

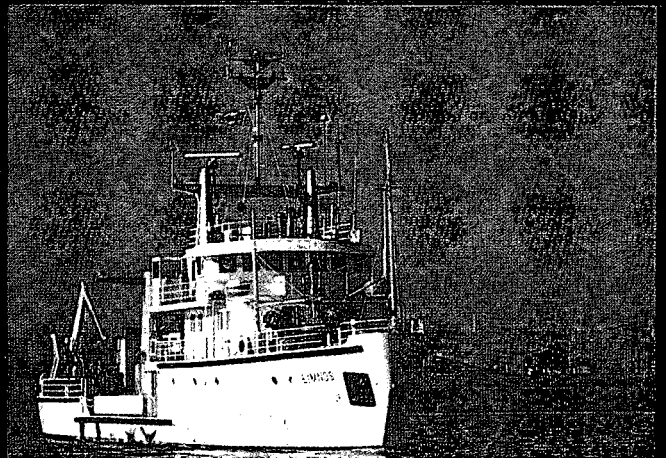
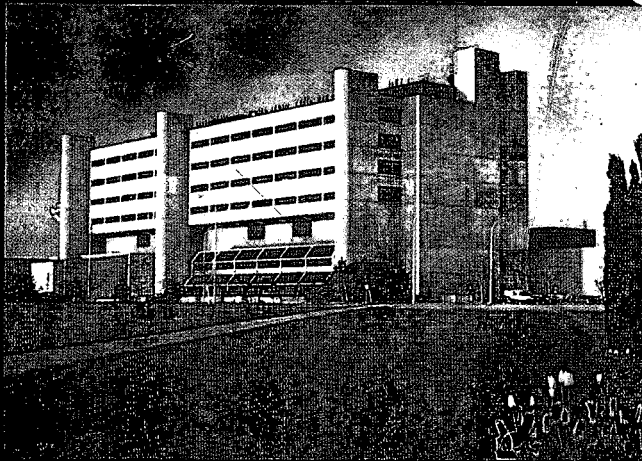
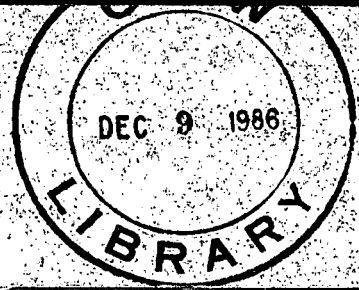


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# National Water Research Institute

## 1985-1986 Annual Report



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**NATIONAL WATER RESEARCH INSTITUTE**

**1985-1986  
Annual Report**

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

## NATIONAL WATER RESEARCH INSTITUTE

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*Our file*    *Notre référence*

It is with pleasure that I introduce this summary of the research accomplishments of the National Water Research Institute, Inland Waters Directorate, Environment Canada, for 1985 and 1986. The results reported here address a variety of issues of national significance associated with the protection, enhancement or sustainable development of fresh water in Canada.

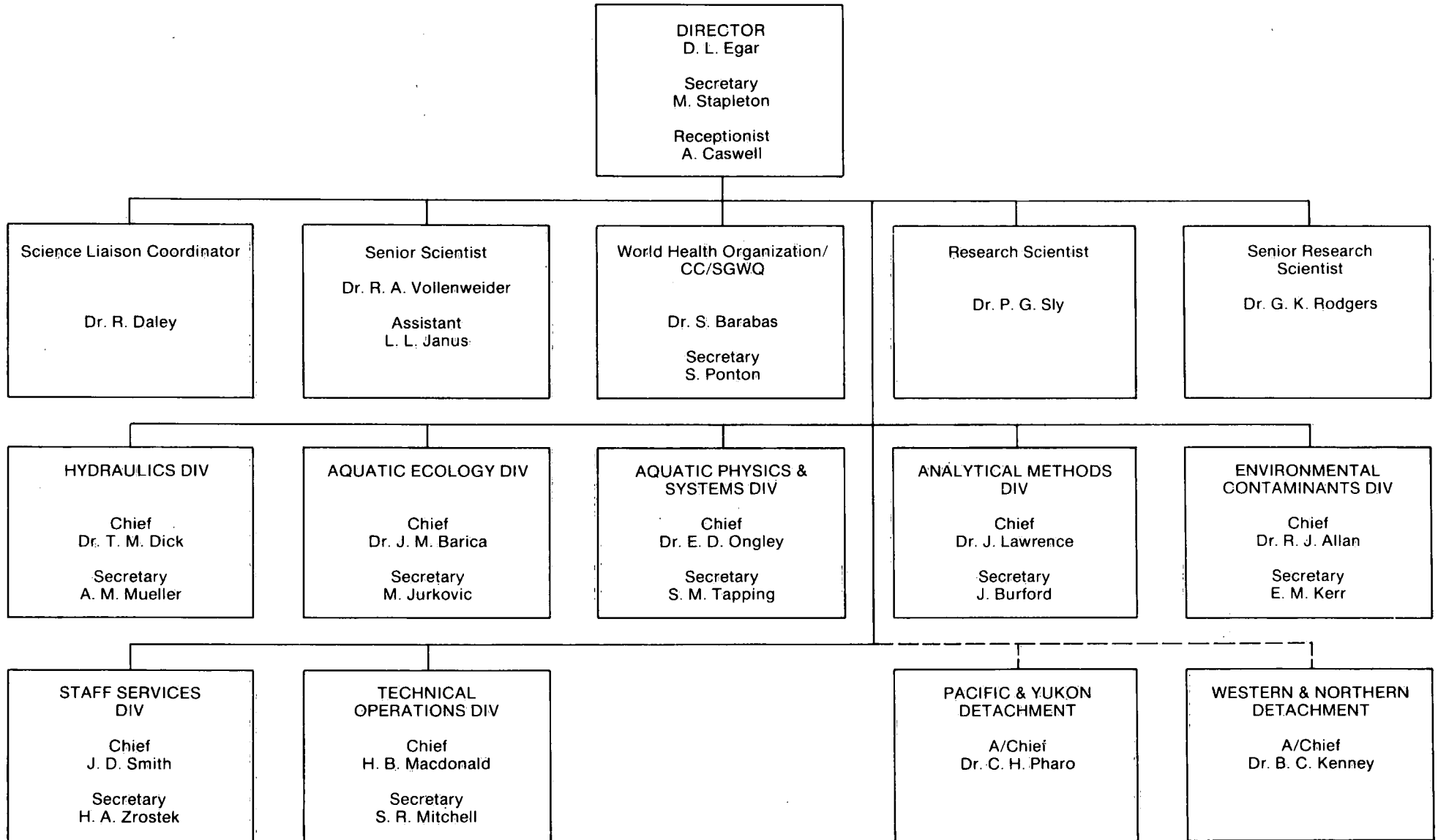
In this edition, the staff report on recent progress in a variety of important areas, including the fate and effects of environmental toxicants, long range transport of air pollution, eutrophication and lake rehabilitation, river flooding and ice jams, predictive modelling and analytical methods development. The research encompasses the full range of scientific disciplines within lake and river limnology.

The Institute is dedicated to scientific excellence and social responsibility. These results represent the efforts of the Institute's talented staff to advance and communicate new knowledge of scientific merit and practical importance. It is my hope and expectation that this knowledge will be of value in the ongoing management of Canada's inland water resources.

D.L. Egar  
Director

**Canada**

ORGANIZATION CHART  
NATIONAL WATER RESEARCH INSTITUTE



## EXECUTIVE SUMMARY

The research accomplishments of the National Water Research Institute (NWRI), Inland Waters Directorate, Environment Canada, for the fiscal years 1984/85 and 1985/86 are summarized. The Institute, located at the Canada Centre for Inland Waters in Burlington, Ontario, undertakes original research on freshwater issues of national significance to Canada. The knowledge and expertise derived from its research are communicated to Environment Canada, the Canadian water management community and the general public for use in resolving aquatic environmental problems.

Historically, research at NWRI has been conducted by five research divisions, each with a particular disciplinary or functional role (contaminants, hydraulics, ecology, lake physics, analytical methods). To enhance the integration and flexibility of the Institute's research programs and to maintain economy and efficiency in a time of restraint, a comprehensive Project Management System was implemented in late 1985. Research activities were organized into a series of multidisciplinary projects, each addressing an issue of scientific and managerial importance. Projects will be the focus for planning and managing future research, for developing internationally recognized expertise and for communicating results and their implications to users. The divisional organization was retained to ensure disciplinary cohesion and administrative stability.

A summary follows of the research and communication highlights of major, "flagship" projects during the review period. New projects, or groupings of projects, which have been implemented for 1986/87 are also briefly summarized. Together, they comprise the core research program that NWRI will undertake over the next several years.

Research results from the Western and Northern and Pacific and Yukon regional detachments of NWRI are included here for the last time. Effective April 1986, these two groups were reorganized as the Limnology Division of the National Hydrology Research Institute, Saskatoon.

**Fate and Effects of Toxic Contaminants.** To develop control strategies and predictive capabilities for management purposes, the properties, pathways, fate and biotoxic effects of toxic chemicals are being systematically characterized through ongoing laboratory and field experiments. Highlights from the review period include the following:

- Research on the fate of chlorophenols in the North Saskatchewan River was undertaken. Anaerobic dehalogenation was shown to be a critical pathway for chlorophenol degradation in this and other systems.
- The rate of mercury methylation in sediments of the Qu'Appelle Basin of Saskatchewan was shown experimentally to be controlled, not by the availability of inorganic mercury, but primarily by trophic conditions.
- Studies of factors affecting methylation, demethylation and bioaccumulation of mercury by fish in northern Manitoba showed that elevated mercury levels are to be expected following flooding by northern hydroelectric reservoirs.
- Toxicity tests using Microtox and octanol-water partition coefficients were found to parallel each other for a wide range of organic chemicals, including chlorophenols, anilines, benzenes, nitrobenzenes and pyridines.
- A study to evaluate organic and inorganic contaminant pathways in the Mackenzie River was initiated in response to native concerns and recognized water data deficiencies. Water, suspended and bottom sediments and biological samples were collected under summer flow conditions.
- Deformities in *Chironomus* larvae are being developed as *in situ* bioindicators to assess the ecological impact of contaminants in the Saskatchewan River Basin.
- Formation of organic coatings by colloidal fibrils in lake water was investigated. These fibrils are important for metal speciation changes in lake water.
- The effects of specific heavy metals on the metabolic activities of natural bacterial populations were evaluated, using populations from Hamilton Harbour.

**Contaminated Sediments.** To aid the development of site rehabilitation guidelines, the availability, biogeochemical pathways and effects of sediment contaminants from the Great Lakes and smaller systems are being determined. Long-term contaminant release from bottom sediments, which can slow recovery following point-source control, will also be quantified. Highlights include the following:

- Bioconcentration factors for chlorinated hydrocarbons by aquatic worms varied with chemical structure and sediment type. The worms selectively accumulate chemicals from the sediments in which they live; this has important implications for fish predators.
- Historical changes in the accumulation of pollutant metals since 1910 were determined using  $^{210}\text{Pb}$  dating of lake sediments. Metal deposition rates in lakes from Nova Scotia, eastern Ontario and upper New York State were comparable.
- Discontinuities were found in the vertical distribution of suspended sediments in Lake Manitoba. The results have important implications for redistribution of sediment contaminants in large, shallow lakes.

**Upper Great Lakes Connecting Channels Study.** This ongoing project is developing the knowledge and expertise needed to assess the magnitude of toxic contamination of the upper Great Lakes connecting channels while protecting Canadian interests in support of remedial action. Contaminant and nutrient sources are being identified and quantified, biological toxicity is being assessed, and models to predict contaminant distribution will be developed. Highlights from the past two years include the following:

- A multidisciplinary NWRI team collaborated with the Ontario Ministry of the Environment in an emergency study to determine the nature, chemical composition and specific source of contaminant "puddles" discovered on the St. Clair River bottom near Sarnia, Ontario. The identity and source of the puddles, other contaminant sources along the river and the extent of contaminant transport across the border were determined. As a result, Dow Chemical removed the sediment puddles, eliminated the plant source and developed procedures to minimize future seepage to the river.
- A special issue of the *Journal of Great Lakes Research* dealing with pollution of the St. Clair River, Lake St. Clair and the Detroit River was published; 10 of the 23 publications were authored by NWRI staff. Many toxic chemicals, such as HCB, HCB and OCS, were identified in the papers. Sources were suggested and pathways of movement, both spatially and into food webs, were resolved. The sources, pathways, fate and effects of tributyltins, alkylleads, many persistent and bioaccumulated organochlorines and volatile organics were also described.

**St. Lawrence River Rehabilitation.** The degree of hazard posed to aquatic biota and humans from toxic contaminants in the St. Lawrence River (and upper estuary) is unknown and the expertise needed for restoration planning has not been developed. Research is undertaken to determine the magnitude, distribution, loadings, principal pathways, fate and biological effects of toxics in the river, as well as the ecological impacts of contaminants at the mouth of the estuary. Highlights from the early phase of work include the following:

- An initial cruise from Lake Ontario to Quebec city was made to collect sediment and water samples for a preliminary assessment of contaminant types, distribution and fate.
- The surface sediments of Lake St. Louis were surveyed and maps showing the extent and size-distribution of the sediments prepared.
- An intensive microbiological study of Lake St. Louis for toxicants and bacterial biomass distributions was undertaken. Over 80% of surface sediments were found to contain toxicants, as determined by the Microtox test.

**Long Range Transport of Air Pollutants.** To improve the information base, expertise and scientific credibility for effective national and international management of LRTAP, a major research effort, in progress, is quantifying the biogeochemical processes which control the response of lakes and rivers to the deposition of acids and other contaminants in eastern Canada. Improved expertise in the design, conduct and interpretation of acid rain monitoring programs is also being developed. Highlights include the following:

- Sulphur stored in the sediments of the Turkey Lakes was determined, by stable isotope techniques, to occur in the reduced form, mostly as organosulphur compounds. Reduction of pollutant sulphur was shown to be the most important process for the generation of buffering alkalinity.
- Low pH stress on natural lake bacteria adversely affects their cellular surface structure, metabolic rates and ability to decompose organic matter.
- Waters in the Atlantic Provinces were shown to be the most sensitive in eastern Canada to acid rain.
- During spring, short-term acidification of surface waters was shown to be strongly influenced by rainfall. In addition, nitrate deposition was found to be as important as sulphate deposition in influencing acidity during snowmelt.
- Several presentations, including plenary papers, describing the research accomplishments of Institute scientists were given at the 1985 International Acid Rain Conference at Muskoka, Ontario.
- Watershed acidification models were developed to assess the aquatic impacts of acid precipitation and to predict geographical areas at risk.
- *Sphagnum* moss was found to be an effective biomonitor of atmospheric metal deposition. The technique is now in use in representative areas across Canada.

**Water Quality Methods Development.** In this ongoing project, new and improved analytical methodologies for the measurement of chemical and biological parameters in water, sediment and biota are developed and transferred to Inland Waters Directorate operational (and research) laboratories. National expertise in instrumentation and analysis is thereby enhanced and analytical accuracy, economy and effectiveness improved. Review period highlights are the following:

- Institute staff organized and chaired two international symposia related to microbiological methodology, the International Symposium on Aquatic Microbial Ecology and the Second International Symposium on Toxicity Testing Using Bacteria.
- Assistance was provided to the International Development Centre, Ottawa, to design and evaluate a three-continent study on the use of coliphage as an indicator of microbial water quality.

- A new method for solubilizing and measuring polychlorinated dibenzo-p-dioxins (PCDD) by a radioimmunoassay technique was calibrated, standardized and used for PCDD screening.
- A flow-injection/atomic absorption method for Ca and Mg was developed and transferred to operational use.
- A flow-injection/colorimetric method for the simultaneous determination of ammonia, nitrate, nitrite and phosphate was developed and transferred to operational use. This is more efficient and cost-effective than previous techniques.
- The traditional molybdate "geo-P" method for analyzing sediment phosphorus was modified to prevent iron (III) interference and to permit estimation of the bioavailable phosphorus fraction by chemical extraction.
- A large-volume, continuous-flow extractor was developed to concentrate organic contaminants which occur at extremely low levels in environmental samples. Units are now operational in both the field and the National Analytical Laboratory.

**Water Quality Monitoring and Modelling Research.** Improved methods of data collection, interpretation, synthesis and prediction are required for national water quality assessment. In this project, improved chemical and biological monitoring strategies, data interpretation protocols and water quality simulation models are developed for Inland Waters Directorate operational use and for interpretation of Great Lakes Surveillance data. Project highlights include the following:

- A fundamental new strategy for monitoring and interpretation of toxic chemicals in rivers was developed and transmitted to operational programs in Canada and the United States.
- A comprehensive statistical assessment of the Great Lakes Surveillance Program was completed.
- Expertise was provided to an operational reevaluation of the role and needs of sediment monitoring programs in Canada.
- A numerical model was modified to assess various phosphorus management options for the control of eutrophication in the four Qu'Appelle fishing lakes.
- An atlas of the optical properties of the Great Lakes (photoc depth, PAR, etc.) was prepared.

**Lake and River Restoration.** Federal and provincial water managers require expert assistance in rehabilitating the Great Lakes and other regional lakes and rivers from the effects of nutrient eutrophication and macrophyte infestations. Applied, site-specific research is undertaken to establish cause-effect relationships and develop specific remedial plans. Project highlights are the following:

- In a joint Inland Waters Directorate-Industry study of eutrophication in the Thompson River, B.C., experimental flowing troughs were used to determine the combined effects of physical conditions and nutrient flux rates (P and N) on periphyton growth. New generalizations on organic production in rivers, with major implications for water quality management, were formulated.
- Sediment dialysis samplers ("peepers") were used to measure regeneration and internal loading of soluble phosphorus to Lake Erie. Fifty percent of the non-apatite sediment phosphorus is potentially regenerated.
- Experiments with sediment traps showed that large quantities of phosphorus can be made available by natural resuspension of sediments in the Great Lakes.
- Experimental lime treatments to restore eutrophic Frisken and Chain lakes (B.C.) were successful. Management advice on the use of the method was provided to government agencies in British Columbia and Alberta.
- *Cladophora*, a filamentous nuisance alga affecting Lakes Ontario, Erie and Huron, was found to have declined about 50% between 1972 and 1983, due to phosphorus reductions.
- Harvesting experiments to control Eurasian milfoil in Buckhorn Lake, Ontario, were completed, and procedures to minimize adverse treatment effects developed. Numerous presentations on the impact of aquatic weeds were given to citizens' groups.
- Analysis of historical data on the recovery of Kootenay Lake, B.C., following severe phosphorus pollution, indicated only slight declines in phytoplankton and no changes in zooplankton, apparently as a result of nitrogen limitation and *Mysis* grazing. Controversial provincial plans to fertilize the lake by aircraft in an attempt to restore declining fish stocks were thus abandoned.

**Near-shore — Open-Lake Interactions.** Point-source pollutants are usually discharged or advected into the near-shore zone of large lakes, a zone that is physically distinct from the open lake. In this project, the physical and sedimentological processes controlling the movement of contaminants between the coastal and offshore zones of the Great Lakes are identified, quantified and modelled. Highlights of this project, which is nearing completion, include the following:

- A comprehensive review and several synthesis reports were published on water circulation in Lake Ontario, with emphasis on near-shore coastal zone dynamics and the transport and fate of toxic contaminants in Lake Ontario from the Niagara River plume.
- A major monograph on effluent transport and diffusion models for the coastal zone of large lakes was published.

**Water Resources and Modelling.** Management of water resources in its various aspects requires knowledge and understanding of the movements and mixing processes of water, as well as its interactions with land and air. In this project, simulation models are developed to predict the physical effects of man-made or natural alterations in the environment. Review period highlights include the following:

- The MOBED river model was modified to deal with non-uniform sizes of bed material and now simulates "paving" effects. MOBED was applied to Qu'Appelle River data to predict the response of the river to the removal of meander loops.
- The RIVMIX model was modified to predict downstream concentrations of some classes of non-conservative pollutants, such as water-soluble, but volatile compounds.
- Institute staff chaired a NATO workshop on urban pollution and contributed to UNESCO manuals on urban drainage and data acquisition.
- The flow component of the HSPF model was installed on the NWRI computer, calibrated, and used to evaluate the effects of urbanization on water quality and quantity in the Waterford River basin.

**Inter-basin Water Transfer.** To develop the interdisciplinary expertise and departmental credibility for effective assessment of future diversions, this new project will systematically identify, and, if feasible, generalize about the physical, chemical and ecological effects of large-scale inter-basin water transfers. The initial focus is on physical processes. Highlights from this subject area are the following:

- A five-year study to determine the environmental sensitivity of the large, deep, ice-covered, riverine headwater lakes of the Yukon River to future hydroelectric impoundments and diversions was completed. Baseline descriptions were provided of important physical, chemical and microbiological processes, with emphasis on circulation patterns and ice formation during winter.
- Available information on the effects of diversions on river regimes was analyzed and reviewed. Research to develop better models of river dynamics, lake erosion and ice behaviour was recommended.

**Flooding and Ice.** To improve ice-jam flood management, this ongoing project will acquire the knowledge needed to develop ice-jam forecasting methods using data on formation, transport and distribution of frazil and anchor ice. Highlights include the following:

- Field measurements of ice growth and decay, frazil dam formation and midwinter streamflow in the Yukon River were obtained in collaboration with the Water Resources Branch. Specific factors which may control ice-jam formation and spring breakup were identified.
- An improved turbulence model to predict flood levels was developed. The model takes into account changing bed roughness as well as overbank flow.
- A mathematical model of ice-jamming was improved so that it can be applied to channels of changing width.

**Fraser River Rehabilitation.** The Fraser River Estuary in British Columbia is an area of environmental degradation. In particular, the effects of chemicals used in wood processing require investigation. Pathways of transport, degradation and bioaccumulation of chlorinated phenols and related contaminants in the estuary will be determined and used as "benchmark" models for other contaminants. The knowledge will aid in the design of monitoring programs and the formulation of water quality objectives within the framework of the Fraser River Estuary Management Program. Highlights of preliminary work include the following:

- Background information was collated and preliminary field work undertaken to determine the fate and effects of chlorophenols in the estuary. Leeches were shown to be excellent biomonitors for detecting waterway contamination by chlorophenols.

**Air/Water Contaminant Exchange.** This project will determine the extent to which atmospheric loading of toxic contaminants may prolong the recovery of the Great Lakes following point-source control. Data on precipitation already reveal the importance of this pathway. Air/water contaminant flux rates will be determined from laboratory and field experiments and novel simulation models to predict aerial loadings will be developed.

- Concentrations of PCBs, alpha-BHC and lindane in rainfall were found to be relatively uniform across southern Canada, east of the Rocky Mountains.

**Fate and Effects of Pesticides.** A departmental source of expertise and a systematic information base on ecotoxic effects of pesticides is needed. This project will systematically determine the pathways, fate and effects of important diffuse-source pesticides. Both laboratory and field experiments, primarily in eastern Canada, will be carried out.

- A national survey of the extremely toxic, anti-fouling pesticide, tributyltin, in water and sediment showed its occurrence is related to boating and shipping activities, mainly in harbours and marinas. Sunlight and bacterial degradation are the main factors controlling the persistence of tributyltin, which has a half-life of several months under Canadian conditions.

**Nutrient-Contaminant Interactions.** This new project will evaluate whether the processes of bioaccumulation, biodegradation and sedimentation of toxic contaminants in lakes are controlled by the nutrient status and biological productivity of the system. An understanding of these complex interactions, which could determine the vulnerability of a particular lake to toxic pollution, will be important in the development of future contaminant action plans.

**Ground-Water Contamination.** More knowledge and expertise are required for the effective management of eastern Canadian ground-water supplies contaminated by toxic wastes and biocides. Better sampling, analytical and modelling techniques will be developed to determine the physical and chemical processes controlling the migration and fate of ground-water contaminants. This new project will focus on dump-site contamination in international reaches of the Great Lakes connecting channels and on potential contamination of potable ground-water supplies in the Maritimes.

## DIRECTOR'S OFFICE

### SENIOR SCIENTIST

Dr. R.A. Vollenweider, the Senior Scientist of the National Water Research Institute, has continued to provide scientific leadership at the Institute. He has contributed to the reformulation of NWRI research programs, and served as advisor to the Director, NWRI. He has also been elected Chairman of the DOE Senior Scientist Committee.

In recognition of his leadership in limnology, Dr. Vollenweider received the 1986 Tyler Prize for Environmental Achievement and was elected a Tyler Laureate. The Tyler Prize is one of the most prestigious environmental awards in the world. Citing Dr. Vollenweider's research on eutrophication, the Tyler Prize Executive Committee described him as the scientist most responsible for reversing pollution in the Great Lakes. In addition, Dr. Vollenweider's scientific contributions to Canadian limnology and water management were honoured by receipt of the "Frank Rigler Memorial" award from the Society of Canadian Limnologists, a biographical sketch in *The Canadian Encyclopedia* and an article in *Saturday Night*.

Dr. Vollenweider was invited as keynote speaker to three international conferences (European Water Pollution Control Association Lake Pollution and Recovery, Rome; Management Strategies for Phosphorus in the Environment, Lisbon; Living in a Chemical World — Special Conference on Lakes and Estuaries, Bologna) and has lectured at several Japanese universities (Shiga, Nagoya, Tzukuba) and Japanese governmental agencies, the University of Constance in Germany, and the Spanish Centre for Hydrographic Studies. He was also the main lecturer at a Pan American Centre for Sanitary Engineering course on Tropical lakes (Guadalajara) and continued as advisor to the Pan American Health Organization Cooperative Program on Warm Water Lakes in South America, and to the Emilia-Romagna Regional Government in Italy, on pollution of the Adriatic Sea. He has been elected as international co-president of the International Centre for Advanced Environmental Studies, Como, Italy, and as a sponsoring member of the International Lake Environment Committee, Otsu, Japan.

### SCIENCE LIAISON AND COORDINATION

The Science Liaison Coordinator (SLC), under the guidance of the Director and Management Team of NWRI, coordinates the planning and communication of the Institute's research programs.

The central focus for effective and flexible research planning within the Institute is the comprehensive Project Management System put into effect in late 1985. Research at the Institute is made up of interdisciplinary research projects focusing on priority problems or issues of national significance.

As a member of the Management Team, the Science Liaison Coordinator is responsible for ensuring the development, approval and documentation of research projects each year in an effective and timely manner. Preparation of the annual Project Directory, Annual Report, departmental Work Plan, monthly progress reports, special project brochures and other research communication documents is undertaken, or coordinated, through this office.

The SLC also assists Division Chiefs designated by the Director to oversee liaison with regional and headquarters

operational components of the Inland Waters Directorate who are principal "users" of the Institute's research results. Operational research needs are evaluated for inclusion in future projects, either by direct contacts or through established committees, and results of past work are communicated to potential users. The SLC will also be responsible for research coordination with the National Hydrology Research Institute, after it is reestablished at the National Hydrology Research Centre, Saskatoon.

Lastly, the Office of the Science Liaison Coordinator provides overall coordination of public information programs and community relations activities at NWRI, ensuring that the accomplishments of the Institute are communicated effectively and responsibly to the public at large. (Daley)

### SENIOR RESEARCH MANAGEMENT ADVISOR

A study is in progress on year-to-year variations in the development of the thermal bar in Lake Ontario from 1965 to the present. Work on a prediction scheme, first published in the early 1970s, will be updated, based largely on extensive temperature surveys carried out by the Institute.

A general review of processes that affect the quality of source water for industrial or municipal intakes around Lake Ontario was presented to the workshop on "Impacts of Source Water Quality on Industrial Processes and Municipal Uses" in Rochester, N.Y. This workshop may stimulate better communication of information about the extensive databases available on water quality in this lake.

Environment Canada liased with the Ontario Ministry of the Environment and Dow Chemical of Canada Ltd. to assist in the cleanup of contaminated bottom sediments in the St. Clair River near Sarnia, Ontario. As senior DOE officer on site he coordinated the acquisition and interpretation of video films of the area before and after cleanup and of the dredging/vacuuming techniques used. (Rodgers)

### WHO COLLABORATING CENTRE ON SURFACE AND GROUND WATER QUALITY

The Institute is designated by the World Health Organization as its Collaborating Centre on Surface and Ground Water Quality (WHO/CC). The main functions of the WHO/CC are coordination of international technical assistance programs to developing countries and representation of Canada's freshwater interests in international forums. The WHO/CC is coordinating the establishment of a worldwide network of water quality monitoring stations on major rivers, lakes and aquifers. 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.

The WHO/CC publishes the quarterly journal *Water Quality Bulletin*, which contains reviews of water management practices around the world. The year 1985 marked the 10th year of uninterrupted publication of the *Water Quality Bulletin*, in separate English and French editions. Over this period, approximately 400 articles from 70 countries were published. The journal is now distributed in 126 countries.

The first issue of Volume 10 was devoted to water toxicity and its effect on human health. Under the theme Toxicity Testing for Water Quality, a number of bioassaying techniques used in different parts of the world were reviewed. The three subsequent issues described the experiences of 30 countries in their national water quality monitoring programs, in particular the implementation of the GEMS/WATER program.

By the end of 1985, over 290 000 measurements had been reported to the WHO/CC Global Data Centre from 449 GEMS monitoring sites located in 60 countries. The recommendations made at the Inter-Regional Review Meeting on Water Quality Monitoring Programs in October 1983, and published in 1984 in the GEMS/WATER Data Evaluation Report, are gradually being implemented. A new GEMS/WATER data form containing a revised listing of water quality variables was distributed. Data are now also distributed on microfiche to participating countries and institutions.

During the report period, study and discussion programs for 17 visitors from Australia, Argentina, China, Japan, Morocco, Nicaragua and Sweden were organized, and requests by WHO regional and national offices for Canadian consultants abroad were processed. A variety of inquiries on water management problems particularly from developing countries were also reviewed. (*Barabas*)

## FISH HABITAT STUDIES

Some lake trout spawning habitats in eastern Lake Ontario appear to be affected by the presence of degrading organic materials. During late September and October, large quantities of *Cladophora* are broken from substrate holdfasts in shallow near-shore areas (water depths of 3–4 m) and these filaments become incorporated within the interstices of nearby cobble-gravel deposits. Later, a similar flux of fragmented milfoil may add to the organic load. Aerobic heterotrophs and nitrifying bacteria then break down these organic materials, resulting in the depletion of dissolved oxygen and the production of ammonia and  $\text{CO}_2$ .

Sediment "peepers" (closed cylinders, having one end fitted with a 0.45- $\mu\text{m}$  membrane filter) were placed in the cobble-gravel substrates and allowed to equilibrate. At depths of 6–10 cm within the substrate, dissolved oxygen levels approached zero and ammonia levels reached as high as 5.5  $\text{mg}\cdot\text{L}^{-1}$ . Such values indicate that the water quality at depths where naturally spawned lake trout eggs occur is potentially lethal to developing embryos. Persistence of such conditions could greatly reduce the survival of eggs from introduced lake trout stocks.

Boxes containing simulated gravel, placed flush with the surface of cobble-gravel substrates, were used to collect particulates entrapped in beach materials during late fall when lake trout spawn. Trapped sediments at two sites contained mostly inorganic sand-size particulates, high concentrations of black sulphide grains and  $\text{H}_2\text{S}$ . Fall storms probably erode near-shore sand deposits containing sulphide-rich layers and the resultant fines add to the oxygen stress within the coarser substrates. During summer and early fall, plankton and *Cladophora* fragments are buried in the sandy sediments, providing ideal conditions for bacterial sulphide production.

These results are directly relevant to the success of the Great Lakes lake-trout rehabilitation program. Further studies are required to define the magnitude of potential problems in historic spawning sites and to determine the relative effect of different types of organic materials. (*Sly*)

## SPECIAL PROJECT: ST. CLAIR RIVER POLLUTION INVESTIGATION

An urgent investigation was carried out in response to the discovery of perchloroethylene puddles on the St. Clair River bottom near Sarnia, Ontario. This effort was an adjunct to the Upper Great Lakes Connecting Channels Study (UGLCCS), a large, Canada–U.S. scientific investigation of the Detroit, St. Clair and St. Mary's rivers, which began in 1984. The purpose of the UGLCC study is to determine the environmental impacts of pollution sources on these rivers as the basis for development of specific remedial action plans and a revised surveillance strategy. The project was requested by the International Joint Commission under the 1978 Canada–U.S. Great Lakes Water Quality Agreement as a means to monitor the restoration of degraded areas. NWRI has a prominent role in this study.

The National Water Research Institute together with other Environment Canada agencies, working closely with the Ontario Ministry of Environment, developed an integrated research plan for the St. Clair River to be completed and reported within six weeks. NWRI initiated intensive sediment and water surveys to define the extent of contamination in the study area while DOE and MOE sampled industrial intakes and point source discharges. Samples were also collected from the CNR St. Clair River tunnel and from the tunnel dewatering discharge. Samples were analyzed for volatile organics, chlorinated extractables, polynuclear aromatic hydrocarbons, and chlorophenols; sediments were also analyzed for dioxins. Some samples of sediment and water in the area of concern had already been collected by NWRI prior to the perchloroethylene spill. Analyses of some of these samples were accelerated for inclusion in the report. In addition, 63 cores of bottom sediment plus overlying river water were analyzed to complement earlier sampling by MOE and the University of Windsor. To assist EPS and MOE, NWRI also analyzed about half of the industrial and municipal intake/effluent samples used for source characterization.

Parallel to this contaminant investigation, NWRI was asked to aid MOE and Dow Chemical in the spill cleanup. The principal activity was the use of a video camera, mounted in a remotely controlled (cable) observation vehicle, to monitor bottom conditions during the dredging of sediments by Dow. In addition, scientific advice was provided on hydraulics and chemistry questions related to the puddle, or "blob," material.

The initial major dredging operation was completed on December 23, 1985, and the St. Clair River Pollution Investigation report was released on January 24, 1986. NWRI is responsible for following up certain recommendations of the pollution report, especially with regard to ambient conditions. Additional work is planned under the auspices of the UGLCC Study. In addition, because the puddles reformed after dredging was complete, NWRI assisted MOE with regular inspections. As the puddle sources were identified, measures to prevent loss of material downstream were put in place and revacuuming of the puddle material undertaken.

The Institute contributed greatly to the scientific aspects of the St. Clair River Pollution report, especially with respect to the "perchloroethylene" puddles, ambient sediment and water conditions, and data interpretation to pinpoint contaminant sources.

For example, the comparison by NWRI of Dow effluent data with data on the chemical composition of the puddles in the river, together with certain Dow findings, resulted in the major effort by Dow to track and eliminate the sources of contaminant on the plant site missed in earlier monitoring. The Dow response included major excavations on the plant site,

removal of one complete drain system from service, development of techniques to minimize future seepage to the river, improved monitoring, improved staff awareness of potential environmental hazards in their work, and improved systems for controlling potential spills and contaminated runoff.

Institute research has also pinpointed other sources of perchloroethylene, volatiles and hex tars along the shore of the river and has clearly shown that contaminants released at the Canadian shore show little, if any, transport across the Canada/U.S.A. boundary within the 8- to 10-km stretch of the St. Clair River studied.

Finally, NWRI work on urban runoff and on mass transport of materials down the river, in conjunction with point-source data, has allowed critical judgements to be made on the relative importance of various sources along the river and on the fate of released chemicals. (Rodgers, Lawrence).

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# AQUATIC ECOLOGY DIVISION

The Aquatic Ecology Division is made up of specialists in the fields of limnology and paleolimnology, microbiology, geochemistry, algal and invertebrate ecology, statistics and plant physiology. The Division addresses departmental issues related to environmental degradation and ecosystem health, particularly in the area of nutrient and contaminant control, lake restoration, acidification, management of aquatic weeds, and water quality monitoring (both chemical and biological). The Division is organized in three multidisciplinary sections: Ecological Impact, Great Lakes Rehabilitation, and Nutrient Pathways.

## ECOLOGICAL IMPACT SECTION

The Ecological Impact Section conducted research in the following areas: long-range transport of atmospheric pollutants (LRTAP) with emphasis on geochemical aspects of lake acidification, peatland development and its impact on water quality, paleolimnology, and statistical methodology for water quality interpretation. The LRTAP-related studies dealt with the use of sulphur isotopes as tracers; metal profiles in sediment cores and the release of metals from sediment upon acidification; the characterization of natural acidity; and the use of diatoms as paleolimnological indicators of pH and of *Sphagnum* moss as a bioindicator of atmospheric deposition of metals. The emphasis of the peatland study was the ecological impact of the mining of peatlands on the receiving waters. One paleolimnological study concentrated on the use of proxy climatic data.

**Lake Acidification.** The sources of sulphur pollution and the sulphur reactions resulting in endogenous production of alkalinity in lakes are critical issues in the current debate about acid rains and lake acidification. The variations in the isotopic signature of the sulphur can, in fact, be used to fingerprint its sources and trace its behaviour in softwater lakes. In the Turkey Lakes watershed, pronounced seasonality in the isotopic composition of bulk precipitation was found. The observed depletion in  $^{32}\text{S}$  suggests a significant contribution of biogenic sulphur to the atmospheric sulphur loading in the region. The isotopic composition of the lake water, however, shows no comparable seasonal variation and, on an annual basis, is very close to the mean value for the bulk precipitation. Most of the sulphur stored in the lake sediments is in the reduced form, mostly as organosulphur compounds. The conversion of pollutant sulphate to the reduced forms is believed to be an important process which is generating significant quantities of alkalinity in this watershed. (*Nriagu*)

Lake sediment often maintains a historical record of the recent increase in the flux of toxic metal pollution into the lake basin. Such sedimentary metal reservoirs can become mobilized and released to the water column during lake acidification.

From the  $^{210}\text{Pb}$  dating of the sediments, the historical changes in the accumulation of pollutant metals since 1910 have been determined. Metal depositional rates in lakes in

Nova Scotia are comparable with those of the remote lakes in Ontario (Algonquin Provincial Park) and the Adirondack Mountain lakes (New York).

A simple mass conversion model based on rare earth elements suggests that only 40% to 60% of the pollutant metal flux into lakes is retained by the sediment. The low retention rate can explain the large intra-basin and intra-lake variations in metal content of sediments and has major implications in terms of  $^{210}\text{Pb}$  dating and the use of pollutant metal profiles in the historical monitoring of environmental changes associated with acid rains.

To characterize the chemical interaction between the dissolved and particulate metal species along a pH gradient, pore water (*in situ*) was sampled at close intervals above and below the sediment-water interface from two acid lakes in Kejimikujik National Park, Nova Scotia. Concentrations of selected pollutant metals including Pb, Zn, Fe, Al, nutrients and rare earth elements were measured. Preliminary data for  $\text{SO}_4$ , Al and  $\text{PO}_4\text{-P}$  in the pore water show a close relationship between pH and the nutrient cycles in the lake sediment column. Relationships between trace metal profiles and hydrogen ion pro-

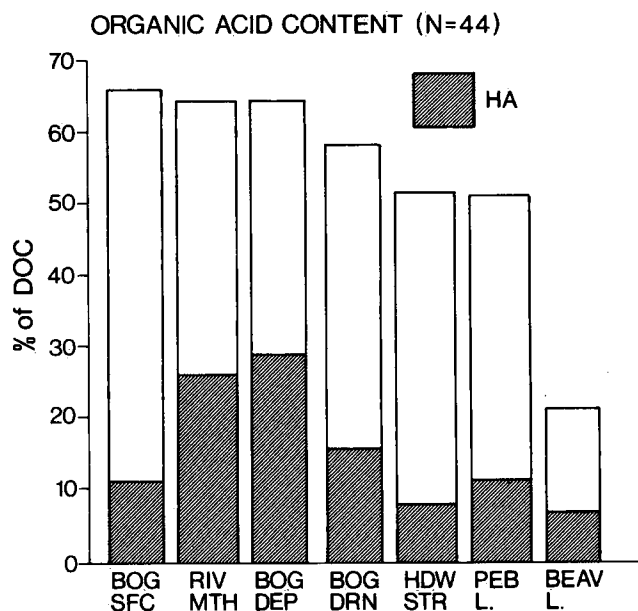


Figure 1. Sum of organic acid fractions from naturally acidic waters. Total height of bars = Fulvic acid (hydrophobic + hydrophilic) + humic acid. BOG SFC - interstitial bog water, 0 - 75 cm; RIV MTH - rivers near their mouths; BOG DEP - interstitial bog water, 1.25 - 2.0 m; BOG DRN - bog drainage creek; HDW STR - headwater streams; PEB L. - Pebblelogitch Lake, coloured; BEAV L. - Beaverskin Lake, clear; HA - humic acid.

duction/consumption are currently being investigated. (Nriagu, Wong)

Natural acidic waters were also studied to understand the effects of anthropogenic acidification of aquatic systems. A comprehensive study of the character of naturally occurring organic acids present in lakes and rivers in southwestern Nova Scotia has been undertaken. Results of seasonal sampling from several sites in Kejimikujik National Park and the Mersey and Clyde rivers indicate that the character of dissolved organic matter (DOM) changes with the annual hydrologic cycle. Most of the DOM can be classified as fulvic acid, the bulk of which consists of hydrophobic acids. Figure 1 shows the relative acidic character of some of our samples grouped by sample type. Near the mouths of rivers, a marked increase in the relative amounts of humic acid is evident. As humic acid is thought to be a diagenetic product of condensation reactions involving fulvic acid (fractions), this may be evidence that changes of character occur along the course of rivers. These changes may in turn affect the metal-binding capacity, acid strength, and liability of the DOM. (Bourbonniere)

**Acidification History.** The spatial variability in diatom frustules as paleoindicators of lake acidification was described for three Precambrian Shield lakes in the Dorset region of southern Ontario.

Three statistical approaches were used to determine the amount of variability in the surface diatom assemblages of the three study lakes: (1) cluster analysis, (2) single and multivariate analysis of variance, and (3) analysis of variance components. The results, mutually collaborative, indicated that all three lakes had a significant amount of heterogeneity in the species composition of their surface diatom assemblages. Hence, one or a small number of random samples cannot adequately represent the "average" diatom flora of a lake. Samples regarded as being most representative of the whole lake occurred in the flat profundal regions located away from the deepest sediments. Factors influencing the species distributions included habitat characteristics, basin morphometry and allochthonous sources of diatoms. (Glooschenko)

Studies on the paleolimnology of acid susceptible lakes have been completed. The diatoms of the Turkey Lakes system show little, if any, impact by atmospheric loading in the area. (Delorme)

**Atmospheric Transport of Pollutants.** Studies have been conducted on the use of *Sphagnum* moss as a biomonitor of the atmospheric deposition of metals. Previous work has concentrated on point sources of metals in Ontario and Quebec, with emphasis on the smelters at Sudbury and Rouyn-Noranda. Also, background levels of metals were determined in remote areas of Ontario. In general, eastern Canadian mosses exhibited high contents of metals except in northern remote areas such as the Hudson Bay Lowland, the lower St. Lawrence River Valley and Labrador. This increased metal level in eastern Canada is undoubtedly related to the high urbanization and industrialization in the area. Sampling has been extended to boreal sites in western Canada from Manitoba to coastal British Columbia, and as far north as Yellowknife, N.W.T. Preliminary results indicate that metals are low and similar in concentration to those in remote, northern areas of eastern Canada. Exceptions included sites located near the smelters at Flin Flon and Thompson, Manitoba. Especially noticeable was lead, which was approximately one-quarter the level found in eastern sites and indicative of lower automobile density in western Canada. This study shows that *Sphagnum*

mosses serve as valuable biomonitors of metal deposition. (Glooschenko)

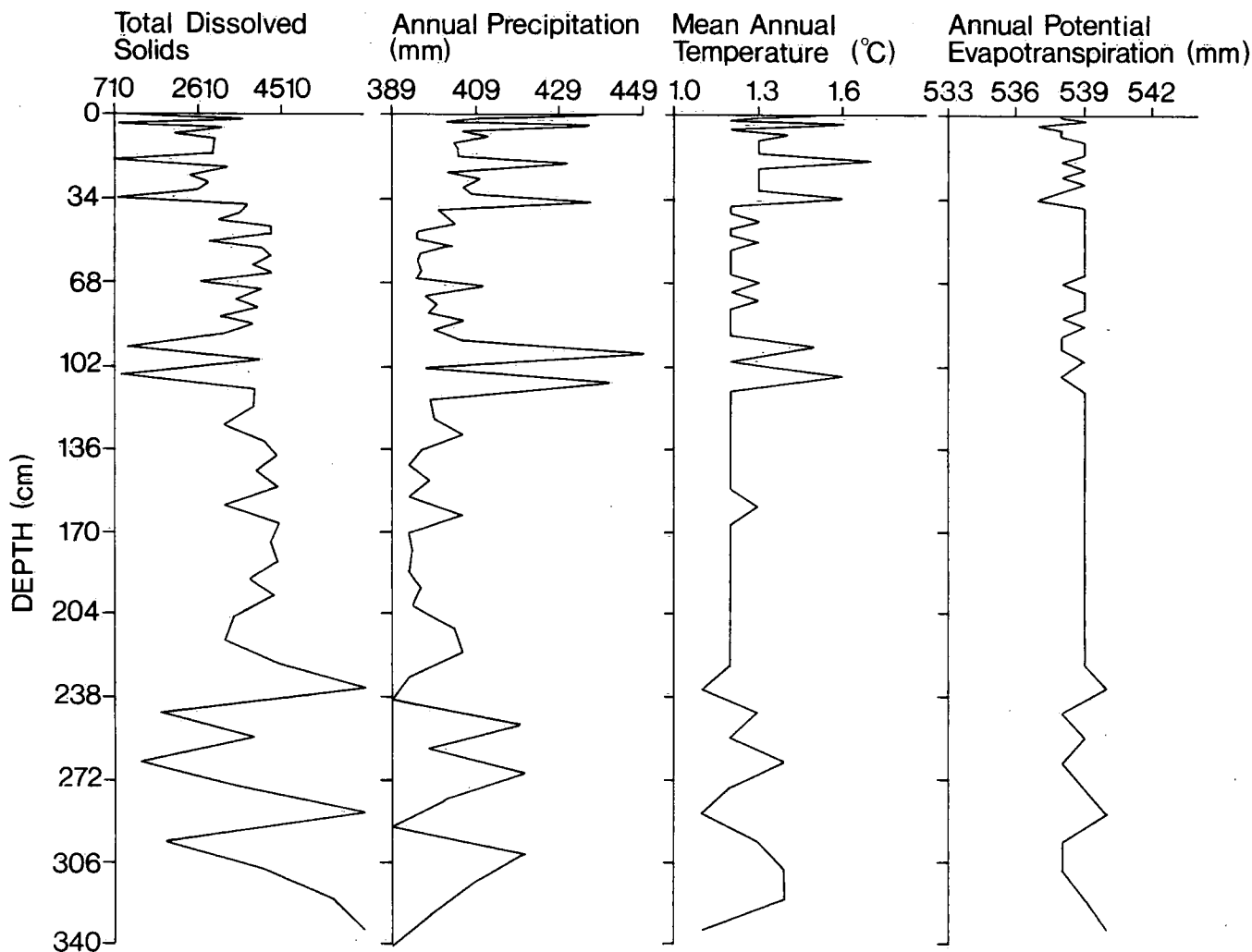
**Peatland Drainage.** The utilization of peatlands for fuel or horticultural purposes is becoming more extensive in Canada. These activities involve the drainage of bogs prior to harvesting. Local modifications of the hydrologic regime may cause significant changes in water quality downstream, which can have an adverse ecological impact. Two sites were chosen to study such effects: Barrington Bog, Nova Scotia, and Sept-Îles, Quebec. At Barrington Bog, seasonal samples were taken from a proposed fuel peat harvesting site, its natural drainage creek, and the estuary into which it flows. At Sept-Îles, samples were obtained from three bogs and their drainages which were at differing stages of development for horticultural peat.

Dissolved organic matter (DOM) that drains from these bogs is predominantly acidic and can be classified as fulvic acid. The DOM in pore waters from deeper layers of the peat contains a greater proportion of humic acid. During periods of low flow (dry summer), the humic acid content of the natural drainage waters is increased relative to wetter periods. This suggests that drainage during drier periods comes from a greater depth in the bogs, exactly what would be expected following ditching. This change in character of the DOM in bog drainage may affect its acid strength, metal-binding capacity, and liability.

Profiles of major and minor elements were determined in pore water samples from a coastal bog (Barrington) and a continental bog (Ontario). Bog waters are depleted in Na, K, Ca and Mg relative to "normal" freshwaters. This fact coupled with their high DOM content means that bog waters are ideally suited for formation of metal-organic complexes. (Bourbonniere, Glooschenko)

**Paleolimnology.** During the past two summers, 12 cores have been collected from small lakes in Saskatchewan and Alberta. The study is supported by the Canadian Climate Program. The goal is the development of climatic proxy data to investigate the relationship between surface water chemistry and climate. The core from Humboldt Lake, Saskatchewan, shows five wet periods in the past 120 years (Fig. 2). This was preceded by three periods when total dissolved solids increased by 88%. (Delorme)

**Statistical Analysis of Water Quality Data.** For many environmental issues, such as lake and river water quality, toxic substances and acid rain, a common element is the need to know whether conditions have changed. The role of statistics is crucial here because there exist a number of sources of variation, and the apparent level of change must be compared with an appropriate level of variability. The results have been of two types: data analysis, and method development and identification. Pollen and diatom concentrations in sediment cores have been analyzed for changes with depth. Toxic contaminant data have been analyzed, and on the basis of three sets of data, it was concluded that an increase in loading of contaminants to the Niagara River is occurring between Fort Erie and Niagara-on-the-Lake. A procedure for grouping multiple depth profiles on the basis of similar form has been developed and this should permit statements about change with depth to be made for homogeneous groups of profiles. To facilitate statistical analyses, a Fortran program for estimating abrupt changes has been made available in a report, and a collaborative project has been undertaken to prepare a data analysis and presentation manual for the Water Quality Branch. (Esterby)



Core 111 Humboldt Lake

Figure 2. Comparative interpretive profiles of total dissolved solids with three climatic parameters for a core from Humboldt Lake, Sask.

## GREAT LAKES REHABILITATION SECTION

The Great Lakes Rehabilitation Section continued work on research projects related to the Canada-U.S. Agreement on Great Lakes Water Quality. Projects included work on internal nutrient loading of lakes, availability of non-point phosphorus loads, oxygen in Lake Erie, trends in Lake Erie water quality, nutrient and contaminant movement in the St. Lawrence River and Lake St. Clair, and the ecology and potential control of nuisance macrophytes.

**Lake Erie.** A compilation of historic water quality data continued as a way of documenting the eutrophication cleanup carried out under the Agreement. The oxygen depletion in the bottom layer of the Central Basin has been of concern for many years and could be expected to improve under present controls but become worse if controls were relaxed. Our research has shown that oxygen levels at the end of the summer depend greatly on the weather. Figure 3 shows that there has not been a clear trend to higher oxygen levels over the last 15 years of nutrient reductions. Surveys conducted using our NWRI profiling equipment revealed widespread low oxygen conditions in 1985 owing to prolonged stratification. On the

other hand, algal populations measured by chlorophyll have decreased by 38% from 1969 to 1978. Transparency, like oxygen, is quite variable, but the offshore waters permit visibility of a Secchi disk to a depth of 7 m, which is more than acceptable for recreational use. The NWRI oxygen/temperature profiler performed well in 1984/85. A calibrating water bath was constructed and engineering developments progressed toward an expanded prototype incorporating turbidity, conductivity and pH sensors. (Dobson, Charlton)

The response of lakes to nutrient loading changes depends on storage and release mechanisms in the sediments. Experiments with sediment traps have shown that large quantities of phosphorus are made available by natural resuspension of sediments. A new effort was made to quantify the internal loading by diffusion of soluble nutrients. Dialysis samplers were installed in the lake bottom and permitted to equilibrate with the pore water before they were removed for chemical analysis. Results (Fig. 4) show that soluble phosphorus (SRP) is regenerated at very high concentrations in the sediments. These regeneration processes may supply significant amounts of phosphorus to the lake water. A statement of the overall importance of internal loading is being prepared. (Rosa)

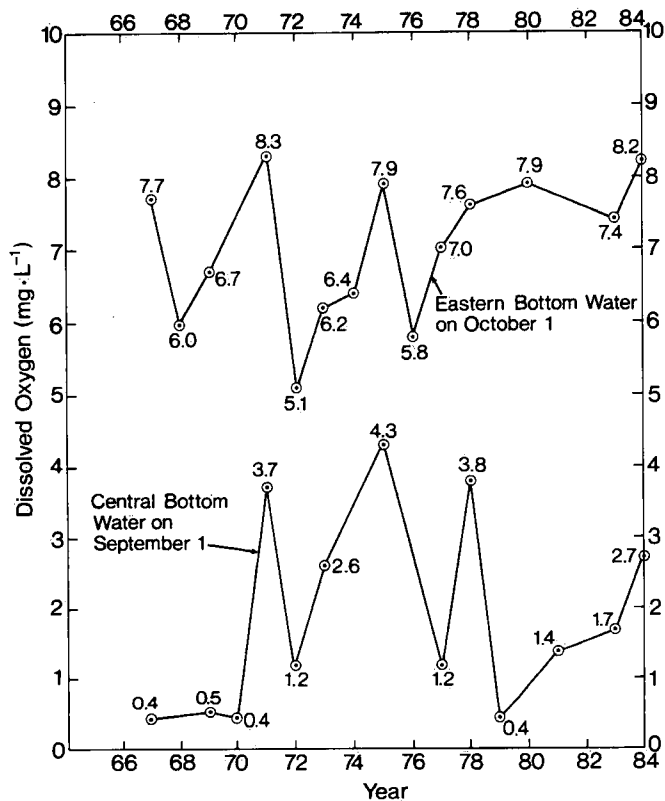


Figure 3. Dissolved oxygen in central and eastern Lake Erie; mean values in the bottom waters in late summer of each year.

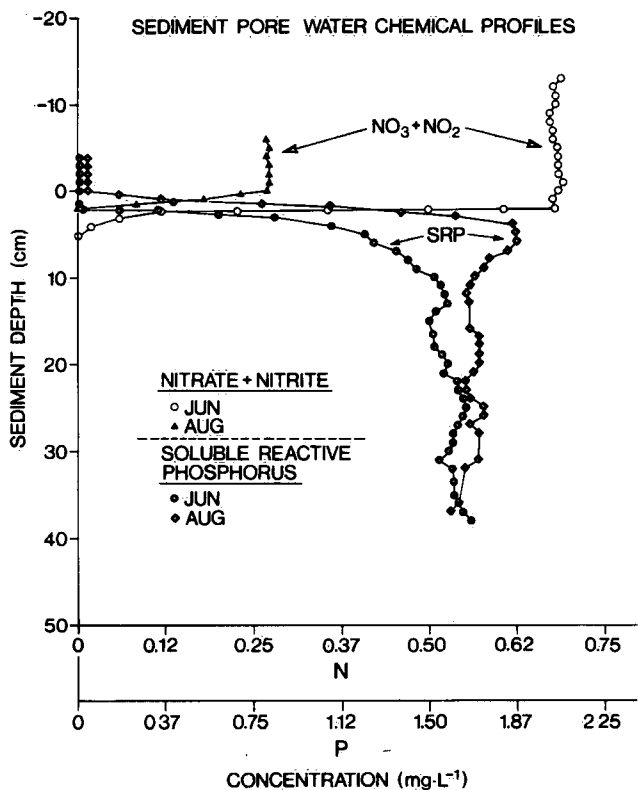


Figure 4. Regeneration of pore water soluble reactive phosphorus (SRP) and hypolimnion nitrogen during stratification in Lake Erie.

**Sediment Chemistry.** Studies of sediment phosphorus forms have shown that approximately 50% of the non-apatite phosphorus (NAIP) can potentially be regenerated. Over the last five years, the oxidation status of Lake Erie sediments has improved. This suggests that while regeneration due to anoxia should become less frequent, an anoxic situation would result in massive release. Lake Ontario sediments in the Kingston Basin were more reduced than Lake Erie sediments. The binding capacity of Lake Ontario sediments is about 3500 t·yr<sup>-1</sup>, which is consistent with target phosphorus loads. Studies of iron-sulphur compounds in lakes of British Columbia and Alberta have revealed that in Figure Eight Lake, the use of copper-based algicides resulted in the disruption of normal sulphate-reducing bacteria in the bottom sediments. This changed iron-sulphur-phosphorus relationships in the water. (Manning)

**Lake St. Clair.** As part of the Canada/Ontario/U.S. Upper Great Lakes Connecting Channels Study, a sediment trap study and water quality surveys were conducted in Lake St. Clair in 1985. The sediment traps collected samples of contaminated suspended sediments. The rate of accumulation in the traps was much higher than in deep lakes, which means that most of the particulate material in the water is derived from resuspended sediments. The study was coordinated with members of the Aquatic Physics and Systems Division, Hydraulics Division and Environmental Contaminants Division. Analyses of contaminants in the samples will be related to industrial effluents in the St. Clair River. (Charlton, Dobson)

**St. Lawrence River.** In cooperation with the Environmental Contaminants Division and Inland Waters Directorate—Quebec Region, a survey of benthic invertebrates was conducted in the St. Lawrence River between Cornwall and Trois-Rivières. A sparse but diverse fauna was found at most sites. A collection of large clams was returned to the laboratory for contaminants analysis. The St. Lawrence carries a considerable suspended sediment load and this was sampled using sediment traps. Despite the currents, the traps caught enough sediment for analyses of moving contaminants. The sediment traps proved to be an efficient way of collecting integrated suspended sediment samples. (Charlton)

**Macrophytes.** The invasion of lakes by Eurasian watermilfoil has created aesthetic damage and reduced recreation opportunities. The ecologically sound control technology of harvesting has not achieved long-term control. Short-term harvesting experiments have demonstrated control extending only to the year after harvesting; long-term experiments were necessary to determine whether the efficacy of harvesting could be enhanced. From 1981 to 1984, we conducted a double harvest each year in a 2-ha plot in Buckhorn Lake, Ontario. A reduction in biomass was achieved (Fig. 5). The areal density of milfoil plants decreased and individual plants were smaller. Effects on tissue chemistry and sediment chemistry were observed. The results of these experiments were interpreted and included in a report, the subject of which was how to maximize the control effect of harvesting.

The nuisance alga, *Cladophora*, grows in rocky shoreline areas of Lakes Ontario, Erie and Huron. Storm events can result in aesthetically unpleasant accumulations on beaches. *Cladophora* was sampled in Lake Ontario during 1972 and again in 1982/83 to determine whether the phosphorus control program had resulted in a reduction of *Cladophora* productivity. The lakewide average biomass had decreased by 58% and the lakewide average tissue phosphorus had decreased by 59%. The tissue phosphorus concentrations did not limit growth in 1972 but were low enough to limit growth in 1982/83.

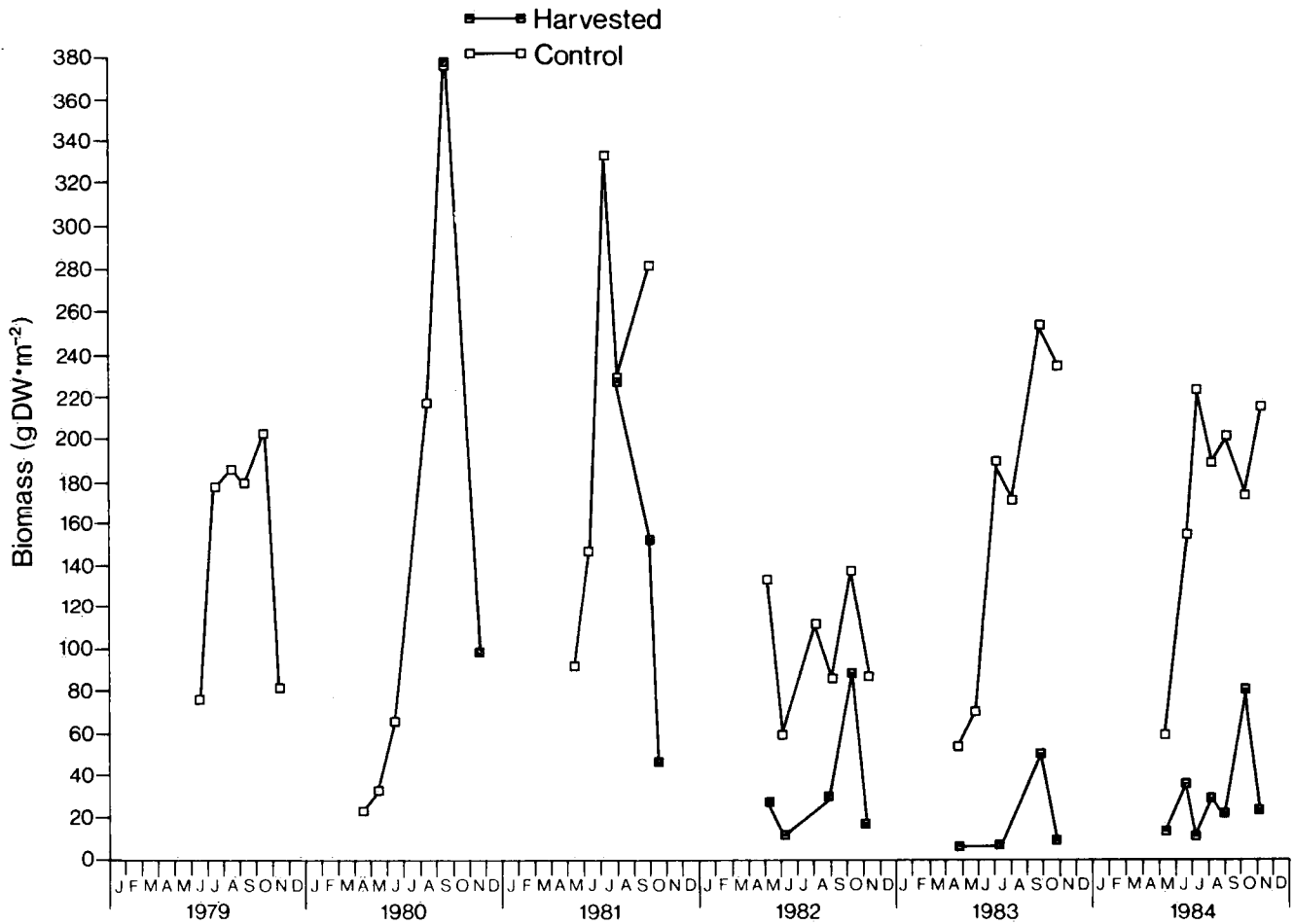


Figure 5. The effect of harvesting on milfoil biomass. DW – dry weight.

Numerous presentations were made to citizens' groups concerned with the impact of macrophytes on their usage of water resources. Predicted growth rates are now also limited by tissue phosphorus (Fig. 6). (Painter)

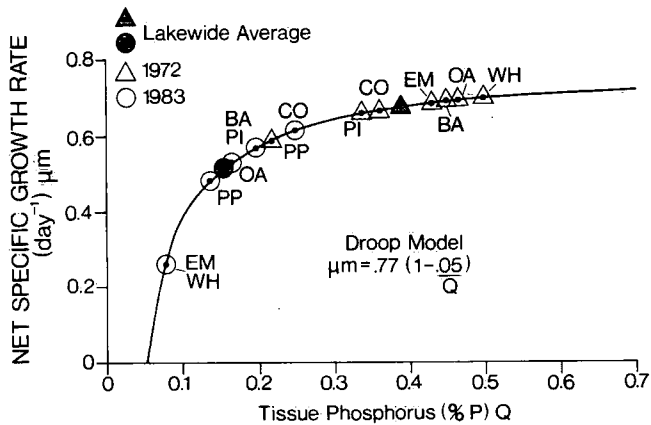


Figure 6. 1972 and 1983 tissue phosphorus in relation to Auer and Canale nutrient-growth model. For symbols see Painter and Kamaitis (1985) in list of publications at end of section.

### NUTRIENT PATHWAYS SECTION

The Nutrient Pathways Section continued to research lake restoration techniques, taste and odour problems in municipal water supplies, the effect of toxic substances and nutrients on biological processes (i.e., algal and bacterial productivity and metabolic activities), and the functional roles of selected organic substances found in lake waters.

**Microbial Ecology.** The effect of certain heavy metals on the metabolic activities (<sup>3</sup>H-thymidine incorporation into DNA) of the natural bacterial population found in Hamilton Harbour was tested. The organisms were found to be very sensitive to mercury (EC<sub>50</sub> = <0.001 ppm) and copper (EC<sub>50</sub> = 0.027 ppm). The organisms were affected to a lesser degree with aluminum and cadmium (EC<sub>50</sub>'s of 0.29 and 1.40 ppm, respectively). The incorporation of thymidine was not affected by the presence of 50 ppm atrazine. A DNA purification procedure was modified and used to improve the accuracy of bacterial productivity determinations. (Burnison)

One of the highlights in this field was the International Symposium for Aquatic Microbial Ecology held at the Canada Centre for Inland Waters on May 13–15, 1985. Thirty-five speakers from nine countries presented their current research interests. (Burnison, Rao—Analytical Methods Division)

**Natural Organics.** Colloidal fibrils in lake water were investigated for their capacity to form organic coatings. Suspended

organic particles (>5- $\mu\text{m}$  diameter) usually displayed an external coating of fibrils. In the interior of complex mixed particles (whose size was the consequence of the aggregation of smaller particles), fibrils were identified as the adhesive material between smaller particles. Thus fibrils appear to modulate sedimentation of smaller particles by two mechanisms: (1) as a surface "lubricant" to affect drag reduction and (2) as a natural "glue" to facilitate flocculation. From this information one can speculate that many particle-contaminant interactions cannot be modelled properly unless fibril modulation of the interactions is considered. In a joint Aquatic Ecology Division—University of Geneva study, a technique was devised to isolate an undegraded fulvic acid fraction from lake water. Using purified isolates of the native fulvic acid, the aggregation properties (loss from solution onto surfaces) of this metal-complexing substance were characterized. Using physico-chemical techniques, colloid formation was described in terms of changes in molecular weight, degree of hydration and fulvic-fulvic acid interactions. Surface-facilitated dehydration was revealed as the mechanism for the formation of organic colloidal coatings from fulvic acids in the dissolved state. The improved understanding of these mechanisms may permit new insight into metal speciation changes in aquatic ecosystems and into design schemes for fractionating lake water by ultrafiltration. (Leppard)

In cooperation with the Water Quality Branch, Western and Northern Region, and the city of Regina, Saskatchewan, sampling and analysis for taste and odour compounds were carried out on the local water supply during the summer of 1984. The results were incorporated into a larger study commissioned by the cities of Regina and Moose Jaw prior to commencement of granulated activated carbon filtration at the Buffalo Pound Water Treatment Plant (BPWTP) for taste and odour removal. The city of Regina was also interested in spatial variations of taste and odour compounds throughout the city to determine whether they could be produced in the distribution system. Quantitative analyses for geosmin and 2-methylisoborneol were carried out on samples from the distribution system and on the raw and finished water from the BPWTP. Geosmin was detected in most samples, while 2-methylisoborneol was absent. Maximum concentrations occurred in late August (Fig. 7). The higher concentrations observed in the finished water may be explained by (1) the analytical method giving lower recovery of geosmin from raw water sam-

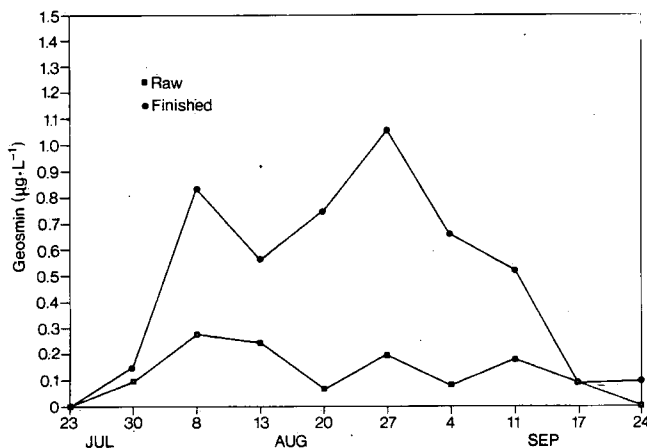


Figure 7. Geosmin concentration in raw and finished water from Buffalo Pound Lake, Sask., 1984.

ples or (2) geosmin being released from algal cells which break open during the water treatment process. Current evidence supports this latter possibility. (Brownlee)

**Lake Restoration.** Advice on lake restoration techniques has been given to various provincial agencies for a number of lakes. Understanding the cycling of iron in lakes is very critical in the selection of the proper method of restoration. Studies on Frisken and Chain lakes, British Columbia, have shown that both lakes have sediments rich in pyrite. The formation of pyrite is thought to contribute to the establishment of iron limitation common in lakes on the Thompson Plateau, B.C. The lime treatments of Frisken Lake in 1983 and 1984 have had a long-term effect on improving water clarity. Figure 8 shows that phosphorus concentrations were lower than pre-treatment values and similar to data from the summer the lake was treated. Chlorophyll concentrations were lower than pre-treatment but not as low as the summer the lake was treated (blue-green algal blooms were blocked throughout the summer of 1984). Lime treatment also resulted in a 50% reduction in the dissolved organic carbon (DOC) in the lake water. The removal of the DOC resulted in an enhanced efficiency of lime treatment. In Figure Eight Lake, Alberta, which had previously been treated with copper sulphate, analyses indicated that pyrite formation had been restricted and bacterial assimilation of acetate suppressed in the lake sediments. Copper toxicity is thought to be the cause of the amphipod collapse and chironomid avoidance of the surface sediments. (Murphy)

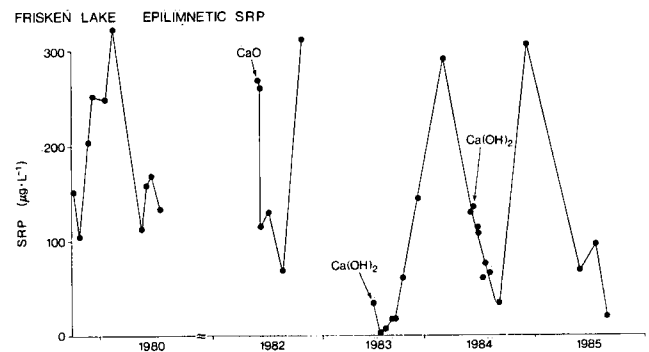


Figure 8. Epilimnetic soluble reactive phosphorus (SRP) concentration in Frisken Lake, B.C.

**Nutrient Limitation.** A joint Aquatic Ecology Division—Aquatic Physics and Systems Division collaboration on Lake Ontario integrated the influence of wind and temperature on currents and stratification patterns with nutrient studies (Water Quality Branch—Ontario Region, and the Aquatic Ecology Division). Seasonal patterns for nutrient changes were observed across a transect crossing the lake from Port Hope. Physiological indicators for phosphate deficiency were compared to determine the duration and degree of phosphate limitation of phytoplankton growth. Rates of regeneration of nutrients by zooplankton grazing were calculated and the size spectrum of the plankton related to the degree of nutrient deficiency. The rates of recycling of phosphorus within the trophogenic zone were calculated and a detailed flow diagram was prepared. A special issue of the *Canadian Journal of Fisheries and Aquatic Sciences* (in preparation) will contain articles relating to Lake Ontario nutrient assessment. (Lean)

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 Metals

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# AQUATIC PHYSICS AND SYSTEMS DIVISION

The Aquatic Physics and Systems Division conducts integrated and multidisciplinary research programs in general areas of physical limnology, environmental optics and remote sensing, environmental modelling and simulation and acidification of aquatic systems. The Division contributes to management of Canadian freshwater resources on two levels. First, it contributes to the fundamental understanding of physical processes and to the elucidation of interactions between components of aquatic systems. Secondly, through the application of models, the Division achieves an appropriate level of synthesis for identification and assessment of water management alternatives in complex aquatic systems. The Division provides support for Data Management, archiving and computer programming assistance for NWRI research programs and the WHO Collaborating Centre. These responsibilities are shared among four sections: Physical Limnology, Environmental Simulation, Environmental Optics, and Data Management.

## PHYSICAL LIMNOLOGY SECTION

The goals of the Physical Limnology program are to describe and quantify physical processes such as mean transport and turbulent mixing to assist the interpretation of biological and chemical experiments, surveillance measurements, and to provide input to water quality concerns involving the transport and dilution of contaminants effluents. To achieve these goals the Section collects field observations, analyzes and interprets data, and synthesizes results through theoretical and modelling studies. Most of the Section's work supports multidisciplinary NWRI programs. Other clients and collaborators are provincial agencies (Ontario Ministry of the Environment, Ontario Ministry of Natural Resources, Ontario Hydro), municipal authorities and consulting engineers.

**Lake Erie Studies.** Although the synthesis report of the 1979 and 1980 Lake Erie experiments has been delayed, and will now be a special issue of the *Journal of Great Lakes Research* in early 1986, further scientific progress has been made. A strong coupling between transient thermal structure and near inertial period currents has been demonstrated. This has been confirmed by analysis of data from the prototype profiling system GVAPS. A successful finite-element storm surge model, a first of its kind, has been developed and tested on the Lake Erie data set that includes data from deep water tide gauges. (Boyce, Hamblin)

**Lake Ontario Studies.** Analysis of the 1982-83 circulation experiment in Lake Ontario culminated in a major report by Simons and Schertzer and a series of papers. The persistent flow eastward along the south shore of the lake and the countercirculating westward flow mid-lake can be related to the distribution of contaminants in the sediments of Lake Ontario.

Concern with respect to the juxtaposition of outfalls and drinking water intakes along the densely populated and heavily industrialized north shore of Lake Ontario prompted a multidisciplinary field program in 1984. The physical study, with its

array of thermistor strings extending from Hamilton to Cobourg, emphasized the alongshore development of flow episodes where previous studies had emphasized the cross-sectional structure of the coastal boundary layer. Alongshore current speeds often exceed  $20 \text{ km-day}^{-1}$ , and episodes between current reversals last from five to ten days; total alongshore displacement of water may exceed 100 km. (Simons)

**Niagara River Studies.** Field experiments continued in the Niagara River area through the 1984 and 1985 field season. Of particular note are the long-term trajectories obtained by satellite-tracked drifters, an example of which is shown in Figure 9. The satellite drifter program has been operated in close participation with the Great Lakes Environmental Research Laboratory (U.S. National Oceanic and Atmospheric Administration [NOAA]) in Ann Arbor, Michigan. These studies were carried out in support of the toxic contaminants surveys undertaken by the Environmental Contaminants Division. (Murthy)

**Lake St. Clair Experiments.** The physical program was undertaken in support of the Upper Great Lakes Connecting Channels Study and focussed on Lake St. Clair. It was coordinated with programs developed at the U.S. EPA laboratory in Grosse Ile and at the NOAA laboratory in Ann Arbor. Two goals were addressed. The first was to provide information on the distribution of horizontal currents in the lake to verify a numerical circulation model. The second was to study the transport of suspended material through the lake, recognizing the importance of this material as a compartment for organic contaminants. The bulk of the current meter information was collected with Neil Brown vector averaging acoustic current meters (model SACM). This is the first time we have deployed these instruments and we have been encouraged by the excellent return of data (>90%). A mid-lake tower was installed and instrumented to serve as the focal point of an intensive sediment resuspension experiment conducted during September and October 1985. (Bull)

**Yukon River Headwater Lakes Study.** A series of under-ice temperature profiles in the outflow regions of several Yukon River headwater lakes resulted in more detailed knowledge of the outflow dynamics of lakes and an estimate of the heat transfer coefficient between ice and water. This information is essential to the modelling of ice-covered lakes. (Hamblin)

## ENVIRONMENTAL SIMULATION SECTION

The main objective of the Environmental 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 that 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

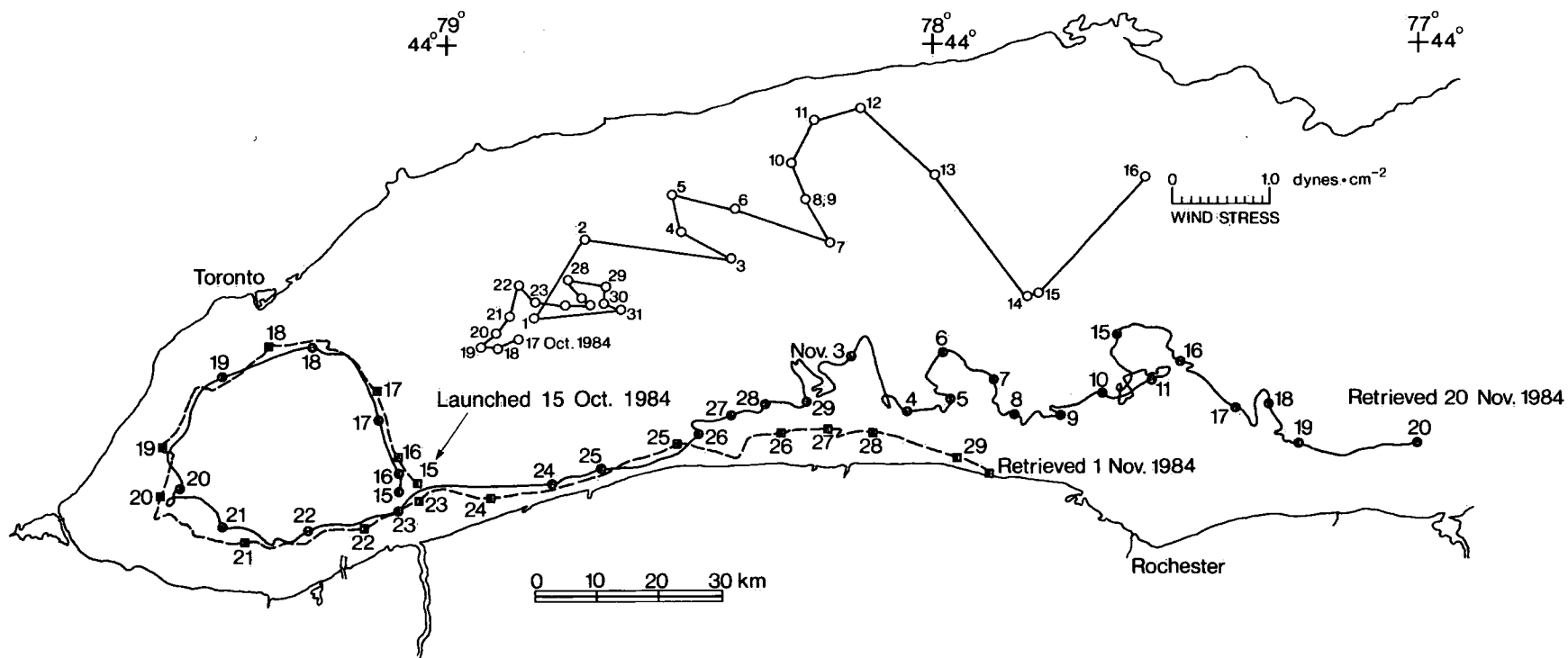


Figure 9. Lagrangian drifter experiment to track Niagara River plume, October 15 to November 20, 1984.

environmental management problems; to provide feedback to ongoing research and monitoring programs on the gaps of knowledge; and to maintain a strong focus of systems modelling expertise in the Aquatic Physics and Systems Division and consolidate modelling efforts by close collaboration with other divisions.

**St. Clair River Contaminant Model.** The St. Clair River system connects Lake Huron with Lake Erie. A large number of industries are located along its shores to utilize the large amount of water flowing through the system (about 6000 m<sup>3</sup>·s<sup>-1</sup>). Toxic contaminants in the river water and in the bottom sediments are the result of the industrial development along the river and lake shores. To assess the hazard or potential hazard of the chemicals, mathematical modelling and simulation techniques can be used to quantify and predict the concentrations of the chemicals in various parts of the system, such as Lake St. Clair. The computer model integrates information on the chemical properties with the environmental properties to produce reliable predictions of the fate of the toxic contaminants found in the system. The mathematical model TOXFATE, previously used to predict the fate of toxic contaminants entering Lake Ontario from the Niagara River, is being adapted to simulate the environmental conditions in the St. Clair River system. TOXFATE is being coupled with a hydrodynamic model of Lake St. Clair to predict the spatial distribution pattern of toxic contaminants and nutrients in the water and in the bottom sediments. Results of the simulations are displayed using personal computers such as the Commodore 64 or the IBM PC; Figure 10 shows an example of such an interactive display. (Halfon, Simons)

**Niagara River Contaminant Loading.** There are two hypotheses regarding the pollution concentration distribution along the Niagara River. One is that the concentration of pollutants is the same throughout the length of the river. The other is that the concentration is generally higher in the downstream portion. Statistical methods and the complete-linkage clustering analysis have been used to test these hypotheses. This method has been applied to the observed data of chlorinated organics and heavy metals collected from large-volume water samples and in suspended sediments at five stations (Fig. 11): Fort Erie (FE), Chippawa (C), Wheatfield (W), Queenston (Q) and Niagara-on-the-Lake (NOTL), with one or two samples per station once during May, July and October–November of 1981, respectively. The general results show that concentrations at NOTL and Q are similar to each other but are different from the concentrations at other locations. The locations FE, C and W always form a group.

More specifically, it is found that out of the 30 chemicals, 16 show a significant increase in concentration in the downstream direction, 8 do not show such a trend, and the remaining 6 are below detection level. (El-Shaarawi)

**Watershed Acidification Model.** A watershed acidification model has been developed to investigate the impact of acidic deposition on Canadian watersheds. The model considers the sulphate ions as mobile entities that follow the complicated water pathways through the snowpack, the surface soil layers, ground water, streams and lakes. Depending on the duration and the nature of the soil and water contact, these ions can cause major disruptions to the chemical balances in the aquatic regimes.

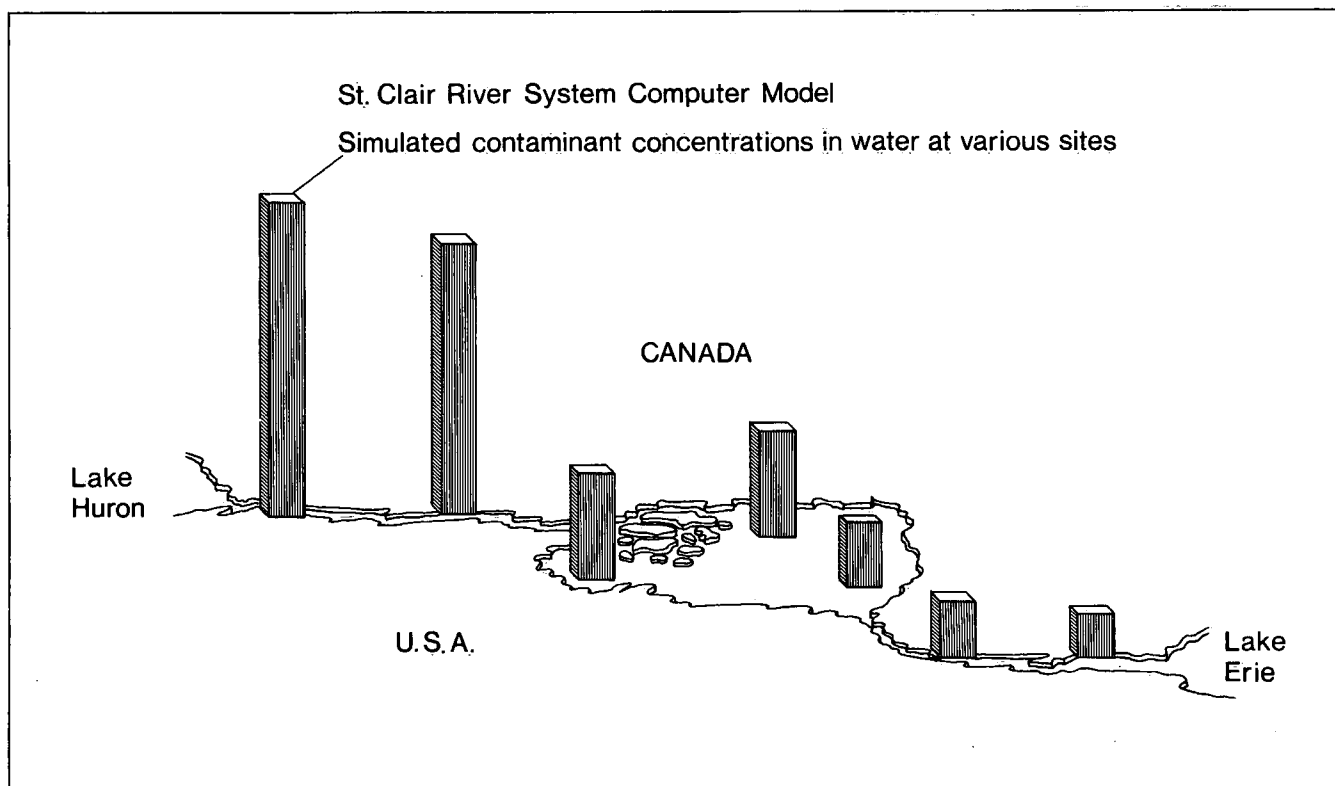


Figure 10. Example of interactive display originated with an IBM PC with the model TOXFATE. The St. Clair River system is located between Lakes Huron and Erie. Sarnia and Detroit are cities located on its shores.

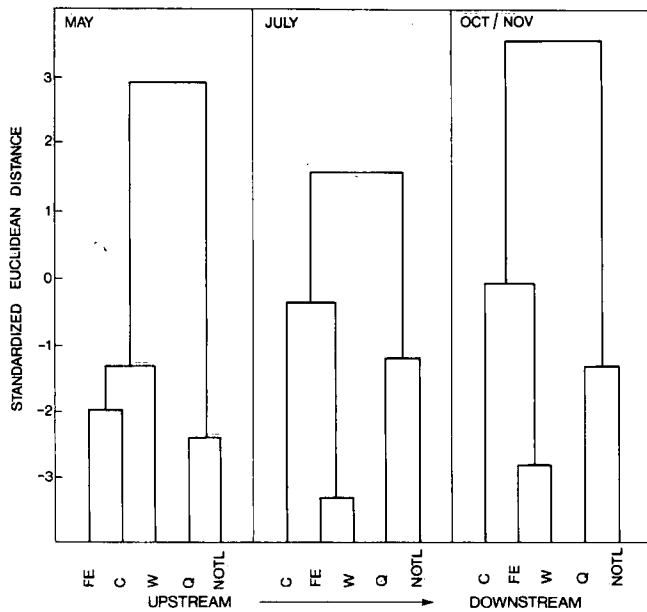


Figure 11. Complete linkage clustering using the standardized Euclidean distance for Water Quality Branch aqueous phase data.

Although most of the variations are due to hydrological events, the depression of pH, which signifies an increase in acidity, during the early springtime, is particularly related to snowmelt episodes. Through a series of model calibration and verification with data from several Canadian watersheds in collaboration with other agencies, we are able to test the general applicability of this model as a research tool for examining detailed impacts of acidic deposition on aquatic regimes. (Lam, Bobba)

**Excess Sulphate Yields of Rivers in Nova Scotia and Newfoundland.** River yields of excess sulphate are often calculated as mean discharge-weighted excess sulphate times mean annual runoff, and the reliability of this method of calculation increases with an increase in the number of samples available. For this reason, data are usually grouped over several years. The data are plotted on Figure 12 for 12 river stations in Nova Scotia; the plot shows a marked decrease, by nearly half, in the river yields of excess sulphate between 1971 and 1973 and 1982 and 1984. A similar comparison (not shown) was made for eight rivers in Newfoundland, and a similar marked decrease in excess sulphate yields was observed.

If the amount of sulphate carried by these rivers has decreased by nearly half, and there is no great change in the cation denudation rates (CDR) of these rivers, then it is reasonable to expect that the mean pH values of these rivers will have increased. It has been found that this relationship holds for the rivers with softer water in Newfoundland. The rivers with the softest water show the largest increases in mean discharge-weighted pH, whereas the pH changes of the two rivers with the hardest water are statistically insignificant.

The case is not so simple for the soft water rivers of Nova Scotia, the pHs of which are dominated to a much greater extent by the presence of organic acids than those in Newfoundland. In Nova Scotia, the greatest increases in pH are seen for the slightly harder river waters with somewhat lower mean DOC. This shows that for rivers in whose watersheds the natural acidification processes have not proceeded too far, a

decrease in sulphate deposition will mean an improvement in river water quality, but not enough is yet known about the natural acidification process in the very soft water river watersheds. Some of these results are used for improvement of the CDR model developed in the Environmental Simulation Section. (Thompson, Fraser)

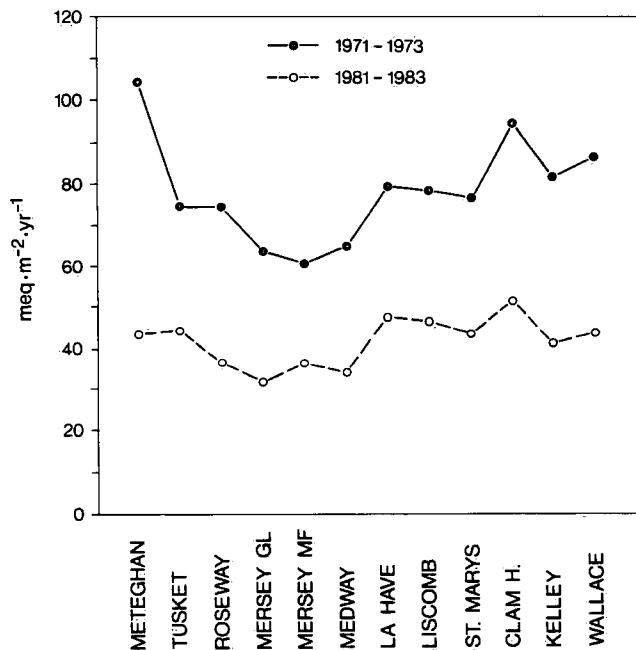


Figure 12. Excess sulphate yields ( $\text{meq}\cdot\text{m}^{-2}\cdot\text{yr}^{-1}$ ) of Nova Scotia rivers. GL - George Lake; MF - Mill Falls; H - Harbour.

**Climate Models.** Contributions to the Canada Climate Program have been oriented toward improved understanding and computer simulation of (a) the seasonal and annual energy balance at the air-water interface and (b) the seasonal variations of thermal structure and stratification of lakes and the upper layers of the ocean.

Goals in the first year of study included improving the physical data base and updating numerical models for computing long-term variations of the energy balance at the air-water interface for Lake Erie and Lake Ontario. Climatological data bases for synoptic observations have been compiled from 1950 to 1983 for both lakes. Numerical model development, climatological analyses of the data, and derivation of the long-term energy balance for each lake have been completed. Figure 13 shows verification results for the major components of the Lake Ontario energy balance, i.e., net radiation ( $Q^*$ ), latent heat flux (QE), conductive heat flux (QH), the surface heat flux (QT) and evaporation indicating high reliability of the model output. (Simons, Schertzer)

**Hydrodynamic Model.** For coastal currents, a combination of spectral techniques, hydrodynamic models and empirical procedures proved conclusively that observed current fluctuations cannot be explained by either a balance of local wind and bottom stress or by free topographic waves but that both processes contribute equally. Semi-empirical transfer function models based on the concept of resonant topographic wave

## ENVIRONMENTAL OPTICS SECTION

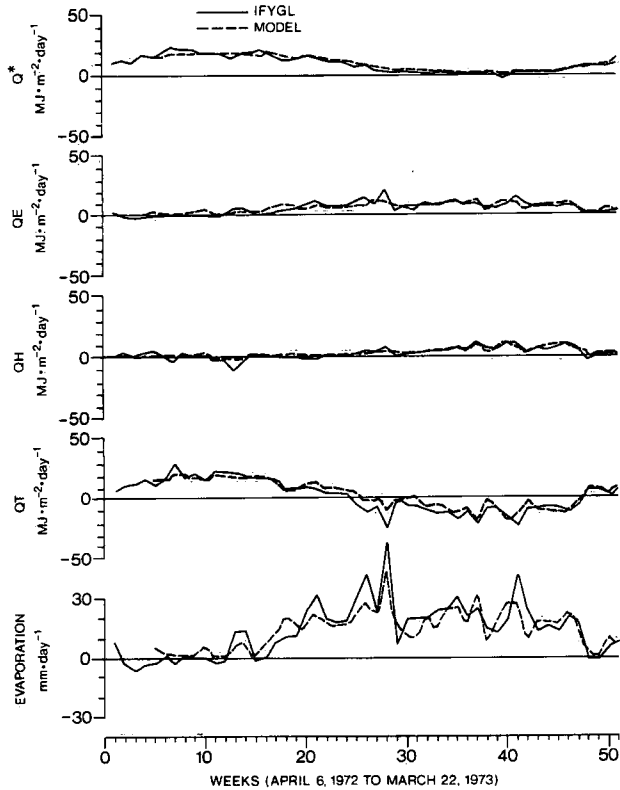


Figure 13. Verification of Lake Ontario energy balance model. IFYGL - International Field Year Great Lakes.

response to wind forcing in the presence of bottom friction were developed and found to explain 70% to 80% of the observed coastal current variations.

With respect to open lake circulation, it was shown that none of the models available in the pertinent literature was suitable to estimate seasonal-mean circulations. It was found that the mean circulation observed during the 1982/83 Lake Ontario field study could only be reproduced by high-resolution non-linear models. To evaluate whether this result was applicable in general, circulations were computed for 12 years of climatological winds. For all years, the circulations obtained from the new model deviated from those computed by conventional models in the same manner. (Simons)

**Technology Transfer.** The Environmental Simulation Section continued to provide mathematical models to government and other users. For example, at the request of PAHO (Pan American Health Organization), a study was undertaken to evaluate the effects of a planned outflow diversion from Lake Chapala in Mexico to improve the water supply to the city of Guadalajara. An operational model for predicting the movement and dispersion of accidental radioactive spills along the north shore of Lake Ontario was developed for the Ontario Ministry of the Environment. The model was based on many years of data collection and modelling studies on Lake Ontario and then adapted for use on microcomputers.

In response to continuing requests for the use of these models and assistance in their application, three of the most frequently requested models were documented in great detail. These models are (1) a single-layer circulation/storm surge model, (2) a multi-level model for computing circulations and temperature changes, and (3) a pollutant transport model. (Simons, Lam)

The principal goal of the Environmental Optics Section is to conduct and apply directly both experimental and theoretical research related to the optical properties of the aquatic environment. The techniques of spectro-optical physics and radiative transfer theory are utilized, in conjunction with directly acquired *in situ* optical data or remotely acquired airborne and/or satellite multispectral optical data, to develop interpretive and predictive optical models and methodologies, and subsequently to apply these models and methodologies to water resource issues and concerns.

The optical physics activity comprises a basic long-term research program together with short-term studies which attempt to comply with specific problems as occasions and circumstances dictate. During the past year, the Section's effort was largely devoted to the Great Lakes region of central Canada. Specific activities included the following:

- (a) A study of pertinent available LANDSAT imagery over the Lake Huron/Lake St. Clair/Lake Erie sediment transport system. The separation of these transport avenues into well-defined independent zones that retain their independent identities over substantial distances throughout the interconnecting channels is clearly evident. Further analyses of these transport phenomena are planned for the coming year. (Bukata)
- (b) Generation of an optical atlas describing the Great Lakes in terms of *in situ* optical data collected by the Section during the time interval 1973-1983. Included in this atlas are such optical features and parameters as surface transmission contours; summer photic depths; transmission transects; relationships among beam attenuation coefficients, irradiance attenuation coefficients, and Secchi disk depths; sighting range; and photosynthetic available radiation among others. The atlas illustrates these optical features in graphical, pictorial, and/or tabular form and intercompares these features for Lakes Erie, Ontario, Superior and Huron/Georgian Bay. It is available for distribution as an NWRI manuscript. (Bukata, Jerome, Bruton)
- (c) Collection of remotely sensed data over Lake St. Clair utilizing the recently developed Shipborne Reflectance Radiometer System (SRRS) and the development of computer methodology to utilize these data to estimate suspended mineral concentrations. (Jerome, Bruton)
- (d) A study of Great Lakes coastal wetland regions utilizing airborne data collected over such areas as Georgian Bay/North Channel and Lake St. Clair. These data were obtained during periods of both high and low water levels, and this project, which is being performed in collaboration with the Great Lakes Fisheries Research Board, attempts to relate the change in areal extent of marshlands to variations in water level. (Bruton, Bukata, Jerome)

## DATA MANAGEMENT SECTION

The Data Management Section provides data management support and EDP software development services to the organizations located at the Canada Centre for Inland Waters. The data archives of NWRI are maintained and managed for the support of the NWRI research and Inland Waters Directorate, Ontario Region operational programs. Consulting services are maintained to provide advice and guidance in such areas as data base usage, software problems, the use of software packages, microcomputer hardware/software selection, and the efficient use of the in-house CYBER 171 mainframe computer.

The Section provides the operational support for the United Nations Global Environmental Monitoring System (GEMS) data base and the Great Lakes Surveillance data base (STAR).

**Major Activities.** Software system design and development support was provided for 53 different studies of the various organizations located at CCIW.

A Treasury Board submission for new mainframe computer facilities at CCIW was done in conjunction with the Computer Services Section and the Systems and Informatics Directorate in Ottawa. This submission included program-related computer requirements, conversion and training requirements along with a "make versus buy" analysis of the various alternatives available to NWRI.

The automated laboratory data acquisition system (AWQUALABS) was completed and the development team disbanded. A total of 109 computer programs were written for this system to provide for data acquisition, analysis and laboratory management functions. The operational support for the system now rests with the National Water Quality Laboratory.

A new release of the System 2000 data base software was installed on the CYBER 171. All data base programs were recompiled to operate under the new version. This new version provides additional features which aid in the development and/or enhancement of the various data base systems that are operational on the CYBER.

Three issues of the Data Management and Computer Services newsletter (UPDATA) were distributed. The distribution of the newsletter is for CYBER users, micro users, study leaders, management personnel and other interested staff. The purposes of UPDATA are to provide a vehicle to exchange information, to improve the awareness of various computer-related topics, and to provide for increased productivity in the use of the CYBER 171. Some topics covered in the newsletter are new general-purpose software, new developments in communications, problems encountered by users, featured applications, hardware, microcomputer links, word processing, and a novice user corner.

Communication links between the CYBER and the Wang OIS system and the CYBER and the MICOM 2001 system were established to aid the integration of text files for document production. In conjunction with the Environmental Protection Service, facilities were established to translate documents from one word processing format to another. Currently, Wordstar to MICOM and MICOM to Wang translations are possible. In future, additional software to translate other formats will be obtained as the need arises.

Data archiving support was provided for the Great Lakes Surveillance, Solar Radiation, Meteorological, GEMS and LRTAP programs. This support consisted of data entry, data documentation, data base updating, software enhancement, data archiving and data retrieval functions.

Input was provided to an international review meeting of the GEMS/WATER program. As a result of the review, a "GEMS/WATER Data Evaluation Report" was produced by the World Health Organization (WHO) in Geneva. The review has led to the redesign of the data input form to reflect more accurately the chemical parameters required for each type of water (lake, river and ground water) sampled. Other changes to the program have been identified and will take place over the next few years. A complete set of data listings and statistical summaries for the 1982-1984 data was produced and forwarded to WHO, Geneva, for distribution to the various regional centres and countries (60) involved in the program. The 1979 to 1981 data were microfiched and distributed to all participants in the program.

All Applied Physics and Systems Division staff publications have been catalogued and the requirements for reprints are being met as they arise.

Introductory and advanced CYBER computer courses as well as a course on the CALCOMP plotter were given to approximately 60 users.

A procurement data base system was developed for the Staff Services Division. This system provides for the partial automation of the procurement function, along with the ability to produce reports to aid the management of the procurement process.

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## ENVIRONMENTAL CONTAMINANTS DIVISION

The Environmental Contaminants Division investigates the pathways, fate and effects of five groupings of contaminants; organic chemicals, toxic metals, organometallics, radionuclides, and ions associated with acid rain. These investigations are conducted both the the field and in the laboratory. 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 that can be implemented in Canada. These 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 primarily at specified polluted aquatic ecosystems but also in the laboratory. Projects include studies in large and small river-lake systems. Atmospheric input of organic contaminants to the aquatic environment is also studied.

**Transport of Persistent Toxic Organic Chemicals in the Niagara River-Lake Ontario-St. Lawrence River Systems.** The use of chlorobenzenes as chemical markers in the determination of the fate of persistent organochlorine contaminants from the Niagara River in Lake Ontario was continued. Radio and satellite tracked drogues and improved large-scale water sampling and extraction methods were employed to extend greatly the area of the plume sampled. The results indicate that up to 50% of the higher molecular weight chlorobenzenes are deposited within 10 km of the river mouth on settling solids, but much of the remainder is transported out of the plume area in solution. Other organochlorine contaminants behaved in a similar fashion, with the more soluble compounds largely transported out of the Niagara River mouth area and significant amounts of the less soluble compounds being deposited on settling solids.

More recently, some of the concepts and techniques used in the Niagara River plume study have been employed in a new investigation of the transport of persistent organochlorine contaminants from Lake Ontario into the St. Lawrence River. Early emphasis in the study has been focussed on establishing the relative importance of different compartments such as water, suspended solids and suspended biomass. The possibility of distinctive contaminant patterns in the North Channel of the St. Lawrence River at Wolfe Island owing to industrial activity in the Bay of Quinte-Kingston areas is also under investigation. (Fox, Carey, Coletta)

**The Fate of 2,4-D in Freshwater Systems.** The focus of the 2,4-D studies was a concern for possible harmful effects of the use of the chemical in milfoil control both on freshwater biota and on water quality in such divergent areas as the Trent River system (Ontario) and the Okanagan Lakes (British Columbia).

Both pond and field studies were completed in 1984. The former, conducted in enclosed ponds, was considered a worst-case study, but showed only marginal toxic effects on fish fry and on clams during the first week after the chemical's introduction. Secondary effects were more noticeable and consisted of the collapsed milfoil beds providing an increased food supply to bacteria, clams and other bottom fauna.

A two-year study in Buckhorn Lake (of the Trent system) showed a wide distribution of the chemical in the whole lake during the herbicide application season (June and July). This was followed by rapid disappearance, then a partial reappearance from the decaying milfoil beds. The chemical had virtually disappeared from the system by late September. Calculated inflows and outflow showed that most of the chemical was not lost in the outflow, but was degraded in the lake. The appearance of 2,4-D in the lake in May, before the milfoil control season, was attributed to the spring runoff carrying residual 2,4-D from land applications of the previous year.

The pond and field studies showed that present 2,4-D uses in milfoil control are not likely to have significant effects on freshwater ecosystems or impair water quality, and that the chemical does not persist in the lakes, or accumulate in the sediments, beyond the growing season. (Nagy, Hart)

**Accumulation and Effects of Toxic Contaminants in Aquatic Biota.** Bioaccumulation studies are a necessary component of research into the fate of contaminants in polluted aquatic systems. They provide important information on contaminant behaviour, including bioavailability, routes and modes of entry into the biota, and responses to metabolic processes (persistence, transformation, degradation). Bioaccumulation studies also identify suitable indicator organisms for use in biomonitoring programs.

The differential bioaccumulation of chlorophenols, benzothiazoles and diphenylamine by common shiners, longnose dace and crayfish was studied on site at Canagagigue Creek, Ontario. After one week of exposure, crayfish were found to have the lowest bioconcentration capacity for all compounds, while the two species of fish were remarkably similar to each other. Concentrations of the various compounds in biota were not always proportional to water concentrations. For example, 2,4,5-TCP accounted for about 30% of the total chlorophenols in biota but only 15% in the water. In contrast, 2,6-DCP accounted for only 10% of the total chlorophenols in biota as compared with 21% in the water. Biota accumulated very high levels of 2-(methylthio)benzothiazole, as would be expected from the high concentrations of this compound in the water. However, the uptake of benzothiazole was surprisingly low. Tissue levels of this compound were similar to those for 2,4-DCP, yet concentrations of the former were 15 × higher in the water. Diphenylamine was present in the water at levels similar to 2,4-DCP, but it was three times more concentrated in the organisms. These results point out the futility of assessing the contamination of an ecosystem on the basis of contaminant concentrations in the water alone. This study is believed to be the first to investigate the bioaccumulation of benzothiazole derivatives by aquatic biota.

The comparative depuration rates of chlorophenols, benzothiazoles, lindane and DDT by the leeches *Dina dubia*, *Erpobdella punctata* and *Helobdella stagnalis* were determined in the laboratory. Contaminated leeches were collected from

Canagagigue Creek, then allowed to depurate their body burdens of contaminants in clean, flowing water for 28 days. The results are presented in Table 1. It is apparent that leeches have inefficient regulatory mechanisms for eliminating chlorophenols and DDT derivatives from their systems. These compounds were most persistent in *E. punctata*, the species which is the largest and has the longest life span. The rapid depuration of 2-(methylthio)benzothiazole is particularly noteworthy, as initial tissue concentrations of this compound were one to several orders of magnitude higher than any other compound.

The persistence of DDT and related compounds in biota is a general phenomenon. However, chlorophenols are known *not* to persist in fish and bivalves. This study demonstrates that leeches would be excellent biomonitors for detecting con-

tamination of a water body by chlorophenols. It also points out that not all organisms are suitable biomonitors for all compounds. Only laboratory studies such as this can identify the best biomonitors to use under various conditions of pollution. (Metcalfe, Carey, Fox, Coletta)

**Atmospheric Deposition of Organic Chemicals.** During 1984, studies were continued on the deposition of persistent organic pollutants in the rainfall. Sampling has been expanded to include stations at Kouchibouguac National Park (New Brunswick) and Cree Lake (northern Saskatchewan); sampling at Caribou Island and Agawa Bay sites on Lake Superior was continued. Volume-weighted concentrations for the 1984 and previous seasons are presented in Table 2.

Table 1. Depuration Half-Lives (days) of Organic Contaminants by Leeches

Compound	Leech species		
	<i>Dina dubia</i>	<i>Erpobdella punctata</i>	<i>Helobdella stagnalis</i>
2,6-DCP	33	NSD	—
2,4-DCP	43	NSD	43
3,4-DCP	30	NSD	100
2,4,6-TCP	25	NSD	33
2,3,6-TCP	NSD	NSD	NSD
2,4,5-TCP	NSD	NSD	30
2,3,4,6-TTCP	NSD	NSD	NSD
PCP	NSD	27	NSD
p,p'-DDT	NSD	NSD	6
p,p'-DDE	NSD	NSD	NSD
p,p'-DDD	10	22	13
o,p'-DDE	NSD	NSD	60
o,p'-DDD	13	34	6
Lindane	<1	1	—
Benzothiazole	10	7	<1
2-(Methylthio) benzothiazole	2	3	—

NSD — No significant depuration over a period of one month.

Table 2. Weighted Averages of Contaminant Concentrations in 1984 Rain (ng/L)

Compound	1976/77 Batch- awana*	1983 Isle Royale	1983 Caribou Island	1984 Caribou Island	1984 Agawa Bay	1984 Kouchi- bouguac	1984 Cree Lake
α-BHC	14	36	15	6.5	6.7	13	6.5
Lindane	8	8.4	4.3	3.0	2.9	6.7	1.2
Heptachlor epoxide	ND	0.31	0.21	0.28	0.18	0.07	0.02
Dieldrin	0.67	ND	0.24	0.96	0.62	0.27	0.38
Endrin	ND	ND	0.02	0.07	0.08	0.66	0.24
pp'-DDE	ND	0.37	0.08	0.17	0.09	0.02	0.07
pp'-DDT	ND	0.03	0.17	0.46	0.11	0.19	ND
pp'-DDD	ND	0.79	0.02	0.06	ND	0.14	0.19
Methoxychlor	2	2.6	2.1	1.4	0.59	0.02	0.09
PCBs	33	6.7	5.9	2.5	3.2	1.1	3.1
HCB	ND	0.03	0.10	0.09	0.03	0.07	0.01
α-Chlordane	ND	ND	ND	0.06	0.02	ND	ND
γ-Chlordane	ND	ND	ND	0.20	0.06	ND	ND

\*Sensitivity and statistical soundness of data are not the same as others.

ND — Not detected.

There is an apparent downward time trend in concentrations for PCBs, alpha-BHC and lindane for the sites at Batchawana, Agawa Bay and Caribou Island, all of which are on the eastern side of Lake Superior. There also appears to be a downward, open-lake trend from west to east (Isle Royale and Caribou Island), and little or no difference between open-lake and on-shore locations (Caribou Island and Agawa Bay) over virtually identical time spans.

The concentrations of these compounds in rainfall from Kouchibouguac, Cree Lake, Caribou Island and Agawa Bay are not significantly different for the major contaminants in this medium and are highly suggestive that atmospheric deposition is comparable across the country, at least east of the Rocky Mountains. Plans are underway to sample in the Pacific region. In addition, a new, all-weather (i.e. rain plus snow) prototype sampler is being evaluated; this equipment includes automatic data recording as well as the wetfall only capability. (Strachan)

**Accumulation/Degradation of Toxic Organic Contaminants in Fluvial Ecosystems.** In the past few years, the major focus of this study has been the pathways of accumulation and degradation of chlorophenols. To provide data on the environmental distribution of these compounds, field sampling was conducted in the Fraser River Estuary, British Columbia, and the North Saskatchewan River, Alberta and Saskatchewan. Chlorophenol levels in water and biota from the North Saskatchewan River were low but both water and fish from the Fraser River Estuary had elevated levels of 2,3,4,6-tetrachlorophenol (2,3,4,6-TeCP) and pentachlorophenol (PCP). Bioconcentration factors for these compounds ranged from 100 for 2,3,4,6-TeCP in starry flounder to 1600 for PCP in sculpins. The isomer ratios and the geographical variation in levels implicated the lumber industry as the source of these chlorophenols to the Fraser River. A more detailed sampling program is planned for the coming year.

We have previously demonstrated that the CP isomers present in the ground water under the chemical disposal area appear to be the products of anaerobic dehalogenation of the original CPs disposed of there. This degradation pathway has now been confirmed in a series of laboratory experiments involving sediments from Windermere Basin, Hamilton Harbour. The steric course of the anaerobic dehalogenation of CPs was studied and ortho-substituents were shown to be the most reactive. In cases where both meta-positions are occupied by chlorine, the para-position is also reactive. Thus, pentachlorophenol (PCP) can undergo loss of three successive chlorines to give 3,5-dichlorophenol, whereas 2,3,4,6-tetrachlorophenol (2,3,4,6-TeCP) loses only two chlorines to give 3,4-dichlorophenol.

The environmental occurrence of this degradation route was confirmed at the site of a major chlorophenol spill which occurred in British Columbia in 1978. In collaboration with personnel from NWRI and NHRI, Pacific and Yukon Region, the ground water under the spill site was sampled. It was shown that whereas the material spilled contained only PCP and 2,3,4,6-TeCP, the ground water directly under the spill contained all the tetra- and tri-chlorophenols found in the laboratory dehalogenations of these compounds. In the field measurements, the half-life for loss of a chlorine via anaerobic dehalogenation was about 10 years. (Carey, Fox, Metcalfe, Coletta, Hart)

## ORGANICS-PROPERTIES SECTION

This Section determines chemical, physical and biological properties of organic contaminants, the qualitative and quan-

titative relationships between such characteristics, and their influence on the distributions, pathways and effects of these substances. Field and laboratory experiments are carried out to determine sources, pathways and sinks of xenobiotic compounds in water, suspended matter and bottom sediments of lakes and rivers, to identify new contaminants, to determine their water/octanol and water/sediment partition coefficients, adsorption/desorption rates, metabolic pathways, products and kinetics, and their toxic effects on representative aquatic bacteria, yeasts and fungi.

**Upper Great Lakes Connecting Channels Research (the Detroit and St. Clair Rivers - Pollution Issue).** The upper Great Lakes connecting channels, in particular the Detroit, and St. Clair rivers and Lake St. Clair, have been recognized as important parts of the Great Lakes ecosystem. These areas of concern are characterized by numerous industrial and municipal effluents, strong flow within the rivers and sedimentary zones in Lake St. Clair and the western basin of Lake Erie. Consequently, persistent contaminants entering this system may be adsorbed onto particulates, and may be sedimented and resuspended repeatedly. Furthermore, dredging of navigation channels, development of shoreline properties for industrial and residential uses, and changing water levels contribute significantly to sediment/contaminant interactions.

As part of a multidisciplinary investigation, Section staff undertook the sampling, analysis and interpretation of water, seston and sediment samples from over 200 stations for volatile and other organic contaminants, yeasts, fungi bacteria, acute toxicity, phenols, PCBs, organochlorines and polycyclic hydrocarbons. In addition, large-volume (200 L) water samples from over 70 stations were centrifuged on site, extracted with methylene chloride and will be analyzed by gas chromatography and mass spectrometry. Preliminary results indicate significant loadings of tetrachloroethylene (Fig. 14); carbon tetrachloride; 1,1,1-trichloroethane and trichloroethylene from the St. Clair River to Lake St. Clair. (Kaiser, Comba)

**Quantitative Structure-Activity Research (QSAR).** Quantitative structure-activity relationships (QSAR) are useful tools for the prediction of many biological and physico-chemical properties of compounds. In particular, bioaccumulation factors (BCF), acute and sublethal toxicities to many aquatic species have been found to be well correlated with molecular (for example ionization potential) and bulk (for example octanol/water partition coefficient [log P]) parameters of the chemicals.

Laboratory investigations on the toxicity (Microtox test) of over 60 chlorophenols, -anilines, -benzenes, -nitrobenzenes, and -pyridines show nearly parallel dependencies on log P of the mentioned groups (Fig. 15). Furthermore, the intercepts of these parallels were found to be related to the (molecular) hydrophilic effect parameter. Research is presently underway on a large series of 1,4-disubstituted benzene derivatives with different functional and substituent groups. (Kaiser, Ribo, Comba)

**Degradation of Toxic Organic Chemicals.** Degradation through chemical interaction with water (hydrolysis), by itself or of contaminant derivatives derived through oxidation, reduction, irradiation and metabolic processes, is a major removal mechanism for many toxic chemicals. Studies are undertaken to elucidate the mechanisms, products and rates of these processes for selected chemicals and contaminant groups.

Aniline and a total of seven chloro-anilines were exposed to four strains of yeast and yeast-like fungi, comprising two oxidative (*Rhodotorula*) and two fermentative (*Pichia* and

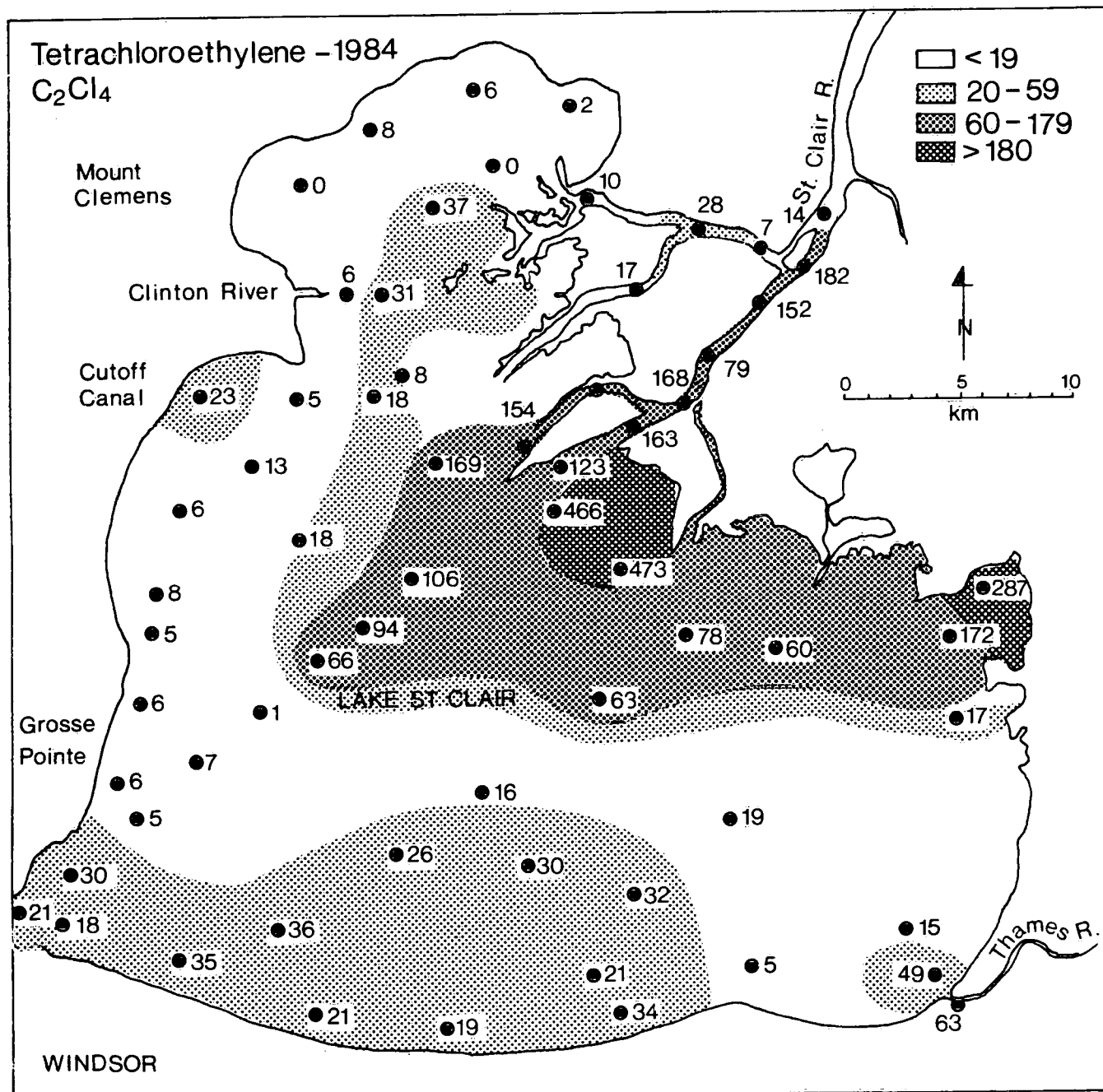


Figure 14. Tetrachloroethylene concentrations in Lake St. Clair surface water in summer 1984. All values are in nanograms per litre.

*Saccharomyces*) species. Partial degradation was observed for the lower chlorinated isomers and the concentrations producing growth reductions of 50% were quantitatively correlated with octanol/water partition coefficients of the isomers. (Kwasniewska, Kaiser).

Four intermediates during the microbial transformation of 2,4-dinitrotoluene have been identified, and two of these were nitroso compounds (2-nitroso-4-nitrotoluene and 4-nitroso-2-nitrotoluene), which are the hypothetical intermediates and have eluded previous detection. Two nitroso compounds were unstable and could be observed only at the early stage of 2,4-dinitrotoluene anaerobic degradation. This study demonstrated the possibility of treating the toxic nitro aromatics with anaerobic biodegradation techniques. (Liu, Thomson)

Chemical oil dispersants have been used to combat oil spills, but their fate in aquatic environments remains uncertain. A study showed that treatment of oil spills with chemical dispersants is unlikely to cause any build-up of organic contaminants in the aquatic environment. The application of biotechnology in the treatment of petroleum waste as well as in the assessment of a chemical's persistence and fate in the aquatic environment were also investigated in an effort to achieve the goal of technology transfer to industry and other governmental agencies. Due to the vast number of existing and newly introduced chemicals in the environment, there is a direct need for a rapid and accurate short-term bioassay procedure to assess the acute and sublethal toxicity of chemical compounds. Therefore, a rapid and inexpensive screening

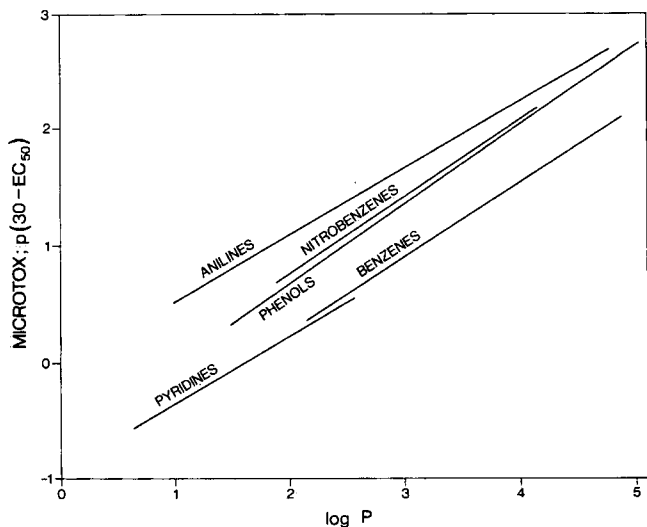


Figure 15. Plot of the toxicities (30-min Microtox test) of 68 chlorinated compounds versus their octanol/water partition coefficients ( $\log P$ ).

procedure based on the quantitative measurement of the interaction between toxicant and microbial dehydrogenase was developed for the toxicity assessment of water-soluble and water-insoluble chemicals. In addition, ten bacterial test systems for the screening of chemical toxicity were also systematically compiled into a book to facilitate the advancement of short-term bioassay. Since alkalinity may affect chemical toxicity, a micro manometric method based on the quantitative measurement of carbon dioxide liberated from a sample by an acidic buffer has been developed for assessing the alkalinity of natural water and wastewaters. To refine the short-term bioassay techniques further, factors affecting the structure-activity relationship were studied using various types of chemicals and bacteria. (Liu, Thomson)

Studies on the conversion of certain PCB components to insoluble humic-like materials have been completed and the results are now in press. An investigation of the biochemistry of pentachlorophenol degradation by bacteria was begun but was interrupted for a period of seven months due to the secondment of the scientist in charge to assist CIDA in Ethiopia. (Baxter)

**Contaminant Fate Research in the Great Lakes.** The potential availability of contaminants adsorbed onto sediment to benthic organisms and, through desorption directly to the water, has been of concern for a considerable time. Therefore, a study was undertaken to determine the uptake of several chlorinated hydrocarbons by aquatic worms from contaminated sediments. It was found that the concentration factor, CF (chemical concentration in worm/chemical concentration in sediment), varied considerably with chemical structure and sediment type. For example, CFs varied from 0.06 for 1,2,4,5-tetrachlorobenzene to 6.7 for octachlorostyrene — a difference of over two orders of magnitude. Because of the different CFs for various chemicals, the oligochaete worms contained a chemical mixture different from the sediment in which they lived. Thus, worm predators such as small fish would be subjected to a different chemical mixture than is found in the sediments.

In contrast to these results, the desorption of chlorinated chemicals from suspended sediments into the aqueous phase

changed very little with chemical structure. Temperature seemed to be the most important variable governing desorption rates. Desorption half-lives decreased from 60 days at 4°C to 40 days at 20°C to 10 days at 40°C under continuous purging of the organics from the water. Some crude estimates of the loadings of chemicals via desorption from bottom sediments in Lake Ontario were compared with loadings of these chemicals from the Niagara River. For compounds with low current loadings from the river, desorption from bottom sediments could play a significant role in controlling lake water concentrations. (Oliver, Nicol)

A two-year study on 31 chlorinated compounds in weekly samples from the Niagara River showed a measurable background concentration for most contaminants (likely because of steady leaching from chemical waste disposal sites along the river), and large unpatterned concentration spikes (likely because of direct chemical discharges to the river). Although some reduction in discharges has been achieved in recent years, this study shows that chemical dumping into the river is still a problem.

The river contaminants adsorbed to settling particles in Lake Ontario have been studied using sediment traps. Contaminant fluxes to the lake sediments were found to be much lower than anticipated, likely due to significant volatilization losses from the lake. The trace organic composition of sediment trap material revealed that considerable resuspension of bottom sediments is occurring in Lake Ontario, particularly during the winter months. (Oliver, Nicol, Charlton)

Studies on the uptake and elimination of contaminants by rainbow trout (with A. Niimi, Great Lakes Fisheries Research Branch) are continuing. The bioconcentration factors determined in these studies have been related to physical-chemical properties of the chemicals. The correlation is good for small compounds with low octanol-water partition coefficients. (Oliver, Nicol)

## INORGANICS SECTION

This Section determines the persistence and fate of inorganic and organometallic contaminants in aquatic ecosystems by conducting investigations of contaminated ecosystems and laboratory studies on the physical, chemical and biological factors that determine the persistence and fate of metals and organometals in aquatic ecosystems. Physical factors include atmospheric deposition to water, volatilization from water, and adsorption to suspended solids and sediment. Chemical factors include metal complex formation and speciation, hydrolysis and sunlight photolytic degradation. Biological factors include uptake by a variety of aquatic organisms, with subsequent transformation (e.g. methylation of metals) and degradation.

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

A survey of water and sediment for tributyltin from 250 locations in Canada is nearing completion. Preliminary results indicate that tributyltin is mainly found in harbours and marinas and other areas of heavy boating and shipping traffic, and this is probably due to its use as an antifouling agent in paint for boats, ships and docks. Table 3 shows some preliminary results on the occurrence of tributyltin.

Table 3. Tributyltin in Water, Sediment and Fish

Medium	Occurrence	Tributyltin concentration range	Most contaminated locations
Water	37 of 110 locations	0.01–18.10 $\mu\text{g}\cdot\text{L}^{-1}$	Toronto, Port Hope and Whitby harbours
Sediment	20 of 76 locations	0.01–3.52 $\text{mg}\cdot\text{kg}^{-1}$ dry weight	Toronto, Montreal and Whitby harbours
Fish	4 of 13 locations	0.01–0.02 $\text{mg}\cdot\text{kg}^{-1}$ dry weight	Hamilton Harbour

Twenty-two of the 37 water samples shown in Table 3 had concentrations exceeding the value of  $0.07 \text{ Sn } \mu\text{g}\cdot\text{L}^{-1}$ , which causes growth retardation in rainbow trout fry, and the tributyltin concentration at one location, Toronto Harbour, exceeded the 24-hour  $\text{LC}_{50}$  value of  $11 \text{ Sn } \mu\text{g}\cdot\text{L}^{-1}$  for adult rainbow trout. Thus there is cause for concern with regard to chronic toxicity of tributyltin to sensitive organisms in these areas. The toxicological significance of sediment-bound tributyltin is still in question. It has generally been assumed that adsorption of tributyltin to sediments constitutes a mechanism for removal from aquatic environments. We have, however, shown that oligochaete worms can take up tributyltin from sediment, thereby making it potentially bioavailable to bottom-feeding fish.

An intensive investigation of the environmental chemistry and fate of tributyltin showed that the main factors limiting the persistence of this pesticide were sunlight and bacterial degradation, and under Canadian conditions, the half-life is at least several months. The ultimate fate of tributyltin is probably conversion to harmless insoluble stannic oxide, and precipitation to the sediments. (Maguire, Tkacz)

**Occurrence and Fate of Alkylleads in Aquatic Environments.** Fish, sediment and surface water microlayer samples from the St. Clair and St. Lawrence rivers were found to contain significant concentrations of tetra-, tri- and dialkyllead species (where alkyl = methyl or ethyl), which are believed to be derived from tetraalkyllead antiknock production plants in the areas. Triethyllead is generally the most toxic of the alkyllead species to aquatic organisms. Freshwater clams (*Elliptio complanata*) accumulate triethyl- and trimethyllead in muscle and viscera, and apparently do not metabolize these species.

Alkyllead compounds are degraded by sunlight in successive dealkylation steps to inorganic lead. Half-lives of degradation are generally of the order of hours to days.

The abiotic methylation of lead (II) to methyllead (IV) by methyl iodide proceeds quickly. Such a process may be environmentally important in view of the presence of methyl iodide in natural waters, and may provide the reason for the existence of methyllead and methyltin species in natural waters remote from anthropogenic sources. Although environmental trans-methylations between some elements have been shown to occur, methyllead (IV) is probably not produced in such a fashion. Methyllead species, however, can transfer the methyl group to other metals such as tin.

Preliminary work has been done on the use of the adenylate energy charge ratio in phytoplankton as an indicator for environmental stress. The ratio is based on the concentrations of ATP, ADP and AMP in an organism. It may have great value as an indicator of environmental stress of pollution if, as hypothesized, the concept can be generalized to all levels of aquatic food chains. (Chau, Bengert)

**Bioavailability of Toxic Metals, Metalloids and Phosphorus in Aquatic Ecosystems.** A study of the geochemical availability of elements in bottom sediments of the Detroit River and western Lake Erie has shown that hydrous iron oxides are the dominant extrinsic factors controlling the environmental mobility of phosphorus, cadmium, zinc, cobalt, lead, chromium, nickel and manganese. In the aquatic ecosystem it is suggested that the presence of a large excess of iron over phosphorus (because of the implementation of abatement measures for the latter) is beneficial because of the efficient scavenging of inorganic contaminants. The Welland River was shown to contribute 12 t of zinc per year to Lake Ontario, which is 9% of the 136 t contributed by the Niagara River. This percentage is expected to rise, since the major source of zinc to the Niagara River, the Bethlehem Steel Corp., ceased steel-making operations in 1983.

Research is underway (1) to validate analytical methods for determining the speciation of cadmium and its availability in water, sediment and other environmental "compartments" and (2) to determine the geochemical pathways of inorganic contaminants in the St. Lawrence River and in Hamilton Harbour. (Lum, Kokotich)

**Metal and Metalloid Speciation and Bioavailability.** The association of metals with various sediment components was investigated by the separation of sediments from Lake Erie and the Niagara and Detroit rivers into seven size fractions. The geochemistry and mineralogy of each size fraction were determined together with concentrations of metals. The results indicated that most of metals were associated either with clay minerals or organic matter in Lake Erie. Fine particles from the Niagara and Detroit rivers contained up to 26 times higher concentrations of lead, zinc, copper, chromium and cobalt than fine particles from Lake Erie. These fine particles are susceptible to resuspension and transport from the Detroit and Niagara rivers into Lakes Erie and Ontario, respectively.

The Shubenacadie River headwater lakes in Nova Scotia are contaminated with arsenic and mercury as a result of past gold mining activities in the area. Studies of pathways of arsenic and mercury through the food chain showed significant uptake by benthic organisms, particularly aquatic worms, chironomids and clams. (Mudroch, Kokotich)

## RADIONUCLIDES SECTION

The major objective of this Section is to study the behaviour of both naturally occurring and artificially produced radionuclides in the Canadian aquatic ecosystems. Studies include the delineation of pathways of radionuclides discharged to rivers and lakes; the measurement of levels of these radio-

nuclides in water, biota and sediments; the development of methods for the determination of these radionuclides; and the application of predictive models for the dispersion of radionuclides in surface waters.

**Uranium-Series Radionuclides in Langley Bay, Lake Athabasca (Saskatchewan) Ecosystem.** Levels of these radionuclides have been measured in over 150 sediment, water, fish and aquatic plant samples in order to study the extent of radionuclide contamination due to an abandoned uranium mine waste site. A preliminary evaluation of the data indicates that the contaminants are being transported by sediments to Lake Athabasca. The radionuclide measurements are now being supplemented by stable element (20) data. The distribution of radionuclides in various fish organs is also being investigated. (Joshi, Platford, Thompson)

**The Port Granby Radioactive Waste Management Site.** Our analyses for radioisotopes leached from the site were completed in 1984. The concentrations in various locations at the site and downstream from it are given by symbols 3 through 9 in Figure 16. The concentrations of both  $^{226}\text{Ra}$  and/or uranium are within the maximum acceptable limits for drinking water (as set out by the Department of National Health and Welfare) at all points more than 1 m out from the shore of Lake Ontario. (Platford, Joshi, FitzGerald)

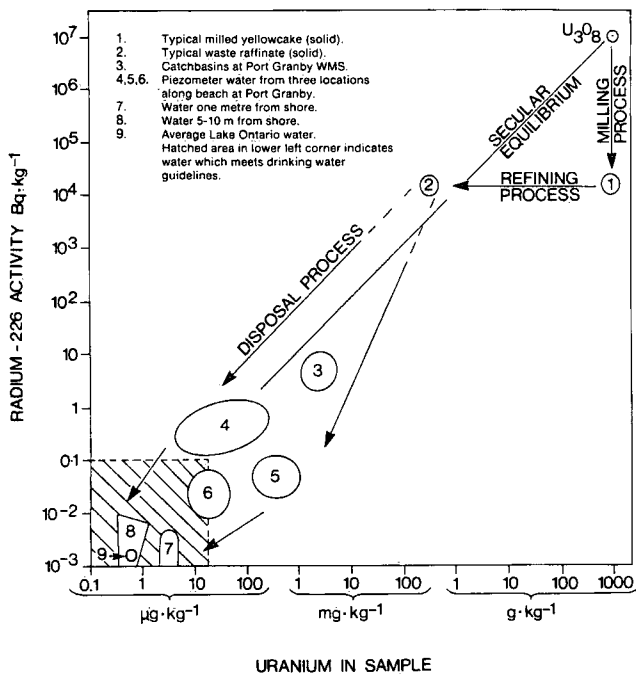


Figure 16. Radium/uranium ratio in typical solid and liquid compartments associated with the Port Granby site in Ontario, WMS – waste management site.

**Radionuclide Pathways in the Niagara River/Lake Ontario.** Levels of  $^{137}\text{Cs}$ ,  $^{238}\text{Pu}$ ,  $^{239,240}\text{Pu}$ ,  $^{241}\text{Am}$  and various uranium and thorium isotopes have been measured in five  $^{210}\text{Pb}$ -dated sediment cores from Lake Ontario. A preliminary analysis of data shows that these locations receive non-fallout inputs of  $^{137}\text{Cs}$ ,  $^{238}\text{Pu}$ ,  $^{239,240}\text{Pu}$  and  $^{241}\text{Am}$ . A unique feature, common to all locations, is the incompatibility of the  $^{137}\text{Cs}$

profile with those for transuranics. Further work is underway to assess these profiles and the role of sediment mixing. (Joshi, Thompson)

## ACID DEPOSITION SECTION

The objective of research projects conducted by the Acid Deposition Section is to quantify and understand the hydro-geochemical 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 balances in the TLW to define the most important geochemical mechanisms controlling the "dose-response" relationship for this basin, and the second study is focussed on determining the factors or processes controlling the short-term acidification associated with spring snowmelt.

The TLW is an undeveloped, hydrologically calibrated basin (area = 10.5 km<sup>2</sup>), located 50 km north of Sault Ste. Marie, Ontario. It is completely forested (mixed hardwood) and contains a chain of five 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<sup>-1</sup> from the headwater to the lowest lake in the chain.

**Geochemical Mass Balances in a Calibrated Watershed.** All data necessary for calculating lake mass budgets have been collected from June 1981 to May 1985. Mass budgets of ions for two "water-years" (June–May, 1981/82 and 1982/83) for a high elevation lake (Batchawana Lake South) and a low elevation lake (Turkey Lake) have been calculated. For example, budgets for selected parameters for the second water-year are given in Table 4. The budgets show that almost all of the hydrogen ion, but only part of ammonium and nitrate entering the lake are retained (Output – Input < 1); therefore all three species play an acidifying role in the TLW. Sulphate budgets are approximately in balance, that is, sulphate in the TLW is in a steady-state condition. Excess output of calcium and particularly alkalinity over input suggests the presence of unaccounted sources for these two ions. Probable sources include ground water and primary production; a possible source is within-lake alkalinity generation via sulphate reduction. The mass budget studies in the TLW are continuing. (Jeffries, Semkin, Neureuther, Seymour, Gough)

**Snowmelt and Acid Shock.** The accumulation and loss of ionic pollutants from the snowpack have been studied in the TLW since 1981. In 1985, a snow-box was used to contain (in

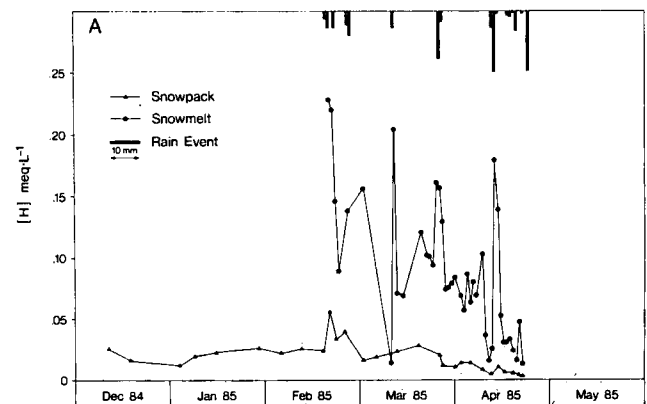


Figure 17. Hydrogen ion in snowpack and snowmelt.

Table 4. Mass Budget (keq) of Selected Ions for Batchawana Lake South and Turkey Lake for June 1982 – May 1983

Ion	Lake	Inputs			Total input	Total output	Out/I
		Bulk deposition	Terrestrial basin	Major inflow			
H	Batchawana	4.3	1.4	0.4	6.1	1.2	0.19
	Turkey	38	0	1	40	0	0
Ca	Batchawana	0.5	42.2	20.8	63.4	91.9	1.45
	Turkey	4	504	1043	1551	1972	1.27
NH <sub>4</sub>	Batchawana	1.5	0.4	0.8	2.7	2.3	0.85
	Turkey	14	2	3	18	10	0.57
Alk	Batchawana	-4.3	4.4	6.0	6.1	28.3	4.68
	Turkey	-38	249	580	788	1260	1.60
SO <sub>4</sub>	Batchawana	4.5	46.5	20.3	71.3	81.3	1.14
	Turkey	40	262	582	883	936	1.06
NO <sub>3</sub>	Batchawana	2.3	6.3	2.3	10.8	9.3	0.86
	Turkey	20	53	78	152	111	0.73

*situ*) the accumulating snowpack and later to channel all meltwater output plus rainfall into a "volume priority" fraction collector. An example of the hydrogen ion concentration in the snowpack and meltwaters is shown in Figure 17. Our studies show that in the TLW, the water quality of snowmelt water is strongly influenced by the occurrence of rainfall. In particular, the major acid anion accumulating in the snowpack is nitrate; with the influence of spring rainfall, however, the dominating anion in the meltwater is usually sulphate. (Jeffries, Semkin, English, Neureuther)

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Organization, TC/SC3-Water Quality/Radiological  
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## ANALYTICAL METHODS DIVISION

The Analytical Methods Division is responsible for the research, development and evaluation of new, improved and more cost effective manual and automated analytical techniques (including sample collection, preservation and screening procedures) for the measurement of chemical, biochemical and microbiological parameters in water, sediment, suspended solids, biological materials and effluents. Analytical methodology support is provided to the Water Quality Branch (National and Regional laboratories), the National Water Research Institute, the Great Lakes Water Quality Program, the Toxic Chemicals Management Program, the Long Range Transport of Airborne Pollutants Program, and other federal and provincial clients. The Division also conducts inter-laboratory quality assurance studies for all major water quality programs within the Department and provides centralized computer service to all components of the Canada Centre for Inland Waters.

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

The Division is made up of four sections: Analytical Chemistry Research, Quality Assurance and Methods, Microbiology Laboratories, and Computer Services.

### ANALYTICAL CHEMISTRY RESEARCH SECTION

The Analytical Chemistry Research Section is engaged in advanced methodology and instrumentation research. The research is directed toward the development of new or improved techniques for the identification and measurement of the priority chemical contaminants in water, sediment and biological material. The Section's main objective is to provide cost effective, validated analytical methods to other agencies within Environment Canada. During the last two years, emphasis has been on the use of analytical techniques such as high pressure liquid chromatography, gas chromatography, mass spectrometry, atomic and molecular spectroscopy, radioimmunoassay, electrochemical, continuous flow and flow injection analyses. The Clean and Hazardous Chemicals Laboratory is also managed by the Section.

The recent interest in supercritical fluid chromatography (SFC) at our laboratory is due to the potential advantages SFC has over high performance liquid chromatography (HPLC) and gas chromatography (GC). This interest was augmented by the development of small-bore column SFC. Small-bore columns are advantageous because column pressure drops are very low. The use of pressure or density programming to effect selectivity as opposed to gradient elution for HPLC or temperature programming for GC permits greater detection flexibility and the use of detectors such as the flame ionization detector. In the near future, we plan to use the mass spectrometer and, eventually, the nitrogen/phosphorus detection

system. SFC can be used to separate a variety of complex oligomeric mixtures of surfactants, nonionic fluorine-containing surfactant FC-171, polyglycerides with molecular weight over 1000 atomic mass units, and polycyclic aromatic hydrocarbons. Future work will concentrate on the application of SFC to environmental analyses. (*Onuska*)

A separation method is being developed for the identification of organic nitrogen-containing compounds in sediment samples. Prefractionation of heteroaromatic compounds (HAC) from sediments into discrete chemical classes is being performed by adsorption column chromatography using small quantities of neutral aluminum oxide and silicic acid. Subsequent high resolution separation of individual components has been achieved by using open tubular column-high resolution gas chromatography (HRGC). Specific compound types are determined by GC-retention data and HRGC/MS. The principal classes identified in solvent-refined coal liquid and petroleum extracts were aliphatic hydrocarbons, polycyclic aromatic hydrocarbons, nitrogen-containing HACs, and hydroxylated PAH fractions.

Water samples and suspended sediment samples from the Ottawa River were analyzed for base-neutrals, PCBs, chlorinated benzenes and organochlorine pesticides. Small quantities of PAHs and phthalates were confirmed by HRGC/MS, and traces of PCBs and OCs were identified by HRGC/ECD. Samples containing 2,3,7,8-TCDD were analyzed by HRGC/HRMS, and a minimum detection limit of 2 ppt in fish and sediment was established. Numerous samples suspected of containing 2,3,7,8-TCDD were analyzed for the Water Quality Branch. (*Onuska*)

Various methods of sample treatment, extraction and cleanup were evaluated in order to develop a suitable analytical scheme for selective determination of polychlorinated dibenzo-p-dioxins by HRGC/ECD or HRGC/MS in a variety of environmental samples. Samples containing dibenzofurans were also subjected to the cleanup and separation procedures. Recoveries of 85% to 98% were obtained. The transfer of this technology to the National Water Quality Laboratory has been completed. Considerable time and resources were spent to maintain the operation and services of the Clean and Hazardous Chemicals Laboratory for internal and external clients.

Radioimmunoassay (RIA) techniques have been proposed for the rapid and inexpensive screening of large numbers of environmental samples for polychlorinated dibenzo-p-dioxins and other trace organic contaminants. A procedure was adapted for labelling 2,3,7,8-TCDD with <sup>125</sup>I, and purifying and characterizing the reaction products on a repeatable basis. The repeatability of the RIA for PCDDs was established using 2,3,7,8-TCDD standards, and the assay was standardized and calibrated. A variety of environmental samples and potential interferences were analyzed using RIA. The interfacing of the RIA for PCDDs with an extraction and cleanup procedure is in progress. A new method for solubilizing PCDDs for analysis by RIA was developed and is being evaluated. (*Sherry, Wilkinson*)

The presence of the pesticide toxaphene in the aquatic environment is a major concern to those responsible for water management. A study was undertaken to develop a method that would measure the concentration of toxaphene and that could be easily transferred to the National Water Quality Labo-

ratory. To this end, the existing organochlorine methodology was modified and the extracts analyzed by capillary detector. The success of the method relies on the selection of suitable peaks to quantify the material. It was found that under specific operating conditions, there were 48 peaks that individually contributed at least 0.7% to the toxaphene formulation. From these peaks, 11 peaks were selected that were not susceptible to interference by other common organochlorines and were recovered quantitatively through the cleanup steps. Under normal conditions using split/splitless GC injection techniques, a minimum of  $10^{-10}$  g could be detected. (Scott)

A continuous liquid-liquid extractor was designed for the extraction of organics from large water samples. This development was undertaken to lower detection limits in the determination of organics, such as organochlorines, pesticides and PCBs. The extractor (Fig. 18) uses a combination of a mixer settler and a counter-current packed column. Two sizes of extractor have been constructed, one for sample flows of up to  $500 \text{ mL}\cdot\text{min}^{-1}$ , and the other for flows up to  $1 \text{ L}\cdot\text{min}^{-1}$ . These extractors have been used to extract up to 50-L water samples with about 150 mL solvent. The practicality of the design has been confirmed by operating them in the laboratory, on board ship and in a vehicle in the field. The preliminary results show that they give essentially complete extraction of the organics. (Goulden)

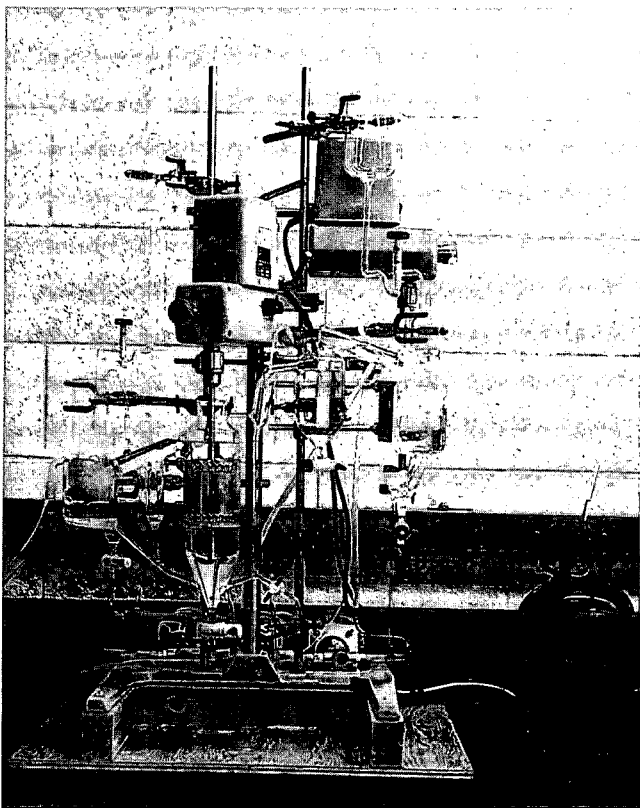


Figure 18. Large sample extractors set up for sequential acid-base/neutral extractions.

**Inorganic Parameters.** Flow injection analysis (FIA) has been adapted for automated sample delivery in atomic absorption spectroscopy. It entails automated insertion of discrete volumes of the sample into a constantly flowing lan-

thanum solution. The system achieves Ca and Mg analyses with high precision (less than 2% relative standard deviation) and low detection limits (1 ppb) at speeds of 120 to 140 samples per hour.

An FIA method for determination of dissolved oxygen has been developed. Samples preserved at the acid stage of the Winkler method are injected into a standard reagent stream and measured by spectrophotometry. Achieved precision is 2% relative standard deviation and the detection limit is 0.05 ppm D.O. at a sampling rate of 100 samples per hour.

Flow injection analysis methods using colorimetric detection for  $\text{NH}_4^+$ ,  $\text{PO}_4^{3-}$ ,  $\text{NO}_3^-$  and  $\text{NO}_2^-$  have also been developed. Simultaneous determination of all four parameters can be performed at a speed of 90 samples per hour. Relative standard deviations are less than 2% and required limits of detection are achieved. A simultaneous calibration curve for  $\text{NH}_3$  and  $\text{NO}_2^-$  is shown in Figure 19.

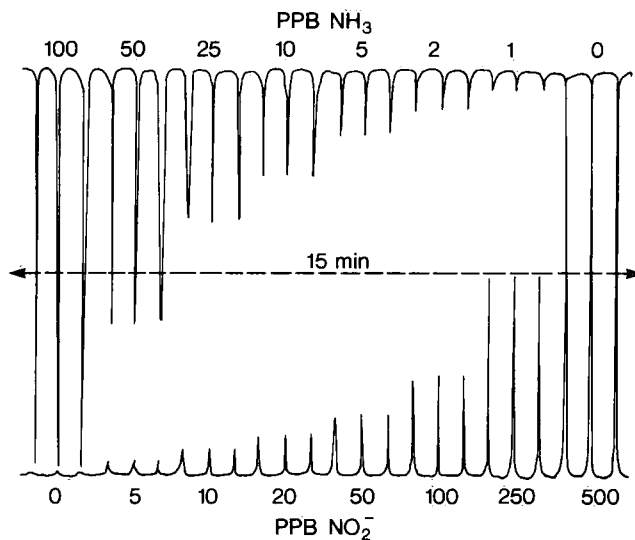


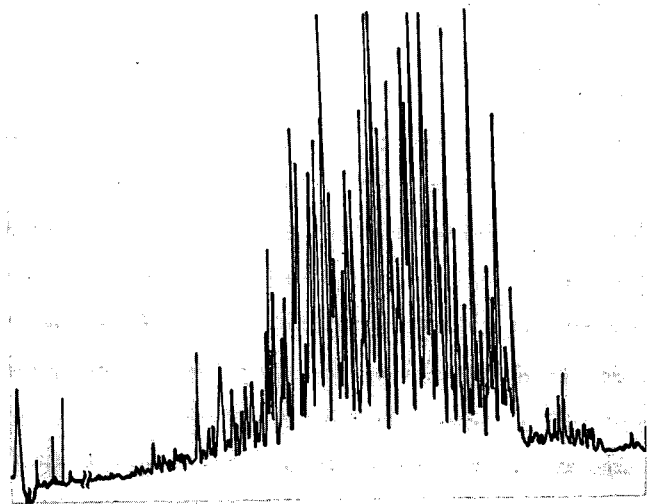
Figure 19. Simultaneous calibration of FIA methods for  $\text{NH}_3$  and  $\text{NO}_2^-$  using colorimetric detection.

Procedures for preservation of water samples for analysis of dissolved oxygen, cyanide and iodide have been developed and evaluated. The procedure for dissolved oxygen is by fixation at the acid stage of the Winkler method. This stabilizes the sample for up to eight weeks. Cyanide samples preserved with NaOH remain stable for nine weeks. Using the developed fixation procedure, iodide samples can be stabilized for up to seven weeks.

Electrochemical methods for sub parts per billion levels of Cu, Cd, Pb and Zn (flowthrough differential pulse stripping voltametry) as well as for low levels of  $\text{CN}^-$  (gas permeable accumulation and amperometric detection) are in progress. (Sekerka)

A study was made of the relative suitabilities of an inductively coupled argon plasma (ICAP) and a microwave excited helium plasma (MIP) as the sources in an element-specific detector for capillary column gas chromatography. The results showed that MIP is more suitable for the determination of Br, Cl and F; both sources are equally suitable for the determination of C, P and S; and ICAP is the preferred excitation source for the determination of organometallics such as Sn and Pb. (Goulden)

# “Research in Action”



## QUALITY ASSURANCE AND METHODS SECTION

The work of the Section comprises three main areas: quality assurance (QA); development of reference and certified reference materials (RMs and CRMs); and methods development. 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 QA programs assess the analytical performance and ensure the generation of reliable, valid and comparable analytical data on a regional, national and international basis. Only by collecting and using data with specified tolerance limits can we be sure that spatial and temporal trends are statistically significant and that data from different laboratories are comparable. Development of CRMs and RMs is essential to increase the effectiveness of these quality control studies.

**Quality Assurance (QA).** Two new studies have been initiated in 1985:

- (1) Federal-Provincial Water Quality Monitoring Agreement QA Program. In response to the Agreement between Environment Canada and the Province of Quebec, a new QA program was developed and initiated in July of 1985. Six QA studies have been distributed to date. (*Gorrie*)
- (2) Upper Great Lakes Connecting Channel Studies (UGLCCS)-QA Program. This binational (U.S. and Canada) program was initiated in late 1984. An overall QA program was developed and individual studies will start in 1986. The Section takes a lead role in the data quality management for the UGLCCS, advising on data quality and conducting interlaboratory studies. (*Chau*)

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

The Long Range Transport of Air Pollutants (LRTAP) QA study was initiated in 1982 in response to a concern about data comparability and quality among laboratories generating data for the LRTAP program. Each year, three multi-sample interlaboratory comparison studies for 40 inorganic parameters in water are designed and sent out to approximately 60 Canadian and several U.S. laboratories. Integrated reports based on percent bias and percent flagged statements are sent to all participants. (*Dookhran*)

The Prairie Provinces Water Board QA study, initiated in September 1982, is designed to assess and improve the comparability of water quality data generated by federal and prairie provincial laboratories (Alberta, Saskatchewan and Manitoba). Twelve studies, each involving 40 inorganic parameters, are conducted each year. Extensive computer programs and several data files are being generated to meet the objectives of the study. (*Alkema*)

Under the auspices of the International Joint Commission, a QA study specifically designed for dredging programs in the Great Lakes Basin was initiated in September 1983. There are four key components in this study: design and conduct of intercomparison studies; development of specific certified reference samples; design of suitable computer programs to assess comparability and short- and long-term laboratory performance; development of QA criteria for analytical contracts for dredging programs. Three interlaboratory studies were completed in this report period. (*Lee*)

The National QC Study includes over 100 federal, provincial, university and private laboratories and contains both inorganic and organic parameters in water and sediment. These national studies serve (1) to assess methodology and data of the

Water Quality Branch laboratories by comparison with peer laboratories, (2) to establish laboratory performance of Water Quality Branch and private laboratories, (3) to permit selection of private laboratories for contract analyses, and (4) to provide additional data for certification of reference materials. This year one interlaboratory study for PAHs in sediment and one for  $\text{SO}_4^{2-}$  in coloured waters were conducted. (*Lee, Cheam*)

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. (*Aspila*)

A QA study for herbicides was designed and conducted under the auspices of the Federal Interdepartmental Committee on Pesticides. (*Lee*)

Research and development of certified reference materials continued in support of the quality assurance programs. Two sediment CRMs for polynuclear aromatic hydrocarbons (PAHs) are now completed, and a third sediment for PAHs is at its final stage of certification. These PAH CRMs are the first of their type available. (*Lee*)

**Sample Stability and Preservation.** The centralization of the Inland Waters Directorate Water Quality Branch laboratories has resulted in 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 sample processing and handling prior to analysis must be addressed. Phase 1 of a preservation study (major ions and nutrients) was completed in 1984, and phase 2 (trace metals) was completed in 1985. (*Arafat*)

**Methods Development and Technical Transfer.** Analytical methods for the following parameters in water were developed: chlorophenols (by *in situ* acetylation, chloroacetylation and pentafluorobenzyl ether formation); 10 acid herbicides by gas chromatography; 11 triazines by gas chromatography; and a multi-class multi-residue method for some 45 organic parameters in water and sediment. The herbicide methodology was transferred to the Water Quality Laboratory for routine application. (*Stokker, Lee*)

## MICROBIOLOGY LABORATORIES SECTION

The Microbiology Laboratories Section has two main functions. The first is to develop, evaluate and modify microbiological methods and criteria for assessing and monitoring water quality. These methods are distributed nationally and internationally through a methods manual entitled "Microbiological Analysis of Waters, Wastewaters and Sediments." To validate the methods, they are used routinely in field and laboratory studies to obtain a data base. Recent studies have been primarily devoted to toxicant screening tests, with a smaller proportion of time being spent on enumeration and isolation techniques related to bacterial populations in sediments, water, sewage and industrial waters.

The second major role that the Microbiology Laboratories Section fulfills is the application of the technologies mentioned above to environmental research. The main thrust of this research is to study the effects of acid rain, and industrial and domestic wastes on microorganisms in the aquatic ecosystem, and the reactions of these contaminated waters and sediments to various microbiological toxicant screening tests.

During the period covered by this report, Microbiology Laboratories Section staff concentrated their efforts in four main areas:

- (1) Completion of the cross-Canada distribution pattern study on Legionnaire's Disease Bacillus (*Legionella*).
- (2) Initiation of a four-continent study on the use of coliphage as indicators of water quality.
- (3) Evaluation of the effects of acid rain on toxic metal interactions with bacteria in aquatic systems.
- (4) Completion of a microbiology study of Lake St. Louis sediments, emphasizing microbial responses to loadings and toxicant distribution patterns based on microbial screening tests.

Microbiology Laboratories staff were also involved in the organization of two international symposia. The First International Symposium on Aquatic Microbial Ecology held at CCIW on May 13-15, 1985, was co-chaired by S.S. Rao. A total of 37 papers were presented by delegates from ten countries. The Second International Symposium on Toxicity Testing Using Bacteria was held on May 6-10, 1985, at the Banff Centre, Alberta. Sixty papers were presented at this symposium by delegates for 21 countries. D. Liu and B.J. Dutka, Co-Chairmen of the Toxicity Symposium Committee, coordinated and managed the symposium with the Department of Environment, Alberta, as the co-sponsor.

Microbiology staff also collaborated with a number of international methods development organizations for microbiology water quality, such as ASTM, APHA standard methods, International Standards Organization, and the AWWA Microbiology Problems Working Group. Microbiology staff participated in several other projects such as Lake Erie studies to ascertain the effects of reduced material loadings on bacterial populations and activities; an inshore Lake Ontario sediment survey (Kingston to Niagara River) to evaluate a battery of microbiological analytical techniques, e.g., fecal sterols, fecal coliform MF and MPN and toxicant screening tests, in order to develop a composite "hot spot" map based on a new battery of biochemical, microbiological and toxicant screening tests; and a study of the Ottawa River at Lemieux Island to evaluate the effect of improved sewage treatment processes on Ottawa River quality by means of bacterial enumeration and toxicant screening tests.

**Legionella Studies.** In 1982/83, in conjunction with the Department of National Health and Welfare, a national survey on the distribution patterns of *Legionella* organisms in natural waters, potable waters and cooling tower waters was initiated with a study centred on southern Ontario. In 1983/84, this survey expanded to include Lake Superior, the rivers and lakes of New Brunswick, Nova Scotia, Prince Edward Island and eastern Quebec, as well as potable water distribution lines and cooling tower waters from buildings in the following cities: Vancouver, Edmonton, Calgary, Poplar River, Regina, Winnipeg, St. Catharines, Mississauga, Ottawa, Montreal, Quebec City, Fredericton and Halifax. During the 1984/85 fiscal year, this cross-Canada study was completed by the collection of water samples from rivers, lakes and hot springs in British Columbia, Alberta, Manitoba, and western and northern Ontario. These studies indicated that Legionnaire's Disease Bacillus could be found in waters across Canada and that this organism is a normal water bacterium. (Dutka)

**Coliphage Evaluation.** In 1983, the International Development Research Centre (IDRC) in Ottawa initiated, with the aid and recommendation of Microbiology Laboratories Section

staff, a project in S.E. Asia (Singapore, Malaysia and Thailand) to evaluate coliphage as an indicator of water quality and health risks. To support this IDRC initiative and provide a Canadian data base, a research study was conducted to evaluate the coliphage procedure in Canadian waters. Water samples for this study were collected from the Fraser River (B.C.), Ottawa River, St. Lawrence River and Lake Ontario. In early 1985, a further international part of this study was initiated by involvement of three South American countries (Brazil, Chile, Peru) and three North African countries (Egypt, Tunisia, Morocco). (Dutka)

**Acid Rain Microbiology.** The effects of acid stress on bacterial activity and bacterial interactions with toxic metals in aquatic environments are of primary importance in the study of the effects of acid rain on aquatic ecosystems. Several sediment cores from Ontario lakes receiving acid precipitation were examined for (1) bacterial activity, (2) toxic metal concentration and (3) assessing the role of certain bacterial species in the sediment sulphate reduction process.

It was demonstrated that low pH stress changed the bacterial cell envelopes, as shown in Figure 20. Bacterial respiration rates, which in turn resulted in a diminution of the normal nutrient cycling processes and bacterial organic matter degradation processes, were altered. Under laboratory conditions, it was shown that acid stressed or low-pH stressed bacteria responded to toxic metals such as copper and aluminum to varying degrees. At pH 5, bacteria responded to copper by forming electron dense particles within their cell envelope, whereas aluminum stressed cells exhibited pleomorphism. This "bacteria-toxic-metal" association at low-pH stress conditions may have important implications in acid stressed lakes, if related to bacterial associated transport of toxic substances through the food chain. Another important aspect of lake acidification process is the accumulation of sulphur at the surface sediments. A joint study by the staff of Microbiology Laboratories, McMaster University and Brock University revealed that sulphate-reducing bacteria in the deeper layers of the sediment contributed to the excessive sulphur by bacterial sulphate reduction. (Rao)

**Lake St. Louis Sediments.** The discharge of contaminants and toxicants into the Great Lakes water systems by municipal and industrial wastewater systems is of much concern. The long-term effects of toxicants to aquatic life, their distribution patterns, transportation and biodegradation rates are being studied within the Canadian Great Lakes Drainage System. The Microbiology Laboratories Section joined with other researchers to provide information on the distribution of toxicants within the sediments and to establish baseline values for long-term monitoring. To this end over 100 water and sediment samples were collected from 50 stations and were tested for total bacteria, respiring bacteria, aerobic heterotrophic bacteria, and certain physiological types of bacteria such as  $N_2$  cycle and S-cycle bacteria. Other tests used on these samples were the Microtox test for toxicant screening data (Fig. 21) and ATP estimations for estimating toxic effect on *in situ* microbial biomass. Preliminary analyses of these data indicate that areas of high and low bacterial densities exist in the sediment, and the lower density areas are generally associated with areas where high concentrations of toxicants are found. Eighty-six percent of the surface sediments (3 cm) and 100% of the deeper sediments (10 cm) were found to contain toxicants, indicating that the effects of remedial actions are being seen in the surface sediments. (Rao, Kwan, Dutka)

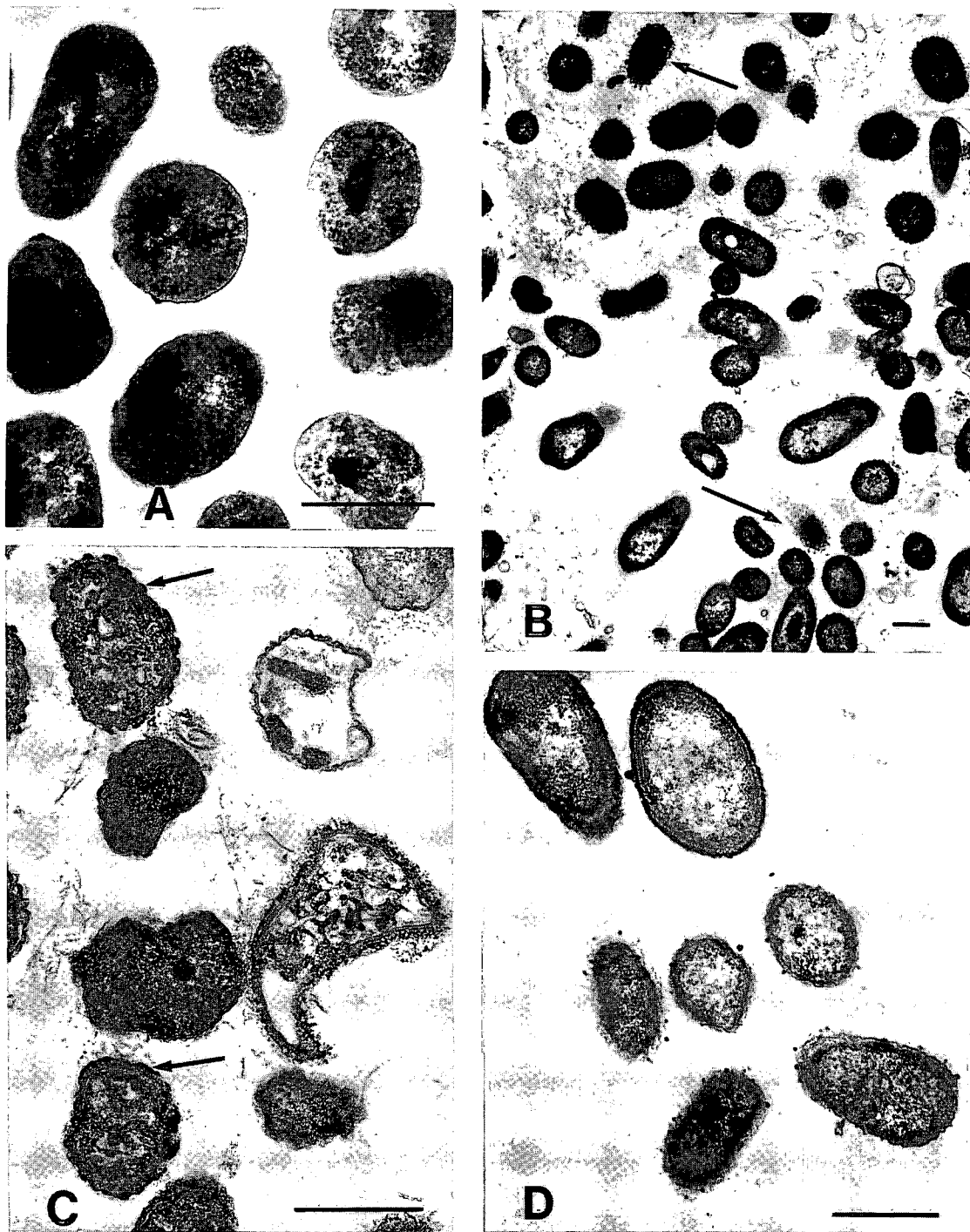


Figure 20. Cell envelope changes as a function of pH in mixed bacterial populations derived from McFarlane Lake, Ont. The marker represents  $0.5 \mu\text{m}$ ; *A* - cells at pH 7; *B* - cells at pH 6; *C* - cells at pH 5; *D* - cells at pH 4.



Figure 21. Sample being processed for toxicity by the Microtox Toxicity Screening Procedure.

## COMPUTER SERVICES SECTION

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

The Section's facilities include a Control Data CYBER 171 Computer System, a Digital Equipment PDP-11/60 Minicomputer, a CALCOMP 925/1036 high-speed plotter and a data entry service.

The Section also provides technical support for the Wang Office Information System, which provides administrative word processing for NWRI and Ontario Region, Inland Waters Directorate.

**Future Requirements Planning.** The contract for the currently installed CDC CYBER 171 System has been extended through July 1986 to permit sufficient time to complete the procurement of a replacement system.

In the third quarter of 1984, a vendor survey was conducted to determine whether a competitive procurement of a new system was required. A letter of inquiry was sent to 47 vendors taken from the DSS Master List of large computer suppliers. In all, 16 vendors replied, two with a positive response. One was Control Data Canada, the present supplier, and the other was IBM Canada. It appears that a competitive procurement will be required.

The Treasury Board Submission requesting approval, in principle, for the acquisition of a new computer system and the accompanying make-or-buy analysis were completed in April 1985. The submission was approved by Treasury Board for approval in December 1985.

**Software Upgrades and Development.** No system software changes were made during the report period. Because the CYBER 171 has insufficient memory to support the current version of the NOS operating system, all software upgrades will have to wait until the new system is installed. The CYBER is currently running with operating system software that is at least three years out of date.

An electronic mail system for the CYBER 171 system was written. This has been particularly useful for communication between NWRI and field parties in the Montreal area. (*Pulley*)

On the PDP-11, application development by staff of the Data Management Section has continued. Digitizing and data editing applications are now operational, and a satellite imagery application is currently under development. Hardware problems with the digitizing table appear to have been resolved, and the Hydraulics Division has made extensive use of this device.

**Computer Operations.** CYBER system usage for the 1984/85 fiscal year was 2763 hours of central processor time. This represents a slight decrease from the previous year's total, 2777 hours. This absence of workload growth is the result of the departure of the Fisheries and Oceans Oceanography group from CCIW and the saturation of the CYBER system in the 8 a.m. to 5 p.m. prime shift period during much of the year.

The equivalent commercial value of services provided to CCIW amounted to \$1 000 000. Non-NWRI usage amounted to 19.9% of the total.

No CYBER 171 system downtime occurred in 1984/85. During the first half of 1985/86, three hours of downtime occurred, the result of problems with the chilled water supply to the central processor. Throughout the report period system availability exceeded 99%.

**Data Communications.** The Section has been involved in the design of the data transmission capabilities of the new telephone system. This involvement included participation in the CCIW team, which provided overall specifications for data requirements and design of the communications for the CYBER 171. The new telephone system will provide more shared ports and higher speeds for users at CCIW.

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 Joint Task Group Section 919, Rapid Detection Methods, APHA Standard Methods  
 Joint Task Group Section 914, Recreational Waters, APHA Standard Methods  
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 ISO/TC147/SC4/WG9, Membranes — Chairman and International Secretariat  
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Lake Huron Task Group Member

International Symposium on Microbial Ecology — Co-Chairman

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**Asplia, K.I., and S. Todd.** 1985. LRTAP intercomparison study L-8, major ions, nutrients and physical properties in water.

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## HYDRAULICS DIVISION

The Hydraulics Division undertakes research into all aspects of the hydraulics of inland waters and provides 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, geophysics and geologic processes in fluvial, lacustrine and man-made environments.

### ENVIRONMENTAL HYDRAULICS SECTION

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

**River Diversions.** A review report on the effects of diversions on river regime has been completed. This report discusses the possible changes in the donor as well as the receiving streams which may occur as a result of the diversion of water from one stream to the other. Methods presently available for predicting these effects are outlined. Research required for improving the predictive capability is discussed. (Lau)

**Resistance for Flows with Rippled Beds.** Alluvial streams often have ripple formations on the river bottom. For calculations of flow level, the ripple characteristics must be known. In addition, for calculating sediment transport, the part of the total flow resistance that contributes toward bed material movement requires evaluation. A series of flume experiments using different sizes of material has been carried out to obtain such information. (Lau)

**Transverse Mixing under Ice Cover.** Data from field experiments in several river reaches under both ice-covered and open-water conditions have been analyzed to show that the dimensionless coefficient  $E_z/U.H$  is the same for ice covered and ice free flow. The data also showed that the mixing coefficient increased with sinuosity. (Lau)

**RIVMIX MK II: Users Manual.** RIVMIX MK II is a computer model capable of predicting the transverse spreading of a non-conservative pollutant released into a natural stream as a continuous steady source. This is an updated version of RIVMIX MK I which deals with the spreading of conservative substances. The Users Manual contains details of the model, input data arrangement and a listing of the computer program. (Krishnappan)

**Prediction of Sediment Sorting Using MOBED: Users Manual Update II.** The model MOBED was updated to include a sediment-sorting algorithm. With this algorithm, the model is now capable of predicting the size distribution of the bed sediment as a function of time and distance along the river in addition to predicting the usual water and bed level changes and other hydraulic and sediment transport characteristics. The details of the algorithm and the changes that resulted to the source code and input data arrangements as a result of the inclusion of the algorithm are described in a users manual update. (Krishnappan)

**Modelling of Flood Plain Flows.** A turbulence model has been developed to predict the three-dimensional velocity distribution and the distribution of shear stress around the wetted perimeter of compound channels consisting of a main channel and wider, shallower flood plains. The model predictions were compared with published data for the total discharge at a given flow depth, the division of flow between main channel and flood plain sections as well as the shear stress distribution around the wetted perimeter. (Krishnappan, Lau)

**Resistance of Sand Waves in Reversing Flows.** At the request of Water Resources Branch, Pacific and Yukon Region, a study is being conducted to investigate the flow resistance in the Pitt River, a tributary of the Fraser, when tidal effects give rise to flows in different directions over the sand waves. The tests are conducted in the 1-m flume using artificial bedforms. (Lau)

**Application of MOBED to the Qu'Appelle River between Craven and Pasqua Lakes.** The model MOBED was applied to the Qu'Appelle River between Craven and Pasqua lakes to test the effectiveness of the channel conveyance improvement scheme proposed by the Saskatchewan Water Corporation. The proposal involves several meander loop cutoffs and dredging of the existing channel at several reaches at an estimated cost of 4.5 million dollars. The model predictions (Fig. 22) indicate significant bed level changes with degradation in the upstream reaches and aggradation in the downstream reaches near the lake. (Krishnappan)

**Flathead River International Study Board: Water Quality and Quantity Technical Committee.** Contribution to the baseline data report on the water quality and quantity of the Flathead River in the upper basin was made as part of the impact assessment of the proposed coal mine development near Cabin and Howell creeks in British Columbia. (Krishnappan)

**Effects of Relative Flow Depth in Physical Models of Sediment Transport in Uni-directional Flows.** Experiments in the 2-m flume were carried out to establish the scale effects in physical models dealing with sediment transport in river flows. A paper describing the experimental procedure and results has been submitted to the IAHR symposium on scale effects in modelling sediment transport to be held in Toronto in 1986. (Krishnappan, Engel)

**CSCE Task Group on River Models.** At the request of the Research Committee of the Hydrotechnical Division of the Canadian Society of Civil Engineers, a task group was initiated, chaired by B.G. Krishnappan, to evaluate the existing (public domain) river flow models. A total of 12 models dealing with both steady and unsteady flows in rigid and mobile boundary channels were selected and will be evaluated by applying them to identical data sets. (Krishnappan)

**Migration Speed of Dunes.** Different methods of computing dune speed from bed profile records as well as the geometric characteristics of dunes are being investigated using experiments in the 2-m flume. The migration speeds of dunes are useful for the computation of bed load discharge in large rivers, whereas bed form heights and lengths provide information

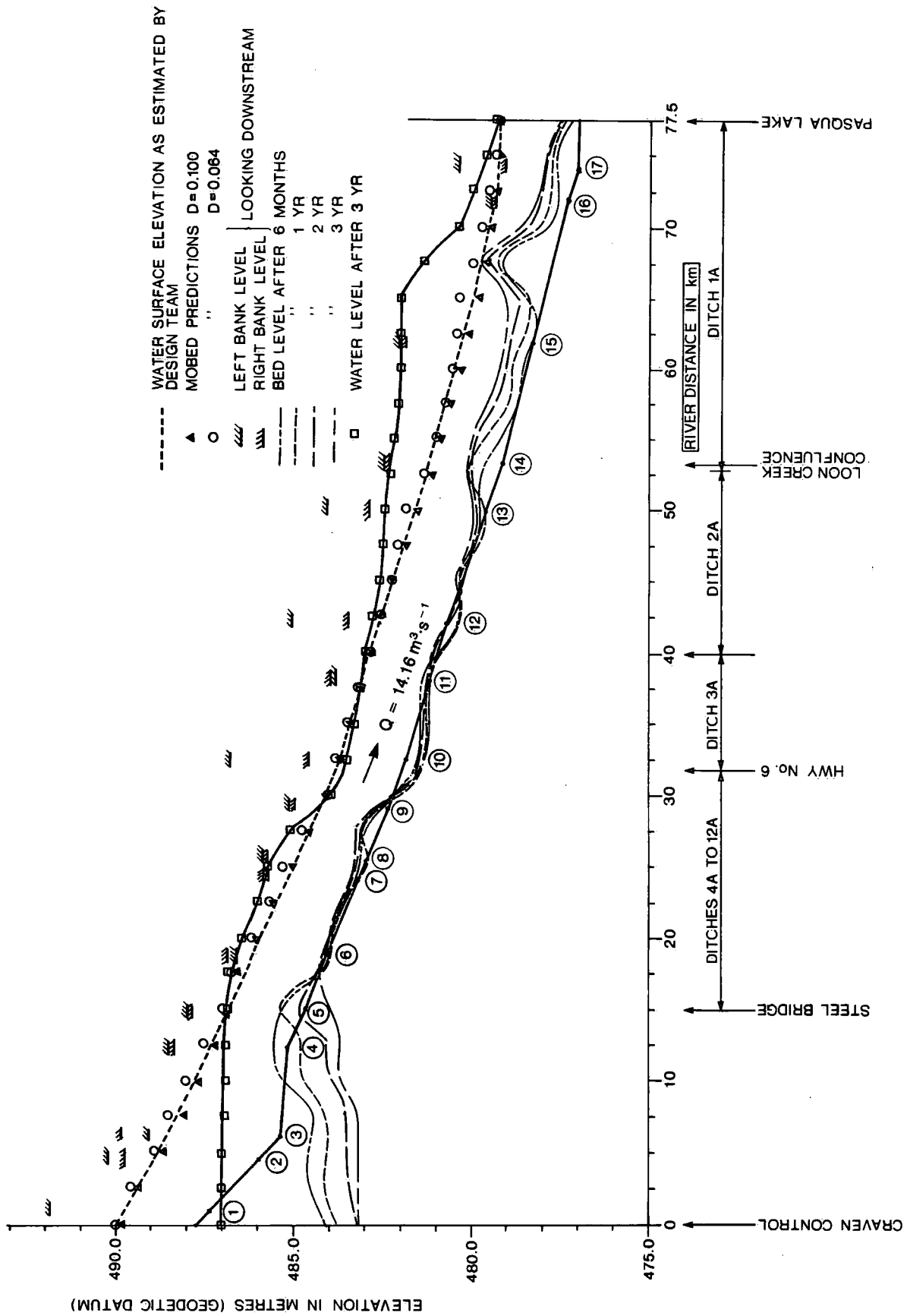


Figure 22. Variation of bed levels as predicted by MOBED for the Qu'Appelle River reach between Craven and Pasqua lakes.

concerning flow resistance and changes in bed elevation of navigation channels. A typical dune bed in a large sediment flume is shown in Figure 23. (Engel)



Figure 23. Dune bed in large sediment flume.

**Hydraulic Efficiency of Bed Load Samplers.** Studying the hydraulic efficiency enables more accurate estimates of local sediment transport. Tests in the 2-m flume are used to obtain the efficiency of the basket and the Helley Smith samplers, and to determine calibration curves. (Engel)

**Performance Characteristics of Current Meters.** Experiments were conducted in the towing tank at the National Water Research Institute to investigate the effect of the 15-lb, 30-lb, 50-lb and 100-lb Columbus type sounding weights on the performance of the Price 622AA current meter when used with the WR2 hangar. The analysis showed that a meter should be used with the same suspension configuration for which it is calibrated. Failure to do so may cause errors of several percent at some speeds but always in excess of  $\pm 0.5\%$  at virtually all speeds. (Engel)

**Development of Current Meter Rotors.** A plastic rotor design has been successfully modified to improve performance. Preliminary tests have indicated that a reduction in threshold speed from 4 to 2 cm/s can be achieved, which is important for low flow measurements. The final design will be supplied to the Water Survey of Canada for future production. (Engel)

**Evaluation of Water Level Recording Systems.** The performance characteristics of float type and gas-purge type sensors, pressure transducers and satellite platforms are being

systematically evaluated in the laboratory. The results will go to Water Survey of Canada to provide baseline information for the updating of water level recording instrumentation. (Engel)

**Field Studies of River Ice Jams and Flooding.** This is a long-term field observation program, initiated in 1979. Emphasis is on collection of quantitative data needed to address deterministic and statistical aspects of river ice breakup and jamming. Freeze-up and winter conditions are also documented, as they have been found to influence the breakup process. Observations were carried out in the Thames and Grand rivers, Ontario. In the Thames River, serious flooding occurred because of an ice jam near Prairie Siding. Contact and cooperation with other agencies interested in jamming problems have been maintained and expanded. (Beltaos)

**Theoretical Studies of Ice Jams.** Field documentation continues to be obtained for a recently developed conceptual model of ice breakup and a dimensionless expression of equilibrium jam stage. Important aspects of ice jamming phenomena are the conditions at the toe (downstream end) that influence the stability of the jam and thence the peak water levels. A mathematical model has been developed to predict the characteristics of the downstream transition of equilibrium jams (Fig. 24). The model utilizes the granular-mass theory of ice jams as well as seepage and hydraulic resistance equations. Reports are available from the Hydraulics Division. (Beltaos)

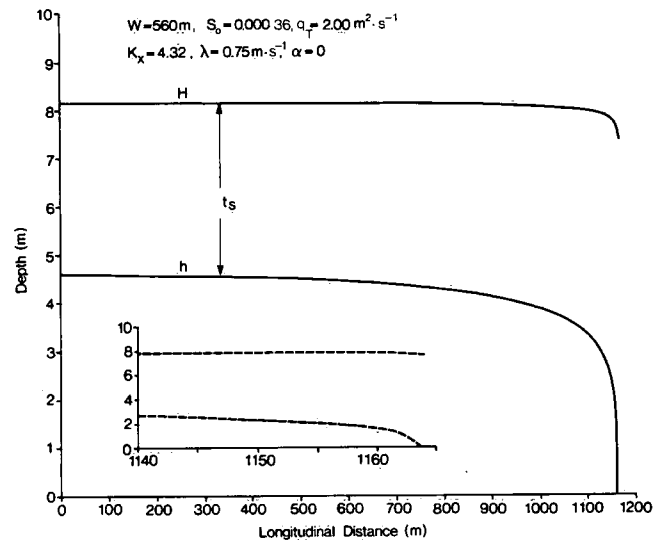


Figure 24. Example of computed ice jam profile for typical conditions in the Athabasca River near Fort McMurray. Insert shows profile in the vicinity of grounding, plotted without distortion.

**Advice to Inland Waters Directorate, Atlantic Region.** Advice on ice-related hydrotechnical problems continues to be provided to IWD, Atlantic Region. The Canada-N.F. FDRP hydrotechnical study on the Exploits River at Badger, Newfoundland, was completed in 1984/85, and a similar study on the Rushoon River at Rushoon is expected to be completed in FY 1985/86.

**Laboratory Studies of Ice Jams.** Tests with plastic blocks have indicated two mechanisms of grounding of ice jams forming at the upstream edge of an intact ice cover: (a) when the

size of submerging blocks exceeds the available water depth, as has been reported by others in the past and (b) when a surface accumulation of ice blocks collapses, leading to a "snowballing" process and formation of very thick jams.

The interaction between an ice jam and a breakable ice cover is an important question that cannot be solved in the laboratory using blocks and sheets of plastic to simulate ice. Work has been in progress to develop an ice-substitute material that, at room temperature, would have appropriately scaled down strength properties. (*Beltaos*)

**Working Group on River Ice Jams.** The National Research Council of Canada has formed a Working Group on River Ice Jams, chaired by Dr. S. Beltaos. Work is nearly completed on the Group's four initial tasks, i.e., guidelines for field data collection programs; guidelines for extracting ice breakup data from hydrometric station records; identification of research needs; and compilation of case studies. The Group's term has recently been extended by two years to prepare a monograph on ice jams.

**Frazil and Anchor Ice.** A cooperative field study with Hydro-Québec to study the frazil and anchor ice in the Lachine Rapids near Montreal and their hydraulic effect was conducted in the winter of 1984/85. The field study was to assist Hydro-Québec's Archipel Project, which is the construction of a low head power station at the rapids.

A photographic study on crystallographic evaluation of frazil crystals was completed.

The data on the frazil effect on water flow in the Beauharnois Canal collected in the winter of 1983/84 are now completed.

The laboratory setup for studying the hydraulic effect of frazil formation in flowing water is nearing completion. (*Tsang*)

**Modelling Runoff Transport in Drainage Networks.** Investigations were undertaken under the sponsorship of the Ontario Ministry of Transport and Communications to complement previous studies by focussing on special structures not investigated earlier. The results of these and earlier investigations were implemented by MTC in their design procedures. The testing of these procedures by MTC indicates that these savings could reach almost 3 million dollars annually depending on the level of road construction activities.

Other poorly understood aspects of runoff transport are the head losses at channel and conduit junctions. Recognizing the importance of junction head losses, the American Public Works Association, through its Ontario chapter, approached the Institute with a request for joint study of junction head losses and provided most of the study funds. Two types of junctions have been studied: T-junctions of a main with a perpendicular lateral and T-junctions of two opposed laterals and a single outfall. In these investigations, a new junction design that reduces typical losses by more than one half was developed.

**Waterford River Basin.** Effects of urbanization on water resources in the Waterford River Basin (Newfoundland) have been studied for several years in cooperation with several federal and provincial agencies. In the first phase of this study, urban runoff processes in fully sewered areas of the Basin were investigated. The study results include the characterization of runoff quantity and quality in the study area, detailed recommendations for the modelling of runoff and model selection, and recommendations of policies and measures to be implemented in future urban developments. Such policies and measures would reduce adverse effects of urbanization and reduce the costs of any abatement measures.

In the second phase of the study, the modelling of stream-flow for the entire basin has been initiated using the Hydrologic Simulation Program — Fortran (HSPF) model. The results of the second phase will indicate the impact of progressing urbanization on flows in the Waterford River. (*Marsalek*)

**Pollutants in Urban Runoff.** Further studies of pollutant sources and their transport were undertaken in two Burlington test catchments. These studies addressed the problems connected with both the conventional and the toxic pollutants.

An evaluation of the rainwater contribution to urban runoff quality was carried out using data from the Blair Road site. It showed that a significant portion of certain pollutants was derived from rainwater and not from the land. Some field data showing the rainwater and runoff pollutant loadings are shown in Figure 25. (*Ng*)

Using the field data on persistent toxic substances in urban runoff, estimates of annual loadings of toxics transported by urban runoff in the Canadian Great Lakes Basin were prepared. These loadings confirm the earlier International Joint Commission finding that urban land runoff belongs to the major sources of toxics in the Great Lakes Basin. Four groups of toxic pollutants were studied: trace elements, polyaromatic hydrocarbons, PCBs, and organochlorine pesticides. Among these groups, trace elements contributed the highest loadings. In particular, the annual loadings of zinc and lead were almost 300 t-yr<sup>-1</sup> and 100 t-yr<sup>-1</sup>, respectively. (*Marsalek*)

**NATO Workshop on Urban Runoff Pollution.** This workshop, funded by NATO, was held in Montpellier, France, from August 26 to 30, 1985, with J. Marsalek serving as the program director. The workshop provided a discussion forum for about 40 invited leading experts from 14 countries. Workshop activities produced state of the art reviews on and future research directions for such discussion subjects as sources of pollution in urban runoff, toxic substances in urban runoff, modelling of runoff quality and impacts on receiving waters, and runoff quality control and management. The final workshop proceedings will be published in early 1986. (*Marsalek*)

**Support of UNESCO Activities under the International Hydrological Program (IHP).** In support of the UNESCO activities under the IHP, final drafts of four chapters for two UNESCO manuals on urban drainage design and acquisition of supporting data have been prepared and submitted to UNESCO. These chapters cover urban drainage design parameters, drainage hydraulics, collection of urban hydrological data, and organization of data collection programs. When published in 1986, the UNESCO manuals will provide authoritative and comprehensive guidance for urban drainage design, with a special reference to the conditions in less developed countries. (*Marsalek*)

**Toxic Contaminants in Urban Runoff Draining into the Upper Great Lakes Connecting Channels (UGLCC).** Evaluation of loadings of toxic contaminants in urban runoff draining into the Upper Great Lakes Connecting Channels has been initiated. Toward this end, field sites for the monitoring of toxics in runoff have been established in Windsor and Sarnia, and additional sites will be selected in Sault Ste. Marie. Runoff samples have been collected in storm sewers as well as at combined sewer outfalls. Collected samples are analyzed for four groups of persistent toxic substances: PCBs, organochlorine pesticides, polyaromatic hydrocarbons, and toxic inorganics. Field data will be used in conjunction with computer simulations to produce monthly loadings of toxic substances in runoff discharges. Such loadings will then form one of the

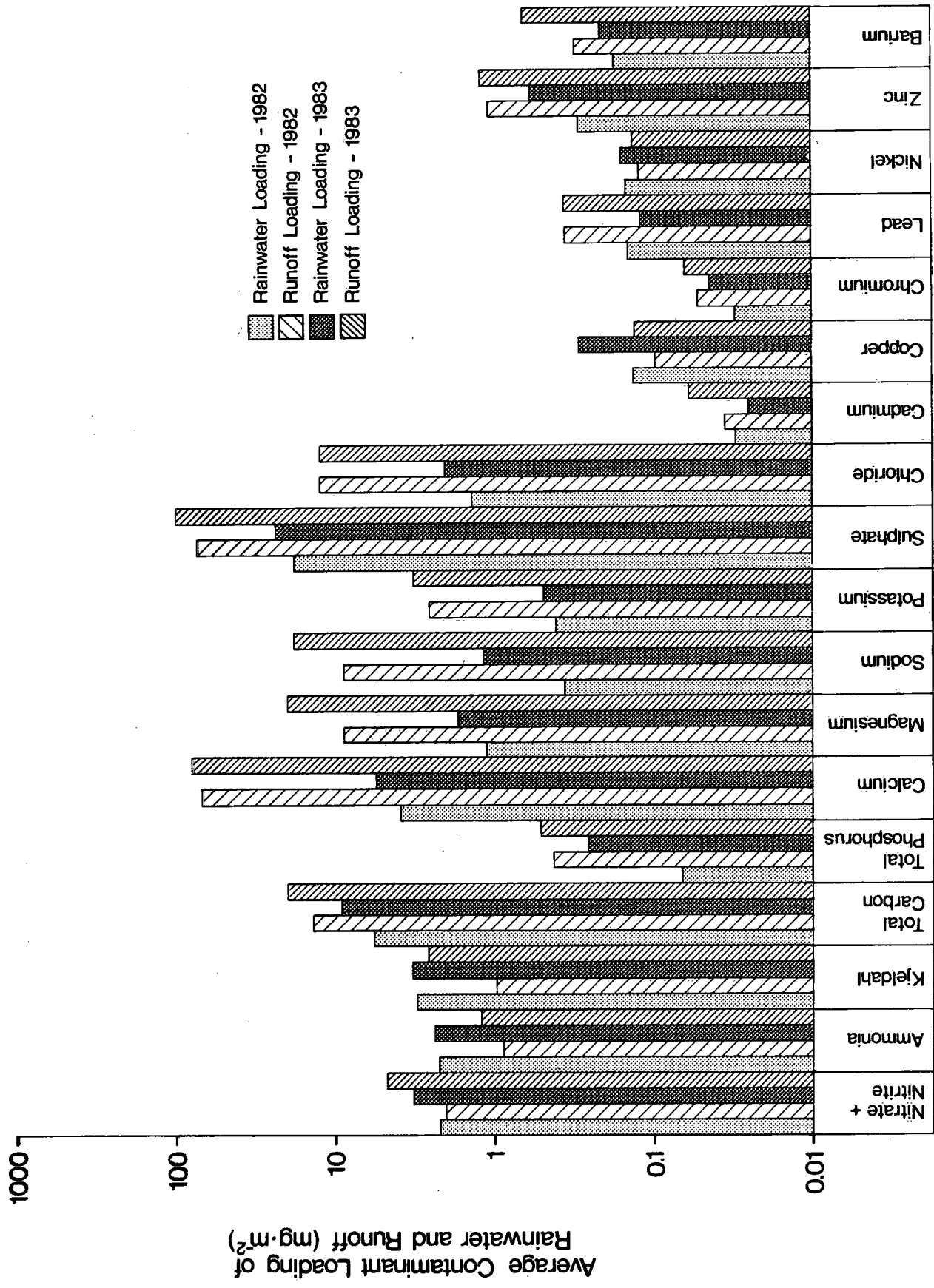


Figure 25. Rainwater and runoff pollutant loadings.

inputs to the inventories of toxics in the Upper Great Lakes Connecting Channels. (Marsalek)

## SHORE PROCESSES SECTION

The work of the Shore Processes Section is concentrated in three areas: air-water interaction, conservation and development; littoral and fluvial sedimentology; and geotechnique.

**Turbulent Mixing beneath Wind-Generated Waves.** A field experiment has been designed to measure some aspects of the interaction between wind-generated waves and turbulence in the wind-driven surface layer. The experiment, to take place in three phases over three years, is being conducted from the National Water Research Institute's offshore tower in Lake Ontario by scientists from both NWRI and the Woods Hole Oceanographic Institution. (Donelan)

**Wave Attenuation.** A laboratory experiment was conducted in the 100-m wind-wave flume to measure the direct attenuation of waves in an opposing wind. The resulting attenuation rates were substantial even when the wave slope was gentle (2.5%). These data will significantly influence the future development of wave generation theories. (Donelan)

**Remote Sensing of Winds.** A composite divided scale model for radar backscatter from the ocean surface was constructed to meet the needs of scatterometry, i.e., the remote sensing of surface winds using microwave radar. The primary scattering mechanism was taken to be Bragg scattering and an equilibrium wave number spectrum was derived on the assumption that the short wave energy density reflects a balance between direct wind forcing and dissipation due to breaking and to viscosity. The effects of tilt and modulation of the short waves by longer waves were included, and the model tests against aircraft scatterometer data with very encouraging results. At low wind speeds, scatterometry was found to be sensitive to surface water temperature because of dissipation of short waves changes with viscosity. For high wind speeds the measurements are less sensitive to water temperature. (Donelan)

**Wave Direction Movements for the Canadian Coastal Sediment Study.** The CCIW Wave Direction Buoy was deployed off Stanhope Lane, P.E.I., in support of the Canadian Coastal Sediment Study (sponsored by the National Research Council Associate Committee for Shoreline Erosion and Sedimentation). Wind and directional wave data were collected from late September to early November 1984, and a data report prepared. (Skafel)

**Floating Tire Breakwater Research.** Mooring load and wave transmission design information, substantiated by field measurements, was presented at a Floating Tire Breakwater Workshop held November 7-8, 1984, in Niagara Falls, New York. The Workshop was co-sponsored by the National Water Research Institute and the U.S. Army Engineer Waterways Experiment Station (WES). Workshop proceedings will be available from WES.

Advice on floating tire breakwaters was given to the Small Craft Harbours Branch, Ontario Region, for locations at Kingston and Belleville. (Bishop)

**Wave Prediction.** A two-dimensional lake wave prediction system developed at the Great Lakes Environmental Re-

search Laboratory in Ann Arbor, Michigan, was acquired and made operational at NWRI. The computer model uses methods developed at NWRI by M.A. Donelan to obtain reliable estimates of wave height, period and direction. (Bishop)

**Caisson Retained Artificial Islands.** A study was undertaken under contract to investigate the modelling of overtopping volumes for caisson retained artificial islands. Modelled overtopping volumes were found to be too large by factors of 2 to 6. Also, spray distribution differed spatially from the prototype. Reasons for these discrepancies were explored; they include the effects of testing with unidirectional (long-crested waves), possible differences in wave groupiness, and shortcomings in the prototype data and analysis. (Skafel)

**Port Granby Waste Management.** A review was prepared for EPS, Ontario Region, of a report on bluff stability and monitoring of the Port Granby Waste Management Area. (Zeman)

**Waste Disposal Sites in the Coastal Zone.** Evaluation of the potential hazards of these sites has been carried out on the basis of proximity to the shoreline, local recession rate, subsurface hydrogeology and the nature of the wastes dumped at the sites (Fig. 26). (Coakley)

**Sediment Erodibility.** A procedure has been developed to make quantitative measurements of the erosion resistance of cohesive sediment using a rotating cylinder apparatus. The erodibility of two Lake Erie tills, not obviously different based on geotechnical tests, was determined. (Zeman)

**Coastal Evolution.** Planning of shore developments requires knowledge to differentiate recession trends that are modern (to a large degree related to cultural activities) from those that are related to natural long-term evolution. A comprehensive study of Lake Erie was concluded in 1984. (Coakley)

**Bottom Shear Stress and Erosion Relationship, Lake Ontario.** A site on the south shore of Lake Ontario at Stoney Creek was selected for a study of the rates and processes of underwater erosion of exposed glacial sediment on the near-shore slope. This is the most common type of substrate in shallow water in the lower Great Lakes, and its erosion has an effect both on the recession of the adjacent shore bluff and on the supply of sediment to the lake. The shear forces caused by waves acting on the bottom of the near-shore zone are important factors in coastal erosion rates. These forces are presently being evaluated at the test site. Waves were measured at regular intervals during the period October-December 1984, and the wave records are presently being analyzed to assess shear forces at the sediment-water interface. A relationship between the shear and the erosion will be tested. (Coakley)

Frames with fixed-transducers were reinstalled at five stations along the profile line at Stoney Creek, and bottom elevation was monitored acoustically and with diver measurements from April to December 1985. Changes from the December data of 1984 were noted in the inshore stations where a sand cover was present, but offshore elevations in the area of exposed till were the same as those previously recorded. (Rukavina)

**Erodibility of Cohesive Sediments.** Erodibility tests on till cores from the Stoney Creek site, including geotechnical tests, have been completed and results have been analyzed. New samples of Lake Erie fine-grained tills have been obtained for

## Lake Ontario Waste Sites

Active Sites : 11

Abandoned : 136

Total : 147

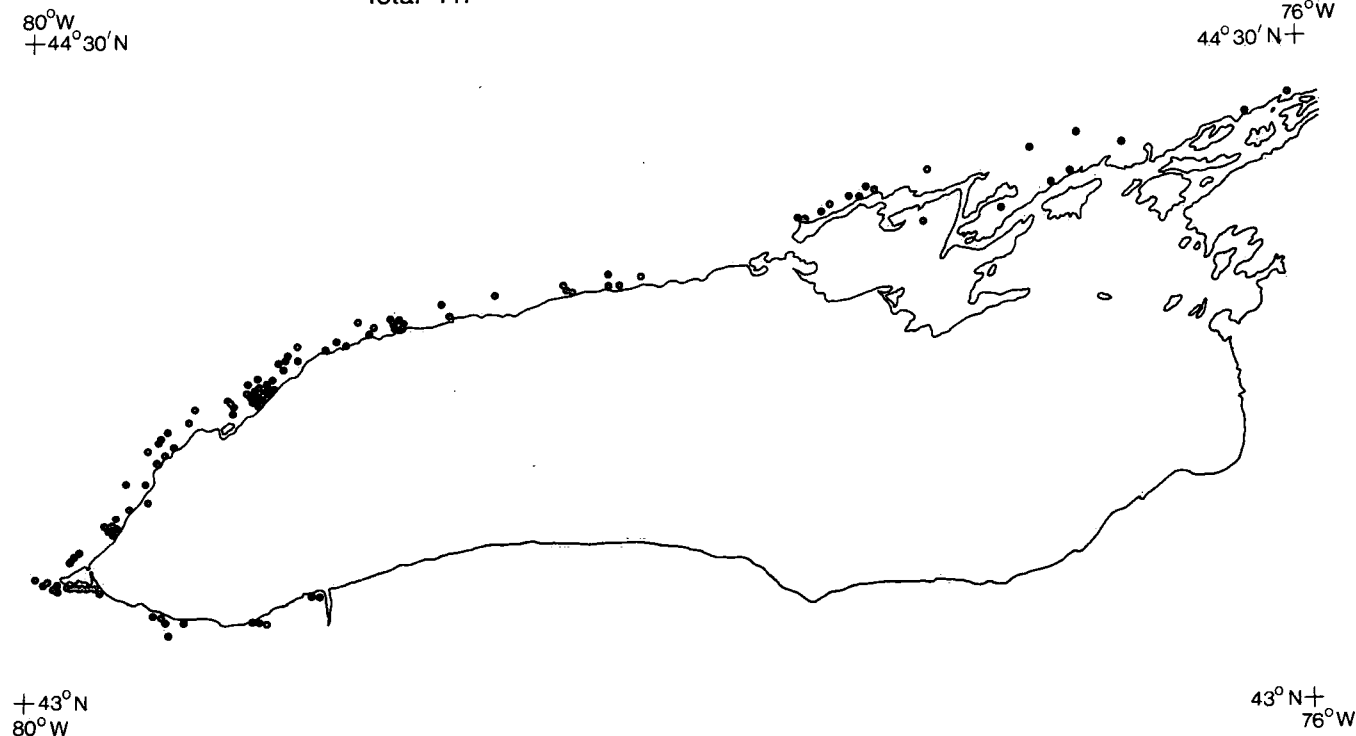


Figure 26. Plot of all waste disposal sites within 5 km of the Lake Ontario shoreline. Plot includes active and closed sites (courtesy of Ontario Ministry of the Environment Waste Disposal Management Branch).

erodibility tests of remolded sediments. A compaction mold, which is to be used for the preparation of remolded samples, is being built. The existing erodibility apparatus has been calibrated for the effect of surface roughness. (Zeman)

### Sediment/Contaminant Dynamics, Toronto Waterfront.

The transport of contaminated sediments from various point sources on the Toronto waterfront may pose a health hazard for local bathing beaches and water intakes. Studies to determine the directional patterns and, possibly, the rate of such transport are now underway (in cooperation with Environmental Contaminants Division and the Ontario Ministry of the Environment). Bottom samples collected in the Humber Bay and Eastern Beaches are being analyzed for grain size and major and trace elements, with a view to identifying potential natural tracers. Concurrent investigations are progressing into artificial means of tracing the transport of fine-grained sediments, which are recognized as major vehicles for adsorbed contaminants. (Coakley)

**Symposium on Cohesive Shores.** Preparations have started for a symposium on scientific and engineering research of rapidly eroding shores consisting predominantly of cohesive sediments. The symposium, sponsored by the NRCC Associate Committee for Research on Shoreline Ero-

sion and Sedimentation, will be held in Burlington in May 1986. (Zeman)

### Coastal Sediment Budget, North-Central Shore of Lake Erie.

Data from the 1979 study of the north-central shore of Lake Erie have been used to develop a coastal sediment budget for the area which examines the long- and short-term changes in coastal erosion and sedimentation and the influence of harbour structures. Results have been reported in a paper submitted to the *Journal of Great Lakes Research*. (Rukavina, Zeman)

**Van Wagners Beach Study.** All sounding records of Profile 18 at Van Wagners Beach have been digitized at points where fixed-transducer data or diver measurements are available. Results for the period 1980–82 are now being analyzed to determine the effects of storms and seasonal water-level changes on the profile form. (Rukavina)

**Lac Saint-Louis Bottom-Sediment Survey.** A survey of the sedimentology and bathymetry of Lac Saint-Louis in the St. Lawrence River was carried out at the request of Inland Waters Directorate, Quebec Region, which is investigating the pollution of the St. Lawrence. Field work was carried out in cooperation with IWD, Quebec Region, and the Quebec Region of the Canadian Hydrographic Service. (Rukavina)

**Great Lakes Near-Shore Sediment Data.** Near-shore file data have been requested by the Environmental Protection Service, Toronto (dredge spoil sites, Sarnia and Owen Sound; PCB Study, Wheatley), Huntco Toronto (geophysical equipment trials, Toronto area), and the city of Port Colborne (local planning). Lake Ontario near-shore data were used in conjunction with lake basin data to select sites for the IJC Lake Ontario Surveillance Program. A description of the near-shore data base was provided to the Ontario Sediment Survey Program Review at the request of WRB. Poster presentations on the structure and contents of the data base were made at the Great Lakes Conference in Milwaukee and the Canadian Coastal Conference in St. John's, Newfoundland. (*Rukavina*)

**Lake St. Clair Bottom Sediments (UGLCC).** Work has begun on the compilation of data on the bottom sediments of Lake St. Clair in support of the UGLCC program and assistance has been provided to the Aquatic Physics and Systems Division in the use of echo-sounding as a means of measuring the thickness of modern basin muds. (*Rukavina*)

**CCIW Open House, 1985.** Two of the displays presented at the Open House in April were a videotape presentation on beach changes and a computer quiz on shoreline facts and issues. (*Rukavina*)

An interactive display featuring the postglacial evolution of the Great Lakes in computer graphics was presented. (*Coakley*)

**Waves and Wave Forecasting.** A section on waves and wave forecasting has been written for a new Handbook of Civil Engineering to be published in 1986. Topics include small amplitude wave theory, wave processes, wave measurement techniques, analysis of wave data, wave statistics and confidence limits, and wave prediction methods. (*Bishop, Donelan*)

**Wave Attenuation by Rough Walls.** Experiments have been conducted in a wave flume to investigate the scale effects of modelling wave attenuation by lining harbour entrances with riprap. Placing rubble at side slopes of 1.5 or 2 to 1 on vertical entrance channel walls is a technique used more and more to correct wave agitation problems in harbours and/or to correct structural problems at the walls. Wave height attenuation was found to be proportional to the wave height raised to the power 1.36, and was found to be inversely proportional to the water depth ( $d$ ) raised to the power 0.36 and to the channel bottom width ( $w$ ). The proportionality factor was found to vary with  $d/gT^2$   $w/d$  and side slope (where  $T$  is the wave period and  $g$  is the accumulation due to gravity). (*Bishop*)

**Measuring Waves with Pressure Transducers.** Experiments to establish the veracity of linear wave theory to predict wave heights from subsurface pressures were completed. (*Bishop*)

**Wave Loads on Submarine Pipelines.** Wave loads on submarine pipelines are normally predicted using the Morrison equation, which uses empirically determined drag and inertia coefficients. Values that should be assigned to those coefficients remain very uncertain. In northern locations, where pipelines may be laid in open trenches to avoid ice damage, little or no data exist. A series of laboratory tests are being done to determine the drag, inertia, and lift coefficients for pipelines in trenches. Details of the flow field were also examined. This work is partially funded by the Panel on Energy Research and Development. (*Skafer*)

## TECHNICAL SERVICES SECTION

**Scientific Support Unit.** Technical staff provide support to scientists and engineers conducting basic and applied research in the Hydraulics Laboratory and related field projects.

A marked increase of field support was provided for the frazil, anchor ice, ice jams and flood studies. Support was also provided to third parties under the Department's cost recovery policy.

Tests to determine the head loss through various components of an automatic sediment sampler were done for the Water Survey of Canada.

**Geotechnical/Sedimentological Laboratory Services.** The sedimentology laboratory classifies sediments by their particle size and determines organic and total carbon in sediments. The geotechnical laboratory undertakes tests of soils as a structural material. These laboratories provide support for Institute projects as well as other government agencies, universities and the private sector. Cost recovery is used.

A new sedigraph was purchased which will be computerized to provide a more accurate and efficient service; modifications have also been made to the settling tube.

A summary of tests and analyses performed follows.

Tests and analyses	1984/85	1985/86
Particle size analysis		
NWRI	1105	1471
Universities	56	150
Private sector	31	53
Carbon analysis		
NWRI	242	4050
Sediment separation		
NWRI	47	76
Geotechnical tests		
NWRI	10	7

**Laboratory Operations Unit.** Users of the laboratory receive support such as carpentry, machining and equipment maintenance, and the supervision of outside contractors working in the laboratory. Consultations with scientists and engineers on construction problems, the inventory and procurement of materials and supplies were also undertaken. Advice on equipment and facility design, as well as on electronics and mechanics to the many users of the Hydraulics Laboratory, was provided by a group of highly qualified technologists.

A laminar flow flume was constructed for studies on meander formation and a frazil ice flume was constructed for laboratory testing of the frazil ice instrument.

**National Calibration Service.** The tow carriage microcomputer data acquisition system has now been in daily operation for over two years. A more powerful 16-bit computer has been procured to improve operations.

A very high accuracy calibration program for Hydro-Québec was completed under a cost recovery agreement involving the calibration of 65 SIAP current meters which will be used for turbine efficiency measurements. This special calibration required 48 different velocities and 12- to 14-hour days to complete the run.

At the request of Sediment Survey Section, Water Survey of Canada, plans were prepared to have Water Survey of Canada's entire inventory of suspended sediment samplers checked, repaired and calibrated. This work will be completed over a two-year period, after which each sampler will be recalled for recalibration every two years.

The use of the towing tank to calibrate current meters and to perform special tests on hydrometric equipment can be broken down as follows:

	Percent time used
Water Survey of Canada	35.1
Other federal agencies	25.3
Provincial governments	14.9
Universities	5.9
Hydro companies	8.4
Consulting engineering firms	10.4

### ENGINEERING SERVICES SECTION

**Volume Weighted Sampler.** The study of contaminant pathways and fates by Environmental Contaminants Division involves the collection of water samples weighted on the basis of the depth and shape of the water body. A portable Volume

Weighted Sampler System has been developed to automate this process for field teams.

A transport case (Fig. 27) contains a small keyboard with display, a microprocessor controlling a sequencing valve and a battery powered pump. The sampler is designed to work with a portable electrobathythermograph (EBT) as primary sensor input. The operator uses the keyboard to input the depth versus weighting characteristic desired for the sample to program the microprocessor controlling the pump and valve operating sequences. The sampling orifice is mounted on the EBT. At the completion of the EBT profile, the sample collected is integrated and volume weighted against depth and shape of the lake or pond. (Desrosiers)

**Suspended Sediment Sensor Study.** Sedimentologists and coastal engineers have a continuing requirement to measure the mass concentration of bed load and suspended material in streams and coastal zones. Acoustic rapid measurement is not yet possible. Engineering research is underway to find a way to monitor suspended solids reliably. (Desrosiers)

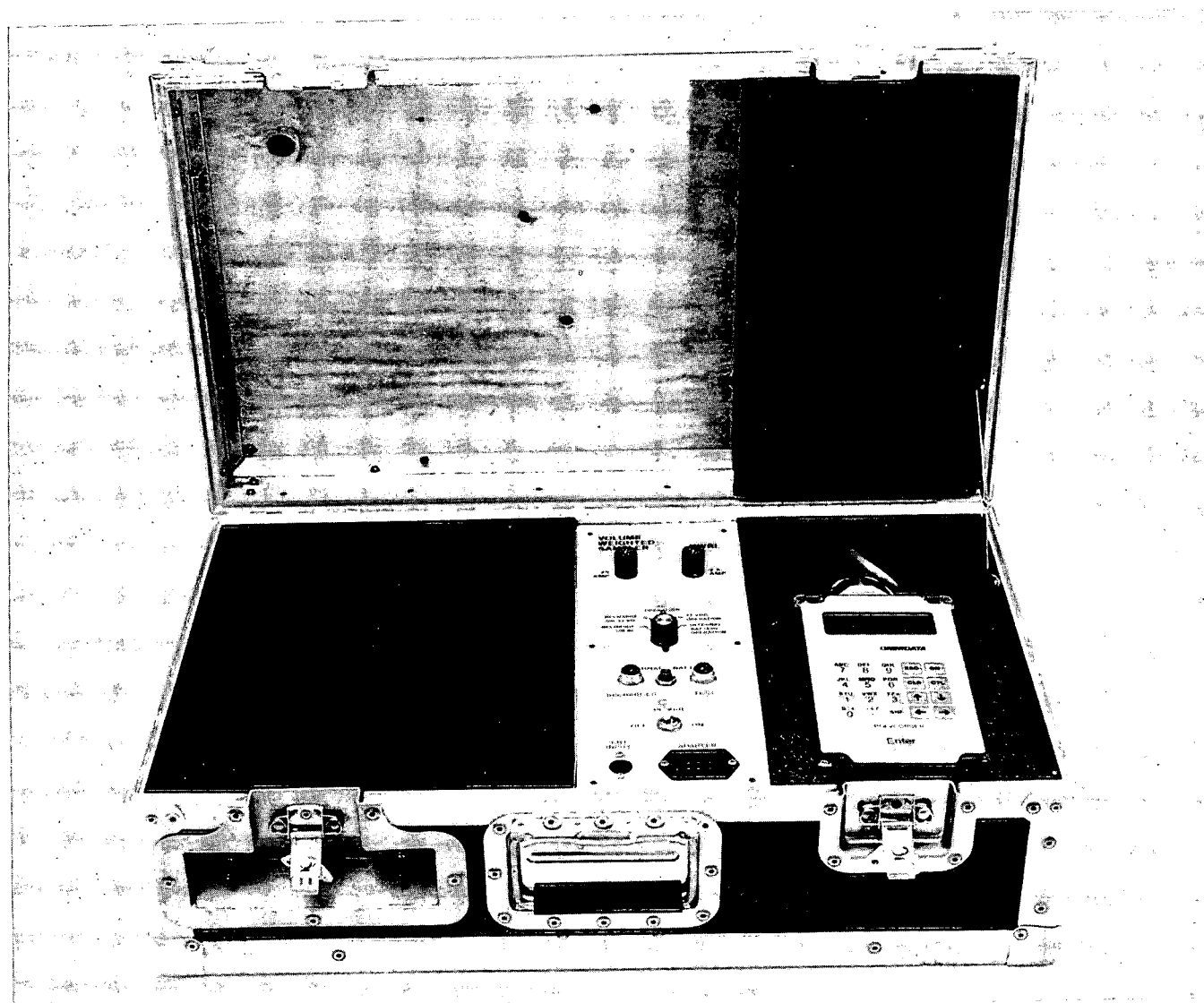


Figure 27. Volume weighted sampler.

**Under-ice Drifter Buoy.** A program by the Aquatic Physics and Systems Division to study currents and mixing in northern lakes required a Lagrangian drifter buoy to operate under an ice cover in order to observe advective currents of low order, i.e., less than  $1 \text{ cm}\cdot\text{s}^{-1}$ . Besides being easily transportable and able to operate at  $-30^\circ\text{C}$ , the buoy can be deployed and retrieved through the ice, and its location can be fixed within a 50-cm circle of error under the ice cover using fish-tracking radio tag techniques. The system has been used on Tagish Lake, Y.T., with good results. (Roy, Savile)

**Frazil Ice Recorder.** Frazil ice formation in river and stream channels influences the conveyance of the channel. Knowledge of frazil ice formation may provide information for the prediction of restriction in winter flows and probability of flooding. In response to a requirement of the New Brunswick River Ice Sub-committee, NWRI has undertaken the development of a frazil ice recorder. A prototype system has been constructed and tests in an icing flume have confirmed the operating principle. Development work is continuing on the prototype toward field trials in the Nashwaak River, near Fredericton, New Brunswick. (Ford)

**Cytometer Development.** Researchers require additional data to obtain a more accurate assessment of biomass and biocontamination. Automation of the process of cell counting and classification would reduce the cost of obtaining this type of biological data.

Flow cytometry appears to be an attractive supplement to traditional microscopy. The literature and commercial systems were reviewed. It was concluded that commercial systems would be too expensive at this time to be justified by most laboratories. A "home built" system was proposed and some of the system components were enumerated. (Desrosiers)

**Program for Industry-Laboratory Projects (PILP).** PILP is the interdepartmental program for stimulating and financially assisting the transfer of technology from federal government research laboratories to Canadian industry for commercial exploitation. PILP activities at NWRI are coordinated by the Engineering Services Section. Equipment for which Contribution Arrangements are now in effect are the frazil ice sensor (Arctec Canada Ltd.), the solid state temperature logger (Metrex Instruments Ltd.), and the lightweight corer (Quest Engineering Ltd.). Another potential transfer being discussed with industry is the NWRI Wave/Wind Direction Buoy. (Roy, Ford, Desrosiers)

**Solid State Logger.** Long-term temperature records are essential for environmental studies. The NWRI Scientific Equipment Development Working Group (SEDWG) decided to develop a single-channel temperature logger using solid state storage devices and microprocessor technology. A unit logger could be a building block in arrays of temperature measurements. Much greater operational flexibility would be possible.

A prototype logger has been designed and constructed. This unit was field-tested and found satisfactory. A contract for the manufacture of five evaluation units of the solid state logger has been completed, and the long-term accuracy and reliability of the design will be evaluated by further field use. The contracting supplier has since received assistance under PILP to transfer this technology from NWRI to their product line. (Ford)

**ICAP Improvements.** The Inductively Coupled Argon Plasma (ICAP) spectrometer has been in use for a number of years by NWRI and the Water Quality Branch. Dr. P. Goulden of the Analytical Methods Division proposed a concept for

dynamic background correction to increase the sensitivity of this spectrometer. In response to a SEDWG request, Engineering Services has designed and installed a modification kit comprising a rotating chopper wheel and associated synchronous detector-preamplifier circuits for 24 spectrometer channels.

This modification has been demonstrated to provide a three-fold reduction in system noise over a short-term integration, which represents significant increase in system sensitivity. A report entitled "Dynamic Background Correction of an ICP Spectrometer" is in preparation. (Desrosiers)

## MANUFACTURING AND TECHNICAL DEVELOPMENT SECTION

The Manufacturing and Technical Development Section (MANTEC) provides technical services in support of scientific and engineering research studies. In fiscal years 1984-86, MANTEC supported a total of 128 studies, of which 114 were in support of NWRI and 14 were in support of non-NWRI studies. The following highlights some equipment and systems developed during these fiscal years. More detailed information of this equipment is contained in various equipment handbooks available from the Section. Other equipment developed by the Section is reported by the Engineering Services Section and other NWRI and non-NWRI clients.

**Snow Corer.** A new box corer for sampling snow was designed and built for the Turkey Lakes project. The corer is designed to take a  $250 \text{ cm}^2$  sample up to 1.2 m long. It is capable of handling snow consistencies ranging from soft and fluffy to firm and containing ice layers. The construction is of type 304 stainless steel. It is equipped with a driver so that it can be hammered into packed or icy material. The front cover can be slid back to enable study of the snow structure or subsampling of various layers. The new unit is lighter, stronger and more rigid than previous models and costs less to manufacture. (Savile)

**Helium Leak Detection Unit.** This unit has been installed to enable pressure case leak testing to  $10^{-9} \text{ cm}^3\cdot\text{s}^{-1}$ .

**Automatic Cycling Pressure Test Vessel.** This vessel has been installed to allow the unattended cycling of the 100 psi pressure vessel. The vessel is controlled by a microprocessor based pumping system which monitors both the hydrostatic pressure and the temperature of the fluid medium.

**Computer Assisted Design and Drafting System.** This system has been installed for the design and drafting of mechanical and electronic drawings and circuit board layouts. The system is based on the IBM-PC Computer Group, using both AUTOCAD and DASH-2 software.

**Metal-Photo System.** This system has been installed to provide for in-house manufacturing of photographic text deposited on aluminum plate, primarily for instrumentation front panel assemblies.

**Snowmelt Sectioning Sampler.** To study the effects of the short-term changes in the melting snow water chemistry at the Turkey Lakes site, a new sectioning sampler was designed and manufactured. It is a completely automated battery-powered 24-bottle sampler. The apparatus design was based on that of a commercial water sampler, incorporating a low power microcomputer. In 1984/85, the apparatus successfully collected over 20 samples. (Dolanjski, Savile)

**Computer-Controlled AC Outlets.** With the increased use of the personal computers in the laboratories of the Institute, there is a frequent need to control devices like pumps, solenoid valves, etc., with the computer. Since at the time the appropriate interfacing device was not available on the market, a unit was designed and built here. At present, the unit can control four outlets, with eight planned for the future. (*Dolanjski*)

## DRAFTING SERVICES SECTION

This Section provides drafting and illustrating support for graphics and visual presentations, technical and scientific illustrations as well as cartographic, mechanical and electronic drawings of a quality suitable for publications.

This Section also provides a photographic service, which includes photography of engineering and scientific research equipment, overhead projection material and slides for conferences and seminars. Outside sources are used for type compositing, printing, reprographic and photo-finishing services.

The Section maintains files of all original drawings, illustrations, and negatives of all photographs and reprographics. This service is provided for the divisions of the Institute and for all other directorates, branches and services within Canada Centre for Inland Waters.

## OFFICE SERVICES SECTION

This Section provides office services, word processing, clerical and record-keeping support to all Sections of the Division operations. Office Services also 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. This Section responds to requests for reprints or copies of unpublished manuscripts, and statistics are kept.

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**Secretary — A. Mueller**

**A/Administrative Officer — S. Hicks  
(assigned to Hydraulics Division by  
Staff Services Division, NWRI)**

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— Chairman

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## NWRI PACIFIC AND YUKON REGION

The Pacific and Yukon Branch of the National Water Research Institute is responsible for the Department of the Environment's water management and limnological research in British Columbia and the Yukon Territory. Formed in 1971, the Branch undertakes applied and basic research to determine the ecological sensitivity and response of regional lakes and rivers to nutrient pollution, biocide contamination and construction of large-scale, hydroelectric impoundments and diversions. Traditional limnological knowledge is not easily applied to the solution of the region's water management problems. Unlike Prairie and Shield systems, most British Columbia and Yukon lakes are long, narrow, deep systems strongly influenced by riverine throughflow and hydrographic variability.

Traditionally, the Branch research program has involved a mixture of longer-term interdisciplinary projects examining the general effects of development (e.g., eutrophication, impoundment) on typical lake or lake/river systems, and shorter-term applied projects aimed at development of rehabilitation strategies at specific sites. In 1983, however, the decision was reached to disband the regional branches of NWRI and to relocate staff to an integrated research facility, the National Hydrology Research Centre, in Saskatoon, Saskatchewan, in April 1986. As a result, the current program focus has been to complete and document ongoing projects prior to relocation. These projects include river eutrophication research in central British Columbia, studies of limnology in Yukon River headwater lakes, and rehabilitation strategies for eutrophic southern British Columbia lakes.

### SOUTHERN LAKES

**Thompson River.** The joint research project with Weyerhaeuser Canada Ltd. continued in 1984/85 and 1985/86. The multiple, continuous-flow facility for periphyton studies was constructed next to the South Thompson River at Chase, B.C. Together with a laboratory trailer, the facility enabled year-round experiments on periphyton accumulation rates and physiology. One experiment examined periphyton photosynthesis for changes in both seasonality and response to the growth-limiting nutrient phosphorus. Six additional experiments have been completed in which the growth kinetics of attached algal communities were examined under the influence of differing N:P ratios and P-pulsing regimes. The influence of natural UV-light on periphyton productivity has also been quantified. Results of these experiments are being analyzed in preparation for publication. Short-term colonization dynamics of periphyton algae were examined using fast-flushing continuous-flow light and dark troughs. Significant differences in periphyton biomass, chlorophyll *a* and algal taxonomic composition between the two parallel troughs were noted within 24 hours. Experiments commencing at the onset of nighttime darkness showed that the rates of algal immigration during the night period were similar in both troughs. Within 4.5 hours of sunrise, however, certain diatom species, most notably *Hanneae arcus* (Ehr.) Patr. and *Diatoma tenue* Ag., selectively emigrated from the dark trough while remaining in the light trough. Better adhering species such as *Achnanthes*

*minutissima* required light deprivation for two photo-periods before significant emigration was noted. Results from substratum-inversion experiments and data on the loss rates of neutral red-stained cells suggested that the mechanism(s) for the rapid differential egress of cells from the dark trough involved an active process which may be associated with changes in cell buoyancy on the disruption of natural light:dark cycles.

Another smaller trough facility was built adjacent to the Thompson River at the Weyerhaeuser Canada Ltd. pulp mill site in Kamloops, B.C. This will provide a direct assessment of the effects of kraft mill effluent on periphyton growth rates and physiology. Two preliminary experiments were completed in October 1985, and the spring of 1986, corresponding to the periods of nuisance periphyton accumulations in the river downstream from the mill. (Bothwell, Jasper, Bolin, Suzuki, Daley)

**Wood Lake.** Thermistor chain data from Wood Lake, located in the Okanagan Valley, were analyzed for internal waves. It was discovered that waves of the first and second baroclinic modes dominated the oscillations of the lake's thermal structure. The lake responded to a wind event by initiating a first-mode seiche, which was followed by a second, as the initial wave was damped. Because the period of the second-mode approximates that of diurnal winds, it is thought that a resonance effect is responsible for maintaining the second-mode oscillations although weak currents were observed associated with second-mode motions. (Wiegand)

**Kootenay Lake.** Two years of thermistor chain records obtained in Kootenay Lake were also analyzed for internal waves. Internal seiches dominated the thermal structure of the lake, while internal surges were an extraordinary feature of the data. The periods of the dominant members of the internal wave field were determined mainly by morphometry, but varied seasonally with stratification. The wind, which initiates internal seiching, also modifies stratification. In a large lake like Kootenay, stratification varies not only spatially but also at time scales similar to those of the internal seiche. Hence the shape and frequency of the waves can vary as they pass through the lake. (Wiegand, Carmack)

### NORTHERN LAKES

**Yukon River/Lake Laberge.** The large lakes and rivers of Canada's North have rich histories as exploration and trade routes and have played an important role in economic development. Their importance as a resource has not diminished owing to their potential use for water storage and power generation. Figure 28 shows a hypothetical northern setting illustrating the central role water plays in social and economic development.

A joint study with Water Resources Branch on the seasonal ice cycle in the Yukon River and Lake Laberge was carried out over the winters of 1984-86. Measurements were made of water temperature, ice accumulation and thickness, snow cover, frazil formation and accumulation under the ice, and

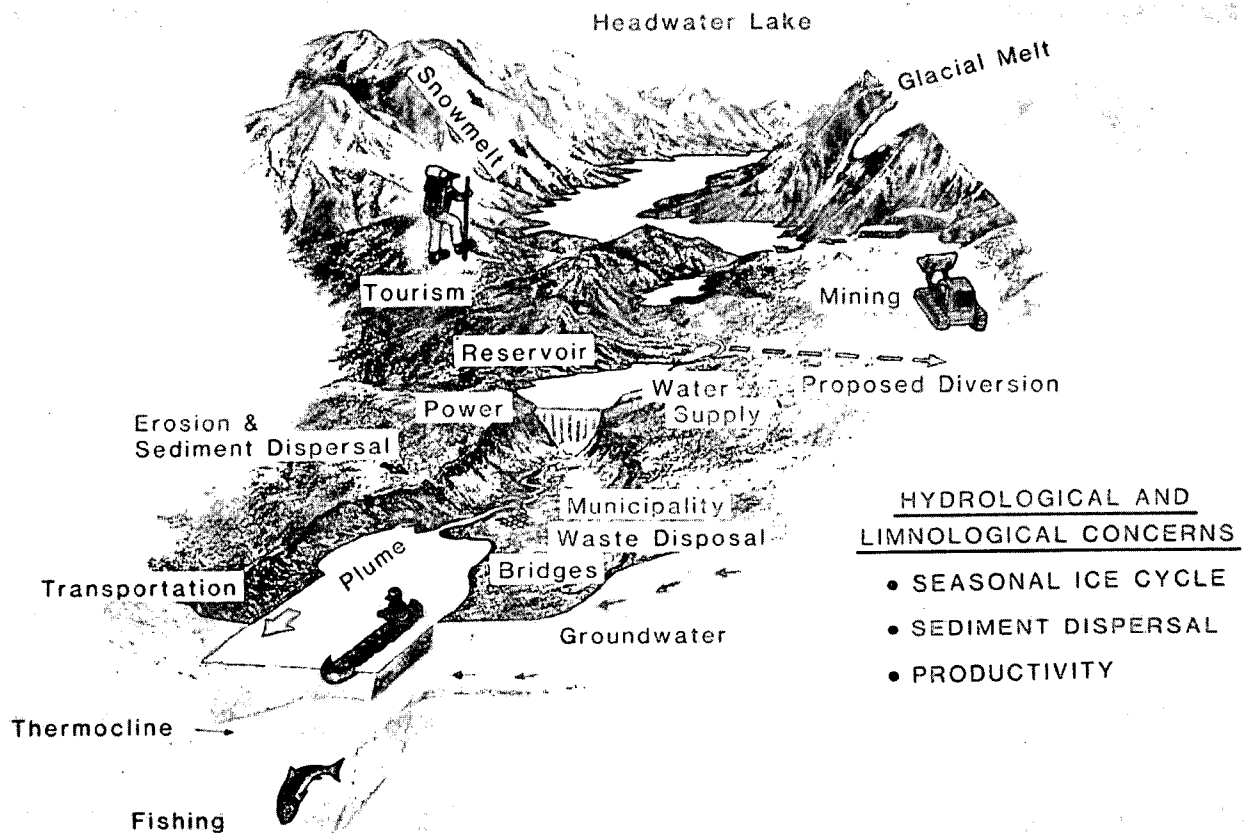


Figure 28. Hydrological and limnological concerns.

degradation of frazil dams. Surveys were also conducted of conductivity/temperature/depth in crosslake and downriver transects. Under-ice moorings recorded temperature and current speed and direction. Detailed through-the-ice measurements of river velocity were also recorded. Several reports on these findings are nearing completion. (Carmack, Alford, Marles, Chamberlain)

Analysis of the data for evidence of internal waves is currently being carried out for Lake Laberge. An attempt is being made to characterize the internal wave field in a statistical sense as well as to describe its seasonal dynamic interaction with river inflow. (Wiegand)

Results from the chemical and biological sampling program on Atlin, Tagish, Marsh and Laberge lakes have been analyzed. Nutrient levels are very low, as are algal and zooplankton biomass, indicating that the lakes are ultra-oligotrophic. Physical factors (temperature, flushing rate, turbidity, and mixing) have pronounced effects on the chemistry and biology of these lakes. With residence times of these lakes varying two orders of magnitude, and the Yukon River being the principal water transfer route (up to 97% of the Marsh Lake input), this suite of lakes is of value to northern reservoir modellers. Marsh Lake is a particularly interesting example of a fast-flushing, shallow northern lake with unusual warming characteristics.

Phosphorus levels are very low ( $DP < 5$  ppb). The major component of total phosphorus was particulate (61% of the growing season total) and is associated with the riverine suspended sediments. Work on the bioavailability of this material is now being conducted. The average growing season total nitrogen was also low (76 ppb), but average nitrate values remained above the detection limit throughout the growing season.

Algal biomass was very low and algal assemblages were dominated by chrysophytes and cryptophytes. Zooplankton biomass was also low, far lower than those reported for smaller Yukon lakes. The growing season mean zooplankton biomass was significantly correlated to total nitrogen but not to total phosphorus, perhaps reflecting nitrogen incorporation into zooplankton protein. (Kirkland, Gray)

## LAKE RESTORATION

**Kootenay Lake.** Many of the important recreational and fisheries lakes in southern British Columbia have undergone nutrient eutrophication, a process often complicated by upstream hydro impoundment activities. One of the most important of these intermontane systems is Kootenay Lake in south-eastern British Columbia. A large study in the mid-1970s by

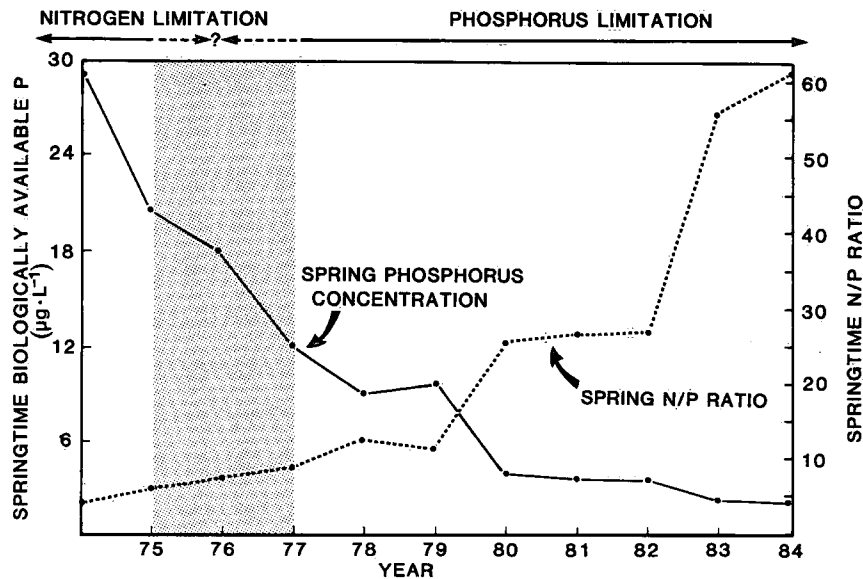


Figure 29. Springtime SRP concentrations and inorganic N/P ratios in Kootenay Lake, B.C., 1974-1984.

this Branch described the effects of phosphorus pollution and its subsequent removal on the lake. The report warned that the combined effects of nutrient removal and upstream impoundments could possibly impoverish the lake to the point that fishery productivity might decline significantly. Recent (1983-85) B.C. Fisheries Branch data now suggest that kokanee and rainbow trout populations may indeed be declining. As a result, an in-depth re-examination of historical data on nutrients, phytoplankton and zooplankton was undertaken in an attempt to link declining nutrients and fish productivity.

Despite a tenfold decline in average water-column phosphorus concentrations over the last 10 years (Fig. 29), average chlorophyll levels have declined by only 20% to 50% (Fig. 30). In addition, the annual average biomass crops of herbivorous zooplankton and of *Mysis relicta*, an introduced invertebrate predator, while variable, also showed no downward trends (Fig. 30). The apparent lack of biological response to phosphorus reductions is explained partly by changes in N:P ratios. At the peak of the P pollution, N:P ratios were below 1, and phytoplankton biomass was strongly N-controlled. Hence, large decreases in P were required to bring springtime N:P ratios back above 10, where P control could be re-exerted. This did not occur until early 1980. Second, there is indirect evidence that epilimnetic phosphorus recycling efficiency has increased as spring P concentrations have declined, so that growing season productivity remained essentially N-controlled even at higher N:P ratios. Under these conditions, large decreases in zooplankton standing crop would not be expected. Therefore, the decreases in fish stocks if confirmed cannot be directly ascribed to a general decline in lake productivity. Proposals for large-scale, long-term aerial fertilization of the lake were rejected as too risky and cost-ineffective. (Daley, Gray)

**Wood Lake.** The sources of soluble reactive phosphorus (SRP) and dissolved inorganic nitrogen (DIN) to the trophogenic zone of Wood Lake during the growing season were evaluated with a new accounting procedure. The external loading (fluvial, atmospheric, groundwater) and hypolimnetic flux were compared with the starting load during four intervals of the growing season (Fig. 31). The starting load was the

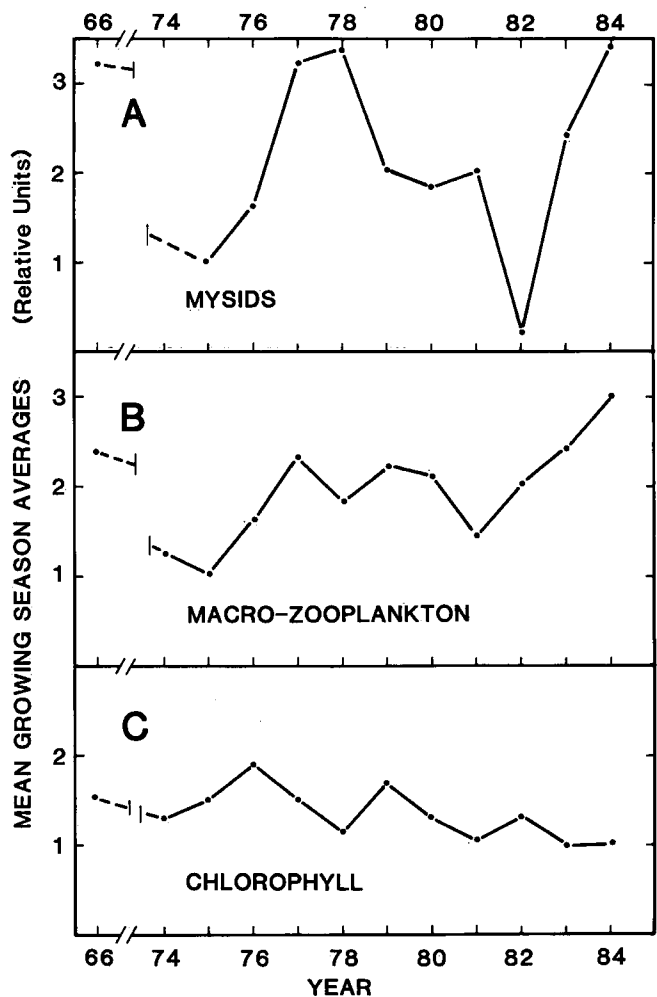


Figure 30. Relative changes in average growing season standing crops of A - mysids, B - macro-zooplankton and C - algal chlorophyll, in Kootenay Lake, B.C., 1966-1984.

content of SRP or DIN in the trophogenic zone at the beginning of each interval. This analysis highlighted the dominance of the starting load in spring and the hypolimnetic flux in late summer and fall. The analysis was useful from a water management viewpoint because it demonstrated that the midsummer blue-green algal bloom was dependent on the starting load of SRP in early summer. This component could be reduced considerably if the spring diatoms were able to take up more SRP and then transport the phosphorus to the hypolimnion. Fertilization of the spring bloom with nitrate was therefore recommended. (Gray, Kirkland)

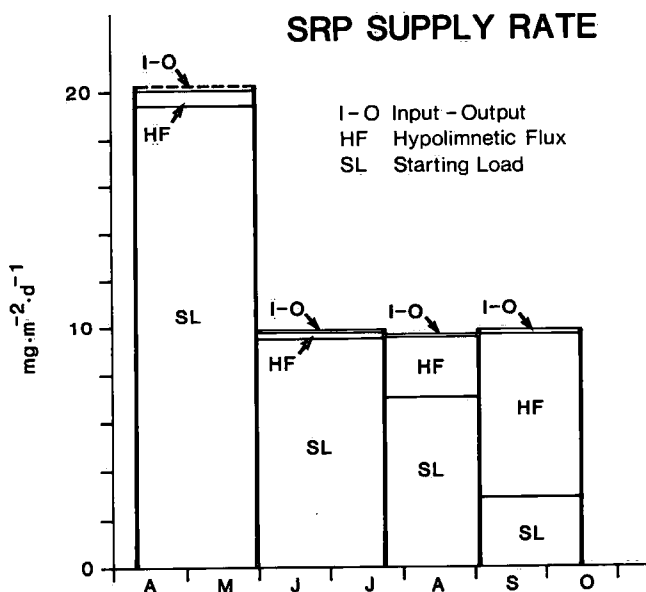


Figure 31. Daily areal supply rate of soluble reactive phosphorus for the trophogenic zone of Wood Lake, B.C.

### ADVICE TO MANAGEMENT

Over the last two years, Branch scientists have provided expert advice and technical information to the following organizations:

- (a) British Columbia Ministry of Environment, Fisheries Branch, on the feasibility of fertilizing Kootenay Lake and on the limnological status of the lake
- (b) British Columbia, Ministry of Environment, Water Management Branch, on loading objectives for six Okanagan Valley lakes using a model developed by Dr. B. Kenny, NWRI, Western and Northern Branch
- (c) British Columbia, Ministry of Environment, Water Management Branch, on evaluating the effectiveness of iron chloride treatment of Wood Lake to decrease phosphate levels
- (d) British Columbia, Ministry of Environment, Waste Management Branch, on a monitoring schedule and parameters for a model to determine the response of Skaha Lake to various sewage treatment options
- (e) Environmental Protection Service on the limnological impact of the Quinsam open-pit coal-mine development on Vancouver Island
- (f) Environmental Protection Service and DIAND on the results of a reconnaissance of the downstream effects of

effluent from the Whitehorse City sewage treatment plant. Tertiary treatment was judged unnecessary at this time.

Staff scientists have also reviewed journal papers and research proposals and acted on student thesis committees.

### STAFF LIST\*

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Office Manager — Ms. S.E. Roberts

#### Researchers

Dr. M.L. Bothwell	biological limnology
Dr. E.C. Carmack	physical limnology
Dr. C.H. Pharo	geophysical 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

\* Due to the Branch relocation to Saskatoon, information with respect to the degrees held by staff members was unobtainable at the time of publication.

### COMMITTEE MEMBERSHIP

C.H. Pharo  
Regional Inland Waters Directorate Health and Safety Committee — Chairman  
DOE Diving Safety Committee  
IJC Flathead International Study Board — Secretary

R.C. Wiegand  
Regional EDP Users Committee

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## NWRI WESTERN AND NORTHERN REGION

The Western and Northern Branch of the National Water Research Institute serves the research needs of the three Prairie provinces and the Northwest Territories. Increasing economic growth and the generally poor quality of water in many prairie communities are causing renewed attention to the historic water supply-demand imbalances in Western Canada. Potential expansion of irrigated and dryland agriculture, increasing demands for water diversion, and the continued development of resource industries and related industrial complexes are raising serious concerns over water supplies and the potential problems of toxic chemicals in western drainage systems. Potential megaprojects in the Mackenzie River Basin are also generating concern for the future of northern drainage systems. These developments are occurring at a time when the federal government is espousing the principles of sustained development without damage to ecological stability.

During the past year research was carried out on the rivers and lakes of the Qu'Appelle Valley (Saskatchewan), Southern Indian Lake and its related reservoirs (northern Manitoba), and the Saskatchewan and Mackenzie River systems. Our activities strike a balance between the practical concerns of toxic substances and the fundamental understanding of nutrient and contaminant behaviour in prairie lakes and rivers. 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.

### TOXIC CONTAMINANTS

**Mackenzie River Study.** Complaints of fish stock degradation together with increasing mining and hydrocarbon developments in the Mackenzie Basin led to a request for research evaluation of organic and inorganic pathways in the Mackenzie River. A synoptic sampling program was completed during summer discharge conditions in 1985; a high flow sampling program is scheduled for July 1986. The NWT Program Office, NWRI-Winnipeg and the Environmental Contaminants Division of NWRI-CCIW are co-participants. (Ongley)

**Saskatchewan Basin Study: North Saskatchewan River.** The rationale and technology developed for the Tobin Lake Project have been extended to the North Saskatchewan River to study the pathways, fate and ecological impact of contaminants in prairie river systems. The purpose of this study is to develop a rational and cost-effective approach for assessing the impact of toxic substances by (1) determining the presence and significance of toxic substances in water and sediment (suspended and bottom) samples from selected locations in the North Saskatchewan River using nematode and bacterial bioassay techniques and by surveying the responses of benthic communities; (2) evaluating the biogeochemical processes involved in the spatial and temporal degradation of selected organic contaminants as downstream recovery occurs; (3) determining the relative contributions of point and non-point sources of contamination to aquatic systems

and assessing the role of the hydrologic regime in the transport of water- or sediment-bound contaminants; and (4) evaluating the ecological impact of selected organic contaminants or benthic organisms. *In situ* determination of chemical stress by benthic organisms (ecotoxicology) may prove more realistic for environmental impact assessment purposes than bacterial or other standard tests for toxicity which are not realistic surrogates of prairie aquatic systems.

The river was divided into nine approximately equidistant sections reflecting point sources, tributary inputs and existing monitoring sites. Each section was sampled in replicate for water, suspended solids and (when possible) bottom sediments. Sampling was conducted during low flow in August 1983 and again during high flow in June of 1984.

The 1983 summer low flow data for physical, nutrient and metallic variables have been made available in an interim report (Ongley, 1984). An end-of-year report for the Toxic Chemicals Management Program (Ongley *et al.*, 1985) will contain spring 1984 data, plus selected organic chemistry, comparative results of nematode bioassay of water versus suspended sediments, and biological species lists from selected sites.

The program has broad relevance to toxic chemical management, both in terms of environmental sensing procedures and control protocols in river and river-lake systems of Canada. It is anticipated that this study will lead to improved monitoring strategies by federal and provincial agencies. (Ongley)

**The Saskatchewan Basin Study: Tobin Lake.** Tobin Lake is a primary sink for residues from pesticide-derived compounds, industrial waste products and other potentially toxic environmental contaminants from throughout the greater prairie region. Chemical properties of individual pollutants are modified and integrated through physical, chemical and biological processes to the extent that the total effect of a large number of minor pollutants may be as great as, or greater than, that of single major pollutants. The objectives of the Tobin Lake study were (1) to establish the relationship between morphological deformities in Chironomidae (Diptera) larvae and contaminant levels in aquatic environments and (2) to develop a "biological screening tool" to detect the presence of toxicants and assess their cumulative effect in aquatic ecosystems.

The potential for deformities in chironomid larvae is immense and the number of responses to chemical stress is great. Deformities may range from mildly abnormal mouthparts (Fig. 32) to grotesque thickening and fusing of all body structures. To date, the usefulness of these deformities as a tool for monitoring environmental contaminants has been limited by the lack of comparable data from stressed and unstressed populations and the lack of standardized procedures and terminology.

Indices based on the incidence and severity of deformation in the antennae of *Chironomus* larvae show that antennae are very sensitive to low-level, chronic contamination. Antennal deformities (Fig. 33) range from simple reduction in length of individual segments to fusion, deformation or loss of all ancillary structures or segments. In comparatively uncontaminated

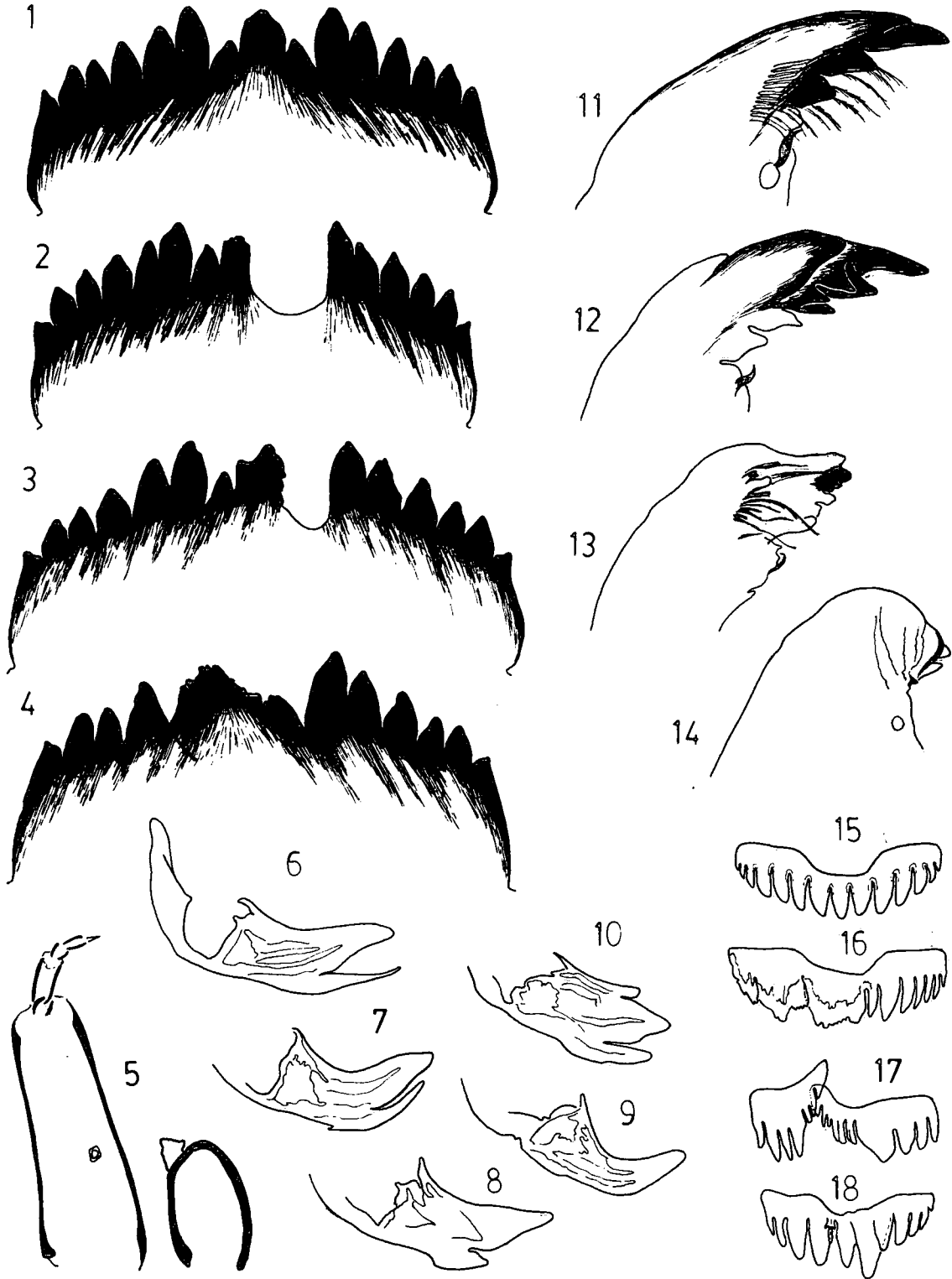


Figure 32. Morphological deformities in the mouthparts of *Chironomus* Meigen: 1 - normal and 2, 3, 4 deformed menta; 5 - normal and deformed antennae; 6 - normal and 7, 8, 9, 10 deformed premandibles; 11 - normal and 12, 13, 14 - deformed mandibles; 15 - normal and 16, 17, 18 deformed epipharyngeal pecten.

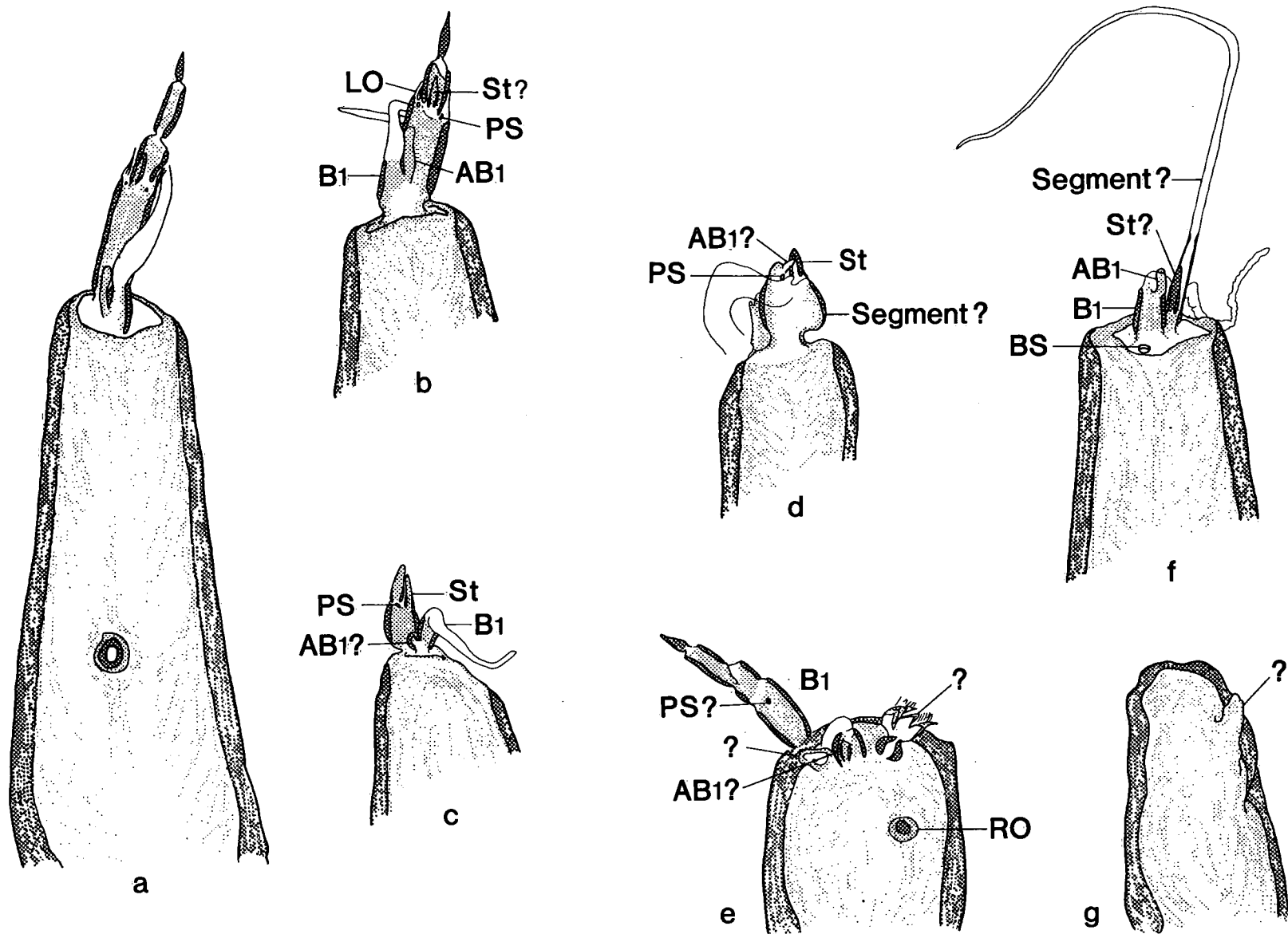


Figure 33. Deformed antennae of *Chironomus Meigen*. (a) Normal antennae. Deformed antennae showing: (b,c) loss of distal segments; (d) questionable second segment; (e) displacement of blade (B1) and accessory blade (AB1), unknown structures and reduced length; (f) fusing of segments and displacement of peg sensillum (PS); (g) fusing of apex of basal segment, loss of ring organ (RO) and unknown structures. Other structures are (LO) organs of Lauterborn, (DP) digitiform processes, (BS) basiconic sensillum. Nomenclature after Warwick (1980). St = style.

areas of Last Mountain Lake, the incidence of deformed antennae was 1.19%; in contrast, the rates were 8.43% and 6.97% in contaminated Tobin Lake. The index of severity of antennal deformation (ISAD) shows the same trends ranging from 0.12 in Last Mountain Lake to 1.64 and 1.19 in Tobin Lake Sites V and VI, respectively. Preliminary experimental data show that both indices decrease as concentration of contaminant increases. These data suggest that the ability of antennae to respond to higher concentrations of contaminants is rapidly saturated and the response is shifted toward the more heavily sclerotized structures of the chironomid head capsule. The inverse relationship between deformed antennae and toxic concentrations indicates the sensitivity of chironomid antennae to low levels of contaminants and suggests increased larval mortality at higher concentrations. Research on the significance of other deformities in the larval head capsule and body is continuing and will eventually be included in an overall biological index for monitoring aquatic contamination. (Warwick)

**The Qu'Appelle River Study.** Concern has been expressed about mercury levels in the Moose Jaw River — Qu'Appelle River-Lake system. The objective of the study was to investigate biogeochemical pathways of mercury and other heavy metals in the river-lake system.

Research revealed that mercury concentrations increased in the river systems below the cities of Moose Jaw and Regina. Microbial methylation of mercury is strongly stimulated by nutrients from sewage effluents and algal blooms — especially at certain times of the year such as autumn when river discharge is greatly reduced (Fig. 34). Methylation apparently is controlled primarily by trophic conditions, rather than by the amount of inorganic mercury from which methyl mercury is

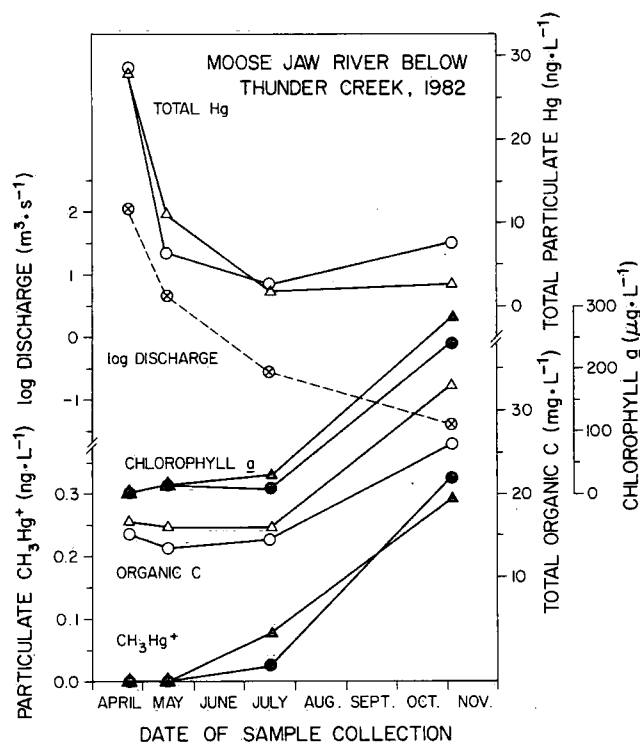


Figure 34. Physical and chemical parameters associated with mercury methylation in the Moose Jaw River at Moose Jaw, Saskatchewan.

synthesized. During the spring flood, when discharge is high and nutrient levels low, methyl mercury levels were low despite high inorganic mercury levels.

The two-year project is now complete. A paper on this work was presented at the Environmental Contaminants International Conference (London, England) and an abstract published in the conference proceedings. A draft manuscript has been prepared for publication. (Jackson)

**The Southern Indian Lake–Notigi Reservoir Study: Methylation and Demethylation Processes.** Mercury levels in fish from Southern Indian Lake–Notigi Reservoir system rose to undesirable levels as a result of the Churchill-Nelson River Diversion. The purpose of the study was to investigate the effects of environmental changes on the microbial methylation and demethylation of mercury in the sediments from former lake basins flooded by impoundment.

Sediment samples were collected for chemical analysis and use in a laboratory experiment to investigate the effects of different physio-chemical variables on rates of methylation and demethylation of mercury by sedimentary microorganisms. The research has shown that organic nutrients introduced into the aquatic environment from flooded land have accelerated the methylation of inorganic mercury from natural sources.

Experimental results have indicated that the rate of methylation is optimized by addition of organic and carbonate nutrients and by the exclusion of both oxygen and sulphide. Comparison of methylation and demethylation processes under different physio-chemical conditions showed that the rate of demethylation did not vary, in the presence or absence of oxygen, if organic nutrients were added. Clay minerals had little effect on the rate of methyl mercury production but greatly increased the rate at which the methyl mercury was subsequently broken down. Thus, the study suggests that enhanced aeration and clay deposition could favour demethylation at the expense of methylation. Further research is currently being done on effects of clay minerals, oxides, humic matter and various heavy metals on the methylation of mercury by sedimentary microbes.

The project is now complete. A seminar and abstract were presented at a conference and a work-in-progress meeting conducted by the Steering Committee administering the Canada–Manitoba Mercury Agreement; a draft manuscript for publication and a final report for presentation to the Steering Committee are in preparation. The project was supported by Canada Water Act funds granted under the terms of the Canada–Manitoba agreement and the funds from the Toxic Contaminants Management Program. (Jackson)

**The Southern Indian Lake–Notigi Reservoir Study: Bioaccumulation of Mercury.** Mercury levels in commercial fish catches from the Southern Indian Lake–Notigi Reservoir System rose to undesirable levels following impoundment and flooding under the Churchill–Nelson River Diversion scheme. Two mechanisms are identified in the literature as routes for mercury accumulation in fish: (1) absorption across the gill membrane from water and (2) ingestion of mercury-contaminated food. The objective of this study was to examine some of the factors governing the transmission of mercury to fish via the latter route. Particular attention was given to the effects of mineral sediment accumulation from bank erosion on the availability of mercury to the benthic community, its effect on the size and composition of the community that acts as the medium of transmission, and the effects of growth rates on body burdens of mercury in individual members of these communities.

Samples of benthic communities and bottom sediments were collected from throughout the Southern Indian Lake-Notigi Reservoir System from sites representing a gradient of different physico-chemical changes and analyzed for mercury content. The results suggest that mineral sediment interference reduces the size of benthic communities and slows their rate of growth by restricting the availability of food resources (probably through burial). Organisms with slower growth rates tend to have higher body burdens of mercury, but because the size of the communities is reduced, less mercury is available for transmission up the food chain. In areas where mineral sediments do not interfere with food availability, body burdens are diluted by rapid growth rates. The reduction in individual body burdens, however, is more than compensated for by the greater populations of benthic organisms inhabiting this more amenable reservoir environment. In the Southern Indian Lake-Notigi Reservoir System, areas in which a large amount of mercury is held within the benthic community correlate with areas in which fish mercury burdens tend to be high. In areas where smaller amounts of mercury are held, fish mercury burdens tend to be lower.

Ancillary work stemming from this research involves an analysis of toxic stress by mercury on the chironomid communities in the different basins. Because of the range of mineral sediment interference created by erosion, the chironomid communities are exposed to a range of mercury contamination. Preliminary evidence shows that deformed chironomid larvae are present in samples from the lake-reservoir system, but at this date, analysis has not reached the point where any definitive statements can be made about the effects of mercury stress on chironomid communities.

Funding for the research on bioaccumulation processes was provided through the Canada Water Act under the Canada-Manitoba Mercury Agreement. (Warwick)

## EUTROPHICATION

**Phosphorus Dynamics.** Hypereutrophic lake conditions and nuisance algal blooms frequently make prairie lake waters unsuitable for municipal water supplies or for most recreational activities. The supply of plant nutrients feeding these blooms is difficult to control at the source. Naturally rich prairie soils, agricultural fertilization practices, and resuspension and recycling of nutrients already in the lakes are likely contributors to the algae problem.

In the present study, physical lake characteristics important to mixing and resuspension of bottom sediments in a large shallow prairie lake were examined to identify and quantify their importance in recycling nutrients in prairie lakes. The application of dynamic concepts to the movement of nutrients through lakes forms a complementary second step toward identification of parameters controlling nutrient availabilities. Accurate simulation of the dynamic flow of total phosphorus may allow rapid quantitative evaluation of engineering alternatives for phosphorus control on the prairie lakes.

A numerical model based on the principles of first order linear dynamics was developed to predict total phosphorus in lakes. The model was tested using published data from Lake Washington and showed that lakes respond as a forced system to changes in inflow phosphorus concentrations. It was concluded that the dynamics of total phosphorus in Lake Washington can be adequately represented by the use of two independent phosphorus sinks: the flushing of phosphorus from the lake through the outlet and the sedimentation to the lake bottom.

The theory of phosphorus dynamics was extended to describe the dynamics of total phosphorus in the upper four Qu'Appelle river-lakes (the Fishing Lakes). Although numerical simulation of total phosphorus was hampered by inadequacies in the quantity and quality of available data, the major trends were successfully modelled. The results suggest that the Fishing Lakes are saturated with phosphorus and no net sedimentation of phosphorus has occurred in the ten-year period for which data are available. This work clearly shows the importance of treating lakes as dynamic systems and has considerable potential for application to other locales. (Kenney)

**Palaeo-indices of Eutrophication.** Palaeo-reconstructions of eutrophication histories have proven valuable to management by presenting the development of eutrophication problems in the historical context. In many cases, however, the "reconstruction" is coloured by the indicator system used and different systems often provide seemingly different stories. This is particularly true of reconstructions based on sediment-borne (benthic) communities and waterborne (planktonic) communities. The purpose of this study was to compare the results provided by the two types of indicator communities and ascertain some of the reasons behind apparent discrepancies.

Sediment samples from the Glenora-B core from the Bay of Quinte, Lake Ontario, were provided to research teams headed by Drs. C.L. Schelske and E.F. Stoermer of the Great Lakes Research Institute, the University of Michigan at Ann Arbor, Michigan, for the measurement of biogenic silica and palaeo-diatom analyses. Warwick (1980) previously reconstructed the eutrophication history of the bay from the same core using subfossil chironomid remains as an indicator system.

Biogenic silica analyses showed that increasing inputs of phosphorus, correlated with cultural development in the bay area, led to the depletion of silica resources in the bay. The process was gradual and offset by silica inputs from tributary sources. In the last seven to eight decades, the pressure on silica resources by phosphorus-stimulated diatom growth became intense and led to silica depletion.

Analysis of subfossil diatom remains indicated that eutrophication of the Bay of Quinte occurred considerably earlier than predicted from subfossil chironomid remains. The discrepancy occurred during a period of rapid mineral sediment accumulation caused by widespread land clearing and erosion which, in turn, caused a period of "artificial oligotrophication" for the benthic community. Comparison of these studies shows that the response of bottom dwelling communities to trophic conditions is mediated by sedimentation processes as postulated by Warwick (1980) in the equation:

$$\text{TROPHY faunal indices} = \text{TROPHY productivity indices} - \text{mineral sediment accumulation}$$

The correlations and comparisons have important ramifications on the interpretation of trophic conditions from contemporary and subfossil community structures. The results of the two studies are presented in Shelske *et al.* (1985) and in E.F. Stoermer, J.A. Wolin, C.L. Schelske and D.J. Conley, "Post-settlement diatom succession in the Bay of Quinte, Lake Ontario," *Can. J. Fish. Aquat. Sci.*, in press.

Research on the Glenora-C core, a companion core to the -B core, is being continued by Dr. B.J. Hahn, University of Manitoba, Winnipeg, Manitoba, using subfossil cladoceran remains as the indicator community. (Warwick)

## PRAIRIE LAKE PHYSICS

**Southern Indian Lake.** Residence time is a primary consideration in calculating chemical and nutrient budgets in aquatic ecosystems. Previous studies on the vertical temperature structure of Wupaw Bay, Southern Indian Lake, showed that the water column was inversely stratified under winter ice cover. The depth of the inverse thermocline varied monotonically along the length of the bay, with the most rapid change occurring in the channel connecting Wupaw Bay to Southern Indian Lake. Since this condition cannot exist in a static environment, the magnitude of the under-ice circulation was measured to determine its contribution to water, chemical and nutrient budgets.

Using prototype instrumentation, two different methods were employed to measure directly the associated under-ice current. Results indicate that frequency temperature fluctuations and mixing do occur in Wupaw Bay and the magnitude of the current is a significant factor in determining the under-ice residence time of water in the bay. Similar results are to be expected in other lakes and bays with similar morphology. This work shows the importance of the winter period to redistribution of chemical and nutrient elements vital to the ecology of lakes. Consideration of the impact on the under-ice environment may be necessary for future development and diversion schemes in the North. (*Kenney*)

**Lake Manitoba.** Physical resuspension of bottom sediments during periods of high wind is thought to be important for nutrient recycling in large shallow lakes. Since conventional sampling techniques usually measure suspended sediments only at the top of the water column, a sampling device was designed to collect suspended sediment samples at closely spaced vertical intervals throughout the water column. The prototype was tested in the shallow southern basin of Lake Manitoba.

The device collected gram quantities of suspended sediment over periods of one month and successfully eliminated the fair weather bias that usually accompanies suspended sediment sampling in lakes. Chemical analyses suggest that resuspended sediment forms a large phosphorus pool which is potentially available to support blooms. Discontinuities in the vertical distribution of the dried mass of resuspended sediments and in the vertical distribution of particle size have important implications for lakewide circulation, the turbulence regime and for the long-range transport and redistribution of sediments in large, shallow lakes.

This device for sampling suspended sediments may have applications for collecting suspended sediments in rivers. (*Kenney*)

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Dr. W.F. Warwick	paleolimnology, benthic biology

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\* Due to the Branch relocation to Saskatchewan, information with respect to degrees held by staff members was unavailable at the time of publication.

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# TECHNICAL OPERATIONS DIVISION

The Technical Operations Division is responsible for a variety of technical support to the field research projects of the Institute. Technical advice and assistance to other federal and provincial departments, agencies, universities and private industries is also provided when possible. Direct technical support was provided to over 70 NWRI studies in each of the last two field seasons including field measurement, sample collection and some analyses of physical, chemical and biological parameters.

The Division arranges for the acquisition and scheduling of research vessels, launches and land sites and coordinates all NWRI field research studies to ensure effective and efficient use of technical staff and materiel and financial resources.

Staff of the Division are responsible for a large inventory of field research-related equipment and provide for the preparation, modification and maintenance of a wide variety of mechanical, electronic and hydraulic sampling and data acquisition systems.

## SHIP SURVEY SECTION

Data gathering on the Great Lakes is accomplished using research vessels as sampling platforms. The Ship Survey Section coordinates the yearly scheduling of the vessels and provides logistics, equipment and technical support to all NWRI studies conducted aboard the three research vessels based at CCIW. The area of operations covered by these vessels during the course of the field season was from Duluth, Minnesota, through Lakes Superior, Huron, Erie and Ontario into the upper estuary of the St. Lawrence River, below Quebec City, Quebec.

**CSS *Limnos*** (Fig. 35). Thirty cruises were completed by the major research vessel *CSS Limnos* in 1984 and 23 during 1985 on Lakes Ontario, Erie, Huron, Superior and the St. Lawrence River. Detailed plans and reports were prepared for each cruise and are available from the Technical Operations Division upon request. A detailed overview of *CSS Limnos* activities can be found in the TOD Annual Activity Summaries for 1984/85 and 1985/86. The multi-disciplinary cruises involved the activities listed below.

**CSS *Bayfield***. Most of the work conducted by this ship was in support of Great Lakes Fisheries Research Branch programs. The ongoing Long-Term Biological Index Monitoring Program continued to collect chemical and biological data simultaneously at selected stations from Lake Ontario on a weekly basis. A total of 32 such cruises were carried out during 1984/85 and 24 cruises in 1985/86. Other work carried out by the *CSS Bayfield* included thermal bar studies, benthos sampling, *in situ* toxicity studies, and deployment and recovery of satellite-tracked drogues.

Microbiology samples were collected and processed weekly in support of the Analytical Methods Division study "Microbiology Responses." The two meteorological buoys located in Lake Ontario off the mouth of the Niagara River were monitored regularly.

**CSS *Advent*** (Fig. 36). During the 1984/85 field season, the *CSS Advent* completed cruises in support of NWRI studies. Eight cruises were conducted on Lake Erie – six in support of the Surveillance Continuity Study to provide historic data suitable for the detection of important changes in Lake Erie, one in

Location	1984/85	1985/86
Lake Ontario	<ul style="list-style-type: none"> <li>5 – Nutrient assessment studies</li> <li>5 – Lake Ontario moorings</li> <li>3 – Long-term bioindex</li> <li>3 – Persistent organic contaminants</li> <li>2 – Chemical forms and availability of phosphorus</li> <li>1 – Diurnal rhythms of planktonic iterations</li> <li>1 – Sediment trap moorings</li> <li>1 – Sediment homogeneity</li> </ul>	<ul style="list-style-type: none"> <li>5 – Open-lake surveillance</li> <li>3 – Persistent organic contaminants</li> <li>2 – Lake Ontario moorings</li> <li>2 – Long-term bioindex</li> <li>1 – Sediment homogeneity</li> </ul>
Lake Erie	<ul style="list-style-type: none"> <li>4 – Sediment and phosphorus resuspension</li> <li>2 – Chemical forms and availability of trace metals</li> <li>1 – Surveillance continuity</li> </ul>	<ul style="list-style-type: none"> <li>5 – Sediment and phosphorus resuspension</li> <li>1 – Sediment homogeneity</li> </ul>
Lake Huron/Georgian Bay	<ul style="list-style-type: none"> <li>1 – Open-lake surveillance</li> </ul>	<ul style="list-style-type: none"> <li>2 – Open-lake surveillance</li> </ul>
Lake St. Clair	<ul style="list-style-type: none"> <li>1 – Chemical forms and availability of phosphorus</li> </ul>	
Lake Superior		<ul style="list-style-type: none"> <li>1 – Open-lake surveillance</li> </ul>
St. Lawrence River		<ul style="list-style-type: none"> <li>1 – Organic and inorganic contaminants</li> </ul>

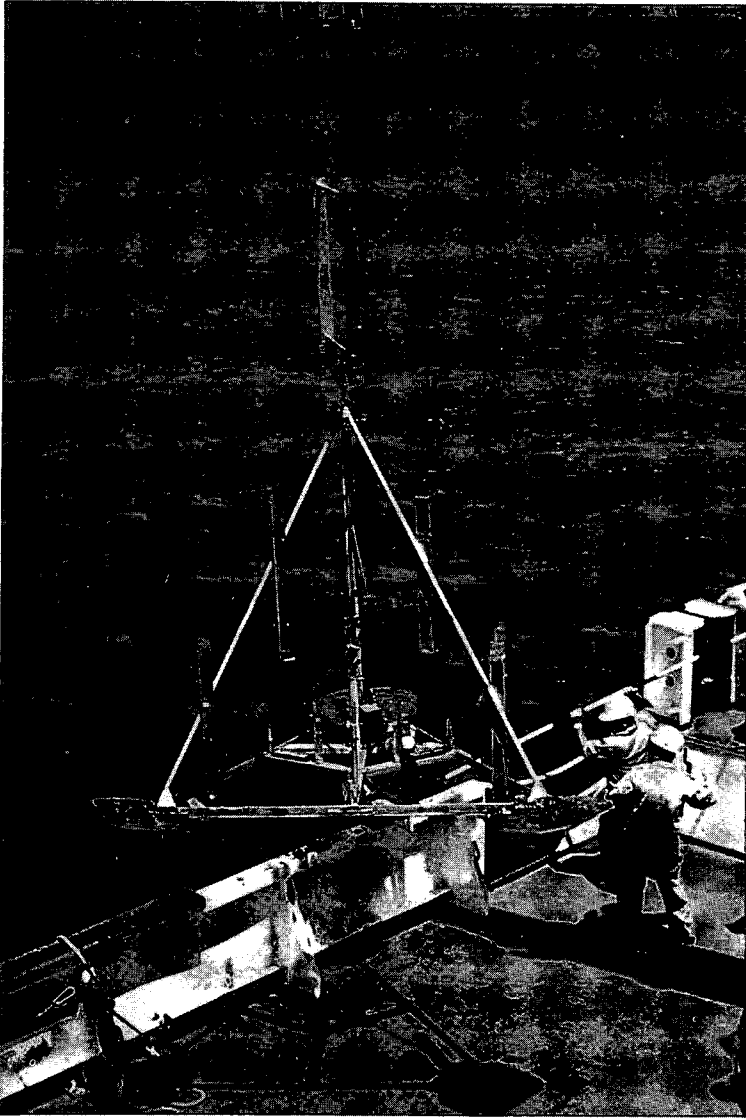


Figure 35. Installing sediment trap mooring from CSS *Limnos*.

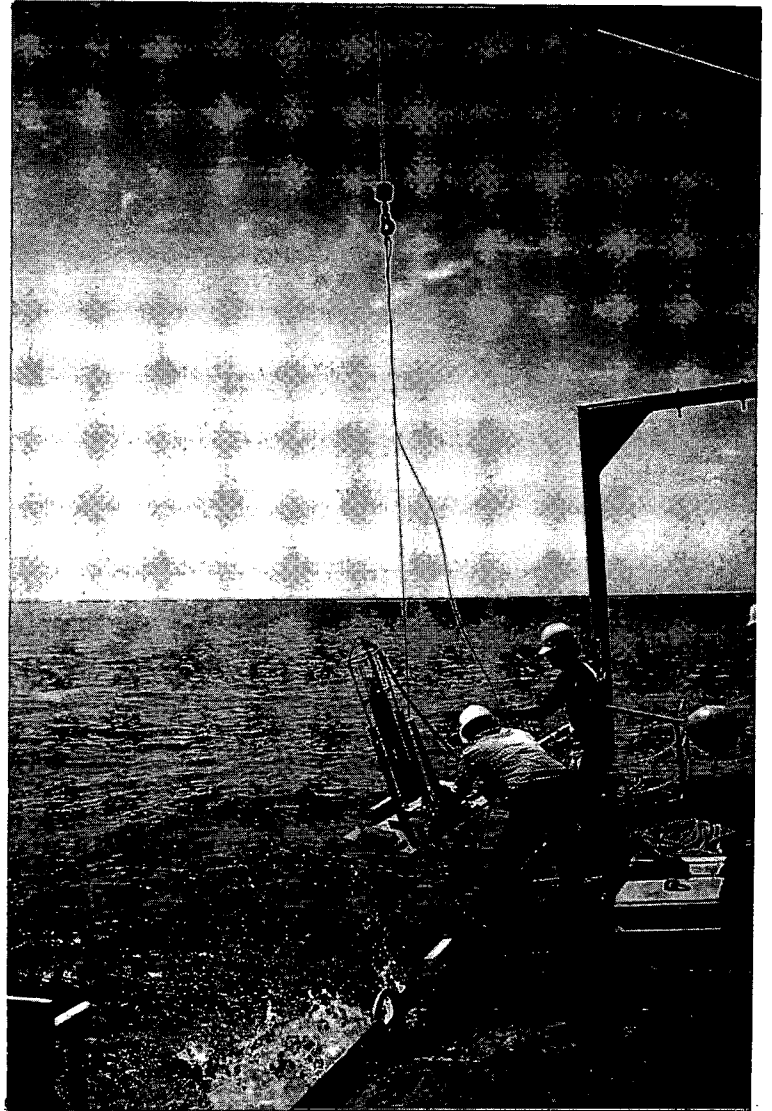


Figure 36. Current meter deployment from CSS *Advent*.

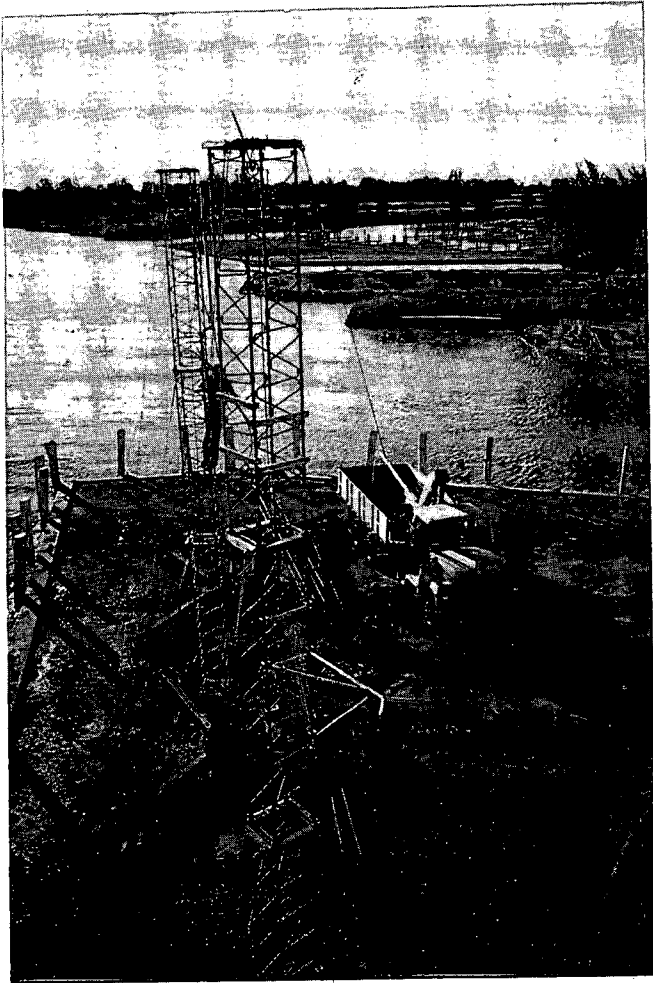


Figure 37. T.O.D. rigger assembles tower from Lake St. Clair study.

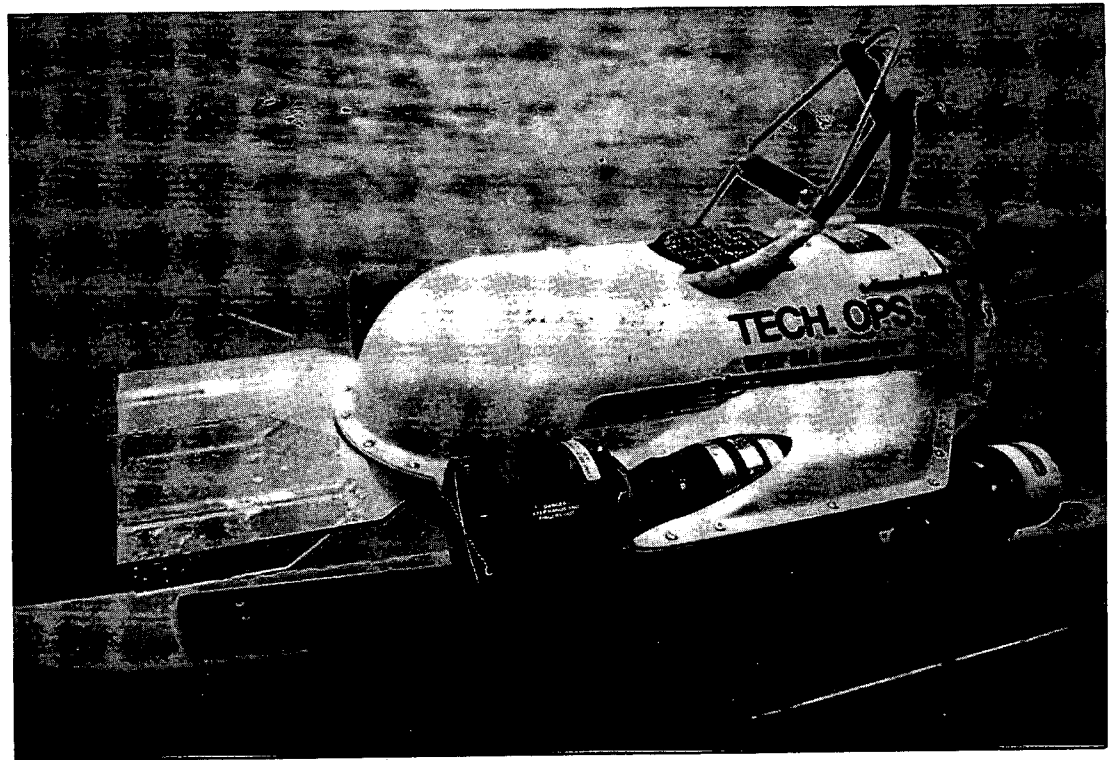


Figure 38. MiniROVER underwater television camera.

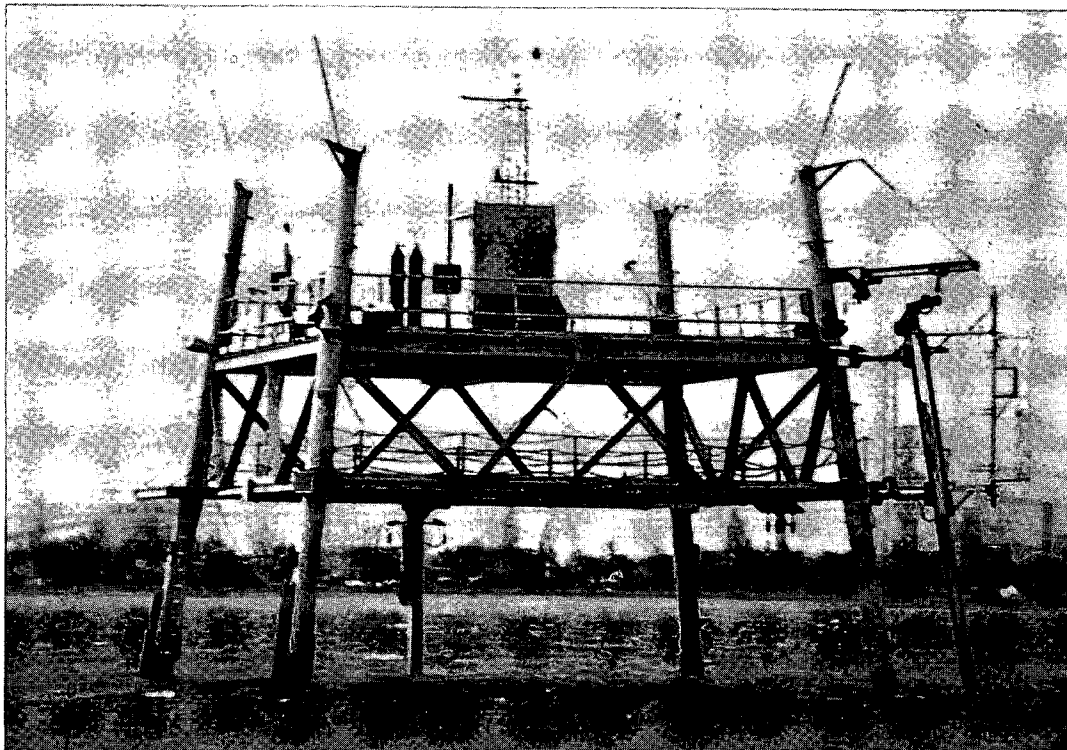


Figure 39. NWRI W.A.V.E.S. tower in Lake Ontario.

support of Sediment and Phosphorus Resuspension and one in support of the Phosphorus Bioavailability Study. Eight cruises were conducted on Lake St. Clair. Seven of these were in support of the Plankton Dynamics Study for the Great Lakes Fisheries Research Branch to study the plankton ecology and dynamics of the lake as well as the impact of contaminants on nanoplankton and picoplankton dynamics; one cruise was conducted on Lake Huron, also in support of the Plankton Dynamics Study.

During the 1985/86 field season, cruises were completed in support of NWRI studies. One cruise was conducted on the St. Lawrence River on Chemical Forms and Potential Availability of Trace Metals which studied contaminants including toxic metal ions arising from sources in Lake Ontario and along the St. Lawrence River. Seven cruises were conducted on Lake Erie – five in support of the Surveillance Continuity Study, one in support of the Bioavailability of Phosphorus Study, and one in support of mooring retrieval with reference to loading from Lake St. Clair. A total of 11 cruises were conducted on Lake St. Clair. These cruises were to provide information on contaminant sources, sinks and historical loading patterns. These cruises also helped to develop a better understanding of factors and chemical properties that control environmental distributions. One cruise was conducted on the St. Clair River in support of the St. Clair River Contaminants Survey to determine the geographical extent of contaminants and localize possible industrial sources of contamination in a 5-km reach of the St. Clair River near Sarnia.

## FIELD SURVEYS SECTION

The Field Surveys Section coordinated and provided technical staff and equipment resources in support to NWRI field research studies throughout Canada and provided technical

advice, equipment loans and support to many Canadian and U.S. government departments, universities and private sector groups. The Section's four organizational units directly supported many shore and launch-based studies as well as providing on-site technical services such as rigging and diving shops, equipment storage and the NWRI video studio facility. Launches, small boats, field research sites, laboratory trailers, sampling equipment and vehicles were acquired and scheduled for field use. Staff were assigned to a wide variety of survey tasks and geographic locations.

**Rigging Unit** (Fig. 37). 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 for loading and unloading ships. Buoys, hardware, winches, generators, mooring arrays and other equipment were prepared for the field. Forklift, heavy-truck driving and trailer towing services were provided. Assistance in the field ranged from Saskatchewan to Prince Edward Island. Another major responsibility was the maintenance of NWRI's 25-unit vehicle fleet.

**Underwater Operations Unit** (Fig. 38). Responsibility was maintained for the safe conduct of all diving operations undertaken by all agencies of DOE and DFO staff at CCIW. The unit maintains close contact with the diving industry and holds a responsible position with the Departmental Committee for Diving Safety which determines and enforces diving policy. The Unit maintains and utilizes a large inventory of specialized research diving equipment, the most notable of which was the remotely operated underwater camera system which was successfully used during the St. Clair River Contaminant Survey. Dive support, training and equipment were provided throughout the past two fiscal years.

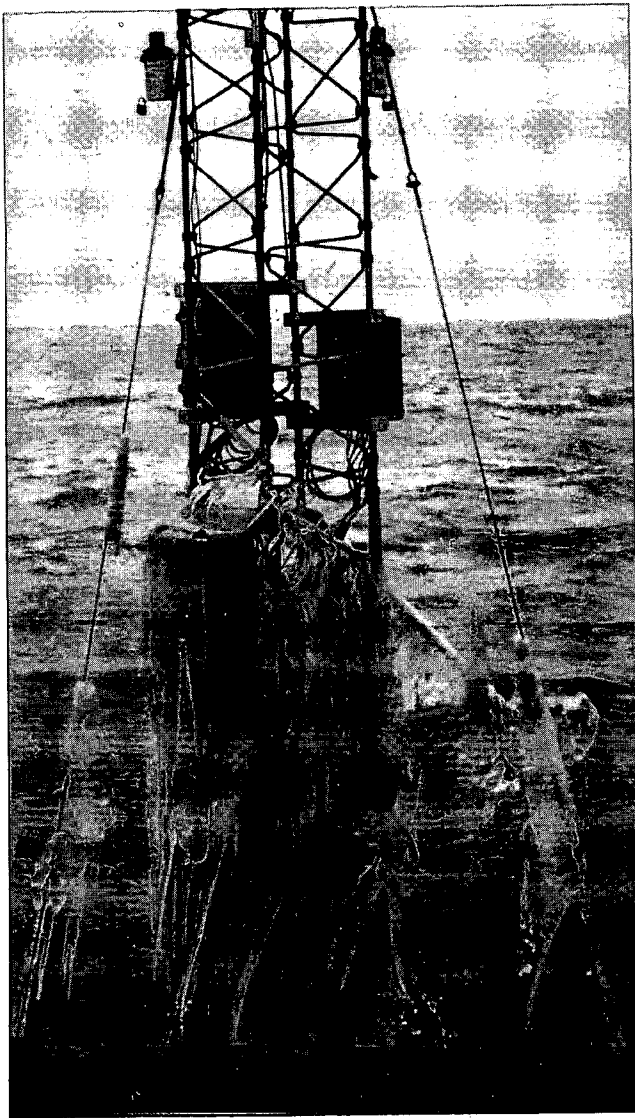


Figure 40. NWRI W.A.V.E.S. tower in Lake St. Clair.

**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 and, as approved, by staff of the other components of CCIW. The scheduling and issue of five vehicles for short-term use by NWRI staff was also provided.

**Field Operations Unit** (Figs. 39, 40). During each of the fiscal years 1984/85 and 1985/86, support was provided to 50 NWRI studies and 15 additional requests from outside agencies. Detailed reports are available for all projects supported by the Unit. Staff supported field studies in all provinces and territories, and are trained and experienced in a wide variety of survey methodologies. The Unit conducted operations from small boats and launches, helicopters and fixed-wing aircraft and, during winter, over-ice operations were conducted using snowmobiles and all-terrain vehicles.

The Unit is also responsible for the maintenance and issue of all coring equipment for NWRI. Technical advice, training and equipment loans are regularly provided to other federal and provincial governments, universities and private industries.

## LIMNOLOGICAL INSTRUMENTATION SECTION

The instrumentation support group provides modification and maintenance of all shipboard electronic data acquisition systems. They are also responsible for the preparation and maintenance of current meters, temperature recording systems, meteorological recording systems, and electronic navigational devices. In fiscal year 1985/86, a major modification was performed. The existing shipboard EBT system was integrated to a transmissometer sensor head to form an EBT/Transmissometer system (EBT<sup>2</sup>). This system was used and field-tested during the latter part of the season.

## STAFF LIST

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

### Field Surveys Section

Head  
 W.B. Taylor

### Field Operations Unit

Head  
 M.R. Mawhinney  
 C. Bisutti  
 T.J. Carew  
 Y. Desjardins  
 E.H. Walker  
 G.D. Bruce

### Field Stores Unit

W.D. Hunt

### Rigging Unit, Head

L.J. Lomas  
 H.E. Greencom  
 G.M. Perigo

### Underwater Operations Unit

F.H. Don

### Limnological Instrumentation Section, Head

J.A. Diaz

### Current Meters and Data Abstraction

J.A. Tyler

### Field Instruments and Meteorological Systems

E.G. Smith

### Ship Survey Section, Head

P.M. Healey

### CSS *Limnos*

B.H. Moore, O.I.C.  
 L.E. Benner  
 K.J. Hill  
 J.A. Kraft, B.Sc.  
 G.G. LaHaie  
 J.E. Tozer

### CSS *Bayfield*

P.R. Youakim, B.Sc., M.Sc.

### CSS *Advent*

S.B. Smith  
 R.J. Hess

# STAFF SERVICES DIVISION

Staff Services Division (SSD) is the lead agency for the provision of administrative, financial, property management, materiel management and records management services to all Environmental Conservation Service (ECS) elements, as well as those of the Environmental Protection Service (EPS), 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) and the Department of Supply and Services (DSS) located at CCIW.

## ADMINISTRATION SECTION

This Section is responsible for providing administrative and financial support to all NWRI Divisions. It also provides various administrative services to the Director, including the rollup of Institute Study Plans, Long-Term Operational Plans and Work Plans, and subsequent quarterly reports to HQ on the Work Plans. As well, it provides Institute-wide functions such as compiling the Conference Travel Plan; chairing the Contracts Review Committee, the CCIW Safety Committee, the CCIW Cafeteria Committee and membership to the IWD Information Technology Committee; providing information in accordance with the Access to Information legislation; preparing and analyzing monthly reports on the utilization of the Institute's person-year resources; liaising and coordinating all personnel-related activities with the DOE Burlington Personnel Office; devising and implementing office automation procedures; providing supervisory functions to all Wang users in ECS components at the CCIW; and coordinating the Canada Savings Bond Drive and the United Way Campaign.

This year a new contract was written for the word processing/ office information equipment, upgrading the central processing system to allow for scientific word processing, faster response time, and additional ports for an expected extension to the system.

A contract was let this year to provide work experience for two handicapped individuals. The original intent of the contract was to provide internal mail delivery service. However, this contract has been so successful that the two contract employees have been assigned other tasks, both inside and external to the Central Registry. As a result of this contract, CCIW has been awarded the "Employer of the Year Award" by the Ontario Association for the Mentally Handicapped.

This Section coordinated the CCIW Open House '85 held April 18-21, 1985. Approximately 30 000 people visited the Centre for what was clearly a most successful venture. Visitors were unanimous in their praise of the friendly reception they received and the quality of the exhibits.

A reference manual was written on the subject of Administrative, Financial and Materiel Management Procedures to provide the Pacific & Yukon and Western & Northern detachments with guidelines on how administrative and financial tasks would be carried out by the Burlington Office this fiscal year.

Visits were organized throughout the year for local public interest and educational groups. Of particular note was a visit

from the Bobingen, West Germany, School Band. A presentation of the CCIW Slide Show and tour of the Centre took place, which was facilitated by German-speaking NWRI staff accompanying the visitors.

The word processing shared resource centre provided support to four research divisions (AMD, APSD, AED and ECD) and the Director's Office staff as well as telecommunications support to the Institute and its detachments in Vancouver and Winnipeg.

The Safety and Security Unit of this Section provided St. John Ambulance first aid and Cardio Pulmonary Resuscitation training courses for staff members. Fire drills were held as well as testing of the emergency voice alarm system.

## 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 on-site agencies. Finally, it is responsible for the telephone (voice and data) system throughout the complex.

Major projects this year include (1) installation of the new SL-1 voice and data system for all units in the complex; (2) installation of a new water disposal method resulting in major yearly recurring savings on sewage surcharges; and (3) implementation of several energy conservation initiatives that have drastically reduced power and water costs.

## 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 (1) implementation of the Automated Procurement Information System; (2) computerization of materiel receipts in the Warehouse Receiving Area, resulting in a more timely payment process in the Finance Section; and (3) automation of the NWRI inventory, enabling updating to the ECS Automated Inventory to be done through the Wang telecommunications mode.

## FINANCE SECTION

The Finance Section provides centralized computer accounting services for all ECS units at CCIW (NWRI, Inland Waters Directorate-Ontario Region, and the Water Quality National 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



Mr. J.D. Smith accepts "Employer of the Year Award" from Mr. J.R. Brokenshire of the Ontario Association for the Mentally Handicapped. *Left to right:* Mrs. E. Rae, Supervisor, Mr. Philip Clark, J.D. Smith, J.R. Brokenshire, and Miss Susan Robertson.

and contracts. The Finance Section participates in the Institute's planning process by completing the annual rollup of Financial and Human Resource Plans and the Institute's Main Estimates.

Laboratory. Telex, telecopier and photocopying services are provided for the Centre. This Section also provides an information service to other government departments and agencies and the general public, providing information on an informal basis or referring inquiries to the proper authority.

### LIBRARY SECTION

This Section provides library services and facilities to all agencies located at the CCIW in support of their research and survey programs. In addition to the day-to-day functions, the following tasks were undertaken this year: (1) conducted a review of library services/operations by completion of a "User Satisfaction Analysis" and on-site visits to research libraries at Atmospheric Environment Service (Toronto) and Bedford Institute of Oceanography (Halifax) from which resulting recommendations were implemented to enhance the CCIW library services/operations and (2) maintenance and practice training sessions of the Library Disaster Plan. Since its inception, several government and private agencies have requested a copy of this plan.

### CENTRAL REGISTRY SECTION

Central Registry provides mail services to all in-house occupants as well as registry facilities for NWRI, Inland Waters Directorate—Ontario Region, and the National Water Quality

### STAFF LIST

**Chief — J.D. Smith, C.D.**  
**Secretary — H. Zrostek**  
**Administrative Officer — C. Kennedy**

#### Administration Section

F. Boyd, Administrative Officer, AED/ECD  
 C. Kennedy, Administrative Officer, SSD/TOD  
 J. Major, A/Administrative Officer, AMD/APSD  
 S. Hicks, A/Administrative Officer, HD  
 E. Jones, Word Processing Operator  
 A. Caswell, Word Processing Operator

#### Building and Property Services

**Head**  
**D.F. Stewart**

#### Support Staff

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G. Johnstone  
K.R. Taylor  
K. McCutcheon  
F. Adams  
A.K. Allaby  
A. Cruz  
J.P. Denomme  
W.A. Johnson  
T. Comiskey  
S. Wynne

**Materiel Management**

**Head**

**D.A. Burton, C.D.**

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J.P. Mellon  
M.A. Eadie  
W. Coventry  
M. Ross

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**J.A. Jagoe**

**Support Staff**

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B. Tittley  
E.A. Wendel  
D.G. Jefferson  
R.J. Haswell  
S. Westmoreland

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**Head**

**E. Dowie, B.A., B.L.S., M.L.S.**

**Support Staff**

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K. Finch  
M. Sinclair  
E. McCallum

**Central Registry Section**

**Head**

**E. Rae**

**Support Staff**

M. Solvason  
J. Sims  
K. Cameron

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