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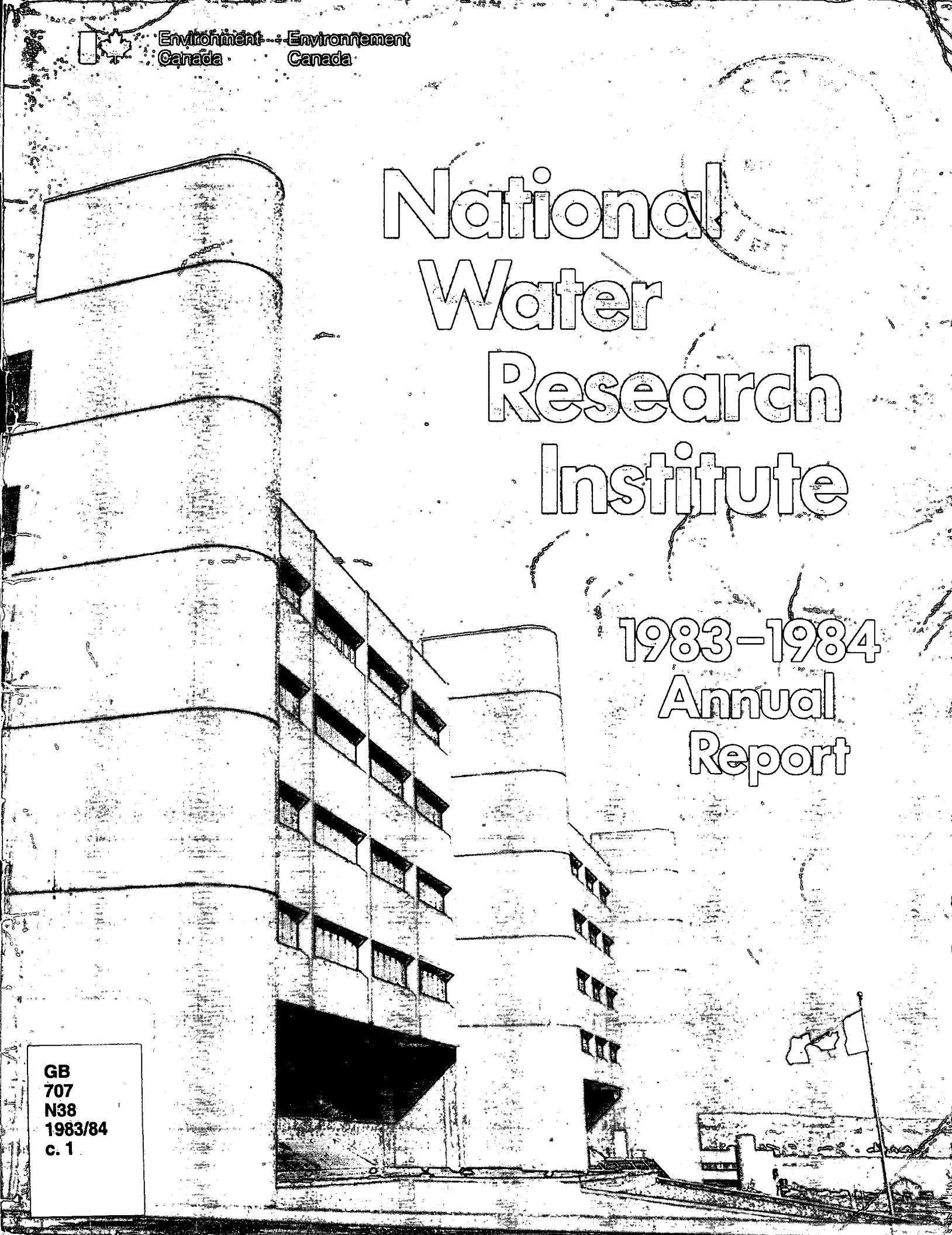
National Water Research Institute

1983–1984 Annual Report



Editor: Dr. J.M. Barica

Production Group: Mrs. N.J. Clegg
Mr. W.D. Finn
Mrs. M.R. Hawkins
Mr. P.C. McColl

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NATIONAL WATER RESEARCH INSTITUTE

1983-1984
Annual Report

Address:

National Water Research Institute
P.O. Box 5050
Burlington, Ontario
Canada L7R 4A6

NATIONAL WATER RESEARCH INSTITUTE

N O T E

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TABLE OF CONTENTS

Your file Votre référence

Our file Notre référence

This is the third comprehensive summary of the programs of the National Water Research Institute (NWRI) of the Inland Waters Directorate, Canada Department of the Environment. These programs address a wide variety of research and technical problems or opportunities associated with the protection, enhancement, development or sustained use of Canada's inland water resources.

In this edition, the staff describe the results of recent work, and outline our on-going activities in the fields of environmental contaminants, hydraulics, aquatic ecology, instrumentation, physical limnology, analytical chemical methodology and microbiology. Because many aspects of our field work, engineering/manufacturing, and support services are unique, these are also described.

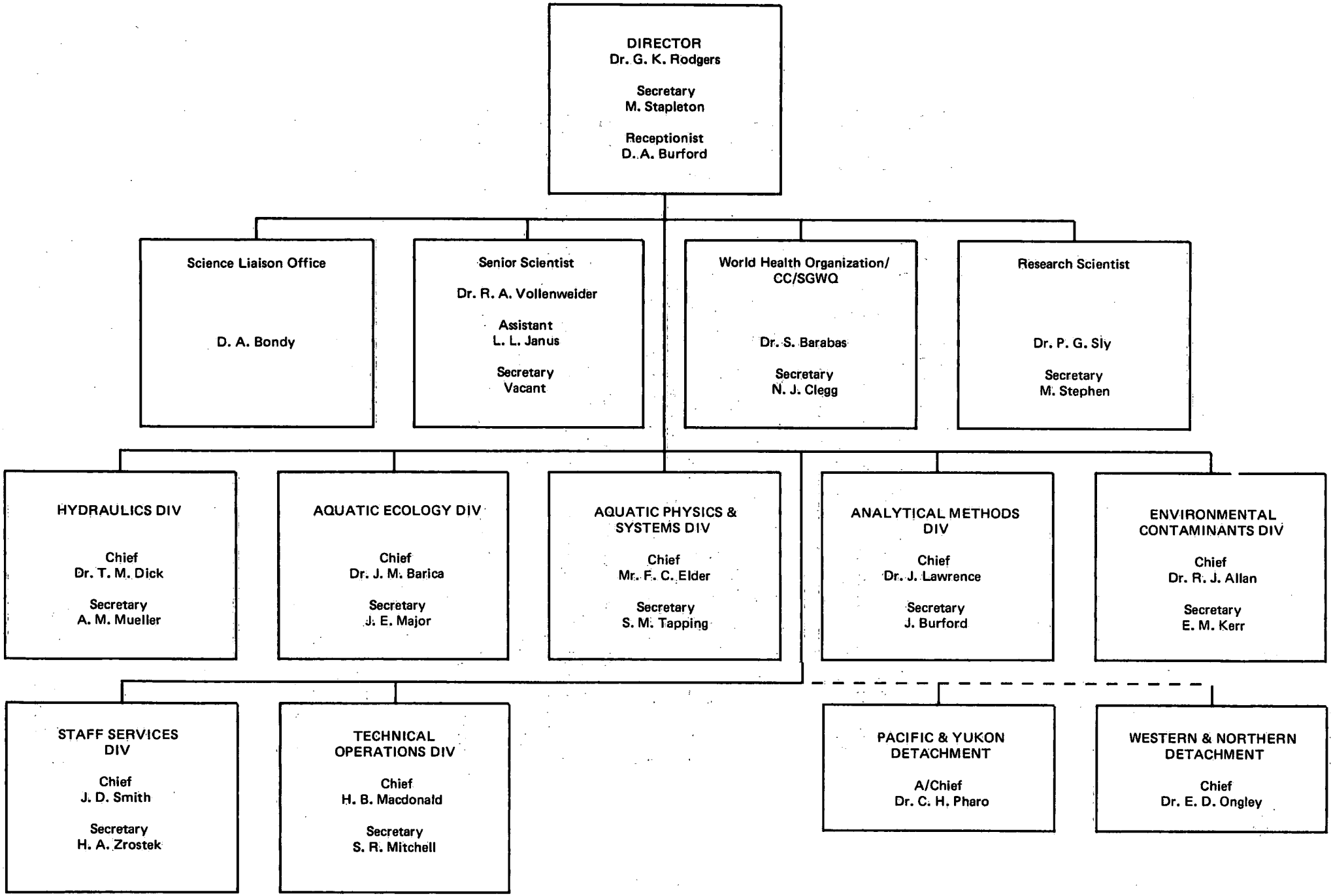
Here we present the results of a dedicated effort to advance, apply and disseminate knowledge of scientific merit and practical importance that will be of value to our clientele in federal and provincial agencies, in universities and industry, and of value to the public at large.

It is my pleasure to introduce you to this record of achievement.

Dr. G.K. Rodgers
Director

ORGANIZATION CHART

NATIONAL WATER RESEARCH INSTITUTE



AS OF MARCH 31, 1984

INTRODUCTION

The National Water Research Institute (NWRI) of the Inland Waters Directorate is an environmental research organization headquartered and largely based at the Canada Centre for Inland Waters (CCIW) in Burlington, Ontario. Two regional units of NWRI are based in Vancouver and Winnipeg. The Institute is part of the Department of the Environment for Canada.

Programs are implemented by five research divisions — Aquatic Ecology, Aquatic Physics and Systems, Analytical Methods, Environmental Contaminants, and Hydraulics and in the two regional units.

NWRI staff have been successful in leading studies that have drawn new subject-specific resources to the Institute in the areas of contaminants and eutrophication, contracting into the Hydraulics laboratory, long-range transport of airborne pollutants (including acid rain), aquatic impact of energy development, infestation by aquatic weeds, and investigations for the Great Lakes Water Quality Agreement.

The National Water Research Institute carries out a program of research and development designed to meet the general objectives of providing the necessary information and understanding of water systems for water management problems or opportunities in Canada. Building on this program of research and development, it seeks to advance, apply and disseminate scientific and engineering knowledge in the fields represented by the research programs. The work includes field and laboratory research on problems of natural or man-modified aquatic regimes. Problems investigated are of national scope or are related to specific geographical sites referred by other agencies within or from outside the Department of the Environment. Part of the total program is the provision of advice or information through publications, services on a consultative basis to other government agencies, service on scientific and technical committees of the government or government-supported institutions such as the International Joint Commission, and the provision of scientific services such as calibrations, analytical services instrument testing, methodology documentation or interlaboratory quality control.

Although the headquarters is at CCIW, detachments of NWRI are located in Winnipeg and Vancouver. Also, one senior staff member has been assigned to the Glenora Research Station of the Ontario Ministry of Natural Resources and a small unit working on the Long Range Transport of Airborne Pollutants is based near Sault Ste. Marie, Ontario. There are many other temporary field sites occupied across Canada as the need arises.

Research in NWRI divisions, which are grouped by scientific disciplines, is carried out within the larger framework of multidisciplinary and interdepartmental national programs, several primarily:

Canada-U.S. and Interjurisdictional Water Management

To resolve interjurisdictional water resource problems and realize interjuridsictional water resource opportunities in accordance with national interests. This includes problems and opportunities relating to water quality management, river basin planning and implementation of plans, and water resources utilization.

Water Management Research

To advance knowledge and provide information and understanding required for the solution of water management problems and the realization of water development opportunities.

Toxic Chemicals

To provide information on the presence of Toxic Chemicals in the environment, the pathways of these chemicals in the aquatic environment and knowledge of their actual and potential impacts on the environment.

Long Range Transport of Airborne Pollutants

To evaluate impacts of airborne pollutants on aquatic ecosystems including their capacity to buffer acidification in lakes and rivers, wildlife populations and lands, and monitor the effects of such impacts.

HIGHLIGHTS

WATER MANAGEMENT RESEARCH

- A major finding of the Lake Erie water quality modelling study indicated that the lake is recovering from eutrophy as a result of the phosphorus reduction program but the oxygen depletion phenomenon remains largely under the influence of natural weather processes. Only when the contribution from these natural processes are identified could the man-made effects be quantified. A new modelling methodology was developed to reconstruct the lake thermal structures, directly linking the climatological forcing functions to the thermal layer thicknesses which in turn affect the oxygen content in the lake. Verified with observed data collected over a twelve-year period, the model results now depict the benefits of the phosphorus reduction program on the oxygen depletion situation under normal, favourable and adverse weather conditions.

- A monograph was prepared and published on 'Effluent Transport and Diffusion Models for the Coastal Zone' to provide the necessary background for the interfacing of different computational methods and physical models for investigators of coastal water quality and for other multidisciplinary concerns in the coastal zone.

- The movement of particles carrying nutrients and contaminants was studied with sediment traps in Lake Ontario. These studies resulted in three reports on the movements of material loaded from the Niagara River and resuspended from the bottom of Lake Ontario. Results indicate that there is much resuspension of bottom sediments which may enhance the availability of nutrients and contaminants in the lake.

- Development and construction of oxygen profiling equipment has resulted in the use of a prototype system in surveys of Lake Erie during 1983. The new equipment uses electronic sensors and a microcomputer to control the lowering winch, interpret the signals, and record the data on diskettes.

- Studies began on the potential impact of drainage waters from peatlands upon receiving water bodies including lakes and streams. Sampling was carried out in Nova Scotia, Quebec and Ontario to obtain peat and drainage water from contrasting sites. Initial work on organic compounds includes isolation of hydrophobic and hydrophilic acids.

- The lime application to Frisken Lake as a whole lake restoration method removed 97% of the phosphate and 80% of the chlorophyll-*a* from the epilimnion. In the hypolimnion, the decomposition of the algae reduced the pH and much of the precipitated phosphate-carbonate complex redissolved.

- Eurasian watermilfoil research (*Myriophylum spicatum*) has concentrated on assessing the long-term impact of harvesting on milfoil regrowth and attempting to determine the mechanism behind the decline of milfoil in several lakes in Ontario.

- *Cladophora* research concentrated on examining the nearshore environmental conditions along the north shore of Lake Ontario that affect *Cladophora* growth. A computer simulation model was used to assess the growth potential of various sites. The model inputs are temperature, turbidity, and phosphorus. The outputs are tissue phosphorus, phosphorus uptake, net and gross photosynthesis and biomass. The model will be used to evaluate the importance of local nutrient inputs compared to the nutrient supply in open lake water.

- It was demonstrated that the beaching and subsequent decay of *Cladophora* in the Hamilton to Oakville area of Lake Ontario coincided with a recent taste and odor event in the local water supply. Geosmin was identified in some of the finished water from the water treatment plant.

- Lake phosphorus dynamics techniques have been developed to simulate phosphorus concentrations that naturally occur in lakes and to predict changes resulting from lake manipulation. Excellent results were obtained for the Qu'Appelle Lakes in Saskatchewan and for Lake Washington.

- Water exchange between Long Bay and South Indian Lake in Northern Manitoba was directly measured under ice. Winter circulation is an important factor that influences environmental response to lake level changes produced by hydroelectric development.

- A press release was issued by the Ministers of Environment and National Health and Welfare (NH&W) on *Legionella* bacteria studies being carried out by Microbiology Laboratories staff and NH&W staff. As a result of this press release, numerous phone interviews were held with newspaper reporters as well as television interviews.

- Methods for the determination of acidity, alkalinity and dissolved oxygen by flow injection analysis had been developed. These techniques could eventually replace colormetric methods for many parameters.

- The success of the joint Wayerhaeuser Canada/ Environment Canada research project to study the causes of excessive benthic algal growth in the Thompson River has resulted in a continuation of the study to define more precisely the relationships between benthic algal growth rate and phosphorus concentration. This project uses a continuously flowing trough methodology in which the flow of natural river water can be precisely regulated. The substrate is optimal for algal accumulation. Light-dark comparisons can be made, and the concentration of nutrients in the water can be accurately controlled.

- Seasonal chemical and physical monitoring of the Yukon River's headwater lakes has confirmed the oligotrophic nature of these lakes. Many opportunities for research into physical processes and sedimentation in high energy river-lake couplets with seasonal ice cover are being explored. Controls on sediment dispersal and deposition in Lake Laberge, where the river flows along the lake as a buoyant plume, contrast sharply with the same processes in Kluane Lake, where the highly turbid plume of the Slims River plunges down the delta face to flow along the bottom as a well-defined turbid plume.

- The annual growth and decay of ice in Lake Laberge and the adjacent upstream and downstream sections of the Yukon River and its effect on the physical, chemical, and biological limnology of Lake Laberge is being examined in detail in a joint venture with Water Resources Branch. The first season's field work is nearly complete and results are very encouraging.

- A Portable Aquatic Video System was developed to inspect underwater objects, especially when an ice cover exists, and is facilitated with the development of an all-weather, watertight video system. The prototype equipment is easily transported and has been used by survey teams on rivers in New Brunswick and in the Arctic.

- A Meteorological Data Buoy was constructed. Measurements of interface phenomena were made accessible in one package with the MET II system. It not only measures selected variables in the air such as wind speed and direction, air temperature and radiation flux, but it also obtains the wave height and frequency statistics as well as the wave energy direction. This buoy is a significant development for instrumenting lakes in any part of Canada. It is equally useful in ocean applications.

- An Automatic Water Sampler was also developed. This device collects and stores samples of water for later analysis on pre-established daily or hourly schedules. Prototypes are in place at Niagara-on-the-Lake, Wolfe Island, and Fort Erie.

- Fundamental studies on meander development have shown that turbulence is not necessary for meanders to develop. Furthermore, the process is not entirely stochastic and is probably governed by a deterministic relationship. These findings permit investigation to focus on the sediment processes as being the deterministic controlling variable for meanders and are essential to predicting the behaviour and flooding of a river which is subject to sediment supply changes or diversion of flow.

- Sediment transport under an ice cover is significant for assessing the impact of northern development or environmental assessments elsewhere. It was found that an ice cover greatly reduces the bottom sediment transport. Moreover, with the correct interpretation, the methods used to calculate transport in open channel flow are applicable to ice-covered flows.

- The River Mixing Model (RIVMIX) is a very versatile model which is able to delineate mixing zones in rivers or to determine the transverse, vertically averaged concentration gradients downstream from a river outfall. It can transfer observed gradient of pollutants to a point downstream. This model is useful for designing or analyzing the results of river sampling programs. It can be used for any plan form such as meanders or any cross section.

- A method to accurately predict the behaviour of a surge wave after an ice jam breaks has been developed. The numerical model MOBED was used to analyze the behaviour of a field case study and it was found that the model provided a good estimate of surge speeds and water elevations. It also could be used to investigate the effect on the mobile bed. Subsequent tests in the laboratory confirmed that MOBED provides a very satisfactory analysis of surges with ice.

- A Frazil Ice Instrument has been developed after several years of work and a prototype instrument to measure frazil ice concentrations has been manufactured. It provides a means to make real progress in ice research and is highly significant for investigation of northern waters.

- A theory to predict the transfer of gas at the air-water interface has been developed which incorporates the effect of breaking waves. Data tends to corroborate the theory which is highly significant for understanding limnological processes as well as being of importance for global weather models. This fundamental study could have significant impact on air-water exchange models.

- A theoretical method to obtain the concentration of resuspended sediment by waves has been confirmed by laboratory tests. The model gives a time-averaged concentration as a function of depth, knowing the wave variables such as wave height, period, and mean water depth, and the sediment variables of grain size and specific gravity. This development is necessary to correctly predict transportation and sedimentation in lakes. Such knowledge is essential to evaluate the impacts of changing the water level of a lake and may be significant for calculations of chemical transfers between sediment and water.

TOXIC CHEMICALS

- A Special Issue of the Journal of Great Lakes Research dealing with the Niagara River-Lake Ontario Pollution Problem was published in June, 1983. Significant findings included evidence of apparent recent reduction in loading to Lake Ontario of several toxic organic chemicals and toxic metals; the presence of a suspended sediment enriched Nepheloid layer extending tens of meters above the bottom of Lake Ontario and possibly of significance to chemical recycling and persistence in the lake, and the concentrations of contaminants in various lower organisms which may control chemical bioaccumulation via food webs.

- Organotins and other organometallics were increasingly discovered in several Great Lakes media using analytical methods newly developed. The occurrence of diethyl-, triethyl-, and tetraethyllead in fish caught in contaminated areas was reported for the first time.
- Computer programs correlated bond strengths of toxic organic chemicals with toxicity data for lower organisms as part of the Structure Activity Correlation technique to assess the dangers of specific chemicals.
- Leeches which are common in Canadian rivers have been shown as potential biomonitors of toxic organic chemicals.
- 2,4-D was shown primarily to be photochemically degraded and that disappearance was rapid in experimental ponds.
- At the Niagara River inflow area of Lake Ontario, amphipods were shown to be active bioaccumulators of toxic organic chemicals.
- The photochemical degradation of the lampricide TFM, which was predicted from previous laboratory studies, was confirmed both in a field test pond and by sampling of a stream during TFM treatment.
- Suspended sediments taken from the North Saskatchewan River during a summer storm event indicate a complex set of sources and pathways for organic contaminants. Results show various contaminants have reached Tobin Lake with serious effects on the benthos.
- Toxic contaminants have compounded serious eutrophication problems in prairie lakes and have contributed to decimation of chironomid communities and other lower members of the food chain in Pasqua Lake, Saskatchewan.
- Processes of biogeochemical cycling of mercury species and its impact on the foodweb have been identified for Northern Manitoba Reservoirs.
- A very successful "First International Symposium on Toxicity Testing Using Bacteria" was held at NWRI on May 17-19, 1983. The emphasis of this Symposium was on the reliability, speed and cost effectiveness of microbial toxicity screening procedures. A method was developed for the separation of 22 isomers of tetrachloro-dibenzo-p-dioxins using narrow bore wall coated open tubular gas chromatography.
- Toxaphene methodology based on solid probe and selected ion monitoring has been developed. Up to 30 samples per day can be analyzed by this technique.
- The first lake sediment reference material for 6 chlorobenzenes and hexachlorobutandiene was completed.

LONG-RANGE TRANSPORT OF AIRBORNE POLLUTANTS

- The "target loading" of 20 kg/ha·yr of sulphate that has been accepted for the Canadian International negotiation for sulphur emission control was derived through application of the Thompson-Henriksen model developed within NWRI and adapted to the water chemistry data base of eastern Canada. While this "target load" must be considered as preliminary, it forms the basis for initiation of control measures to correct the environmental acidification concern.
- Variations in sulfur isotopes and in the Se/S ratios have been used to study the sources, dispersion pathways and ultimate sinks for the two elements in lakes of northern Ontario. The data obtained suggest that sulfur is relatively immobile in sediments and that the accumulation of excess sulfur reflects the increasing inputs of pollutant sulfur into the lakes.
- Studies on the paleolimnology of acid susceptible lakes (Kejimkujik Lake, Nova Scotia) indicate organic soils and bogs have controlled the acidity of this lake. Diatom evidence indicates the pH trend has been to a lower pH. An increase in alkalinity is reflected by the diatom assemblage for the period 1850 to 1950 as a result of deforestation and burning of lumber refuse.
- A sampler for use in measurement of toxic organics in precipitation was designed and tested.
- The release of acidifying ions from the snowpacks is dependent on the amount of rain and the rate of snowmelt.
- Microbiological studies of lakes receiving acid precipitation indicate that acidification of the lakes below pH 5.5 drastically affects microbial populations and organic matter degradation. Increased levels of organic matter in acid stressed lakes have been attributed to retarded microbial activity.
- Three interlaboratory quality assurance studies for laboratories contributing data to the Long Range Transport of Airborne Pollutants Program have been completed. Some US laboratories are now participating in these studies.

- An atlas of water chemistry data has been compiled with the aim of showing changes in Lake Ontario due to lake phosphorus management policies over the past 15 years. The spring concentration of soluble reactive phosphorus has decreased dramatically during the period of controls.
- A directory for the Global Environmental Monitoring System for water (GEMS/WATER) project which is part of the United Nations Environment Program was published. This directory contains the countries and laboratories that are participating in the project along with an inventory of the current station locations.
- A guide to the relationships between sediments and water quality was published in a form of a technical paper by UNESCO, as a contribution to the International Hydrological Programme.
- A quality assurance program for the Prairie Provinces Water Board laboratories was initiated. Twelve interlaboratory comparison studies were compiled.

DIRECTOR'S OFFICE

SENIOR SCIENTIST

Dr. R.A. Vollenweider, the Senior Scientist of the National Water Research Institute, has continued to provide leadership in international activities. Sponsored by PAHO (Pan American Health Organization) he has visited Ecuador, Brazil, Colombia and Mexico, where he lectured in courses organized by countries and co-sponsored by CEPIS (Centro Panamericano de Ingenieria Cientifica y Cientias del Ambiente, Peru). The objective of these courses was to familiarize sanitary and civil engineers, as well as university graduates, with the problem of eutrophication and water quality in lakes and reservoirs, and techniques of rehabilitation and prevention. Course attendance was normally between 25 and 50 participants from a majority of Latin American countries.

Further to this, he assisted CEPIS in developing a Latin American cooperative project on "Eutrophication in Warm Water Lakes and Reservoirs", and has advised national government institutions on lake and reservoir management (Poza Honda Reservoir, Ecuador; Lago Paranoa, Lago Santa Maria, Lago Descoberto, Brazil; Lago Tota, Colombia; Lago Chapala, Lago Cajititlan, Lago Zirahuen, Lago Patzcuaro, Lago Tequesquitengo, Mexico).

Further, Dr. Vollenweider has been invited by the Swedish Environment Protection Board as member of an international board to review and advise on eutrophication studies in the Baltic Sea, and by the Wahnbach Reservoir, Germany, authorities to advise on studies in that reservoir. He has assisted UNESCO on production of a Eutrophication Manual, and was chairman of a review workshop on "Results and Problems of the OECD Cooperative Programme on Eutrophication". He was also invited as discussion leader of the Closing Session of the conference on "Lake Léman Rehabilitation" at Geneva, co-sponsored by Switzerland and France, and as Session Chairman of the conference on "Chemical Processes in Lakes", Stans, Switzerland, organized by EAWAG, Dübendorf. He lectured at the University of Uppsala, the Swiss Federal Technical High School, and the Institute of Hydrobiology, Pallanza, Italian National Research Council. Also, he chaired the first and took part as a member of the second Inter-regional Review meeting for GEMS/WATER, under the responsibility of WHO, and contributed to the final reports.

In recognition of his international leadership in eutrophication studies and management, he has been given the Award of Excellence by the Rawson Academy of Aquatic Science, and has been proposed as a nominee for the Tyler Prize in Ecology.

SCIENCE LIAISON OFFICE

This office was set up in August 1981 to assist the Director of NWRI in promoting the efficiency, effectiveness and relevancy of NWRI's Water Management Research. The office co-ordinates the Institute's multidisciplinary research program; participation in Environmental Impact Assessments, subventions programs, and committees; and public information.

The office was instrumental in the formulation and operation of a comprehensive Study Planning System. To facilitate research planning, the Institute is guided by a detailed Study Planning Manual and a computerized budget plan including information on national programs, support services, external funding programs, shadow costs, and operational research needs. A system has been developed which solicits "research needs" from the operational components of Inland Waters Directorate to guide managers and scientists in planning their research activities. The system identifies Operational Contacts for research studies that are of direct interest to IWD Operational components. This is to formalize interaction among operational and research staff.

HABITAT STUDIES

After a major absence of most stocks of lake trout from the Great Lakes during the past 30-40 years, due to the combined effects of over-fishing, lamprey predation and contaminants, there appear to be problems in achieving successful reproduction by hatchery stock introductions. The reasons for this are not clear but may relate to one or more of the following hypotheses: Habitat has been degraded, threshold trout densities have not been met, natural behavioural patterns are not yet properly re-established, it is too soon to tell what is responsible for the lack of natural reproduction.

Field observations in many parts of the Great Lakes, and inland lakes, indicate that active cobble-gravel beaches, coarse lag deposits, and talus slopes and irregular bedrock surfaces may all serve as spawning substrates. In most inland lakes, spawning takes place in shallow water (1-2 m); in the Great Lakes it may occur at depths as great as 30 m. Shallow water spawning occurs when fall temperatures drop to about 10°C. Deep water spawning is often below the thermocline and may occur in late summer (Lake Superior) or early fall (Seneca Lake).

Egg predation (particularly by fish and crustanceans) is high, during and immediately after spawning. Eggs, which fall into suitable substrates, swell and harden and become wedged between pebbles; during their incubation period they are very sensitive to movement and, therefore, further losses will occur if the substrate is not stable. Development during early stages of embryogenesis is easily disrupted by temperature shocks and by detrital accumulation. Embryo development is largely temperature controlled and, therefore, early hatches (shallow water) can be expected during short/warm winters, and late hatches following long/cold winters. Although egg-sac absorption provides a nutrient source for early stages of fry development, suitable forms of plankton must be available in sufficient concentrations to allow fry to complete the switch to exogenous feeding.

Substrates for deep water (sub-thermocline) spawning are not available in Lake Ontario, and studies of nearshore temperature data suggest that, because of rapid and extreme temperature changes during the fall overturn (Fig. 1), much of western Lake Ontario is frequently unsuitable for shallow fall spawning by lake trout (ripening is adversely affected by major temperature fluctuations). Temperature regimes are more suitable in the eastern part of the lake, and there is evidence that some natural reproduction by introduced stocks has occurred here. The numbers of observed spawning fish, however, are small and, therefore, the effects of predation are high. At sites where spawning has been observed, the fish appear to be using active (clean) cobble-gravel as a preferred spawning substrate. Because of the effects of fall storms and ice-movement it

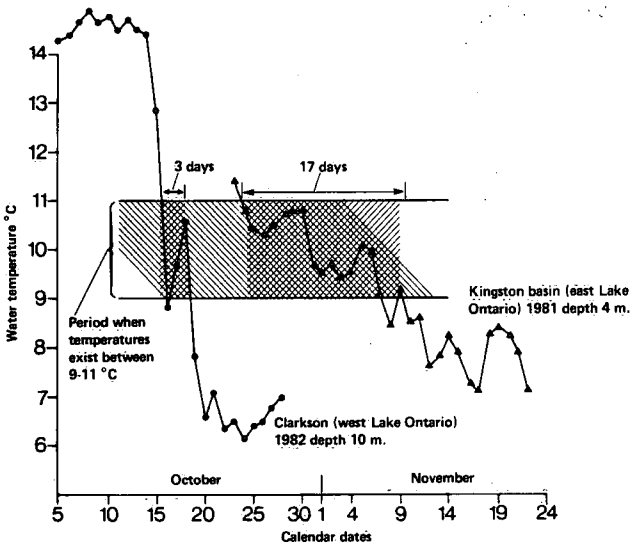


Figure 1 Lake Ontario temperature data showing extended period of 11-9°C water temperatures at the eastern end of the lake.

is likely that egg losses, during the incubation period, are high. Coarse substrates, at depths below wave disturbance, would seem to offer a better chance for egg survival but, because of the presence of aquatic weeds (often cladophora and milfoil), many sites, which formerly were used by lake trout (historical documentation), appear to have become degraded.

In Lake Ontario, therefore, it is probable that restoration of selected substrates and further improvements in near-shore water quality (and possible local weed removal) will increase the chances for successful reproduction by introduced stocks of lake trout.

WHO COLLABORATING CENTRE ON SURFACE AND GROUND WATER QUALITY

In October 1974, the Canada Centre for Inland Waters was designated by the World Health Organization as its Collaborating Centre on Surface and Ground Water Quality (WHO/CC). The main function of the WHO/CC is (i) coordination of international technical assistance programs to the developing countries; and (ii) representation of Canada's freshwater interests in international forum.

In January 1976, the WHO/CC had initiated the publication of a quarterly journal WATER QUALITY BULLETIN, devoted to reviews of water management practices around the world. Furthermore, as of January 1977, the WHO/CC has assumed the responsibility of coordinating the establishment of a world-wide network of water quality monitoring stations on major rivers, lakes and aquifers around the world. The network is an integral component of the United Nations Global Environmental Monitoring System (GEMS). The main objective of this program is monitoring long-term trends in environmental pollution.

GEMS/WATER. By the end of 1983, over 200 000 data points had been reported by 435 monitoring stations located in 58 countries. To evaluate such data a group of international experts met at NWRI in July 1983. (Fig. 2) Its conclusions and recommendations are contained in a report entitled GEMS/WATER Data Evaluation Report 1983.

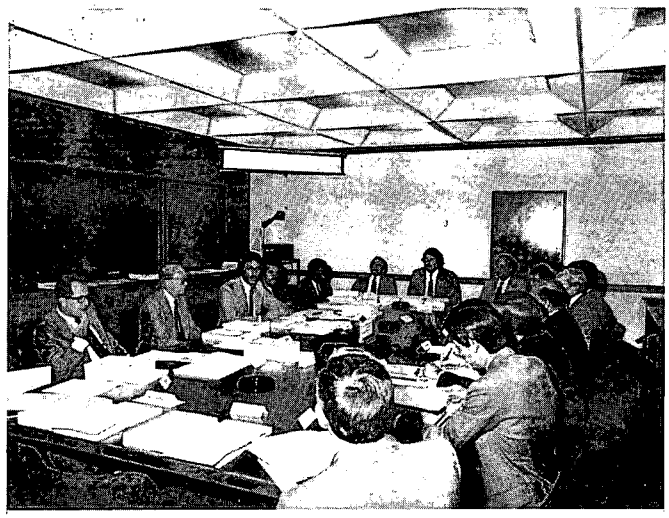


Figure 2 Participants at the GEMS/WATER Interregional Review Meeting at NWRI, October 17-21, 1983.

To review and act upon the recommendations of the group of experts, an Inter-Regional Review Meeting on Water Quality Monitoring Programs was held at NWRI in October 1983. The meeting, chaired by Dr. S. Barabas, was attended by official representatives of the six world regions and the participating U.N. agencies (WHO, UNEP and WMO).

The meeting agreed on the following:

1. *Networks* — (i) to add more river baseline stations to the network, particularly from the dry and humid tropics; (ii) to broaden the representativity of the rivers discharging into the oceans by raising its coverage to about 54% of all rivers; and (iii) to broaden the representativity of the world's lakes by establishing monitoring stations in 23 additional major lakes and reservoirs.

2. *Variables* — A revised list of water quality variables (formerly determinands) has been developed. The following variables have been dropped: MBAS, non-ionic tensides (detergents), Ni, Ba, Li, volatile suspended solids, total dissolved solids, Mirex, phytoplankton counts and volume, and primary production. The following variables have been added: TOCl and Al in acidified waters. Only the following elements can be reported as both dissolved and total concentrations: As, Cd, Cr, Cu, Fe, Hg, Mn, Pb, Se, and Zn.

3. *Study Projects* — The meeting agreed that the program can greatly benefit by undertaking additional studies which may include field work and/or synthesis of existing information on some problems previously identified. The following investigations have been suggested. (i) Review of the water quality-quantity relationships particularly in the wet and dry tropics in order to optimize the sampling frequency. (ii) Study of river sediments as a carrier of pollutants. (iii) Study of deposited sediments in lakes used as a record of water quality trends (e.g. for nutrients and trace metals(s). (iv) Identification of algae which can release toxins in waters.

Other important problems have been identified but will not be considered in the program since they are or will be studied in other major projects. These are the effect of acid precipitation on freshwater resources, the contamination of groundwaters by refuse dumps, and the generation of toxic organics through chlorination.

4. *AQC Training Course* — The first official GEMS/WATER Regional Training Course on analytical quality control (AQC) was held in Sao Paulo, Brazil during the period 2-13

May 1983. The course sponsored by WHO/PAHO and the Brazilian Government was hosted by the State of Sao Paulo Corporation CETESB. There were some 30 participants of which one half came from cities and towns from across Brazil and the other half from the following Latin American countries: Argentina, Chile, Colombia, Equador, Mexico, Peru and Uruguay. Dr. Barabas of the WHO/CC participated in the development of the course program and gave the introductory lecture at the course.

WATER QUALITY BULLETIN. Four quarterly issues of the Bulletin, in separate English and French editions, were published as scheduled. They were devoted to the following themes: (1) Water Around the World - Part 2; (2) Acid Precipitation - Part 1; (3) Acid Precipitation - Part 2; and (4) Wastewater and Hazardous Wastes Management. In all, 42 articles were published, written by 58 authors from the following 23 countries: Australia, Belgium, Canada, Denmark, Hungary, Italy, Japan, Kenya, Kuwait, Malaysia, Netherlands, New Zealand, Norway, Philippines, Poland, Rumania, South Africa, Sweden, Switzerland, United Kingdom, USA, USSR and Yugoslavia. The two issues of the Bulletin dealing with acid precipitation were particularly noted for their timeliness. It might be of added interest the increase in the number of pages published: from 196 pages in 1982 to 252 pages in 1983, or by over 28%.

Foreign Visitors and Consultants Abroad. During the year, study and discussion programs for 16 visitors from the following 12 countries were organized: Colombia, Egypt, France, Germany (FRG), India, Japan, Kenya, Peru, Switzerland, Tanzania, U.K., and U.S.A. Moreover, a water quality engineer from Tanzania was received at NWRI for a 2-month training period. Furthermore, several requests by WHO regional and national offices for Canadian consultants abroad were processed.

Technical Assistance. Inquiries received from around the world, particularly from the developing countries on different aspects of problems of water management, have been responded to.

STAFF LIST

Director — Dr. G. Keith Rodgers
Secretary — Mrs. M. Stapleton
Receptionist — Mrs. D. Burford

Science Liaison Officer	Mr. D.A. Bondy
Senior Scientist	Dr. R.A. Vollenweider
Assistant	Miss L. Janus
World Health Organization/CC/SGWQ	
Manager	Dr. S. Barabas
Secretary	Mrs. N.J. Clegg
Glenora Fisheries Research Station	
Scientist	Dr. P.G. Sly
Secretary	Mrs. M. Stephen

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- IWD Research Subventions Committee
- Water Research Advisory Committee
- Canada-Ontario Rideau Trent System (CORTS)

Dr. R.A. Vollenweider

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- Departmental Committee for the Scientific Research Group
- Advisor to CEPIS/PAHO, Lima, Peru on "Latin American Cooperative Programme on Eutrophication in Warm Water Lakes and Reservoirs"
- Fellow, Rawson Academy
- Editorial Board of "Memorie dell'Istituto Italiano di Idrobiologia", Verbania-Pallanza, Italy
- Editorial Board, WHO "Water Quality Bulletin"
- Review Board, GEMS/WATER Data Evaluation — Chairman
- Scientific Advisory Committee "Cervia Ambiente", Italy
- Advisory board, Expert Group on Marine Eutrophication, to the Research Committee of the National Swedish Environment Protection Board

Dr. P.G. Sly

- Editorial Board, "Canadian Research"
- Editorial Board, "Canadian Geotechnical Journal"
- International Association Great Lakes Research — President
- Lake Ontario Working Group, Great Lakes Fisheries Commission
- Committee on Lake Trout Research, Great Lakes Fisheries Commission

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AQUATIC ECOLOGY DIVISION

The Aquatic Ecology Division is involved in the solution of the problems associated with environmental degradation of Canadian waters due to eutrophication, acidification, and infestation by aquatic weeds, with the objective to contribute to the management of their quality.

The Aquatic Ecology Division is organized in three multidisciplinary sections: Ecological Impact, Great Lakes Rehabilitation, and Nutrient Pathways.

ECOLOGICAL IMPACT SECTION

The major area of research of the Ecological Impact Section has been related to acidification of lakes with emphasis upon the long-range transport of atmospheric pollutants. Studies have emphasized sulfur isotopes as tracers of acid rain; metal deposition from such sources as mining and smelting activities at Sudbury and Atikokan, Ontario and Rouyn-Noranda, Quebec; the use of diatoms as indicators of the acidification history of lakes and the impact of acidification on the carbon cycle in lake sediments. Other areas of research by section members include the impact of peat mining upon aquatic ecosystems; the application of statistical methodology to limnological problems; organic geochemistry of Great Lakes sediments; indicators of climatic change, and impacts of coal-fired power plants on the environment.

Acid Rain Studies. Analysis of sediments and suspended particulates from a number of lakes in the area of Sudbury are being carried out to determine the degree to which they record ecological changes. Naturally occurring hydrocarbons, fatty acids, alcohols and sterols (geolipids) were found to be conservative with respect to organic carbon. Thus, distribution changes for the geolipids in the sediments may be used to indicate environmental changes in the lakes. Organic carbon and geolipid contents from surficial sediments of ten lakes correlated inversely with pH. These results are consistent with studies which show decreased microbial activity in lakes of lower pH. Detailed GC and GC/MS analyses are underway which will give more specific information on ecological changes and on the cycling of organic matter in these lakes. (*Bourbonniere*)

The present-day and historical inputs of heavy metals into the lakes of the Algonquin Provincial Park areas of Ontario have been assessed. Lake water, particulate matter and sediment cores were collected in this area and analyzed for Pb, Zn, Cu, Ni, Cd and other trace pollutants.

The sedimentary profiles for Pb, Zn and Ni demonstrate the impact of atmospheric input as a result of long-range transport of materials. There has been rapid increase in Pb burdens of the atmosphere in the past 50 years and the sedimentary record in these remote lakes documents the great intensity of Pb input into the park ecosystem. The Zn profile clearly indicates a 2-fold enrichment in the surficial sediments compared to the precolonial levels. Also, similar Zn profiles are observed in the Adirondack and New England Lakes confirming that the introduction of Zn is a regional atmospheric phenomenon. The precolonial concentration of Ni in the Algonquin Lake sediments is close to the crustal abundance, compared to approximately a 2-fold enrichment of Ni in the surficial sediments. With only 90-120 km separating the Sudbury smelter stacks and the Algonquin Lakes, the possibility that most of the excess Ni is derived from Sudbury cannot be discounted.

Metal flux rates from sediment trap experiments were observed to increase with water depth. Large difference in flux between surface and bottom traps are most likely to be caused by resuspension of bottom sediments. Metal flux rates from May to June were 0.9-2.6, 0.8-3.2, 4.0-12.2, 5.5-36.0 and 3.5-24.0 mgM^{-2} day^{-1} ($x10^2$) for Cu, Ni, Pb, Zn and Fe respectively. A comparison of spring and summer particulate metal fluxes with annual values from recent sediments (Pb-210 dated) and the estimated atmospheric input suggest that a major portion of the pollutant metals is being transported, exported and deposited during the warmer months when the lakes are not ice covered. (*Wong & Nriagu*)

Variations in sulfur isotopes and in the Se/S ratios have been used to study the sources, dispersion pathways and ultimate sinks for the two elements in lakes of northern Ontario. The data obtained suggest that sulfur is relatively immobile in sediments and that the accumulation of excess sulfur reflects the increasing input of pollutant sulfur into the lakes. This implies that sulfur and selenium in sediments represent potential tracers for recent changes in the composition and acidity of rainfalls in northern Ontario. (*Nriagu*).

Studies continued on the paleolimnology of acid susceptible lakes. Results from Kejimkujik Lake, Nova Scotia, indicate organic soils and bogs have controlled the acidity of this lake. Diatom evidence indicates the pH trend has been to a lower pH. An increase in alkalinity is reflected by the diatom assemblage for the period 1850 to 1950 as a result of deforestation and burning of lumber refuse. Results from the headwater lake (Batchawanna) part of the Turkey Lakes system indicate several diatom species which are acidiphilous or acidobiontic. Species such as *Tabellaria flocculosa, Surirella delicatissima, Eunotia flexuosa,* and *Actinella punctata* are tolerant of low pH. The establishment of a beaver dam around 1400 A.D. had the effect of altering the floral assemblage as indicated by the presence of *Nitzschia amphibia*. (*Delorme*)

Peatlands Development and Conservation. The use of peat combustion for energy production is receiving renewed interest. Large power plants, up to 600 MW, exist in Finland and the U.S.S.R., while smaller scale operations occur elsewhere.

Canada is estimated to have the largest peatland acreage in the world, 170×10^6 ha. The major Canadian peat reserves are found in Ontario with an estimated 26×10^6 ha; 9.9×10^6 ha occurs south of the permafrost line.

Since peat needs a water content of 50-55% for combustion, one tonne of peat dried to this moisture content would release four tonnes of water to nearby aquatic ecosystems. Two major areas of environmental concern are apparent: (1) the impact of peat "mining", and (2) the impact of peat combustion.

Peat extraction, using conventional technology, requires drainage of peatlands followed by dewatering. In general, such discharge waters are low in pH, high in colour, aluminum, mercury, nitrogen, and phosphorus, i.e. similar in composition to lakes subjected to acid rain problems. There also has been some observations that water discharging from exploited peatlands has impaired fish spawning, both in the U.S. and Nova Scotia (salmon). As for combustion, peat is similar in potentially toxic metal concentration to coal, but sulfur is lower.

In 1983, studies began on the potential impact of such drainage waters upon receiving water bodies including lakes and streams. Sampling occurred in Nova Scotia, Quebec and Ontario to obtain peat and drainage water from contrasting sites. Initial work on organic compounds includes isolation of hydrophobic and hydrophilic acids. Naturally occurring constituents of bog plants are being surveyed to aid in determining sources of organics found in peat and drainage water. (*Glooschenko, Bourbonniere*)

Atmospheric Transport of Pollutants. Mining and smelting activities can result in the atmospheric transport and deposition of potentially toxic elements such as metals, arsenic, and selenium. Monitoring of deposition of these substances can be done by analysis of lower vegetation collected at various distances from sources.

At the present time, a coal-fired electrical generating station is under construction at Atikokan which is scheduled to go on line in the winter of 1984. A baseline study has begun in which replicate samples of *Sphagnum fuscum* moss and leaves of the low shrub *Chamaedaphne calyculata* have been collected from 5 bog sites. In addition, forest floor litter was collected at two sites. These have been analyzed for potentially toxic metals and sulfur. The same sites will be resampled for several years after the plant begins operation to determine if the plant significantly increases atmospheric metal deposition in the area. (*Glooschenko*)

Sphagnum moss was also collected at varying distances from two iron-mining and processing centres in northern Ontario — Atikokan and Sudbury — and analyzed for Fe. All samples were collected in ombrotrophic bogs which receive chemical inputs strictly from atmospheric deposition.

Mosses from the Atikokan area had elevated concentrations of Fe up to 7352 mg kg^{-1}. Atikokan, a mining and ore-processing centre caused elevated Fe levels up to 50 km distance from the town, while Sudbury exhibited a greater influence due to the tall stack there. At Sudbury, levels ranged from 2478 mg kg^{-1} near the town to 382 mg kg^{-1} in remote sites. Results from these moss analyses were similar to those obtained from direct precipitation sampling of other authors. (*Glooschenko*)

The Noranda copper smelter in Rouyn-Noranda, Quebec is a major source of SO_2. Heavy metals and other elements occur in sulfide ores which when smelted, emit large amounts of heavy metals associated with the ores into the atmosphere. A study was made to assess metal distributions due to atmospheric deposition, and runoff from mine tailings on lakes in the area. Sediment cores were collected from lakes in the study area for metal analysis. Enrichment factors were calculated for lake sediments (Fig. 1). Such cores exhibited high metal loadings in the top 7 cm of sediment of Cu, Zn, Fe, Pb and Mn in lakes near the smelter, lower levels were found in lakes further away within a 70 km radius. Metal loadings were attributed to a variety of sources including mine tailings, land runoff, and aerial deposition. Enrichment factors for heavy metals, when compared with those of Lake Erie, were greater and varied from 10X to 500X, particularly for Cu, Fe, Zn and Cd. The surface water analysis from lakes within 10 km radius exhibited high sulfate, calcium, magnesium and sodium when compared with other regional lakes. The elevation in calcium may be attributed to the liming of mine tailing ponds in the area with subsequent lake water contamination through spring runoff or streams. (*Arafat*)

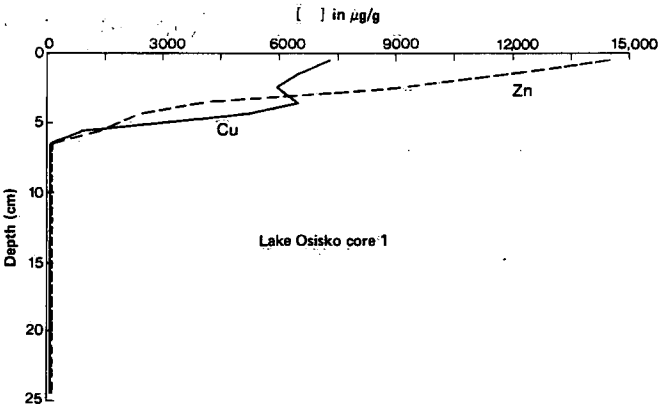

Figure 1 Distribution of zinc and copper with depth in a core from Lake Osisko at Rouyn-Noranda. Note enrichment of these elements at 6 cm depth corresponding to beginning of smelter operation.

GREAT LAKES REHABILITATION SECTION

The Great Lakes Rehabilitation Section continued research on topics related to the Canada-U.S. Agreement on Great Lakes Water Quality. These topics included the chemical and biological response to lake management, the movement of nutrients and contaminants, the distribution of bottom dwelling organisms, the storage mechanism of nutrients in sediment and the distribution of aquatic macrophytes in response to nutrient loading.

Lake Erie. Eutrophication in Lake Erie has been one of the dominant themes of the research of the Great Lakes Rehabilitation Section. New technologies have been used to monitor the response of summertime oxygen depletion to nutrient loading reduction. Development and construction of oxygen profiling equipment began in 1980 and has resulted in the use of a prototype system in surveys of Lake Erie during 1983. The new equipment uses electronic sensors and a microcomputer to control the lowering winch, interpret the signals, and record the data on diskettes. In addition to reducing labor costs and reducing transcription errors, the profiler reveals details of oxygen/temperature stratification which could not be sampled adequately with previous bottle techniques. The oxygen profiles are displayed on the screen of the microcomputer as the sensor is lowered and are later printed so a hard copy of the information is produced instantly (Fig. 2). (*Charlton*)

Total phosphorus loading to Lake Erie has been decreasing since 1968. To determine how the lake concentrations responded to loading decreases, survey data from 1968 to 1981 were plotted to show concentration changes in the Central Basin (Fig. 3). The total phosphorus concentrations for the uppermost layer under stratified conditions and otherwise, for the whole water column were averaged for each station in the Central Basin during the whole year. The loadings decreased by 1170 $\pm$ 130 tonnes yr^{-1}, while the lake concentrations decreased at a rate of 0.57 $\pm$ 0.11 $mg.m^{-3}yr^{-1}$, from 1968 to 1981. This means that for every 1000 tonnes of phosphorus removed from annual loadings, the concentrations in the lake decreased by approximately 0.5 $mg.m^{-3}$. (*Rosa*)

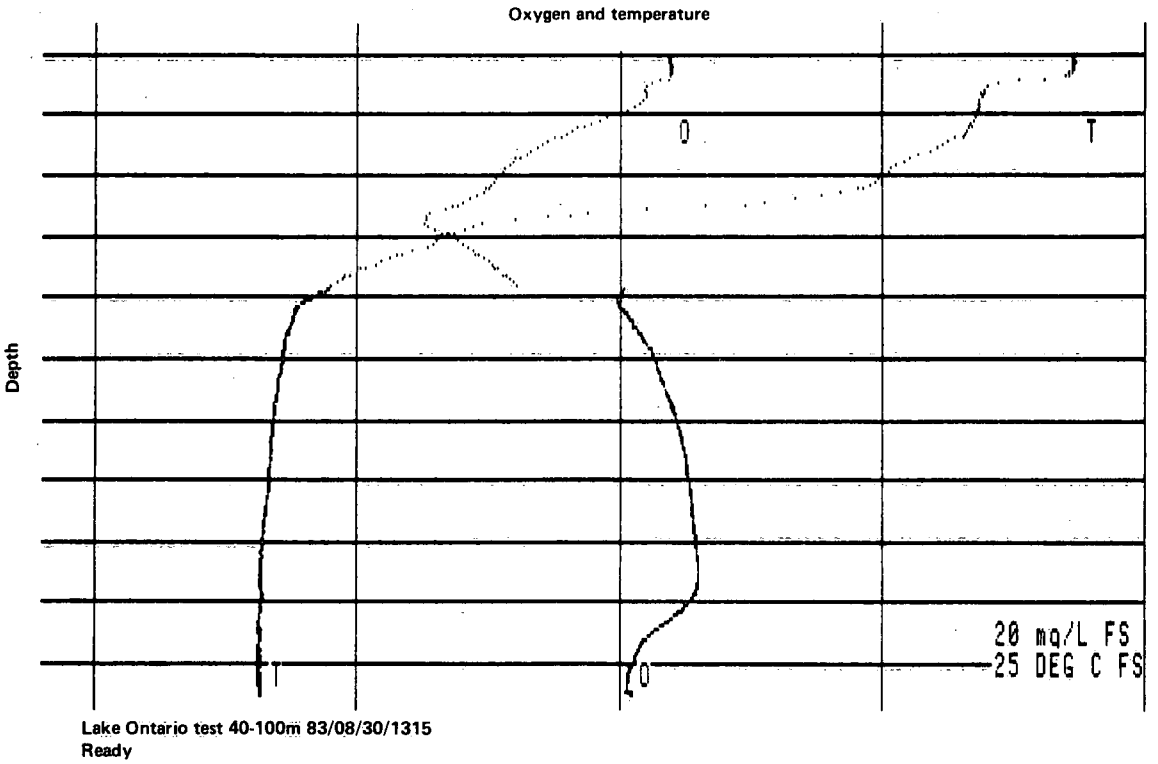

Figure 2 Oxygen and temperature profiles measured with a digital oxygen profiler.

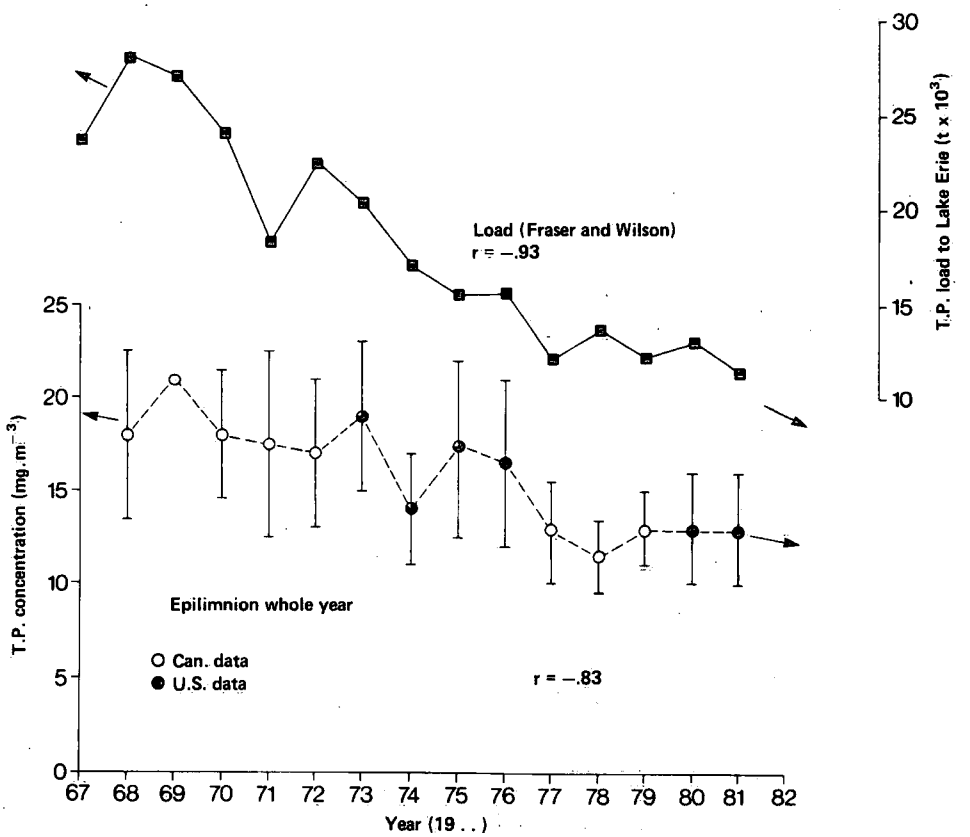

Figure 3 Lake Erie, central basin changes in phosphorus loadings and open lake phosphorus concentrations during the last 15 years. Arrows indicate the ends of trend lines through the data.

Water Quality Trends. The water chemistry of the Great Lakes has been monitored for the past 15 years. The purpose of the monitoring has been to detect any unacceptable conditions and to follow the response of the lakes to environmental controls imposed in the early 1970s. Due to phosphorus controls at sewage plants, the concentration of soluble reactive phosphorus was expected to decrease in the lakes. An atlas of water chemistry data has been compiled with the aim of showing changes in Lake Ontario due to lake management policies. The spring concentration of soluble reactive phosphorus has decreased dramatically during the period of controls. The Atlas also revealed seasonal cycles of water chemistry parameters and time-depth diagrams of the concentration of biological indicators such as chlorophyll. (*Dobson*)

The movement of particles carrying nutrients and contaminants was studied with sediment traps in Lake Ontario. These studies resulted in three reports on the movements of material loaded from the Niagara River and resuspended from the bottom of Lake Ontario. The study of the fate of Niagara River inputs was extended to the whole lake area in 1983. Results indicate that there is much resuspension of bottom sediments which may enhance the availability of nutrients and contaminants in the lake. (*Charlton, Rosa*)

Phosphorus Availability. Phosphorus storage in lake sediments delays the response of lakes to increases and decreases in phosphorus loading. Knowledge of the exact form of phosphorus which is both regenerated from sediments and absorbed by algae is important to understanding lake response to management actions. Most of the phosphorus in sediment entering lakes is in the form of "apatite" which is not available for algal growth. The non-apatite inorganic phosphorus (NAIP) fraction contains bioavailable forms and these are being investigated by chemical extraction and Mossbauer spectroscopy methods. Chemical extraction reveals the amount of NAIP while spectroscopy provides information on the type of iron-phosphorus compounds which comprise NAIP. The combination of the two methods shows that sediment NAIP is largely related to oxygen sensitive iron (Eh-sensitive Fe^{3+}) with a background portion related to other chemically resistant iron compounds. The oxygen sensitive iron-phosphorus compound is likely phosphate-iron-hydroxide. Another widely used way to estimate bioavailable phosphorus is with O.I.M. NaOH. NaOH-extractable phosphorus does not correlate as well as NAIP to Eh-sensitive Fe^{3+}. (*Manning*)

Aquatic Weeds. Eurasian watermilfoil (*Myriophylum spicatum*) is a nuisance aquatic plant currently infesting many recreational lakes in Canada. Environment Canada's research has concentrated on assessing the long-term impact of harvesting on milfoil regrowth and attempting to determine the mechanism behind the decline of milfoil in several lakes in Ontario. A harvesting experiment is in its third year and the growth in the harvested plot has been reduced to a quarter of the control area. Laboratory experiments have indicated that the high sediment levels of hydrogen sulfide and ammonium and low levels of iron are not responsible for a decline in milfoil biomass which has been observed in several lakes in Ontario in recent years. A further experiment is necessary to test the effect of low sediment porewater phosphorus. (*Painter*)

Cladophora research is now concentrated on examining the nearshore environmental conditions along the north shore of Lake Ontario that affect *Cladophora* growth. A computer simulation model was used to assess the growth potential of various sites. The model inputs are temperature, turbidity, and phoshporus and the outputs are tissue phosphorus, phosphorus uptake, net and gross photosynthesis and biomass. The model will be used to evaluate the importance of local nutrient inputs compared to the nutrient supply in open lake water. Figure 4 illustrates a typical output from the model. The inputs were temperature, turbidity and phosphorus for the 1981 summer at Port Credit. The model output is the seasonal phosphorus uptake and tissue phosphorus concentrations of *Cladophora*. Tissue phosphorus concentrations above 0.13% are widely believed to be optimum for growth. Therefore, the Port Credit area appears to be ideal for *Cladophora* growth. (*Painter, Charlton*)

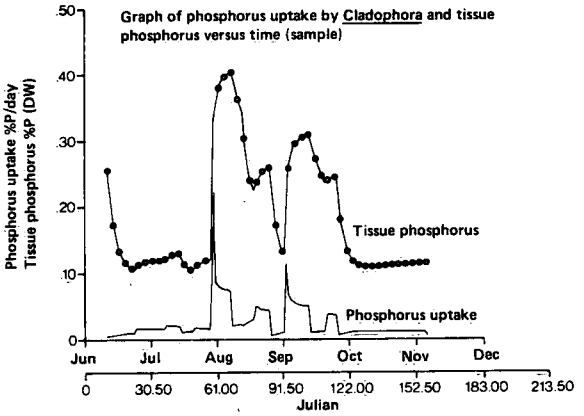

Figure 4 Changes in phosphorus uptake and tissue phosphorus of Cladophora predicted by computer model for a site at Port Credit, Lake Ontario.

NUTRIENT PATHWAYS SECTION

The Nutrient Pathways Section continued to concentrate on understanding the complex interrelated processes of nutrient availability (or limitation), algal growth (and biomass), nutrient regeneration, dissolved organic substances (their presence and defining their roles in the environment), zooplankton grazing, and lake restoration methods.

Microbiology. Chroococcoid cyanobacteria (0.7-1.3 m in diameter) were discovered to be a significant component of the Lake Ontario plankton. Using epifluoresent microscopy, the densities of these microorganisms were found to vary by 4 orders of magnitude with a single large abundance peak (6.5×10^5 cells mL^{-1}) corresponding to the time of maximum water temperature (15°C). Figure 5 illustrates this seasonal pattern and how the organisms are correlated to temperature. The Chroococcoid cyanobacteria consituted 10% of the bacterial numbers in the epilimnion during its peak abundance, approximately 40% of the biomass of prokaryotes 2.0 m, and 30% of the biomass of all microorganisms 20 m in size. Cyanobacteria observed in the food vacuoles of heterotrophic microflagellates and in the guts of rotifers suggest that these organisms may be important consumers of this prokaryote population. (*Lean*).

In a combined AED-AMD project, the effect of low pH stress (acid rain stress) on lake bacteria was shown to in-

volve both physiological and structural adjustments by the bacteria. The bacteria in lakes with decreasing pH levels (pH 7 to pH 4), showed progressive changes in (1) their surface structure, (2) their respiration rate, and (3) their physiological capacity to decompose organic substrates. Exposing a pure lakewater bacterial culture to increasing pH levels, we discovered that the bacterial surface structure could be used as an indicator of acid stress levels. By photographing a high-resolution electron microscopic image of the surface of a stressed bacterial cell, one can record diagnostic structural features which indicate the external pH. (*Leppard*)

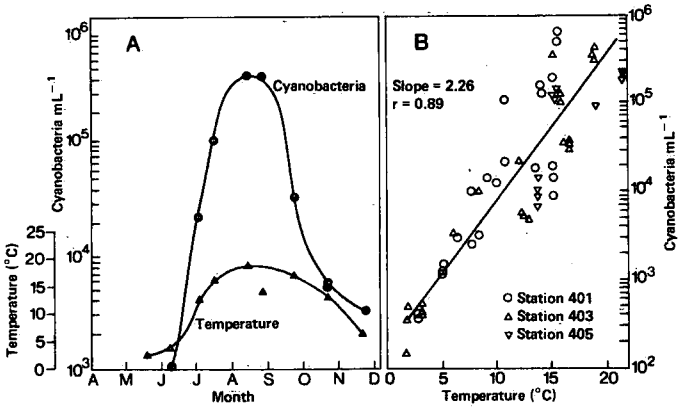

Figure 5 Chroococcoid cyanobacteria in Lake Ontario. (A) Seasonal pattern in 1982. (B) Correlation of Chroococcoid cyanobacterial abundance at all tested stations as a function of temperature.

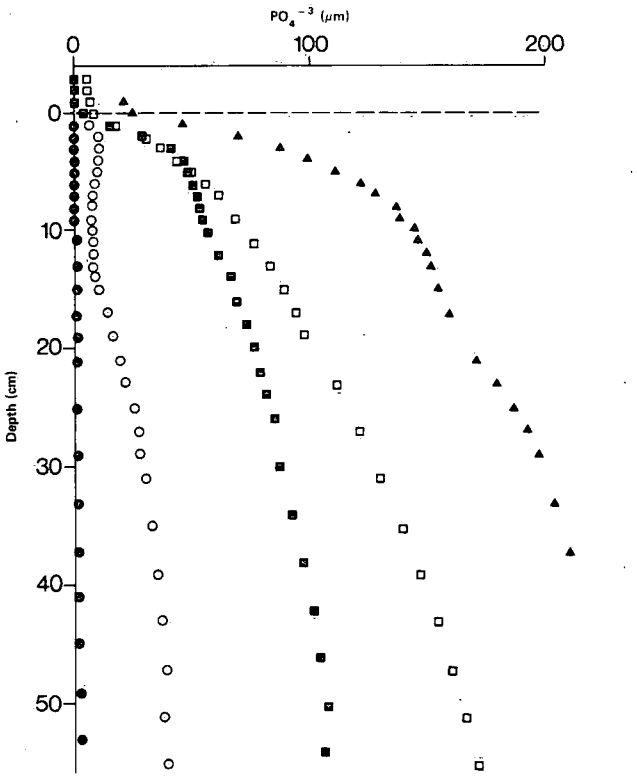

Figure 6 Concentration profiles PO_4^{-3} in Jacks Lake sediments at various water depths. 4m (●), 10m (○), 15m (■), 18m (□), 21m (▲).

Internal Nutrient Loading. After the phosphorus loading to lakes is reduced, there is sometimes a delay in the predicted rate of improvement which is caused by internal loading of phosphate from the sediments. The extensive literature on the influence of oxygen in forming a redox boundary at the sediment water interface suggests that, in the presence of oxygen, iron compounds would reduce internal loading. Throughout the world there have been a number of experiments where oxygen or air has been added to the hypolimnion in the hope that internal loading would be reduced and iron compounds in the anaerobic water would precipitate the soluble phosphate making it biologically unavailable. Unfortunately, the success rate in lake restoration using this technique has been only about 60%. In a carefully controlled experiment at Lake St. George, the explanation for the low success rate was discovered. In lake sediments where hydrogen sulfide is produced, all the iron available for phosphate complexation is permanently immobilized. Aeration under these conditions has little effect. Only by the addition of iron will aeration provide the reduction of algal biomass.

In an attempt to measure internal loading rates from lake sediments, pore water peepers were positioned in the muds of Jacks Lake. Using these diffusion chambers, the diffusion rates for many substances can be determined (phosphate, iron, manganese, carbon dioxide, methane, hydrogen sulfide, ammonium, etc.). Concentration profiles for PO_4^{-3} are shown for several water depths in Figure 6. In the one basin PO_4^{-3} input rates varied considerably with depth but the predicted rate, from diffusion calculations, was close to the actual measured input from the hypolimnion. Internal loading was found to be the major mechanism which influences the vertical stratification of elements during summer stratification. (*Carignan, Lean*)

Nutrient Manipulation. The weathering of phosphate minerals and cattle feedlots are both uncontrollable sources of nutrients in the south central interior of British Columbia. In several sites the eutrophication of lakes results in fish kills and large algal blooms. We resolved to determine why some lake restoration projects in the dry interior of British Columbia are unsuccessful, and to develop a new lake restoration technique, lime addition. Our studies were done in collaboration with the B.C. Fish and Wildlife Branch and the Pacific and Yukon detachment of NWRI. We have confirmed our earlier observations that carbonate lakes have too little reactive iron for lake aeration to precipitate ferric phosphate. In carbonate lakes, lake aeration probably cannot precipitate phosphate. We have observed in several hardwater lakes a highly variable amount of phosphate coprecipitation with calcium carbonate. We enhanced this natural reaction in one naturally eutrophic lake with 23 tonnes of lime. The lime application to Frisken Lake removed 97% of the phosphate and 80% of the chlorophyll *a* from the epilimnion. In the hypolimnion, the decomposition of the algae reduced the pH and much of the precipitated phosphate-carbonate complex redissolved. *Daphnia* were not killed by the lime, and they appeared to move into a zone of intense heterotrophic activity in the hypolimnion. When the top of the hypolimnion mixed with the alkaline epilimnion, 50% of the phosphate in the lake precipitated to the sediments. Because the initial mixing had consumed the excess alkalinity, further mixing of the hypolimnion had no effect on phosphate solubility. (*Murphy*)

In collaboration with DFO-Freshwater Institute, Winnipeg, field experiments with snow clearing on Rock Lake, Manitoba were completed and the feasibility of using this method to improve dissolved oxygen conditions was

evaluated. Verification of previously proposed summerkill and winterkill predictive models was also finalized. (*Barica*)

Bioavailability. One of the Section's mandates is to study the bioavailability of phosphorus. The main reason why this is so important is because we cannot accurately measure the concentration of orthophosphate in lakewater. Limnologists have to resort to terms such as soluble reactive phosphorus (SRP) to identify the fraction of the phosphorus in lakewater which is measured by the standard chemical test (Murphy-Riley procedure). However, the SRP value may or may not be accurate. Often the SRP is 10-100 times higher than a value determined by a non-routine radiobioassay. Many researchers have felt that undescribed phosphorus-containing compounds would hydrolyse under the acidic conditions used to measure SRP. An attempt was made to resolve this controversy by labelling lakewater compartments with radioactive orthophosphate. Gel chromatography was used as a monitoring aid to determine what happened to the radioactive colloidal phosphorus compound when subjected to the Murphy-Riley procedure. No hydrolysis to orthophosphate was detected. The reason behind the discrepancy still is unknown and illustrates the need for an accurate method for phosphorus bioavailability. (*Burnison*)

Cladophora is a nuisance filamentous algae causing problems in nearshore areas of the Great Lakes. We demonstrated that the beaching and subsequent decay of *Cladophora* in the Hamilton to Oakville area of Lake Ontario coincided with a recent taste and odor event in the local water supply. We studied this problem in cooperation with Halton Region. Water samples from the Burlington water treatment plant (WTP) and from shoreline areas were analyzed for geosmin and methylisoborneol, two frequently reported compounds associated with taste and odor problems in water supplies. Geosmin was identified in some of the finished water from the WTP. Methylisoborneol was not detected in any of the samples. The source of the geosmin is not clear at this point. There is some indication that the lakewater is one source; but since the finished WTP water had higher concentrations than the raw water, the WTP may have produced geosmin. Other volatile compounds are present in the lakewater which have offensive odors. For example, during a massive dieoff of *Cladophora*, methylindole and elemental sulfur were produced. Two other compounds were tentatively identified as dimethyl tetrasulfide and dimethyl pentasulfide. (*Brownlee, Painter*)

STAFF LIST

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Nutrient Pathways Section

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R.A. Bourbonniere
- Peat Environmental Committee

B.K. Burnison
- CCIW Radionuclide Control Committee
- Editorial Board, WHO "Water Quality Bulletin"

M.N. Charlton
- Lake Erie Surveillance Task Force
- Lake Superior Surveillance Task Force

L.D. Delorme
- International Union for the Conservation of Nature
- IUCN Survival Service Commission
- Canadian Committee on Climatic Fluctuations and Man
- Task Force on Proxy Data
- Atmospheric Environment Service, IWD Contact Person for the Carbon Dioxide Committee

S.R. Esterby
- ASTM Biometrics Sub-Committee on Water
- Canadian Committee on Climatic Fluctuations and Man

W.A. Glooschenko
- Peat Environmental Committee
- Editorial Board, "Geoscience Canada"
- DOE Coal Group
- National Wetlands Working Group
- Canadian Committee on Ecological Land Classification
- Society of Wetland Scientists — President 1983/84

D.R.S. Lean
- Standard Methods Advisory Group

S. Painter
- Aquatic Plant Harvesting Guidelines Committee
- Aquatic Plant Management Society, local chapter's committee

J.O. Nriagu
- Canadian National Committee for SCOPE
- SCOPE Scientific Committee on Metal Cycles
- International Committee for Symposia on Environmental Biogeochemistry
- Editorial Board, "Chemical Geology"
- Editorial Board, "Tellus"
- Associate Editor, "Science of the Total Environment"
- Editor, "Advances in Environmental Science and Technology"
- Editorial Board, "Reclamation and Revegetation Research"
- NRC Associate Committee on Scientific Criteria for Environmental Quality, Subcommittee on Heavy Metals

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AQUATIC PHYSICS AND SYSTEMS DIVISION

The Aquatic Physics and Systems Division of NWRI conducts a program of research incorporating balances of experimental measurements, and numerical theoretical analysis. The emphasis in this work is on understanding physical processes such as circulation, mixing, and diffusion, and their interrelationship with dissolved and suspended materials. In support of these and other research programs the Division maintains archives of environmental data and provides computer programming assistance. These responsibilities are shared among four sections: (i) Physical Limnology, (ii) Environmental Simulation, (iii) Environmental Optics, and (iv) Data Management.

PHYSICAL LIMNOLOGY SECTION

The goals of the Physical Limnology program are to describe and to quantify physical processes in lakes. Of particular interest are processes such as mean transport and turbulent diffusion that affect water quality. These goals are approached through a combination of field observations, data analysis and interpretation, and theoretical or modelling studies.

Lake Erie Studies. Analysis of data collected in Lake Erie in 1979 and 1980 has continued. A numerical simulation of vertical transfers of heat and momentum using a turbulent energy budget approach (Dynamic Reservoir Simulation Model) and undertaken by J.C. Paterson (visiting scientist) and G.N. Ivey (PDF), has confirmed earlier analysis by Ivey and Boyce (1982) of episodes of entrainment into a turbulent hypolimnion. This study shows that downward entrainement characterized by simultaneous thickening and warming of the hypolimnion takes place only when the thermocline or metalimnion is sufficiently thick. When the thermocline is thin, the epilimnion and the hypolimnion are coupled directly and the more energetically mixed layer grows at the expense of the other. Further research is needed to determine the rules governing this process. Under contract to NWRI, J.C. Paterson and his associates coupled the DYRESM model with a dissolved oxygen model and obtained encouragingly realistic results. A. Zahawhary, Ph.D. candidate at McMaster University, is analysing temperature and current data taken near Cleveland, Ohio as partial fulfillment of his degree requirements. He has compiled a data report on this information and has recently completed an analysis of the mixing characteristics of the nearshore flow. The 1979, 1980 Lake Erie data is being used to test improved methods of storm-surge forecasting now under development. Louise Royer (NSERC post-doctoral fellow) is presently working on a description of water movements in mid-Central Basin. A final synthesis report of the Lake Erie experiments is being assembled jointly by NWRI, the Centre for Lake Erie Area Research (Ohio State University), and the Great Lakes Environmental Research Laboratory (NOAA, Ann Arbor, Michigan). The report will be published as a special issue of the Journal of Great Lakes Research in 1984. (*Boyce*)

Lake Ontario Studies. Extensive fieldwork was carried out in Lake Ontario in 1982. An array of current meters and thermistor chains was installed on the north shore of the Lake between Ogden Point and Bowmanville, with transects running from Port Hope, Ontario to Point Breeze, New York, and from Toronto, Ontario, to the Niagara River

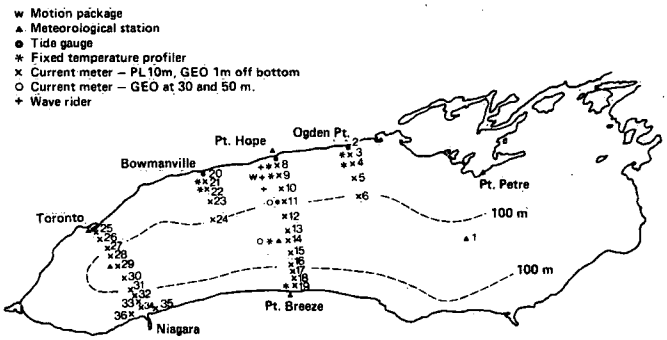

Figure 1 Lake Ontario — 1982 Mooring Locations

mouth (Fig. 1). This experiment was designed to test theoretical explanations of the current reversals observed to take place following episodes of strong winds. The northshore experiments ran through the summer and fall of 1982, while the transects remained in place through the winter (4 November, 1982 to 23 March, 1983). The winter observations show an intensification of eastward current near the south shore of the lake in contrast to the theoretical distribution which would call for a more equal distribution of eastward flow on both the north and south shores of the lake. This is a significant observation and an explanation is being sought.

The results of the Lake Ontario North Shore Study are valuable in the interpretation of the Lake Ontario Nutrient Assessment Surveys simultaneously conducted by the Aquatic Ecology Division.

In support of biochemical surveys conducted at the mouth of the Niagara River to determine the fate of potentially toxic chemicals entering the lake from the river, a series of seven, five day physical experiments was conducted in the area of the river mouth, from April to November, 1982. Three similar experiments were conducted in the summer of 1983. The purpose of these experiments, which included detailed EBT surveys and the tracking of clusters of drogues, was to delineate the horizontal distributions and flow characteristics of the plume of water emanating from the Niagara River. This information served to guide the biochemical sampling and as input to numerical simulations of the river-lake interaction. Experiments show that the plume is hydraulically controlled or jet-like within the first two or three km from the river mouth and beyond that, the plume is controlled by winds and ambient currents. A comprehensive report on the Niagara plume experiments will be published in 1984. (*Murthy*)

Limnology of Yukon Lakes. Responding to a need to assess the potential impact of hydroelectric power developments on watersheds in Northern British Columbia and the Yukon Territory, NWRI, Pacific and Yukon Branch, has undertaken a long-term study of selected lakes in that region.

NWRI Burlington, has contributed to that program. Under the leadership of P.F. Hamblin, a Neil Brown acoustic current meter was modified for use under an ice-

cover. A field experiment was carried out on Lake LaBerge in February, 1983 to determine the distribution of flow in a narrow, ice-covered lake. Modelling studies of ice-covered lakes have also been pursued in support of this program. P.F. Hamblin and G.N. Ivey conducted experiments in the Hydraulics Research Division cold room on vertical circulation and horizontal heat transfer in the vicinity of a thermal bar. (*Hamblin*)

Other Activities. A feasibility study was conducted during January and February 1983, in the canal connecting Hamilton Harbour with Lake Ontario, in order to find out whether water levels from each end of the canal could be transmitted by semi-rigid tubing to a sensitive differential pressure transducer, thus providing a direct measuire of the mean sea-surface slope. Current meter observations were made in support of the slope measurements. Analysis has shown that the current observations are consistent with the water level observations (Simons, Schertzer, 1983). The concept will be further tested in the more demanding lake environment in the autumn of 1984. If successful, the technique could prove to be a valuable adjoint of more conventional measurements. (*Boyce*)

The Section continues to provide data processing services (subject to available resources) to outside agencies, such as Ontario Ministry of the Environment. Information and analyses have been provided to Ontario Ministry of Natural Resources (fish kill problem) (Boyce, Roach, 1983), Public Works Canada (nearshore circulation in Lake Erie), Ontario Hydro and Ontario Ministry of the Environment (Niagara River, Humber River, and 1983 Beach Closures, etc.).

ENVIRONMENTAL SIMULATION SECTION

The main objective of the Enviromental Simulation Section is to develop and maintain a modelling capability for the integration of research results and data from the various disciplines of water sciences. This is achieved by developing a general modelling framework which can be readily adapted to address a wide range of environmental problems such as lake eutrophication, toxic contamination and watershed acidification. The purpose of the models is threefold: to make predictions and provide guidelines and trend analysis for environmental management problems; to provide feedback to the ongoing research and monitoring programs on the gaps of knowledge; and to maintain a strong focus of systems modelling expertise in APSD and consolidate modelling efforts by close collaboration with other divisions.

Niagara River Plume Model. The modelling study on the Niagara River plume forms part of the research teamwork shared by physical limnologists, chemists and ecologists. Its main thrust has been on the simulation of the complex transport and dispersion processes in the plume, as the major environmental concern is on the fate and pathways of the toxic substances found in the river. From past efforts, a hierachy of hydrodynamic and transport models has been already implemented operationally. The application of these visiting models to the case of the Niagara River was quite straightforward and involved the use of nested grid techniques. First, a lakewide hydrodynamic model with a coarse (5 km x 5 km) grid was applied to the entire lake; then, an intermediate size (1 km x 1 km) grid was used for the coastal zone (Fig. 2) near the river with the boundary conditions defined by the coarse grid results; finally, a fine (0.2 km x 02. km) grid was imposed on the river itself using solutions with the intermediate size

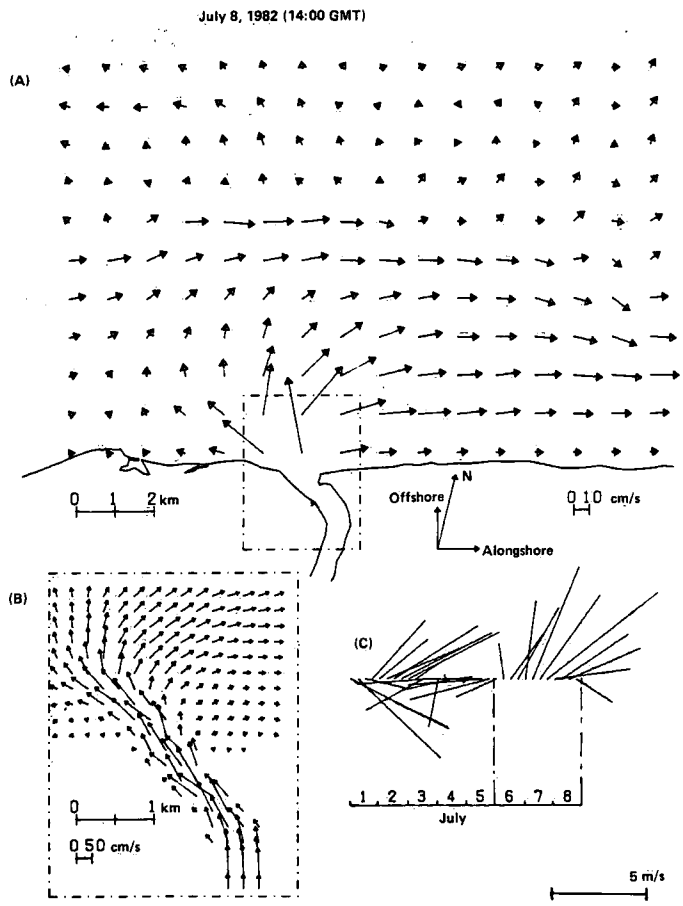

Figure 2 (A) Computed currents with 1 km x 1 km grid; (B) computed currents with 0.2 km x 0.2 km grid; (C) observed winds.

grid as boundary conditions. This telescoping technique has the advantage of not having to use the fine grid over the entire lake and still achieving reasonable accuracy near the river.

The computed hydrodynamic currents were found to be capable of simulating the observed drogue movements satisfactorily, showing the distinctive effects of the mean river flow; the ambient currents; and the environmental turbulent diffusion. These plume characteristics have been used by the chemists for a better grid resolution in their sampling strategy. (*Simons, Lam*)

An ecological model incorporating the toxic substances processes has also been developed, following the food chain of benthic organisms, plankton, and fish for the Niagara River area. This model is based upon the averaged transports obtained by the above hydrodynamic model. Verification of this model awaits availability of biological and chemical data. (*Halfon*)

Circulation in a North-South Transect of Lake Ontario. Whereas the hydraulic flow of the Niagara River exerts considerable influence over the transport and dispersion of pollutants in its immediate vicinity, the offshore circulation is affected mainly by wind forcing, earth's rotation and other geophysical factors. A good example is shown in Figure 3(a) in which the interpolated total longitudinal transport (+ denotes eastward flow; — denotes westward flow) is depicted for a transect across Lake Ontario from Port Hope, Ontario to Point Breeze, N.Y. Here, the hydraulic flow represents only about 10% of the total

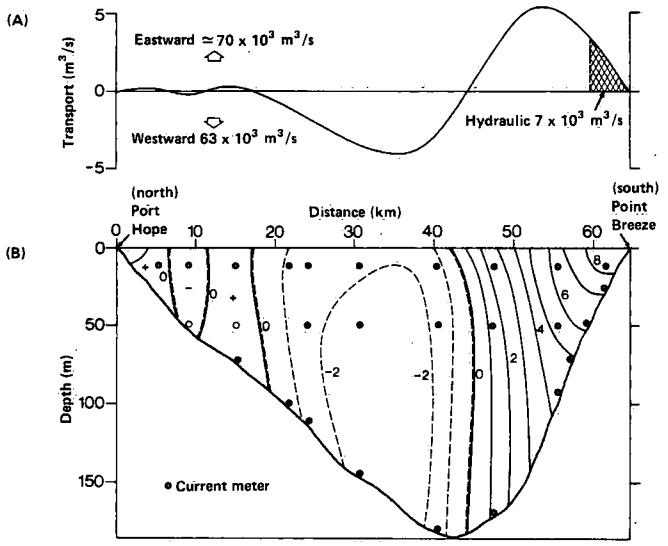

Figure 3 (A) Longitudinal transports integrated across a north-south transect of Lake Ontario (shaded area represents the Niagara River flow).
(B) the contours showing the mean velocities (cm/s).

eastward transport. The circulation is dominated by a strong eastward flow along the south shore and a return flow in the middle part of the lake. Similar but smaller circulation gyres can be found near the north shore.

The implication of these gyre formations is that contaminants originating along the south shore will be transported by the strong alongshore eastward current (Fig. 3(b)) and some of them will be returned westward when they reach the middle portion of the lake because of lateral dispersion. A more detailed analysis of the data is being carried out as to the frequency of occurrences of such episodes. A hydrodynamic model for the transect has been developed to study the downwelling and upwelling events thought to be crucial for the nutrient regneration cycle in this region of the lake. (*Simons*)

Port Granby Radionuclide Transport Model. Port Granby radioactive waste disposal site is a 10 hectare area located on a bluff 25 m above lake level, on the north shore of Lake Ontario, approximately 15 km west of Port Hope, Ontario. Hydrogeologically, the strata in descending order are: (i) a moderately permeable unit of upper sandy clay silt; (ii) a unit of glacial till of low permeability; (iii) a moderately permeable unit of lower sands and silts; (iv) a unit of glacial till of low permeability; and (v) a moderately permeable unit of fractured bed rock aquifer. The site is bounded on three sides by groundwater drains: East Creek, West Creek and Lake Ontario. A two-dimensional finite element method was used to simulate groundwater flow patterns along several north-south geological cross sections through the site. The calibrated model simulates the water table, including the location of a groundwater divide, the hydraulic head distribution and the velocity flow field. The groundwater divide indicates that all of the recharging water is flowing to the deeper formations and discharging to Lake Ontario. Springs were also observed along the contact between the glacial till unit and upper sandy clay silt strata.

Contaminant plumes of radium-226, uranium and nitrate have been computed by a two-dimensional finite element model and the results (Fig. 4) were found to compare satisfactorily with the data collected by the Radionuclides Section of ECD. Current efforts are being devoted to the interfacing of the groundwater transport model with the previously developed coastal zone effluent transport model to determine the pathways of the radionuclides. (*Bobba*)

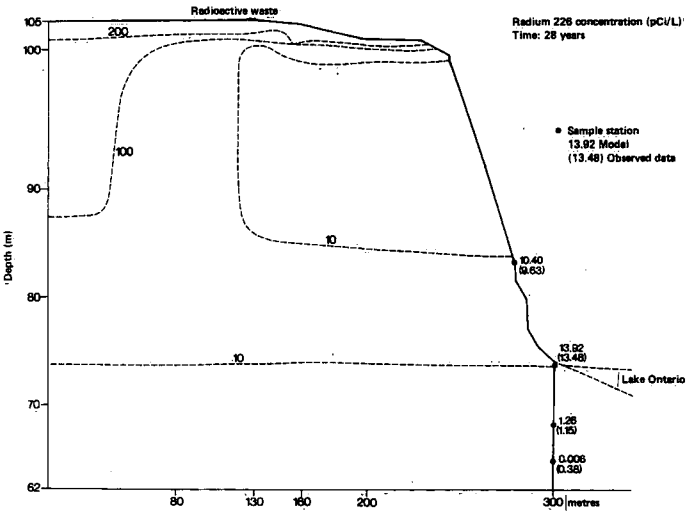

Figure 4 Simulated dilution contours of contaminant concentration at the Port Granby site.

Turkey Lakes Watershed Acidification Model. The Turkey Lakes Watershed is a completely forested, headwater drainage basin located 50 km north of Sault Ste. Marie, Ontario. An integrated observational study, co-ordinated by the Acid Deposition Section of ECD has been conducted since 1979 on the biological, chemical, hydrological, geological and meteorological aspects of the basin. The 10.5 km^2 watershed contains five interconnected lake sub-basins and numerous small streams. The headwater lake (Batchawana Lake) at 497 m above mean sea level, has the lowest pH, Ca^{++}, alkalinity and carbon uptake rate. There is a general spatial gradient of these parameters across the watershed with the lower portions being the less acidic and more productive.

While the atmospheric deposit of acids is moderate (rain pH = 4.5) and uniform over the whole basin, and so is the availability of nutrients, these differences in both the acidity and the primary production among the lakes over such a small area stand out prominently in the data.

In order to explain this phenomenon, a watershed acidification model has been developed and modularized to take into account the snowmelt, surface runoff, stream flows, lake stratification, soil layer chemistry, canopy effects, unsaturated zones and groundwater flows. The model shows that at the headwater basin, the buffering capacity has been depleted substantially and the pH could drop to below 5, particularly after snowmelt events. The carbon uptake rates due to primary production are affected adversely by the low alkalinity, although there are nutrients available.

By contrast, at the lower portions of the watershed, cation exchange occurs more freely and groundwater flows appear to enhance primary production. An interesting example is the Little Turkey Lake (the fourth in the series) where a major influx of Ca^{++} and Mg^{++} from the groundwater appears to occur at the lake bottom almost all year around. In the summer period, this lake is thermally stratified but the favourable alkalinity and nutrient conditions in the epilimnion still sustain relatively higher

primary production than Batchawana Lake.

The complexity of the model development has necessitated the collaboration of the other Divisions at NWRI and several government agencies. (*Lam*)

Long Range Transport of Airborne Pollutants: Empirical Modelling and Analysis. A multivariate factor analysis which discriminates major influences on the chemistry of natural waters was undertaken, examining regions in Newfoundland, Nova Scotia, Quebec and Ontario (Thompson). By use of this procedure, five major factors have been identified: (1) seasalt from marine sources; (2) chemical weathering; (3) long range transport; (4) terrestrial dust; and (5) industrial emissions.

Factor analysis for 15 variables on precipitation chemistry data for Sept-Iles, Quebec clearly showed long range transport effects as factor 1, with pH loaded in opposition to sulphate accounting for 40% of the total variance. Clustering of chloride, sodium, and magnesium on factor 2 (21% of variance) identified the marine effect, and illustrated the need for adjustments in the data where long range transport or terrestrial effects are to be determined accurately. Effects of local industry and development were indicated by clustering of iron, lead, and zinc on factor 3 (10% of variance). Terrestrial dust of agricultural origin was indicated by clustering of total phosphorus, potassium, calcium, and nitrate on factor 4 (9% of variance).

An examination of sulphur yields of Quebec rivers was undertaken to determine the retention of depositional sulphate within watersheds in regions of Quebec, lying within the continental deposition plume (Thompson). As an example, Figure 5 shows the sulphur yields for the major rivers located in the Eastern Townships of Quebec. The resultant yields of sulphur generally follow the known pattern of atmospheric wet deposition. High sulphur yeilds which exceed the expected levels, are associated with highly populated and industrialized areas and include municipal, terrestrial and dry depositional sources. (*Thompson*)

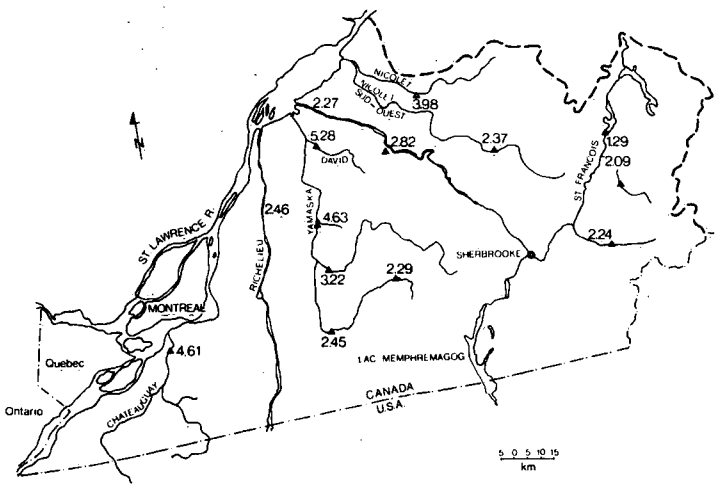

Figure 5 Sulphur yields of rivers in the Eastern Townships of the Province of Quebec ($g.m^{-2}\ yr^{-1}$)

Eutrophication Modelling. The eutrophication process in lake waters is a complex phenomenon which depends upon the hydrodynamic, chemical, physical, biological and geological characteristics of the water body of interest. To take into account all these phenomena in a mathematical model is very difficult. Thus Ecological Modellers usually analyze only a few factors at a time.

Phosphorus is a nutrient which is often a limiting factor in the eutrophication of a lake, thus knowledge of the rates and pathways of phosphorus cycling in a water body is very important to determine the trophic state of a lake. Mathematical models can be used to quantify the cycling rates through the various components of the ecosystem, e.g. phytoplankton, zooplankton, colloidal matter, water. A large scale mathematical model may require too much information from field experiments to quantify all parameter values. When information is incomplete, a smaller mathematical model is preferred. System identification techniques can be used to determine the minimum number of components required to model the phosphorus dynamical behaviour, and assist planning field programs to collect optimum number and types of samples.

A four compartment model proposed by D. Lean (1973) accounting for only soluble phosphorus, colloidal phosphorus, organic phosphorus compounds and particulate phosphorus was applied to data from Kootenay Lake, B.C. Results indicate that the model is adequate to describe the fresh water phosphorus cycle. (*Halfon*)

ENVIRONMENTAL OPTICS SECTION

The Environmental Optics Section of APSD carries out both experimental and theoretical research concerned with the optical properties of the aquatic environment. The techniques of spectro-optical physics and radiative transfer theory are utilized, in conjunction with multispectral data acquired by *in situ* and remote (airborne and satellite) optical sensors, to develop interpretive and predictive optical models and methodology, and to apply these methodologies to water resource issues and concerns.

The optical physics activity comprises a basic long-term research program upon which are superimposed short-term studies as the opportunity arises. During the past year, the Section's effort was concentrated on the Great Lakes. Some of the pertinent studies included:

(a) The application of a Ship-borne Radiometer Reflectance System (SRRS) to the remote determination of water quality (in terms of suspended mineral, suspended chlorophyll *a*, and dissolved organic carbon concentrations). Data collected over Lakes Superior and Ontario are currently being analyzed. (*Jerome*)

(b) Completion of a report dealing with the application of *in situ* irradiance reflectance measurements to water quality indicators stressing the importance of the specific absorption and specific scattering properties of lake waters; and describing, in both mathematical and non-mathematical terms, the conditions under which realistic descriptions of lake water quality may be obtained from direct measurements of optical parameters. (*Bukata*)

(c) Completion of a comprehensive evaluation of the use of chromaticity (a tri-color separation of the natural irradiation incident upon a water body) in the remote measurements of water quality. Standard CIE chromaticity analyses were applied to upwelling irradiance spectra at the air/water interface. Results illustrate dramatically, the conditions under which such chromaticity techniques may

be applied with reasonable confidence; and those conditions within the aquatic environment which present severe restrictions to the application of cheomaticity to water quality measurement. (*Bukata*)

(d) Work was completed and published concerning the pitfalls associated with attempts to infer acid stress in lakes (pH does not, of its own, induce a color change in water) from passive satellite spectral data (which measure water color). This is an area which, perhaps largely due to an understandable zeal to apply the large wealth of acquired satellite data to acid lake concerns, is resulting in both misunderstanding and controversy, and should be carefully approached by both the generators and users of such remote sensing methodologies. (*Bukata*)

(e) The Section's final effort in subsurface contaminant transport (prior to the transfer of this effort to the newly formed Environmental Simulation Section) was the determination of diffusion coefficients (molecular and bioturbation) associated with the transport of ^{210}Pb radionuclides in lake bed sediments. This work emphasizes the significance of bioturbation effects (assumed a direct consequence of the burrowing activity of benthic organisms) in the description of contaminant transport through the sediment of the Laurentian Great Lakes. (*Bukata*)

(f) Work is nearing completion on the generation of an "optical atlas" describing the Great Lakes in terms of optical data collected during the past CCIW programs. (*Jerome*)

DATA MANAGEMENT SECTION

The Data Management Section of APSD, NWRI provides all components at the Canada Centre for Inland Waters with operational data management and EDP software development services. The corporate data archives of NWRI are maintained and managed for support of the NWRI research and IWD-OR operational programs. The Global Environmental Data Base for Water Quality is also maintained.

Major Activities. Software system design and development support were provided for 62 different studies within 15 organizational components at CCIW.

The major Acid Rain data base system and analysis facilities were expanded to meet added study requirements for the LRTAP program.

The major automated laboratory data acquisition systems were moved to a VAX 11/750, and training was provided for Water Quality Branch technicians.

The UNEP/UNESCO Global Environmental Monitoring System for water (GEMS/WATER) was enhanced and operated. A directory of stations, labs and personnel involved in the project was produced, along with a data summary for 1979-1981.

Interactive graphics facilities in support of research were developed including implementation of new digitization hardware and software. Interactive time-series data editing using color graphics was implemented (Fig. 6).

A Centrewide review and long-term projection of program-related computing requirements was completed. Conversion requirements were documented, benchmark programs selected, and alternatives were further evaluated.

A number of administrative data bases were implemented on the Cyber computer.

The Management Information System to support program planning was implemented on behalf of NWRI management.

Technology Implementation. System 2000 data base management now includes all corporate data bases, providing vastly improved access to data.

Major operational data bases such as Great Lakes surveillance and global (GEMS/WATER) data have been micrographically reproduced and distributed to government and university libraries. The GEMS microfiche were distributed to WHO headquarters, Geneva, and to six global regions.

Introductory and advanced computer courses presented by DMS drew total attendance in excess of 200 during the past year.

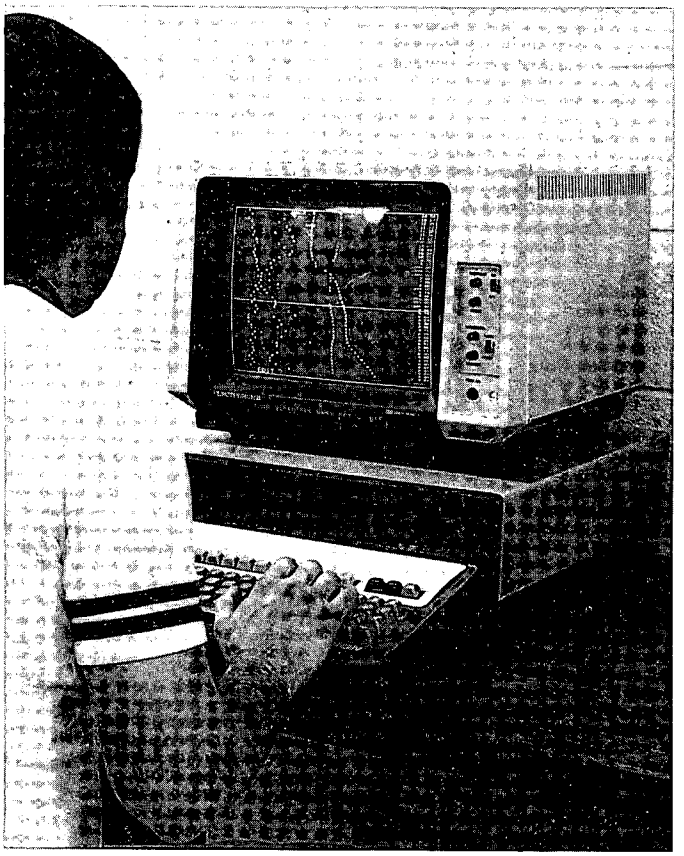

Figure 6 Interactive graphics being used for editing of time-series data.

STAFF LIST

Chief — Mr. Floyd C. Elder
Secretary — Mrs. Sandy Tapping
Administrative Officer — Mr. S.C. Smith

Physical Limnology	
Head, Mr. F.M. Boyce	physical limnology
Researchers	
Mr. J. Bull	physical limnology
Mr. K. Miners	coastal zone research
Mr. F. Chiocchio	physical limnology
Mr. D. Robertson	physical limnology
Mr. M. Kerman	physical limnology
Dr. C.R. Murthy	physical limnology
Dr. P. Hamblin	physical limnology
Environmental Optics	
Head, Dr. R.P. Bukata	lake optics and satellite studies
Researchers	
Mr. J.E. Bruton	lake optics remote sensing
Mr. J. Jerome	lake optics remote sensing
Environmental Simulation	
Head, Dr. D. Lam	water quality monitoring
Researchers	
Mr. G. Bobba	hydrogeology and remote sensing
Mr. A. Fraser	water quality monitoring
Dr. T. Simons	hydrodynamic modelling
Mr. W. Schertzer	water quality modelling
Dr. M.E. Thompson	aquatic effects of LRTAP
Dr. E. Halfon	toxic substance modelling
Dr. A. El-Shaarawi	statistical modelling
Data Management Section	
Head, Mr. J. Rogalsky (retired 1 January 1984)	data management services
Mr. R. Duffield (A/Head)	data base administration
Computer Programmers	
Mr. A. Zingaro	software development
Mr. S. Beal	microcomputer applications
Mr. W. Nagel	data archiving
Mr. J. Byron	data archiving
Mrs. J. McAvella	data archiving
Mrs. H. Comba	software development
Ms. C. Minnie (resigned August 1983)	word processing
Mr. B. Hanson	software development
Ms. J. Dowell	software development
Mr. J. Hodson	software development
Mr. U. Ventresca	software development
Mrs. K. Miles	software development

COMMITTEE MEMBERSHIP

C.R. Murthy
- DOE Working Group on Environmental Codes of Practice for Steam Electric Generating Stations
- IJC Great Lakes Modelling Task Force
- Ph.D. Candidate Supervisory Committee, Department of Civil Engineering, McMaster University
- Executive Council, Canadian Applied Mathematics Society — Vice-President

D.C.L. Lam
- Editorial Board, "International Journal of Advances in Water Resources"

P.F. Hamblin
- Associate Editor, "Physical Limnology Journal of Great Lakes Research"
- Ph.D. Candidate Supervisory Committee, Department of Civil Engineering, McMaster University
- International Association for Great Lakes Research, Membership Committee

A.H. El-Shaarawi
- Biometrics Subcommittee — Vice Chairman
- Head, Descriptive Mathematics Section, American Society for Testing of Material

A.S. Fraser
- IJC Working Group on Data Management and Interpretation

F.M. Boyce
- Associate Editor "Atmosphere Oceans" (Journal of Canadian Meteorological and Oceanographical Society)
- Scientific Committee, CMOS 1983-1986
- Board Member, IAGLR 1983-1986
- Rapporteur, Oceanography, Canadian Geophysical Bulletin

E. Halfon
- Directors Board, International Society of Ecological Modelling, North American Chapter
- Ph.D. Candidate Supervisory Committee, Department of Systems Science, State University of New York, Binghamton

W.M. Schertzer
- CCIW Physical Studies Seminar Series — Chairman
- IWD Hydrologic Research Program Committee
- Ontario Regional Climate Advisory Committee

M.E. Thompson
- Associate Editor, "Hydrological Sciences Journal"
- Ph.D. Supervisory Committee for Moira Wadleigh

F.C. Elder
- Federal/Provincial LRTAP Research and Monitoring Coordinating Committee, Co-chairman of Aquatic Effects Subcommittee
- Environmental Conservation Service, LRTAP Steering Committee, IWD Member
- Program Committee Chairmn, International Symposium on Acid Precipitation
- Canada-Ontario Agreement, Great Lakes Surveillance Committee

Canada-Ontario Agreement, Federal/Provincial Phosphorus Task Force

Great Lakes Water Quality Program, Strategic Planning Workgroup

Great Lakes Water Quality Program, Eutrophication Issues Workgroup

B. Duffield

IWD Information Technology Committee

IWD Security Committee

R.P. Bukata

Limnology Working Group, Canadian Advisory Committee on Remote Sensing — Chairman

Representative, CCIW Remote Sensing Specialty Centre, Canadian Advisory Committee on Remote Sensing

J.E. Bruton

Limnology Working Group, CACRS — Secretary

Computer Compatible Tapes Usage Working Group, CACRS

Toronto Hydrology Working Group

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ENVIRONMENTAL CONTAMINANTS DIVISION

The Environmental Contaminants Division investigates in the field and in the laboratory, the pathways, fate and effects of five groupings of contaminants: organic chemicals, toxic metals, organo-metallics, radionuclides, and ions associated with acid rain. Research information produced by the Division is valuable in substantiating recommendations for water management actions in polluted river basins. These actions may involve control of effluents, banning of chemicals, guidelines for consumption of biota or water, and many other procedures which can be implemented in Canada. Data may be valuable in negotiations on water quality matters, either interprovincially or internationally. Much of the published information is equally valuable as part of the total input required for toxic chemical assessments. Division activities are carried out in five sections as follows.

ORGANICS PATHWAYS SECTION

The objective of this Section is to resolve the entry, fate, distribution, and transfer of organic contaminants in aquatic ecosystems. Research is conducted at specific polluted aquatic ecosystems, in experimental ponds, and in the laboratory. Intercompartmental transfer (water, suspended sediment, sediment, benthic fauna, and flora) and effects of organic contaminants are examined. Atmospheric input of organic contaminants to the aquatic environment is being studied.

Pathways of Niagara River Contaminants in Lake Ontario. A relationship was found to exist for some contaminants between concentrations on river suspended solids, Lake Ontario surficial sediments and amphipods. However, many of the Niagara River contaminants appeared to be in the "dissolved" form rather than associated with suspended solids. The initial movement of these compounds in Lake Ontario will be determined by the dynamics of the river plume. This study was therefore divided into two parts:

a) A sediment, benthos, and fish survey designed to continue the investigation of bioaccumulation of two different classes of contaminants.
b) A study of the transport of contaminants in the Niagara River plume.

Sediment, interface water, fish and benthos were collected from sites in Lake Ontario near the Niagara River and from reference sites to the east and west of the river mouth. Chlorobenzene levels were higher in amphipods than in oligochaetes while the reverse was true for chlorophenols. There appears to be poor correlation between sediment levels and benthos concentrations of these contaminants.

Chlorobenzenes were selected as a chemical marker of the Niagara plume because these compounds were easily detectable in river water but were generally absent from the surface waters of Lake Ontario. Concurrently the course of the plume was followed and plotted through the use of drogues. The chlorobenzenes were transported with the plume as it was influenced by weather conditions. Figure 1 shows the 1 m profiles of 1,2,3,4-tetrachlorobenzene under westerly and easterly wind conditions in May and October, 1982, respectively. Refinements to the sampling and analytical procedures in 1983 have permitted the examination of a wider variety of compounds. (*Fox, Carey, Metcalfe, Coletta*)

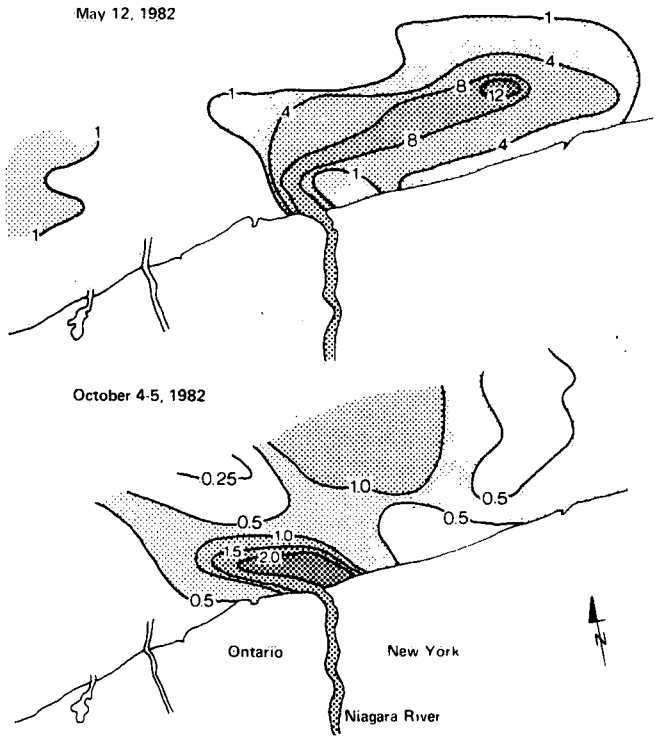

Figure 1 Tetrachlorobenzene in the Niagara River plume.

Prediction of the Environmental Distribution of Toxic Chemicals. The purpose of this project is to develop predictive systems to obtain good estimates of the distribution of organic chemicals in the environment. Three distribution models developed elsewhere are being translated to be run on micro-computers and are being compared for their sensitivity to small changes in input parameters.

Sorption on sediments is one of the major processes affecting the behaviour of chemicals in the aquatic environment. The process is characterized by a partition constant, K_d. A large sample of Lake Ontario sediment was fractionated using settling times to give coarse ($\phi < 4$) and fine ($\phi > 8$) fractions. These were freeze-dried to provide homogeneous and reproducible substrates. Samples of these fractions were suspended in water and equilibrated with hexachlorobenene (HCB) and dichlorodiphenyldichloroethylene (DDE) at concentrations below their saturation levels.

Solubilities were also determined on a large number of replicates. The K_d values for HCB and for DDE, were in reasonable agreement with literature values. It appears that there is a negligible affect on K_d of the concentration of the suspended load. It also seems that there are no differences arising from the use of coarse or fine suspended sediments. (*Strachan*)

Atmospheric Deposition of Persistent Organic Chemicals. A major pathway for the entry of organic chemicals to the Great Lakes system and elsewhere is from the atmosphere. PCBs and DDT are substances which have been severely limited or banned from North American usage for more than ten years and yet they continue to appear in rainfall. An automated rain sampler was designed, built and evaluated as a collecting and concentrating device for per-

sistent organic chemicals in rain. Three samplers were installed on each of Isle Royale and Caribou Island in Lake Superior. Sample columns were collected from each sampler and analyzed for PCBs, toxaphene, and organochlorine pesticides. (*Strachan*)

Pathways of Contaminants in Fluvial Systems. Laboratory investigations are coupled with field work both at the Canagagigue Creek site (Elmira, Ontario) and at other locations across Canada. A survey of chlorophenol residues in the benthic community (Table 1) revealed that leeches have a high bioaccumulation potential for these compounds.

Table 1. Chlorophenol levels in biota and water from CN-3 in Canagagigue Creek.

Sample	Chlorophenol concentration (ppb)			
	2,4,6-TCP	2,4,5-TCP	2,3,4,6-TTCP	PCP
Leech (*Dina dubia*)	2201	10 262	508	188
Leech (*Glossiphonia complanata*)	639	1688	100	19
Leech (*Helobdella stagnalis*)	371	2461	140	72
Snails (*Physa* sp.)	25	27	7	21
Damselfly larvae (*Enallagma* sp.)	116	169	58	54
Cranefly larvae (*Tipulidae*)	83	9	9	25
Water	0.065	0.083	0.007	0.007

Additional research goals were to define the bioconcentration curves for the various species of leeches, to identify the factors responsible for this high bioconcentration capacity and to evaluate the potential of leeches as biological indicators or "sentry" organisms. Only aquatic oligochaetes had comparable residues. In preliminary laboratory tests, specimens of the leech *Dina dubia* did not eliminate any of their body burden of chlorophenols within a two-week period in clean water. Leeches are ubiquitous and easy to sample. As they are not easily damaged during handling, they are ideal for laboratory up-take and depuration experiments. They are relatively sedentary and therefore representative of their immediate environment.

Four species of leeches in Canagagigue Creek were collected and analyzed for chlorophenol residues to compare the bioaccumulation potentials and to determine whether animal size is an important parameter in uptake. Results suggest that *Dina dubia* has the highest body burden of chlorophenols. As the life histories of Canadian leech species are very poorly known, a study on the age structure and food habits of three of our species was conducted. To expand the range of contaminants and leech species under investigation, studies of the Grand River watershed in Ontario and selected sites in New Brunswick were initiated.

A fish census of Canagagigue Creek revealed that most species avoided the highly contaminated areas, and that specimens of at least one species (rock bass) caught in these areas tended to be in poor condition. To provide good estimates of potential long-term hazards of chemicals, tests with sensitive early life stages of fish were carried out. Survival of the early life stages of the common shiner (*Notropis cornutus*) 1.7 km below the Elmira Water Pollution Control Plant (WPCP) was compared with survival at a clean site 2.3 km above the outfall. Survival to hatch was high at both sites. However survival to the critical swim-up stage was reduced from 69% upstream to 49% downstream. Rainbow trout fingerlings were reared for six weeks at the two sites described above. No differences in mortality or growth rates between sites were noted. The uptake rates of chlorophenols by trout will be described and levels of chlorophenols in trout and their various organs will be compared with those of indigenous fish species.

Disappearance of chlorophenols from the stream show a weak seasonal fluctuation in rate, although levels vary occasionally by more than two orders of magnitude. Rate constants for this disappearance have been calculated and indicate that chlorophenols have a 6 to 10 hour half-life in the stream. This short halflife contrasts with a much longer time previously found in the Bay of Quinte, Ontario and indicates that the rate and pathways of degradation of contaminants is strongly dependent on the individual ecosystem. In Canagagigue Creek, the biofilm covering the rocks on the bottom of the stream functions as a very efficient biological reactor. In the Bay of Quinte, photoreactions appear to be the main mode of degradation.

The disappearance rate of the substituted benzothiazoles were much more variable than those of the chlorophenols. The results may indicate that 2(methylthio)-benzothiazole (MMBT) and its oxygen containing derivatives are produced in the stream by non-chromatographable precursors. The route of formation of the oxygen-containing MMBT derivatives is still unknown. Degradation studies of benzothiazoles, sulfenamides and of MMBT failed to produce these compounds.

Samples from the Qu'Appelle, Saskatchewan, system were analyzed for chlorophenols and part of this system contains significant levels of pentachloro — and related phenols.

Photodegradation studies of dissolved humics were carried out and superoxide was found to be a product of the photolysis of aquatic humus. This species may be responsible for a variety of indirect photoreductions of contaminants in natural waters. (*Carey, Metcalfe, Fox, Coletta, Hart*)

Contaminant Studies in Ponds. The lampricide, 3-trifluoromethyl-4-nitrophenol (TFM), was added to three lined, sedimented ponds to determine the fate of this chemical and its effect on the benthos of quiescent waters. In two ponds, technical grade TFM was applied and in the third, TFM purified from the commercial formulation. The environmental rate of the disappearance of commercial grade and purified TFM was 0.070 mg/day. Appreciable concentrations of TFM were measured in the sediment for two weeks following treatment, but concentrations diminished after that time. Trace amounts of TFM were detected in the sediment 117 days following treatment. The water and sediment samples were analyzed for known decomposition products of TFM but no measureable quantities were detected.

The disappearance of the N,N-dimethylamine formulation of 2,4-D in four ponds best followed first-order kinetics with a rate constant of 0.039 mg L^{-1} day^{-1}. The plot for the concentration of 2,4-D for the ester formulation exhibited two distinct patterns, the first resulting from the dissolution of the 2,4-D from the clay pellets into the water column. This was followed by a gradual decrease in the 2,4-D concentration. This decrease followed first-order kinetics, with a rate constant of 0.41 mg L^{-1} day^{-1}.

To compare results with an actual field application of 2,4-D, sampling surveys were conducted in Buckhorn Lake. A May 1983 survey of Buckhorn Lake sediment cores showed the presence of 2,4-D in all samples. Concentrations ranged from about 10 ppb in mid-lake to 840 ppb in one of the treated areas. The 2,4-D was found distributed throughout the sediment column (up to 50 cm depths).

Surface sediment samples were collected in the same locations in September 1983. The 2,4-D concentrations in all of these samples were much lower than the May values,

suggesting that high degradation rates may have removed most of the new 2,4-D inputs from the summer applications. (*Scott, Nagy, Carey, Hart*)

ORGANICS PROPERTIES SECTION

The objective of this Section is to determine the chemical and physical characteristics of toxic substances which govern their effects and pathways in aquatic systems. Field investigations are carried out to determine the distribution of certain contaminants, of contaminant-degrading microorganisms and to identify new contaminants and their sources. In the laboratory, experimental measurements of water/sediment and water/octanol partition coefficients, of bioaccumulation and depuration rates, and of the toxic effects of contaminants, are carried out.

Structure-Activity Research. A Workshop on Quantitative Structure-Activity Relationships (QSAR) in Environmental Toxicology was organized at McMaster University, Hamilton, 16 to 18 August, 1983. This workshop was attended by speakers from overseas, the United States, and Canada.

The toxicities of selected chlorophenols to five strains of yeasts as model eukaryotic organisms were investigated in detail. Quantitative measurements showed the sensitivity to such contaminants to increase in the order: *Saccharomyces* sp., *Pichia* sp., *Torulopsis* sp., *Rhodotorula* sp., *Rhodotorula rubra*. The toxicities of the various chlorophenol (P's) were found to increase in the order: Phenol 4-Cl-P; 2,4-Cl_2-P; Cl_5-P; 2,4,5-Cl_3-P.

From largely theoretical work on the comparison of linear and power curve regression analyses of several sets of congeners, it is suggested that the increased chlorine substitution of aromatic and heterocyclic parent compounds, such as benzene, aniline, pyridine, and diphenyl results in declining increases of the octanol/water partition coefficients. The partition coefficients of the chloro congeners follow the general equation

$$\log P_N = (N+1)^b * \log P_o$$

where N is the number of chlorine substituents, $\log P_o$ the partition coefficient of the parent compound and b is a constant specific for each set of congeners. The parameters $\log P_o$ and b are also correlated with each other by the equation

$$b = z * \log P_o^Y$$

where z and y are the same constants for all sets. Together, the two equations allow the quick estimation of the partition coefficient of any congener from the known value of another. This ability is of special importance for compounds with 4 logP, where experimental values are difficult to obtain. (*Kaiser, Ribo, Kwasniewska, Liu*)

Niagara River Research. Water samples from 95 stations in Lake Ontario and 16 stations in the lower Niagara River were analyzed for volatile halocarbons and carbon disulfide. The following contaminants were observed at many stations with their lake-wide means and standard deviations: trichlorofluoro-methane (Freon 11), 249 882 $ng \cdot L^{-1}$; methylene chloride, 572±1826 $ng \cdot L^{-1}$; chloroform, 18±92 $ng \cdot L^{-1}$ (Figure 2); bromodichloromethane, 3±9 $ng \cdot L^{-1}$; and tetrachloroethylene, 9±65 $ng \cdot L^{-1}$. Six compounds were observed in virtually all Niagara River samples and were traceable into the lake. Both industrialized and urban areas, such as Toronto, Hamilton, and the Niagara River, as well as comparatively small tributaries, such as Twelve Mile, Eighteen Mile, Oak Orchard Creeks, Black River, and the Welland Canal, appear to be sources for several of the observed contaminants.

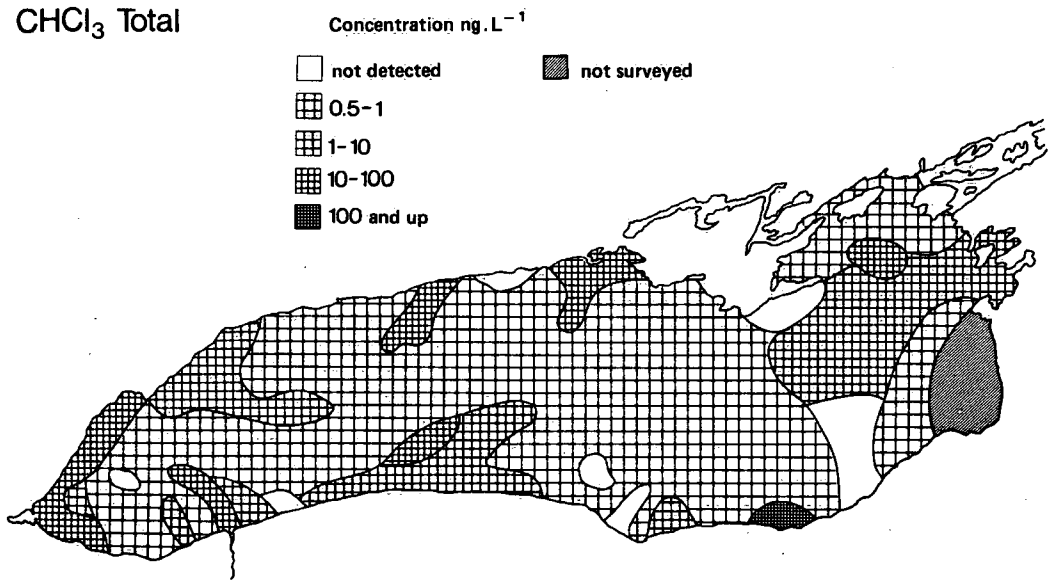

Figure 2 Total chloroform concentrations in Lake Ontario water.

Surveys of selected volatile contaminants in water of the Welland River, a tributary of the Niagara River, show high levels of carbon disulfide, methylene chloride, and chloroform immediately below two industrial outfalls. Downstream from these point sources, a rapid decline in the contaminant concentration is noted due to dilution, degradation and/or volatilization of the compounds. The concentrations of the volatile contaminants are several orders of magnitude lower than those at which acute toxic effects on biota are observed. Studies were also completed on trihalomethanes from chlorination of water and dihaloacetonitriles from drinking water treatment. The effect of humics on natural water acidity, and the potential buffering capacity of lake sediments was investigated as an adjunct to the acid rain research program.

Because of the importance of the Niagara River as a source of chlorinated organic contaminants to Lake Ontario, a sediment core near the mouth of the river was analyzed in detail for organics and radionuclides to study historical trends[4]. Peak discharges of many chlorinated chemicals such as chlorobenzenes to Lake Ontario from the river occurred in the 1960's and are significantly lower today. A study of macroinvertebrates living in bottom sediments near the river mouth showed that they accumulated many of the chlorinated organics that were present in the contaminated sediments.

When rainbow trout were exposed to water contaminated with chlorobenzenes, CB's, they bioconcentrated the CB's from the water. The bioconcentration factor, BCF, (fish conc./water conc.) varied from about 800 for dichlorobenzenes to 13,000 for pentachlorobenzene and was closely related to the chemical's octanol/water partition coefficient. A prediction of CB concentrations in field populations of rainbow trout from Lake Ontario, based on laboratory BCF's and measured Lake Ontario concentrations was, in good agreement with the observed residues for most CB's. The half-lives of individual PCB congeners in rainbow trout showed marked differences — the higher the degree of PCB chlorination, the longer the half-life.

The zonation of aquatic macrophytes, particularly *Typha* and *Sagittaria* sp. and associated periphyton communities, were investigated in relation to industrial point source discharges to the Welland River, Ontario. Severe reductions of macrophyte species densities and macrophyte and periphyton diversity were found immediately below the outfalls with distinct recovery zones in the downstream part. Normal macrophyte and periphyton density and diversity occurred at sites approximately 1.6 km below the outfall. (*Kaiser, Comba, Oliver, Nicol*)

Biodegradation of Organic Contaminants. Commercial PCB formulations, MMBT, aniline and Marlon A were systematically investigated for their biodegradation behaviour and fate. This study resulted in the development of a biological process for the treatment of wastewater containing PCB and the discovery that naturally-occurring humic substances enhance biodegradation of aquatic contaminants.

The toxicity of various halogenated phenols was investigated and the data indicate that the positions of chlorine substituents in the chlorophenols and the octanol/water partition coefficient affect their toxicity. The toxicity of chlorobenzenes to microorganisms was also assessed at the enzyme level and the results indicated the mechanism of chlorobenzenes' biotoxicity is primarily due to their ability to uncouple the oxidative phosphorylation process.

A study has been undertaken to learn the mechanisms whereby the biochemical reactions carried out by microorganisms interact with other processes to degrade polychlorinated biphenyls (PCBs) or to effectively remove them from the environment. Many PCBs are converted by bacteria to bright yellow products. These may be further degraded by light, so that a combination of biochemical and photochemcal reactios is more effective in destroying these contaminants than either type of reaction alone.

PCB metabolites may undergo conversion by dark-colored insoluble materials resembling natural humic substances. It was found that this reaction proceeds spontaneously, i.e., once the the metabolites have been formed, their further transformation no longer requires the presence of microorganisms. This type of reaction is especially evident with Aroclor 1221 which contains appreciable amounts of biphenyl. The evidence suggests that a substance called catechol produced by the metabolism of biphenyl is co-polymerized with one or more of the yellow metabolites from chlorinated biphenyl to form the insoluble product. (*Liu, Baxter, Thomson*)

Analytical Research. An improved analytical headspace method is described for the quantitative determination of volatile contaminants in water. Detection limits at the 1.0 $ng \cdot L^{-1}$ level or better can be achieved for carbon tetrachloride using a suitable capillary column gas chromatograph and electron capture detector. The method is also applicable to the analyses of haloforms and associated halomethanes and haloethanes in drinking water or quantitation of low ppt concentrations in ground or surface waters. This headspace technique is simple, inexpensive, easily applied to field conditions and well-suited for cryogenic capillary column chromatography. (*Kaiser, Comba*)

INORGANICS SECTION

The objective of this section is to determine the persistence and fate of inorganic and organometallic contaminants in aquatic ecosystems.

Fate of Tributyltin in Aquatic Environments. Tributyltin is a pesticide which is extensively used in lumber preservation, as a slimicide in cooling towers, and as an antifouling agent in boat paint It is very toxic to aquatic life. The goal of this study is to determine its persistence and fate in aquatic ecosystems.

Tributyltin and its degradation products, dibutyltin, butyltin, and inorganic tin, are extracted from water or sediment and analyzed by combined gas chromatography-atomic absorption spectrophotometry. Tributyltin appears to be moderately stable chemically; the rate-limiting step of degradation is sunlight photolysis in natural water, with a half-life of at least three months. It is, however, degraded by algae, with a half-life of four weeks at 20°C. Further experiments are under way on adsorption to sediment, bacterial degradation and transformation, and uptake and metabolism by trout, as well as a survey of butyltin occurrence in water and sediment across Canada. (*Maguire, Tkacz*)

Determination of Alkylleads and Alkyltins in Aquatic Environments. Dialkyllead and trialkyllead compounds which have been historically difficult to analyze were for the first time quantitatively extracted by the use of a chelating agent, sodium diethyldithiocarbamate. After butylation to

the tetrasubstituted form, the alkyllead species are analyzed by the GC-AAS method. A GC-AAS chromatogram of the ten alkyllead species is shown in Figure 3.

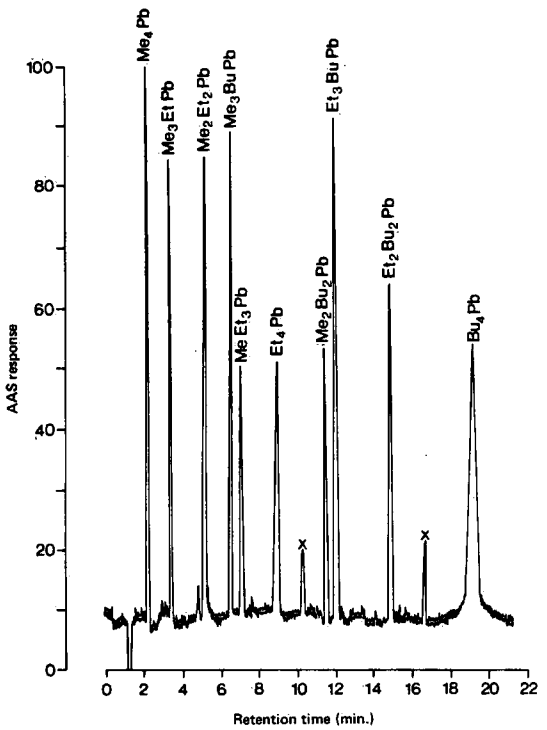

Figure 3 Gas chromatography–atomic absorption spectrometry of five tetraalkyllead compounds (10 ng each); four butyle derivatives of dialkyl– and trialkyllead (8 ng each) and Pb (II) (15 ng). x – unidentified lead compounds.

A survey of the occurrence of methyltin species in the aquatic environment reveals that significant concentrations of methyltin compounds were present in harbours and heavily-industrialized areas associated with organotin usage. The source of methyltin compounds is likely due to the methylation of inorganic tin and the degradation products of other organotins (such as butyltin) of anthropogenic origin. The toxicity of the alkyltin compounds has been found to be related to the chain length of the organic group and the degree of substitution. Diethyllead and triethyllead compounds were for the first time found in fish, sediment, macrophytes and water in the St. Lawrence River off Maitland.

Isolates from four genera of freshwater green algae have been found capable of methylating inorganic arsenic compounds to the various methylarsenic acids undernatural conditions. Such methylation by green algae constitutes an additional source for the formation and cycling of organo-arsenic compounds in freshwater ecosystems. (*Chau, Bengert*)

Metal and Metalloid Speciation and Bioavailability. A bioassay was developed using natural phytoplankton populations and sediment elutriate from the Great Lakes. This bioassay was applied to different types of sediment from Great Lakes' harbours and depositional basins. Changes in the phytoplankton community were induced by synergistic effects of nutrient/metals and metals/organic compounds.

Contaminants distributions in the Niagara River/Lake Ontario system indicated the Niagara River as a major source of contaminants found in Lake Ontario sediments. Statistical analyses were carried out on three data sets for organics and metal concentrations in Niagara River sediment.

High concentrations of mercury and arsenic were found in sediments collected from Shubenacadie River headwater lakes of Nova Scotia. Sampling of suspended solids and water indicated a transport of arsenic and mercury by suspended matter. Correlation of gold and mercury concentrations in lake sediments suggested that the mercury contamination originated from the amalgamation process used for gold refining during the past mining activities in the area. (*Mudroch, Kokotich*)

Chemical Forms and Availability of Elements of Environmental Importance in the Great Lakes. Sequential chemical extractions have been done on suspended particulate matter and surficial sediments from the Niagara River-Western Lake Ontario and Detroit River-Western Lake Erie systems. For example, for seven samples collected weekly in the summer of 1982 at Niagara-on-the-Lake, the concentrations of potentially readily-available forms of Cd exceed the Ontario guidelines for open-water disposal of sediments contaminated with this element. For phosphorus, these forms are present in concentrations ranging from 52-460 μg g^{-1}. Total P in Great Lakes sediments are generally 1000-1600μg g^{-1}. The geochemical mobility of Zn is also quite high and for this data set, the concentration range is 40-120 μg g^{-1} for potentially-available forms.

For surface waters, the measurement of dissolved metal forms is more relevant to assessing potential availability to plankton. In a vertical profile of dissolved Zn at an offshore station (100 m depth) in Lake Ontario, concentrations ranged from 0.22-1.88μg g^{-1}. The profile showed evidence of release of Zn by sedimenting plankton or fecal pellets and at the 98 m depth a maximum concentration likely caused by resuspension and mixing of pore waters. (*Lum, Kokotich*)

RADIONUCLIDES SECTION

The major objective of this Section is to investigate the behaviour of both naturally-occurring and artificially-produced radio nuclides in aquatic ecosystems. Studies include the determination of pathways of radionuclides discharged to lakes, the measurement of levels of these radionuclides in water, biota, and sediments, the application of predictive models for the dispersion of radionuclides into surface waters, and the development of methods for the determination of these radionuclides.

Levels of Fallout Radionuclides in the Great Lakes Waters. The levels of ^{144}Ce, ^{137}Cs, ^{125}Sb, and ^{90}Sr in the open waters of the Great Lakes — measured over the period 1973-81 — were found to be very low. The data indicate that the concentrations of all these radionuclides have decreased with time. The measured dose equivalent commitments (0.19 mrem/yr in 1973; 0.10 mrem/yr in 1981) are well within the Canada/US Great Lakes Water Quality Agreement's water quality objective for radioactivity (1 mrem/yr). (*Joshi, Platford, Livermore*)

Uranium-Series Radionuclides in Langley Bay, Lake Athabasca (Saskatchewan) Ecosystem. Levels of these radionuclides in sediments, waters and fish samples are be-

ing determined with the view of determining aquatic pathways of naturally-occurring radionuclides and impact of the abandoned Gunnar uranium mine tailings. The newly developed technique of low-energy gamma-ray spectrometry (Figure 4) is being applied. Preliminary results indicate elevated levels of ^{210}Pb and ^{226}Ra in Langley Bay sediments in the immediate vicinity of the tailings pile (1557 and 1519 vs. ambient levels of about 20 and 2 pCi/g respectively). (*Joshi, Platford, Livermore*)

Pathways of ^{226}Ra from Port Granby Radioactive Waste Management Site to Lake Ontario. Investigations have continued into the groundwater leaching of ^{226}Ra from the site. A two-dimensional finite element method has been used to simulate groundwater flow patterns along several cross-sections through the site. The groundwater divide indicates that all of the recharging water is flowing to the deeper formations and discharging to Lake Ontario. Contaminant plumes for ^{226}Ra, U, and NO_3 have been delineated. (*Platford, Joshi, FitzGerald*)

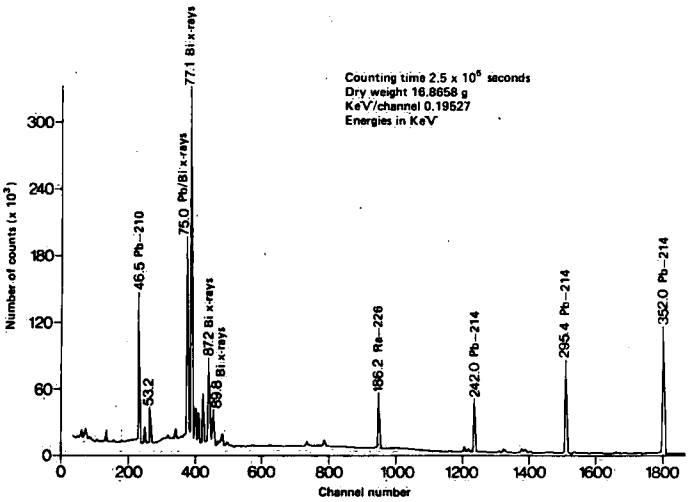

Figure 4 Low energy gamma ray spectrum of Langley Bay sediment sample.

Radionuclide Pathways in the Niagara River/Lake Ontario. The possible introduction of transuranics into Lake Ontario from a shut-down nuclear reprocessing plant at West Valley, N.Y., via Cattaraugus Creek/Lake Erie/Niagara River is being investigated. Analytical procedures required for this study have been completed and are currently being used to determining the concentrations of $^{239,240}Pu$, ^{241}Am, and isotopic U in sediment cores from 5 locations in Lake Ontario. Levels of ^{210}Pb, ^{226}Ra, isotopic Th, and gamma-emitting nuclear fission products in cores are also being measured. (*Joshi, Livermore*)

ACID DEPOSITION SECTION

The objective of research projects conducted by the Acid Deposition Section is to quantify and understand the hydrogeochemical response of acid-sensitive basins to the deposition of air pollutants. Two projects are underway, both utilizing the remote Turkey Lakes Watershed (TLW) as the field study-site. The first study employs calculation of mass balance(s) in the TLW in order to define the most important geochemical mechanisms controlling the "dose-response" relationship for this basin, while the second study is focused on determining the factors or processes controlling the short-term acidification which is associated with spring snowmelt.

The TLW is an undeveloped, hydrologically-calibrated basin (area = 10.5 km^2) located 50 km north of Sault Ste. Marie, Ontario. It is completely forested (mixed hardwood) and contains a chain of 5 lake basins which exhibit a range of geochemical sensitivity and response to acidic deposition. For example, mean lake alkalinity increases from 0.04 to 0.19 meq L^{-1} from the headwater to the lowest lake in the chain. Basin geology and geochemistry have been described.

Geochemical Mass Balances in a Calibrated Watershed. A June to May "water-year" has been selected for calculation of the mass budgets, and chemical data for two complete years (81-82, 82-83) have been collected, edited, and stored in the computerized national water quality data base (NAQUADAT) for streams and lakes. Stream hydrology has been measured in cooperation with the Water Survey of Canada and flow data are available through 1982. Atmospheric inputs to the watershed are measured. All the necessary meteorological and physical data required for determination of lake evaporation have been collected and evaporation calculated for 1981 and 1982. The first important component of the lake mass balances (e.g., stream loading) is being calculated using a recently developed computer program which automatically accesses the intermittent NAQUADAT and continuous (e.g., daily) hydrology data records. (*Jeffries, Semkin, Neureuther, Langlade, Jones*)

Snowmelt and Acid Shock. The accumulation and loss of ionic pollutants in the snowpack and the effect of snowmelt on surface water chemistry in 1981 and 1982 was studied in the TLW. The contaminants stored in the snowpack were rapidly and preferentially (with respect to water) removed at the beginning of the melting period (Figure 5). The extremely dilute residual snowpack remaining after the initial ion loss still contained over half of the water.

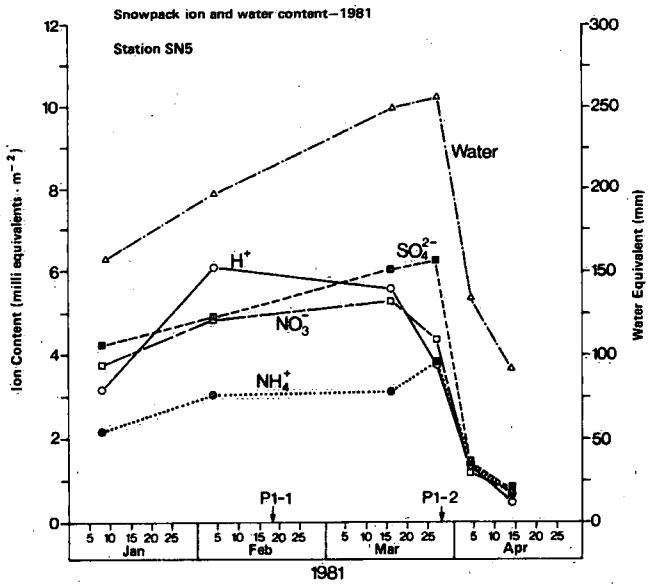

Figure 5 Hydrogen ion, SO_4^{-2}, NO_3^-, NH_4^+ (meq.m^{-2}), and water (mm) content of snowpack at station SN5 from January to April 1981. Dates of important rainfall events are indicated on the horizontal axis.

In response to snowmelt, stream waters exhibited a pH depression and decreases in the concentration of alkalinity and basic cations (Figure 6). The magnitude of pH depression was related to the rate of melting and runoff, being greater in 1981 when the melt period was influenced by continuously warm air temperatures and occasionally heavy rainfall. Only minor variations in SO_4^{2-} and NO_3^- concentrations were observed. These results are different than those observed in Scandanavia and probably reflect the interaction of the deeper, generally unfrozen soils present in the TLW with runoff waters prior to their appearance in the streams and lakes. (*Jeffries, Semkin, English*)

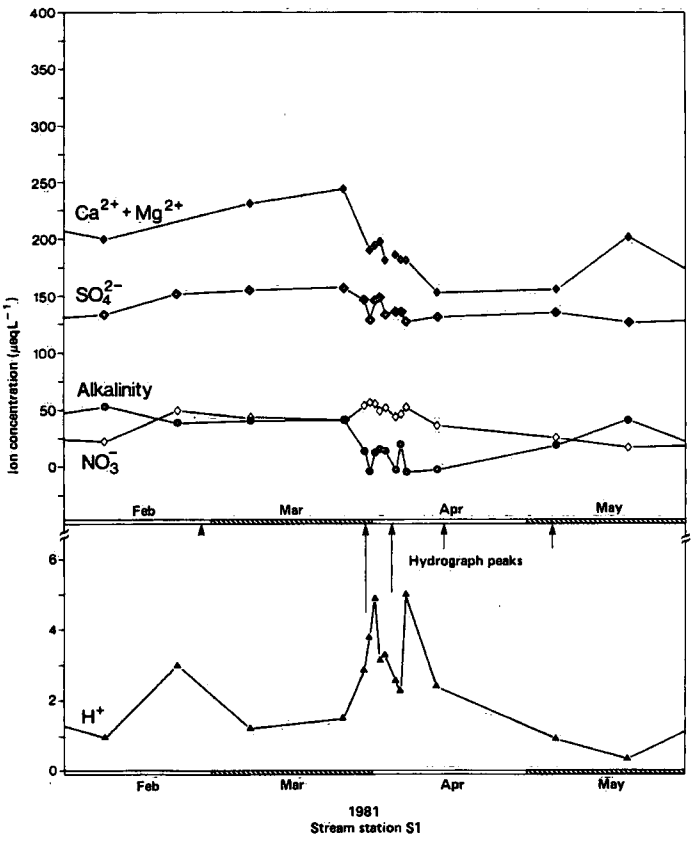

Figure 6 Variation in the concentration (μeqL^{-1}) of Ca^{2+}, Mg^{2+}, SO_4^{2-}, Alkalinity, NO_3^-, and H^+ at stream station S1 from February to May 1981. Note that the scale for H^+ is different from the rest. Dates and relative size of the hydrograph peaks are also shown.

STAFF LIST

Chief — Dr. R.J. Allan
Secretary — Mrs. E.M. Kerr
Administrative Officer — Mr. F. Boyd

Organics-Pathways Section

Head, Dr. J.H. Carey	photodegradation of organic contaminants

Researchers

Mr. M.E. Fox	persistent organic contaminants in aquatic ecosystems
Mrs. J.L. Metcalfe	biological fate of contaminants
Dr. E. Nagy	fate and effects of herbicides
Dr. W.M.J. Strachan	organic contaminants in aquatic ecosystems, especially rain

Technical Staff
Miss L. Coletta
Mr. J.H. Hart

Organic-Properties Section

Head, Dr. K.L.E. Kaiser	structure-activity correlations of organic contaminants

Researchers

Dr. R.M. Baxter	biochemistry and degradation products of PCBs
Mrs. K. Kwasniewska	biodegradation of organic contaminants and toxicity to microorganisms
Dr. D.L.S. Liu	biodegradation of organic contaminants
Dr. B.G. Oliver	sources of aquatic organic contaminants, water chlorination by products

Post Doctoral Fellow

Dr. J.M. Ribo	structure-activity correlations of organic contaminants

Technical Staff
Mr. M.E. Comba
Mrs. K.D. Nicol
Mrs. K. Thomson

Inorganics Section

Head, Dr. R.J. Maguire	aquatic fate of organometallics

Researchers

Dr. Y.K. Chau	chemical and biological processes of organo-metallics in the aquatic environment; metal speciation and toxicity
Dr. K.R. Lum	chemical forms of trace metals and geochemistry of particulate matter
Mrs. A. Mudroch	chemical forms of trace metals and geochemistry of particulate matter

Technical Staff
Mr. G.A. Bengert
Mr. R.J. Tkacz
Miss E. Kokotich

Acid Deposition Section
Head, Dr. D.S. Jeffries — geochemical processes controlling lake acidification; metal geochemistry

Researcher
Mr. R.G. Semkin — geochemical processes controlling lake acidification

Post Doctoral Fellow
Dr. M. English — snow chemistry

Technical Staff
Miss M.D. Jones
Mr. J. Longlade
Mr. R. Neureuther

Radionuclides Section
Head, Dr. S.R. Joshi — aquatic pathways of radionuclides

Researcher
Dr. R.F. Platford — physical chemistry of radionuclides

Technical Staff
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Mrs. S.A. Thompson

COMMITTEE MEMBERSHIP

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- Algoma Watershed Acid Rain Steering Committee

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- NRC Environmental Secretariat Panel on Organotins
- NSERC Environmental Toxicology Panel
- Standards Council of Canada

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- IJC-SAB Task Force on Non-Phosphate Detergents

D.S. Liu
- Standards Council of Canada
- ASTM Oxygen Uptake Group
- UN-FAO Marine Fouling Group

B.F. Scott
- International Standards Organization
- DOE Ontario Region Environmental Emergency Team
- AGRAD Working Group on Fate of Oil

E. Nagy
- AGRAD Working Group on Fate of Oil

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ANALYTICAL METHODS DIVISION

The Analytical Methods Division is responsible for research and development of analytical methodologies for chemical and microbiological pollutants in the aquatic environment, for conducting national and international quality assurance programs and for providing centralized computing service to all components of CCIW. The Division undertakes national and regional research programs in analytical chemistry, microbiology and quality assurance and transfers completed technology to the national and regional laboratories of IWD and other clients.

The staff of the Division maintains close contact with scientists in other Canadian federal departments, provincial governments, U.S. federal and state agencies, and with universities. In some cases collaborative studies are undertaken. The Division strongly supports the work of the International Joint Commission, the International Standards Organization, American Society for Testing and Materials, Federal Interdepartmental Committee on Pesticides, and Association of Official Analytical Chemists, by membership on committees and task groups.

The Analytical Methods Division is divided into four Sections covering analytical chemistry research, quality assurance and methods adaptation, microbiology and computer services.

ANALYTICAL CHEMISTRY RESEARCH SECTION

The Analytical Chemistry Research Section (ACRS) is engaged in advanced methodology and instrumentation research. The main objective is to provide analytical methods to IWD regional laboratories and other agencies within the federal government. The techniques currently employed include atomic and molecular spectroscopy, high resolution gas chromatography, GC/MS, high pressure liquid chromatography, radioimmunoassay, electrochemistry and flow-injection analysis. Analytical methods are developed for water, sediment, soil, fish, aquatic plant materials, waste waters, solid wastes, road funoffs, leachates, etc. The sensitivity of the methods developed within ACRS vary depending upon the need of the end user and sample matrix.

Heavy Metals. A modified method was developed for the determination of chromium in water by atomic absorption spectroscopy. In this work it was shown that the problems of the existing method were due to the chromium not being completely oxidized to Cr^{VI} in the presence of the organics in the sample and hence not being complexed and extracted. The preferred oxidant was found to be potassium persulfate. This completely oxidizes the chromium, destroys the organics and can be thermally decomposed after the oxidation is complete.

Hydride generation and inductively coupled argon plasma emission spectroscopy has been used for the determination of tin in environmental samples. The chemistry for the optimum production of stannane has been determined and a study made of the ways to physically separate the stannane. This has resulted in a very sensitive method, having a detection limit of 0.01 μgL^{-1} Sn in water.

The method for the digestion of fish tissue for the determination of arsenic and selenium has been developed that does not use perchloric acid. It has been shown that a nitric-sulfuric acid mixture can be used for this digestion, eliminating the hazards and the need for special facilities in using perchloric acid. (*Goulden*)

Inorganic Parameters. The development of the dynamic mode of electrochemical sensor operation continued with the incorporation of pH, chloride and water hardness sensors into a previously developed system for dissolved oxygen, conductivity and temperature. An immersible micro-processor based digital system suitable for *in situ* operation was designed and tested. Mathematical equations for computing and correcting experimental data as well as for calibration of the system have been derived.

A conductometric acid-base titration method for the determination of alkalinity and acidity of water samples has been developed. It has been shown that the conductometric titration is superior to the potentiometric titration in terms of detection limits (0.1 mgL^{-1}), sampling rate (30 s/sample) and precision (±2%). No interfering effects from other constituents were observed. This technique is ideally suited to low buffered waters and precipitation samples and hence is extremely useful in the acid rain program.

A method for the determination of acidity and alkalinity utilizing flow-injection analysis has also been developed. The basis of the method is that the injection of the reagent results in a change of the conductivity. This change is registered in the form of peaks and related to the concentration of alkalinity or acidity in the sample. Linear calibration curves down to 0.1 $mgL^{-1}CaCO_3$ were obtained with a relative standard deviation of 5%. Ten mL of the sample is sufficient to produce five replicate peaks at a sampling rate of up to 30 samples/hour. (*Sekerka*)

Organic Parameters. A method for the determination of phenols in a variety of environmental samples with improved preconcentration, cleanup and quantitation steps has been developed. It involves extraction of the sample in acidic medium using toluene or methylenechloride. The initial fractionation of the extract is achieved by preparative gel permeation chromatography using a styrogel column. Further cleanup involving extraction with sodium triphosphate is followed by acidic back extraction and quantitative analysis by HPLC or derivative GC. The spike recoveries ranged from 80-93%.

A method for the analysis for polychlorinated dibenzo-p-dioxin (PCDD) was developed which included soxhlet or liquid/liquid extraction, preparative GLC using styrogel, trisodiumphosphate extraction and alumina and carbon fibre cleanup steps. Quantitative analysis was carried out using high resolution GC-low resolution mass spectrometry. The method was validated for water, fish, wood preservative, technical phenols and related samples. The recoveries of selected PCDDs ranged from 56 to 85%.

An improved method for analysis of chlorophyll pigments was developed. It includes improved extraction, optimization of the conditions to minimize hydrolysis and decomposition of chlorophyll, improved preservation techniques and HPLC with fluorescence detector for quantitation of individual pigments at ultratrace levels. The method was compared with conventional spectrophotometric method and found to be superior.

Considerable advances have been made with narrow bore capillary column gas chromatography. Theoretical considerations and experimental results demonstrate the ability to increase the speed of analysis and/or the resolving power for such compounds as PCB's and toxaphene. These columns can be used without modification to commercial chromatographs. Splitless and on-column injectors were evaluated for use in multi-residue analysis of PCBs. It was found that for quantitation of wide boiling

range mixtures at picogram levels, on-column injection is the only technique which yields satisfactory results. This method for PCBs allows the determination of individual isomers, homologous groups and total PCBs as low as 0.1 mg/kg in sediment samples. Chromatograms of toxaphene residues are complex and some means of establishing similarities in residue profiles are needed. Three methods for quantitation of toxaphene are being evaluated.

A. Narrow-bore wall coated open tubular (WCOT) gas chromatography with Electron Capture Detection (ECD) can provide fingerprints suitable for estimation, but lacks specificity. The detection limit is 0.5 mg/kg.

B. GC-MS selected ion monitoring using electron impact induced ionization gives the detection limit of 1.1 mg/kg.

C. Electron impact mode — SIM in medium resolution produces 1μg/kg limit of detection. (*Onuska*)

Radioimmunoassay (RIA) techniques have been proposed for rapid and inexpensive screening of large numbers of environmental samples. A radioimmunoassay laboratory has been established and preliminary research undertaken to develop an RIA procedure for polychlorinated dibenxo-p-dioxins and polychlorinated dibenzofurans. 1-N (5-iodovaleramide) — 3,7,8 trichlorodibenzo-p-dioxin was synthesized, labelled with ^{125}I and evaluated. The chemistry of the labelling reaction was subsequently examined and an improved procedure proposed. (*Sherry*)

QUALITY ASSURANCE AND METHODS SECTION

The work of the Section comprises three main areas: quality assurance; development of certified reference materials (CRMs) and reference materials (RMs); and methods development (Figure 1). The quality assurance programs involve the design and implementation of several types of quality control (QC) studies as well as investigations of sample homogeneity and stability. These programs assess the analytical performance and ensure the generation of reliable, valid and compatible analytical data on a regional, national and international basis. Development of CRMs and RMs are essential to increase the effectiveness of these quality control studies. Reference materials and CRMs are also required for methodology development, for the evaluation of precision and accuracy of laboratory data and for QC studies for the selection of contract laboratories.

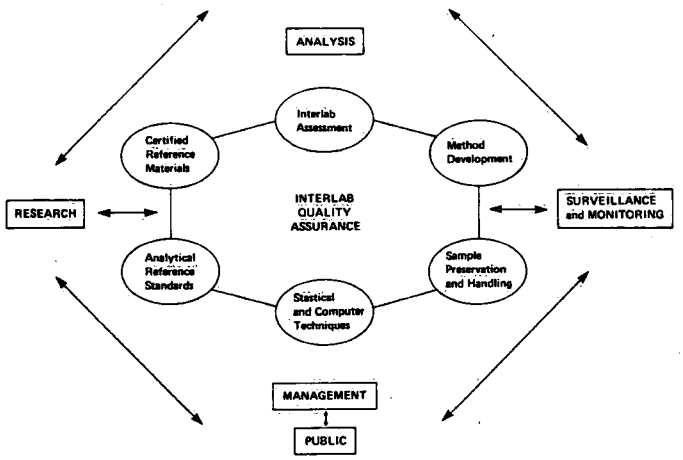

Figure 1 Diagram showing the components and interrelationship of interlaboratory quality assurance.

The methods development program involves applied research to develop or validate analytical methods for water, sediments and biota. The Section also provides expert advice to the operational laboratories of the Water Quality Branch.

Quality Assurance (QA). Three new programs have been initiated this year:
(a) Long Range Transport of Air Pollutants (LRTAP) QA Program,
(b) Prairie Provinces Water Board (PPWB) QA Program, and
(c) Dredging QA Program.

(a) LRTAP QA Program: This program was initiated in 1982 in response to the concern about data compatibility and quality among laboratories generating data for the LRTAP program. Each year, 3 multi-sample QC studies for some 40 inorganic parameters in water are designed and sent out to about 60 Canadian and a few U.S. laboratories. (*Aspila*)

(b) Prairie Provinces Water Board QA Program: This program, initiated in September 1982 is designed for assessing and improving the compatibility of water quality data generated by the Federal and the Alberta, Saskatchewan and Manitoba Provincial laboratories. Twelve studies, each involving some 40 inorganic parameters, are conducted per year. Extensive computer programming and several computer files are being generated to meet the objectives of the program. This program is an extension of the existing interregional QC studies for the national and regional Water Quality Branch Laboratories. (*Alkema*)

(c) Dredging QA Program: Under the auspices of the International Joint Commission, a new QA program for organic and inorganic parameters specifically designed for dredging programs in the Great Lake Basin, was initiated in September 1983. There are four key components in this program: design and conduct of intercomparison studies; development of specific certified reference samples; design of suitable computer programs to provide capability information and short and long term laboratory performance; development of QA criteria for analytical contracts for dredging programs. (*Lee*)

In addition to these three new activities the Section actively continued its ongoing national and international quality assurance studies.

The National Q.C. Study involves over 100 federal, provincial, university and private laboratories and includes both inorganic and organic parameters in water and sediment. These studies serve to assess methodology and data of the Water Quality Branch laboratories by comparison with peer laboratories, establish laboratory performance of the Water Quality Branch and private laboratories to permit selection of private laboratories for contract analysis and provide additional data for certification of reference materials. This year an organics study for pesticides in sediment was conducted. (*Lee*)

In addition to the Dredging QA program, the Section has also provided a lead role in QA for the International Joint Commission's Great Lakes International Surveillance Program. International intercomparison studies for phosphorus in effluents, trace metals in water and organics in fish have been conducted this year. A QC study for chlorinated pesticides was designed and conducted under the auspices of the Federal Interdepartmental Committee on Pesticides.

Research and development of certified reference materials continued in support of the quality assurance programs. The certification of three sediment CRMs for three different levels of Arsenic, Selenium and Mercury was completed this year. Two sediment CRMs for polynuclear aromatic hydrocarbons (PAHs) have also been prepared. These PAH CRMs are the first of this type available. (*Lee*)

Sample Stability and Preservation. The centralization of the Water Quality Branch laboratories will involve longer time periods between sample collection and sample analysis. Since a major consideration in the reliability of any laboratory measurement is that of sample integrity, technological needs for the sampling process and handling prior to analysis must be addressed. A study of currently used preservation techniques was initiated in 1983 for all inorganic and organic parameters routinely analysed by the National Water Quality Laboratory. Phase one of this study, major ions and nutrients, will be largely completed by mid 1984. (*Chau*)

Methods Development. A multi-residue method for the analysis of 15 chlorophenols in water was developed and a multiclass method for acid and neutral herbicides in sediment and in water is at its final stage of development. An evaluation of current methodologies for sulfate determination (Technicon colorometric and Ion Chromatographic) was completed as part of the LRTAP program. Highly coloured waters should only be analysed for sulfate by ion chromatography. (*Cheam*)

MICROBIOLOGY LABORATORIES SECTION

The Microbiology Laboratories Section has two main program areas. One is to develop and evaluate microbiological methodologies and criteria for monitoring, assessing and maintaining water quality from the standpoint of chemical contaminants and microbiological hazards. The other is to conduct environmental research into the effects of pollutants on the population of microorganisms in the aquatic ecosystem.

As most of the microbiological expertise of the Department of the Environment is consolidated within the Microbiology Laboratories Section directional guidance for the research is based on:

1. perception of the needs of NWRI and the Department of the Environment to fulfill their mandates;
2. requests for specific environmental microbiological information from the various Inland Waters Directorate regions across Canada;
3. priorities of the IJC Water Quality Board and the Long Range Transport of Airborne Pollutants program, and
4. national and international contacts who inform us of present or upcoming microbiological problems in their areas or countries.

During the past year the Microbiology Laboratories Section staff concentrated their efforts on three main areas:

1. The distribution patterns of *Legionella* organisms in Canadian natural and domestic waters and *Legionella* growth studies.
2. Comparison studies of various microbial toxicity screening procedures and holding the First International Symposium on Toxicity Testing Using Bacteria.
3. The effects of acid rain (LRTAP) on microbial populations and physiology.

Coupled with these scientific efforts Microbiology Laboratories staff also participated in a variety of joint research and support studies such as, electron microscope studies on the effects of acid stress on bacterial morphology, ASTM round robin studies on methods evaluation, provision of microbiological data to the IJC on potential problem areas in Lake Superior and the evaluation and revision of nitrogen cycle enumeration methodology for our methods manual "Methods for the Microbiological Analyses of Waters, Wastewaters and Sediments". Over 700 of these methods manuals have been distributed by request, to virtually every country in the world performing environmental microbiology research.

Legionella Studies. In cooperation with the Department of Health and Welfare, a study is being carried out to ascertain if *Legionella* organisms can be isolated from public and industrial building water distribution systems in major cities across Canada. As part of this study an intensive investigation of rivers and lakes in the three Maritime provinces, Prince Edward Island, Nova Scotia and New Brunswick was carried out during the summer using a mobile laboratory. From the preliminary data collected this year, it would appear that the *Legionella* organisms can be readily found in potable and cooling tower water systems. Laboratory studies were also performed to elucidate the survival characteristics of *Legionella*. these studies centred around longevity of the organism in fresh and salt water, soil, on porous and non porous material, in ice and under the stress of sunlight. (*Dutka*)

Toxicity Screening. One of the highlights of this project was the holding of he First International Symposium on Toxicity Testing Using Bacteria on May 17-19, 1983 at the Canada Centre for Inland Waters. Thirty-nine papers were presented by delegates from 11 countries, from Russia in the East to Japan in the West. Based on the very positive response to this first Symposium, it was decided to hold similar symposia every two years. (The next will be in Banff, May 6-10, 1985).

This year saw the completion of much of our basic comparison studies of various microbial toxicity screening tests using pure and mixed chemical solutions ie. Microtox, *Spirillum volutans*, synthetic activated sludge, *Pseudomonas fluorescens* density inhibition etc. All of the information from those studies has now been documented in various research journals and in-house publications.

The evaluation of a new and novel toxicity screening procedure was initiated this year. The microbial electrode for toxicity screening is based on the use of an oxygen probe onto which a pure culture of bacteria is attached by means of a membrane filter. This procedure is being evaluated using our standard set of pure and mixed chemicals and then it, along with the other procedures evaluated in our laboratories will be field tested next year using sewage effluent and river water samples. (*Dutka*)

Effects of Acid Stress on Microbes. As part of the LRTAP studies Microbiology Laboratories Section staff studied the effects of acid precipitation on aquatic micro organisms. Several water and sediment cores from 8 lakes receiving acid precipitation near Sudbury, Ontario were collected and examined for total, respiring and aerobic heterotrophic bacterial populations. These studies were complemented with laboratory experiments using laboratory fermenters to illustrate the effects of acid stress on microbial activity and morphology.

Changes in bacterial population (No./mL)

Substrate/populations	pH 7.2 Time 0hr	pH 7.2 Time 3hrs	pH 4.0 Time 0hr	pH 4.0 Time 3hrs
1. Glucose				
Total bacteria	9.1×10^9	9.5×10^9	2.8×10^7	3.2×10^8
Resp. bacteria	$1.3 \times \underline{10^9}$	$1.5 \times \underline{10^9}$	ND	ND
2. Glutanic acid				
Total bacteria	7.3×10^9	7.4×10^9	1.9×10^8	2.7×10^8
Resp. bacteria	$0.7 \times \underline{10^9}$	$0.7 \times \underline{10^9}$	ND	ND
3. Sodium acetate				
Total bacteria	8.3×10^9	8.5×10^9	2.3×10^8	2.7×10^8
Resp. bacteria	$2.2 \times \underline{10^9}$	$9.7 \times \underline{10^9}$	ND	ND

ND—not detected

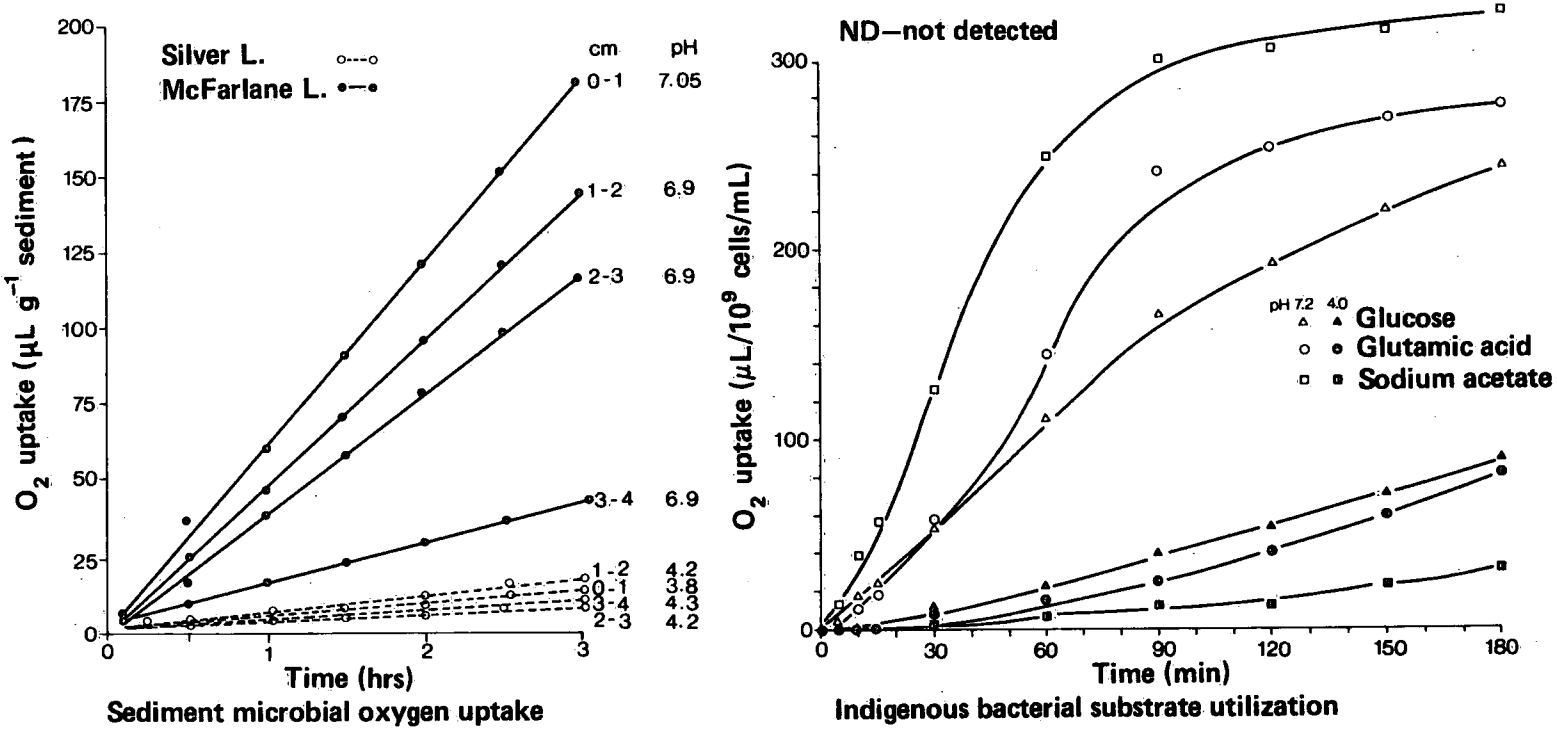

Figure 2 Microbial activity from acid stressed and non-acid stressed lakes.

Data indicated that a strong relationship existed between lake acidification and bacterial activity. pH values below 5.5 appear to be critical for bacterial respiration and multiplication. In acid stressed lakes (pH 3.8) the sediment respiration was 15-20% of that in a normal lake (pH 7.2) (Figure 2). Associated with this, a strong correlation was demonstrated between pH and total organic matter (Figure 3), the lower the pH, the higher the organic matter content. Bacterial ultrastructure and cell diversity can also be correlated with a specific level of pH. The retarded metabolic activity in bacteria is attributed to the alteration in the selective permeability of the cell membrane. (*Rao*)

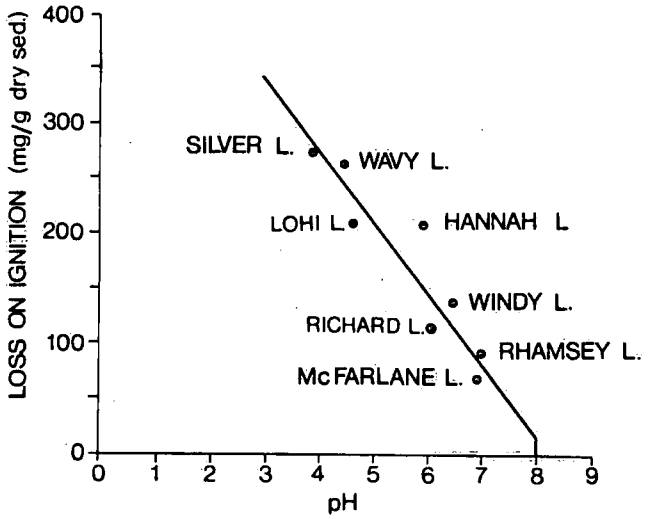

FIGURE 3
pH AND TOTAL ORGANICS IN LAKE SEDIMENTS

COMPUTER SERVICES SECTION

The Computer Services Section operates and provides system software support for the large scale scientific computing facilities at the Canada Centre for Inland Waters. Services are provided to all components of the Centre since much of current environmental research is dependent on the availability of adequate computer resources. The Section's work affects many NWRI research programs.

The facilities of the section include a Control Data (CDC) Cyber 171 computer system supporting batch and time-sharing access, a high speed Calcomp plotting system, two minicomputers, and a data entry service.

Future Requirement Planning. Since the contract for the currently installed CDC Cyber 171 Sytem will expire in June of 1984, a study team was formed in mid-1982 to evaluate the future computing requirements for CCIW. After polling managers throughout IWD, it was concluded that the scope of services provided by the Section would remain essentially unchanged during the next few years. A technical evaluation team, with members from the Computer Services and Data Management Sections (NWRI) and Computing and Applied Statistics Directorate, was formed for the purpose of evaluating specific computing requirements and assisting the Section in the procurement phase.

Upgrades and Software Development. In the spring of 1983, the Section was able to acquire the PDP-16/60 minicomputer which had been leased by Water Quality Branch for the AWQALABS system. This computer was installed to replace the aging PDP-15 computer which had been in use since 1971. The system software development to support existing PDP-15 applications (time-series data editing, digitizing) was completed in October 1983. Applications development in these areas is being done by the Data Management Section.

Interactive access to magnetic tapes became available on the Cyber 171 system in the fall of 1982. This feature was initially provided on a short-term test basis and was later made permanent as no problems had arisen. Users reaction was extremely favourable. Software to drive an MVI-7 colour graphics terminal with standard Calcomp subroutine calls was written in October 1982. This allowed the display of color graphs and contour maps. The Calcomp contour plotting program was later modified to provide hard copy multicolor maps. (*Pulley*)

Operations. The volume of work handled by the Section has continued to increase. During fiscal year 1982/83, Cyber 171 computer usage increased by 34%. Growth in other areas has been less dramatic, and the demand for card-based services continued to decline.

During FY 1982/83, 113 500 batch jobs and interactive sessions were run on the Cyber 171 system and 2830 hours of central processor time were used. The system was in operation for over 5000 hours and system availability continued to exceed 99%. The estimated value for all services provided to CCIW by the secion in FY 1982/83 was in excess of $1 000 000. (*Pulley*)

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Mr. K.I. Aspila	IJC Q.C. program and LRTAP Q.C. studies
Dr. H.B. Lee	national and IJC Q.C. (organics), standard reference materials (inorganics), sample storage conditions, methods evaluation
Mrs. Y. Stokker	organic method development, some Q.C. studies

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- Task Group Chairman for various ASTM task groups: Nutrients in Sediment, Chlorinated Dioxins, Liquid Chromatography and ATP (these task groups form an integral part of ASTM Subcommittees 6, 7 and 24)

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- Appointed Member, Quality Assurance Committee, AOAC Coordinator for Water and Sediment, FICP Check Sample Programs, FICP

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- Task Group D19:24:06.06, Sulphate reducing bacteria — Chairman
- Task Group D19:24:06.07, Toxicity Tests; D19:24:08.08, Mutagen Tests; D19:24:08.09, Epifluorescence Microscopy; D19:24:08.18, Heterotrophic Bacteria
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F.I. Onuska

Panel Member on PAH in Water, Subcommittee on Water of NRCA Associate Committee on Scientific Criteria for Environmental Quality

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HYDRAULICS DIVISION

The Hydraulics Division has mandates to undertake research into all aspects of the hydraulics of inland waters and to provide a multi-disciplined engineering capability in design, manufacture and maintenance of special equipment and measuring systems to support other inland water research teams.

National programs are undertaken in applied and basic research related to hydraulic, fluid mechanic, hydrologic, geophysic and geologic processes as they apply to fluvial, lacustrine and man-made environments.

The Hydraulics Division is organized in three research sections and three service sections: Environmental Hydraulics, Shore Processes, Technical Services, Engineering Services, Manufacturing and Technical Development, and Drafting Services. There is also an Office Services Section.

ENVIRONMENTAL HYDRAULICS SECTION

There are three main areas of research in the Environmental Hydraulics Section: open-channel hydraulics, river ice engineering and urban water resources.

Flow in Mobile Bed Channels. Work continued on the development of models for the prediction of transport of water and sediment in alluvial rivers and on the investigations of basic physical relationships which are required for improving theories and models.

Experiments were carried out to investigate the causes of meander formation. It was found that meanders formed even in laminar flows which were free of secondary circulations. Thus the popular hypothesis that turbulence-driven secondary circulation is the cause of meander formation should be abandoned. (*Krishnappan*)

Conditions for the beginning of sediment transport are being investigated, including the critical mean flow velocity, and the effects of sediment density and grain size distribution. An equation for the critical mean flow velocity in terms of flow depth and sediment size has been developed. This equation is convenient for hydraulic design purposes. A review of recent data have identified effects of sediment density on the Shields curve which is generally used to determine the beginning of sediment transport. New experiments are underway to assess the density effects as well as the effects of sediment size distribution. (*Engel*)

Performance of Bed Load Sampler. Dimensional analysis was used to express the sampler catch and sampling efficiency of the VUV type bed load sampler in terms of flow condition, sediment properties and sampler geometry. Existing data and new data obtained in a large sediment flume, using a scale model of the half size VUV sampler, were used to examine the effects of the pertinent independent variables whereas the sampling efficiency could be defined in terms of one dimensionless variable. The sampling efficiency was found to vary from 60% to about 30% over the normal operating range. (*Engel*)

The effects of ice covers on the sediment transport and bedforms in rivers have been investigated by laboratory experiments. It was found that sediment transport rate can be significantly reduced by the presence of an ice cover. Velocity and sediment concentration measurements are being used to investigate different methods of calculating the rate of sediment transport in ice-covered rivers. (*Lau*)

The effects of suspended sediments on the velocity distribution as well as the effects of sinuosity and bedform on the friction factor of stream flows have also been investigated. (*Krishnappan*)

A turbulence model has been used to predict the vertical distribution of suspended sediment in two-dimensional, uniform flows with ice covers. A family of curves have been derived, giving the relative concentration as a function of distance from the bottom (Fig. 1). These curves show that the sediment distribution is dependent on the ratio of bed roughness to top-cover roughness and that the sediment concentration is lower than in free surface flows at the same relative height. The turbulence model has been further developed into a three-dimensional model. It uses an algebraic relation to evaluate the Reynolds stresses which are required for the computation of the turbulence driven secondary circulations. The model has been used to predict the secondary circulations in channel flows with various aspect ratios, and is being used to calculate the flow and shear stress distributions in compound channel flows with flood plains. (*Krishnappan*)

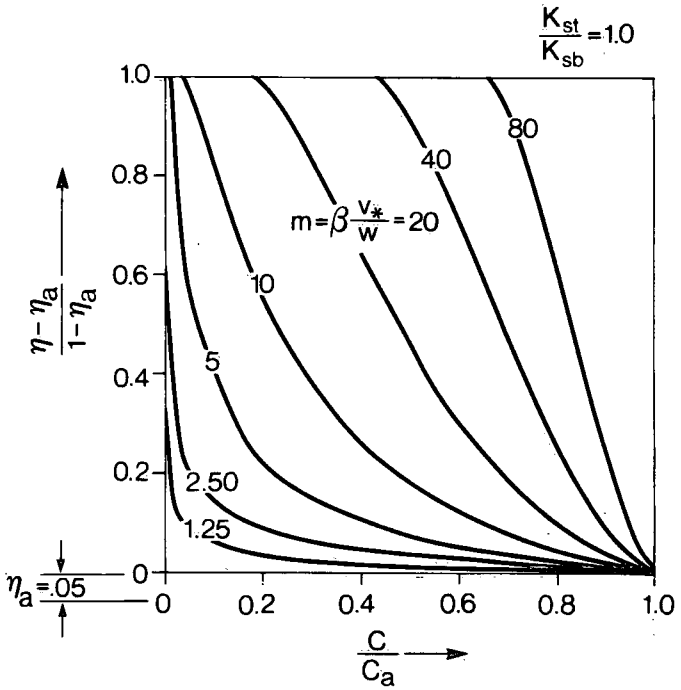

Figure 1. Suspended Sediment Distribution for Flows with Top Covers.

The flow model MOBED which was developed by the Hydraulics Division was used to predict the depths of scour resulting from flow constrictions such as bridge piers, artificial islands, etc. These predictions were compared with the calculations made using a method recommended in the Guide to Bridge Hydraulics. It was found that the method recommended in the guide often could not give accurate predictions. MOBED was also used to predict the degradation of the streambed below the Gardiner Dam in the South Saskatchewan River. The predictions are being compared with those made using HEC6 which is a model developed by the U.S. Army Corp of Engineers. The goal of the study is to evaluate the applicability of HEC6, which is a steady state model, to the unsteady flow conditions which are generally encountered in practice. (*Krishnappan*)

The computer model RIVMIX, which was designed for predicting transverse mixing in natural streams, was documented in a users' manual. The model is suitable for problems such as delineation of "mixing zones" or determination of concentrations from outfalls discharging into rivers. It also is capable of transferring water quality profiles downstream. (*Krishnappan, Lau*)

The Research Committee of the Hydrotechnical Division, Canadian Society for Civil Engineering initiated several task groups. The Environmental Hydraulics Section played a leading role in the Task Group for River Mixing which has completed a state-of-the-art report, to be published in the Canadian Journal for Civil Engineering. (*Lau*)

Ice Jams and Flooding. The field observation program which was initiated in 1979 was continued, with the emphasis being on collection of quantitative data needed to address deterministic and statistical aspects of river ice breakup and jamming. Freeze up and winter ice conditions were also documented as they have been found to influence the breakup process. Ice observations were carried out for the fourth and fifth years in the lower Thames River and for the third and fourth years in the Upper Grand River. Cooperation with other agencies interested in jamming problems has been expanded. (*Beltaos, Wong*)

A dimensionless expression for the stage caused by jams in equilibrium was developed. This expression is convenient for practical applications and was obtained by combining ice jam theory with hydraulic resistance considerations. Field documentation for the verification of the expression is continuing. (*Beltaos*)

A well known and often fearsome event during breakup is the surging ice run that follows the release of a major ice jam. Theoretical analysis has shown that approximate surge calculations can be performed by neglecting the effect of moving ice fragments. Following initial confirmation of this result using a field case study, complete verification was made with detailed laboratory measurements (Fig. 2). (*Beltaos, Wong*)

Conditions at ice jam toes are largely unknown at present, despite their importance in jam formation and release mechanisms especially in cases of grounding. Laboratory tests were carried out with two different model ice block sizes. These indicated non-laminar seepage flow through the jam voids and are consistent with pertinent dimensionless relationships for flow through porous media. Experiments are now in progress to study possible mechanisms of grounding. (*Beltaos, Wong*)

To define breakup characteristics and develop forecasting methods, water level records of hydrometric gauges operated by Water Survey of Canada were analyzed. The analysis led to the development of a conceptual model of the breakup process. An important factor facilitating the onset and progress of breakup has been identified as the available water surface width relative to the size of separate ice sheets formed by transverse and longitudinal cracking. This was verified by direct observations in the Thames River and enabled derivation of dimensionless relationships that can partly account for findings in different rivers. However, there remain many unknowns, including the mechanisms of the initial ice cover cracking and the effects of thermal ice deterioration. These processes are now under investigation while the analysis is applied to additional gauges each year. This study is carried out in partial cooperation with the Guelph office of Water Survey of Canada and the N.B. Subcommittee on River Ice. (*Beltaos*)

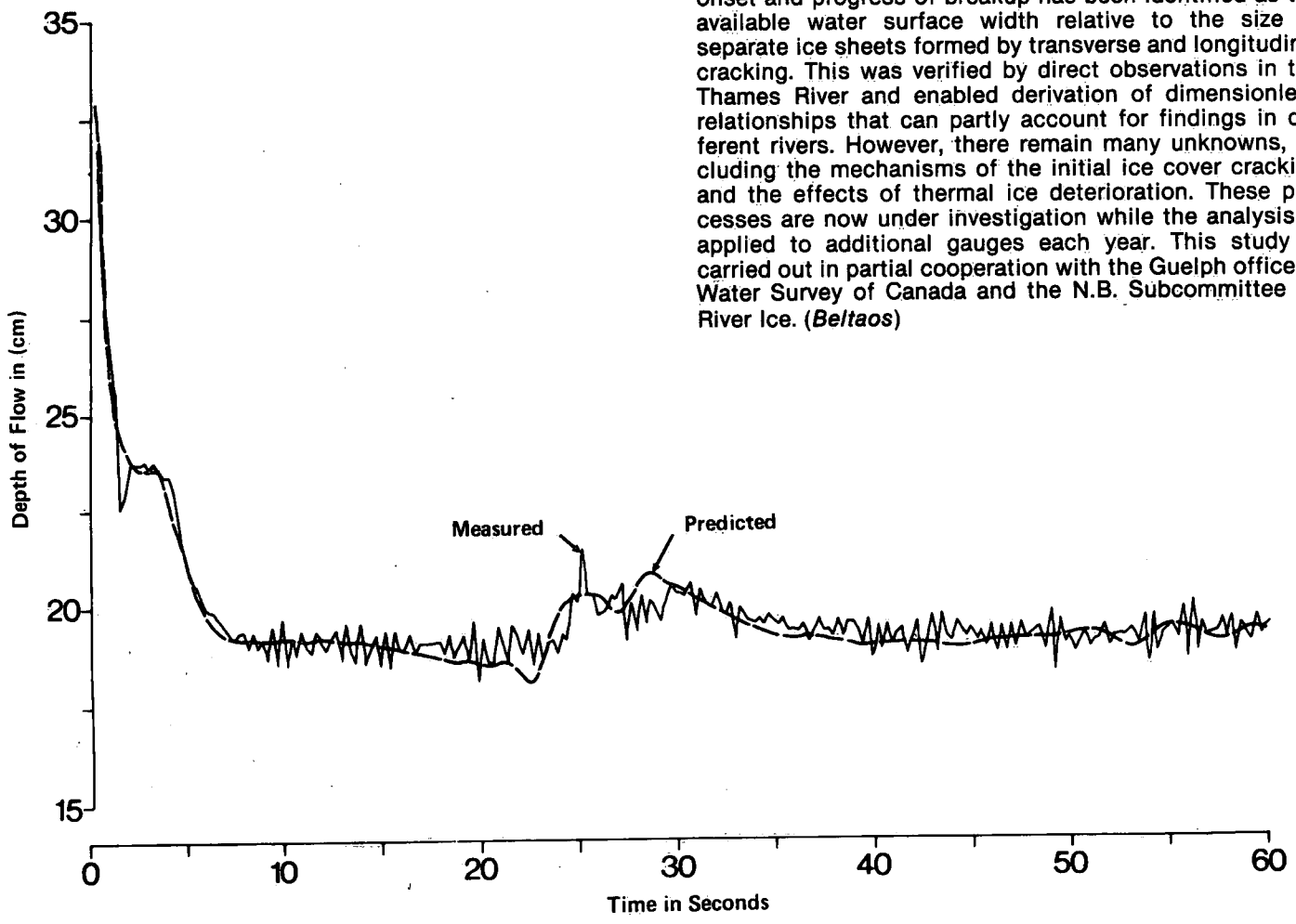

Figure 2. Measured and predicted depth-time variations after ice jam release in a laboratory channel.

The National Research Council of Canada has recently initiated a Working Group on River Ice Jams. The Environmental Hydraulics Section has been invited to chair this Group. Work is in progress on four tasks, i.e., guidelines for needed field data collection programs, guidelines for extracting ice-breakup data from hydrometric station records, identification of research needs, and compilation of case studies. Preparation of a monograph on ice jams is contemplated as a future task. (*Beltaos*)

Frazil Ice. After many years of work, a frazil measurement instrument was successfully developed and tested in the laboratory to be satisfactory. The instrument has also been adapted to saltwater frazil measurement. In the winter of 1983/84, the instrument was also field tested in the Beauharnois Canal and the experimental results are being analyzed. Further river testing of the instrument and the testing of the instrument in the Arctic under the saltwater environment are being planned for the winter of 1984. The instrument can measure the point concentration of frazil in water to 0.1 percent. Figure 3 shows the prototype of the instrument and a sample of a frazil recording. (*Tsang*)

A PILP grant has been given to Arctec Canada to market the instrument under licensing. A half a million dollar sales of the instrument in five years has been projected by

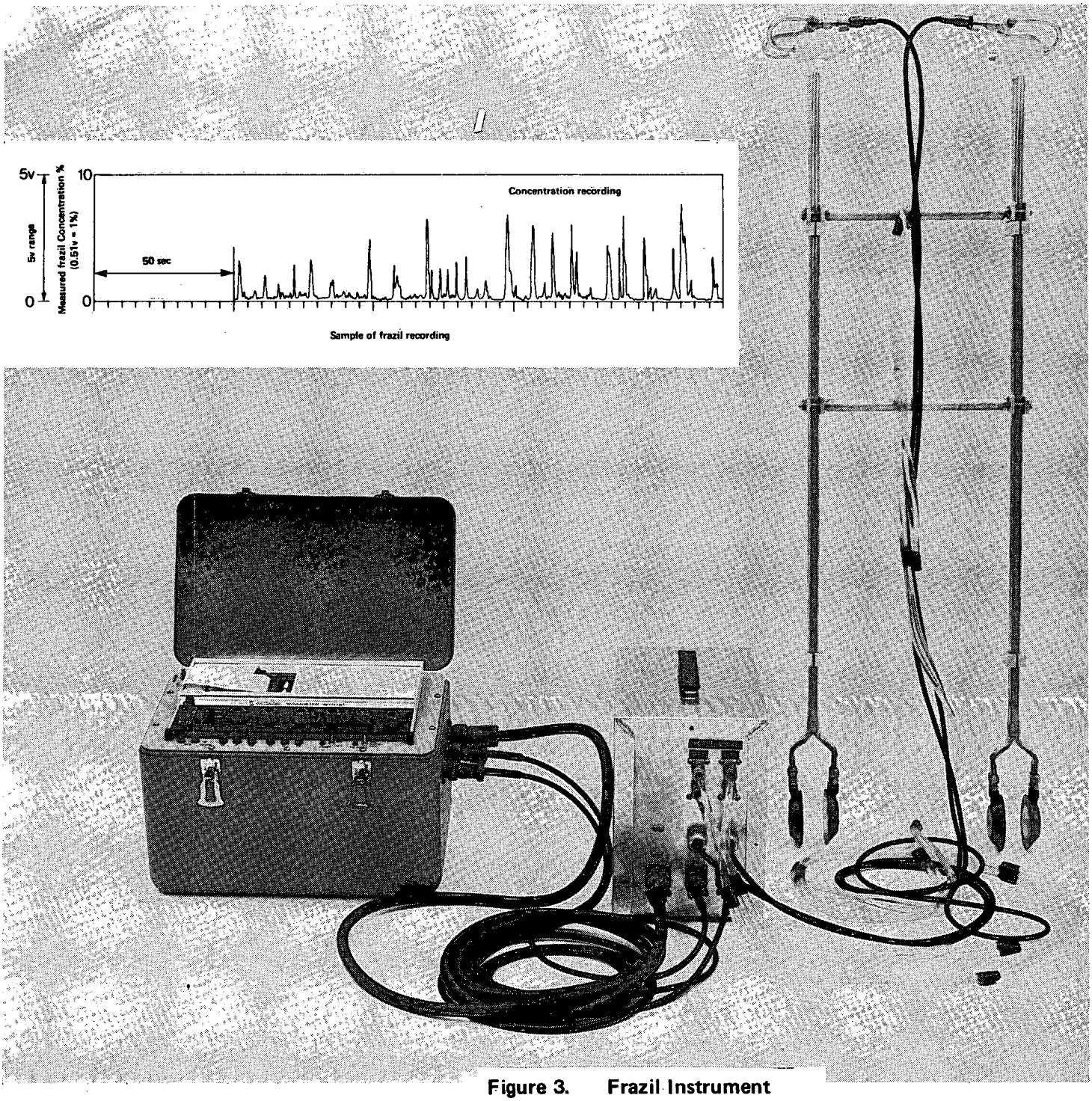

Figure 3. Frazil Instrument

Arctec Canada.

Besides instrumentation development, the formation of frazil in water of different salinities and at different supercoolings was also studied. The property of frazil in fresh water and seawater was found to differ greatly. A small contamination of the freshwater by small amount of salt can greatly alter the physical properties of the ice. A universal semi-empirical equation has been obtained by which the concentration of frazil in frazil producing water under different parametric conditions can be predicted. The crystallography of frazil formed in water of different salinites was and is still being studied. Results may be highly significant for offshore operations in cold regions. (*Tsang*)

Modelling of Urban Runoff. Several studies have been undertaken to develop or refine methodologies for the modelling of urban runoff. Such work focussed on rainfall inputs, pollutant sources, and runoff transport processes. Starting with rainfall inputs, an annotated bibliography on design storms was prepared. Further investigations dealt with temporal distributions for design storms, and finally, a new type of comprehensive urban design storms was proposed and recommended for Canadian practice. In an adjunct study, the feasibility of deriving runoff peak frequency curves from a series of discrete event simulations was demonstrated and the results further served for verification of the Storm Water Management Model. For the applications of this model, a new procedure for catchment discretization into subcatchments was developed. (*Marsalek*)

Urban runoff quality was studied in Burlington, Ontario and St. John's, Newfoundland. Results of these studies served for identification of sources of pollution in runoff and for establishment of pollutant loading rates which may be transferred to other areas.

In modelling of runoff transport, the division between the surface and subsurface transport routes is an important issue. Such phenomena were studied experimentally for common drainage structures which are used in road and bridge deck drainage. Using the observed data, a new drainage design procedure was developed for the study sponsors, the Ministry of Transportation and Communications. MTC evaluations of this new procedure indicate that it can reduce road drainage costs by about $50 000 per mile of a fourlane highway.

Runoff transport is also influenced by headlosses at at sewer pipe junctions. Such losses then reduce the overall system capacity. Investigations of head losses and means of their reduction were conducted for straight-flow-through junctions, for a 90°bend and for laterals entering at different angles. Recent experimental data for the 90°bend junction indicate a significant loss reduction resulting from the installation of a benching at the junction. These studies are conducted in cooperation with the American Public Works Association. (*Marsalek, Ng*)

The complexity and large scope of urban water resources studies dictate the necessity to combine the resources and expertise of various agencies interested in such studies. Towards this end, the Hydraulics Division actively participated in the Rideau River Stormwater Management Study, the Toronto Area Watershed Management Study, and the Waterford River Basin Urban Hydrology Study. All these studies addressed the water resources problems caused by progressing urbanization and developed the means of reducing or estimating such adverse effects. (*Marsalek*)

Another important activity was technology transfer on the national as well as international level. This included contributions of several chapters to the UNESCO and American Society of Civil Engineers manuals on urban drainage, preparation of a chapter on urban design floods for the Design Flood Guide for Canada, a report on stormwater detention in various countries, and reports on urban hydrology research and urban runoff control in Canada. (*Marsalek*)

Persistent Toxic Substances in Urban Runoff. Urban land runoff has been identified by IJC as one of the major sources of toxics in the Great Lakes Basin. In response to environmental concerns, a field study of PTS in the Niagara River Basin was conducted. Among the 51 substances studied, the highest loadings were observed for heavy metals, followed by polyaromatic hydrocarbons, chlorinated benzenes, PCB's, and organochlorine pesticides. Similar estimates of toxics loadings are now being prepared for the entire Great Lakes Basin. (*Marsalek*)

SHORE PROCESSES SECTION

The work of the Shore Processes Section is concentrated in the areas of wind-generated waves and shore evolution.

Wind-Generated Waves. A theory was developed for the transfer of gases across natural air-water interfaces. Special effects of surface wave distortion to the air flow and of breaking waves are considered. The theory has been successfully tested against published experimental data and is a considerable step forward in estimating gas transfer to and from lakes and oceans. Results may be very useful for thermodynamic models of long term climate change.

A comprehensive description of the directional properties of wind-generated waves has been gleaned from array measurements in Lake Ontario and the laboratory. The results are significant for improvements in describing wave properties, particularly spectral shapes, spreading functions and propagation speeds.

The sampling variability of spectra of wind-generated waves has been tested against the predictions of the theory of waves as a stationary random quasi-Gaussian process. The theory is found to be applicable and theory and observation indicate that common practice in wave monitoring yields uncertainties of about 12% and 5% in the significant height and peak frequency. (*Donelan*)

Wave Direction Buoy. The performance of the CCIW wave direction buoy relative to other wave direction buoys at the Atlantic Remote Sensing Land Ocean Experiment off Duck, North Carolina is the subject of a paper in a special issue of the IEEE Journal of Oceanic Engineering. Comparison of wave measurements with a nearby Waverider and cloverleaf buoy showed agreement within the sampling variability of both systems. Wind speed measurement show no bias between the CCIW and the XERB buoys, and the scatter appears within the expected mesoscale variability over a separation of 24 km. Some systematic differences were noted in the wind direction measurements between the CCIW and the XERB buoys. Comparisons of nondimensional height and period with independently derived fetch-limited relations yield agreement within the 90% confidence limits of the CCIW buoy. Without an absolute standard, the accuracy of the system cannot be established. However, these comparisons show that CCIW Wave Direction buoy performed well and that the variability of the measurements is about that expected from sampling theory. (*Skafel, Donelan*)

The wave direction buoy was deployed off Pointe Sapin, New Brunswick in 1983 in support of the Canadian Coastal Sediment Study sponsored by the National Research Council Associate Committee for Research Shoreline Erosion and Sedimentation. (*Skafel*)

Nearshore Sediment Transport. A paper describing several years work measuring longshore suspended sediment transport caused by waves at Van Wagner's Beach, Lake Ontario, was presented at the 18th International Conference on Coastal Engineering. The data were collected under some of the largest waves encountered during experiments of this type, although the angle of approach was small. The range of suspended sediment concentrations and the range of transport rates are similar to those reported elsewhere. The relation between longshore transport and longshore energy flux derived from our data suggests that about half the amount of sediment is moved in suspension compared to the total transport reported by Komar and Inman (J. Geophy. Res., 75:30 pp. 5914-4927). (*Coakley, Skafel*)

Suspended Sediment Distribution in a Wave Field. Sediment resuspension due to wave agitation has been formulated using the diffusional approach. The classical Schmidt equation is solved to obtain the vertical distribution for time-average sediment concentration. The diffusion coefficient is assumed to be proportional to the product of shear velocity at the bed and orbital velocity just outside of the boundary layer. A bed layer concept is proposed to evaluate the absolute values of sediment concentration as a function of the height from the bed knowing the wave parameters such as the wave height, period and the mean water depth and the sediment characteristics such as the grain size and the specific gravity. Laboratory experiments are used to evaluate the dimensionless diffusion coefficient and the bed layer thickness in terms of the dimensionless parameters controlling the phenomenon. The present formulation is compared with the experimental data of other investigators and a reasonable agreement between the two is obtained. Undertaking of these processes provides essential steps for general modelling of the resuspension and transportation of lake sediments. (*Skafel, Krishnappan*)

Coastal Processes in Lake Erie. A comprehensive study was made into the postglacial development of the Lake Erie shoreline, with special emphasis on the origin and evolution of the major forelands which occur there: Long Point and Pointe-aux-Pins. A large amount of relevant geological and geomorphological data was assembled but the main focus was on recently-obtained borehole samples. The sediment profiles constructed represent an excellent record of changes in the critical nearshore depositional environment since the low-level stage following deglaciation. One major conclusion is that lake levels in the Erie basin did not rise uniformly from the initial low-level stage to its present situation. Rather, the lake level trend shows peaks and troughs superimposed on the rising trend. These deviations were apparently associated with major changes in the hydrological regime, while the underlying trend is believed to reflect isostatic and tectonic uplift since deglaciation.

Major forelands formed much further offshore when lake levels were much lower and were originally situated along the crest of existing glacial moraines formed in the lake. With rising lake levels, they migrated northward and gradually assumed their modern form. The evolution of the Long Point foreland is schematically presented in Figure 4. (*Coakley*)

Erosion Resistance of Cohesive Sediments. The scour resistance of cohesive sediments is still poorly understood, yet it is of importance in research concerned with shore and subaqueous erosion. The design of a more accurate rotating-cylinder apparatus was completed during the fiscal year 1982-1983. Using the apparatus, it is possible to measure directly and accurately the critical shear stress at which a sediment begins to erode, and erosion rates per unit time and area at higher shear stresses. A testing program is in progress to determine the erosion resistance of two different tills from the Lake Erie north shore. Results of erodibility tests are being related to sediment geotechnical properties, including water content, shear strength, Atterberg limits, and particle size distribution. A bibliography and annotated abstracts of twenty-nine research papers and eleven review papers concerned with erosion of cohesive sediments were compiled in an internal report to provide a perspective for future studies. (*Zeman*)

A model to obtain a relationship between wave energy reaching a cohesive bluff and the rate of erosion was tested using available data. A linear relationship between recession and wave energy normal to the bluff was found. The geotechnical processes contributing to the erosion of the bluff were shown to be signficant but the influence of the nearshore sand layer was not established. (*Dick, Zeman*)

Geotechnical Study of Eroding Bluffs. Monitoring of pore pressures at the study site, which is located approximately 3 km east of Port Burwell on the Lake Erie north shore, was terminated in June 1983 when a massive landslide destroyed cables leading to two remaining piezometers. A continuous record of pore-pressure data for a period immediately preceding the landslide has been retrieved. Two survey lines were measured in the summer of 1983 to establish bluff-slope profiles at the end of the monitoring program. During the eight year period of monitoring, the bluff receded by about 36 metres at the two sites where piezometers and slope-indicator casings were installed. (*Zeman*)

Eleventh International Congress on Sedimentology, Hamilton, Ontario, August 1982. J.P. Coakley and A.J. Zeman participated in the organization of IAS Field Trip 9B. They acted as guides for the first day of the trip, which focussed on shoreline forms representative of the Lake Erie north shore, high, rapidly retreating bluffs in the Port Burwell area, and the sandy beaches and dunes of the Long Point Foreland.

Nearshore Sediment Program. All nearshore sediment data for Lakes Ontario, Erie, Huron and Georgian Bay have been edited and archived as a series of computer files. Data on surface-sediment samples and cores, sediment-thickness and nearshore bathymetry have been subdivided into records on the basis of location; each record corresponds to one of the National Topographic Series 1:50 000 maps. The records and a procedure designed to retrieve them have been transferred to the Data Management Section along with responsibility for handling routine requests for nearshore data.

A cooperative study funded by the Ontario Geological Survey was set up with the University of Guelph to report on the nearshore deposits of eastern Lake Ontario and on the resource potential of Lake Ontario nearshore deposits in general. Further work in this area included the preparation of two reports for OMNR on the nearshore sand and gravel deposits of Lakes Ontario and Erie. (*Rukavina*)

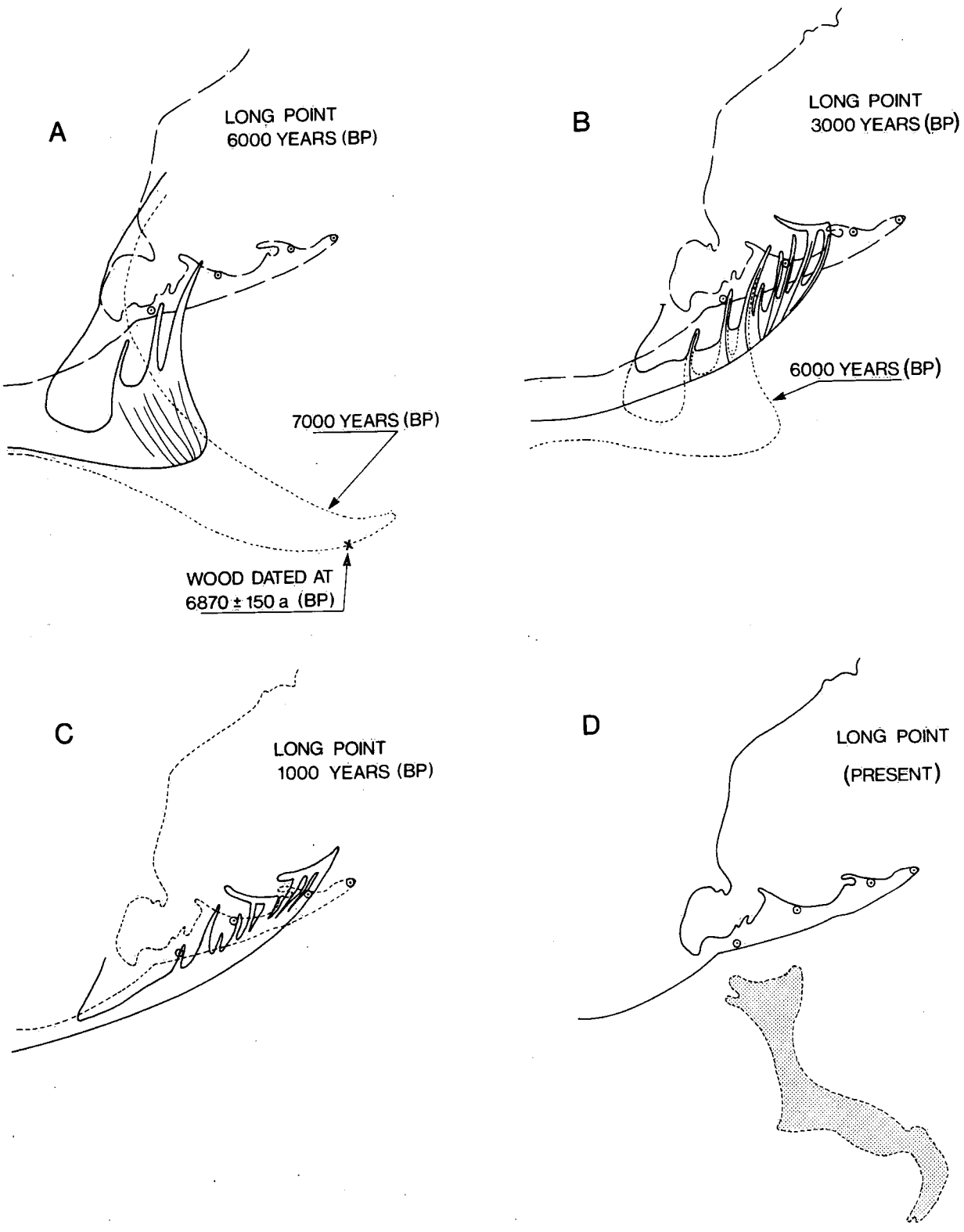

Figure 4. **Schematic Reconstruction of the Evolution of Long Point, based on the Lake Level History Changes in the Pattern and Orientation of Beach Ridges Preserved on the Point and Borehole Sediment Interpretations.**

Third Coastal Workshop. The Hydraulics Division hosted the Third Workshop on Great Lakes Coastal Erosion and Sedimentation at CCIW on November 1-2, 1982. Forty-five invited attendees participated in a program of research summaries and discussions of coastal engineering practice and research needs. A proceedings volume has been published and is available from the National Research Council, Ottawa. (*Rukavina,* Editor)

Floating Tire Breakwater Research. A field program to monitor the Goodyear floating tire breakwater in Burlington, Ontario, was successfully completed. Wave transmission and mooring force data were collected using a Sea-Data logger, two submerged pressure cells, and three electronic and four mechanical load cells on a 128 m long by 18 m wide test section. Good data was obtained during three storms (September to November, 1982). Results from these field measurements will be compared with existing design information from model tests.

Random-wave tests of Pipe-Tire and Goodyear floating tire breakwaters made from 8.5 cm diameter tires were conducted.

The buoyancy requirements of three types of floating tire breakwaters (Wave-Maze, Goodyear, Pipe-Tire) were determined in a desk study, with some supporting laboratory measurements of prototype tires. Flotation balance equations were derived to allow the estimation of supplemental flotation requirements for a given floating tire breakwater under any known site specific conditions. A report was completed.

A cooperative effort with the New York State Sea Grant Extension Program and the University of Rhode Island Marine Advisory Service has produced a guideline report on floating tire breakwaters. (*Bishop*)

Shore Protection. A review of existing literature on shore protection was conducted. Shore erosion is recognized as a predominantly natural process that can be mitigated or aggravated by the actions of man. In cases where shore protection is warranted, a possible alternative to the use of seawalls, groynes or artificial beach nourishment is the use of artificial headlands. The equilibrium plan geometry of headland-bays has a characteristic log spiral shape that is predictable if there is a known dominant wave energy direction (Fig. 5). Empirical design information is provided in two reports. (*Bishop*)

Port Burwell Comparative Literature Study. Literature was

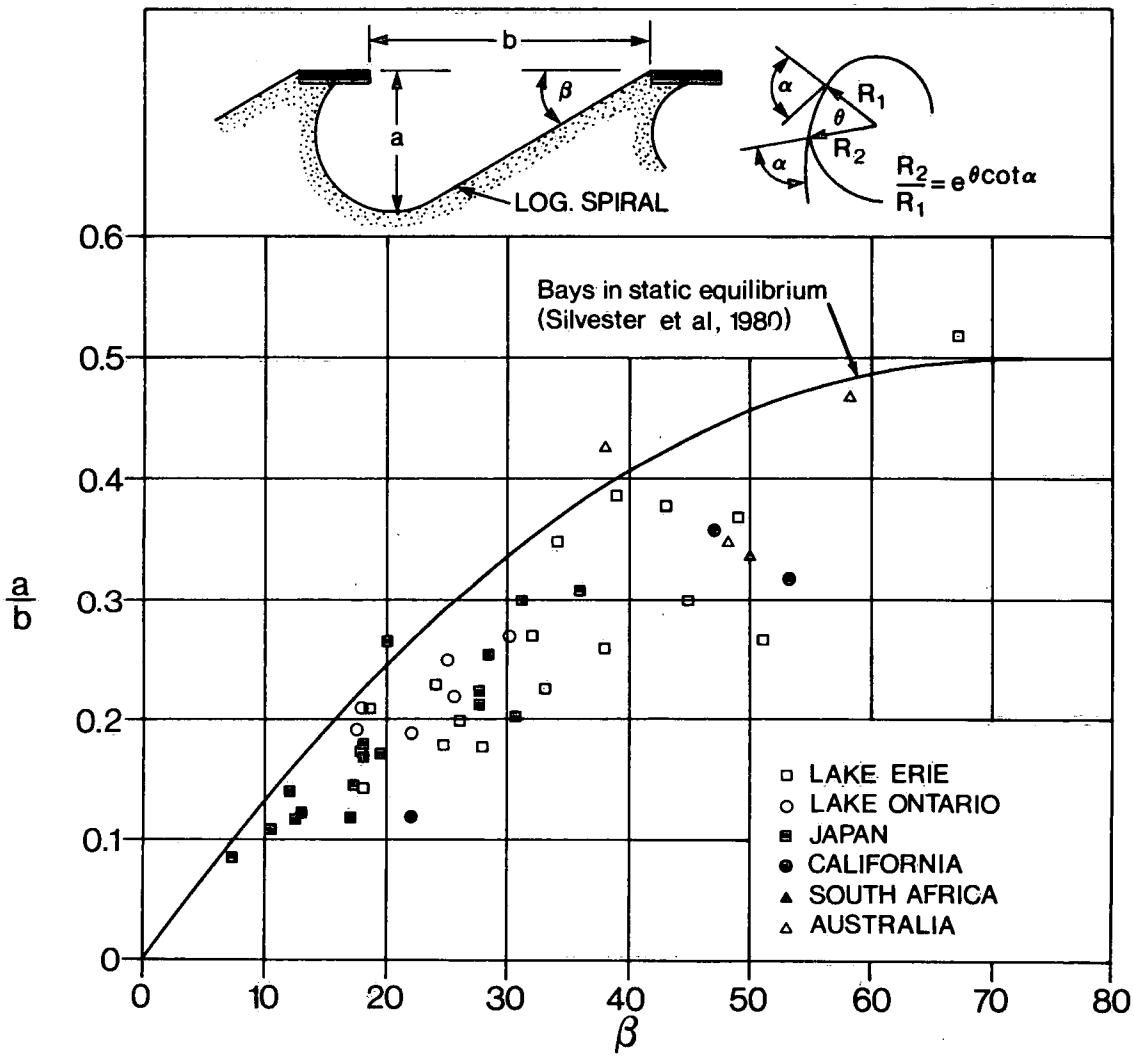

Figure 5. Measured values of the ratio of bay indentation to headland spacing versus the obliquity of the dominant waves to the headland alignment for some natural headland bays.

reviewed, summarized and critically evaluated relating to two topics associated with the erosion of till bluffs near Port Burwell on Lake Erie. One report dealt with site specific studies of harbour structures thought to have impacted on shore erosion. The other dealt with studies of the behaviour of cohesive coasts. (*Bishop*)

Harbour Models. Two hydraulic models were constructed and tested in the Hydraulics Laboratory. The harbour at Glace Bay, Nova Scotia, was modelled at a scale of 1:60 to investigate remedial works to improve wave conditions within the existing harbour. The entrance to a proposed small craft marina at Lakefront Promenade Park, Mississauga, Ontario, was modelled at a scale of 1:36 to determine several feasibile entrance breakwater configurations. Both studies were conducted in support of Small Craft Harbours, Fisheries and Oceans Canada. (*Bishop*)

TECHNICAL SERVICES SECTION

The Section provides technical support to scientists and engineers conducting research in the Hydraulics Laboratory and related field work.

An important function of the Section is the operation of the National Calibration Service which undertakes calibration and performance evaluation tests on all current meters and sediment samplers for Water Survey of Canada with its vast network of over 3000 stations across Canada. Different types of hydrometric equipment and current meters are also calibrated for other federal agencies, provinces, municipalities, consulting engineering firms and others in the private sector.

Shore Processes Support Unit. Technical staff of the unit are assigned to research studies under guidance of the scientists of the Shore Processes Section. The unit operates sedimentological and geotechnical laboratories where grain size and geotechnical analysis of sediment samples and cores are undertaken. These facilities provide support for ongoing research within the Division as well as a service to other government agencies, universities and the private sector.

Environmental Hydraulics Support Unit. Assistance was provided to scientists and engineers conducting research in the Hydraulics Laboratory and related field work. This period has seen an increase of activities for the staff as support was also provided for third parties under the Department's cost recovery policy. Several harbour models were constructed in the wave basins and tests were conducted in the wind wave flume, towing tank and environmental flumes.

Laboratory Operations Unit. Support to users of the Hydraulics Laboratory was provided in areas such as carpentry, machining and equipment maintenance. The supervision of outside contractors working in the laboratory, advice and consultations with scientists and engineers on problems and the inventory and procurement of materials and supplies were also undertaken.

National Calibration Service. The National Calibration Service was re-organized into a unit of four members. The responsibility of electronic design, maintenance and advice has become part of this service mandate. The first phase of the replacement of the towing carriage data acquisition system has been completed involving the procurement, installation and testing of the microcomputer system. Software development by Data Management is continuing. A total of 161 requests were processed resulting in 984 calibrations and 641 hours of testing.

Effects of Transverse Velocity Gradients on the Performance of the Price Current Meter. Theoretical analysis and experimental data were used to show that the Price meter registers incorrectly when the approaching flow has a transverse velocity gradient. The error can be several percent. (*Engel*)

Comparison of Current Meter Calibrations from Different Towing Tanks. Owing to the initiative of Québec-Hydro engineers, comparative ratings of five Siap ME 4001 type current meters were made at four different towing tank facilities. These facilities were located at: Institute Di Idraulica, University of Perdua, Italy; Station d'Étalonnage de Moulinets Hydrométriques de Beauvert, Grenoble, France; Eidgenossisches Amt fur Wasserwirtschaft, Berne, Switzerland; and the National Water Research Institute, Burlington, Canada. Analysis of the data has shown that this type of meter can be calibrated to an accuracy of 0.4% at the 99% confidence level. The study further demonstrated that the calibration accuracy in the towing tank at Burlington equals or exceeds that obtained at the other towing tank facilities. (*Engel, DeZeeuw*)

ENGINEERING SERVICES SECTION AND MANUFACTURING AND TECHNICAL DEVELOPMENT SECTION

The activities undertaken by the two engineering support sections involve all phases in the equipment life cycle, from conception and definition, through detail design, manufacture, and commissioning, to maintenance and modification as required.

In the reporting period, some 60 separate projects were undertaken, of which 13 were new systems, 26 were new items of equipment, and 21 were maintenance or modification to existing equipment.

River Ice. Two frazil ice measurement systems were carried to laboratory prototype stage. One is based on the conductivity principle suggested by Tsang (1983). This is a portable sensor, suitable for spot measurements through holes in the ice surface (Fig. 3). A second system is based on the principle of a through-flow calorimeter. The sensing head of this system is designed for season-long installation in the stream. A shore station with recording facilities provides long term time series measurements of frazil concentrations, as well as alarm signal outputs to warn of excessive ice concentrations or system functional problems. (*Ford* for Burrell, WRB, MOE, N.B.)

The condition of the under surface of the ice cover influences river flows thus the ability to see hanging dams of frazil ice and to examine the under surface of jams is useful. The under-ice video system (Fig. 6) was designed and constructed to obtain video presentation and recording from a camera which may be inserted through a small hole in the ice. The portable, weather-tight equipment has been used by Water Survey of Canada in New Brunswick for river ice study. It has also been found useful by Fisheries and Oceans biologists in the Arctic for viewing biota under sea ice. (*Valdmanis* for Burrell, WRB, MOE, N.B.)

Ice thickness profiles are required for operational and research programs. After a review of various approaches (Watson, 1982), a decision to apply existing ground probing radar technology for ice thickness has been made. Con-

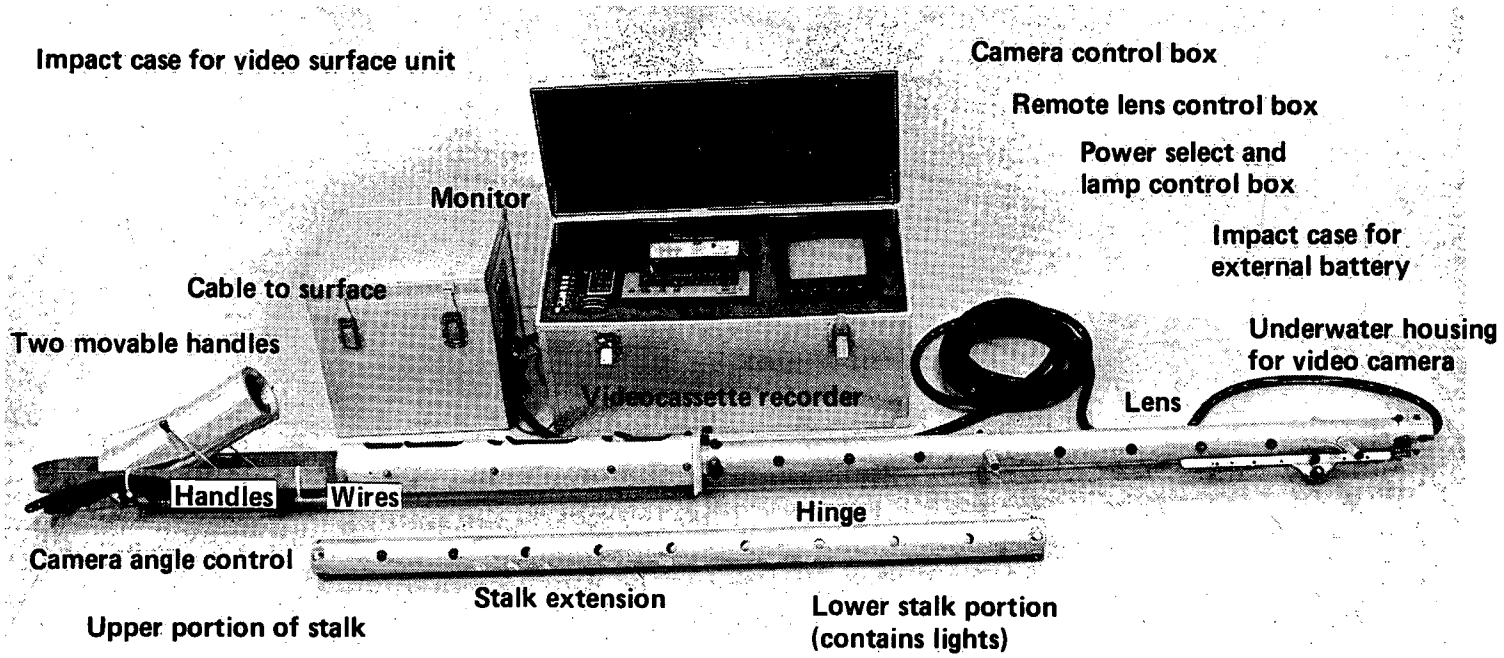

Figure 6. Under Ice Video System

tracts have been undertaken with outside consultants to establish the performance requirements of such radar. (*Watson* for Burrell, WRB, MOE, N.B.)

Botton Shear and Sediment Transport Instrumentation. The character of the bottom boundary layer in lakes is essential information for modelling of lake circulation and of sediment transport.

For the 1982 summer period, the Benthic Boundary Array System was produced to obtain time series episodes of water current, and temperature at three elevations in the 0.5 m thick bottom layer. The system has a capacity to record 10 minute sequences every three hours for 23 days. Two field deployments demonstrated a 99.9% data return during the Lake Ontario Coastal Study at Cobourg. During the 1983 season, a simpler, lower cost sensor platform designated CATS/83, was designed, built, and tested. This system carries one electro-magnetic current meter 1 m from the bottom, four thermistors arranged to profile the bottom temperature gradient, a pressure transducer, an attitude indicator, and a data logger. This system collects data to supplement that obtained with BBA. (*Desrosiers* for Boyce, APSD)

A sediment resuspension sampler was designed and built to determine sedimentation rates and estimate resuspension in the bottom 10 m layer. This device comprises a set of tube traps supported at intervals from the bottom. All the traps are sealed during deployment, and the caps automatically removed 60 minutes after deployment by operation of an electronic timer controlling a pneumatic system. (*Savile* for Rosa, AED)

Lake Dynamics Instrumentation. Development of the Generalized Automatic Profiling System (GVAPS) has been underway for several years. In 1982, the system was deployed as part of the Lake Ontario Coastal Study. The GVAPS collects long time series of synoptic profiles of water velocity and temperature versus depth at a fixed location. The profiled data has a depth resolution of 10 cm and a time resolution of about 30 minutes. (*Roy* for Boyce, APSD)

Measurement of meteorological conditions at the lake surface is essential to supplement other air and water mass observations. The development and field testing of a second generation meteorological data buoy (MET II) to replace existing equipment was conducted in 1982 and 1983. The MET II will provide an instrument complement of improved accuracy and reliability. Solar power and satellite monitoring systems as well as increased recording capacity have been added to extend the time between visits by field crews. It is expected that the MET II will be phased into the operational inventory in 1984 (Fig. 7). (*Valdmanis* for Boyce, APSD)

Studies of current meters were also conducted during the 1982/83 period. In some cases of oscillating flow, distortions in the flow past spherical sensing head type meters can cause a bias in averaged readings. An analytical and experimental study was carried out to evaluate the significance of this distortion in the range of Reynolds Number typical of shallow lake and nearshore application. (*Ford*)

In 1983, preparatory to a major program for replacement of obsolete current meter inventory, an intercomparison study of current meters from six manufacturers was conducted. This involved field deployment in Lake Ontario for a four week period, followed by post field calibration tests in the Hydraulics Division tow tank. As part of this task, and also in support of a Fisheries and Oceans current meter calibration study, a universal current meter mount was designed and built for use with the Hydraulics Division tow tank carriage. This mount allows the meter to be held rigidly under test at 15° increments over 360° rotation in azimuth and 5° increments over 30° of inclination angle over the full range of carriage speed. The experience and data obtained from azimuthal and inclinated axis will provide a basis for selection of meters required for the next several years. (*Baird, Valdmanis*)

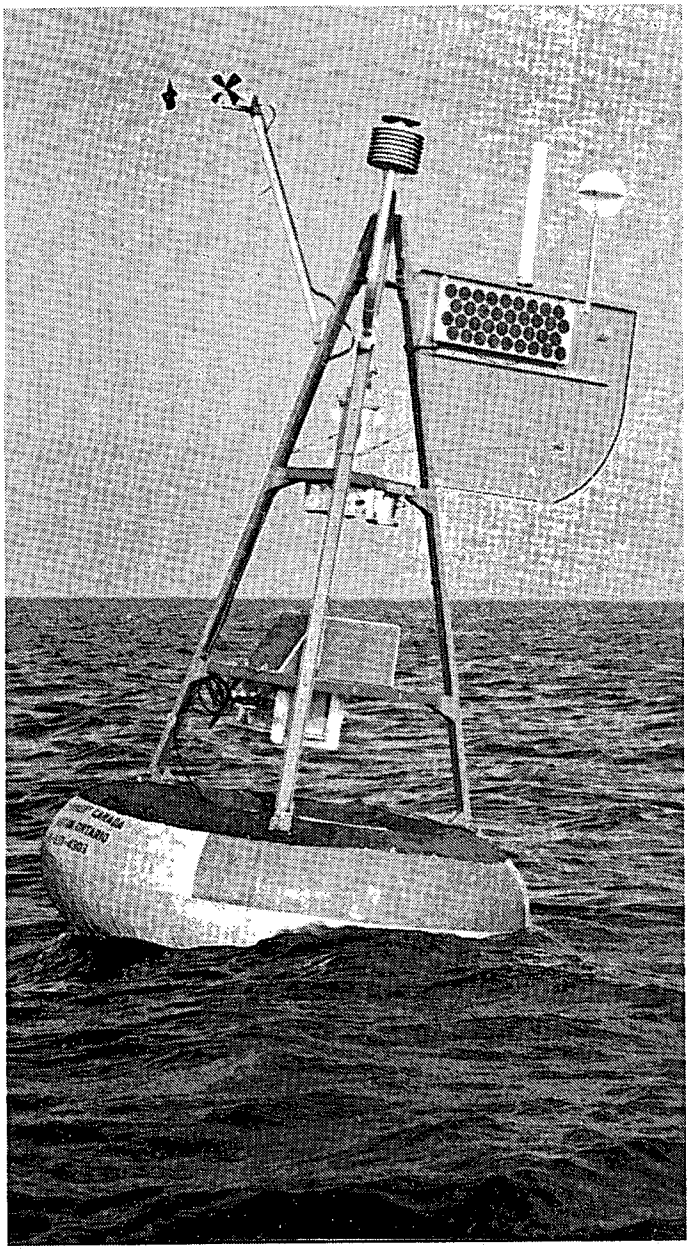

Figure 7. MET II Buoy

Equipment for the laboratory study of lake dynamics was also produced. A hydraulically driven wave machine was designed and built for the Cold Room Flume in the Hydraulics Laboratory. An accessory to this was a remotely controlled profiler to carry hot wire anemometers for profiling the air stream above the flume surface. (*Valdmanis, Donelan*)

NWRI Sea/Air Direction-Sensing Buoy (P.I.L.P. Program). This NWRI buoy system, together with its data-processing software, was put forward as a candidate for possible technology-transfer to the private sector, with a view to ultimate commercialisation. This submission was approved by the NRC/Interdepartmental PILP Review Board. A contract for Phase One — analysis of the potential market which this technology might stimulate — is underway with Lapp Associates, Toronto. (*Watson* for *Donelan)*

Harbours and Breakwater. Modifications were made to the Kelk wave machine to extend the range of paddle motion from purely hinged motion to a combination of hinged and piston motions. (*Madsen,* for *Skafel*)

A special sensor and data logging system was provided to measure the effectiveness of a floating tire breakwater installed for the La Salle Marina, Hamilton Bay. Sensors included wave pressure, mooring forces, wind speed and wind direction. Threshold sources were used to limit recording observations to significant events. (*Valdmanis,* for *Bishop*)

Water Quality Instrumentation. Systems and equipment to support water quality studies were provided.

The Shipboard Radiometer System measures the spectral volume-reflectance of lake water. In 1983, a digital data logger was included, and the system was installed on CSS LIMNOS during the Lake Superior Study cruises. (*Watson* for Bukata, APSD)

An oxygen profiling sensor system comprising a sonde, computer controlled winch, and a North Star desk top computer was produced for Aquatic Ecology Division. This system allows semi-automated operation of the winch and sonde to profile and log dissolved oxygen, temperature, and depth with much greater facility than previous techniques based on water sampling and Winkler titration methods. Field tests of the system were conducted in 1983, as well as a series of survey cruises on Lake Erie. (*Ford* for Charlton, AED)

Two pieces of equipment for field preconcentration of organic contaminants in water samples have been developed. The portable centrifuge, used to separate contaminant bearing particulates from through-flow sample water, is based on the standard centrifuge used by NWRI. Modifications have been made to reduce its mass, provide portability, and replace the electric motor drive with a gasoline engine. The Aqueous Phase Liquid Extractor (APLE) has been miniaturized to provide a highly transportable unit for field use. This unit thoroughly mixes the water sample with a dense organic solvent which preferentially dissolves organic materials in the water. After mixing, the solvent settles to the bottom of the drum, where it can be drawn off, giving an initial concentration increase of 19 to 1 over that of the original water sample. Further evaporation of the solvent increases the contaminant concentration, allowing identificaton and measurement. (*Savile* for McCrae, WQB.)

A water surface micro-layer sampler was designed and built for Environmental Contaminants Division, based on Harvey (1966). This device is essentially a porcelain coated cylinder, rigged with its axis horizontal, and supported on a pair of pontoons. The cylinder is driven by a variable speed electric motor. The apparatus is designed for attachment to a 16 foot Boston Whaler. The sample is collected by means of the surface tension between the water and the drum, the speed of which is adjusted to match the translation speed over the water surface. Field evaluations in 1983 were qualitatively successful. Quantitative calibration tests are planned for 1984 prior to extensive field application (Platford et al, 1983). (*Madsen* for Platford, ECD)

Since 1975, IWD/Water Quality Branch has been conducting a daily sampling program at Niagara-on-the-Lake, based on an automatic sampler designed and built by the Engineering Support Sections. This sampler, controlled by a series of timers, is designed to collect and store samples on either a daily or hourly schedule depending on program objectives. The station at Niagara-on-the-Lake monitors inflow into Lake Ontario. A second station at Wolfe Island near Kingston monitors lake outflow into the St. Lawrence. The success of this methodology led in 1983 to the con-

struction and installation of a third station at Fort Erie Ontario, at the outflow from Lake Erie. This newest sampler retains the basic design features of the earlier two, and incorporates some modifications to details arising from the extended operational experience. (*Boucher* for McCrae, WQB)

Calibration Laboratory. The Calibration Laboratory provides the transfer standards for calibration of sensors on all measurement systems used by the Institute.

During 1983, the Calibration Laboratory entered a joint program with Tidal Development and Engineering Support, Canadian Hydrographic Service, to develop a mobile absolute pressure calibration station to meet the high standards of depth transducers now in use in recording tide gauges and other systems. The new station upgrades obtainable accuracy from 0.025% to 0.01%, enables absolute pressure calibrations to be made, and may be easily moved to other test stations to allow two variable calibrations, e.g., temperature and pressure simultaneously. (*Mollon* for White, BLMSS)

DRAFTING SERVICES SECTION

The Drafting Services Section provides a Centre-wide service by undertaking graphic, technical and scientific illustrations as well as cartographic, mechanical and electronic drawings of a quality suitable for publication purposes. The Section also provides a photographic service which includes photography of engineering and scientific research equipment, overhead projection materials and slides for conferences and seminars and provides, through outside sources, the requirements for reprographic and photofinishing services.

In preparation for Open House '82, the drafting office processed over 3000 items which included drawings, photographs, text and headings for displays. Photographic coverage included opening ceremonies, panel discussion, general public relations and a complete record of individual displays.

The Drafting Service also provided the facilities for and coordinated a project for the Canada NEED Program which entailed the updating and metric conversion to the architect's original drawings of the Canada Centre for Inland Waters building plans by a team of architectural drafting personnel.

OFFICE SERVICES SECTION

This Section provides office services, word processing, clerical and record-keeping support to all Sections of the Divisional operations. Office Services manages the orderly production and distribution of reports and publications on scientific and engineering subjects, implementing the bilingual publishing policy of the Department of the Environment, and ensuring the communication of new information and knowledge to all sectors of society in Canada. The Section maintains a permanent file of all research and technical reports, and responds to requests for reprints or copies of unpublished manuscripts.

Statistics on requests for publications have been maintained since 1976. The relevance of the work to the scientific community is indicated by the continual increase of the number of requests for reports and publications. In the calendar years 1982 and 1983, approximately 1700 reports have been distributed.

STAFF LIST

Chief — Dr. T.M. Dick
Secretary — Mrs. A. Mueller
Administration Officer — Mrs. C. Leacock
(assigned to Hydraulics Division by Staff Services Division, NWRI)

Drafting Services Section
Head, Mr. W.D. Finn

Draftspersons
Mr. M. Donnelly
Mrs. J. Field
Mr. P. McColl
Mr. J. Van Nynatten

Engineering Services Section
Head, Mr. F.E. Roy

Project Engineers
Mr. R. Desrosiers
Mr. J.S. Ford, P.Eng.
Mr. E. Harrison, P. Eng.
Mr. N. Madsen
Mr. A.E. Pashley, P. Eng. (retired April 1983)
Mr. J. Valdmanis, P. Eng.
Mr. A.S. Watson, P. Eng.

Environmental Hydraulics Section
Head, Dr. Y.L. Lau — river dynamics

Researchers

Dr. S. Beltaos	river ice studies
Mr. P. Engel	river engineering
Mr. B. Greck	urban hydrology
Dr. B.G. Krishnappan	river dynamics
Mr. J. Marsalek	urban hydrology
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Dr. G. Tsang	ice studies
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(presently with National Defence Headquarters, Ottawa)
Mr. H. Savile

Instrument Calibration Laboratory
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Mr. L. Peer
Mr. J. Thompson

Machine Shop
Supervisor, Mr. D. Whyte
Mr. J.G. Ford (joined Division November 1982)
Mr. K.K. Kalter
Mr. G. Olsen

Office Services Section
Head, Mrs. M. Hawkins

Mrs. D. Bowman, Divisional Clerk
Mrs. E.J. Jones, Word Processing Operator
Mrs. N. Snelling, Word Processing Operator

Shore Processes Section
Head, Dr. M.G. Skafel coastal engineering

Researchers

Mr. C.T. Bishop	coastal engineering
Mr. J.P. Coakley	coastal sedimentology
Dr. M.A. Donelan	air-water-interaction
Dr. N.A. Rukavina	coastal sedimentology
Mr. A. J. Zeman	geotechnical studies

Technical Services Section
Head, Mr. C. DeZeeuw

Laboratory Operations Unit
Mr. R. Klainka
Mr. E. Nash
Mr. G. Voros, Unit Head

Environmental Hydraulics Support Unit
Mr. D. Doede
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(presently with Technical Operations Division, NWRI)
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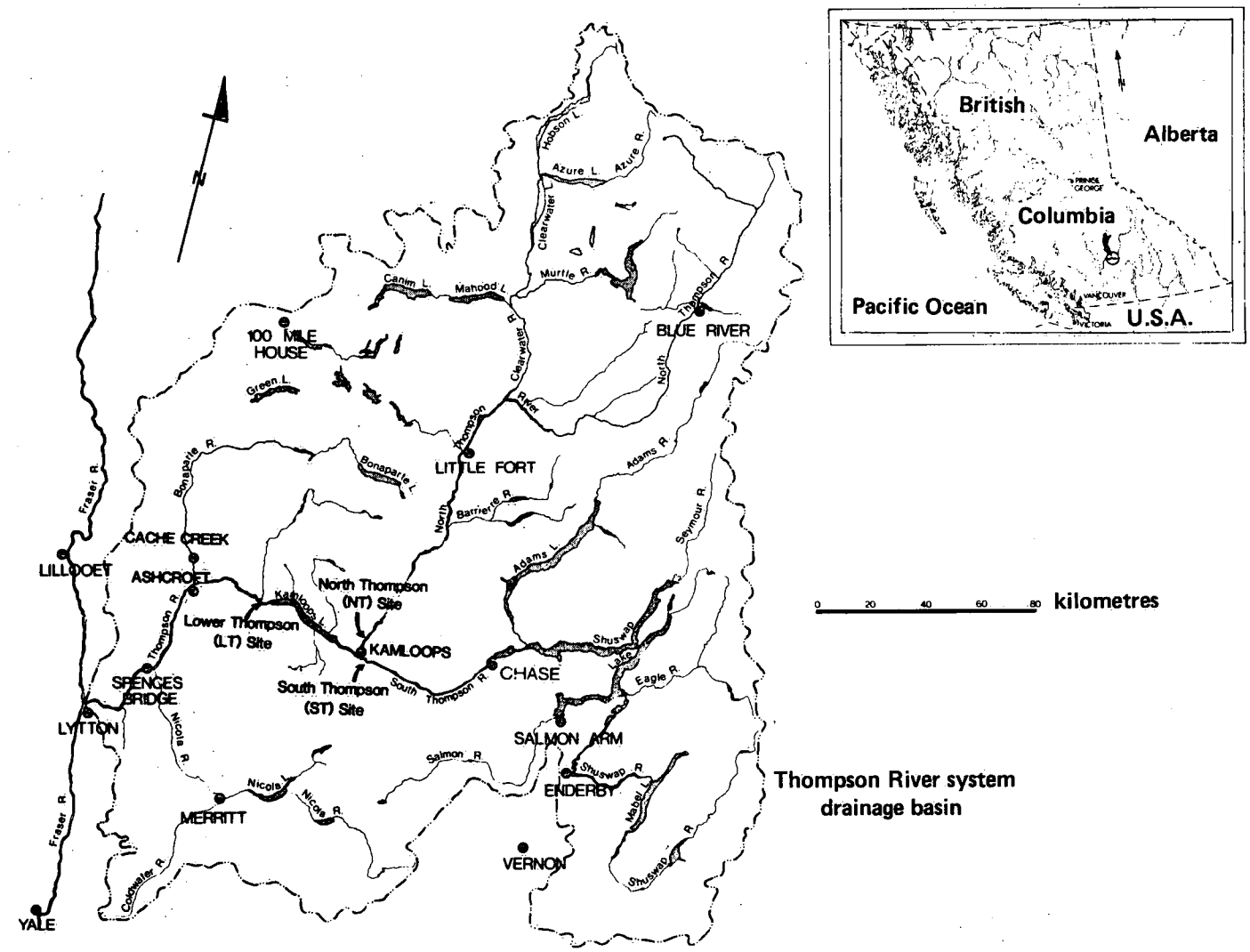
The Pacific and Yukon Regional branch of NWRI, located in West Vancouver, B.C., conducts applied research related to regional water management problems. It has traditionally used a multidisciplinary approach to develop an understanding of how regional limnological systems function. Ultimately an attempt is made to predict the ecological sensitivity and response of regional lakes and rivers to the application or removal of such anthropogenic environmental stresses as nutrient-rich effluent loadings, industrial waste discharges, placer-mine wastes, acidic and metal-rich mine drainage and tailings, hydro-electric reservoir construction and operation, and large-scale inter — or intra-basin diversions.

The geomorphologic uniqueness of this region defies easy transfer of conclusions drawn from the study of lake systems in the prairie or shield areas of Canada. Most of the lakes in B.C. and the Yukon are long, narrow and deep, and are strongly influenced by riverine flows. All have marked seasonal water-level fluctuations, especially those lakes that are used as storage reservoirs for hydro-electric power generation.

In the past the branch concentrated on single issues of regional importance, prompted either by public political protest, federal-provincial agreement in response to public consultation, or by direct government initiative. More recently, however, the regional research focus has shifted to a wider spectrum of studies reflecting the diversity of environmental issues and ecological problems in the region. Research is currently being directed at three broad environmental issues: river eutrophication, hydro-electric developments (especially in the north), and lake restoration and eutrophication.

River Eutrophication: Thompson River Benthic Algae. A joint research project with Weyerhaeuser Canada Ltd. in 1979-1981 examined the causes of excessive benthic algal growth in the Thompson River downstream of Kamloops Lake (Fig. 1). Using continuous flowing troughs to deter-



Thompson River system drainage basin

Figure 1 Map showing location of the Thompson River 1979-81 study sites LT, NT and ST, and the present field site at Chase.

mine algal growth rates and physiological status, evidence was collected that benthic algal growth rates were faster downstream of the lake compared with upstream. In addition, the phosphorus nutrition of the downstream algae was found to be considerably better.

The methodology and results of this project have been compile into three publications. A detailed description of the continuous-flow trough methodology and its adaptation for use in sub-zero weather was given. An extension to the methodology that incorporates the use of dark trough controls was reported. Using dark troughs it was possible to correct light trough accumulation for passive settlement of algae. The resultant net growth rate estimates were as low as one-third of unadjusted estimates. The final publication provides a detailed examination of the data from this two-year project. Despite the low river temperatures during most of the study (1- 6°C) all three experimental sites showed algal growth rates limited by phosphorus. Using a suite of chemical and physiological tests, differences in the three algal populations could be distinguished even though the phosphorus concentrations at the three sites were similar and very low (SRP levels: zero to 1-2 ppb at the two upstream sites and zero to 3 ppb at the downstream site).

A continuation of this research involved a second joint project with Weyerhaeuser Canada Ltd., signed in the summer of 1982. This project, in operation now, will attempt to assess the relationship between benthic algal growth rate and concentration of the limiting nutrient, phosphorus. Other parameters such as temperature, light, and current velocity (thought to be interactive with phosphorus concentration in controlling growth rates) will also be examined.

The first phase of the project was to select a site on the Thompson River system that could deliver clear, low-phosphorus water. A location at Chase near the outlet of Little Shuswap Lake (Fig. 1) was chosen. The second phase involved construction of a multiple 12-trough facility (Fig. 2) and establishing a field laboratory at the site. This will allow physiological tests and growth rate measurements to be determined over a range of phosphorus levels. Light intensity and current velocity in each trough can be controlled independently and the experiments will be conducted year-round to investigate effects of temperature.

The next two years will involve data collection, analysis and documentation of the results from this study. (*Bothwell, Jasper*)

Northern Hydro Limnology: The Yukon River Headwater Lakes. Results obtained to date in this project have necessitated changes to the original plan. The project is now considered to be primarily a physical limnology and sedimentology study. The chemistry and biology sampling and analysis showed that productivity was relatively low and the nutrient concentrations were at times at the limit of detection (Fig. 3).

Detailed bathymetric charts and compilations of morphometric and hydrologic parameters of Lakes Laberge, Marsh, Tagish and Bennett have been completed and are available in a regional IWD report (Pharo, 1984). Surface sediment samples and some cores from Lake Laberge have been analysed for sedimentological and geochemical compositions and that data is available in an in-house data report (Chamberlain and Pharo, 1984). Cores collected at intervals along the lengths of the other lakes are now being examined.

An experimental attempt is being made to understand and to define the dynamic processes affecting intra-lake sediment transport and deposition in Lake Laberge and in Kluane Lake. Sediments entering Lake Laberge are carried through the lake via a buoyant, surface overflow. In Kluane Lake, by contrast, the inflowing river water is of such high sediment concentration that transport is effected by subsurface turbidity currents. While through-lake transport in

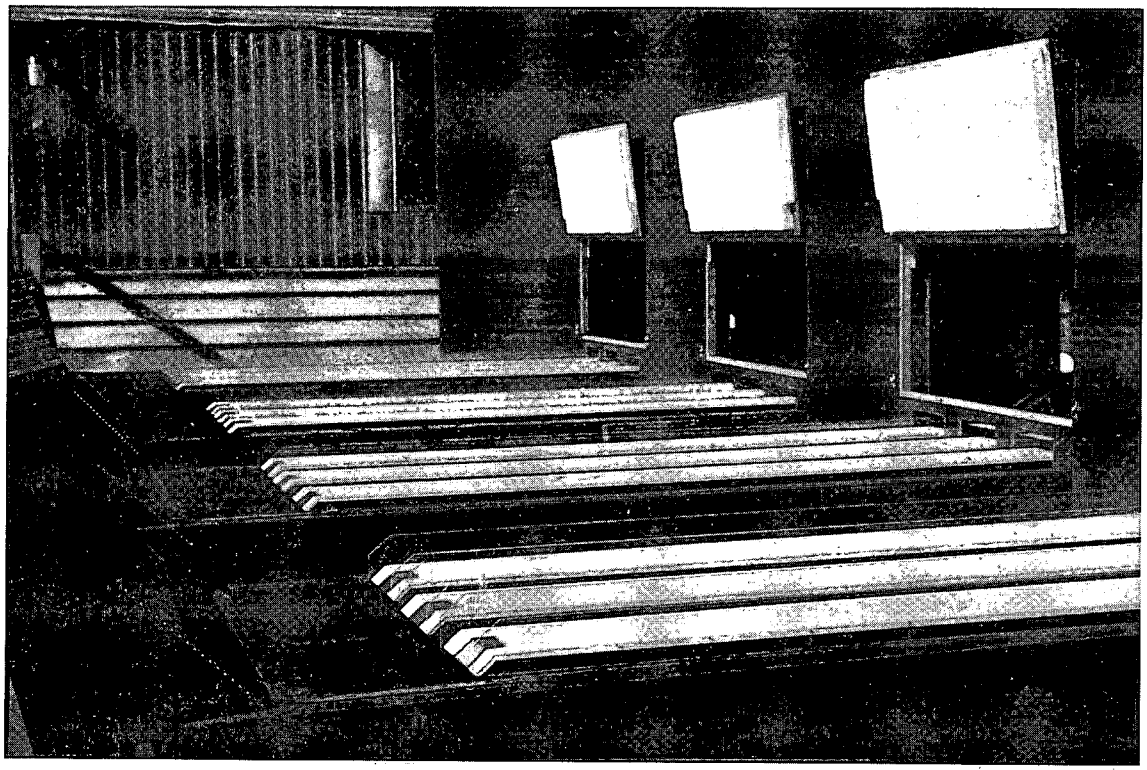


Figure 2 Multiple trough facility for periphyton.

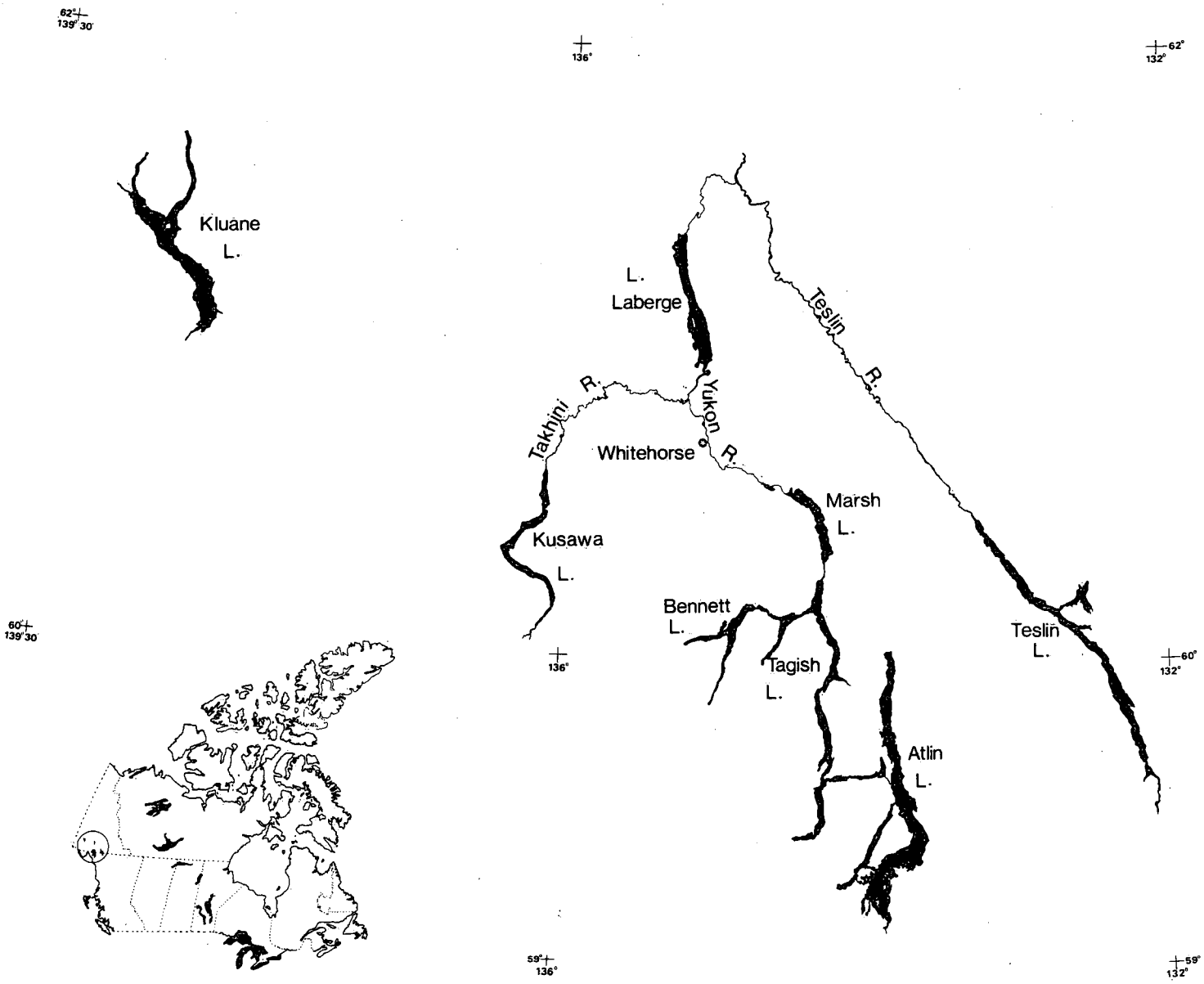


Figure 3 **The Yukon River headwater lakes in southern Yukon and northern British Columbia.**

Lake Laberge takes place within a geostrophically-controlled boundary current along the eastern shoreline of the lake, the cross-lake movement of particulate material (and thus the underwater light climate) may be influenced by barotrophic instabilities. In the case of Kluane Lake, the key to understanding sediment transport seems to lie in defining the processes that occur along the lake-river front: e.g. the transition from river flow to turbidity current. (*Pharo, Carmack*)

To obtain a general description of physical seasonality, a limnological transect, consisting of temperature/salinity/depth profiles, was flown from Atlin Lake through Tagish, Marsh, and Laberge lakes. Although these lakes belong to the same river system, their residence times, suspended sediment concentrations, and source water characteristics all vary widely, thus providing an excellent system for comparative studies. Flights were made in summer, 1981; in winter, spring, summer, and fall, 1982; and in the winter of 1983. Initial examination of the data suggests that the intra-seasonal evolution of water masses within individual lakes may provide a means for determining dominant circulation patterns.

Additional seasonal data is being collected from moored, self-recording instruments in Lake Laberge, instruments in Lake Laberge, including a meteorological station, thermographs at both the inlet and outlet, and three thermistor chains. Since these instruments record data at 30-90 minute intervals, they should yield the kind of information on mixing processes required to formulate and calibrate representative physical models of northern lake-river systems. An early finding of these data is that spring overturn in Lake Laberge is initiated by the inflow of the Yukon River, and that this river-driven ventilation process first affects the mid-depth layers of the lake before moving progressively downwards. This mechanism will influence the lake's heat balance during ice break-up, and dominate the lake's flushing characteristics throughout spring.

A major change to the original plan and addition to the physical limnology program is a joint study with Water Resources Branch Pacific and Yukon Region, to document

and interpret the seasonal ice cycle from the point of view of lake-river interaction. Its objectives are to describe the ice dynamics of an upstream river, the influence of that river on the ice cover and temperature structure of a recipient lake, and the effects of lake outflow on ice conditions in a downstream river. Lake-river interactions have been largely ignored in past studies on ice behaviour, but such an approach is necessary to understand the consequences of reservoir construction and operation in northern latitudes. The study area for this experiment consists of the Yukon River from Whitehorse to lake Laberge, the lake itself, and the Yukon River immediately downstream of Lake Laberge. Data on the lake is being obtained both by self-recording instrumentation and by means of conductivity/temperature/depth surveys carried out from snowmobile and ski-plane. Studies on the upper and lower rivers are largely concerned with evolution of ice cover and its relationship to hydraulics. One promising outcome of this work will be the ability to compute changes with time in the composite resistance of the river reach immediately below Schwatka Reservoir in the presence of an advancing ice front. Another goal of the Lake Laberge experiment is to gain a quantitative understanding of the formation of outlet polynyas, as these large, ice-free areas provide an essential bird habitat. In addition, a combined ice-cover/thermal structure model is currently being developed at NWRI-Burlington. Our data will be used to refine, calibrate, and verify this model for generational use on ice-covered lakes and reservoirs. (*Carmack, Kirkland, Gray*)

Lake Restoration and Eutrophication: The Southern Lakes. Work done under this project involved finishing projects on Wood Lake in the Okanagan Valley, completing a diffuse nutrient loading study in the Okanagan, as well as testing and refining a suspended-sediment/nutrient collecting and analysis methodology. The biologically available portion of the nutrients supplied to Okanagan Valley lakes by streams and rivers was evaluated by chemical analysis of water and suspended material. Biologically available phosphorus (BAP) varied between 16% and 98% of total P while the biologically available nitrogen (BAN) varied from 56% to 98% of the total N. (*Gray, Kirkland*)

The Pacific and Yukon Regional Branch of NWRI has also been involved in such major referrals as the Okanagan Basin Implementation Board Implementation Agreement and the Thompson River Task Force on proposed effluent discharges from the city of Kamloops into the Thompson River. Scientists on staff have reviewed and refereed numerous journal papers, proposals, and grant requests, and have acted on student thesis advisory committees. Specialist advice and consultation has been extended on request to other branches of IWD, Environment Protection Service, Fisheries and Oceans, Energy, Mines and Resources, and to the Ministry of Environment of the Province of B.C.

STAFF LIST

Branch Chief (Acting) — Dr. C.H. Pharo
Office Manager — Ms. S.E. Roberts

Researchers

Dr. M.L. Bothwell	river ecology
Dr. E.C. Carmack	physical limnology
Dr. R.J. Daley	microbial limnology
Mr. C.B.J. Gray	chemical limnology
Mr. S. Jasper	biological limnology
Mr. R.A. Kirkland	chemical limnology
Mr. R.C. Wiegand	physical limnology

Technical Staff
Ms. V.A. Chamberlain
Mr. E.W. Marles
Ms. K.E. Suzuki

COMMITTEE MEMBERSHIP

C.H. Pharo
Regional IWD Health and Safety Committee — Chairman

DOE Diving Safety Committee

R.C. Wiegand
Regional EDP Users Committee

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NWRI WESTERN AND NORTHERN REGION

This branch of the National Water Research Institute was established to serve the research needs of a region which extends across the three prairie provinces and the Northwest Territories. Whereas water quality issues in the Great Lakes have historically dominated water resource management concerns in Canada, this pattern is changing. Success in managing nutrient problems in the Great Lakes, together with an increasing emphasis on economic growth in Western Canada, are causing renewed national attention to the historic water supply-demand imbalances in this Region and the generally poor quality of water in many prairie communities. Potential expansion of irrigated and dryland agriculture, increasing demand for water diversions, and the continued development of resource industries and related industrial complexes, are raising serious concerns over water supply and the potential problem of toxic chemicals in western drainage systems. Additionally, potential megaprojects in the Mackenzie River Basin are generating concern over the future of northern drainage systems. These developments are occurring at a time when the federal government is espousing the principles of sustained development with maintenance of ecological stability.

The past year focus was on the rivers and lakes of the Qu'Appelle Valley in Saskatchewan, the Churchill Diversion from South Indian Lake and its related reservoirs in Northern Manitoba, the North Saskatchewan River system and the Wabigoon-English River system. Our activities have been balanced amongst the practical concerns of toxic substances, the severe prairie problem of excessive enrichment of surface waters, and the fundamental understanding of nutrient and contaminant behaviour in prairie rivers and lakes. This blend of research achieves the dual objective of appropriate response to regional concerns and the increase of knowledge necessary to meet the long term objectives of DOE in this region.

THE QU'APPELLE RIVER SYSTEM

Phosphorus Dynamics. Phosphorus is a dynamic variable in lakes. Previous attempts to evaluate phosphorus in lakes using the assumption of static equillibrium have been shown to be inadequate and/or incorrect. Lake phosphorus concentrations fluctuate as a forces response to changes in the inflow phosphorus concentrations. Using mean annual inflows the time varying phosphorus concentration was accurately simulated for Lake Washington for the entire period for which published data are available (1962-1978). The use of monthly mean data (1970-1978) improved the simulation of phosphorus concentrations in Lake Washington and provided substantial insight into the effects of the 1972 and 1975 floods. The simulation of phosphorus concentrations in the four Qu'Appelle Lakes required extension of the dynamics concept to account for high prairie evaporation, precipitation and variable lake levels. It was found that three time scales were necessary to dynamically describe this chain of four lakes: the phosphorus inflow time scale, the phosphorus inflow time scale and the sedimentation time scale. Using a time series of instantaneous inflow concentrations that were available at random times from 1970 together with the 72 hour composite data collected by WQB from 1980-1983, the lake phosphorus concentrations were accurately simulated for the Qu'Appelle Lakes. The results suggest that not net sedimentation occurs and that the lakes are saturated with respect to phosphorus. (*Kenny*)

Palaeolimnology of Pasqua Lake. The study of the palaeolimnology of Pasque Lake was originally initiated to determine the impact of cultural development on the historical trophic state of the downstream Qu'Appelle River lakes by interpreting the succession of larval chironomid (Chironomidae:Diptera) remains in the sediments. Initial analysis of contemporary chironomid communities, however, indicated that contaminants may also be a problem in the lakes. Sampled to provide baseline data for the palaeo-study, the surviving chironomid fauna display varying degrees of morphological deformities.

Analysis of the sub-fossil fauna from Pasqua Lake indicate (Fig. 1a) that members of a shallow-water lake community dominated by species of *Chironomus* (Meig.) have dominated the fauna throughout the period of history (ca. 300 years) defined in the sediments of Core P-7-M. Prior to colonization, the trophic state of the lake varied between eutrophic (TIN 13) and strongly eutrophic (TIN 14). The increase in organic loadings coincident with the beginning of colonization (Fig. 1b) indicate that the input of nutrients from cultural sources has increased the productivity of the lake. The interpretation is difficult to confirm from the faunal record, because the more recent chironomid communities have been decimated. The increase in eutrophy,, possibly to conditions of gross eutrophy (TIN 15), may account for the decline in fauna but the effects of contaminants, magnified by already severe trophic conditions, probably were the crucial determining factor. (*Warwick*)

Toxic Substances. A two year study of biogeochemical pathways of methylated and unmethylated mercury and other heavy metals and their seasonal and sit-related variations in the Qu'Appelle system is to be completed in 1984. Samples of water, suspended and bottom sediment, and biological material were collected at different seasons at many different sites extending from the cities of Moose Jaw and Regina downstream to the Qu'Appelle River beyond Round Lake. The data suggests that the mercury is mainly derived from sources of pollution in Moose Jaw and Regina. Although the ecological effects of mercury (for instance, accumulation by fish) tend to decrease in the downstream direction, seasonal and site-specific factors complicate the picture. For instance, in one sampling season total mercury levels in water were highest near the sources of pollution, but methyl mercury levels were highest further downstream, probably owing to enhanced microbial growth resulting from introduction of nutrients by tributary waters. Elevated primary production apparently stimulates methylation of mercury. (*Jackson, Ongley*)

SOUTH INDIAN LAKE (SIL)

Winter Circulation. The effect of impoundment on SIL is being studied by DFO using water and nutrient budgets from an adjoining bay, Long Bay. Vertical temperature profiles along the axis of Long Bay suggest the presence of an under-ice circulation that theoretically could dominate the water renewal time in the bay with concomitant impact on the budget studies. An ultra low velocity (ULV) current meter was designated and constructed to directly measure

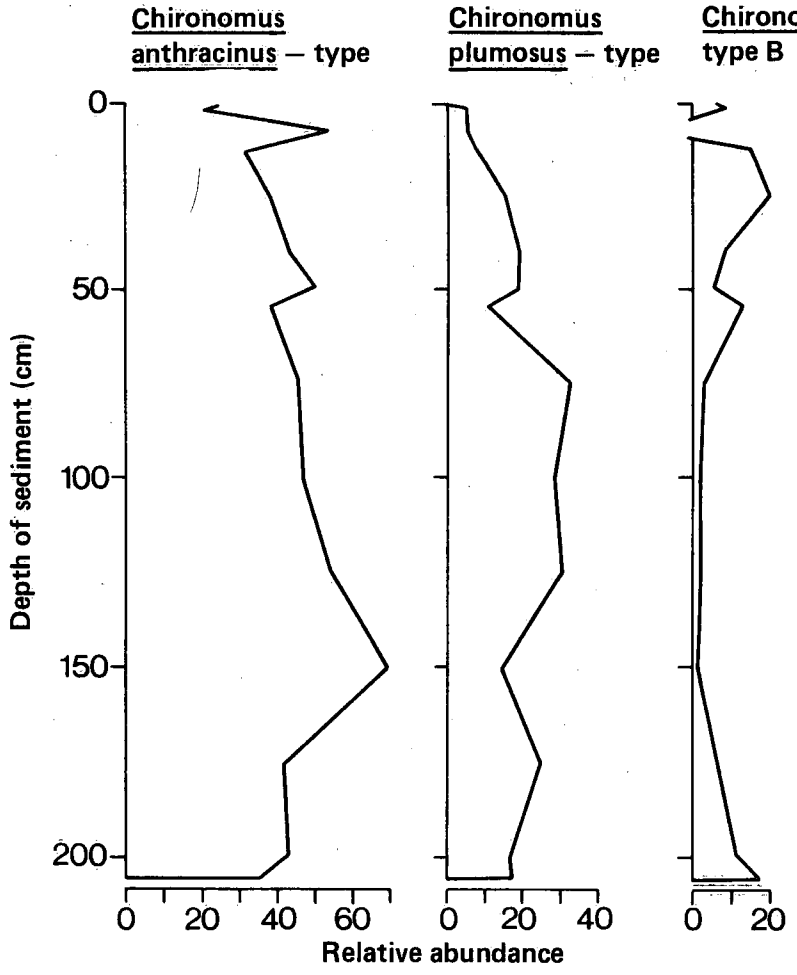

Figure 1a Sub-fossil fauna from Pasqua Lake.

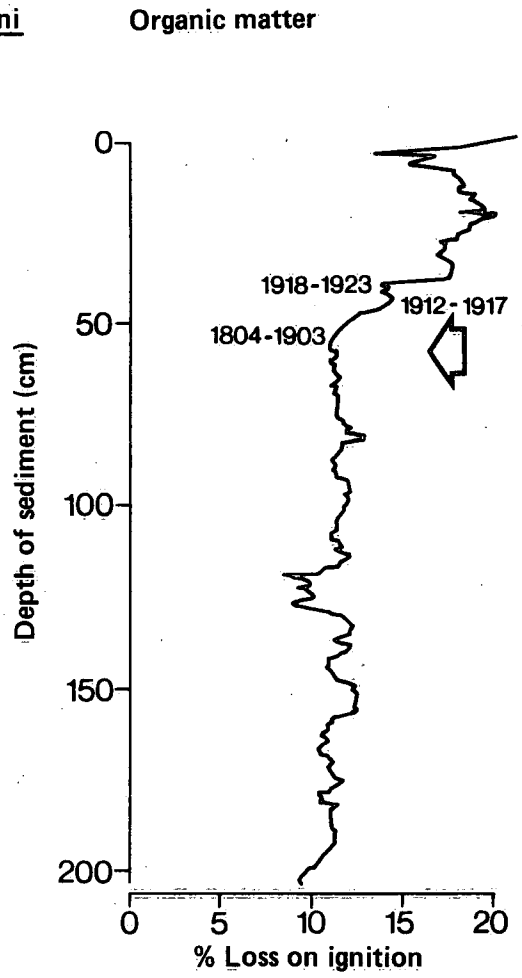

Figure 1b Organic content of sediments in Pasqua Lake.

the flow in the narrow strait joining Long Bay to SIL. Highly variable currents in excess of 1 cm/s were measured. Temperature fluctuations accompanying the two layer flow are intense and show large changes in the thermal structure over a short period (Fig. 2). Winter circulation is likely to dominate water renewal in all embayment with similar morphometry. (*Kenney*)

Toxic Substances. A study was initiated in 1981 to determine the bioaccumulation and transfer of mercury from the reservoir sediment through the food chain to the upper level carnivores, fish and man. The purpose is to investigate effects of environmental alteration due to impoundment on the speciation and bio-availability of mercury. Samples from the sediments, water, plankton and benthic communities as well as shoreline plants and soil were collected from two sites (Long and South bays) in South Indian Lake and three sites (Rat, Mynarski and Notigi lakes) in the new Notigi reservoir for analysis and especially for utilization in experiments.

The individual components were analyzed for methyl and total mercury and other trace metals; the sedimentary environment was defined by primary ignition analysis and particle-size measurements. A series of laboratory experiments on methylation and demethylation of mercury by microbes in the bottom sediments under different environmental conditions have yielded encouraging results. Our findings are in agreement with data gathered independently by DFO and indicate major regional differences in the abundances and biogeochemical behaviour (chemical speciation and bio-accumulation) of mercury, as well as some important seasonal variations. The regional pattern of variation is related to environmental changes caused by shoreline flooding resulting from impoundment, and the same basic pattern is discernible in the samples collected in 1983. A final report of the results is in progress.

In the summer of 1982 a project on the effects of humic matter on iron nutrition and primary productivity in Southern Indian Lake was undertaken in collaboration with DFO. This continues an earlier study where we advanced the hypothesis that humic matter in the water inhibits primary production by sequestering iron. Subsequent field experiments by DFO have yielded data which appear to confirm this conclusion. (*Jackson, Warwick*)

THE NORTH SASKATCHEWAN RIVER SYSTEM

This study, originally known as the Tobin Lake Study, seeks to establish the dynamics of contaminant transport

processes within the North Saskatchewan system and to develop an ecotoxicological approach for measuring the effects of contaminant input to Tobin Lake. Participants in the study include EPS, University of Manitoba and NWRI.

Tobin Lake, because of its location well downstream, integrates the input of toxic substances from most of the river basin. Ecotoxicology in the lake has been examined over the past several years, (i) to develope workable chemical fractionization scheme and biological assay protocol which would permit rapid and cost-effective screening for groups of similar organic contaminants and, (ii) to examine impact of toxic substances on in-situ benthic organisms.

Objective (i) was achieved and is now in place in the regional organic contaminants laboratory of EPS. Results from bottom sediments indicate that a range of organic contaminants have reached Tobin Lake which have mutagenic and, in some instances, lethal effects on lower members of the food web. It is not now known where these chemicals originated, whether they are diffuse or point source in origin, under what circumstances these were delivered to Tobin Lake, nor whether there is any impact on higher forms of life. Suspended sediment samples taken from various sites on the North Saskatchewan River during a summer storm event in July of 1981, inducate a complex set of sources and pathways for organic contaminant transport in the North Saskatchewan. These may involve point and diffuse sources as well as spatial and temporal effects. Sources, transport mechanisms and fate of organic contaminants are currently under investigation at nine locations starting upstream of Edmonton. (*Ongley, Warwick*)

WABIGOON-ENGLISH RIVER SYSTEM

The final report of the Canada/Ontario study presenting resulting of the second year's research and a summary of final conclusions and recommendations covering the entire project was completed.

A laboratory project that deals with synergistic and antagonistic effects of copper, cadmium, and zinc on the biomethylation of mercury by microbes in Clay Lake and Wabigoon River sediments was completed in 1982. With increasing concentration of Cu(II), Cd(II), or Zn(II) chloride in a sediment-water slurry containing added Hg(II) chloride, methylation is progressively inhibited until a threshold concentration is reached, after which there is a large increase in methyl mercury. These results are interpreted as representing ecological succession among different species or strains of methylating microbes. At lower metal concentrations, the more metal-sensitive methylating microbes are inhibited, but at higher levels relatively metal-tolerant methylating microbes, which had been suppressed by the more sensitive ones at lower metal levels, rise to a position of dominance in the microbial community. Analysis of sediments from different lakes near Flin Flon showed that this process is probably occurring in nature. Effects of different sedimentary materials were also examined.

A laboratory project on the availability of methyl mercury to trout fry under various controlled conditions (for instance, in the presence and absence of different kinds of particulate matter) has also been completed. Preliminary evaluation of results suggest inhibition of methyl mercury uptake under certain conditions. (*Jackson*)

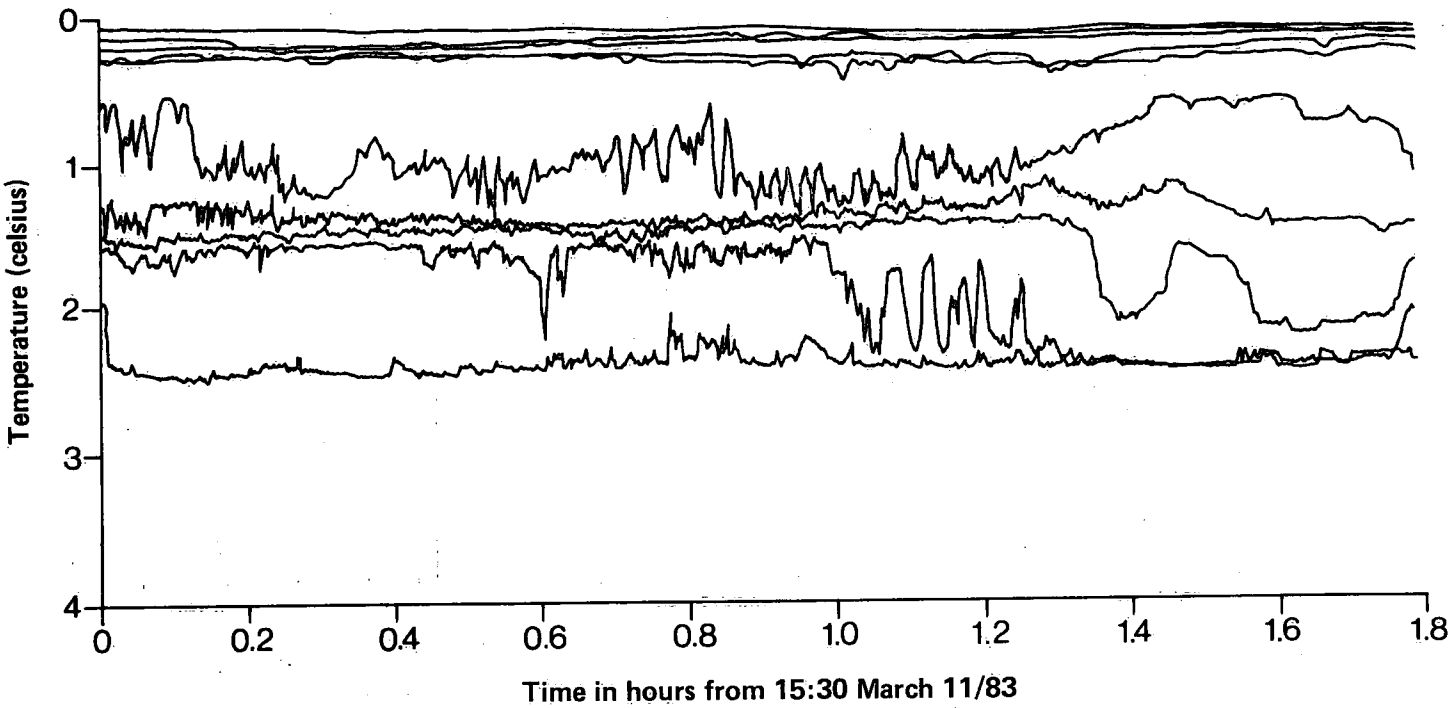

Figure 2 **Inverse stratification under ice in Long Bay, South Indian Lake. Temperatures were measured at depths of 1.4, 2.4, 2.9, 3.4, 4.4, 4.9, 5.4, 5.9 and 6.4 m.**

TECHNOLOGY TRANSFER

An essential component of our research activities is the transfer of knowledge to operational sectors of Inland Waters Directorate and to the rest of the Department. In the past year input was provided to: negotiations for Qu'Appelle Implementation; the Canada-Manitoba Mercury Agreement; Parks Canada both the water quality program definition in Nahanni National Park and in regards to Implications of the Slave River hydro proposal; the Environmental Protection Service for program definition and scientific guidance of their Scientific Programs Branch; the Regional Director General's office on issues of water concerns and water resource management and research; Water Quality Branch Headquarters in developing effects monitoring policy and programs; Manibota Environment for mercury and heavy metal monitoring strategies in the Red River and elsewhere; and to all sectors of Inland Waters Directorate within Western and Northern Region. Other technology transfer activities included nine formal lectures and seminars that were delivered by invitation to government and external groups within the region and throughout Canada.

In 1983 a workshop on Prairie Lake Restoration and Manipulation was hosted for the purpose of developing a research strategy to meet client needs for surface water rehabilitation in the southern prairies. Workshop participants who came from as far afield as the United Kingdom, Switzerland and France represented a broad spectrum of disciplines and practical experience with lake restoration.

STAFF LIST

Chief — Dr. E.D. Ongley

Researchers

Dr. T.A. Jackson	metal biogeochemistry, nutrient geochemistry
Dr. B.C. Kenney	mixed layer dynamics, nutrient dynamics, physical limnology
Dr. E.D. Ongley	fluvial geomorphology, sedimentology
Dr. W.F. Warwick	paleolimnology, benthic biology

Technical Staff
Ms. C. Casey
Mr. J.C. Mollison
Mr. K. Supeene
Mr. J.P. Tisdale

COMMITTEE MEMBERSHIP

E.D. Ongley

IWD Regional Management Committee

Executive Committee, International Association for Sediment Water Science — Treasurer

Technical Advisory Committee, Canada-Manitoba Mercury Agreement

Regional Pesticides Committee

PUBLICATIONS

Jackson, T.A. 1983. Effects of Inorganic Cadmium, Zinc, Copper and Mercury on Methyl Mercury Production in Lake Sediments — Evidence for Selective Inhibition and Stimulation of Microbial Species Based on Variation in Heavy-metal Tolerance. IN: J.O. Nriagu (ed.), Environmental Impacts of Smelters, John Wiley & Sons, N.Y. (In press).

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TECHNICAL OPERATIONS DIVISION

The Technical Operations Division provides a wide variety of technical support to the field research studies of NWRI, its regions and, where possible, to other departments, agencies and universities.

Areas of responsibility include field measurement, sample collection and some basic analyses of physical, chemical and biological parameters and sediment from freshwater systems aboard major research ships, launches, shore-based field parties and diving operations. The Division is also responsible for the preparation, modification, field use and maintenance of a wide variety of mechanical, electronic and hydraulic sampling and data acquisition systems.

The Division arranges for the acquisition and scheduling of major research ships, launches and land sites; the coordination of all NWRI field research studies to ensure effective and efficient use of technical staff, vehicles and equipment. The Division also ensures a high level of safety for all field operations.

During 1983/84, TOD maintained 10 studies in support of NWRI and outside research requirements. The division also provided direct technical support to 76 NWRI studies.

SHIP SURVEY SECTION

All data gathering on the Great Lakes is done on measurement platforms from research vessels by the Ship Survey Section — a major contribution being water quality and eutrophication parameters which form the data base input to the Water Quality Board Annual Report to the International Joint Commission.

CSS ADVENT. Twelve lower Great Lakes cruises were completed by CCS ADVENT in support of NWRI studies. In Lake Ontario, 3 Sediment Trap Mooring cruises were conducted to 1) measure sedimentation and regeneration rates of nutrients and contaminants; 2) relate phytoplankton response to loading changes and the effect of eutrophication on contaminant management. The Niagara River Survey was conducted to determine the seasonal characteristics of the river plume in support of toxic contaminants and other related biochemical studies.

In Lake Erie, the ADVENT conducted 5 Surveillance Continuity cruises to establish and standardize an annual survey program and to provide historical data suitable for the detection of important emerging pattern changes. A two-week cruise supported Chemical Forms and Potential Availability of Trace Metals — its purpose to study contaminants, including toxic metal ions, arising from sources in the Detroit River watershed and their impact on Lake Erie. The ADVENT was utilized to collect sediment samples from the Upper Niagara River for determination of practical size and composition effect on concentration of selected contaminants in sediment samples. The ADVENT was also utilized to refurbish a sediment trap mooring in Lake Erie initially installed by CSS LIMNOS.

CSS BAYFIELD. The majority of work conducted by CSS BAYFIELD was in support of three Great Lakes Fisheries Research Branch programs. The Long Term Bioindex Monitoring Program was continued to collect chemical and biological data simultaneously at selected stations on Lake Ontario on a weekly basis. A total of 32 such cruises were carried out during the field season. Other work carried out by BAYFIELD included benthos sampling and thermal bar studies between the Genesee River and Pt. Weller. Picoplankton and in situ toxicity studies were carried out to assess the effects of stress from sediment-associated toxic substances on algal metabolism, especially picoplankton and ultraplankton. On nearly fifty percent of the cruises, additional piggyback work was coordinated and conducted. Many water and sediment samples were taken as well as deployment and recovery of satellite-tracked drogues.

CSS LIMNOS. Thirty-six cruises were completed by the major research vessel, CSS LIMNOS on Lakes Ontario, Erie, Huron and Superior. Detailed plans and reports were prepared for each cruise and are available from Technical Operations Division upon request (Fig. 1). A detailed overview of CSS LIMNOS activities can be found in the TOD Activity Summary '83/84. The multi-disciplinary cruises consisted of:

Lake Ontario
- 5 — Sediment Trap Mooring
- 3 — Open Lake Surveillance
- 3 — Contaminants — Plankton Dynamics
- 3 — Current Meter Mooring
- 2 — Aquatic Invertebrates Collection
- 2 — Chemical Forms and Potential Availability of Trace Metals
- 1 — Water Quality Branch Field Trials

Lake Erie
- 3 — Contaminants — Plankton Dynamics
- 2 — Sediment and Phosphorus
- 1 — Sediment Bank Study
- 1 — Surveillance Continuity Study

Lake Huron
- 3 — Contaminants — Plankton Dynamics
- 1 — Sediment Bank Study

Lake Superior
- 4 — Open Lake Surveillance
- 1 — Sediment Bank (Fig. 2)
- 1 — Productivity and Phosphorus Limitation

FIELD SURVEY SECTION

The Field Surveys Section coordinates and provides logistics, equipment and personnel resources in support of NWRI field research studies. The Section's four organizational units directly supported many shore and launch-based studies as well as provided technical services to other support sections at NWRI. Launches, small boats, land sites, sampling equipment, labortory trailers and vehicles were acquired and scheduled for use. Staff were assigned to a wide variety of survey tasks and geographic locations.

Rigging Unit. The rigging staff, shop, outdoor compounds and highbay warehouse facilities provided direct and indirect support to most NWRI field activities.

Services were provided at dockside to support loading and off-loading ships. Buoys, hardware, winches, generators, mooring arrays and other equipment was prepared for the field; forklift, heavy-truck driving and trailer towing services were provided. Field support for samples and equipment transport ranged from Sault Ste. Marie, Ontario

	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
							1
JANUARY	2	3	4	5	6	7	8
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FEBRUARY	6	7	8	9	10	11	12
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	27	28	1	2	3	4	5
MARCH	6	7	8	9	10	11	12
	13	14 Lake	15 Ontario	16 Surveillance	17 Lake	18 Ontario	19 CCIW
	20 CCIW	21 CCIW	22 Trace Metals	23 Lake	24 Ontario	25 Moorings	26 Lake Ontario
	27 CCIW	28 Trace Metals	29 CCIW	30 Trace Metals	31 CCIW	1 CCIW	2 CCIW
APRIL	3 CCIW	4 CCIW	5 Lake	6 Ontario	7 Surveillance	8 Lake Ontario	9 CCIW
	10 CCIW	11 Lake Ontario	12 Sediment	13 Trap	14 CCIW	15 CCIW	16 CCIW
	17 CCIW	18 CCIW	19 CCIW	20 CCIW	21 CCIW	22 CCIW	23 CCIW
	24 CCIW	25 W.Q. Trials	26 CCIW	27 CCIW	28 CCIW	29 CCIW	30 CCIW
	1 CCIW	2 Lake	3 Ontario	4 Aquatic	5 Invertebrates	6 CCIW	7 CCIW
MAY	8 CCIW	9 Lake Ontario	10 Sediment	11 Trap	12 CCIW	13 CCIW	14 CCIW
	15 CCIW	16 Upper	17 Lakes	18 Surveillance	19 Upper	20 Lakes	21 Surveillance
	22 Upper	23 Lakes	24 Surveillance	25 Upper	26 Lakes	27 Surveillance	28 Upper
	29 Lakes	30 Surveillance	31 Lake	1 Erie	2 Sediment	3 and	4 Phosphorus
JUNE	5 Resuspension	6 Lake Erie	7 Sediment	8 Trap	9 Moorings	10 CCIW	11 CCIW
	12 CCIW	13 CCIW	14 CCIW	15 CCIW	16 CCIW	17 CCIW	18 CCIW
	19 CCIW	20 Lake	21 Superior	22 Surveillance	23 Lake	24 Superior	25 Surveillance
	26 Lake Superior	27 Surveillance	28 Lake Superior	29 Surveillance	30 Lake	1 Superior	2 Surveillance
JULY	3 Sault Ste Marie	4 Sault Ste Marie	5 Lake	6 Superior	7 Productivity	8 and	9 Phosphorus
	10 Limitation	11 Sault Ste Marie	12 Lake	13 Superior	14 Sediment	15 Bank	16 Study
	17 Lake	18 Superior	19 Sediment	20 Bank	21 Study	22 Lake	23 Superior
	24 Sediment	25 Bank	26 Lake	27 Superior	28 CCIW	29 CCIW	30 CCIW
	31 CCIW	1 CCIW	2 CCIW	3 CCIW	4 CCIW	5 CCIW	6 CCIW
AUGUST	7 CCIW	8 Lake Ontario	9 Sediment Trap	10 Moorings	11 CCIW	12 CCIW	13 CCIW
	14 CCIW	15 Lake	16 Erie	17 Sediment	18 and	19 Phosphorus	20 Resuspension
	21 CCIW	22 Lake	23 Ontario	24 Trace	25 Metals	26 CCIW	27 CCIW
	28 CCIW	29 Lake	30 Superior	31 Surveillance	1 Lake	2 Superior	3 Surveillance
SEPTEMBER	4 Lake Superior	5 Surveillance	6 Lake Superior	7 Surveillance	8 Lake	9 Superior	10 Surveillance
	11 Lake	12 Huron	13 Lake Erie	14 Surveillance	15 Continuity	16 CCIW	17 CCIW
	18 CCIW	19 Lake Ontario	20 Aquatic	21 Invertebrates	22 CCIW	23 CCIW	24 CCIW
	25 CCIW	26 CCIW	27 Lake Ontario	28 Moorings	29 Lake	30 Ontario	1 CCIW
OCTOBER	2 CCIW	3 Lake	4 Ontario	5 Surveillance	6 Lake Ontario	7 CCIW	8 CCIW
	9 CCIW	10 CCIW	11 Lake	12 Superior	13 Surveillance	14 Lake	15 Superior
	16 Surveillance	17 Lake	18 Superior	19 Surveillance	20 Lake	21 Superior	22 Surveillance
	23 Lake Superior	24 Surveillance	25 Lake	26 Superior	27 Surveillance	28 CCIW	29 CCIW
	30 CCIW	31 CCIW	1 CCIW	2 Lake Ontario Moorings	3 CCIW	4 CCIW	5 CCIW
NOVEMBER	6 CCIW	7 Lake	8 Ontario	9 Sediment Trap	10 Moorings	11 CCIW	12 CCIW
	13 CCIW	14 CCIW	15 CCIW	16 CCIW	17 CCIW	18 CCIW	19 CCIW
	20 CCIW	21 CCIW	22 CCIW	23 CCIW	24 CCIW	25 CCIW	26 CCIW
	27 CCIW	28 CCIW	29 CCIW	30 CCIW	1 CCIW	2 CCIW	3 CCIW
DECEMBER	4 CCIW	5 Whitby	6 Dry	7 Dock	8 Whitby	9 Dry	10 Dock
	11 Whitby	12 Dry	13 Dock	14 Whitby	15 CCIW	16	17
	18	19	20	21	22	23	24
	25	26	27	28	29	30	31

Figure 1

CSS LIMNOS 1983

Figure 3
Liming of Frisken Lake, B.C. in support of study AED 437.

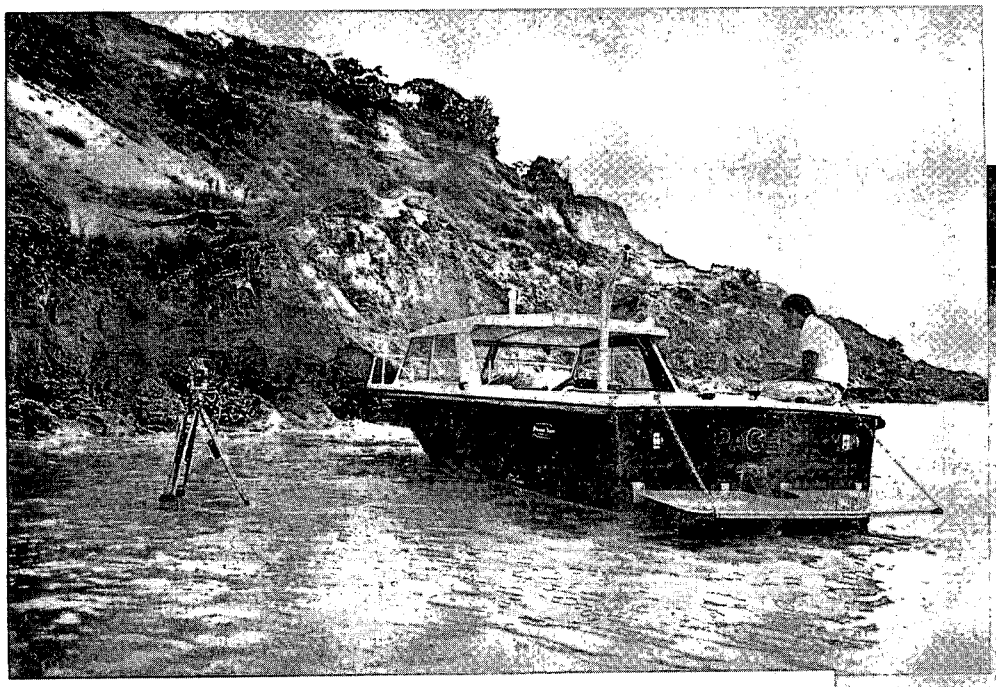

Figure 5
The final bluff survey, Port Burwell, study HD 345.

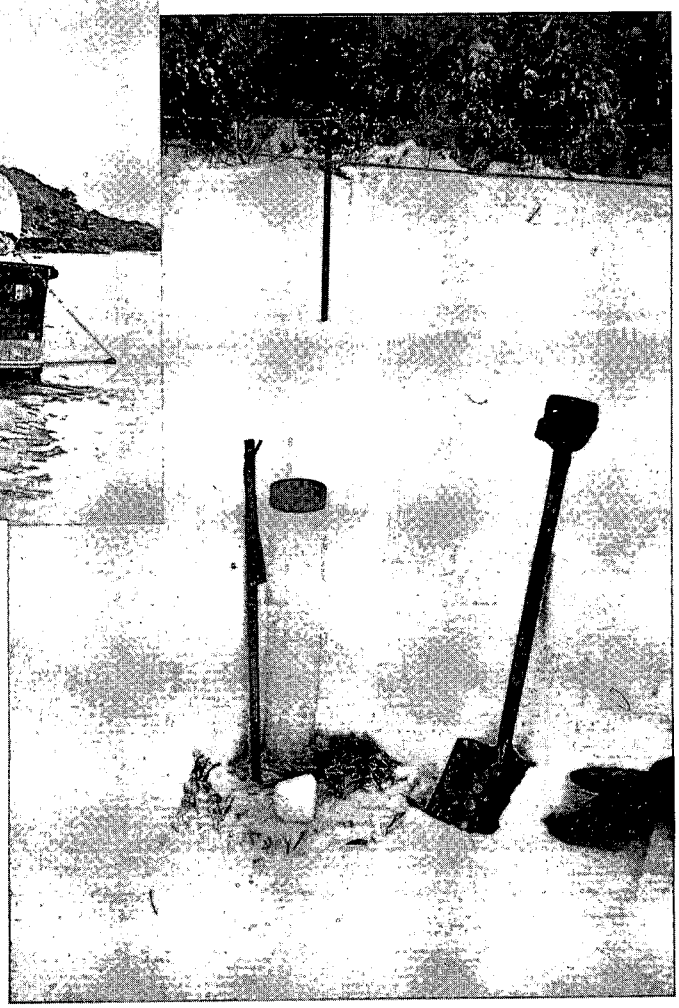

Figure 6
Snow coring at the Turkey Lakes watershed, Sault Ste. Marie.

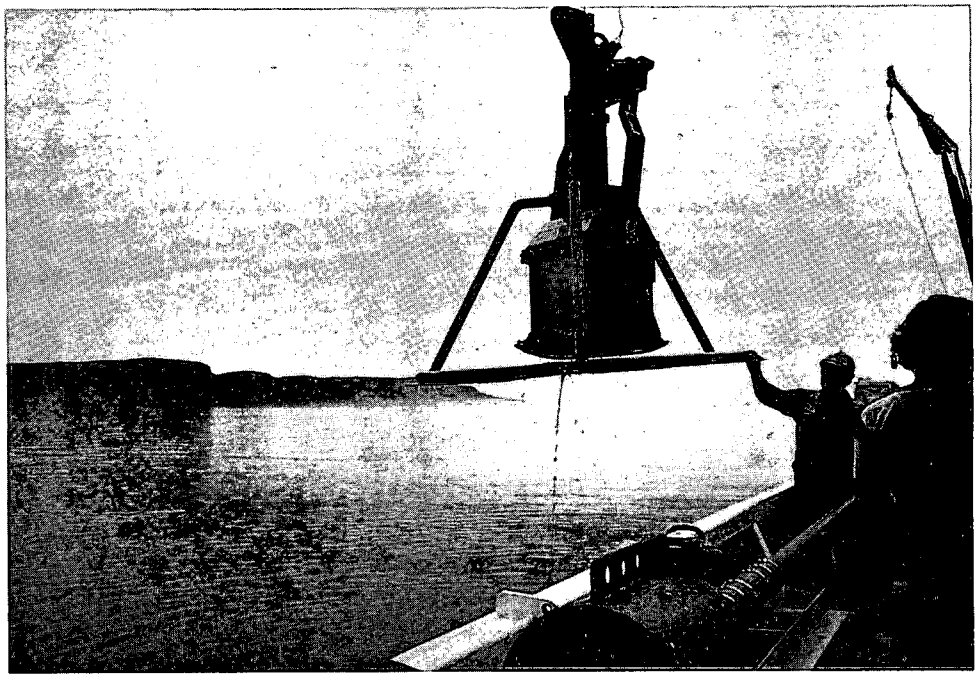

Figure 2 **Box coring from CSS Limnos on Lake Superior near Thunder Bay.**

to Pt. Sapin, New Brunswick. Another major responsibility has been the maintenance of the NWRI vehicle fleet.

Field Stores Unit. This Unit maintained, issued and received a store of field sampling and support equipment. The inventory of over 500 line items was in constant use by field staff of NWRI. The scheduling and issue of 5 vehicles for local use by NWRI staff was also provided.

Underwater Operations Unit. Responsibility was maintained for the safe conduct of all diving operations undertaken by DOE and DFO staff at CCIW. The Unit holds a responsible position with the Departmental Committee for Diving Safety which determines and enforces diving safety policy. The Unit utilized a large inventory of specialized research diving equipment. Dive support was given to a number of NWRI field studies during 83/84.

Shore and Launch Operations Unit. Support was provided to 62 NWRI studies as well as 55 minor additional requests during the year. All services provided were in support of approved NWRI activities and detailed reports are available. A few of the major field studies are listed:

No. 432 — Elmira Streams for sources and fate of ammonia-nitrogen in highly eutrophic or heavily polluted streams

No. 223 — Elmira Streams to determine pathways and accumulation rates of organic contaminants in fish

No. 411 — Algonquin Park sediment traps for metals related studies

No. 437 — South Central British Columbia to evaluate carbonate-phosphate chemistry of interior lakes (Fig. 3)

No. 109 — Eastern Lake Ontario for fish habitat studies (Fig. 4)

No. 345 — Pt. Burwell final bluff erosion topographic survey (Fig. 5)

No. 803 — Lake Superior for Canadian Wildlife Service re effects of toxics on Herring Gull colonies

No. 806 — Georgian Bay for GLFRB conducting LRTAP and primary production experiments

No. 236 — Shubenacadie River, Nova Scotia for toxic metals studies

No. 231 — Full-time staff at Sault Ste. Marie Turkey Lakes Watershed in support of LRTAP studies (Fig. 6 & 7)

No. 625 — Sudbury Lakes LRTAP sampling

No. 224 — Lake Superior Toxaphene Study

No. 314 — Moose River Ice Jamming studies

No. 216 — Niagara River surface microlayer sampling

LIMNOLOGICAL INSTRUMENTATION SECTION

Instrumentation support services at NWRI keep increasing with emphasis on new and varied types of equipment. The staff have kept abreast of state-of-the-art systems to provide the necessary support. During the year, the staff were busy upgrading, retrofitting or modifying existing equipment for optimum field performance. Seven major modifications to equipment were performed as follows:

1. Two new EBT's were manufactured and are awaiting temperature sensors.
2. The rack-mounted acoustic release deck unit was converted to portable use and fitted with rechargeable batteries.
3. A new and improved aklaline battery was designed and tested, and is in use in all Geodyne current meters and digitizers, with excellent results.

Figure 4 Under ice diving in eastern Lake Ontario in support of habitat studies DO 109.

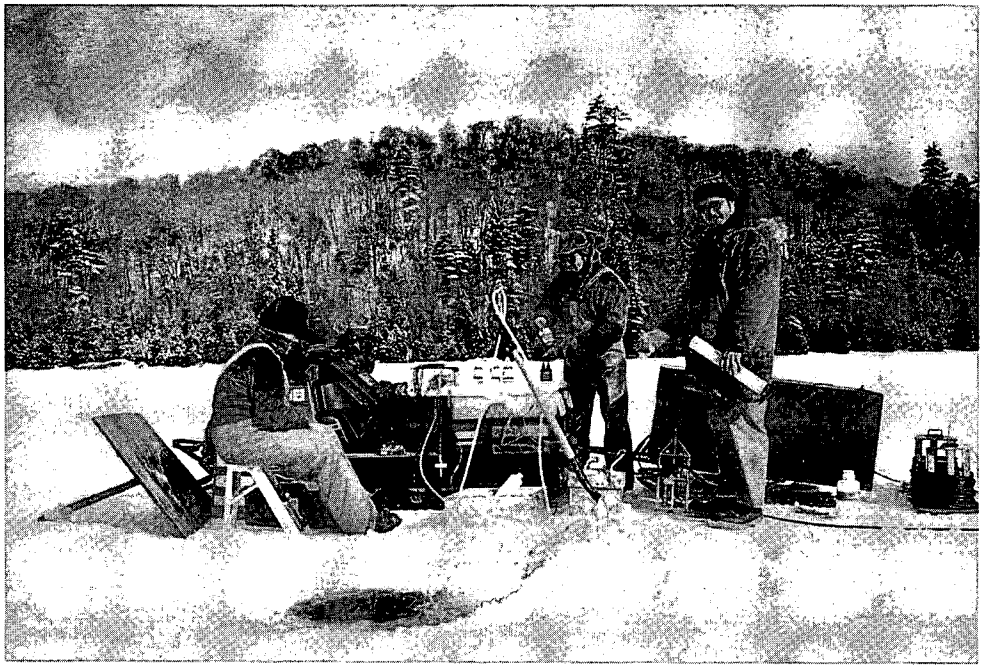

Figure 7 **Little Turkey Lake 40 miles north of Sault Ste. Marie.**

4. A new, improved and cheaper cassette was tested. After a few modifications, it is working well and is the standard cassette used in all Geodyne current meters and digitizers.
5. A new battery is in the design stage for the acoustic release units. If it proves successful, a significant cost saving will result.
6. An existing portable EBT system was integrated to a transmissometer sensor to form a portable EBT/transmissometer system. The system has been in use at the P&Y Region and field reports are very encouraging.
7. Year-round operation of meteorological and solar radiation sites has been upgraded for winterized operation.

STAFF LIST

Chief — Mr. H.B. Macdonald
Secretary — Mrs. S.R. Mitchell
Administrative Officer — Mrs. C. Kennedy

Ship Survey Section
Head, Mr. P.M. Healey

Sr. Technical Staff

Mr. B.H. Moore	OIC CSS LIMNOS, Nova Scotia
Mr. S.B. Smith	OIC CSS ADVENT/CSS BAYFIELD, science cruises CSS LIMNOS, Niagara-on-the-Lake, Yukon
Mr. P.R. Youakim	OIC CSS BAYFIELD
Mr. E.H. Walker	surveillance, CWS, Algonquin, Moose River

Technical Staff

Mr. J.A. Kraft	surveillance, science cruises, field projects
Mr. K.J. Hill	surveillance, diving, Pt. Burwell
Mr. G.G. LaHaie	OIC CSS ADVENT, surveillance, science cruises
Mr. R.J. Hess	OIC CSS ADVENT, IWD

Students

Mr. G.W. Stobbe	CSS LIMNOS
Mr. J.P. Haynes	CSS LIMNOS

Secondment from Water Survey of Canada, Guelph

Mr. A.C. Kular	surveillance, science cruises

Field Surveys Section
Head, Mr. W.B. Taylor
Sr. Field Officer, Mr. M.R. Mawhinney

Sr. Technical Staff

Mr. T.J. Carew	LRTAP — Sault Ste. Marie
Mr. L.E. Benner	CWS, surveillance
Mr. G.J. Koteles	Yukon, Algonquin, science cruises

Students

Ms. M.L. Walli	surveillance, shore projects
Ms. K. Gracey	shore projects
Mr. A.K. Szitas	rigging shop, Turkey Lakes

Contract

Mr. K. Weber	shore projects, LIS

Rigging Unit

Head, Mr. L.J. Lomas	foreman rigger, Nova Scotia

Support Staff

Mr. H.E. Greencorn	rigger, Nova Scotia
Mr. G.M. Perigo	vehicle maintenance, Nova Scotia

Underwater Operations Unit
Head, Mr. F.H. Don

Support Staff

Mr. G.D. Bruce	diving, OIC GLFRB Owen Sound, Turkey Lakes runoff
Mr. J.E. Tozer	diving, Turkey Lakes runoff, surveillance, field projects
Ms. C. Bisutti	diving, science cruises, surveillance, paleolimnology

Field Stores Unit
Mr. W.D. Hunt

Limnological Instrumentation Section
Head, Mr. J.A. Diaz

Student

Mr. G.L. Voros	LIS, rigging shop

Current Meters and Data Abstraction Unit
Head, Mr. J.A. Tyler

Field Instruments and MET Systems Unit
Head, Mr. E.G. Smith

STAFF SERVICES DIVISION

Staff Services Division (SSD) is the lead agency for the provision of administrative, financial, property management, material management and records management services to all Environmental Conservation Service (ECS) elements, as well as to those of the Environmental Protection Service, located at the Canada Centre for Inland Waters (CCIW). In addition, common support services are provided to those agencies of the Department of Fisheries and Oceans (DFO) located at CCIW as well as to the Department of Supply and Services and the Ontario Area Personnel Office, Department of the Environment (DOE).

ADMINISTRATION SECTION

This Section is responsible for providing administrative and financial support to all NWRI Divisions. Additionally, it provides Institute-wide functions such as compiling the NWRI Conference Travel Plan, writing new and updating existing Institute Administrative Procedures, providing liaison and coordination of personnel-related activities with the Ontario Area Personnel Office, DOE, information services, the coordination of student hiring programs, the Canada Savings Bonds Drive and the United Way Campaign, the preparation and analysis of monthly reports on the utilization of Institute's person-year resources, and expertise in all matters concerning safety, fire and security.

This year Office Automation was introduced, servicing NWRI Divisions as well as the Inland Waters Directorate-Ontario Region and the National Water Quality Laboratory. The coordination of the project rests with a staff member of this Section. The first phase of this project is a familiarization with the equipment and its capabilities for project automation as well as word processing. A study was undertaken to identify the needs for office automation within the Institute and a strategy developed for implementing automation over the longer time frame.

A newly-constituted CCIW Safety Committee has been introduced with expanded terms of reference to ensure greater participation by Senior Management and the Unions. It is intended that this Committee be more involved and pro-active in all matters concerning safety. Regular safety inspections have been conducted with effective follow-up taking place. Fire drills have been held to test the Institute's emergency organization. St. John Ambulance first-aid courses and on-site fire-fighting equipment training and CPR training courses were held for staff.

A Contracts Review Committee has been formed to ensure that all NWRI Contracts for Services and Materiel comply with Governmental and Departmental Contracts Directives.

The Information Unit of this Section provides answers to queries received from Provincial and Municipal authorities, other Federal Government Departments, academics and scientists, as well as from the general public. Information is provided informally, or in accordance with Access to Information legislation. Requests for speakers on specific subjects by service clubs, professional groups, universities and colleges are accommodated on an individual basis, and tours of the Centre are coordinated.

The Administration Section also provides management consultation for the DOE Equal Opportunities for Women Committee.

BUILDING AND PROPERTY SERVICES SECTION

This Section is responsible for the physical operation and maintenance of the buildings, intrinsic equipment and the grounds, roadways and parking lots within the confines of the complex. It also provides technical assistance and advice concerning alterations, modifications or equipment installation for all onsite agencies. Finally, it is responsible for the 55-line PBX servicing over 600 telephones, data and other communications systems throughout the complex.

Major projects this year included: (l) the completion of the CCIW Laboratory Space Reallocation Project undertaken in order to house the new National Water Quality Laboratory; (2) the installation of the Emergency Voice Alarm System to service all agencies at CCIW; and (3) the commencement of the first phase in making CCIW barrier-free to the Handicapped.

MATERIEL MANAGEMENT SECTION

This Section is responsible for providing, on a day-to-day basis, procurement, inventory control and assets management, disposal, warehousing and stores and shipping/receiving services to all ECS agencies located at the CCIW. Highlights of this year's work include: (l) a complete update of the computerized Capital Assets Inventory, including the location of major items; and (2) completion of a wall-to-wall inventory, including furniture.

FINANCE SECTION

The Finance Section provides centralized computer accounting services for all ECS units at CCIW (NWRI, Inland Waters Directorate-Ontario Region, Lands Directorate-Ontario Region and the Water Quality Laboratory). It also provides the accounting function for funds provided by the Regional Director General-Ontario Region for the Great Lakes Water Quality Agreement. In addition, the Section is responsible for providing liaison between other government departments (federal, provincial and municipal) and suppliers with regard to payment of accounts and contracts.

LIBRARY SECTION

This Section provides library services and facilities to all agencies located at the CCIW in support of their research and survey programs. Highlights for the period covering this report include: (l) the installation of a security system which has been found to be most effective in reducing losses of books and journals; and (2) the finalization of a Disaster Plan to safeguard the collection in the event of fire, flood, etc. Also, Disaster Teams made up of CCIW staff have been established to respond to any and all emergencies on an around-the-clock basis.

CENTRAL REGISTRY SECTION

Central Registry provides mail services to all in-house occupants as well as registry facilities for NWRI and Inland Waters Directorate-Ontario Region. Telex, telecopier and photocopying services are provided for the Centre.

STAFF LIST

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Secretary — Mrs. H. Zrostek

Financial Services
Head, Mr. A.B. Mitchell

Support Staff
Mrs. B. Titley
Mrs. Y. Hutton
Mr. D. Jefferson
Mr. R. Haswell
Mrs. E. Wendel

Central Registry
Supervisor, Mrs. E. Rae

Support Staff
Mrs. M.T. Solvason
Mrs. J.A. Sims
Mr. D. Foran

Materiel Management
Head, Mr. D.A. Burton

Support Staff
Mr. J.P. Mellon
Mr. S.E. Hicks
Mrs. M. Eadie
Mr. W. Coventry
Ms. M. Ross

Building and Property Services
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Safety Officer, Mr. R.J. Gray Nurse, R. Calcott

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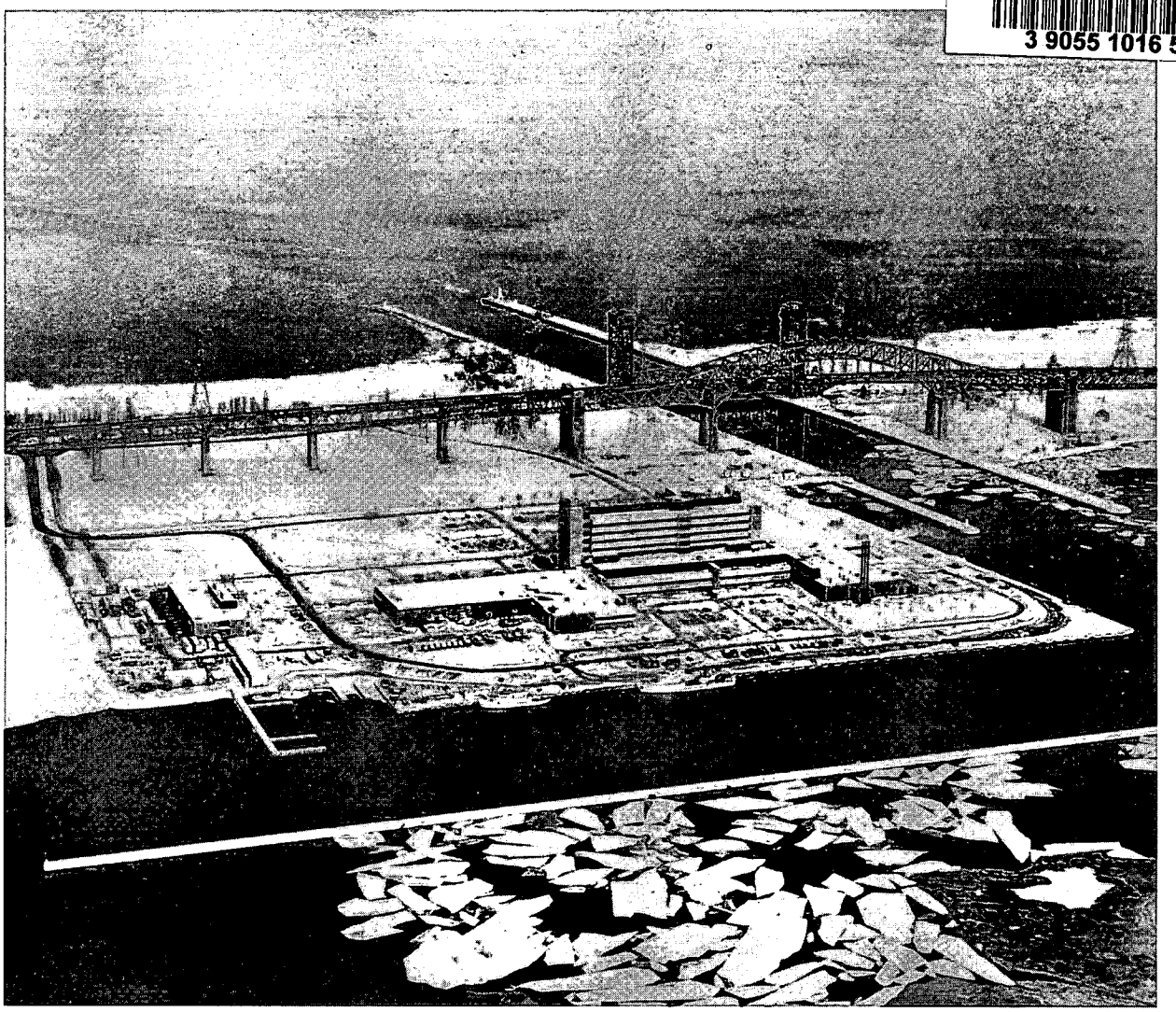
Mr. R.J. McCurdy
Mr. W. Murphy
Mr. M.S. Wyne
Mr. G.R. Johnstone

Library Services
Head, Ms. E. Dowie

Support Staff
Ms. P. Haley
Mrs. J. Tinney
Mrs. K. Finch
Ms. P. Bennett

Information Unit
Officer, Vacant

Canada Centre for Inland Waters



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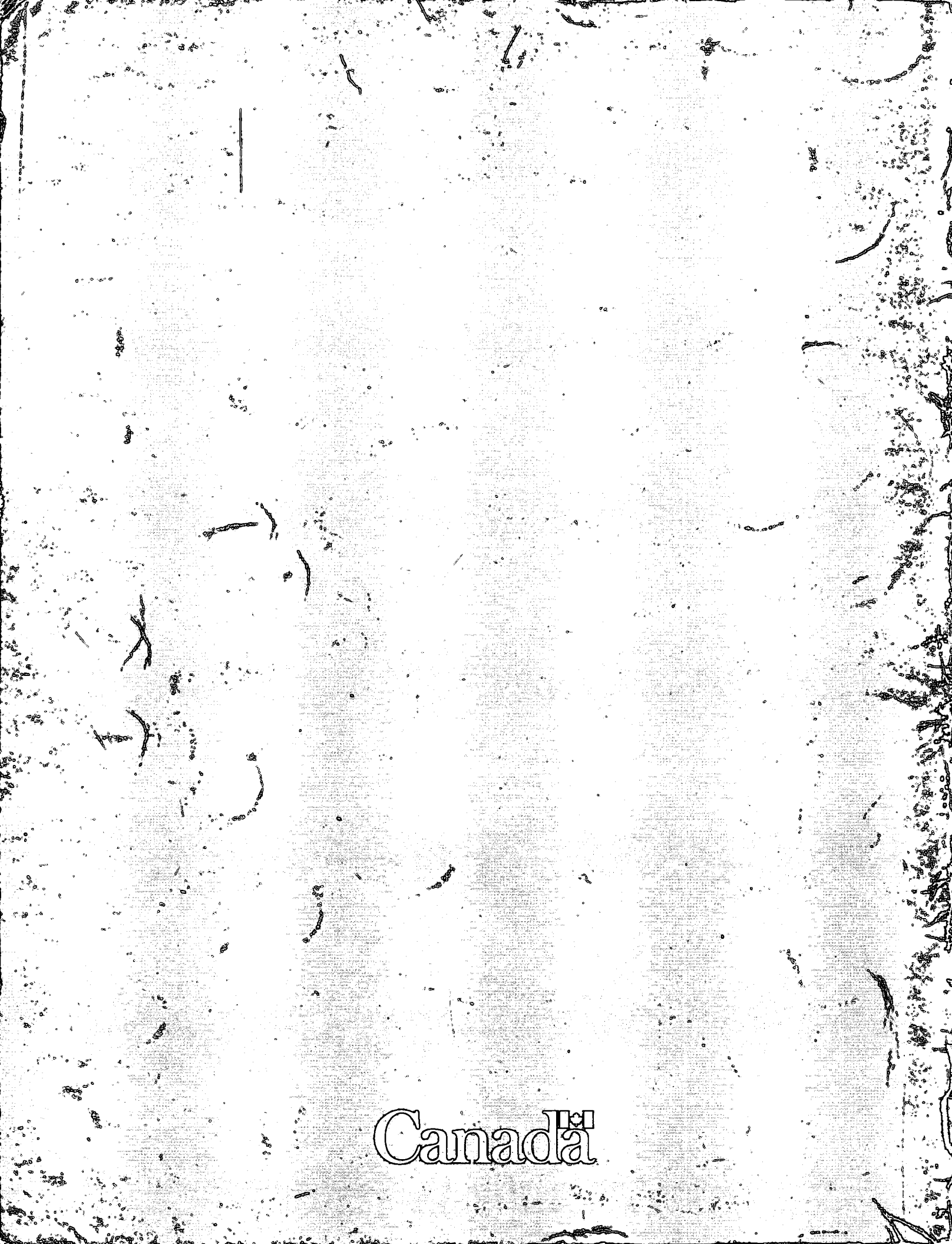
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