

NWRI CONTRIBUTION 88-69

RESEARCH AND APPLICATIONS BRANCH  
ANNUAL STUDY REPORT

1987 - 88

## FORWARD

I am pleased to present an Annual Study Report on the work of the Research and Applications Branch, National Water Research Institute.

The Scientists and Technologists of the Branch join with me in recognizing the support and stimulation provided by our many partners in these Research and Development initiatives.

We look forward to your comments and suggestions as we take on new challenges in our three special areas:

Analytical Chemistry Research  
Quality Assurance  
Hydraulics Studies

John Lawrence  
Director  
Research and Applications Branch

RESEARCH AND APPLICATIONS BRANCH  
ANNUAL STUDY REPORT

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RESEARCH AND APPLICATIONS BRANCH

John Lawrence, Director

OVERVIEW

The Research and Applications Branch of the National Water Research Institute conducts mission oriented basic and applied research in areas of analytical chemistry and hydraulics. It is also responsible for transferring research and technology to the operational sectors of the Department and for providing technical and scientific services such as current meter calibration, sedimentology and geotechnical services and analytical quality assurance. The work addresses priority issues of the Inland Waters/Lands Directorate and other agencies of the Department.

New, improved and more cost effective analytical techniques (including laboratory automation) are developed and evaluated for the measurement of priority chemical and biochemical parameters in environmental matrices. The Branch also has lead responsibility for analytical quality assurance for most C&P chemical monitoring programs. The major clients for this analytical work include the Institute, the Water Quality Branch National and Regional laboratories, Federal/Provincial Water Quality Agreements, the program on Long Range Transport of Airborne Pollutants, Prairie Provinces Water Board and Great Lakes Water Quality Program.

New knowledge of the dynamics of water is sought to provide a framework for the management of water resources, and for biology and chemistry research in the aquatic environment. The interfaces between water and the atmosphere, bottom sediments, and shore are studied to explain the mechanisms controlling the transport of pollutants and erosion. Advances are made in river metrology to improve management of that resource. The major clients are the Water Resources Branch, Water Planning and Management Branch, Great Lakes Water Quality Program, Environmental Protection, and the Atmospheric Environment Service.

Universities and private industry are encouraged to make use of the Branch facilities and expertise either by collaborative studies with the professional staff or leasing of the facility with or without technical support. The Branch maintains a well equipped hydraulics laboratory, sedimentology and geotechnical laboratories and a special clean and hazardous chemicals laboratory in addition to conventional chemical laboratories. All direct requests from external agencies are cost recovered, in full or in part, in accordance with the Treasury Board Cost Recovery Policy.

PROJECT OVERVIEWS - HIGHLIGHTS

## ANALYTICAL CHEMISTRY RESEARCH PROJECT

Ivan Sekerka, Project Chief

### Introduction

The mandate of the Analytical Chemistry Research Project is to advance knowledge and provide expertise on environmental analytical chemistry. The Project is essential for successful management and utilization of water resources and for research on water pollution, especially for identification of emerging problems.

The Project conducts mission-oriented basic and applied research of environmental analytical chemistry. New, improved and effective analytical techniques, including laboratory automation, are developed and evaluated for measuring priority chemical parameters. Clients for this analytical work include other research and operational branches of Environment Canada as well as other Canadian environmental laboratories.

The objectives of the Project are:

- a) To develop new and improved analytical methods as well as screening and sampling procedures which are accurate, and cost-effective, sensitive and unambiguous for the identification and quantification of contaminants in aquatic ecosystems.
- b) To play a lead role in documentation, validation and standardization of analytical methodologies to ensure accuracy and reliability of analytical data.
- c) To provide a service of sophisticated instrumentation and facilities such as gas chromatography-mass spectrometry and the Clean and Hazardous Chemical Laboratory.
- d) To transfer developed methods and technologies to the National and Regional laboratories of Inland Waters Directorate and to other clients.

### Research Highlights

Several major accomplishments were made in analytical methods development for both organic and inorganic parameters in a variety of environmental substrates. These include advancements in techniques such as high performance gas chromatography, high pressure liquid chromatography (HPLC), emission and absorption spectroscopy, flow-injection analysis, radioimmunoassay (RIA) and electrochemical techniques. Developments have been made in both broad screening techniques and detailed quantitative techniques, as well as improved sample collection and extraction techniques.

A fully automated ion-chromatography method was developed for sub-parts per billion (ppb) levels of cadmium in water samples. The detection limit achieved is 0.1 ppb which exceeds the objective of 0.2 ppb and will substantially improve our ability to provide baseline data on cadmium.

A comprehensive method for simultaneous determination of 20 chlorophenols and 21 chloroanisoles in fish was developed. This will assist studies on the pathways and degradation of chlorophenol, and on the potential environmental hazard of chloroanisoles in areas such as the Fraser River where chlorophenols are in heavy use.

A simple and inexpensive ion-exchange cartridge suitable for "in-line" preconcentration of ionic species was developed. This translates into an improvement of detection limits for Atomic Absorption (AA) determination of heavy metals to parts per trillion (ppt) levels. Its incorporation into Inductively Coupled Plasma Emission Spectrometry will improve detection limits to the levels required for precipitation samples.

A method for determination of non-ionic surfactants by supercritical fluid chromatography (SFC) was developed. This is the first method of SFC capable of quantitative determination. SFC methods are being developed to provide the National and Regional Water Quality Laboratories with alternative analytical methods where gas and liquid chromatography are not suitable.

A working version of a radioimmunoassay (RIA) technique for dioxin detection was achieved. RIA is used to screen samples and is a rapid way to screen many samples at one time to identify those which are dioxin-free, eliminating the need to analyze those samples by more costly techniques. A detection limit of 5 picograms (50 ppt) for TCDD (tetrachlorodibenzo-p-dioxins) was achieved using a lake trout matrix which is quite comparable to standard chemical detection techniques.

Improvements to clean-up procedures for chromatography were made with the concentration of a first generation of graphite fibre clean-up columns. The columns are suitable for GC as well as LC application. The procedure for activating graphite fibres was developed. This work is part of the research being conducted to improve dioxin clean-up procedures.

Methodologies were developed for organochlorines and polychlorinated biphenols that produce first-class chromatographs on a highly reproducible basis in the dual column, splitless/split injection mode. These methods are an improvement over existing methods in terms of accuracy and precision of detection.

A validation program for the 24-hour Goulden Large Sample Extractor (GLSE) was completed. This led to acceptance of the GLSE by the four parties involved in the Niagara River Toxics Management Plan, as the standard method for sampling organic contaminants. Also the United States Environmental Protection Agency Large Lakes Research Station and University of Minnesota selected GLSE technology as a method to use in their water quality survey of Green Bay, Wisconsin. Initial steps are being taken to have the GLSE commercially manufactured.



## QUALITY ASSURANCE PROJECT

Alfred Chau, Project Chief

### Introduction

The mandate of the Quality Assurance (QA) project is to heighten the awareness of the need for a coordinated quality assurance program and to ensure that analytical data generated for Environment Canada are of good and comparable quality. The Project is essential for successful management and utilization of water resources and for research on water pollution, particularly toxic chemicals and acid rain. Above all, the assurance of data quality enables the Department to provide authoritative, credible, scientific advice on control and remediation strategies derived from interpretation of scientific data.

Chemical data are essential to all decisions made by government in environmental assessments and pollution control. Biased measurements lead to errors in assessment and in subsequent control actions. In addition, the expense of data collection and interpretation makes the cost of discarding questionable data very high; therefore, data must be suitable, compatible and reliable for the intended use. A comprehensive QA program is the essential first step to achieving reliable data for environmental assessment. The long-term goal of the QA Project is to assist management to develop comprehensive quality assurance programs for the Institute and the Department.

- As lead responsibility centre for quality assurance, the QA group:
- a) Plans, coordinates, and implements quality assurance and control programs to ensure accuracy, comparability and reliability of analytical data.
  - b) Develops and prepares Certified Reference Materials (water, sediments and biota) and reference materials for use in quality assurance and analytical method research and environmental assessment studies.

Project activities include developing management plans for quality assurance, advising on field, laboratory and data management quality control procedures, development of Certified Reference Materials (CRM) and designing and conducting interlaboratory comparisons studies. Quality assurance studies are conducted for federal, provincial, university and private laboratories producing analytical data for departmental programs. Methodology evaluation and sample preservation are also carried out in support of these studies.

The QA Project is also initiating an active marketing component in advertising our products and expertise. In this regard, the first phase of the marketing activity is to advertise more aggressively the CRMs developed and prepared by the QA group. Also as resources and time permit, papers on QA and CRMs are presented at scientific conferences and symposia. A brochure describing CRMs has been designed and will be printed within the next few months.

### Research Highlights

This year marked the completion of the Upper Great Lakes Connecting Channel Surveillance Program (UGLCCS) which was established in 1985 as a binational study to monitor the upper connecting channels with the purpose of defining the pollution controls necessary to establish a safe environment. The Quality Management Work Group (QMWG) was appointed, with the QA Project Chief acting as chairman, to ensure that quality data was produced. The QA program that was designed for UGLCCS is a highly regarded example of QA management involving two countries, several levels of government and laboratories. The work of the QMWG has heightened the awareness of the advantages and needs for a coordinated QA program in both environmental research and management.

The QA Project carried out nine interlaboratory studies for UGLCCS in 1987-88 which helped participating laboratories to identify and correct quality control problems. In addition, three reports were written to provide an overall data review of interlaboratory performance assessment which assisted project leaders and managers in implementing QA management strategies. Two forms, "Project QA Self-Audit" and "Report Quality Assessment" were designed and distributed to project leaders and managers to assist data interpretation and report writing.

The final report of the QMWG was submitted to the Management and Activity Integration Committees of UGLCCS. This report is a compilation of all of the QA activities and provides recommendations on issues that arose in the UGLCCS QA program but which are relevant to other multi-agency, international surveillance programs.

Two large interlaboratory QA studies were finalized in the Great Lakes Water Quality (GLWQ) Surveillance QA Program. These were toxic organics in ampules and sediments and total P in sewage effluent. Two other QA studies, total P in water and total metals in sediments were initiated. The GLWQ Surveillance QA Program is designed to ensure the quality and compatibility of data generated by both American and Canadian agencies who monitor water quality in the Great Lakes. The QA program has improved the quality of data produced by the laboratories involved in the GLWQ Surveillance program.

In addition to these two international QA programs, the QA Project has programs ongoing for three national programs. The Federal/Provincial Agreement QA Program was created in 1986 to ensure that data generated by Environment Canada and provincial laboratories involved in the Federal/Provincial Agreements are of good and comparable quality. The Prairie Province Water Board QA Program (initiated in 1982) was established to improve the compatibility of provincial and federal water quality data collected from interprovincial and international streams in the prairie provinces. The data that is generated in both programs is compiled in NAQUADAT which is used extensively by a large number of users.

For these two programs, two interlaboratory QA studies were sent out every month. Six data summaries and six final reports were sent to participants. For the Prairie Province Water Board, a large integrated report on laboratory performance during the year was also generated.

For the Long Range Transport of Airborne Pollutants (LRTAP) QA Program, three large QA studies for major ions and nutrients were designed and conducted. Six QA reports (two per study) were generated. In addition, computer programs were developed to provide information on laboratory performance and data quality for any given laboratory over a given time period. This is the first time such information can be provided quickly to managers and data users on data quality.

Data quality in the laboratories of the FPA, PPWB and LRTAP programs have generally been improved and data quality problems have been identified for corrective action. These QA programs have a continual positive impact to data quality.

Two national QA studies were also conducted this year. At the request of the Groundwater Contamination Project of NWRI and the Atlantic Region, an interlaboratory QA study was designed to evaluate the degree of confidence in, and comparability of methods for the analysis of aldicarb (a pesticide) and its oxidative metabolites in groundwater. Both Canadian and American laboratories participated in this study which helped to validate a method for determining aldicarb that was developed at NWRI.

Another QA interlaboratory study was conducted for chlorophenols at the request of the Pacific and Yukon Region in support of the Fraser River Estuary Management Program. With the growing concern for toxic organic substances in the aquatic environment, it is anticipated that more interlaboratory studies for these substances will be conducted.

In the technology transfer work of the QA Project, a multi-residue method for the analysis of chlorophenols in sediment was transferred to the National Water Quality Laboratory. Also a scientist from the Institute of Environmental Health and Monitoring, Chinese Academy of Preventive Medicine, spent a year training with the QA Project and collaborated on the development of a method for simultaneous trace-level determinations of cadmium, cobalt and manganese in water.

## HYDRAULICS PROJECT

Michael Skafel, Project Chief

### Introduction

The physical dynamics of water and its interaction with air, sediments, shores and man-made structures are the focus of the Hydraulics Project. Research studies on wave mechanics, river flow and sediment transport provide new scientific knowledge for use by water resource managers and engineers in Environment Canada and elsewhere. Special attention is given to understanding hydraulic processes that could lead to structural failure with serious environmental consequences.

The research program in wave mechanics creates new knowledge on the accurate parameterization of fluxes of mass, momentum, energy and heat across the air/water interface. This work has direct consequences in understanding toxic gas transfer, diffusion of pollutants, wave prediction, lake circulation, seasonal thermocline development, weather forecasting and climatic change.

The coastal engineering program addresses the questions of lake bottom interactions such as the resuspension of cohesive (polluted) sediments by waves and prediction techniques to develop wave climate data for studies of sediment resuspension, shoreline evolution, and wave-structure interaction.

The fluvial engineering program is directed at improved understanding of fluid mechanics and sediment transport in rivers, the development of new and improved techniques for monitoring river processes, and flow-structure interaction.

### Research Highlights

Several fluvial engineering projects were carried out this year at the request of the Water Survey of Canada (WSC) to improve accuracy and efficiency of water measurement. Evaluations were completed on a prototype acoustic flow meter developed by WSC for river discharge measurement applications. Work continued on the Milk River study to devise and evaluate discharge measurement schemes. Data on stage-discharge curves for different approach channel conditions are being analyzed. A weir design suitable for prototype applications is currently undergoing tests.

A theoretical analysis, together with laboratory measurements, were conducted for WSC to determine the performance characteristics of a float type of water level recorder system. A theoretical equation has been developed which will be used to compute the water column elevation from the total pressure recorded with pressure transducers used with gas-purge systems.

Extensive tests were carried out for external clients on two types of modular erosion control systems in a large tilting flume to determine the stability and flow resistance of these systems. The results indicate that these systems are effective and economical ways of stabilizing small conveyance channels which are common in urbanized areas.

Construction began on a physical model of Windermere Basin which is an enclosed body of water located on the southern end of Hamilton Harbour. Deposition of solids primarily from Red Hill Creek has resulted in the present unaesthetic condition of the basin. As part of the Hamilton Harbour Remedial Action Plan, a partial dredge and filling scheme has been proposed to improve the appearance and environmental characteristics of the basin. The physical model is being used to conduct tests under various flow conditions to determine the optimum position of berms, dredge areas and other proposed features that will be used to improve the hydraulic characteristics of Windermere Basin.

Coastal engineering research continued to make improvements to wave climate prediction and wave forecasting techniques. With improved waveclimate (i.e., seasonal patterns of wave height, period, etc.) prediction models, man-made structures can be better designed to withstand the forces of waves. These models can also be used to provide data that is essential for studies on polluted sediment resuspension.

Steady-state wave prediction equations (the SMB, JONSWAP and Donelan similarity equations) were evaluated, as were the procedures for applying these that were revised by the US Army Corps of Engineers and presented in their Shore Protection Manual. Predictions were compared to measured wave data from Lake Ontario and from several other sources including the original JONSWAP data. These three equations can be used for wave climate predictions and for developing wave forecasts from weather forecasts, information that is important to marine operations. The SMB and Donelan similarity equation provide the best results. The revised procedures given in the Shore Protection Manual consistently overpredict both wave height and period.

Another comparison study of one-dimensional wave climate prediction models began, using the PHEW model, the model used by Public Works Canada and the model used by Hydraulics Research of Wallingford, U.K. Predictions were compared to measured wave data from Lakes Ontario, Erie and St. Clair and from the Gulf of St. Lawrence. Detailed analysis of the comparison data will be completed in 1988. In addition, the Donelan two-dimensional wave prediction model was adapted to run in a wave climate mode.

A literature review on Great Lakes Water levels was completed and provides Public Works Canada with background information to develop guidelines for design water levels for harbour structures. Due to the wide interest in the relationships between climate change and water levels, this report received wide circulation. Recent years of high water levels also prompted good attendance at public seminars on shore processes and shore protection alternatives which were held at several locations around the lower Great Lakes.

Field experiments to investigate the joint probability distribution of wave heights and periods in shoaling waves were successfully completed in Lake Ontario. Data analysis will begin in 1988.

The third and final phase of the WAVES (Water-Air Vertical Exchange Studies) field study on the behaviour, dynamics and effects of deep water wave breaking was completed successfully. The collaboration between the Woods Hole Oceanographic Institution (WHOI) and NWRI produced a very comprehensive data set for the exploration of wave-turbulence interaction. We are just completing a careful comparison of the different instruments used and finding that although the NWRI and WHOI instruments depend on completely different physical principles, there is excellent agreement in their responses to both mean flow and turbulence which provides a significant measure of confidence in the data. Detailed analysis is underway and shortly we will be able to draw firm conclusions.

NWRI's array of wave gauges were shown to yield high resolution and very accurate wave directional spectra. Early results from the analysis of these data (partially complete) show some interesting new findings, including: a) the downwind spectral densities are quasi-saturated but the spreading increases linearly with frequency away from the spectral peak thereby causing the frequency spectra to follow  $f^{-4}$  law; b) at twice frequency of the peak frequency a large dip in the directional spectrum appears in the direction of the waves at the peak of the frequency spectrum. It appears that the dip may be caused by the attenuation of short waves caused by the passage of white caps through them.

The collaboration with the US Naval Research Laboratory (NRL) has yielded radar data with continuous azimuthal information. This is the first data of its kind obtained from a tower and, with the simultaneous boundary flux data, promises to be extremely useful for interpreting the data from airborne and space-borne microwave radars to infer winds over oceans.

A new recirculating wind tunnel for gas transfer studies was designed and construction is now 70% complete. The wind tunnel will excite waves and enhance gas transfer in the existing 32 m flume which is being equipped with a closed circulation system for the water phase. The maximum fluid velocities in air and water are 22 cm/s and 50 cm/s respectively. In addition, the flume has been equipped with a hydraulic wave maker. A series of experiments has been designed to determine the air/water transfer of toxic gases and appropriate surrogates. The first tests will use the common pesticide, Lindane. The flume will be equipped with sensitive instrumentation for monitoring wave and boundary layer characteristics; samples of air and water will be withdrawn for gas chromatographic analysis. Many of the tests will hinge on the overall change in concentration of the contaminant in both phases. Consequently, for this, as well as for safety reasons, the flume-tunnel system is being subjected to thorough leak tests.

Preliminary tests are being conducted in a small flume with a view towards understanding the nature of turbulent mixing due to the breaking of short gravity waves.

STUDY REPORTS

ANALYTICAL CHEMISTRY RESEARCH PROJECT





Study 84009 (continued)

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consulted with laboratory personnel from the Western and Northern Region of the WQB in order to facilitate the transfer of the HPLC method for the analysis of chlorophyll-a.

Publications:

Ryan, J.F., H.B. Lee. 1987. A Review of Analytical Methods for Glyphosate: Application to the Analysis of Water Samples. NWRI Contribution 87-159.

RESEARCH AND APPLICATIONS BRANCH  
Study Progress Report

STUDY NO: 84011

DATE: March 1988

TITLE OF STUDY: Negative Ion Chemical Ionization Mass Spectrometry and  
Supercritical Fluid Chromatography

STUDY LEADER: F. Onuska

TEAM: K. Terry

- GOALS:
1. Applicability of supercritical fluid chromatography to non-ionic surfactants, PAHs and pesticides
  2. Investigate applications of NICI-MS for analysis of chlorinated contaminants and other compounds
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RESULTS:

As the continuation of 85/86 study, we re-designed our inhouse SFC system for capillary column applications by replacing a Brownlee dual micropump with a Lee Scientific large volume piston pump. This pump is computer-driven and provides both pressure and density programming capabilities. Also, we changed an injection system. At present it is automated in respect to the duration time period for a sample introduction. This system represents state-of-the-art in SFC.

Work has continued on the quantitation of non-ionic surfactants of the alkoxyethoxylate type (Dobanol). A qualitative characterization of a standard and quantitative analysis of water samples have been performed. It is shown that sensitivity of a flame ionization detector is not sufficient for its utilization in environmental analysis of surfactants.

Work is near completion on the analysis of PAHs in sediments by means of SFC and flame ionization detection. The sensitivity using FID is sufficient for environmental analysis at mg/kg levels.

Continuation of the work on supercritical fluid extraction resulted in the design of a working extraction unit for sediments, soils and tissue samples. The extractor has been tested and further work is focusing on its direct interfacing with a PTV-injector of the gas chromatograph.

A feasibility study was initiated and a spiked sediment was extracted under supercritical conditions using CO<sub>2</sub> as the extractant. The recoveries were incomplete but modifications are planned to enhance the recoveries as well as separation and detection sensitivity using electron capture detection.

A significant amount of time was devoted to evaluate various GC/MS systems and to prepare justifications for an eventual purchase of the GC/MS system.

The investigations of the applications of NICI-MS for the analysis of chlorinated contaminants and other compounds was not carried out because of lack of funding.

Study No. 84011 (continued)

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Publications:

Onuska, F.I. and K.A. Terry. Supercritical Fluid Chromatography of Alkylene Oxide-Fatty Alcohol Condensates: Their Quantitation in Water Samples. High Resolution Chromatography and Chromatography Communications Journal. In press.

Presentations:

Onuska, F.I. Supercritical Fluid Chromatography: An Alternative to Gas Chromatography and HPLC. Presented at the Research and Development Symposium (MOE-LSB/NWRI-RAB) in Toronto, Ontario, November 25, 1987.

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STUDY NO: 84012

DATE: March 1988

TITLE OF STUDY: Preconcentration for Ultra-Trace Analysis

STUDY LEADER: P.D. Goulden, D.H.J. Anthony

TEAM:

- GOALS:
1. Investigate the use of large sample extractor technology in the determination of trace metals.
  2. Investigate chemistry of in situ phenols derivatization using large sample extractor technology.
  3. Modify existing large sample extractor systems to allow completely enclosed operation and to provide solvent recovery from extractor effluents.
- =====

RESULTS:

The unexpected death of Dr. P.D. Goulden in November 1987 resulted in a drastic modification of the Work Plans.

Investigation of the use of large sample extractor technology in the determination of trace metals and the investigation of the chemistry of in situ phenols derivatization using large sample extractor technology were suspended due to prioritization.

The modification of the existing large sample extractor systems to allow completely enclosed operation and to provide solvent recovery from the extractor effluents is near completion and will be finalized in the next fiscal year.

A "rush" validation program for the 24-hour Goulden Large-Sample Extractor (GLSE) was completed. The program led to acceptance of the 24-hour GLSE, by the four parties involved in the Niagara River Toxics Management Plan, as the standard method for sampling organic contaminants in the Niagara River at NOTL and FE monitoring stations.

Demonstrated GLSE technology, and its incorporation in WQB sampling and analytical protocol, to visiting scientists interested in utilizing the technology in their own operation (US EPA-LLRS, Grosse Isle, Michigan; U. of Minnesota - Dept. of Environmental and Occupational Health; USGS-NWQL, Denver, Colorado; TVA, Chattanooga, Tennessee). As a result of these demonstrations, the US EPA-LLRS and U. of Minnesota selected GLSE technology as a method to be tested for use in the Green Bay, Wisconsin, RAP. The USGS and TVA have begun set up of this technology in their operations.

Study 84012 (continued)

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Supervised the proper use of GLSE technology, in cooperation with the US EPA-LLRS and U. of Minnesota, during a preliminary water quality survey of Green Bay, Wisconsin, on board the US EPA research vessel "Roger R. Simons", 09-20 Nov '88. Results of this study including a presentation on the use of GLSE technology, will be presented at the IAGLR 31st Conference, 17-20 May '88, McMaster University, Hamilton. It is expected that, at this time, GLSE technology will be accepted as "standard" in more thorough water quality surveys of Green Bay.

Initiated, through Canadian Patents and Developments Ltd. (CPDL) a study of the possibility of patenting/licensing GLSE technology.

Through continuing cooperation with Pegasus Industrial Specialties Ltd., have developed interest on their part in forming a licensing agreement to market GLSE technology presently available and GLSE technology as it is further developed.

Have maintained communications on GLSE developments with existing clients (WQB/NWQL, WQB/OR, NWRI, US EPA-LLRS, TVA, USGS, Pegasus-Industrial Specialties Ltd., Zenon Environmental Inc.).

Mr. D.H.J. Anthony acted as an NWRI representative for the Metals Task Force (Y.K. Chau, Chairman). Contributed to the Metals Task Force Report to the National Water Quality Working Group (February '88).

Publications:

Goulden, P.D. 1987. Liquid-Liquid Extraction. Proceedings of a Workshop on Preconcentration of Trace Organic Compounds from Large Volumes of Water. Held at the Canada Centre for Inland Waters, Burlington, Ontario, June 23, 1987.

Afghan, B.K., J. Caron, P.D. Goulden, J. Lawrence, D. Leger, F. Onuska, J. Sherry and R. Wilkinson. 1987. Recent Advances in Ultratrace Analysis of Dioxins and Related Halogenated Hydrocarbons. Can. J. Chem., 65:1086-1097.

Neilson, M., R. Stevens, H. Biberhofer, P.D. Goulden and D.H.J. Anthony. 1987. A Large Sample Extractor for Determining Organics in the Great Lakes. Water Quality Branch, IWD Technical Bulletin #157.

Presentations:

Kuntz, K.W., P.D. Goulden, D.H.J. Anthony and H. Biberhofer. Sampling and Extraction of Large Volume Water Samples for Environmental Contaminants. Presented at the American Water Resources Assoc. Symposium. "Monitoring, Modelling and Mediating", Syracuse, NY, May 17-20, 1987.

Anthony, D.H.J. A Large-Sample Extractor for Preconcentrating Organics from Natural Waters. Presented at the Research and Development Symposium (MOE-LSB/NWRI-RAB) in Toronto, Ontario, November 25, 1987.

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STUDY NO: 84013

DATE: March 1988

TITLE OF STUDY: Electrochemistry and Flow Injection

STUDY LEADER: I. Sekerka

TEAM: J.F. Lechner, J.S. Ford

- GOALS:
1. Develop the system of "in line" preconcentration and/or separation suitable for continuous flow analysis.
  2. Automation of FIA including sample presentation.
  3. Transfer developed methods (nutrients, Na, K) to NWQL.

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RESULTS:

A simple, inexpensive and flexible cartridge suitable for "in line" preconcentration of ionic species has been designed and tested. It eliminates the problems associated with swelling and shrinking of ion-exchange resins during loading and eluting processes. Several cation exchangers have been evaluated. Best results were obtained with Chelex 100 resin. Using 2 min. preconcentration and 20 s elution time an enrichment factor of one hundred has been achieved. This translates into an improvement of the detection limits for AA determination of heavy metals to parts per trillion levels. Its incorporation into ICP system will improve the detection limits to the levels required for precipitation samples.

Experiments with the application of microwave irradiation of samples containing complexed ions have been initiated with very promising results. The goal is to develop the system capable of digesting samples in continuous flow mode.

A valving system allowing dual column reverse in-line operation suitable for flow analysis techniques has been developed. It is suitable for in-line preconcentration and elution, of organic as well as inorganic species from water samples. Its second application is in-line filtering of turbid samples. The system automatically filters the sample, preconcentrates and elutes the species of interest and backwashes the filter for next sample.

FIA colorimetric method for low levels of Boron determination (NWQL request) has been developed. It includes in-line accumulation of boron on IRA-743 boron selective resin and consequent elution into a colorimetric (Azomethin H) FIA system. The timing of the accumulation-elution cycle allows boron to be measured down to 0.1 ppb. The method is interference free. Report is in preparation.

After intensive testing and engineering effort a system comprising a robotic arm, piercing station, a bar code reader and a bottle handling cart has been selected and constructed. The communications circuits connecting the PDP11, the robot and the bar code reader are complete. They passed the first stage of testing.

Study No. 84-013 (continued)

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Further testing awaits the other accessories. A microcomputer provides the master control and communication with the VAX. A software for several operation modes has been written. It contains - Sample Labelling Mode - Standards, Spikes and Blanks Labelling Mode - Incoming Data Entry - Sample Selection List - Robotics Mode - Data Gathering Mode - Data Presentation Mode - Data Transmission Mode.

The entire system (excluding the actual interfacing to the analytical system) is in the operation.

Previously developed method for low levels of cyanide has been transferred to the WQB, W&N Region. Joint report is in preparation. Other technology transfer continued on an ongoing basis.

Advice and consultation concerning analytical chemistry were provided to various organizations, agencies and industry on a frequent basis. Ten scientific manuscripts were reviewed for Analytical Chemistry.

Presentations:

Sekerka, I. On-Line Enrichment in a Flow Injection System. Presented at the Research and Development Symposium (MOE-LSB/NWRI-RAB) in Toronto, Ontario, November 25, 1987.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84014

DATE: March 1988

TITLE OF STUDY: Analysis of Organics in Concentrated Sample

STUDY LEADER: B.F. Scott

TEAM:

- GOALS:
1. To develop an HPLC method for cleanup procedures for compounds of interest (OCs, PCBs, organo-sulphur compounds), then quantitate in WQ automated gas chromatography laboratory.
  2. Continue transferring toxaphene methodology (detailed evaluation of NWQL automated laboratory).
- 

RESULTS:

Previous work has shown that for dense phases, exclusive of fish, HPLC can be used for cleanup. This involves using micro-stryagel for lipid cleanup and a porasil column for the regular silica cleanup. Some instrumentation is now in place, programmable pump and automated switching valves, to facilitate the automation. The only aspect missing is collecting the effluent of the stryagel column then introducing it to the top of the porasil column as a plug. This aspect was deemed less important to resolve than the thrust of the project over the past six months. The aspect that has been investigated is the fine-tuning of the detection system so that it can quantitate the compounds of interest in a complex chromatogram with a high degree of accuracy. This involves goal 2 and the last part of item 1.

To this end, it was decided that for standards which contained organo-chlorine pesticides and chlorobenzenes, the reproducibility should be better than 5% as determined by the coefficient of variance from at least nine separate injections. As in the normal operation of the NWQL, this was to be run in the splitless mode of injection, using capillary columns. The desired degree of reproducibility was achieved after altering the chromatographic conditions, but attempting to leave the integrating parameters constant over the duration of the run. Then other columns of varying polarity were investigated as was the addition of guard columns before the working columns. Except for the last two peaks (methoxychlor and mirex) the CV was about 5% for all columns. These columns included SPB1, SPB5, and SPB608 type columns as well as a thin liquid phase SPB5 type column. Although on some of the columns one or two of the peaks may have co-eluted, the CV value of 5% for splitless mode is better than has been reported in the literature. Serial dilutions were performed on the standards which allowed a check on the linearity of the response of the detector to the particular compound and obtain a value for the minimal detectable amount, defined as three times the noise over baseline. The correlation coefficients were greater than 0.97, often above 0.99. Also the minimal detectable amounts, which were as low as  $10^{-13}$ g, were a factor of 10 less than usually obtained.



Study 84014 (continued)

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To facilitate the statistical treatment of the data generated from chromatograms, a program was developed to use the capability of the computer controlling the gas chromatographs. This was essential as the next step was to run PCBs (four Anachlor mixtures) and PCBs plus OCs. This produces about 127 peaks, and the transferring of this by hand to another computer for statistical analysis would take several days for each series of runs.

The next step was the chromatography of the PCBs, aiding in the technology transfer of the PCB method developed by Dr. F. Onuska. Initially, a deactivated XE52 liquid phase capillary column was used and this produced excellent chromatography. CV's of less than 5% were obtained for over 70 PCB congeners with the detector giving as linear response over a range of 100. When mixed with the OC standards containing 34 components, only three components overlapped.

As the NWQL protocols requires samples to be analyzed by two columns of different polarity so as to confirm the identification and quantitation of a compound of interest, a deactivated OV-1 capillary column was installed separately. Once this was proven to produce acceptable results analyzed on a separate detector, dual column mode was initiated. Guard columns were installed before the working columns. Using new "but connectors" the guard columns can be replaced in the chromatograph oven. The use of the guard columns will extend the life of the working columns and thereby decrease the work necessary to recalibrate a new column. Difficulties were encountered with the XE-52 columns, and the thin liquid phase XE-52 column used in the OC work was installed in tandem with the OV-1 column. A standard mixture using arachlors 1221, 1016, 1254 and 1262 was made up with the internal standard decachlorobiphenyl added. This was serially diluted to produce a 100 fold range of concentrations. The PCBs could be detected at the one ppt level for individual congeners generally with a CV of less than 5% for most of the compounds. Also the response was linear. A program was developed that listed the concentration of the various PCBs by the degree of chlorination and isomer number.

Presentations:

Scott, B.F. Enhanced G.C. Performance for Analysis of Contaminants Including OC's, PCB's, and Toxaphene. Presented at the Research and Development Symposium (MOE-LSB/NWRI-RAB) in Toronto, Ontario, November 25, 1987.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84016

DATE: March 1988

TITLE OF STUDY: Operation of CHCL and Separation of Organics

STUDY LEADER: I. Sekerka

TEAM: R. Wilkinson

GOALS: 1. Provide the services of CHCL.  
2. Develop procedures for simultaneous digestion and sulfur removal.  
3. Investigate the application of carbon liquid chromatography for cleanup and separation procedures.

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RESULTS:

The operation and services of the CHCL were provided as required. Proper and safe procedures for the handling and transportation of toxic substances and standards for interlaboratory operations have been maintained.

The instrumentation (GC/ECD AND GC/MSD) has been maintained in operational condition and the laboratory environment has been properly maintained on a continuing basis.

Sediment samples from the Niagara River (WQB) have been successfully analyzed for dioxins and furans. Recoveries of greater than 40% were obtained for <sup>13</sup>C labelled tetra-octa isomers.

Fifteen fish samples were processed through various steps of cleanup for RIA and numerous samples were cleaned-up for the NWQL.

Experiments on sulfur removal by digestion with Bi<sup>+3</sup> have been postponed because the high priority samples were analyzed for dioxins and furans.

Two kinds of carbon (graphite fibres and porous vitreous carbon) were selected to investigate the application of carbon for cleanup and separation procedures. Columns containing these materials were constructed and method of activation was developed. Carbon columns were found suitable for GC as well as LC applications. Columns of both types were tested for their adsorption capacity and separation characteristics. A report is in preparation.

Evaluation of the existing protocol for the determination of Dioxin in Pulp and Paper Mill Industry Samples has been initiated.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84017

DATE: March 1988

TITLE OF STUDY: Radioimmunoassay Technique for Dioxins

STUDY LEADER: J.P. Sherry

TEAM: R. Wilkinson

- GOALS:
1. Completed development of RIA for detection of PCDDs in aquatic environmental samples.
  2. Investigate use of monoclonal antibodies (when available) in the RIA for PCDDs (in collaboration with Stanker group at Lawrence Livermore National Laboratories, USA).
  3. Investigate the use of enzymatic methods for the detection of PCDDs in environmental samples.
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RESULTS:

The first set of experiments required for the calibration and validation of the RIA for PCDDs using fish matrices has been completed. An unanticipated delay has occurred in these investigations as a consequence of the deterioration of the hapten reagent during storage. Several attempts to synthesize fresh hapten by labelling a bromo-substituted valeramide derivative of dioxin with <sup>125</sup>I proved unsuccessful, even though this reaction offered several theoretical advantages over the standard procedure. It was concluded that in order for the reaction to proceed as anticipated, the reactants would have to be refluxed at 5°C for 24 hours; this was not possible given the levels of radioactivity involved. A fourth batch of 1-N-(5-iodovaleramide)3,7,8-trichlorodibenzo-p-dioxin was then synthesized and characterized using GC, GC/MS, and TLC. This compound has been labelled with <sup>125</sup>I, and is currently being characterized using immunoassay procedures.

The RIA was observed to have a sensitivity of 6 pg in the presence of fish matrix. The least amount of 2,4,7,8-dioxin detected in lake trout was less than 10 pg. The effect of sample size on assay performance was examined. In general, assay performance appeared to deteriorate with increased sample size.

A second set of fish samples has been prepared to facilitate an examination of assay performance in the presence of a minimally cleaned-up sample extract.

Further efforts have been made to improve the dioxin labelling procedure including the development of a synthetic route for the preparation of a long chain tyrosine-like derivative of 3,7,8-TCDD which should yield several major benefits. A HPLC method for the analysis of dioxin derivatives (labelled and unlabelled) was developed.

Study 84017 (continued)

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Monoclonal antibodies to TCDD were obtained and evaluated with disappointing results. It is intended to re-evaluate a fresh batch of monoclonal antibodies in the future.

The literature pertaining to the use of enzymatic assays for screening environmental samples for the presence of toxic substances was reviewed. Suitable instrumentation was evaluated and acquired. Reagent synthesis awaits funding.

Publications:

Sherry, J.P., B.K. Afghan, J. ApSimon, J. Collier, F. Bishai and P.W. Albro. Radioimmunoassay for the Detection of Polychlorinated Dibenzo-p-dioxins in Environmental Samples. 1: Introduction, Description of Initial Method, and Preliminary Evaluation". NWRI Contribution. In press.

Sherry, J.P., J. ApSimon, L. Collier, B.K. Afghan and P.W. Albro. Radioimmunoassay for the Detection of Polychlorinated Dibenzo-p-Dioxins in Environmental Samples. 4: Method Description. NWRI Contribution. In press.

Presentations:

Sherry, J. Screening Techniques for the Detection of Trace Organic Contaminants. Presented at the Research and Development Symposium (MOE-LSB/NWRI-RAB) in Toronto, Ontario, November 25, 1987.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84018

DATE: March 1988

TITLE OF STUDY: Development of Methods for Chlorophenols and Chlorinated  
Anisoles

STUDY LEADER: H.B. Lee

TEAM:

- GOALS:
1. To develop a method for chlorophenol analysis in fish homogenate as required by the Fraser River Estuary Management Program.
  2. To develop a method for the determination of chlorinated anisoles in water.
  3. To develop methods for the analysis of pyrethroids.
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RESULTS:

A simple and sensitive method for the determination of 19 chloroanisoles (from monochloro to pentachloro) and two chloromethylanisoles was developed for water samples. The method involved dichloromethane extraction, Florisil column cleanup and final analysis using GC-ECD and GC-MSD with suitable capillary columns. Recoveries of chloroanisoles were between 70 and 85% and detection limits were 0.02 µg/L for mono- and di-chloroanisoles and 0.002 µg/L for the tri-, tetra-, and penta-chloroanisoles. Another method for the determination of the above chloroanisoles in sediment samples was also developed. Extraction was performed by a Soxhlet apparatus using a mixture of acetone and hexane. The sediment extracts were then cleaned up and analyzed as described above for the water samples. Detection limits were 0.002 µg/g for mono- and di-chloroanisoles and 0.001 µg/g for the higher chlorinated anisoles. In both types of samples, the MSD was used for quantitative and confirmation purposes. A report was written for the above methods.

A comprehensive method for the simultaneous determination of 20 chlorophenols and 21 chloroanisoles in fish tissue was developed. This method was validated at 500, 100, 50 and 10 ppb levels using a fortified lake trout and a composite sample of starry flounders collected from Fraser River, B.C. Detection limit was ca 2 ppb for the tri-, tetra- and penta- chlorophenols and chloroanisoles and a few times higher for the lower chlorophenols and chloroanisoles. Final sample analyses were performed by GC-ECD and GC-MSD. A final report is being typed.

A final report for the analysis of four synthetic pyrethroids and their major metabolites in water samples was also prepared.

Publications:

- Lee, H.B. 1987. Determination of 21 Chloroanisoles in Water and Sediment Samples. NWRI Report 87-69.  
Lee, H.B. Analysis of Chlorophenols and Chloroanisoles in Fish Tissues. NWRI Report. In press.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84019

DATE: March 1988

TITLE OF STUDY: Method Development for Low Level Cd by IC

STUDY LEADER: V. Cheam

TEAM:

GOAL: 1. To develop an ion chromatographic method for determination of sub ppb levels of Cd in water.

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RESULTS:

An ion chromatograph was set up. It consists of an analytical pump, separator column, a post-column reactor and a UV-visible detector. At the initial stage, many interferences were encountered. However, after several experiments using different kinds and combinations of eluents and post-column reagents, an optimum condition was found. A detection limit of 0.1 ppb is attainable and the recovery of an NBS reference material is satisfactory.

A fully automated IC method has been developed for low- and sub-ppb Cd analysis in water preserved with 0.2% HNO<sub>3</sub>. The detection limit of 0.1 ppb satisfies the various guidelines and objectives of 0.2 ppb Cd. The method is also applicable to determination of Co and Mn down to 0.1 ppb.

Publications:

- Cheam, V. and A.S.Y. Chau. 1987. Analysis of Anions, Monovalent and Divalent Cations in Soft Waters. Am. Chem. Soc. (Div. Env. Chem.) 27(1):139-143.
- Cheam, V., and A.S.Y. Chau. 1987. Automated Simultaneous Analysis of Anions, Monovalent and Divalent Cations. Analyst, 112:993-997.
- Cheam, V. and A.S.Y. Chau. 1987. Sulfate in Colored Waters. II. Evaluation of Approaches for Correcting Historical Colorimetric Data. Environmental International, 13:261-270.
- Cheam, V. and E Xue Li. 1988. Determination of Low Level Cd, Co and Mn in Water by Ion Chromatography. NWRI Contribution 88-65.

Presentations:

- Cheam, V. Analysis of Anions, Monovalent and Divalent Cations in Soft Waters. Presented at the 193rd ACS National Meeting in Denver, Colorado, April 5-10, 1987.
- Cheam, V. Method for Simultaneous Analysis for Anions, Mono- and Divalent Cations. Presented at the Research and Development Symposium (MOE-LSB/NWRI-RAB) in Toronto, Ontario, November 25, 1987.

STUDY REPORTS

QUALITY ASSURANCE PROJECT

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84021

DATE: March 1988

TITLE OF STUDY: Organic Quality Assurance

STUDY LEADER: Y.D. Stokker

TEAM: H.B. Lee and A.S.Y. Chau

- GOALS:
1. To develop a new organic certified reference material for sediment (No. EC-6) and one for fish to support ongoing and new QA programs.
  2. To evaluate the stability of chlorophenols, OCs and PAHs in fish homogenates and PCBs, CBs, OCs and PAHs in fortified sediments.
  3. To generate reference values for new organic parameters (OCs) for 2 or 3 existing CRMs.
  4. To conduct interlaboratory studies for the Federal Interdepartmental Committee on Pesticides (FICP) and Fraser River Projects and to initiate interregional QC studies for organics.
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RESULTS:

The development of new certified reference materials continued with pre-screening analyses for selected organic parameters in two new sediment reference materials. This past year, preliminary analyses for PCBs, chlorobenzenes, and PAHs were performed on sediments EC-6 from Lake Erie and EC-7 from the St. Clair River. Results indicated that EC-6 and EC-7 had approximate total PCB contents of 100 ng/g and 20 ng/g, respectively. Chlorobenzene levels were very low in EC-6 (<5 ng/g), but were higher in EC-7 (between 10 and 60 ng/g). PAH levels in both EC-6 and EC-7 were less than 0.4 µg/g.

In response to a request generated by Water Quality Branch, Pacific and Yukon Region, a study on the preservation and stability of chlorophenols in fish homogenates was carried out. Results from this study on both fortified and naturally contaminated fish homogenates indicated that the integrity of chlorophenols in fish was maintained for a minimum of 15 weeks when the samples were preserved under deep-freeze (-20°C) conditions. A final report has been generated (Ref. 8).

A method for the analysis of 18 PAHs in fish tissue was developed and validated on Rainbow Trout muscle tissue prior to investigating the preservation of fortified fish samples. Using this method, a 15-week study to evaluate the stability of these 18 PAHs in frozen fish tissue homogenates was successfully completed. A report has been drafted (Ref. 9).

Due to the loss of human resources, evaluation of the stability of selected organic parameters in fortified sediments was not pursued this year.



Study 84021 (continued)

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Preliminary screening results on the existing sediment CRMs indicated that the organochlorinated insecticides (OCs) were present at levels too low for certification purposes and therefore no further development work was done. Instead, a sediment mixing study, begun the previous year, was pursued further. The concentration levels of PAHs, PCBs and chlorobenzenes in more than 100 sediment extracts from both certified and secondary reference materials were determined. The results of this study indicate that the mixing procedure was successful at generating secondary reference materials and that these RMs are stable and homogeneous for at least 12 months after their initial preparation. A Data summary and preliminary report for these three classes of compounds has been generated.

An interlaboratory FICP study on the analysis of chlorophenols in water was completed. A data summary has been generated and the information forwarded to the Chairman of the FICP Check Sample Program (Ref. 12).

A special study for chlorophenol analysis in fish and related materials was conducted for the laboratories involved in analyzing samples from the Fraser River Estuary. The results of this study indicated that comparable and reproducible data were obtained from the participants for pentachlorophenol and 2,3,4,6-tetrachlorophenol in the naturally contaminated fish samples. Results for 2,4,6- and 2,3,6-trichlorophenols were, however, more divergent. Erratic in-house standard solutions were likely to be the major source of analytical error in this study. A final report was distributed to the participants (Ref. 10).

A National QC Study (No. 36) was conducted to meet the requests of Water Quality Branch - Atlantic Region and the Groundwater Contaminants Group of NWRI. This study, which included laboratories across Canada and from the United States, was designed to evaluate the degree of confidence in, and comparability of, methods for the analysis of aldicarb and its oxidative metabolites in groundwater. Following the successful completion of this study, a final report was drafted and sent to all participants as well as the two requesting agencies (Ref. 13).

Preparations have been made to initiate a new Organic QA Program to respond to the requirements of the Federal-Provincial Agreements on Water Quality. Potential participating laboratories in these special organic QC studies have been contacted and the necessary reference standards and other materials have been gathered.

Four methods developed by this section have been submitted to the National Water Quality Laboratory for inclusion in the IWD Analytical Methods Manual as follows:

- a) Method for the Analysis of Dinoseb in Natural Waters by in situ Acetylation (NWRI Contribution 87-61).

Study 84021 (continued)

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- b) Method for the Analysis of Nitrophenols in Natural Waters (NWRI Contribution 87-62).
- c) Method for the Analysis of Nitrophenols in Sediments (NWRI Contribution 87-60).
- d) Multi-Class, Multi-Residue Method for the Analysis of OCs, PCBs, Chlorobenzenes and Neutral Herbicides in Sediments (NWRI Contribution 87-121).

As a final note, the technology transfer of the methodology for the analysis of chlorophenols in sediment, including the provision of advice and training to chemists in the NWQL, was completed. This method, previously developed by this section in its Organic Methods Development Program was successfully transferred and is now working well in the NWQL. (Method references: Report No. 136-AMD-6-86; NWRI Contribution 86-161; and J. AOAC 70:1003,1987).

Publications:

- Lee, H.B., Y.D. Stokker and A.S.Y. Chau. 1987. Analysis of Phenols by Chemical Derivatization. V. Determination of Pentachlorophenol and 19 Other Chlorinated Phenols in Sediments. J. AOAC 70(6):1003, 1987.
- Stokker, Y.D. 1987. Method for the Analysis of Dinoseb in Natural Waters by in situ Acetylation. NWRI Contribution 87-61.
- Stokker, Y.D. 1987. Method for the Analysis of Nitrophenols in Natural Waters. NWRI Contribution 87-62.
- Stokker, Y.D. 1987. Method for the Analysis of Nitrophenols in Sediments. NWRI Contribution 87-60.
- Stokker, Y.D. 1987. Multi-Class Method for the Analysis of Organochlorinated Pesticides, Polychlorinated Biphenyls, Chlorobenzenes and Neutral Herbicides in Sediments. NWRI Contribution 87-121.
- Stokker, Y.D. 1988. Method for the Analysis of Acid and Neutral Herbicides in Sediments. NWRI Contribution 88-67.
- Lee, H.B., Y.D. Stokker, N. Arafat and A.S.Y. Chau. 1987. Preservation of Organics. Part II. Stability of Chlorophenols in Preserved Natural Water Samples. NWRI Contribution 87-123.
- W.C. Li, H.B. Lee and A.S.Y. Chau. 1987. Preservation of Organics. Part III. Stability of Chlorophenols in Preserved Fish Homogenates. NWRI Contribution 87-125.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84022

DATE: March 1988

TITLE OF STUDY: Development of a Sediment Reference Material for Heavy Metals  
and Major Ions

STUDY LEADER: V. Cheam

TEAM: K. Aspila and A.S.Y. Chau

GOAL: To develop a sediment reference material and generate preliminary  
reference values for Co, Ni, Zn, Fe, Mn, Ca, Mg, C and N.

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RESULTS:

Diversity of research areas demands diversity of Reference Materials (RMs) in matrices as well as in concentration levels. Great Lakes research demands Great Lakes RMs. Our RMs are being and will be used by the scientists of NWRI, WQB and many outside agencies. The development of more sediment Great Lakes RMs helps fulfill the diversity requirement.

A sediment reference material has been developed. Several hundred analyses from an interlaboratory study and contract laboratories were evaluated. For heavy metals, the data from four different methodologies were shown to be compatible and were pooled. Eight heavy metals namely Co, Ni, Zn, Fe, Mn, As, Si and Hg were certified by the multi-laboratory multi-methodology approach. The certified reference material provides diversity (in matrix, analytes, and concentration levels) of quality control samples and thus enhances the effectiveness of the QA program at NWRI. The first draft of a final report has been written.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84023

DATE: March 1988

TITLE OF STUDY: PPWB and Fed./Prov. Quality Assurance (QA) Program

STUDY LEADER: H. Alkema

TEAM: H. Alkema and A.S.Y. Chau

- GOALS:
1. To ensure that data generated by Federal, PPWB (Prairie Province Water Board) and Quebec, British Columbia, New Brunswick and a Northern Affairs Program (NAP) laboratory are of good and comparable quality.
  2. To complete two quality control studies for the above three programs every two months.
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RESULTS:

This project responds to the mandates of the PPWB and the requirements of the Federal-Provincial Agreements on Water Quality. Laboratories in these programs produce chemical data for health and environmental concerns, for Environment Canada and for those provinces that have Water Quality Agreements with the Federal Government. Constituents in this project include trace metals, major ions, nutrients and physical parameters. Program data for which this project addresses, is compiled in NAQUADAT. NAQUADAT has a very large list of data users.

Seventeen preliminary data evaluations were completed and communicated to the 13 laboratory heads (two Quebec laboratories received a french version).

Sixteen final reports were prepared and sent to laboratory and program managers of the PPWB, Fed/prov. and Northern Affairs Programs. These reports were: IR148-9, IR150-1, IR152-3, IR154-5, PP53-4, PP55-6, PP57-8, PP59-60, PP61-2, PP63-4, FP13-14, FP15-6, FP17-8, FP19-20, FP21-2 and FP23-24. The FP reports are in English or French.

Six bimonthly QC studies were distributed to the IR, PP, FP and NAP participants. These studies dealt with trace metals, major ions, nutrients and physical parameters in surface waters or standard reference waters.

Under the auspices of the Federal-Provincial Agreements, two laboratories - Environment New Brunswick and the PEI Department of Community and Cultural Affairs have joined the FPQA program. The number of laboratories in this ongoing FPQA study is now 14.

With the advent of the Federal-Provincial Water Quality Agreements, the Environment Canada Inter-regional QC program has been merged into the Fed.Prov. QA program. The IRQC interlaboratory studies have therefore drawn to a close after more than 15 successful years. The IRQC study numbering has now reverted to the FPQA numbering.

Study 84023 (continued)

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Computer programming is in progress to convert the PPWB sequential data base into a hierarchical one (System 2000). This data base is designed to allow quick access to data and easy transfer of data between our interlaboratory QA data bases. Other QA programs interested in these reference values or specific laboratory results would include IJC, LRTAP and UGLCCS as well as individual laboratories in the FP and PPWB QA programs.

Publications:

Alkema, H. 1987. Summary Report FPQC Studies 7-18 (July 86 - June 87) for Inorganics in Surface Waters (Rapport Sommaire PAQFP, Substances inorganique dans des eaux surface). Compiled report NWRI Contribution 87-124 in English and French).

Alkema, H. 1987. Summary Report IRQC Studies 144-155 (Sept. 86 - Aug. 87) for Inorganic Constituents in Surface Waters. NWRI Contribution 87-150.

Alkema, H. 1987. Summary Report PPQC Studies 49-60 (Sept. 86 - Aug. 87) for Inorganic Constituents in Surface Waters, NWRI Contribution 87-151.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84024

DATE: March 1988

TITLE OF STUDY: Quality Assurance Program - UGLCCS

STUDY LEADER: A.S.Y. Chau

TEAM: W. Li and E. Kokotich

GOALS: To serve as the chairman of a Quality Management Work Group for UGLCCS; to plan, develop and coordinate activities relating to quality assurance and to manage an interlaboratory QA program.

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RESULTS:

Thirteen interlaboratory QC studies were conducted and for each study, three reports were sent. Eleven final reports on Interlaboratories Performance Assessment Studies for QM-3 to QM-13 were generated and sent to laboratories, managers and chairmen of Management Committee (MC) and Activity Integration Committee (AIC). The final report "Report of QMWG Quality Management Work Group" were submitted to Chairmen MC/AIC. It reviews the QA activities and outlines the recommendations from the QMWG.

Advice was given to both the Management Committee and the Activation Integration Committee on laboratory performance and to another work group chairman regarding the write-up of data quality in their final reports. Two forms for self-auditing on data quality were designed and distributed to Project Leaders and Managers to assist in data interpretation and report writing.



Study 84025 (continued)

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Study	Distribution of Study	Closing Date	Design	No. of Samples	No. of Participants Expected	No. of Participants with data
L15	April '87	July '87	Major Ions	10	48	44
L16	Aug. '87	Oct. '87	Major Ions	10	52	49
L17	Jan. '87	Feb. '88	Major Ions	10	54	48

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Publications:

Summary reports have been provided to all participants. Formal reports for publication are being drafted for review.



RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84026

DATE: March 1988

TITLE OF STUDY: IJC Quality Control (Interlaboratory Studies)

STUDY LEADER: K. I. Aspila

TEAM: A.S.Y. Chau

GOAL: To provide three interlaboratory quality control comparison studies to laboratories in the Great Lakes Basin that support the Canada/US Great Lakes Water Quality Agreement

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RESULTS:

This project provides interlaboratory quality assurance studies to those laboratories directly or indirectly involved in the Great Lake International Surveillance Program. The studies are prepared and distributed by NWRI with some costs recovered (\$25 K) through budget allocations from DOE and US EPA. The selection of studies, substrates and parameters are made through consultation with both the Data Quality Work Group and Surveillance Work Group members. Efforts are made to deliver three studies per year. Study data are interpreted by IJC Great Lakes Regional Office staff and the Data Quality Work Group.

Studies consist of a mixture of natural and synthetic substrates. Results for laboratory data sets are interpreted for measurement bias by the rank-order method of Youden. Results on individual samples are flagged high or low when they deviate significantly from interlaboratory median values. When studies are completed, performance appraisals are provided to each laboratory head and pertinent managers. This distribution of laboratory appraisals now includes members of the Water Quality Board.

In 1985 the data evaluation process was expanded to include graphics and a more powerful process to discern bias using the Wilcoxon rank sum techniques.

Several interlaboratory studies were addressed during the fiscal year.

- Study 52: Toxic organics in ampules and sediments - was finalized in 1987. This large study (a three-part study) clearly demonstrated that one critical area responsible for laboratory data not being very comparable were the calibration standards in laboratories. A new study, No. 59, is being scheduled to address toxic organic standards.
- Study 57: Total phosphorus in sewage plant effluents - was also finalized in 1987. As with previous studies on STP effluents, this study also demonstrated that many small facilities (perhaps 20 out of 90) have difficulties in estimating phosphorus in sewage plant effluents.
- Study 58: Total phosphorus in water-ambient levels - was a study initiated and completed in 1987. As with previous studies this study once again demonstrated that several laboratories have difficulty in estimating ambient concentrations of phosphorus in open lake, near shore and tributaries in the Great Lakes Basin.
- Study 56: Total metals in sediments - was a study initiated and distributed in the spring of 1988. It will be evaluated and reported on in the next fiscal year.

STUDY REPORTS

HYDRAULICS PROJECT



RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84032

DATE: March 1988

TITLE OF STUDY: Fluvial Engineering

STUDY LEADER: P. Engel.

TEAM:

GOAL: To develop methods of flow and sediment transport measurements in open channel flow and to guide and advise resources engineers and managers on technical developments relevant to fluvial engineering.

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RESULTS:

The first phase of a joint study with Water Survey of Canada (WSC) to evaluate the AFFRA acoustic flow meter in the towing tank was completed. The meter is being developed by WSC for river discharge measurement applications. A preliminary report entitled "Preliminary Evaluation of the AFFRA Acoustic Flow Meter" was submitted to WSC. The second phase of this joint study with WSC to evaluate this flow meter in the towing tank was completed. A report entitled "Evaluation of the AFFRA Acoustic Flow Meter Phase II" was submitted to WSC for comments. A report outlining towing tank tests and field tests has also been prepared and is being finalized. This report is entitled "Preliminary Laboratory and Field Testing of the AFFRA Acoustic Flow Meter".

Work is continuing on the Milk River study. Data on stage-discharge curves for different approach channel conditions are being analyzed. A weir design which is hoped to be suitable for prototype applications is currently undergoing tests.

Work is continuing on the evaluation of different ways of measuring water levels for open channel flow. Work has been completed on float type water level recorders and a report entitled "Performance of Float Actuated Water Level Recording Systems" has been submitted to WSC. A theoretical equation has been developed which will be used to compute the water column elevation from the total pressure recorded with pressure transducers used with gas-purge systems. A report is being prepared for the Water Survey of Canada.

Tests were conducted to determine the effect of the transition in the crest of a V-notch/rectangular weir on the stage-discharge relationships. A report entitled "State-Discharge Equation for Sharp Crested Compound Weirs" was prepared.

An experimental study to determine the friction factor and the critical velocity for a stream bed protection system marketed in Canada and the United States was completed in the 1 m flume of the Hydraulics Laboratory. The report was submitted to the client and was very well received.

Study No. 84032 (continued)

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Model tests were conducted to determine the stability of a matrix of interlocking blocks marketed by a Canadian manufacturing company for erosion protection. A report was prepared and accepted by the client. The study was extended to a second phase to determine the flow resistance of this erosion control matrix in open channel flow. A report was prepared and accepted by the client.

A large physical model was designed and constructed to study the hydraulic characteristics of the proposed design of the Windermere Basin Rehabilitation Works. The study will extend into the next fiscal year and a report will be prepared at the conclusion.

Two meetings were held with representatives of Ontario Hydro regarding an extensive bedload measuring program near Pickering, Ontario. Advice was sought and given on the types and efficiencies of suitable bed load samplers for this program. A laboratory evaluation of the sampler chosen is anticipated for the next fiscal year.

Publications:

Engel, P. Bed Load Transport in Gravel Bed Streams. Journal of Hydraulic Engineering of the American Society of Civil Engineers. In press.

Krishnappan, B.G. and P. Engel. Measurement of Sediment Transport and Friction Factor in Mobile Boundary Open Channel Flow. Proceedings of the Symposium on Fluvial Hydraulics to be held in Budapest, Hungary in 1988. In press.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84033

DATE: March 1988

TITLE OF STUDY: Coastal Engineering

STUDY LEADER: M. Skafel

TEAM: C. Bishop and M. Donelan

GOAL: To develop methods to predict the effects of waves on shorelines and structures especially under changing water level conditions, and to guide and advise water and coastal zone managers on developments relevant to the nearshore zone.

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RESULTS:

The analysis of the impact of a new breakwater on the littoral processes at Goderich has been completed and a report prepared.

A report reviewing literature on Great Lakes water level variations has been prepared for Public Works Canada. Further study is underway using historical and archaeological information pertaining to Great Lakes water level variations. Presentations have been made in Buffalo and at Queen's University. A revised report is in preparation.

Technical assistance and advice has been given to the Ontario Ministry of Natural Resources Hazard Lands Technical Committee. Wave runup was calculated at 85 cross-sections for the lower Great Lakes.

Public seminars on Shore Protection Alternatives were held at Kincardine, West Lake, Owen Sound, Belleville and Goderich.

Evaluation of wave climate models continued. The SMB, JONSWAP, and Donelan similarity steady state equations have been tested against field data from Lake Ontario and the Gulf of St. Lawrence. These methods within one model (PHEW) have been intercompared against data from the model used by Public Works Canada. The Donelan 2-dimensional model has been adapted to run in a wave climate mode. The HINDWAVE model of Hydraulics Research Ltd., Wallingford, UK, has been obtained and is being compared with the PHEW and Donelan models. Comparison of wave directional results has begun.

Assistance was given to Parks Canada on a study to seek long term solutions to erosion at the northeast corner of Point Pelee National Park.

The analysis of suspended sediment and corresponding wave data from the field experiment in Lake St. Clair was completed. A report has been drafted. Work is underway to incorporate these data into the resuspension models of Simons and Schertzer.

Study No. 84033 (continued)

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Work has been initiated to examine the joint distribution of wave heights and periods in shoaling waters. Most of the effort went into preparing for the field experiments. These will coincide with field work in wave mechanics so that each will benefit from the other's data. The emphasis here is on the joint distribution of wave heights and periods in shoaling water. This information is extremely valuable to offshore and coastal engineers and helps us deal with erosion of coastal areas. The experimental set up consists of three towers inshore of the WAVES tower in 8m, 4m, and 2m of water. These are installed and are being instrumented.

A report that reviews the Shore Protection Manual's wave prediction procedure has been shortened and revised.

The strain gauge instrumentation to measure wave forces on submarine pipelines has been modified by pinning the flex elements. Preliminary tests of the new configuration showed encouraging results. Tests to debug the system will resume after Open House.

Publications:

Bishop, C.T. Wave Attenuation by Rubble-Lined Channel Walls. 1987. Canadian Journal of Civil Engineering, 14(6):828-843.

Bishop, C.T. and M.A. Donelan. 1987. Measuring Waves with Pressure Transducers. Coastal Engineering, 11:309-328. Also presented at the Canadian Coastal Conference 1987.

Nece, R., E. Nelson, and C.T. Bishop. Some North American Experiences with Floating Breakwaters. Proceedings of the Breakwaters '88 Conference, Institution of Civil Engineers, held in Eastbourne, England, May 4-5, 1988,

Presentations:

Skafel, M.G. and M.A. Donelan. Settling and Resuspension of Fine Sediments by Waves. Presented at the Canadian Coastal Conference in Quebec, PQ., July 7-10, 1987.

Skafel, M.G. and C.T. Bishop. Wave Climate Modelling and Intercomparison. Presented at the Canadian Coastal Conference in Quebec, July 7-10, 1987.

RESEARCH AND APPLICATIONS BRANCH  
Study Progress Report

STUDY NO: 84034

DATE: March 1988

TITLE OF STUDY: Wave Mechanics

STUDY LEADER: M. Donelan

TEAM: M. Skafel, I. Tsannis, K. Kahma, WHOI staff, NRL staff

GOAL: To discover or develop theories and/or models to describe and predict the interaction of wind and water, including surface waves; fluxes of mass and energy; turbulence; orbital velocity beneath breaking waves.

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RESULTS:

Last fall (October-December) was the last field season in the current collaboration on wave-turbulence interaction and radar scattering with the Woods Hole Oceanographic Institution and the U.S. Naval Research Laboratories. A great deal of effort (scientific, engineering, technical, programming) went into preparing the wave follower system. It was installed on the tower the week of 5 October. It performed beautifully and will help us get some very valuable information on wave generation and decay and mixing just beneath the surface.

The final field season included some important radar measurements from the tower using the NRL radars. The C-band radars were fixed as before, but pointing west instead of north. The ku-band radars, on the other hand, were mounted on a rotating and tilting mount to allow us to scan over full azimuth and elevation ranges in 90 minutes. This is the first time a microwave scatterometer has been so mounted on a tower and the data promises to be very revealing.

The wave-turbulence-radar program was extremely successful in terms of the quantity, quality and variety of data collected. We are now working through the data analysis systematically and on many fronts: Drs. G. Terray, B. Brumley and Y. Agrawal (Woods Hole Oceanographic Institution) are analyzing the acoustic current meter, acoustic backscattering meter and laser-Doppler velocimeter data; Dr. K. Kahma (Finnish Marine Research Institute) and Dr. I. Tsanis (PDF - soon to be on the faculty at McMaster) are analyzing the drag sphere current meter and directional wave data; Dr. W. Plant and Mrs. M. Colton (Naval Research Laboratories) are examining the radar data; Dr. M. Donelan is analyzing the pressure, wave follower and flux data; Dr. I. Tsanis is looking at turbulent energy dissipation in the air and Drs. Terray, Brumley and Donelan are examining it in the water.

Once the analysis is complete, we will start to interpret the data in terms of the objectives and goal of the study relating to mixing of pollutants, forces on structures, satellite remote sensing for weather and climate, wave propagation characteristics, wave generation and decay and the interfacial fluxes of momentum, heat and mass. By the end of FY 88/89 several more manuscripts will have been prepared and this extensive and comprehensive experiment will continue to bear fruit.



Study 84034 (continued)

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Publications:

- Donelan, M.A. and W.J. Pierson. 1987. Radar Scattering and Equilibrium Ranges in Wind-Generated Waves with Application to Scatterometry. JGR, 92(5):4971-5029.
- Venkatesh, S., M.A. Donelan, H. Graber, P. Liu, D. Schwab and M.A. Skafel. 1988. Finite Depth Wind Waves - A Preliminary Study on Lake St. Clair. Published in the preprint volume of the American Meteor. Soc. 7th Conference on Ocean-Atmos. Interaction, January 1988.
- Li, J.C. W.H. Hui, and M.A. Donelan. 1987. Effects of Velocity Shear on the Stability of Surface Deep Water Wave Trains. Proceedings of the IUTAM (Intl. Union of Theoretical and Applied Mechanics) meeting on Non-Linear Waves, Tokyo, August '87.

Presentations:

- Donelan, M.A. and W.J. Pierson. A New Model for Scatterometry Based on an Energy Balance in the High Wave Number Spectrum of the Bragg Waves. Presented at the 1987 IGARSS (Intl. Geoscience and Remote Sensing) Symposium, Ann Arbor, MI, May 1987.

RESEARCH AND APPLICATIONS BRANCH  
Study Progress Report

STUDY NO: 84035

DATE: March 1988

TITLE OF STUDY: Transfer of Toxic Gases

STUDY LEADER: M. Donelan

TEAM: N. Merzi and W. Strachan, M. Servos

GOAL: To establish the dependence of the transfer of gases at the air-water interface on the descriptions of the interface.

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RESULTS:

A new wind tunnel has been designed and a contract awarded for its construction in September. Construction began at the end of October and the tunnel will be ready for use in the fall of 1988. Design and manufacture of various monitoring instruments is in progress. This tunnel will have highly accurate instrumentation to facilitate the study of the mechanics and rates of transfer of gases across the air-water interface. We expect to be able to add significantly to the present state of understanding of gas transfer, particularly the aspects pertaining to cross-media pollution.

While the new toxic gas transfer flume is being constructed, some preliminary experiments were conducted on the flow characteristics and energy dissipation just beneath the air-water interface. A small wind-wave tank was used for this purpose and the experiments were conducted with tap water and with a surfactant added to the tap water to suppress the generation of wind-waves. A method of measuring the rate of dissipation of turbulent kinetic energy in the water was developed. High levels of turbulence near the interface are believed to enhance the transfer of pollutants that are "liquid phase limited". In this experiment we are exploring how the formation and breaking of small waves influences the level of turbulence near the interface.

When the new gas transfer flume is complete we will be able to measure the transfer rate of such pollutants (and non-toxic surrogates) directly. We expect to start the commissioning tests of the new flume in early August, and to do the first exploratory experiments in September.

Publications:

Merzi, N. and M.A. Donelan. 1987. Gas Transfer at Air-Water Interfaces. NWRI Contribution 87-157.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84036

DATE: March 1988

TITLE OF STUDY: National Calibration Service

STUDY LEADER: C. DeZeeuw (W.B. Taylor acting)

TEAM: D. Fekyt, C. Bil, B. Near

GOAL: Calibration and performance testing of water current meters, sediment measuring apparatus, and other hydrometric equipment used for data collection purposes.

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RESULTS:

The National Calibration Service has a commitment to calibrate and repair all flow meters owned and used by the Water Survey of Canada (Water Resources Branch, Environment Canada). For the Fiscal Year 1987/88, we completed 396 meter repairs/adjustments and 495 calibrations.

In addition to the services provided to WSC and NWRI, we were able to provide calibration and instrument repair services to outside clients on a cost-recovery basis. A total of 82 requests were actioned from other Federal agencies, municipalities, provincial governments, Ontario and Quebec Hydro Utilities, universities and the private sector. The revenue generated from these activities totaled \$87.4 K.

The tow carriage system underwent a detailed condition evaluation by an Engineering consultant from Germany. Although the facility is considered to be in very good condition for its age, there are a number of maintenance requirements to be performed next fiscal year.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84037

DATE: March 1988

TITLE OF STUDY: Hydraulics and Sedimentology Laboratory Support

STUDY LEADER: C. DeZeeuw (W.B. Taylor acting)

TEAM: Technical Services staff

GOAL: To provide expert technical support staff and fully operational laboratories and equipment for hydraulic geotechnical research and related activities.

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RESULTS:

The human resources of the Technical Services Section were fully utilized to complete priority tasks. Due to some flexibility in time available and the need to provide technical support, we are providing input to the new re-circulating flume for gas transfer studies. Due to the illness and retirement of our Carpenter, Mr. Klainka, and the resignation of Sedimentology Technician, Mr. Salisbury, some backlog has occurred, particularly in the Sed. Lab. The strength of the lab is down one third, and further backlog and delays are expected. This situation impacts most heavily on the Lakes Research Branch, and they have been made aware of the planned reduced level of support for the 1988/89 fiscal year.

The annual lab equipment maintenance program was completed, and in addition, the lab underwent a major cleanup and appearance improvement as part of Open House preparations. The annual lab equipment maintenance program has been completed. The motor-generator set providing DC to the tow carriage has been completely overhauled for the first time since its installation. The three pumps for the main water supply to the lab have been overhauled due to corrosion.

RESEARCH AND APPLICATIONS BRANCH  
Annual Study Report

STUDY NO: 84038

DATE: March 1988

TITLE OF STUDY: Applied Research and Engineering

STUDY LEADER: C. DeZeeuw (W.B. Taylor, acting)

TEAM: Scientific, Engineering and Technical Staff in RAB & RRB

GOAL: To maximize the development of new technology and technology transfer by making the Hydraulic Laboratory more accessible to Canadian private sector industries, municipal and provincial governments, and other federal departments

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RESULTS:

This study is the umbrella study for all third party revenue jobs in the Project.

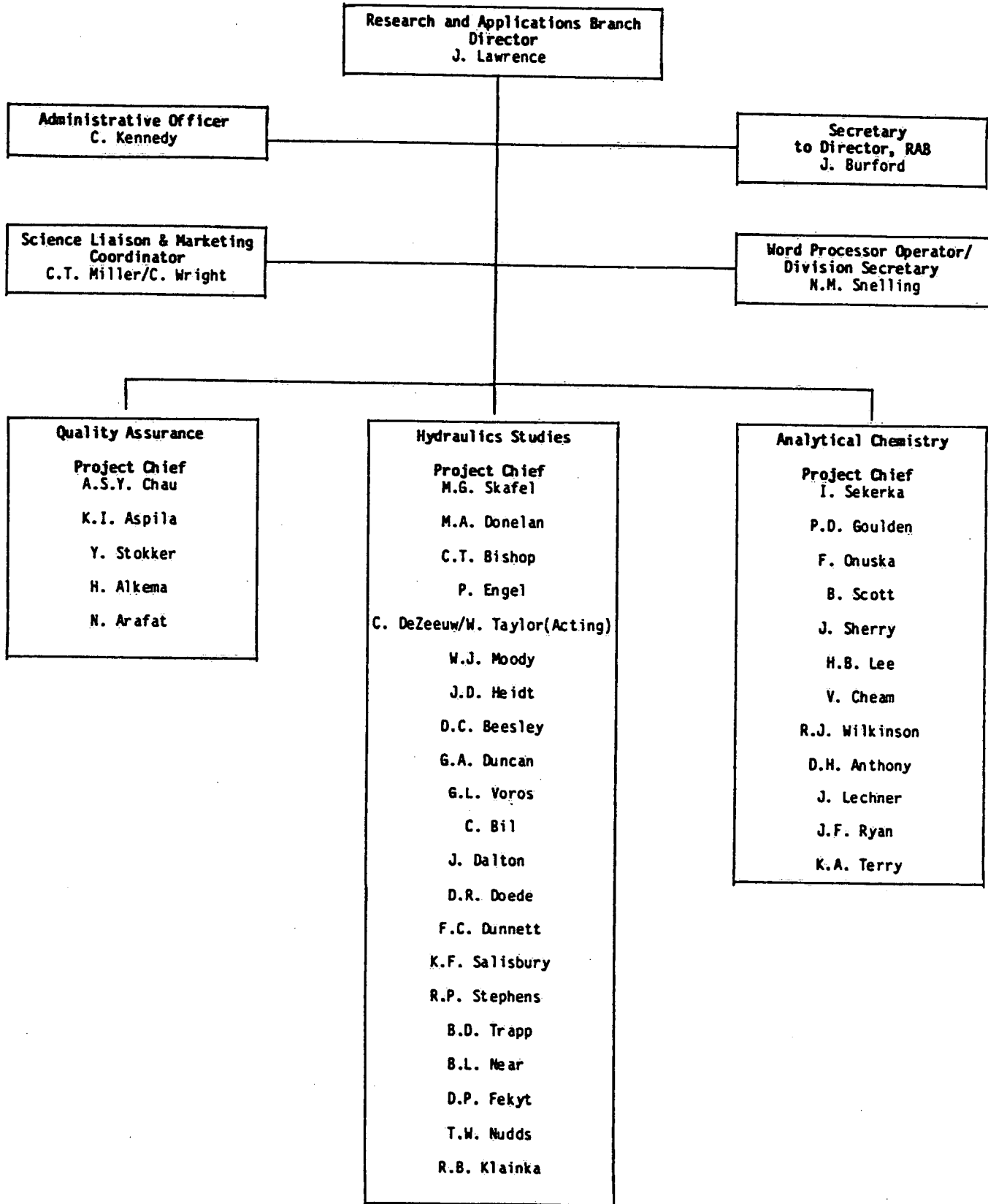
Administration and technical support was provided to third party revenue jobs in the Hydraulics Laboratory led by Study Leaders in RAB and RRB. Sixteen outside clients were served through this study, generating \$172 K in the 87/88 fiscal year. This is a significant increase over revenue generated in 1987/88. This includes the revenue generated by current meter calibrations as described in Study 84036, National Calibration Service.

To maximize potential revenues in the future, new initiatives were undertaken. The services of management consultants Stevenson, Kellogg, Ernst & Whinney were contracted to provide a plan to improve the utilization of the Hydraulics Laboratory. The final report was prepared in February 1988, and implementation of many of the recommendations has begun.

Technical support was provided to scientists for the Geo-Web, Mini-Slab and Windermere Basin studies.

APPENDIX

ORGANIZATION CHART



RESEARCH AND APPLICATIONS BRANCH

Director's Office

Director

J. Lawrence, B.Sc., Ph.D. (Bristol)  
Analytical Chemistry and Quality Assurance

Science Liason Coordinator

C.T. Miller, B.Sc., M.Sc. (Queen's), Ph.D. (Western Ontario)  
Environmental Toxicology

C. Wright, B.E.S. (Waterloo), M.A. (Guelph)  
Resource Policy

Secretaries

Ms. Joyce Burford  
Ms. Norma Snelling

Administrative Officer

Ms. Colleen Kennedy



ANALYTICAL CHEMISTRY RESEARCH

STAFF LIST

Project Chief

I. Sekerka, RNC., RNDr. (Prague), CSc. (Ostrava)  
Electroanalytical Chemistry and Flow Injection Analysis

Project Scientists

F.I. Onuska, P.Chem.Eng. (Bratislava), M.Sc. (Prague), CSc. (Brno),  
Ph.D. (Waterloo)  
Gas Chromatography, GC/MS and Separation Techniques

J.P. Sherry, B.Sc., Ph.D. (N.U.I.)  
Mycology and Radioimmunoassay

P.D. Goulden, B.Sc., Ph.D., (London), P.Eng  
Automation and Atomic Spectroscopy

H.B. Lee, B.Sc. (Hong Kong), Ph.D. (McMaster)  
Gas Chromatography, GC/MSD and High Pressure Liquid Chromatography

B.F. Scott, B.Sc., M.A., Ph.D. (Toronto)  
High Pressure Liquid Chromatography and Gas Chromatography

V.F. Cheam; B.S., Ph.D. (Oklahoma)  
Ion-Chromatography and Atomic Spectroscopy

Research Technologists

J.F. Ryan  
R.J. Wilkinson  
J.F. Lechner  
D.H. Anthony, B.Sc. (McMaster)  
K.A. Terry

QUALITY ASSURANCE

STAFF LIST

Project Chief

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Reference Materials and Quality Assurance

Project Scientists

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Federal/Provincial QA Program and Preservation

K.I. Aspila, B.Sc., M.Sc. (Carleton)  
Quality Assurance

V. Cheam, B.S., Ph.D. (Oklahoma)  
Methods Development (Inorganic) and Quality Control

W. Horn, B.Sc. (McMaster)  
Interlaboratory Studies

H.B. Lee, B.Sc. (Hong Kong), Ph.D. (McMaster)  
Quality Assurance, Standard Reference Materials, Sample Storage Conditions,  
and Methods Evaluation

P. Leishman, B.Sc. (McMaster)  
Interlaboratory Studies and Acid Rain

Y. Stokker, B.Sc. (Guelph), M.Sc. (Queen's)  
Organic Method Development and Quality Assurance

Technologists

N. Arafat, B.Sc. (Waterloo)

HYDRAULICS STUDIES

STAFF LIST

Project Chief

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Ph.D., (Cambridge); P.Eng., Coastal Engineering

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P. Engel, B.A.Sc., M.A.Sc., (Waterloo); P.Eng., Fluvial Engineering

Technologists

C. De Zeeuw, Head, Technical Services Section

W.B. Taylor, Acting Head, Technical Services Section

D. Beesley

C. Bil

J. Dalton

D. Doede

G. Duncan

F. Dunnett

D. Fekyt

J. Heidt

R. Klainka

W. Moody

B. Near

T. Nudds

K. Salisbury

R. Stephens

B. Trapp

G. Voros