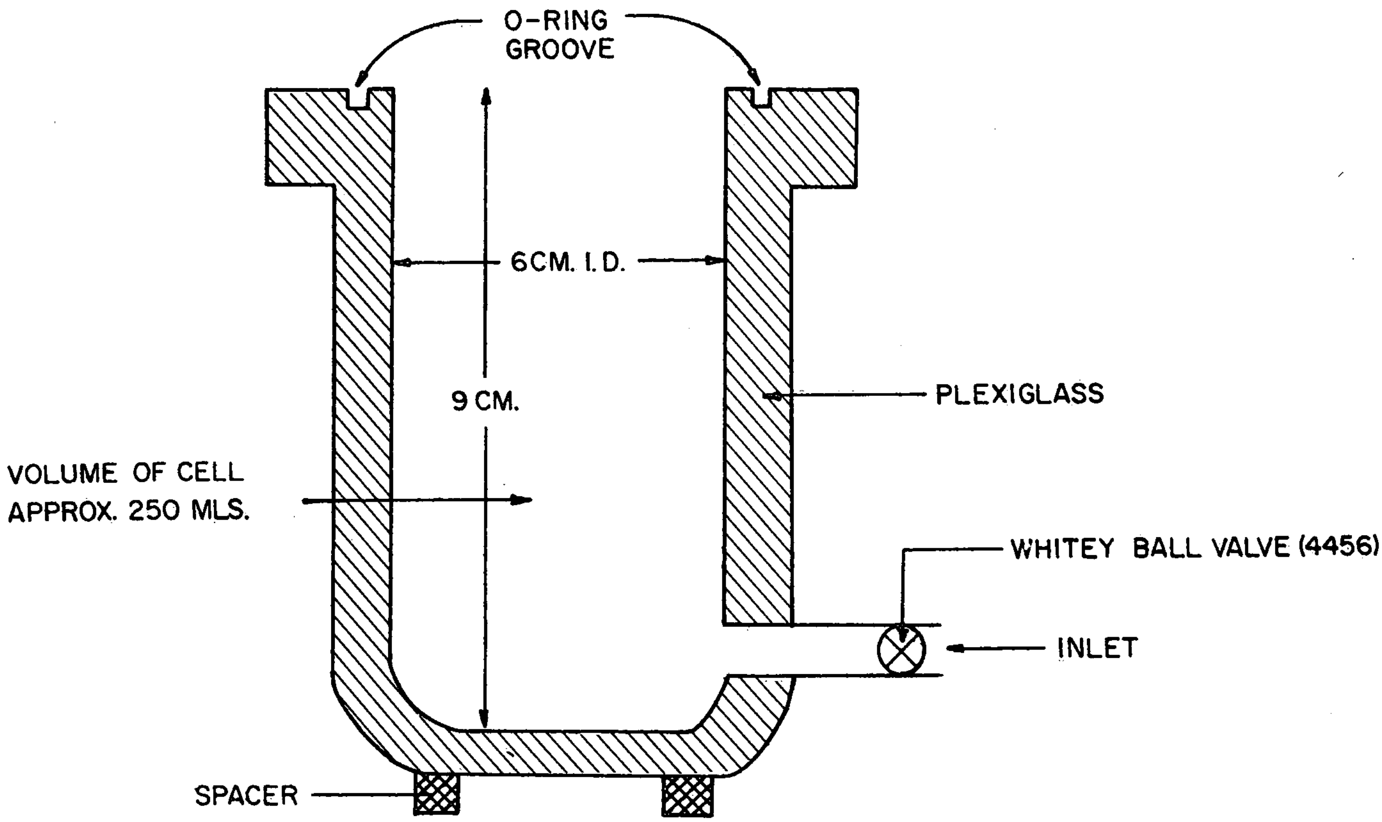


*Figure 75.1.9. Air-tight sampling cell.*

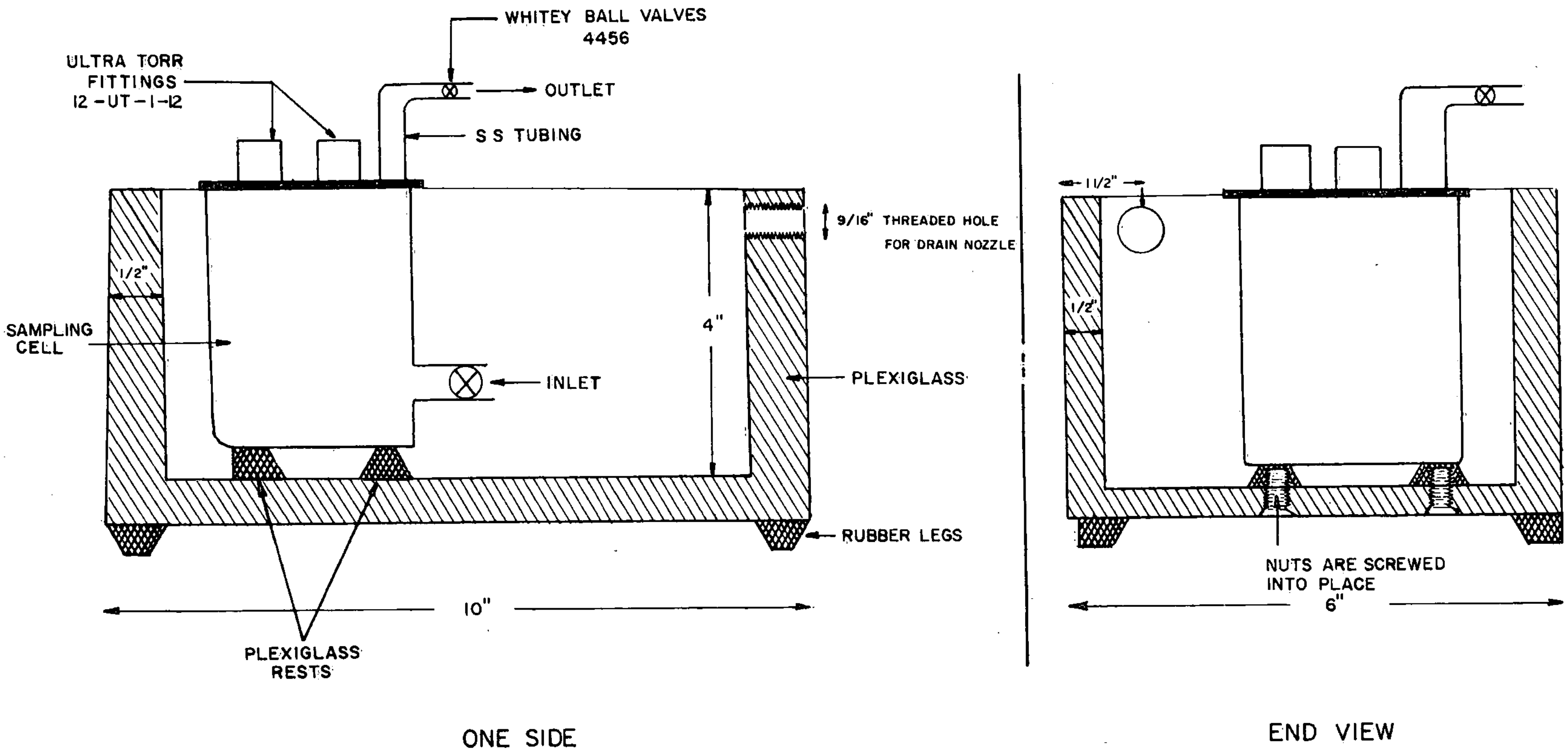


*Figure 75.1.10. Air-tight sampling cell installed in ice bath.*

## LABORATORY METHODS

The first step in the laboratory is the filtration of the samples collected in the field. This is accomplished by pouring the ground water into a 300 ml Gelman magnetic filter funnel containing a 0.45 micron millipore HA membrane filter, which has previously been soaked in 10% $HNO_3$ and then washed in demineralized water to prevent contamination (Wagemann and Graham, 1974) and which in turn is fixed with a rubber stopper into a 1 litre Erlenmeyer glass flask connected to a vacuum line. (This procedure can be carried out in the field with the vacuum pump replaced by a Nalgene Mityvac hand-operated vacuum pump). Following filtration 1 litre is stored unacidified for later anion analysis and the rest is acidified to pH1.5 to prevent precipitation or sorption of the cations during storage (Robertson, 1968) and kept in a large polyethylene bottle. A separate 250 ml polyethylene bottle for silicon analysis at Canada Centre for Inland Waters (CCIW) is kept unacidified and a 200 ml glass bottle of sample is acidified to pH1.5 with $H_2SO_4$ for dissolved organic carbon (DOC) analysis at CCIW. All samples are stored in a cold room at 4°C.

Within one hour of sampling and after allowing the sample to rise to the laboratory temperature, the bicarbonate alkalinity is determined on a filtered sample by potentiometric titration to an end point indicated by the maximum change of pH versus millilitres of titrant added (Barnes, 1964). However, an experiment was conducted to determine the change in alkalinity in stored samples with time. It was found that there was no change in the bicarbonate concentration over a 23-day period for tightly capped polyethylene and glass sample bottles which have been fully filled. Consequently the necessity for field measurement of alkalinity (Barnes, 1964 and Roberson <u>et al</u>., 1963) seems to have been overstated for samples which are undersaturated with respect to carbonate minerals. Furthermore Edmunds (1971) has noted no change in bicarbonate alkalinity over a six-week period for fully filled and tightly capped samples from a limestone aquifer in Britain.

Other anions which are measured in the hydrogeochemistry laboratory at Chalk River include sulphate, chloride and fluoride. Sulphate is measured by the Thorin method (Environment Canada, 1974) which is a colorimetric titration in which the change in absorbence is measured by titrating into a test tube placed within a Spectronic 20 colorimeter. The chloride and fluoride measurements are conducted using specific ion electrodes and an Orion 801A digital pH meter. The chloride analysis is conducted in a solution containing 50% sample and 50% ZnOAc to prevent electrode interference by the sulphide ion (S. Rettig, USGS, pers. comm). The general procedures of specific-ion electrode potentiometry which were followed are outlined in Whitfield (1971).

For cation analyses both flame emission and atomic absorption spectrophotometers are used. Sr, Ca and Na are analysed by flame emission and Cs, K, Mn, Fe, Mg and Ba are analysed by atomic absorption. The method of standard addition is used for all elements.

## SUMMARY

Standard methods of ground water sampling, preservation and analysis have been adopted and modified to suit conditions at Chalk River.

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# GROUND WATER DYNAMIC ASPECTS OF OPEN-PIT MINING AND DEWATERING

Project No. HR 75-2

K. U. Weyer*

*Interaction Between Fluid Dynamics and Extraction of Resources*

## INTRODUCTION

Proper application of fluid dynamic methods provides significant assistance in the solution of problems of ground water management. But there still exists a strong need for further scientific development. The extraction of resources exerts significant influence on water management questions by changing local and regional flow pattern of fluids in the subsurface. On the other hand, fluid dynamic conditions in the subsurface can have an important and even limiting impact on the economics and methods of extraction of all kinds of resources (water, mineral, energy). Consequently this research project is concerned with basic studies and development of methods that will benefit the water management aspects and, in many cases, also the resource extraction aspects.

## SUMMARY OF PROGRESS

Research activity in 1975 was focused mainly on an exploratory evaluation of the following subjects:

(1) Interaction between open-pit mine dewatering and regional ground water flow.

(2) Behaviour of fluid dynamic force fields.

(3) Development of the user-oriented program package "CAPFEA" for calculation and plotting of finite-element arrays.

(4) Effect of gas field depressurization on ground water flow.

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(1) *Interactions between open-pit mining, dewatering and regional ground water flow* were studied by the principal investigator in several countries under different geologic and climatic environments. Some of these studies antedate his employment by IWD but are of interest because of the analogies with Canadian cases.

In tropical South India at the Neyveli lignite mine a private feasibility study was conducted for a German bank consortium. Two reports (Ref. 1 and 2) evaluate the relationship between the geology (unconsolidated rock), regional fluid dynamics, stability conditions and the dewatering requirements. Results of these investigations, dealing with the study of regional ground water dynamics on Landsat images, were presented at a meeting of the German section of the International Association of Engineering Geologists and printed as abstract (Ref. 3).

Private preliminary investigations were also conducted on the dewatering scheme for a planned German temperate-climate lignite open-pit mine to be developed in consolidated and unconsolidated deposits. An internal report (Ref. 4) shows the findings. Shorter and longer field trips were made to existing open-pit mines in mountain valleys and slopes in British Columbia (Fording Mine, Kaiser Mine) and in Alberta (Canmore). Open-pit mines and projects were also studied in the prairie environment of southern Saskatchewan.

In the northern environment advice was given to the Water Board of the NWT on a dewatering problem at Pine Point Mine. A short field study was conducted at the mine site and in the surrounding area. Results have been laid down in an internal report (Ref. 5).

Concerning the common overall outcome of the studies conducted - especially those at Pine Point and Neyveli - it can be concluded that regional ground water flow often strongly affects mine dewatering operations. In turn the dewatering scheme can be designed to minimize the environmental impact and to improve the economics of the mine operation at the same time. Moreover, regional fluid dynamics can be of major assistance in management decisions concerning the economics of planned mines, in respect to slope design and dewatering costs. Thus basic fluid dynamic research will be of considerable benefit for mine operation and for the minimization of certain unavoidable environmental impacts.

(2) *Behaviour of Fluid Dynamic Force Fields* - The action of fluid dynamic force fields on ground water and porous media is by no means fully understood. To date Hubbert's force field theory has not been widely used in the solution of various practical problems of a plain hydrodynamic nature, such as dewatering, horizontal flow, hydraulic fracturing or reservoir engineering. Moreover, the coupling of fluid dynamic force fields with force fields inside the skeletons of porous media has not yet been solved satisfactorily. Terzaghi's effective stress concept can be opposed by strong fluid dynamic arguments. Consequently, stability problems of various kinds cannot to date be described and handled in all cases by an overall physically consistent theory that is not in contradiction to some other aspects of physical knowledge (Ref. 6).

Research is undertaken to develop an improved understanding of the fluid dynamic mechanisms that lead to various kinds of stability changes associated with changes in ground water flow such as subsidence, landfalls and slope failures. In this respect a hydraulic column experiment is being undertaken in cooperation with J. Banner. Catastrophic landfall initiated by water invasion in subsurface mines has been investigated at Ronnenberg Salt Mine and Hückelhoven Coal Mine, both situated in West Germany.

(3) *Development of the User-Oriented Program Package "CAPFEA" for Calculation and Plotting of Finite-Element Arrays* - The program set CAPFEA is being developed to enable efficient and reliable calculation and analyses of force and flow fields associated with ground water flow on local and regional scales.

Logically the program set can be divided into two parts, the main calculation and the plotting part.

On the basis of a finite-element numerical solution, the distribution of hydraulic potential is calculated in a two-dimensional network. The respective subroutine accepts one-dimensional elements with two end nodes and two-dimensional elements of triangular or rectangular shape with corner nodes. It works for heterogeneous and anisotropic conditions. The logic of CAPFEA is built in such a way that it does not seem to be difficult to exchange the calculation subroutine for another one.

Its characteristic and unique feature is given to CAPFEA by its second part, the accompanying calculation procedures and plotting subroutines. The calculation procedures take the stored results of the finite-element calculation and convert them through the use of analytic equations into values for other field properties, as for example gradients or amounts of flow per unit area. The results are usually plotted at the same time.

Plotting subroutines plot the input as well as the output data. With regard to the input, the plotting of the finite-element net and of the permeability distribution and geologic structure proved to be very useful in overcoming a major drawback of finite-element calculations - the time-consuming checking of the input. As the program stands now, equipotential lines, head distribution and flow arrows are plotted as output.

The program provides for dimensional exaggeration and is equipped with plotting facilities for heterogeneous and anisotropic conditions. This will make it possible to draw exaggerated cross sections of flow patterns in a relatively short time and with much more accuracy than before.

The program has been provided with extensive explanatory comments to enable later outside users to understand the logic and functioning of the program easily.

The work is being done in cooperation with H. Pearse. Further development of the existing program set CAPFEA 2 into an extended program set CAPFEA 3 is anticipated.

(4) *Effect of Gas Field Depressurization on Ground Water Flow* - Increasing evidence has made it obvious that extended and deeply penetrating flow systems exist in the subsurface. The different fluids moving therein are subject to fluid dynamic force fields in such a way that local changes of energy conditions, such as depressurization of oil or gas fields, may change the underground flow patterns significantly. Normally the detection of these changes in ground water discharge areas may be very difficult because of large regional extension of the total flow system involved. However, this may be different in the locally restricted flow systems in high mountain regions. There pronounced ground water discharge areas occur in valleys where they are intersected by highly transmissive systems, like fault zones or karstic layers. During a visual investigation of mountain discharge areas, one of them was found dry while others nearby were still very wet. Geographically this discharge area is close to a producing gas field. As the possibility exists that the depressurization of the gas field may be the causing factor for a change in ground water flow further investigations are contemplated there.

The necessary next step, however, will be a vegetation study to determine whether the plants in the discharge area show signs of water stress. This investigation will be conducted in cooperation with Dr. D. Hocking of Canadian Wildlife Service. Decisions on future work will be based, in part, on the outcome of this initial investigation.

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# PUMP TESTING IN NONHOMOGENEOUS AQUIFERS

Project No. HR 75-4

A. Vandenberg*

*Annual Progress Report*

One of the prime requirements of the idealized aquifer which is used to obtain mathematical models of ground water flow is the homogeneity of its hydrologic characteristics. Whether the applications of the model are short or long term, local or regional, no simple mathematical relation (as for example between drawdown and pumping rate) can be established without the assumption that the transmissivity, T and storativity, S , do not vary in space and time. And of all the simplifying assumptions that go into such a model, and are occasionally questioned, the assumption of homogeneity is most obviously contrary to our everyday experience.

Most hydrologists however express the belief that, if only a pump test is conducted for a long enough period, analysis by the Theis method or with the leaky aquifer model will give values of T and S that are representative of a large area (Tóth, 1966, 1967; van der Kamp, 1975). Freeze (1975) on the other hand, doubts the validity of the assumption that "it is possible to define an equivalent uniform medium that will act in every sense like the actual nonuniform one".

Even accepting the concept of the equivalent uniform medium, there is still doubt about the way in which, for example, time-drawdown data from a pump test should be interpreted. Are the representative aquifer parameters obtained by the best fit of the type curve to the whole curve or is it better to use only the later data and ignore the early part completely? Or is there some useful information to be obtained from a comparison of parameters derived from different sections of the curve? And in what way do the different results obtained for different observation wells reflect local variation of the medium?

## THE MODEL INVESTIGATION

In Project No. HR 75-4 an answer is sought to some of these questions by using a finite-difference model of a pump test in a heterogeneous, confined aquifer and analyzing the resulting time-drawdown curves at a large number of nodes by the Theis method. In order to handle the 624 analyses, and also avoid subjectivity in fitting the drawdown curves, T and S are determined by a least-squares technique, in which a fixed number of pairs of time-drawdown values are taken, and values of T and S are adjusted iteratively until the sum of squares of the difference between calculated and observed drawdown becomes a minimum.

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The heterogeneity of the aquifer is introduced by assigning random values of T to each of the nodes, taken from a uniform distribution between T = 0 and T = 0.1 $m^2$/minute. The diffusivity, T/S, is held constant at 100.

The simulation was carried out over a simulated test period of 75 days, in 70 time steps of increasing size. For each determination of T and S, 10 pairs of time-drawdown data were selected:

1) To obtain the best fit to the whole drawdown curve the points were divided evenly between the first time step at which the drawdown exceeded 1 cm and the last observation;

2) To obtain the best fit to only a small segment of the drawdown curve, the 10 time steps immediately following a specified time step were selected, and the least-squares calculation was repeated for four different time intervals, 454 minutes to 2 days, 1 to 5 days, 2 days to 10 days, and from 12 to 70 days.

The whole procedure was carried out twice on different random input data for T and S.

## SOME PRELIMINARY RESULTS

Figure 75.4.1 shows the histograms of the calculated values of T and S, as calculated from the complete drawdown curve, in comparison to the histogram of the actual values of T which were specified at the nodes of the finite-difference grid. The calculated values of T are virtually normally distributed in a very narrow range (compared to the actual distribution) about the expected average value of 0.05 $m^2$/min. Calculated values of S are more widely distributed around the expected average of 0.0005, but the range is still narrow in comparison with the actual distribution of S. This result indicates that, whatever the actual distribution of transmissivity, and whatever the transmissivity at the location of the observation well or the pumped well, the best fit of the Theis curve to the measurable part of a pump test of 70 days, yields transmissivities and storativities which are close to their spatial averages.

Results of the calculation of T and S from small sections of the drawdown curve seem to indicate that:

1) Average apparent transmissivity decreased from 0.05 $m^2$/min in the early interval to 0.0445 $m^2$/min (0.0475 $m^2$/min in the second trial run) in the late interval.

2) Average apparent storativity increased with time, but only for observation wells close to the pumping well. For wells over 300 m distant the time period of the analysis made little difference in the computed values of S.

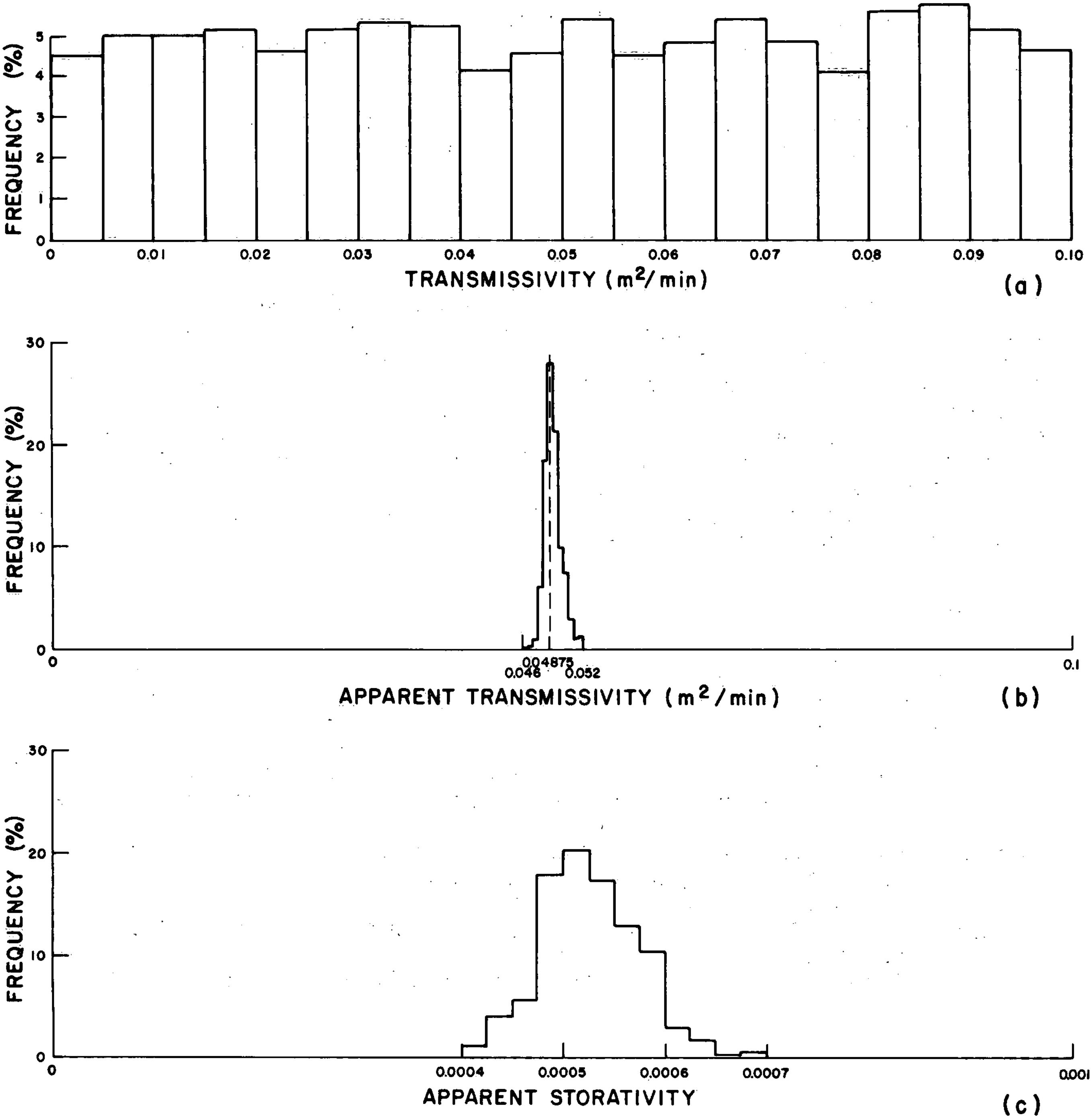


*Figure 75.4.1. Comparisons of histograms for apparent transmissivities and storativities with transmissivity frequency distribution utilized for heterogeneous model.*

3) Standard deviation of apparent T decreased with increasing time, but increased with distance from the well.

4) Standard deviation of apparent S decreased with time and with distance from the well.

## FUTURE WORK

A similar analysis as the one presented can also be applied to the distance-drawdown data, however, where the time-drawdown curves are smooth and more or less of the shape of the Theis curve, the distance-drawdown curves are more bumpy, as might be expected, and more difficult to analyze by a computerized least-squares technique. On the other hand, it might be possible to learn something about the areal distribution of T by comparing the actual drawdowns to the computed drawdowns (for average T and S). Although only of a qualitative nature, a residual map could at least indicate where T is higher and where lower than the average regional value; even this qualitative information seemed to be entirely lacking from the calculations on the time-drawdown data.

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# INVESTIGATION OF AN UNDERGROUND GASOLINE SPILL IN FLIN FLON, MANITOBA

Project No. HRO 74-3

J.A. Vonhof*

*Annual Progress Report*

This study was funded by the Environmental Protection Service, Environment Canada. It involved the field investigation of a long-standing (since 1968) underground leakage problem at Flin Flon, Manitoba. There were four objectives: (1) to delineate the shallow subsurface area contaminated with gasoline liquid and vapour, (2) to determine the source of the gasoline, (3) to define the stratigraphic framework for the contaminated area and its surroundings, and (4) to suggest the best possible clean-up technology.

A test drilling program to define the extent of subsurface contamination was conducted over an area of about 150,000 $ft^2$ (14,000 $m^2$) during the fall and early winter of 1974-75. One hundred and fifty test holes were drilled. The fan-shaped area of contamination was shown to extend down-gradient from a suspected source probably located at or in the vicinity of a local gasoline service station. It consisted of a central portion in which liquid gasoline was found floating on the water table and a surrounding fringe area in which no liquid gasoline was found but for which gasoline vapours were in evidence. The liquid gasoline layer, where present, varied in thickness from about 1/16 to 10 in (1.5 to 250 mm) and gasoline vapours were also noted in this central region. The total contaminated area was 61,500 $ft^2$ (5,600 $m^2$) and the area containing liquid gasoline was 39,800 $ft^2$ (3,700 $m^2$).

A rough estimate of gasoline now present in the ground gives a figure in the 1,500 to 3,000 imperial gallon (7,000 to 14,000 l) range. Taking earlier clean-up operations into account, the total amount lost into the ground is probably in the 3,200 to 4,700 gallon (14,500 to 21,000 l) range. The cost to clean up the existing contamination may be in the $100,000 range.

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# HYDROGEOLOGY OF GROS MORNE AND KOUCHIBOUGUAC NATIONAL PARKS

Project No. HRO 74-4

R.L. Herr*

*Annual Progress Report*

Reconnaissance surveys were undertaken in Gros Morne and Kouchibouguac National Parks during the month of August 1974. A five-day period (August 5 - 9) was spent in Kouchibouguac National Park and a seven-day period (August 12 - 18) in Gros Morne National Park. During these periods a survey was made of stream conditions, water wells and general geology of the areas.

Kouchibouguac National Park occupies a 16-mile (26-km) crescent along the low shores of Kouchibouguac Bay and extends inland 5 to 6 miles (8-10 km) with elevations rarely exceeding 100 feet (30 m) over the entire area.

A map showing the estimated depths to ground water and interpreted flow directions was constructed for the park area. This map was based on observed surface water levels and the assumed influence of topography on ground water flow.

Water samples were taken from existing water wells and surface streams. Previous to this survey, Parks Canada had installed three deep wells in their main campsite and were using several shallow wells at the beach, at temporary campsites and near temporary administration buildings. It was demonstrated that several of these shallow wells had become contaminated by effluent from nearby latrines. These observations indicated the need for expert hydrogeological advice prior to the development of further new supplies.

In Gros Morne National Park a helicopter was used for reconnaissance flights into the rugged interior of the park while along the coast access was provided by paved and gravelled roads. In the park area itself, the inhabitants for the most part use shallow holes dug in the banks of lakes. The water that filters into these holes is then piped several hundredsof feet (up to 100 m or more) to the point of use. The use of drilled wells in the park area was very limited. A map showing estimated depths to water and flow direction was constructed again using the surface water level data as indicators of ground water levels. This map gave a rough approximation of ground water conditions on the upraised coastal plain but was lacking in detail in the rugged interior of the park.

Samples were collected from selected sites in the park and were analyzed at the Water Quality Branch laboratories in Moncton. At the present time, little if any use is made of ground water from drilled wells in Gros Morne National Park.

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If and when it is deemed necessary to tap these ground water supplies, it is recommended that an exploratory drilling and pumping test be undertaken under the direction of a hydrogeologist to evaluate supplies.

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# INVESTIGATION OF GROUND WATER FLOW SYSTEMS, RICHMOND LANDFILL SITE, RICHMOND, B.C.

Project No. HRO 75-1

H.M. Liebscher*

*Annual Progress Report*

The major concern with this landfill site is its current use by the federal Department of Public Works to dispose of so-called "International Wastes". These wastes arrive in the Vancouver area via international airline flights and sea traffic. The problem involves periodic ground water and leachate migration locally into Richmond Municipality drainage ditches. Sometimes the leachate, identified by its black colour and odour, migrates into the integrated Richmond ditch system. The disposal environment of these wastes and resulting leachates is currently under study to determine the ground water flow patterns both within and peripheral to the landfill site.

Prior to the present investigation the Department of Public Works had drilled 73 test holes within a restricted area of the present site to determine the thickness of overlying peats and the physical nature of the underlying confining basin (in places located above sea level and overlain with peats). This area has since been covered with a variety of international, domestic and demolition wastes.

During late 1975 a number of test holes were drilled into the completed landfill site in an attempt to monitor:

(1) Ground water flow patterns,

(2) Effect of high and low tides within the adjacent Fraser River on the peat bog water and leachate,

(3) Topographic influence of the underlying confining basin on flow patterns,

(4) Permeability of peats, dykes and underlying materials,

(5) Vertical and lateral variations in chemical character of leachates,

(6) Leachate migration as it becomes integrated with the ground water flow system.

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* Hydrology Research Division, Vancouver

A second more comprehensive drilling program will be carried out in early spring over the whole 2½ square miles (6½ $km^2$) of existing and proposed landfill site once basic information on the present study area is completed.

The project is funded by the Environmental Protection Service and Hydrology Research Division in carrying out the site investigation and analysis of data collected from test holes and monitor stations.