

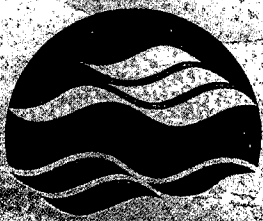
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Current Research 1998-1999

BY:

M. Zarull and R.J. Allan

NWRI Contribution No. 99-256

CURRENT RESEARCH 1998-1999

EDITED BY M. A. ZARULL AND R. J. ALLAN

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NWRI CONTRIBUTION NUMBER 99-256

PREFACE

This report presents an overview of the research conducted in 1998-1999 by scientists in the Aquatic Ecosystem Restoration Branch of Environment Canada's National Water Research Institute. It also includes research studies that have been completed or are ongoing in partnership with other government agencies, universities and the private sector.

This report is designed to provide the reader with an encapsulated view of the large number of studies that were conducted by AERB scientists on aspects of assessment and restoration of aquatic ecosystems during the past year. A list of published papers and presentations made at scientific conferences may assist you in searching for additional information in your field of interest.

If you require additional copies of this report, or further information on any of this research, please see the National Water Research Institute's web site at <http://www.cciw.ca/nwri/intro.html> or contact Mike Zarull (905-336-4783; Michael.Zarull@cciw.ca).

**R. J. Allan
Director, Aquatic Ecosystem Restoration Branch
National Water Research Institute**

PRÉFACE

Le présent rapport dresse le bilan des recherches menées de 1998 à 1999 par les scientifiques de l'Institut national de recherche sur les eaux, Direction générale de la restauration de l'écosystème aquatique, Environnement Canada. On y retrouve aussi des études en cours ou qui ont déjà été réalisées en collaboration avec d'autres organismes gouvernementaux, des universités et des membres du secteur privé.

Ce rapport a pour objet de donner au lecteur un résumé du grand nombre d'études qui ont été réalisées par les chercheurs scientifiques de la Direction générale sur divers aspects de l'évaluation et de la restauration des écosystèmes aquatiques au cours de la dernière année. Une liste des publications et des présentations faites lors de congrès scientifiques peuvent aussi vous aider à trouver d'autres renseignements dans votre champ d'intérêt.

Si vous désirez obtenir d'autres copies de ce rapport, ou d'autres renseignements sur divers aspects de ces recherches, veuillez visiter le site Web de l'Institut national de recherche sur les eaux à l'adresse suivante : <http://www.cciw.ca/nwri/intro.html> ou communiquez avec Mike Zarull (905-336-4783; Michael.Zarull@cciw.ca).

R. J. Allan
Directeur, Direction générale de la restauration de l'écosystème aquatique
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MANAGEMENT PERSPECTIVE

Research results have been incorporated into departmental reporting and the next year's planning cycle. In addition, results have been reported to clients and partners, and have been published in the scientific literature.

Research continues on identified studies.

SOMMAIRE À L'INTENTION DE LA DIRECTION

Les résultats de recherche ont été ajoutés aux rapports ministériels et au cycle de planification de l'an prochain. De plus, les résultats ont été signalés aux clients et aux partenaires et ont été publiés dans des revues scientifiques.

Les recherches se poursuivent sur des études déterminées.

TABLE OF CONTENTS

1. INTRODUCTION.....	1
2. DIRECTORS OFFICE.....	3
3. RESEARCH STUDIES AND ACCOMPLISHMENTS	
• LAKE ASSESSEMENT AND RESTORATION PROJECT.....	5
• SEDIMENT ASSESSMENT AND RESTORATION PROJECT.....	9
• GROUNDWATER ASSESSMENT AND RESTORATION PROJECT.....	15
4. PUBLICATIONS.....	19
5. SCIENTIFIC PRESENTATIONS AT CONFERENCES/WORKSHOPS/SYMPOSIUMS.....	31
6. SELECTED SCIENTIFIC COMMITTEES.....	39
7. EDITORIAL BOARDS AND OFFICERS OF PROFESSIONAL SOCIETIES.....	41
8. ADJUNCT PROFESSORSHIPS.....	43
9. STAFF LIST	
A) FULL TIME.....	45
B) RESEARCH ASSOCIATES.....	49

1. INTRODUCTION

The Aquatic Ecosystem Restoration Branch (AERB) of the National Water Research Institute (NWRI) has a goal similar to its name, 'to restore aquatic ecosystems', which means to restore degraded ecosystems to a level that can be permanently sustained through conservation and protection. More realistically, the Branch expects to mitigate effects or remediate degraded ecosystems to ones that have a higher order of ecological stability. Restoration can occur naturally, but more often involves reductions of stresses such as nutrient or contaminant levels, waste heat or management practices for example with reservoir operating procedures. Assessments of degraded aquatic ecosystems allow decisions to be made as to what to control to remediate effects or how much can be relied on nature to clean itself. To achieve ecosystem stability or sustainability requires decisions on what to do, including *in situ* options such as bioremediation or biomanipulation as well as developing ecosystem indicators of progress towards restoration.

Remediation towards a less degraded but not necessarily pristine ecosystem requires decisions as to how far to go or 'how clean is clean'. To arrive at such conclusions and to monitor progress towards them for surface and groundwater requires the development of indicators of ecosystem health, stability and sustainability. If these criteria are met, the ecosystem can be declared as remediated to acceptable conditions, perhaps even restored. The level of protection or control or regulation required to reach this state is dependent on the recovery or restoration of the ecosystem and the state that needs to be maintained.

Restoration then deals with degraded aquatic ecosystems which are remediated to some level of stability or sustainability involving minimization of stresses, *in situ* treatments, and probably conservation of components of the total aquatic ecosystem that have not yet been degraded.

Sustainable development assumes some economic growth of acceptable degree and rate. If a pristine ecosystem such as a national park sees no development, its ecosystem stability is conserved. However, development seldom can occur, if ever, without some degree of degradation. The question then is how much development and what type of development can occur before the aquatic ecosystem is degraded to a non-sustainable degree. This upper boundary may well be similar to that which is arrived at when degraded aquatic ecosystems are restored. In essence, the restoration of degraded ecosystems, which are those that have seen development, may result in a state of the aquatic ecosystem commensurate with a level of development that can be sustained. Of course, it may be that an acceptable recovery of an aquatic ecosystem may result in a state that is not acceptable in the case of development as opposed to conservation of pristine ecosystems.

The Branch conducts research to restore the chemical, physical and biological integrity of aquatic ecosystems and contributes to the Mission of the National Water Research Institute by:

- assessing aquatic ecosystem health, stability and sustainability;
- developing indicators of ecosystem health and recovery (how clean is clean); developing water quality, ecosystem health and sustainability guidelines and objectives;
- producing information for State-of-the-Environment reports;
- developing, proposing and implementing, if feasible, procedures for contaminated-sediment studies, mitigation measures or remedial techniques at degraded sites.

As a Goal, the Branch focuses on the restoration of degraded and ecologically disturbed sites, for example, the Areas of Concern (AOC) which are mainly bays and harbours in the Great Lakes or similar degraded sites elsewhere in Canada; on the more stressed of the Great Lakes, i.e., Ontario and Erie; on lakes impacted by mining or used as sites of tailings disposal; and on local sites where groundwater degradation is severe and preferably has a federal component, e.g., the Niagara Frontier. However,

whereas the overall Branch Goal is restoration, the realistic objective in most cases is partial restoration, mitigation or remediation. In rare cases with time, almost complete restoration may be accomplished.

2. DIRECTOR'S OFFICE

The Director's office ensures efficient use of resources to support research studies in individual projects. It also performs liaison and coordination of research activities with collaborating research and operational groups in the Environment Canada (DOE) headquarters in Ottawa, five DOE Regions, other federal and provincial government departments, international agencies (particularly U.S.-Canada International Joint Commission, IJC), and numerous universities and institutions doing aquatic research in Canada and abroad. The Director's office staff prepare overview and synthesis publications on environmental issues such as toxic chemical pollution, eutrophication, ecosystem remedial techniques, and aquatic ecosystem health, stability and sustainability. The staff also organize, convene and chair national and international workshops, symposia and conferences. The Director's office releases over a hundred publications per year on issues of high priority to the Department both nationally and internationally.

3. RESEARCH STUDIES AND ACCOMPLISHMENTS

LAKE ASSESSMENT AND RESTORATION PROJECT

The Lake Assessment and Restoration Project of AERB, NWRI conducts research to assess and remediate lake ecosystems. Limnological properties of systems are investigated and assessed in terms of ecosystem health. The trajectories of water movements associated with contaminated plumes are measured as a way of delineating affected areas and the sizes of nearshore mixing zones. Physical measurements of currents and mathematical models are used to infer open lake circulation and mixing of large river plumes in the Great Lakes. Collections of sedimenting particles are used to follow the contaminant status of particles contributing to sediment deposits. Nutrient dynamics of *in situ* sediment deposits are used to determine the importance of phosphorus sources to water quality. Organic contaminants are determined in water, particulate, biological, and sediment substrates as a way of characterizing the contaminant status of lake ecosystems. Advice is provided to Remedial Action Plans under Great Lakes 2000 although studies may be conducted anywhere in Canada. Specific areas of research include:

Limnology of Large Lakes, Reservoirs, and Coastal Areas

- Studies of currents and resulting transport of plumes and patterns of flow.
- Measurement of nutrients and physical factors such as dissolved oxygen which determine the biological integrity of ecosystems.
- Problem definition and assessment of progress toward goals of restoring ecosystem function.
- Measurements and modelling of mixing in lakes and reservoirs.

Sedimentology of Contaminated Deposits in Lakes

- Identification of sediment sources and pathways in nearshore areas.
- Development of conservative sediment tracers to determine net sediment transport.

Organic Chemistry

- Development of techniques for solvent-free analyses of low level organics.
- Analyses and interpretation of PCBs, OC, PAHs, and other organics of interest in ecosystem samples.

Bioavailability of Phosphorus and Metals

- Measurement of the sources of phosphorus to sediments and the subsequent reflux rates of available phosphorus.
- Measurement and interpretation of metal-iron oxide compounds which determine the importance of heavy metals to biota.

Mixing and Flow in Riverine Systems

- Determination of effect of underwater features such as weeds on flow patterns.
- Detection and tracing of contaminated plumes using acoustic methods.

Sustainability Issues

- Implications of increasing numbers of drinking water intakes and sewage discharges in large lakes and embayments.
- Implications of nutrient loading controls and invasions of exotic species to sustainable fish yields in Lake Erie.

Charlton, M.N. (Project Chief)

Lake Erie: The oxygen situation has reverted from good conditions during the last four years to typical poor conditions in 1998. The majority of productivity change in the lake occurred due to nutrient reduction before mussels invaded.

Hamilton Harbour: Under partnership funding with local municipalities research in 1998 showed that while ammonia was still above specifications the phosphorus concentrations responded to improvements at Burlington's STP.

Lake Erie: Partnerships with scientists and students at University of Waterloo continued during five research expeditions on Lake Erie. This collaboration resulted in publications and further plans for more extensive research.

Coakley, J.P.

Promising results were obtained from two seasons of data collection at the tracer experiment site 1 km offshore from Burlington, in the area proposed for an expanded sewage plant outfall. The artificial sediment tracer used was a solid mineral tracer containing non-radioactive cesium. Initial interpretation shows that dispersion rates during both periods were relatively low, and were directed offshore and toward the southeast. This suggests low mixing and dispersal rates of any sewage outfall placed there, but the results will be interpreted in more detail prior to publication. Studies of contaminant sediment dispersal were also carried out at the points of contaminant discharge in the western end of the lake (Toronto, Oakville, Bronte, and Hamilton)

A detailed sediment substrate map of western Lake Erie prepared by Dr. Coakley and co-workers (Dr. N. Rasul and Mr. Rolf Pippert) has been incorporated onto the EC Internet site (GLIMR) and is now accessible to the general public. This work and other initiatives on Point Pelee and on cores from the central basin of Lake Erie have led to several publications on important changes in the basin (see publication list). Examples are long-term climatic and hydrologic trends as deduced from sediment records and the dynamics of zebra mussel expansion to soft sediment areas of the lake.

Hamblin, P.F.

Publication of a review on exchange flows as a contribution to a book on physical limnology (see publication list) and continued to develop three-dimensional hydrodynamic and transport models for Hamilton Harbour and the western end of Lake Ontario.

Completed study of the Arrow Lakes Reservoir, British Columbia and reported on some aspects of study at an international conference

Continued to collect and reported on observations of surface meteorology, water temperature time series and currents in an African great lake at an international workshop.

Began collection of field data in a pilot study of the impact of caged aquaculture on water quality of the Great Lakes in collaboration with Ontario Ministry of Environment.

Hecky, R.E.

Completed measurements of benthic photosynthesis and respiration in Lake Erie littoral on rocky and sandy habitats (near Long Point).

This year's focus was primarily to evaluate photosynthetic light response of Cladophora stands compared to zebra mussel dominated substrates and to look at effects of these different stands/substrates on nutrient (N and P) demand. The results will allow evaluation of benthic photosynthesis enhancement by mussels in the littoral areas of Lake Erie.

Organized and chaired session at annual meeting of International Association of Great Lakes Research "The Great Lakes of Africa" Arranged sponsorship for several African participants from UNU-INWEH.

Marvin, C.H.

Completed work on fecal sterols in Hamilton Harbour sediments in collaboration with Dr. John Coakley (LAR/AERB). These compounds are used as tracer compounds to track the influence of sewage treatment plants or other anthropogenic inputs into aquatic systems. This project has also resulted in information that will lead to the optimization of the analysis methodology for fecal sterols; this technology will be transferred to academia, government and private sector agencies through collaboration, reports and research publications.

Initiated a joint research project with Dr. GG Leppard (AEPB) to investigate the role of particles and flocs as contaminant carriers in Hamilton Harbour. The results of the first stage of this project were published in Environmental Science and Technology; this work has drawn considerable interest from CCIW staff. Extensions of this work are being pursued and expanded upon as outlined in the 1999/2000 study forecast.

A study of polychlorinated dioxins and furans in sediments and zebra mussels at a site in western Lake Ontario (Port Dalhousie) was completed (November 98). The study was initiated in 1995 and was undertaken in collaboration with the Ontario Ministry of the Environment. The results include a comparison of PCDD/PCDF levels in colonized and non-colonized sediments, PCDD/PCDF levels in mussel tissue, calculation of biota-sediment accumulation factors (BSAFs) and areal estimates of toxic equivalents (TEQs) in sediment and mussel biomass. These results contribute to our knowledge of POPs in the Great Lakes and the potential impacts of zebra mussels on contaminant pathways.

Murthy, C.R.

Coastal zone research of large lake systems and coastal oceanic systems are synthesized within the context of sustainable use of nearshore water uses and resources relevant for GLAP/AOC and Integrated Coastal Zone Management of Resources.

Skafel, M.

The flow conditions at the Cootes Paradise Fishway (outlet of Cootes Paradise) were documented in support of the Hamilton Harbour RAP. Guidelines to assist in the development of an operational plan for the fishway were prepared which make use of episodes of extended flow in either direction.

The bottom currents at a trout spawning shoal in Lake Ontario were monitored during the autumn. These are the first extended flow measurements made in support of trout egg mortality studies. The ultimate goal of this work is to identify the threshold of physical conditions that adversely affect mortality.

As part of the commercialization initiative at NWRI, a Canadian company (Waterwall Inc.) was helped to assess its products through transfer of technology in the field of civil engineering (small gravity dams and hydraulics). Once the company successfully develops its products they will be in a position to aid both the public and private sectors in emergency preparedness.

SEDIMENT ASSESSMENT AND RESTORATION PROJECT

The Sediment Assessment Restoration Project of AERB, NWRI conducts a multidisciplinary research program on the pathways and effects of sediment-associated contaminants and nutrients on aquatic ecosystems in Canada. Emphasis is placed on studies relevant to the assessment of sediment quality and remediation of contaminated sediments. In support of sustainable development in the metal mining industry, multidisciplinary studies are carried out on the effects of metal mining on aquatic ecosystems and new techniques are developed and tested for subaqueous disposal of acid generating mine tailings and waste rock. Knowledge generated from this research is used to support programs such as Great Lakes Action Plan, Fraser River Management Plan, Sustainability Sectors, Environment Canada regional activities, EEM program development for mining, and CEPA assessments such as the assessment of Cu and Zn smelter and refinery emissions. There are presently eight study leaders with expertise in physicochemical and geotechnical properties of sediments, the acoustics of sediments, sediment biogeochemistry, benthic invertebrates and sediment porewater geochemistry. Research is conducted in the following specific areas:

Assessment of Sediment Quality

Studies of the relationship between benthic community structure and sediment biogeochemistry. Laboratory testing and field studies of uptake and toxicity of sediment contaminants to benthic invertebrates including identification of the cause of sediment toxicity. Investigation of historical changes of concentrations of contaminants in bottom sediments.

Remediation of Contaminated Sediments

- Laboratory studies of effectiveness of different methods for *in situ* treatment of contaminated sediments.
- Field demonstration and monitoring of the efficiency of in-situ treatment of contaminated sediments.

Acoustic Mapping and Monitoring of Contaminated Sediments

- Development and field trials of innovative equipment and procedures for locating contaminated sediments and measuring their stability.
- Application of the above in Areas of Concern to map the geometry of contaminated sediments and measure their stability and to support remediation programs like dredging and capping.

Transport of Sediment-Associated Contaminants

- Laboratory and field studies of migration of trace elements and nutrients via sediment pore water into lake water.
- Investigation of partitioning of persistent toxic substances in suspended sediments and lake water.
- Field studies of resuspension and redeposition of sediment-associated contaminants.
- Field studies of transport of pesticides from agricultural activities into coastal marshes and lakes nearshore zone.
- Evaluation of the role of waves in the transport of fine-grained sediments.

Sustainable Sectors Mining

- Multidisciplinary studies (field and laboratory) of effects of metal mining on aquatic ecosystems.
- Laboratory and field studies of feasibility of subaqueous disposal of acid generating metal mine tailings and waste rock into different lakes and man made reservoirs.

Reynoldson, T.B. (Project Chief)

Almost all the Great Lakes Areas of Concern have documented sediment contamination. Current sediment guidelines are based on the comparison of chemical concentrations at a site to those which have been established as representing a perceived safe concentration on a chemical by chemical basis.

As an alternative, Environment Canada have developed biological sediment guidelines.

There are two basic assumptions behind these biological sediment guidelines. First, that it is the effects of sediment contamination on biological processes that are the primary concern and that therefore assessment of biological effects is paramount. Second, that the complexity of the sediment matrix makes chemical concentration a poor predictor of the biological availability of contaminants.

The biological sediment guidelines incorporate (a) the structure of benthic invertebrate communities by using predictive models that relate site habitat attributes to an expected community, and; (b) functional responses (survival, growth and reproduction) in four sediment toxicity tests (bioassays) with benthic invertebrates using ten test endpoints. For both community structure and toxicity guidelines have been established that allow determination of the community as either, unstressed, potentially stressed, stressed or severely stressed and the sediment as either non-toxic, potentially toxic or toxic. BEAST software has been developed which incorporates the complex multivariate analysis required by this approach and presents the user with straightforward categories of sediment quality on a site by site basis. The BEAST combines new methods with a simple, straight-forward software user interface. The result is a powerful new tool for sediment assessment.

The assessment of pollution in the catchment of the Fraser River, British Columbia, Canada, was addressed by using benthic macroinvertebrates to develop a biomonitoring program based on the reference-condition approach to water-quality assessment. Macroinvertebrate community structure, and habitat and water chemistry variables, have been measured from 219 reference samples and 98 test, repeat or quality assurance samples from three field seasons. The sites encompass 23 sub-catchments, including the main stem Fraser. This represents the most comprehensive benthic macroinvertebrate community sampling for the basin. Family-level predictive models that use reference groups of benthic invertebrates and up to 27 predictor variables have been developed. Assessments on test sites indicate that effects from logging, mining and agricultural activities can be evaluated. The analytical technique, using multivariate assessment methods, allows a judgement on the direct likely cause for the impairment (e.g., physical disturbance versus increase in numbers of organisms).

Canada has major, cumulative environmental problems that affect fresh water. These problems include pervasive hydroelectric development, long-range transport of atmospheric pollutants (LRTAP), forestry practices, agriculture, and the introduction of exotic species. We currently assess the effect of these environmental disturbances by a patchwork of biomonitoring programs. There is a need for a nationally coordinated biomonitoring program for aquatic ecosystems. NWRI is promoting the use of the reference condition approach as the basis of a national reference site data base programme that could be used in different EEM programmes and to address other site specific aquatic ecosystem health issues. This programme would provide a reference database that can be used as is, or that can be added to over time.

Bioassessment methods cover a range of biological scales from sub-cellular to ecosystem, each scale has advantages and disadvantages. Small scale methods can be well controlled but have limited ecological relevance and vice versa. Determination of the correlation between scales is limited and current research is investigating the relative sensitivity at different scales. New methods for assessing effects for sediment contamination that provide diagnostic capability at the community level are being developed using both stressor specific community level response and linking metallothionein induction (a diagnostic test for metal stress) with reproductive performance in the oligochaete *Tubifex tubifex* and growth in the midge *Chironomus riparius*.

Borgmann, U.

An extensive collaborative study (with T. Reynoldson, F. Rosa and T. Jackson) on the effects on metal deposition from smelters was continued in 1998. An interim report summarizing findings from the first two years has been produced, including effects on sediment chemistry (surface and depth profiles), in-situ benthic community structure and sediment toxicity to four benthic invertebrate species in 12 lakes in the

Sudbury area. Additional sediments were collected in a second field trip in 1998. Metal bioaccumulation/bioavailability studies with *Hyalella* and other measurements not completed during the first trip in 1996 were conducted. Additional benthos samples were also taken, using a larger sampler to compensate for the low benthos density in these lakes compared to Great Lakes sediments. In addition to the Sudbury project, a preliminary study was done on sediment toxicity and metal bioavailability in the Rouyn-Noranda area in collaboration with the University of Waterloo as part of the Metals In The Environment Research Network study at Rouyn.

Metal toxicity to aquatic biota cannot be predicted reliably from concentrations in water or sediments because metal bioavailability can vary dramatically from one region/water body/sediment type to another. Metal concentrations within aquatic organisms themselves can be much better predictors of toxic effects because they quantify the bioavailable fraction of the metal directly. However, this requires reliable data on the relationship between bioaccumulation and toxicity, including knowledge of potential complicating factors such as regulation of internal metal concentrations by the biota. Several studies were conducted to further our understanding of bioaccumulation-toxicity relationships for metals. A study on lead toxicity to *Hyalella* in sediments was completed. It showed that toxicity could be predicted from bioaccumulation and that toxicity was due primarily to dissolved metal. It also demonstrated that the cone static test method, developed for use with sediments from Sudbury area lakes, gives identical toxicity and bioaccumulation measurements as the standard beaker test method. Bioaccumulation and toxicity of Ni in three different Ni-spiked sediments has also been measured. Toxicity was proportional to Ni bioaccumulated, but not Ni in sediment or Ni in water. Tests are currently being repeated in Imhoff cones for verification and to attempt to get a better estimate of bioavailable Ni concentrations in water at toxic levels. These bioaccumulation-toxicity relationships are will be used to quantify the contribution of individual metals to toxic effects in sediments from the Great Lakes and inland lakes exposed to smelter emissions.

Cheam, V.

Metal data for Pb, Zn, Al, Cd and Tl show seasonal variations of high levels during the winter-early spring period and low levels during the summer-fall period. In spite of the implementation of unleaded gasoline, the Agassiz Ice Cap still received a significant amount of lead, more than central Greenland, due to the low/medium altitude and the Eurasian anticyclones (on a water-concentration basis, thallium was more toxic to *Hyalella* than Ni, Cu, or Zn, but less toxic than Cd or Hg. However, on a body-concentration basis, the toxicity of Tl, Cd, Hg and Pb were all similar. Thus, thallium is a highly toxic element).

Jackson, T.A.

Carried out research on the stable isotope composition of mercury in aquatic environments. The samples include cores and biological specimens from the Niagara Basin of Lake Ontario and cores from lakes polluted by the Noranda-Rouyn smelter in Quebec. Isotope ratios of anthropogenic and natural mercury deposits in core sections are being compared. This is the first time that work of this nature has been done. The research was initiated in the spring of 1998 and is still in progress.

Initiated research on the accumulation and partitioning of heavy metals by various bacteria and nonliving particles in sediments from four lakes polluted by emissions from the smelters at Sudbury, Ontario. Semiquantitative data for metallic and nonmetallic elements will be obtained from statistically meaningful numbers of visually selected, individually analysed microbes and microscopic particles using the techniques of energy dispersive X-ray microanalysis and transmission electron microscopy. This work follows up on a preliminary pilot study and on a successful related project involving microanalysis of mine-waste polluted sediment from Larder Lake, Ontario.

Initiated part 2 of a research project on the speciation and toxic effects of heavy metals (chiefly copper and nickel) in various lakes polluted by emissions from the smelters at Sudbury. The work is still in progress. The principal purpose of part 2 is to examine effects of metal species (and the environmental factors that control speciation) on the activities of microbial communities in sediments.

Murphy, T.P.

Field observations confirmed our earlier studies that the algal toxin microcystin is present when and where ducks die. A new microcystin was identified and isolated for ongoing analysis of its structure and toxicity. Data are being organized into a GIS system to resolve what triggers the production of the toxin.

In Lake Biwa, Japan we confirmed our earlier observations that the formation of vivianite (ferrous phosphate mineral) governs the recycling of phosphorus from the sediment to the water column. The spatial variation in the sulphide content in the north basin sediment indicates a major loading of organic matter from the south basin is dissolving vivianite. Also typhoons are strong enough to mix the sediments of the deep basin (90 m) thus enhancing the release of any dissolved phosphorus.

After our publications and public presentations, Dofasco issued a contract to collect and treat the runoff from its coal piles. This runoff was highly contaminated and precluded any sediment management in this area of the harbour. The research had been supported by Dofasco and lawyers were not involved in the corrective measures. However, late in the study, legal actions were threatened by EP staff and Dofasco cooperation has ceased.

Rosa, F.

Completed field study on the impact of Atmospheric Transport of Metals from Smelters on Sudbury Area Lakes. Lake-water concentration levels were measured in 12 lakes, and data was interpreted and reported as a joint NWRI publication by team members. A follow-up study was conducted and the data is presently being interpreted.

Retrieved dialysis chambers to estimate pore-water migration from contaminated Sediments, through the sand cap to the overlying water, over time.

Deployed and retrieved sediment traps at two stations in the Harbour, monthly, to monitor sediment movement in and around the sand cap area.

Joint efforts between NWRI (T. Reynoldson, F. Rosa & M. Chariton) and Ontario Region (S. Painter) have resulted in the successful completion of the Lake Ontario surficial sediment survey. The purpose of the survey was to define the present status of the surficial sediment contaminants (most of Tier I and Tier II, requirements), and compare these results with those of the early 1970 surveys. A total of 94 sites were sampled, which generated more than 600 sediment samples.

Rukavina, N.A.

Characterization of the properties, geometry and stability of contaminated St. Lawrence River sediments at Cornwall, Ontario. Completion of a five-year study of a contaminated deposit on behalf of the Cornwall RAP. Results will be used for remediation planning and implementation. The study provided the opportunity for developing, testing and applying a number of innovative procedures for mapping and monitoring contaminated sediments which should be useful in AOCs in general.

Evidence and implications of disturbed sediments in Hamilton Harbour. Sediment-core properties, morphological data from side-scan sonar records, and comparison of 1915 and 1976 harbour bathymetry all indicate that there have been large-scale changes along the south industrial shoreline as the result of ship traffic, dredging and dumping. The resultant disturbance of sediments has to be taken into account in using chemical profiles to properly interpret the contaminant history and to track the recovery of harbour sediments.

Acoustic procedures for monitoring capping and dredging activities. The sand-cap project in Hamilton Harbour provided the opportunity for testing of four acoustic procedures for monitoring cap placement and measuring changes in bathymetry and bottom type. All procedures should apply equally well to the monitoring of dredge projects.

Collaboration with EPA on a trial of acoustic procedures for mapping contaminated sediments in the Grand River at Grand Haven, Michigan. The survey demonstrated that NWRI's approach, based on the RoxAnn™ seabed-classification system, could quickly delimit the fine-grained sediments most likely to be contaminated, provide preliminary data on sediment type and bathymetry in realtime, and apply GIS and other procedures to generate the maps and areal analysis required.

Collaboration with a consortium of colleges in western New York State on a survey of the sediments and sedimentary processes of the eastern coast of Lake Ontario. This was an opportunity to compare NWRI's mapping procedures and data with the sidescan, sub-bottom profiling and ground-penetrating radar of the other collaborators and to develop the information needed for shoreline management of this fragile area.

Continuation of mapping of the Toronto waterfront sediments for the Toronto Region Conservation Authority. Data are being used by the authority to develop the shoreline and by NWRI to look at the evolution of the shoreline since its original nearshore surveys there in 1968.

Wong, H.K.T.

Completed the study of erosional impacts and biotoxicity in the distribution of CEPA priority metals in an abandoned gold mining site.

Successfully measured the transfer of toxic Hg from abandoned gold mine tailings to the atmosphere and determined (preliminary data) that mine tailings can be a major source of mercury from crustal material and terrestrial antropogenic Hg to the atmosphere. Work in collaboration with AES Atlantic in Bedford, N.S.

Successfully tested a method for the determination of low level aerosol-Hg aloft during Fire III sampling activities in the Arctic region using clean methodology and an isokinetic inlet device. In collaboration with AES Downsview.

Successfully converted an *in situ*, dialysis method for the sampling and analysis of sediment interstitial water Hg. Preliminary results indicate Hg profiles with depth consistent with source material. In collaboration with F. Rosa (AERB).

Successfully distinguished toxic metals component(s) in fatty fish tissue (Preliminary results) and its implications in sampling and analysis. In collaboration with NLET.

Zeman, A.

Multidisciplinary monitoring of the Hamilton Harbour is completed at present in a report to be submitted to the Cleanup Fund (an incomplete draft version has been submitted for internal use). The remaining portion of the report (chemical analysis of porewater samples) is expected to be completed by the end of the current fiscal year.

Comprehensive guidelines for *in situ* capping have been finalised by the US Army Corps of Engineers and the US EPA in 1998 with the technical input from NWRI based on the 1995 *in situ* capping project and subsequent monitoring of the Hamilton Harbour site. This information is readily available at two different Internet sites. Apart from further upgrading of research results, there is no further need for in-situ capping guidelines.

Although porewater data are essential for the completion of monitoring report, no migration of contaminants have been confirmed by geochemical cores after capping and by sediment pore-water monitoring. In general, ongoing physical, chemical and biological post-capping monitoring has so far confirmed two principal objectives of the demonstration project: i. a sand cap can be successfully and accurately placed on very soft sediments without substantial sediment disturbance; ii. primary sediment-bound pollutants remain isolated in the sediment below the cap.

Feasibility study has been started on *in situ* capping of contaminated sediments occurring at Peninsula Harbour, Lake Superior. The Peninsula Harbour AOC has problems associated with degraded fish and benthic communities and high levels of toxic contaminants (Hg and especially MHg) in fish and bottom sediments. Stage 2 draft report recommends in-situ capping of the area of highest contamination as the preferred course of action. The issue is going to be addressed by the joint NWRI-McMaster team under the Toxic Substances Research Initiative.

GROUNDWATER ASSESSMENT AND RESTORATION PROJECT

The Groundwater Assessment and Restoration Project conducts a multidisciplinary research program on the remediation, protection, and sustainability of groundwater resources in Canada. The research is conducted under the auspices of the Federal Water Policy, the Boundary Waters Act, the Pesticide Control Act, and the Atomic Energy Control Act. Emphasis is placed on determining the physical and chemical processes controlling the transport and fate of contaminants in a variety of groundwater environments. New techniques for preventing or restoring existing groundwater contamination are being developed. Research is also conducted on the role played by groundwater in regional water budgets and wetlands. Knowledge, generated from this research, is used to support regional activities within Environment Canada, and programs such as CEPA, the Great Lakes and Atlantic Canada Action Plans. There are presently five study leaders with expertise in physical and chemical hydrogeology, biological systems in groundwater, and groundwater geomechanics and numerical modelling. Research is conducted in the following specific areas:

Contaminated Sites

- Laboratory development and field testing of geochemical and biological methods for improving the quality of groundwater contaminated with petroleum products and chlorinated solvents in porous formations.
- Investigation of the processes of contaminant migration and restoration in complex fractured, groundwater environments such as are found beneath contaminated sites in southern Ontario and Atlantic Canada.

Sustainable Groundwater Resources

- Development of regional and watershed scale methodologies for determining the sustainable development of groundwater resources, and the relation of these resources to aquatic ecosystems.
- Investigation of the role of groundwater in the hydrological balance and sustainability of wetlands in the Great Lakes Basin.
- Development of modelling tools and data analysis techniques for assessing the impact of climate change on groundwater resources in regional scale settings.
- Assessing the migration and persistence of septic-system derived nutrients in groundwater environments and transport to wetlands and surface water bodies of the Great Lakes.

Mining and Groundwater

- Research on the management and improvement of groundwater environments contaminated by high concentrations of metals from mine wastes.
- Development of geochemical models for predicting metal solubility in very acidic groundwater.

Pesticides and Groundwater

- Development and application of numerical models for improved prediction of pesticide transport and persistence in groundwater environments.
- Field studies to assess the long-term persistence of pesticides in soil, and potential impact on shallow groundwater resources.

Crowe, A.S. (A/Project Chief)

A study is being undertaken at Point Pelee National Park to (1) develop a conceptual model of groundwater flow within the barrier bars, and (2) determine if septic-system derived nutrients are being transported to, and impact on, the marsh. The hydrogeological research program at Point Pelee National Park is continuing with the focus on long-term monitoring of groundwater levels and chemistry. During the past year a major portion of the research was published. The primary deliverables for FY 98/99 was the

development of a numerical model which can simulate groundwater flow and contaminant (nutrient) transport within the barrier bars in response to fluctuations in the marsh, Lake Erie and precipitation.

The large scale use of the pesticide DDT between 1948 and 1967 occurred at Point Pelee National Park for mosquito control in recreational areas and pest control in the former apple orchards. Given the degradational properties of DDT, it would be expected that the DDT and its degradation products DDD and DDE would no longer exist at Point Pelee. However, during 1998 these compounds were detected in the shallow soil at several locations within the Park. Following reports of high concentrations of DDT in the soil and water at the Camp Henry camp ground at Point Pelee National Park, Parks Canada requested the assistance of the National Water Research Institute in determining the extent of contamination at the camp ground. Since April, 1998, Allan Crowe has lead an extensive field and analytical program to:

1. verify that the previous reported results (from University of Windsor) are correct;
2. determine the extent (spatially and depth) of the reported zones of high levels of DDT;
3. determine if other areas of high levels of DDT exist in the soils within the Park;
4. check several of the Park's drinking water wells for dissolved DDT;
5. determine if other harmful chemicals (e.g. Dieldrin) exist at these sites.

After several successful field trips to Point Pelee, and analyses soil and groundwater samples, Parks Canada was able to identify which areas of the Park should be restricted to visitors and plan a remedial strategy for the Park

Lapcevic, P.A.

Since 1995, I have been involved in an extensive field and laboratory hydrogeological research program at the Smithville Site under the direction of Dr. K. Novakowski. Over the past year we have completed the bulk of the field and lab work necessary to build a detailed conceptual model of the groundwater flow and contaminant transport in the fractured dolostone. This work has included detailed characterization of rock core, measurement of rock properties such as organic carbon and porosity, hydraulic testing at three different scales, geochemical and isotopic measurements, and a long term hydraulic head monitoring program. Tracer experiments at a scale of over 100 m were completed this summer in a single fracture at the site. Most previous experiments have been limited to less than 50 m and this increase in scale will be significant in furthering our understanding of solute processes in fractures at the field scale and allowing us to better predict the advance of contaminant plumes in fractured rock systems. Additionally, preliminary work with a point-dilution probe developed by NWRI has measured velocities up to 30 m/day in fractures less than a millimetre in width. During this past year various aspects of the research have been written up (eg. Geochemistry). The final report on the conceptual model will be completed in the next few months. The research program is continuing with a focus on long-term monitoring of hydraulic head and work to further characterize the source zone. The study has yielded a unique data set which will be amenable to further interpretations in the years to come. The results of this research program will further our understanding of the hydrogeology of heterogeneous rock systems and improve our ability to predict and prevent the environmental effects of toxic substances in groundwater and ultimately potable water supplies.

Lesage, S.

The enhanced solubility of petroleum-derived compounds in humic acid solutions is the basis for a new groundwater remediation technology. A three year pilot-scale study of flushing methylnaphthalenes from diesel fuel placed below the water table in a sand tank has demonstrated the utility of the method. In addition to the enhanced solubility and transport by humic acids, sorption and biodegradation must be considered as important processes when modeling the results. Losses due to biodegradation had to be avoided in laboratory tests conducted to measure sorption parameters.

A paper was presented at the International Symposium on the Degradation of Chlorinated and Recalcitrant Compounds in Monterey CA in May 1998. A laboratory feasibility study was conducted for a US Department of Defense site, where a relatively unusual solvent, 1,1,2,2-tetrachloroethane, was found to be recalcitrant to bioremediation efforts. The water at the site is also contaminated with carbon tetrachloride, tetrachloroethylene and trichloroethylene, making it an ideal site for the application of the

vitamin B12 catalysed process. The laboratory study consisted of both microcosms and column study. The two-column experimental set-up was itself very innovative, as it was designed to represent the recirculation well system that will be used in the field. Two reports were prepared and a presentation was made at Americana in March 1999. A pilot scale application on-site is planned for next fiscal year. The potential application of new polymers marketed as Imbiber Beads™ that are currently manufactured for spills was studied as a potential alternative to charcoal. Although the commercial polymers outperform charcoal in the treatment of pure phase solvents, it was not competitive for the treatment of solvents when they are dissolved.

The potential use of humic acids as complexing agents in the remediation of soils contaminated with both metals and PAHs, was studied in collaboration with GSI Environnement from Quebec. Humic acids from different sources were compared with surfactants and chelating agents for their ability to remove hydrocarbons and metals from a contaminated soil. Humic acids from different sources varied tremendously in their ability to complex hydrocarbons and metals, but the best ones proved to be competitive with chemical surfactants and chelating agents. Electrokinetics trials were too brief to be conclusive.

Piggott, A.R.

Advanced methods of numerical groundwater modelling were developed for regional scale application in the Grand River watershed. These methods allow groundwater conditions to be determined as an explicit function of climate and water use.

Climatic and hydrologic data for southern Ontario for the period of 1970 to 1995 were assembled in a computational setting that allows rapid evaluation of relations among the data, and linkage of the data to supporting information such as geologic mapping.

Water well construction records, water taking permits, and census data were used to determine groundwater usage in southwestern Ontario. Areas with elevated rates of inadequate water quality and quantity were also identified and mapped.

Ptacek, C.J.

Studies were conducted to evaluate the long-term release of phosphorous accumulated at tile bed sites. Phosphorous is initially accumulated in the unsaturated zone in discrete layers beneath tile beds and on aquifer solids. This phosphorous is slowly released to groundwater for years to decades after tile beds have been abandoned. As a result, groundwater discharging to surface water bodies can lead to elevated concentrations of phosphorous in surface waters and stimulation of algal blooms. The study focused on quantifying the mass and form of accumulated phosphorous, the rate of groundwater transport, and geochemical processes occurring at the groundwater/surface water interface. Incorporation of the study results into predictive models will provide improved estimates of long-term phosphorous release from wastewater disposal sites and improved watershed management practices.

Geochemical analysis of mine drainage water, including Geochemical reactions in extremely acidic water.

Laboratory column studies were conducted to assess acid-neutralization and metal release mechanisms in mine tailings under highly controlled flow conditions. Input of acidic solutions into mine tailings resulted in step-like declines in pH in the column effluent over time. During each pH buffering stage, specific metals were released. Results of the studies will be incorporated into a reactive solute transport model.

Studies on the thermodynamic processes occurring in extremely acidic waters were conducted to assist in the interpretation of geochemical processes occurring at extremely acidic mine sites. Under certain conditions, mine drainage waters can develop very high concentrations of acid (< 0.5 pH) and metals (> 50,000 mg/L). Laboratory analyses and Pitzer ion interaction model calculations were performed. The study results provide information for improving waste disposal practices for existing mines, and rehabilitating former mining areas.

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5. SCIENTIFIC PRESENTATIONS AT CONFERENCES/ WORKSHOPS/SYMPOSIUMS:

Beauchamp, S., R. Tordon, H.K.T. Wong, F. Boudala, I. Folkins, and J. Witte. Mercury flux from contaminated and natural surfaces. Conference on Mercury in Eastern Canada and the Northern States (EMAN) Fredericton, New Brunswick, 1998.

Boegman, L., P.F. Hamblin, and M.R. Loewen. Two-dimensional modelling of zebra mussel effects in Lake Erie, stage one: Validation of temperature, currents and water levels. 42nd Conference, International Association Great Lakes Research. Cleveland, Ohio, 1999.

Bootsma, H.A. and R.E. Hecky. The Nutrient Budget of Lake Malawi. Annual Meeting of North American Lake Management Society, 1998.

Borgmann, U. Assessing the toxicological significance of metals in sediments: the importance of bioaccumulation and bioaccumulation-toxicity relationships. Third International Symposium on Sediment Quality Assessment, Amsterdam, Keynote Presentation, 1998. (Invited).

Burt, J.A. J.J.H. Ciborowski, and T.B. Reynoldson. Baseline levels of mouthpart deformities in Chironomids of the Great Lakes. North American Benthological Society meeting. Charlottetown, PEI.

Burt, J.A. J.J.H. Ciborowski, and T.B. Reynoldson. Chironomidae (Diptera) deformities in Great Lakes reference sites. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Campbell, L. and R.E. Hecky. Hg contamination in Lake Victoria fishes; An emerging issue. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Charlton, M.N. Current Trophic Status of Lake Erie. Conference on Phosphorus Strategy for the Management of Lake Erie, Kent State University. (Invited).

Charlton, M.N. The Hamilton Harbour Remedial Action Plan. Societas Internationalis Limnologiae, Dublin, 1998.

Charlton, M.N. Water Quality Changes in Lake Erie. 18th International Symposium of the North American Lake Management Society. Banff, Alberta, 1998.

Chase, M.E., J.J.H. Ciborowski, T.B. Reynoldson, and M.N. Charlton. Modelling recovery of *Hexagenia* mayfly populations in western Lake Erie. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Cheam V. Lead pollution in the Arctic. 25th annual conference of the Federation of Analytical Chemistry and Spectroscopy Societies (FACSS). Austin, Texas, 1998.

Coakley, J.P., A.S. Crowe, C.F.M. Lewis. Review of late Holocene levels in the Lake Erie basin: the "Nipissing flood" revisited. 42nd Conference, International Association Great Lakes Research. Cleveland, Ohio, Ontario, 1999.

Coakley, J.P. and C.F.M. Lewis. Post glacial history and sedimentation in Lake Ontario: 12,000 years B.P. to Present. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Coakley, J.P. Tracing contaminated sediment transport in western Lake Ontario. 15th. Int. Sedimentological Congress. Alicante, Spain, 1998.

Crowe, A.S. and C.J. Ptacek. Groundwater flow and septic-system derived nutrient transport within a barrier bar separating Lake Erie from the Point Pelee marsh, Ontario, Canada. 19th Annual Meeting of the Society of Wetlands Scientists. Anchorage, Alaska, 1998. (Invited).

Crowe, A.S. and S.G. Shikaze. Numerical modelling of transient groundwater flow conditions in response to seasonal variations in wetlands hydrology. 19th Annual Meeting of the Society of Wetlands Scientists. Anchorage, Alaska, 1998.

Crowe, A.S., C.J. Ptacek, P.A. Huddart, F.J. Longstaffe and G. Moulard. The relationship between groundwater flow and the marsh at Point Pelee National Park, Ontario. 41st Conference, International Association of Great Lakes Research. Hamilton, Ontario, 1998.

Culver, D., Li, H., Edwards, W., Babcock-Jackson, Weisberger, K., Loewen, M., Boegman, L., Hamblin, P., Charlton, M., and Coakley, J.P. Ecological modeling of Lake Erie trophic dynamics. 42nd Conference, International Association Great Lakes Research. Cleveland, Ohio, Ontario, 1999.

Curran, M., K. Irvine, T.P. Murphy and I. Droppo. The Contaminant Runoff from the Dofasco Coal Piles. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Fletcher, R., T.B. Reynoldson, and W.D. Taylor. Application of multivariate analyses to interpret benthic community response. North American Benthological Society meeting. Charlottetown, PEI.

Fletcher, R., T.B. Reynoldson, and W.D. Taylor. The use of benthic macroinvertebrate community structure in the diagnosis of sediment contamination. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Gillis, P. L., T.B. Reynoldson, D.G. Dixon, and L.C. Diener. Metallothionein as a Biomarker for Trace Metal Exposure and Effects in *Tubifex tubifex* and *Chironomus riparius*. Aquatic Toxicity Workshop. Quebec City, Quebec.

Gillis, P.L., T.B. Reynoldson, D.G. Dixon, and M.D. Dutton. Metallothionein as a biomarker for trace metal exposure and effects in the freshwater oligochaete *Tubifex tubifex*. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Glozier, N., T.B. Reynoldson, J. Culp, C. MacDonald, E. Porter, and F. Wrona. Canada's environmental effects monitoring (EEM) program for benthic invertebrate communities: standardized study designs, methods and data analyses. North American Benthological Society meeting. Charlottetown, PEI.

Hamblin, P.F. Acoustical and optical methods of monitoring suspended sediment plumes. North American Lakes Management Society meeting. Banff, Alta., 1998.

Hamblin, P.F. Physical Studies in Lake Malawi/Nyasa, 1997-1999. Lake Malawi water quality workshop. Senga Bay Research Station, Malawi. (Invited).

Hamblin, P.F. NWRI, presented an oral contribution on the influence of dam construction in the Upper Columbia River Basin on the thermal regime of the Columbia River. North American Lakes Management Society meeting. Banff, Alta., 1998.

- Hamblin, P.F. and Bootsma. Upwelling in Large Lakes. Symposium on the African Great Lakes, Lake Malawi. (Invited).
- Hecky, R.E. Eutrophication effects and biodiversity decline in African Great Lakes. Annual Meeting of North American Lake Management Society (Plenary).
- Hecky, R.E. Phosphorus in Lake Victoria; why has it increased and where did it come from? 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.
- Hendzel, L.L., R. Mugidde and R.E. Hecky. Pelagic nitrogen fixation in Lakes Malawi and Victoria. Annual Meeting of North American Lake Management Society, 1998.
- Huddart, P.A., J.P. Coakley and A.S. Crowe. Subsurface stratigraphy of the Point Pelee foreland and marsh, Ontario. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.
- Jackson, T.A. Long-range atmospheric transport of mercury to ecosystems. Science Experts Workshop on Mercury. Las Vegas, Nevada, 1998. (Invited).
- Jackson, T.A. The stable isotope composition of mercury in sediments and food chain organisms in mercury-polluted lakes. Canadian Network of Toxicology Centres Annual Research Symposium. Hull, Québec, 1999. (Invited).
- Jackson, T.A., M.M. West, and G.G. Leppard. The accumulation and partitioning of heavy metals by individually analysed bacterial cells and associated nonliving material in lake sediments polluted with mine tailings and smelter fallout. Canadian Network of Toxicology Centres Annual Research Symposium. Hull, Québec, 1999. (Invited).
- Kempthorne, R.A., Barrera, E., Coakley, J.P., Tevesz, M.J.S., and Miller, B.B. Holocene Environmental Changes in the Lake Erie Basin. 42nd Conference, International Association Great Lakes Research. Cleveland, Ohio, 1999.
- Kilgour, B.W., R.C. Bailey, and T.B. Reynoldson. A comparison of ordination and model-affinity approaches for assessing impacts on communities. North American Benthological Society meeting. Charlottetown, PEI.
- Lapcevic, P., and K.S. Novakowski. A Conceptual Model for Groundwater Flow and Contaminant Transport at the Site-Specific Scale in a Fractured Dolomite: A Case Study of the Smithville PCB Site in Southern Ontario. SEPM Research Conference: Fluid Flow in Carbonates: Interdisciplinary Approaches. Door County, Wisconsin, 1998. (Invited).
- Lapcevic, P., and K.S. Novakowski. A geostatistical interpretation of the fracture distribution and transitivity in the Lockport Dolomite underlying Smithville, Ontario. American Geophysical Union Spring Meeting. Boston, MA, 1998.
- Lapcevic, P. Database Presentation. Site Characterization and Remediation Alternatives Workshop. Toronto, Ontario, 1999. (Invited).
- Lesage, S., D. Sorel, K. Millar and S. Brown. Reductive Dechlorination By Vitamin B₁₂ And Titanium Citrate: Field Application. 1st International Conference on the Remediation of Chlorinated and Recalcitrant Compounds. Monterey, CA, 1998.

Lewis, C.F.M.; Anderson, T.W.; Blasco, S.M.; Cameron, G.D.M.; and Coakley, J.P. Did early Holocene Lake Erie experience closed basin conditions? 42nd Conference, International Association Great Lakes Research. Cleveland, Ohio, 1999.

Lewis, C.F.M., Mukhopadhyay, P.K., Kruge, M.A., and Coakley, J.P. Environmental geology of western Lake Ontario: acoustic lineaments and organic components of surface sediments. Meeting of the Soc. Organic Petrologists. Halifax, Nova Scotia, 1998.

McKay, R.N.L., J. LaRoche, T.J. Geider, and M.N. Charlton. Assessing trace metal availability using an immunodiagnostic approach. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Milani, D., T.B. Reynoldson, and J. Kolasa. The Relative Sensitivity of Four Benthic Invertebrates to Selected Metals in Spiked Sediment and the Evaluation of a Contaminated Field Sediment. Aquatic Toxicity Workshop. Quebec City, Quebec, 1998.

Milani, D., T.B. Reynoldson, and J. Kolasa. The Relative Sensitivity of Four Benthic Invertebrates to Selected Metals in Water-Only and in Spiked Sediment Tests. Annual SETAC Meeting. Charlotte, N.C., 1998.

Mowder, C., S. Lesage, T. Llewellyn, D. Green, K. Millar, S. Brown and H. Steer. A Combined Anaerobic Biological and Abiotic Treatment of Chlorinated Aliphatic Hydrocarbons. Americana, Montreal, 1999.

Murphy, T.P., A. Lawson. Algal Toxins as Initiators of Avian Botulism. North American Lakes Management Society. Banff, Alberta, 1998.

Murphy, T.P. Eutrophication of Lake Biwa. Japanese SIL Conference. Matsumoto, Japan. (Invited).

Murphy, T.P. How Sediments Influence Avian Botulism. Aquatic Ecosystem Health Conference. Amsterdam, Netherlands, 1998. (Invited).

Murphy, T.P. Review of sediment treatment. Special Workshop sponsored by Japanese Ministry of Transportation and Industry. Hiroshima, Japan. (Invited).

Murphy, T.P. Review of progress on sediment remediation. Norwegian/Canada workshop on sediment contamination. Vancouver, B.C. (Invited).

Murphy, T.P. Lake restoration studies in Canada. 1st International Workshop on Remediation of Marine Sediments. Sandefjord, Norway. (Invited).

Murphy, T.P. Progress on Sediment remediation. Norwegian/Canada workshop on sediment contamination. Mississauga, Ontario.

Murphy, T.P. Progress on Studies of Algal Toxins as Initiators of Avian Botulism. Avian Botulism Workshop. Saskatoon, Saskatchewan, 1999. (Invited).

Murphy, T.P. Review of algal toxins initiation of avian botulism outbreaks in Whitewater and Pakowki lakes. National Wildlife Health Center, Binational Avian Botulism Workshop. Madison, Wisconsin. (Invited).

Murphy, T.P. Sediment release of phosphorus in Lake Biwa. Cyanobacterial Risk Assessment of Lake Biwa Workshop. Otsu, Japan.

Murphy, T.P. Sediment treatment in Fraser River. Workshop of potential clients. Vancouver, B.C.

Murphy, T.P. "Vivianite Formation in Lake Biwa Sediments". SIL Conference. Dublin, Eire, 1998. (Invited).

Murthy, C.R. Base-line Climatology of Currents, Temperature and Exchange Processes in the Coastal Zone of the North American Great lakes. Coastal Zone Canada-98 Conference. Victoria, B.C, 1998.

Murthy, C.R. Operational Hydrodynamic and Water Quality Models for Large Lakes. EU Workshop organised by the Finnish Environment Institute. Helsinki, Finland. (Invited).

Norwood, W.P. and U. Borgmann. Comparison of solid phase and overlying water as sources of toxicity to *Hyalella azteca* in lead-spiked sediments. Aquatic Toxicity Workshop. Quebec City, 1998.

Novakowski, K.S., and P. Lapcevic. Characterization of the Smithville Site. Site Characterization and Remediation Alternatives, Workshop. Toronto, Ontario, 1999. (Invited).

Novakowski, K.S., A. Brown, P. Lapcevic, S. Lesage, and D. Ketcheson. Estimating DNAPL penetration in fractured sedimentary rock having horizontal stratification. 1st International Conference on Remediation of Chlorinated and Recalcitrant Compounds. Monterey, California, 1998.

Novakowski, K., A. Brown, P. Lapcevic, S. Lesage, E. Sudicky and D. Ketcheson. DNAPL Penetration in Fractured Sedimentary Rock Having Horizontal Stratification. 1st International Conference on the Remediation of Chlorinated and Recalcitrant Compounds, Platform Abstract E5-4. Monterey, CA, 1998.

Paonessa, D., J.J.H. Ciborowski, T.B. Reynoldson, D.W. Schloesser, K.A. Krieger, and T.F. Nalepa. Relative efficiency of eight benthic samplers in western Lake Erie. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Piggott, A.R. "Groundwater characterization of the Grand River watershed. "The focus of the presentation was the inter-disciplinary, collaborative, and quantitative approach that is being developed. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Piggott, A.R. "Preliminary characterization of fracturing at the site of the Chalk River Laboratories." Spring 1998 Meeting of the American Geophysical Union. Boston, Massachusetts. (Invited).

Piggott, A.R. "Regional groundwater assessment of the Grand River watershed." 51st Canadian Geotechnical Conference. Edmonton, Alberta.

Piggott, A.R. "Regional groundwater modelling within the Grand River watershed." Groundwater in a Watershed Context. Burlington, Ontario.

Ptacek, C.J., A.S. Crowe, and G. Moulard. Influence of redox zonation on transport of sewage-derived nutrients in a barrier bar marsh complex, Point Pelee, Ontario. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Ptacek, C.J., D.L. Thompson, A.S. Crowe. Nutrient dynamics in relation to geochemical changes at the groundwater-surface water interface, Point Pelee Marsh, Ontario. American Geophysical Union Annual Spring Meeting. Special Session: Contaminant Transport Across the Groundwater/Surface Water Interface. Boston, Massachusetts, 1998. (Invited).

Ptacek, C.J. and A.S. Pratt. Nutrient transport in relation to redox transitions below a septic system tile bed and in a sand aquifer. 8th Annual V.M. Goldschmidt Conference, Special Session "Biotic Versus Abiotic Control of Geochemical Processes: Biogeochemical Dynamics of Redox Transitions". Toulouse, France, 1998.

Ptacek, C.J. and D.L. Thompson. Influence of redox zonation on nutrient attenuation from on-site sewage disposal systems. American Geophysical Union Annual Meeting. Boston, Massachusetts, 1998. (Invited).

Reynoldson, T.B. and T. Pascoe. Handling large data sets: a freeware data management system for the reference condition approach. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998. And North American Benthological Society meeting. Charlottetown, PEI.

Rukavina, N.A., A.J. Zeman and T.S. Patterson. Acoustic monitoring and mapping of the placement of a sand cap on contaminated sediments in Hamilton Harbour, Ontario, Canada. 41st Annual Meeting of the Association of Engineering Geologists. Seattle, Washington, 1998.

Rukavina, N.A. Physical Properties and Stability of St. Lawrence River sediments at Cornwall, Ontario. 5th Annual International Conference on the St. Lawrence River Ecosystem, Cornwall, Ontario.

Rukavina, N.A. and Turner, L.J. Sediment disturbance in Hamilton Harbour and its impact on the interpretation of contaminant profiles. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Schellenberg, S. and A.R. Piggott. An assessment of groundwater usage in thirteen counties in southern Ontario. Groundwater in a Watershed Context. Burlington, Ontario, 1998.

Shikaze, S.G. and A.S. Crowe. A numerical analysis of groundwater flow through a barrier bar at Point Pelee National Park, Ontario, Canada. Annual Meeting of the Geological Society of America. Toronto, Ontario, 1998.

Shikaze, S.G. and A.S. Crowe. Impact of flooding and flood mitigation on groundwater quality. Conference Groundwater in a Watershed Context. Burlington, Ontario, 1998. (Invited).

Skafel, M.G. Current Reversals at the Cootes Paradise Fishway. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Steinbachs, J.N., R.A. Schincariol and A.S. Crowe, A. Maun. Hydrogeological and biological interactions in the Old-Ausable River channel watershed, Brand Bend, Ontario. Annual Meeting of the Geological Society of America. Toronto, Ontario, 1998.

Thompson, D. and C.J. Ptacek. Groundwater geochemistry and PO₄ enrichment at the groundwater/surface water interface: Point Pelee marsh, Ontario. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Van Stempvoort, D. R., S. Lesage and J. Smith. A Challenges for Modeling the Remediation of Organic Contaminants in Aquifers: Biodegradation and Enhanced Transport by Dissolved Humic Acid. Americana, Montreal, 1999.

Wong, H.K.T. and C.M. Banic. Trace metals in aerosol: a field method study. American Geophysical Union, Fall meeting. San Francisco, 1998.

Wong, H.K.T., J. Carrier, and G.D. Sardella. Metal fractions in whole fish (trout) fatty and non-fatty tissue by acid digestion. 44th International Conference on Analytical Sciences and spectroscopy, Queens University. Kingston, Ontario, 1988.

Zanini, L., K.S. Novakowski, P. Lapcevic, G.S. Bickerton, J. Voralek, and C. Talbot. Regional Groundwater Flow in the Fractured Dolomite underlying Smithville, Ontario as Inferred from Combined Hydrogeological and Geochemical Measurements. Geological Society of America Annual Meeting. Toronto, Ontario, 1998.

Zarull, M.A. "Aquatic Ecosystem Response to Rehabilitative Measures Taken in Great Lakes Areas of Concern." XXVII Congress of the International Association of Theoretical and Applied Limnology, University College. Dublin, Ireland, 1998.

Zarull, M.A. "Contaminated Sediment in the Great Lakes." Great Lakes Mayor's Conference. Windsor, Ontario, 1998.

Zarull, M.A. "Overcoming Obstacles to Sediment Remediation in the Great Lakes Basin: I. The Problem." 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Zarull, M.A. "Quantifying Aquatic Ecosystem Health Targets." XXVII Congress of the International Association of Theoretical and Applied Limnology, University College. Dublin, Ireland, 1998.

Zeman, A.J., T.S. Patterson and F. Rosa. Great Lakes Conference, Hamilton Harbour in-situ capping demonstration project monitoring results. 41st Conference, International Association Great Lakes Research. Hamilton, Ontario, 1998.

Zeman, A.J., and T.S. Patterson. Results of physical and chemical monitoring at the in-situ capping site in Hamilton Harbour, Lake Ontario, Canada. 41st Annual Meeting of the Association of Engineering Geologists. Seattle, Washington, 1998.

6. SELECTED SCIENTIFIC COMMITTEES:

Allan, R.J.

- International Programme Committee, IAWQ Ecohazard'99
- Scientific Programme Committee, Silver Anniversary, International Conference on Heavy Metals in the Environment

Borgmann, U.

- Metals in the Environment (MITE) Working Group
- The University-Industry-Government MITE Research Network (MITERN)
- Environmental Effects Monitoring for Mining - Benthos Work Group
- Environmental Effects Monitoring for Mining - Water and Sediment Work Group
- Environmental Resource Group for CEPA review of emissions from copper and zinc smelters and refineries.

Charlton, M.N.

- Lake Erie Lakewide Management Plan Working Group
- Chair, Hamilton Harbour Remedial Action Plan Technical Team
- CEPA Ammonia Assessment Committee
- CEPA Chloramine Assessment Committee
- National Nutrient Science Committee
- Lake Erie at the Millennium Bi-National Conference organizing committee

Crowe, A.S.

- Organizing Committee for the conference "Groundwater in a Watershed Context"
- Organizing Committee for the conference "Quebec 2000 Millennium Wetland Event"

Hamblin, P.F.

- Scientific Committee for the International Conference on Stratified Flow

Hecky, R.E.

- Lake Erie LAMP, Beneficial Use Impairment Assessment Subcommittee
- International Decade for East African Lakes Steering Committee
- Steering Committee SADC/GEF Lake Malawi Biodiversity Conservation Project

Jackson, T.A.

- CEPA(PSL-2) environmental effects of copper and zinc smelters and refineries.

Lapcevic, P.A.

- Organizing Committee for the workshop "Groundwater and Urban Development: Issues and Solutions"

Lesage, S.

- Chair of the Panel on Energy Research and Development (PERD) interdepartmental committee on land-based remediation in the oil and gas program.
- NSERC review panel for Strategic Grants, Committee D, Environmental Technologies.
- site visit and review committee for the NSERC industrial chair of Groundwater and Soil Bioremediation at l'École Polytechnique in Montreal.

Murphy, T. P.

- Binational Avian Botulism Task Force
- CRAB (Cyanobacterial Risk Assessment of Lake Biwa)
- Japanese In-Situ Sediment Treatment Association

Murthy, C.R.

- Canadian National Committee of the Scientific Committee on Oceanic Research (CNC-SCOR)
- International Committee of the Scientific Committee on Oceanic Research (SCOR)

Piggott, A.R.

- Hydrology and Groundwater Committee of the Grand River Conservation Authority
- Groundwater Protection Video Working Group
- Groundwater in a Watershed Context Organizing Committee

Reynoldson, T.B.

- EEM metal mining benthic community expert working group
- SEDS Ontario-Canada working group for Selecting Ecological Decisions for Sediment management.
- National Aquatic Ecosystem Health programme working group.

Rosa ,F.

- Mine Environment Neutral Drainage (MEND) Prevention and Control Committee.
- Spanish Harbour RAP Team.

Zarull, M.A.

- International Joint Commission's Sediment Priority Action Committee
- IJC's Science Advisory Board's Work Group on Parties Implementation

7. EDITORIAL BOARDS AND OFFICERS OF PROFESSIONAL SOCIETIES

Allan, R. J.

- Series Editor, Environmental Sciences Book Series, Springer
- Editorial Board of Journal of Geochemical Exploration
- Chair, ICWQ/IAHS Officer Election Committee

Borgmann, U.

- Associate Editor, Canadian Journal of Fisheries and Aquatic Sciences
- Editorial Board of Environmental Pollution Journal
- Editorial Advisory Board of Aquatic Ecosystem Health and Management Journal

Crowe, A.S.

- Associate Editor of Hydrogeology Journal
- Co-chair of the Canadian National Chapter of the Society of Wetland Scientists

Lesage, S.

- Editorial board of Environmental Toxicology and Chemistry Journal
- Editorial board of Water Quality Research Journal of Canada,
- Editorial board of Advances in Environmental Research Journal

Lapcevic, P.A.

- Organizing Committee for the International Association of Hydrogeologists (Ontario Chapter)

Murphy, T. P.

- Editorial Advisory Board of Aquatic Ecosystem Health & Management Journal

Piggott, A.R.

- Associate Editor of Hydrogeology Journal
- Chair of the Hydrogeology Division of the Canadian Geotechnical Society

Reynoldson, T.B.

- Associate Editor of Journal of Great Lakes Research
- Board of Directors International Association of Great Lakes Research

8. ADJUNCT PROFESSORSHIPS

Borgmann, U.

- University of Waterloo, Biology Department.

Crowe, A.S.

- University of Western Ontario, Department of Earth Sciences.

Hamblin, P.F.

- University of Toronto, Mechanical and Industrial Engineering,
- University of Western Ontario, Civil Engineering.

Hecky, R.E.

- University of Manitoba, Biology Department,
- University of Waterloo, Biology Department.

Lesage, S.

- University of Waterloo, Department of Earth Sciences.

Novakowski, K.S.

- University of Waterloo, Department of Earth Sciences,
- Brock University, Department of Earth Sciences.

Ptacek, C.J.

- University of Waterloo, Department of Earth Sciences.

Reynoldson, T.B.

- University of Waterloo, Biology Department,
- University of Windsor, Biology Department,
- McMaster University, Biology Department.

9. LIST OF STAFF

A) FULL-TIME

AQUATIC ECOSYSTEM RESTORATION BRANCH

DIRECTOR'S OFFICE:

Director:

R.J. Allan, B.Sc. (Aberdeen), M.S. (Wisconsin), Ph.D. (Dartmouth), D.Sc. (Aberdeen)
(*applied geochemistry*)

Science Liaison Officer:

M.A. Zarull, B.Sc., M.Sc., Ph.D., (McMaster)
(*ecology, limnology, toxicology*)

Executive Assistant to the Director:

L.N. Schouls

Administrative Officer:

E. Wendel

Administrative Assistant:

L. Davis

Scientific Wordprocessor:

D. Crabtree

LAKE ASSESSMENT AND RESTORATION PROJECT:

Project Chief:

M.N. Charlton, B.Sc., M.Sc. (Toronto)
(*limnology*)

Study Leaders:

J.P. Coakley, B.Sc. (St. Francis Xavier), M.Sc. (Ottawa), Ph.D. (Waterloo)
(*nearshore processes and sediment dynamics*)

P.F. Hamblin, B.Sc. (Toronto), M.Sc. (U.B.C.), Ph.D. (Washington)
(*dynamics and thermodynamics of lakes and reservoirs*)

R.E. Hecky, B.Sc. (Kent State), Ph.D. (Duke)
(*large lake limnology*)

C.H. Marvin, B.Sc. (Waterloo), M.Sc. (Brock), Ph.D. (McMaster)
(*analytical chemistry*)

C.R. Murthy, B.Eng. (Mysore), M.Eng. (Indian Institute of Science), Ph. D. (Waterloo)
(*turbulent transport and diffusion processes in lakes*)

M.G. Skafel, B.A., B.E., M.Sc. (Saskatchewan), Ph.D. (Cambridge)
(*coastal engineering*)

Scientific Support:

F. Chiochio, B. Eng. (Waterloo)
(*physical limnology*)

K.C. Miners, B.A. (Western Ontario)
(*physical limnology*)

Technologists:

D. Doede
P.A. Thiessen

SEDIMENT ASSESSMENT AND RESTORATION PROJECT:

Project Chief:

T.B. Reynoldson, B.Sc. (Leeds), M.Sc. (Calgary), Ph.D. (Lancaster)
(*benthic invertebrate ecology bioassessment*)

Study Leaders:

U. Borgmann, B.Sc., M.Sc. (British Columbia), Ph.D. (Ottawa)
(*zoology, oceanography, biology*)

V.F. Cheam, B. Sc., Ph. D. (Oklahoma)
(*chemistry*)

T.A. Jackson, B.A. (Columbia), M.Sc. (Wisconsin), Ph.D. (Missouri)
(*biogeochemistry*)

T.P. Murphy, B.Sc. (Queen's), M.Sc. (Toronto), Ph.D. (U.B.C.)
(*restoration limnology*)

F. Rosa, B.Sc. (McMaster)
(*sediment-water processes and contaminant cycling*)

N. Rukavina, B.A. (Toronto), M.Sc. (Western Ontario), Ph.D. (Rochester)
(*sedimentology of freshwater sediments*)

H.K.T. Wong, B.Sc. (Waterloo)
(*applied geochemistry*)

A.J. Zeman, B.Sc. Eng. (Queen's), M.Sc. (McGill)
(*sediment geotechniques and remediation*)

Technologists:

J. Dalton
N. Nguyen
W. Norwood, B.Sc. (Toronto)
J. Rajkumar
S.P. Thompson, B.Sc. (Guelph)
B. Trapp

GROUNDWATER ASSESSMENT AND RESTORATION PROJECT:

A/Project Chief:

A.S. Crowe, B.Sc. (Waterloo), M.Sc., Ph.D. (Alberta)

P. Lapcevic, B.Sc., M.Sc. (Waterloo)
(earth sciences, applied geology and hydrogeology)

S. Lesage, B.Sc. (Ottawa), Ph.D. (McGill)
(biochemistry, chemistry)

K. Millar, B.Sc. (Toronto), M.Sc. (Guelph)
(botany and microbiology)

A.R. Piggott, P.Eng., B.A.Sc., M.Eng. (Toronto), Ph.D. (Pennsylvania State)
(groundwater geomechanics)

C.J. Ptacek, B.A., M.Sc. (Wisconsin), Ph.D. (Waterloo)
(hydrogeology and geochemistry)

Technologists:

S. Brown

J.A. FitzGerald

B) RESEARCH ASSOCIATES

Contractors

Bickerton, G.	Groundwater Assessment & Restoration Project
Dunnnett, M.	Sediment Assessment & Restoration Project
He, C.	Lake Assessment & Restoration Project
Logan, C.	Sediment Assessment & Restoration Project
Marenco, N.	Groundwater Assessment & Restoration Project
Milani, D.	Sediment Assessment & Restoration Project
Pascoe, T.	Sediment Assessment & Restoration Project
Schellenberg, S.	Groundwater Assessment & Restoration Project
Shikaze, S.	Groundwater Assessment & Restoration Project
Van Stempvoort, D.	Groundwater Assessment & Restoration Project
Wang, X.	Lake Assessment & Restoration Project

Intern

Neron, R.	Sediment Assessment & Restoration Project
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Students

Bartlett, A.	Sediment Assessment & Restoration Project
Cabral, C.	Sediment Assessment & Restoration Project
Cihula, T.	Groundwater Assessment & Restoration Project
Diener, L.	Sediment Assessment & Restoration Project
Gillis, P.	Sediment Assessment & Restoration Project
Fletcher, R.	Sediment Assessment & Restoration Project

Terms

Lawson, A.	Sediment Assessment & Restoration Project
Voralek, J.	Groundwater Assessment & Restoration Project

Visiting Scientist

Rao, Y.	Lake Assessment & Restoration Project
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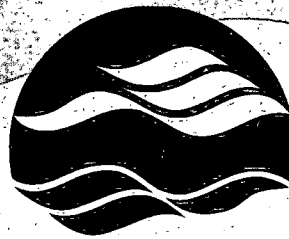
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