Linking Water Science to Policy:

Experts Workshop on Water Quality Monitoring

The Current State of the Science and Practice

A CCME sponsored workshop

October 16 and 17, 2002 **Vancouver, BC**

CCME Linking Water Science to Policy Workshop Series

Experts Workshop on Water Quality Monitoring: The Current State of the Science and Practice

October 16 and 17, 2002, Vancouver, BC

A workshop sponsored by the Canadian Council of Ministers of the Environment

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Workshop Context and Overview

The Canadian Council of Ministers of the Environment (CCME) provides a forum for federal, provincial and territorial governments to cooperate on priority environmental issues. The CCME has made water quality one of its top priorities because of concerns about water safety and the value placed on water by Canadians.

The CCME directs efforts towards ensuring that its members, and policy and decision makers in particular, are kept up-to-date on the latest science with respect to various water quality issues. The CCME seeks opportunities for its members to provide input to the scientific community on priorities for water quality-related science activities.

This report is the fifth in the series *Linking Water Science to Policy*, and synthesizes presentations and discussions that took place during a two-day workshop held on October 16 and 17, 2002 in Vancouver, BC. The workshop, which was co-chaired by Environment Canada and the Province of British Columbia, brought together over 70 participants from federal, provincial and municipal government departments, Canadian universities and industry, as well as representatives from the U.S. Environmental Protection Agency, U.S. Geological Survey, Finnish Environment Institute, the EUROWATERNET, and the U.K.'s Cranfield Biotechnology Centre. The workshop was organized by the Water Quality Monitoring Sub-Group of the CCME Water Quality Task Group. Members of the workshop organizing committee were:

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Sincerely,

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Executive Summary

The Canadian Council of Ministers of the Environment (CCME) is a major inter-governmental forum in Canada for discussion and joint action on environmental issues of national and international concern. In the fall of 2001, in response to concerns about water quality in Canada, the CCME initiated a workshop series titled *Linking Water Science to Policy* to provide a forum to discuss priority water quality issues. Organized by Environment Canada's National Water Research Institute, with provincial partners, the series intends to communicate the results of new research and management practices to senior decision and policy makers, and to provide a mechanism for scientists and water managers to contribute expert input to Canadian water programs.

The CCME Water Quality Task Group's Sub-group on Monitoring organized the *Experts Workshop on Water Quality Monitoring: The Current State of the Science and Practice*, held in Vancouver, BC, on October 16 and 17, 2002. The goal of the workshop was to facilitate a national dialogue on Canadian water quality monitoring and share information on best practices in this area. This national workshop presented a forum for national and international water quality monitoring experts, managers and practitioners to present and discuss their experience with water quality programs, and to explore some of the challenges and lessons learned. Ultimately, the workshop aimed to identify opportunities for enhancing linkages among monitoring networks and to build on the strengths of our collective water quality monitoring capacities.

Over 70 participants from federal, provincial, territorial and municipal government departments, Canadian universities, industry and environmental non-government organizations, as well as representatives from the U.S. Environmental Protection Agency, U.S. Geological Survey, the Finnish EUROWATERNET and the U.K.'s Cranfield Biotechnology Centre attended the workshop. This report compiles the workshop's presentations and discussions on water quality monitoring current practices and programs, integrating water quality monitoring programs, building water quality monitoring networks, innovative monitoring technology and methods, as well as data interpretation and reporting out.

The recommendations and observations put forth in the following executive summary and proceedings attempt to best reflect the key and most salient points from the presentations and discussions of workshop participants.

Setting the Stage

The first three presenters at the workshop outlined the importance of water quality monitoring within the overall context of understanding and managing water quality and the rationale for the commitment to this by the CCME. Over the last decade or more, existing and emerging threats to water (e.g., industrial farming, endocrine disrupting chemicals, microbial pathogens, municipal waste water effluents) have led to increasing public demand for sound water quality information. However, the concomitant reduction in water quality monitoring capacity across all levels of government has resulted in significantly diminished ability to provide decision makers and the public with comprehensive information on the quality of Canadian waters.

Currently, the level of effort on water quality monitoring across the CCME jurisdictions varies greatly. Limitations of water quality information put pressure on virtually all levels of government to develop solutions for obtaining water quality monitoring data. The CCME has acknowledged there are inconsistencies in monitoring practices in Canada, as well as a lack of a cohesive network to disseminate information. The CCME has committed to providing a forum for enhanced coordination in these areas, while recognizing that it is the actions of the individual jurisdictions that are needed to protect water quality.

The Current State of Practice - Water Quality Monitoring in Canada

Several presenters were concerned that the current lack of communication among and within jurisdictions has led to shortcomings in water quality monitoring programs across Canada. Sharing information and methods on water quality monitoring practices would result in more cohesive and coordinated programs. There are good water quality data being collected in Canada, but the reporting-out mechanisms may not adequately reflect this or ensure the data reaches the appropriate decision makers. These factors have led to inadequate interpretation of data, fragmentation of programs, and knowledge gaps for emerging issues.

- *Inadequate interpretation* has resulted in decreased use of data, decreased reporting in a timely and efficient manner, and duplication of efforts.
- *Fragmentation of programs* has occurred as a result of jurisdictions and diverse agencies undertaking water quality monitoring programs in isolation without a full understanding of the benefit of collaboration or cooperation.
- *Knowledge gaps for emerging issues*, such as microbial pathogens, endocrine disrupters, and genetically modified organisms, require coordinated efforts among jurisdictions to ensure adequate water quality monitoring programs are developed.

There is room for improvement in all water quality monitoring programs. This will require on-going communication and coordination among all CCME jurisdictions to maximize the utility of their respective activities and thereby contribute to the most comprehensive coverage possible. Currently, many water quality monitoring programs are operating in a diminished capacity as a result of a lack of, or outdated, infrastructure, methodologies, instrumentation and data management.

Water quality monitoring programs need to be dynamic and flexible to meet the changing needs of decision-makers in specific regions. Surface and ground water both need to be monitored to ensure safe drinking water is distributed to the public. Currently, little is known about the behaviour and fate of contaminants in groundwater. The development of a Canada-wide Framework for groundwater can help focus efforts needed for developing tools to monitor and map groundwater.

A number of new efforts are underway to improve practices for surface water quality monitoring activities. The development of the *Source to Tap* multi-barrier approach to drinking water protection includes source water protection and monitoring, thereby ensuring drinking water is adequately monitored prior to intake and during distribution. Individual jurisdictions, such as the Greater Vancouver Regional District (GVRD), have implemented this approach. The GVRD has coordinated efforts with multiple stakeholders, resulting in water quality monitoring programs that are tailored to the specific needs of the region.

Efforts are also underway by many community-based environmental monitoring groups that are concerned about the quality of water in their area and interested in taking an active role. These activities and the data generated are powerful resources that are sometimes under-utilized in current reporting-out mechanisms.

Designing Water Quality Monitoring Programs and Networks - Water Information Needs

A network of water quality monitoring programs should be able to provide the water quality management community, from source water and water treatment facility managers to policy makers, with the necessary information to support sound decisions on the quality, uses and availability of water. The development of a Canada-wide framework for water quality monitoring activities would improve collaboration and cooperation among programs in all Canadian jurisdictions. Examples of current programs that demonstrate how a water quality monitoring network could operate were presented at this workshop, including:

- water quality monitoring programs in British Columbia;
- water quality monitoring networks in Quebec;
- collaborative water quality monitoring framework used by U.S. Geological Survey;
- the Northern Rivers Basin Study and the Northern Rivers Ecosystem Initiative;
- the U.S. National Water Quality Assessment (NAWQA) Program; and
- the European EUROWATERNET water quality monitoring network.

Each of these utilize multiple stakeholders to ensure adequate water quality monitoring is carried out. In order to achieve this level of cooperation and coordination, it is important to ensure that adequate involvement by all stakeholders occurs at the time of program initiation. Furthermore, specific collaboration issues and goals need to be identified to ensure that the needs and responsibilities of all stakeholders are considered.

Integrating Water Monitoring - Moving Beyond the Stovepipes

It is acknowledged that institutional and functional barriers (e.g., environment and health, water quantity and quality) can hinder collaborative efforts to integrate monitoring programs. Several recommendations were noted that could lead to better water quality monitoring practices.

- Water quality monitoring programs need to be current and flexible.
- Conventional water quality monitoring tools and parameters, such as turbidity, need to be better understood to be more effective as indicators of drinking water safety.
- There needs to be better coordination between water quality and quantity monitoring networks.
- Water quality information from the scientific community should be utilized and incorporated into current source water monitoring programs for drinking water. The scientific community has developed many useful monitoring tools, indices and technologies that provide useful and comprehensive information on the health of aquatic ecosystems.
- Water quality monitoring programs that integrate an aquatic ecosystem health-based approach to source water monitoring provide a holistic, area-specific snapshot of the current state of water quality. For example, the Cumulative Effects Assessment (CEA) framework has been developed as a tool to determine water quality in a region as well as a mechanism to promote sustainable development by providing an understanding of the existing environmental state.

Water Quality Monitoring Technologies and Methods – Innovations and Challenges

Drinking water systems are vulnerable to water treatment-resistant pathogens as well as the inability of current monitoring and laboratory technologies to expediently identify all pathogens of concern. The growing range of natural and anthropogenic threats to aquatic ecosystems result in increasing pressure on water assessment and management communities to detect, identify and quantify existing and emerging stressors. Advances in water quality monitoring technology and methods need to occur and be applied within experimental and operational programs.

Several new leading-edge technologies were profiled at the workshop. Water quality monitoring technologies are currently being developed or modified that will assist monitoring programs by providing low cost and rapid, or even real-time, information on both chemical contaminants and pathogens. New sensor technologies are being developed that will allow water quality monitoring to move from a reactive to a more proactive state. However, the development of sensor technology is an expensive undertaking that will require increased collaboration and partnerships, sometimes multinational, to develop, test and operationalize.

- Sensor systems are being developed by the European Network on *Sensors for Monitoring Water Pollution*, or SENSPOL, to detect and characterize water pollution. Currently, sensors are commercially available to measure pH, temperature, dissolved oxygen concentrations, redox potential and conductivity.
- Micro-electromechanical based (MEMS) sensor systems are capable of nearly real-time water quality assessment. This technology is both portable and affordable with performance features very similar to laboratory-scale instruments.
- Remote satellite technology has been used to collect water quality data, such as chlorophyll concentrations and suspended and dissolved organic matter, for decades in Canada. The science and technology of remote aquatic sensing are sound and now need to be applied to water quality monitoring and aquatic ecosystem assessment programs.
- Molecular techniques, such as the polymerase chain reaction (PCR) assays, are being modified to identify waterborne pathogens, such as *Escherichia coli*. Microfluidics, antibody-based detection, gene probes, and DNA micro-arrays are all techniques that may be further developed for tracking pathogens and their sources.

Recommendations were put forth to promote a greater understanding and application of these new technologies and methods within the appropriate water management community.

- There needs to be communication and collaboration among all sectors of water monitoring programs, from environmental pollution researchers, water treatment operators and health officials, to the developers of water quality monitoring technology.
- The drinking water and aquatic ecosystem management communities need to enhance their linkage to the defense and water infrastructure security sectors, where much of the leading edge technology being developed in this area is focused.
- A water quality monitoring network of networks needs to be developed to ensure that information on the best available technologies is readily accessible.
- Laboratories need to become more than just data generators and processors in water quality monitoring programs, and take a more active role in the decision-making process and water management practices as well technological innovations.

Building Water Quality Knowledge Networks

Monitoring networks in Canada vary in scope and scale from local watersheds managed by municipalities to transboundary water systems managed at the national and international level. There are many tools and great potential to link water quality monitoring networks. The next step is to develop networks that increase sharing of existing water quality monitoring data and information. Several examples of how some water quality monitoring networks have been constructed were given at the workshop.

- The Red River Basin Decision Information Network (RRBDIN) is a network that was developed to improve water management by sharing information, data and related tools.
- The US EPA Office of Water developed the Watershed Assessment, Tracking and Environmental Results System (WATERS) to integrate water quality monitoring data,

state-reported water quality assessments, and the status of total maximum daily loads (TMDL). This reporting mechanism also takes into consideration any legal obligations and the environmental results associated with the Clean Water Act.

- The Finnish EUROWATERNET is one part of the water monitoring network organized by the European Union Council of Ministers. There are nearly 30 European countries involved in the EUROWATERNET, which is working towards common water quality monitoring practices.

The preferred venue for sharing data is a web-based approach, that is both efficient and facilitates easy access to the data by all partners. In order to implement successful information-sharing among the numerous jurisdictions in Canada, it will be important to have stakeholders who both contribute to and use the data/information in the networking process, as well as a system to coordinate the networks and provide ongoing financial support.

Interpretation and Reporting - Getting Relevant Information Out

Further dialogue is needed on the type of Canada-wide network of water quality monitoring programs required. One of the most important elements of any program that analyzes, aggregates and/or distributes information is the underlying principle that good comparable data in will mean good comparable information out. A framework needs to be put in place that will determine representative site selection, and define minimum sampling frequency and variables for each type of station. If we want to have access to compatible data, then Canada should more carefully consider the design of existing multi-jurisdictional frameworks, such as the EUROWATERNET. The other option is to maintain the *status quo*, which means we will continue to have a patchwork of water quality monitoring that is done by each jurisdiction, but that may not be compatible among jurisdictions.

The CCME has developed the Water Quality Index (WQI), a mathematical tool that provides a consistent assessment of the quality of water across the country. Additional statistical programs have been developed by the U.S. Geological Survey that are able to analyze and explain trends of variables in water, both temporally and spatially.

Lastly, the Canada-wide Water Quality Data Referencing Network, an infobase on water quality monitoring data, is currently under development as a project under the Canadian Information System for the Environment (CISE). This resource will support the goal of expediently providing Canadians, both generalists and specialists, with information on water quality by providing an on-line web-based information system.

Suggestions for Framework Development

A framework or a set of common guiding principles among the 14 federal, provincial and territorial jurisdictions is needed to complement and advance current efforts, minimize duplication, and maximize output through efficient communication and collaboration. A number of suggestions were made as to how a Canada-wide strategic water quality monitoring framework could be set up to encompass the needs of all the jurisdictions. First, communication among stakeholders is necessary to ensure that the appropriate partnerships are built.

- It has been suggested that a steering committee of existing water quality committees be founded to facilitate the development and promote the implementation of a Canada-wide water quality monitoring framework. This steering group would guide water quality monitoring practices and should include representatives from government, monitoring and research, drinking water, aquatic ecosystem health and laboratory communities. Once established, the steering committee would need to set goals and objectives based on gaps/needs of common interest and/or benefit. Achievable, realistic activities would then be developed along with a process for their implementation.

Second, the development of a framework for water quality monitoring in Canada will require a collaborative effort among all 14 jurisdictions to ensure that timeframes are established and identifiable milestones delivered.

- An evaluation of water quality monitoring programs and capacities needs to occur. There is a lot of information in existing inventories that could be used in creating future frameworks and water quality monitoring networks.
- An inventory of water quality monitoring tools and technologies needs to be taken to ensure that water quality monitoring programs are using the best available technologies and practices.
- Workshops may be necessary to bring together water quality monitoring practitioners from all sectors (government, science, research, development, water treatment facilities and decision-making communities) to ensure a framework is being developed that will meet the needs of individual jurisdictions.
- The development of a Canada-wide strategy for water quality monitoring will be the last step in the process and result in the framework itself which will act as a guide to monitoring practices. A framework is necessary to promote Canada-wide consistency, facilitate data sharing and collectively contribute to the water quality monitoring and information needs of all jurisdictions.

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Introduction

Recent tragic water contamination events and increased stresses on water have resulted in elevated demands for water quality information, as well as heightened public awareness and expectations of governments. The Canadian Council of Ministers of the Environment (CCME) recognizes this need and agrees that, while most actions to better protect water quality are taken by individual jurisdictions, the CCME can provide a forum for enhanced coordination in this area.

The *Experts Workshop on Water Quality Monitoring: The Current State of the Science and Practice,* sponsored by the CCME, was organized to facilitate a national dialogue on Canadian water quality monitoring practices, techniques and technology. The goal of the workshop was to identify opportunities towards enhancing linkages among existing monitoring networks and building on the strengths of our current water quality monitoring capacities.

The session topics included 1) an examination of current federal, provincial and territorial water quality monitoring activities, 2) designing water quality monitoring programs and networks and assessing water information needs; 3) integrating water monitoring practices; 4) examining new technologies and methods (including innovations and challenges); 5) data and information management; 6) interpretation and reporting information; and 7) recommendations regarding next steps towards the development of a Canada-wide water quality monitoring framework.

Prior to the workshop, the Monitoring Sub-Group of the CCME Water Quality Task Group invited workshop participants to share their views on water quality monitoring in Canada via a pre-workshop Participant Questionnaire. The responses were examined and summarized to convey common themes from the questionnaire; the summary is included in Appendix 1.

Workshop Content

<u>Setting the Stage</u>

Chairs: Robert Kent and Les Swain
Wednesday, October 16, 2002

Overview:
Recently, there has been an unprecedented level of concern, interest, and commitment in the area of water quality in Canada as a result of the unfortunate circumstances in Walkerton and North Battleford. These incidences have led the CCME to a greater level of commitment, specifically in the area of water quality monitoring. The CCME has committed to play a strategic role in forwarding the agenda on water and being a catalyst in key areas of research, monitoring, guidelines, communication and outreach in Canada. This is certainly not a new initiative, but rather a reaffirmation by the CCME and its federal, provincial, and territorial counterparts to develop the *Source to Tap* multi-barrier approach as a recommended framework of the proper assessment and management of safe and secure water supplies. A great deal of emphasis has been placed on the need for interjurisdictional and interdisciplinary cooperation, collaboration and support across traditional boundaries of environment and health as well as the resource departments. Recent events have demonstrated that water quality is very much a shared responsibility across all levels of government. Key priorities, such as threats and stressors affecting drinking waters and aquatic ecosystems in Canada have recently been identified by

scientists from across the country. Identifying these threats gives us the opportunity to assess what is known, what is not known and what should be known in order to go forward with better understanding and management of these issues.

Observations/Recommendations:

- The lack of water quality information continues to put pressure on all levels of government to develop and explore ways to enhance the capacity and efficiency water quality monitoring.
- It is important to recognize that the lack of monitoring capacity across Canada is something that a whole host of authoritative evaluations, from federal auditor generals to provincial commissioners, have recently identified.

Summary of Presentations:

From Source to Tap: A CCME Commitment to Safe, Clean and Reliable Drinking Water
Jennifer Moore (Environment Canada)

Water is a growing global concern in terms of human needs and health related issues, quantities available, and the impact that human use of water has on the environment. Presently, the distribution of safe drinking water is a major concern of Canadians due to recent outbreaks of waterborne disease. As well, considerable effort is also centered on the effects that human activities have on the quality and quantity of clean water. The CCME action plan on water is an interconnected framework undertaken by all 14 jurisdictions to act collectively on issues of common concern. The primary purpose of the CCME is to provide an “intergovernmental forum in Canada for discussion and joint action on environmental issues of national and international concern”. To achieve this goal, the CCME has committed to collaborate on priorities for water research, share best management practices, accelerate the development of water quality guidelines, and link existing water quality monitoring networks to ensure that Canadians have access to comprehensive information. Furthermore, the CCME is advocating a multi-barrier approach that will integrate source water protection with drinking water treatment and distribution.

Observations/Recommendations:

- There are challenges that need to be overcome regarding the adequacy of water treatment, operator training and certification and/or overall operating regime.
- The northern and remote communities face unique challenges, in terms of their ability to assess water quality and quantity, that need to be addressed.
- There are concerns regarding threats to drinking water and infrastructure security. Canada has a dedicated critical infrastructure and an emergency preparedness capacity under the Department of National Defence that is collaborating with the scientific community to obtain the information necessary to protect Canada’s water systems. As well, recent investments in research and technology development in the area of chemical, nuclear, radiological and biological threats should further contribute to greater knowledge and improved management.
- There needs to be a network in place to ensure that all Canadians have access to existing water quality monitoring data.

The Scope of the Challenge: Threats to Water Quality
Fred Wrona (National Water Research Institute, Environment Canada)
John Lawrence (National Water Research Institute, Environment Canada)

A national team of water quality experts met in January 2001, to identify the most immediate and pertinent threats to sources of drinking water and discuss aquatic ecosystem health in Canada. This assessment of water quality identified 15 priority threats to sources of drinking water and aquatic ecosystem health. The expert team addressed issues pertaining to the following threats: pathogens, algal toxins, pesticides, nutrients, acidification, endocrine disrupting substances, genetically modified organisms, long-range atmospherically transported pollutants, municipal wastewater effluents, industrial wastewater discharges, urban run-off, landfills and waste disposal, agricultural and forestry land use impacts, natural sources of trace element contamination, and water quantity changes affecting water quality due to climate change, diversions and extreme events. For each of these threats a short 'state of the science' report including current status, trends and knowledge, and program needs was prepared. The document *Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada* can be found on the National Water Research Institute web site: http://www.cciw.ca/nwri/.
Observations/Recommendations:
- Emerging global trends, such as climate change and increasing pollution, will continue to have a significant impact on water quality and quantity in Canada.
- Impacts to water quality are projected to increase without renewed efforts to understand threats to water quality through monitoring and research activities.
- There needs to be increased awareness of water quantity related issues, especially how water quantity impacts water quality.
- Strategies that enhance collaboration between environment and health departments (both provincial and federal) on the issue of pathogen monitoring in source waters are needed.
- It is essential to develop effective communication tools (e.g., appropriate water quality/quantity indicators) that can successfully communicate water quality and quantity data to policy makers.

Session 1: The Current State of Practice - Water Quality Monitoring in Canada

Chair: Dwight Williamson (Manitoba Conservation)
Wednesday, October 16, 2002

Overview
Communication was a key theme throughout this session. Within Canada, it was recognized that there is a lot of valuable water quality monitoring data that is being collected, but may not be readily accessible. These data need to be communicated to the proper authorities, such as stakeholders, policy makers, water treatment operators and regulators, and health officials, to ensure knowledge is shared to promote the most efficient and effective actions regarding drinking water and aquatic ecosystem management. A situational analysis of water quality monitoring in Canada identified common themes, strengths as well as inconsistencies and gaps. There are challenges that need to be overcome to increase the efficacy and efficiency of water quality monitoring. Currently, water quality monitoring practices are operating in a diminished capacity as a result of the lack of a national network of water quality monitoring networks. Water quality monitoring is fragmented across Canada because individual jurisdictions are conducting programs that are not compatible to programs that are occurring in other jurisdictions. Inefficient data management has resulted in decreased interpretation and reporting out as well as

duplication of efforts. There tends to be some duplication in water quality monitoring activities by source water protectors and municipal drinking water facilities that could be minimized with greater communication. Improved linkages are also needed between health officials who are responsible for providing safe water from water treatment facilities and environment officials who are responsible for ambient water monitoring networks. The Greater Vancouver Regional District (GVRD) provides an example of integrating source water protection and monitoring with the degree of treatment needed within a water treatment facility. The GVRD utilizes the multi-barrier approach to ensure safe drinking water is distributed to the public. Furthermore, community based organizations are concerned about the quality of water in their regions and are willing to volunteer time and resources to monitor water. These community monitoring groups tend to be independent of the government and have a significant role to play in future monitoring in Canada. Lastly, our knowledge and understanding of surface water systems started decades ago whereas our understanding of groundwater systems is much less developed. Sophisticated modeling systems and monitoring programs are being developed to understand the nature of groundwater and ensure safe drinking water reaches the public.
Observations/Recommendations:

- There needs to be a commitment to monitoring water quality by the federal and provincial governments in all jurisdictions to ensure that water quality monitoring programs are effective and have similar reporting out mechanisms.
- An important element in maintaining monitoring networks is to ensure that there are water quality monitoring agreements between the federal and provincial governments in all jurisdictions.
- Improved linkages are also needed between health officials who are responsible for providing safe water from water treatment facilities and environment officials who are responsible for ambient water monitoring networks.

Summary of Presentations

Overview of Current Water Quality Monitoring in Canada Based on the CCME Inventory
Brian Wilkes (Brian Wilkes and Associates Ltd.)

An analysis of water quality monitoring activities in Canada was conducted to identify the common strengths as well as gaps or inconsistencies in the 14 CCME jurisdictions. The data gathered by interviews and inventory reports showed that there are many common elements among the jurisdictions. All jurisdictions have some sort of monitoring network in place with similar rationale for implementing the programs - to understand the nature, ecology and baseline conditions of water resources and to track trends in water quality over time. Other common elements include: similar water quality inventories; the emergence of the watershed protection approach to managing water quality; efforts to improve the safety of drinking water; the vulnerability of water monitoring networks to budget cutbacks; and a lack of ability to achieve all water quality goals due to limited resources. Strengths observed in managing water quality were the willingness to use the watershed and multi-barrier approach, inclusion of watershed management councils (e.g., the Fraser Basin Council), expertise of the people conducting water quality monitoring programs, and use of web-based and GIS techniques. Several gaps in water quality monitoring were also identified, for example, surface and drinking water have different monitoring requirements and there appears to be a lack of coordination and/or communication between drinking and surface water monitoring staff. Furthermore, there is a lack of common language for elements of water quality monitoring which will make linking databases difficult. Lastly, agreements between the federal and provincial governments that commit both sides to water quality monitoring are not in place in all jurisdictions.

Observations/Recommendations:

- The watershed and multi-barrier approach for protecting source water is being more broadly used across the country and will improve the quality and safety of water.
- The use of the CCME Water Quality Index (WQI) for assessment and public reporting is one of the strengths across the country. However, not everyone is using WQI and it takes a lot of time to explain the context and purpose of the Index so that it is clearly understood by the public.
- Ensuring that there are water quality agreements among all jurisdictions is an important component of maintaining monitoring networks.
- There appears to be a lack of communication between the monitoring community and policy makers. For example, one of the issues raised is that there is a tendency to look at land use first and then the necessary water quality monitoring rather than water quality monitoring available for making land use decisions.
- It is recommended that stakeholders in water quality management come to some understanding regarding collective actions that will lead to improved water quality monitoring networks. It is important to develop a more coordinated approach or a networks of networks that results in collaboration among stakeholders.

The Role of Monitoring & Surveillance in the 'Source to Tap" Multi-Barrier Approach - Finished Drinking Water Monitoring in Canada
Thon Phommavong (Saskatchewan Environment)

The primary objectives of drinking water monitoring are to ensure that safe water is being supplied to customers and that an adequate supply is available. Other objectives include aesthetics, transparency and accountability of water managers, monitoring water quality trends to determine potential threats, and assessing water treatment requirements and distribution efficiencies. Current water quality monitoring requirements in municipalities have typically depended upon: 1) the variability and vulnerability of source water; 2) availability of source water quality data; 3) past trends in water quality; 4) analytical capabilities; 5) size of the municipal population; 6) water treatment type and performance; and 7) the size, condition and configuration of the distribution system. Routine source water quality monitoring is not commonly required by water treatment facilities, but source waters may be monitored by other means such as primary network stations and permits of pollution control facilities. It is necessary for better communication links to be formed between water quality monitoring practioners and the current state of science pertaining to the types of parameters that should be monitored at specific sites in Canada. Some of the future trends and issues of drinking water monitoring would include more frequent monitoring, continuous on-line monitoring, monitoring for waterborne pathogens, such as *Cryptosporidium* and *Giardia*, and pharmaceuticals, and recording water consumption.
Observations/Recommendations:

- Sampling methods within a distribution system may need to be changed to ensure that the water that reaches the consumer meets all the Guidelines for Canadian Drinking Water Quality.

We need to decide where water quality monitoring begins and ends. Contamination of drinking water may be a result of problems with source water, the water treatment facility or the distribution system. For example, monitoring should be conducted at the tap to protect the public from metals, such as lead, which may leach from the pipes in the distribution system and residences.

Water Quality Monitoring in Canadian Municipalities (Source to Tap) - An Example from the Greater Vancouver Regional District
Bob Jones (Greater Vancouver Regional District)

There are four barriers in the multi-barrier approach to ensuring safe and secure water reaches the public: 1) protection of the source water; 2) appropriate treatment of the source water; 3) protection of the water supply in the delivery system; and 4) monitoring water quality from the source to tap. Water quality monitoring provides proof of the effectiveness of the other three barriers. Prior to 1999, the Greater Vancouver Regional District (GVRD), which supplies water to the Greater Vancouver area, monitored the quality of water up until the point that the water entered the municipal systems. Bacteriological monitoring of water was carried out by the municipalities, but there was no formal requirement to report the findings. In 1999, all water purveyors were required by Health Officials to develop a monitoring plan and report the findings annually to municipal councils, public health authorities and the public. The Water Quality Monitoring and Reporting Plan for the GVRD and the Member Municipalities was developed as a joint approach to meet monitoring requirements and avoid monitoring duplication. The Distribution System Water Quality (DSWQ) Committee, consisting of representatives from water supply, water treatment and water quality control, was formed as an internal review process to ensure optimization of water quality. As part of the review process, water quality monitoring data is coupled with GIS outputs to produce geographic representation of data. This information is then used to determine the need for system and/or water treatment level adjustments in order to optimize water quality in the distribution system.
Observations/Recommendations:

- Water quality monitoring is a key component of the multi-barrier approach that ensures that the other barriers are effective in the supply of safe water to the public.
- Water quality monitoring data used in conjunction with GIS results in a powerful tool that can be used to guide system and water treatment adjustments for the optimization of water quality.

Community-Based Environmental Monitoring in Canada: A Community Perspective
Jeff Borisko (Citizens' Environment Watch)

Increasing numbers of Canadians are becoming aware of environmentally relevant issues and taking an active role by participating in community-based environmental monitoring (CBEM) groups. These groups, such as Citizens' Environment Watch, exhibit a willingness to carry out monitoring activities both independently of and collaboratively with traditional monitoring organizations. There are four types of CBEM for water quality in Canada: 1) participatory monitoring, which includes education, awareness and stewardship; 2) baseline monitoring, which involves monitoring not specifically linked to an impact or issue; 3) impact monitoring, which includes areas such as resource use and protection or restoration; and 4) strategic monitoring, which uses monitoring for planning, policy, and advocacy. One of the key challenges facing CBEM in Canada is the requirement from traditional monitoring agencies for creditable, standardized methodologies and protocols to be followed. Other challenges faced by CBEM groups are definition and scope of problems, and finding and evaluating resource options. Volunteers, training, technical support such as equipment and laboratory space, and funding are typical resource requirements. Furthermore, CBEM is highly developed in some areas, but there is little evidence that the data collected has any real contribution for the decision-making process. Greater communication links need to be formed between CBEM groups and the proper authorities to ensure that the data collected does contribute to the decision making process.

Observations/Recommendations:

- CBEM can make positive contributions to all components of the water quality assessment process (e.g., defining goals and outcomes) and is not just confined to the data collection process.
- CBEM groups are handicapped by a lack of funds, partnerships and access to proper technical equipment training and support as well as the ability to effectively report and communicate data to decision makers.
- There may be difficulties overcoming the expectations of traditional monitoring organizations that expect standardized protocols to be followed.

Developing Groundwater Monitoring Networks
Harvey Thorleifson (Geological Survey of Canada)

Groundwater is a source of water for nearly one third of Canadians, and for livestock and irrigation operations, as well as an integral component of the hydrologic cycle. Surface water in Canada has been extensively mapped, whereas relatively little is known about the types and extent of groundwater. While the time scales for contaminant transport in surface water are well documented, the temporal and spatial scales of transport of contaminants in groundwater can be highly variable, and may extend to residence times of thousands of years. In order to effectively monitor groundwater, a new framework needs to be developed independent of but complementary to surface water monitoring. Groundwater monitoring can be far more expensive and challenging than surface water sampling, and sampling protocols and interpretation are different. Over the last two years, a federal-provincial-territorial panel has coordinated to develop the *Canadian Framework for Collaboration on Groundwater*, which outlines the recommended process and steps required to secure the fundamental information necessary to manage and protect groundwater resources nationally. Presently, the Framework has identified gaps regarding monitoring of Canada's groundwater, such as the lack of long-term data, tools to interpret and access data, and the need to develop a cooperative network across the federal, provincial and territorial jurisdictions. Information on the groundwater framework can be found at http://cgg-ggc.ca/cgsi/index-fr.html.

Observations/Recommendations:

- Regularly updated guidelines will be required regarding design, construction, quality assurance, and operation of groundwater monitoring networks.
- On-going re-assessment of groundwater monitoring networks will ensure their maintenance and adaptation to changing circumstances.
- The benefits of establishing a cooperative federal, provincial and territorial network will be reduced cost, enhanced scope and better access to information and data.

Session 2: Designing Water Quality Monitoring Programs and Networks - Water Information Needs

Chair: Haseen Khan (Department of Environment, Government of Newfoundland and Labrador)
Wednesday, October 16, 2002

Overview

The collection of water quality data is a basic prerequisite in understanding and managing water quality. It is important to realize that without the development of adequate communication tools, water quality and quantity information may not reach the appropriate decision makers and the general public. A network of water quality monitoring programs may provide both water managers and the general public with the necessary information to make sounds decisions on the quality, uses, and availability of water. Furthermore, collaboration among programs reporting in all Canadian jurisdictions is essential in developing a framework for water quality monitoring assessment. Fundamental to ensuring the success of any monitoring program initiative or network, is the design and underlying rationale for the information needed.

Observations/Recommendations:

- Common problems encountered in coordination of monitoring programs include: getting everyone to the table to build relationships, and to think and act collaboratively; identifying specific collaboration issues and goals; developing technical strategies; and developing a sustainable national strategy for water quality assessment.
- The development of a monitoring framework can be guided by the need to answer fundamental questions, such as "Can I drink the water, Can I swim/fish in a particular water body, etc.", and the need to determine whether water quality targets, either broad or specific, have been met.
- The question(s) or information needs determine the spatial and temporal dimension of the program, the extent of the partners, the conduct of the program, and how the information will be collected, interpreted and reported.
- A broad spectrum of stakeholders and partners (e.g., watershed organizations) need to be involved in monitoring programs.
- Monitoring programs or networks must be designed for a specific purpose and to answer specific questions. The design of monitoring networks should take into consideration data gaps/needs, and geographic and ecozone coverage.
- A framework should be developed that has a long term vision of monitoring, has the capacity and resources to achieve its goals, and provides opportunities to cooperate with existing programs. Lastly, the framework should be descriptive rather than prescriptive.

Summary of Presentations:

Water Quality Monitoring in British Columbia

Les Swain (British Columbia Ministry of Water, Land and Air Protection)

In the mid-1980s, British Columbia implemented five types of programs to provide information on which to base management decisions and to inform the public about the state of water quality. The five types of ambient water quality monitoring in BC are: 1) baseline assessment; 2) impact assessment; 3) trend analysis; 4) water quality objective development; and 5) water quality objectives attainment. Each of these programs was designed to answer specific questions. All programs continue to be challenged by a lack of resources, though a recent investment has increased some capacity. A reporting method using the water quality index, listing five ranges (excellent, good, fair, borderline and poor) for water quality was developed. Using this ranking system of waters to generate public reports met with some success. Eleven water bodies were listed as poor or borderline, which raised considerable media attention. Other water bodies, listed as good to excellent, caused water managers to be concerned that they may be held accountable if these same bodies were to be given a lower ranking in the future. Lastly, BC has implemented three unique and successful public reporting programs that may be useful templates for other jurisdictions. These reports are: *British Columbia Water Quality Status Report* (1996), *Water Quality Trends in Selected British Columbia Waterbodies* (2000); and *Environmental Trends in British Columbia* (1998).

Observations/Recommendations:

- Reporting programs may be hampered by water authorities who hesitate to report the state of their water quality to avoid future actions or accountability with respect to the state of their water.
- The water quality reports indicate that BC is meeting its objective to understand the current state of its water quality.
- It is imperative that the results of monitoring programs be reported out to ensure that the data are fully understood, and used to facilitate adjustments and modifications in response to new and emerging water quality issues.

Water Quality Monitoring Networks in Quebec

Serge Hébert (Ministère de l'Environnement du Québec)

Quebec operates a variety of monitoring networks to assess the quality of its surface water. There are 162 long-term ambient river stations that conduct basic river monitoring, primarily associated with populated areas. The impacts of agriculture on surface waters is monitored by flow dependent sampling, which estimates nutrient and sediment loading in six small agricultural watersheds. Parameters monitored in both the river and agricultural watersheds include fecal coliforms, total phosphorous, total nitrogen, $N\text{-}NH_3$, $N\text{-}NO_3NO_2$, chlorophyll, turbidity, suspended solids, conductivity, pH, dissolved organic carbon, O_2, and temperature. Pesticides are monitored on a long-term basis in four agricultural watersheds and on a five year cycle in 50 private wells in potato croplands and three rivers draining apple orchards. Two drinking water intakes are monitored by automatic samplers for toxic contaminants (PAHs, PCB, dioxins, furans, etc.) and assessment of toxic loadings. Eutrophication is monitored in 50 human impacted lakes; ten lakes are monitored in five-year cycles for transparency, chlorophyll a, total phosphorous, O_2, pH, conductivity and temperature profiles. There is a pilot project for a volunteer network, which monitors 14 lakes, and aims to monitor 100 lakes, for phosphorous (once/summer) and Secchi disk (six times/summer). Cyanobacteria is monitored in four lakes every two weeks from June to October, and every five days during blooms. Lake acidification recovery from SO_2 emissions is assessed in 48 northwestern lakes in the winter on a five-year cycle by the Noranda Network. Parameters monitored include anions, cations, SiO_2, Cl, pH, alkalinity, dissolved organic carbon, colour and total phosphorous, iron and aluminum. The Collaborative Mercury Research Network (COMERN) program monitors 15 Canadian Shield lakes for mercury in fish on a ten-year cycle.

Observations/Recommendations:

- A lot of monitoring is done within the scope of specific studies and outside any network, specifically for toxic contaminants.
- Quebec has several monitoring networks, each network being designed to answer specific questions. A unique network cannot deal with all of our water quality concerns.
- Watershed organizations need to be involved in monitoring programs.
- Volunteer networks for lake and basic stream monitoring need to be enhanced.

- Pesticide and toxic contaminant monitoring needs to be more extensive, and a biological monitoring network needs to be developed.

A Framework for Collaborative Water Quality Monitoring
Charles Peters (United States Geological Survey)

Like Canada, there are a wide range of practitioners involved in water quality monitoring in the United States. The U.S. established the National Water Quality Monitoring Council (NWQMC) and the Methods and Data Comparability Board (MDCB) in 1998. The Council was established to "provide a national forum to coordinate consistent and scientifically defensible methods and strategies for improving water quality monitoring, assessment, and reporting". The Board's challenge "is to identify, examine, and recommend water-quality monitoring approaches that facilitate collaboration amongst all data-gathering organizations and yield comparable data and assessment results". The NWQMC and the MDCB are partnerships of water-quality experts from Federal agencies, States, Tribes, municipalities, industry, and private organizations. A framework for water quality monitoring was developed to help guide the activities of the Council and Board to overcome water quality assessment monitoring inefficiencies and decrease redundancy. Each year, there is a lot of monitoring activity that takes place by government agencies, industry, academic researchers, and private organizations. However, there has been very little collaboration among these monitoring efforts or structured exchanges of monitoring information among various groups. The lack of coordinated monitoring activity has created critical differences in sampling design, sampling and analytical methods, and data management and interpretation that have made it difficult for monitoring data to be shared among potential data users. The Council and Board are tasked to develop a national monitoring strategy that facilitates collaboration and yields comparable data and assessment results. The NWQMC has defined a framework by the flow of "information" through a series of sequential activities, each of which carefully builds upon the earlier steps to ultimately produce and convey water information. The sequential steps of the framework include: 1) identification of monitoring objectives; 2) designing a monitoring project to meet objectives; 3) collecting data in the field and laboratory; 4) managing data; 5) interpreting data; and 6) conveying information and results. To facilitate the framework, three outreach programs have been developed. The Core Water Quality Data Elements (WQDEs) provides information about the data (meta data) that is needed to facilitate basic data exchange. The National Environmental Methods Index (NEMI) is a web-based, searchable compendium containing method summaries of field and laboratory protocols (NEMI is available at www.nemi.gov). And, the Environmental Monitoring and Measurement Advisor (EMMA) is a prototype expert system designed to ensure that all critical questions are asked when planning an environmental monitoring program.

Observations/Recommendations:

- The Monitoring Council promotes better use of available monitoring resources through coordination of programs, provides better information to respond to legislation, improves reporting to the public, and promotes awareness of the need for monitoring.
- Common problems encountered by the Council and Board include: getting everyone to the table to build relationships, and to think and act collaboratively; identifying specific collaboration issues and goals; developing technical strategies; and developing a sustainable national strategy for water quality assessment.

The Role of Research in Designing and Implementing Monitoring Programs - Experience from the Northern Rivers Basin Study and the Northern Rivers Ecosystem Initiative

Fred Wrona (National Water Research Institute, Environment Canada)
William Gummer (Environment Canada)

The Northern Rivers Basin Study (NRBS) was launched to assess the cumulative impacts of industry, particularly pulp mill-related effluent discharges in the Peace, Athabasca and Slave river basins. Begun in 1991 and completed in 1996, the NRBS had eight scientific components: 1) fate and distribution of contaminants; 2) food chain impacts; 3) nutrients; 4) hydrology/hydraulics and sediment transport; 5) uses of water resources, 6) drinking water quality, 7) traditional knowledge; and 8) synthesis and modeling. Although initiated by the federal, provincial and territorial governments, the NRBS was set up to be at "arms length" and managed by a 25 member Study Board from industry, environmental groups, aboriginal peoples, health, agriculture, education, municipalities, and the federal, provincial and territorial governments. The study identified the following monitoring short-comings at the onset of the NRBS: inconsistencies in data quality pertaining to analytical methods and archiving; inadequate sampling frequency for several parameters; and the lack of or improperly defined effects-based endpoints. There was also inadequate public access to monitoring information and a need for improved QA/QC protocols. Using a weight-of-evidence approach from the data collected, the NRBS was able to make a number of site-specific and basin-wide scientific and management related recommendations to the Ministers regarding regulatory and policy changes, basin management, monitoring options, and future research priorities. Following this research, the Northern Rivers Ecosystem Initiative (NREI) was launched in 1998. This five-year program focused on pollution prevention, contamination, water quality, climate-change impacts, and improved environmental effects monitoring. Both the NRBS and NREI are excellent examples of the importance of conducting ecosystem-based, interdisciplinary science and the need for public involvement in program design and implementation for effective environmental monitoring programs and decision-making.

Observations/Recommendations:

- The NRBS and NREI are examples of a multi-disciplinary approach that integrates ecological science with socially-relevant indicators of water quality ("drinkable, swimable, fishable"), thereby strongly linking science to policy development in assessing and managing aquatic ecosystems in Canada.
- The research generated by the NRBS and NREI has helped optimize monitoring and assessment design, identified ongoing research priorities and fostered increased cooperation amongst federal, provincial, territorial and municipal governments and industry, aboriginal groups, non government organizations, and other stakeholders.

Design of the Trend Network for Rivers and Streams in the National Water Quality Assessment (NAWQA) Program

David Mueller (United States Geological Survey)

The U.S. Geological Survey's National Water Quality Assessment (NAWQA) program was implemented to understand the status of water resources, assess trends and changes in water quality, and identify, describe and explain factors that govern water quality. Sampling and data analysis during the initial 10 years of the program, referred to as Cycle I, were recently completed. Cycle II was initiated in 2001 to assess water quality in 42 large areas of the U.S., generally major river basins. One of the objectives of Cycle II is to evaluate trends in the chemical and biological quality of rivers and streams and to relate these to probable causes. To achieve this objective, a network of sampling sites was designed to represent the major land uses in the U.S. and the diversity of hydrologic landscapes and stream ecosystems. Within this monitoring network there are four types of sampling sites: integrator sites, agricultural sites, urban sites and reference sites. Integrator sites were chosen to represent regional examples of river basins influenced by a typical mix of land uses. Land-use indicator sites, which include agricultural and urban sites, were selected to represent the most extensive agricultural settings and the largest and fastest growing urban areas. Reference sites were chosen to provide a comparative basis for evaluating the ecological effects of urban and agricultural land uses. The majority of sites were selected from those that had been routinely sampled during Cycle I. The network consists of 159 sites with mean annual flow ranging from less than 10 to more than 40,000 cubic feet per second in watersheds ranging from about 10 to more than 85,000 square miles. Physical and chemical parameters measured at each site include stream-flow, temperature, DO, pH, major ions, suspended sediment, nutrients, pesticides, volatile organic compounds, and organic carbon. Biological measures include habitat characteristics, fish and invertebrate communities, and periphyton algae.

Session 3: Integrating Water Monitoring - Moving Beyond the Stovepipes

Chair: Pierre-Yves Caux (Environment Canada)
Wednesday, October 16, 2002

Overview

The recurrent theme throughout this session was moving beyond traditional institutional and functional barriers that hinder collaborative efforts to integrate water quality monitoring programs. Integration of the water quality monitoring efforts amongst government departments is fundamental to the delivery of a network of networks approach to monitoring. There is a realization that to be effective, water quality monitoring needs to steer towards activities that relate to human health outcomes as well as environmental health outcomes. Furthermore, there is growing awareness that water quantity and availability should be linked to water quality when developing a monitoring network. Water quality monitoring activities in Manitoba were given as an example of successful water management in Canada. Different chemical and biological metrics/indexes were used to provide significant information for making sound environmental decisions. One of the key points was the recognition that monitoring efforts should be based on an ecosystem approach. The Environmental Effects Monitoring program is an example of another approach that compiles, analyses and reports data in a fashion that is amenable to decision makers. The key to this program is the implementation of Cumulative Effects Assessment that evaluates the quality of surface water.

Observations/Recommendations:

- Collaboration of the different jurisdictions and government agencies is continually needed to ensure that water quality monitoring programs are evaluated and updated.
- There needs to be better coordination between water quality and quantity monitoring networks.
- Water quality information from the scientific community should be utilized and incorporated into current source water monitoring and protection programs. The scientific community has developed many useful monitoring tools, indices and technologies that provide useful and comprehensive information on the health of aquatic ecosystems.

Summary of Presentations:

Linking Health and Environment: Water Quality & Surveillance of Health Outcomes
Ray Copes (BC Ministry of Health Planning)

Water quality monitoring from a health perspective needs to primarily focus on the relatively small number of biological, chemical and physical agents that may result in actual cases of illness or premature mortality in the population. As water treatment and the distribution system may cause an increase or decrease in the concentration of harmful agents, the most useful monitoring for purposes of assessing human exposure considers what is 'at the tap'. It is not possible to set concentration-based standards protective of human health for the pathogens believed to be responsible for most waterborne disease. There are a number of differences between water monitoring and health surveillance. Drinking water quality monitoring tends to group parameters to be monitored into categories such as metals, pesticides, etc, rather than looking at parameters that may be linked to a particular set of health outcomes. While reliance on passive laboratory surveillance of pathogens can identify many outbreaks of waterborne illness, it may not be sensitive enough to detect all small outbreaks and does not provide good information on the possible role of water in endemic illness. GIS may be a useful tool to demonstrate a geographic link between the occurrence of disease outbreaks and postal codes. Lastly, chemical by-products may be formed during water treatment processes that have been linked to human health concerns such as cancer and reproductive problems.
<u>Observations/Recommendations:</u>

- Water quality monitoring from source to treatment to tap may be able to indicate whether pathogens and contaminants were present prior to treatment or were introduced within the treatment facility or distribution system.
- Turbidity has been used in the past as an indicator of the quality of water and in some cases as a guide to treatment. We still lack a clear quantitative understanding of how turbidity affects the risk of waterborne disease. Further research in this area may improve our ability to use turbidity as a guide to managing water quality.
- We lack clear 'no risk' levels for pathogens and chemicals (e.g., disinfection by-products, arsenic) that are likely responsible for most of the illness and premature mortality attributable to drinking water in the Canadian population. Simply assessing compliance or lack of compliance with concentration-based standards or guidelines (e.g., the Canadian Drinking Water Quality Guidelines) is a poor surrogate for risk to the consumer.

Threats to Freshwater Availability in Canada
Fred Wrona (National Water Research Institute, Environment Canada)
Jim Abraham (Meteorological Service of Canada, Environment Canada)

The Meteorological Service of Canada and the National Water Research Institute of Environment Canada co-sponsored an experts workshop, in Victoria BC, September 26-28, 2002, directed at producing an assessment document titled *Threats to Freshwater Availability in Canada*. A panel of more than 60 water quantity experts from Canada and the United States, spent three productive days in developing the initial drafts for 15 chapters describing the major threats to water availability in Canada. This initiative will result in a significant assessment document on water quantity threats that will compliment a major water quality threats document prepared in 2001 by the National Water Research Institute. This document will be of value to senior decision makers, water managers at all levels of government, the public and the scientific research community at large, with the final production and distribution targeted for completion by 2003.

Observations/Recommendations:

- One of the key issues identified was the need for improved strategies in water quantity monitoring and integration of some of the newer technologies into water quantity monitoring networks.
- There needs to better coordination between water quality and quantity monitoring networks. Furthermore, these networks need to improve database management to enhance access to the data and QA/QC consistency among the various regions/jurisdictions.
- The design of effective water quantity monitoring networks needs to account for information requirements at appropriate temporal and spatial scales.

Integrating Chemistry and Biology in Water Quality Monitoring in Manitoba
Dwight Williamson (Manitoba Conservation)

Manitoba has maintained a network of water quality monitoring at 45 sites since the mid 1960s for some sites and early 1970s for others. Routine water quality monitoring measures water chemistry variables such as nutrients, major ions, indicator bacteria, trace elements, industrial organics, and agricultural pesticides. Biological monitoring since the early 1970s was for short-term, site specific investigations. However, in 1995 Manitoba Conservation incorporated routine collection of bottom-dwelling aquatic invertebrates into its water quality monitoring program. Biological data are assessed using taxa richness, percent contribution of the dominant taxon, and a number of biological indices (e.g., Ephemeroptera-Plecoptera-Trichoptera (EPT) Index). Biological assessments are used to indicate the extent of impairment relative to expected reference conditions and are now reported annually to the public along with the CCME's Water Quality Index for each site.
Observations/Recommendations:

- The integration of chemical and biological water quality monitoring may be a useful tool that can be used to create a ranking system to indicate the health of surface waters.

Building an Aquatic Cumulative Effects Assessment (CEA) Framework From Integrated Environmental Effects Monitoring
Monique Dube (Environment Canada)

The Cumulative Effects Assessment program is a useful means by which to promote sustainable development. This approach is effects-based and assesses the existing environmental state using state-of-the science processes. The Cumulative Effects Assessment framework quantifies which indicators to measure, how to measure them, and how to quantify a magnitude of change in a "developed" area relative to natural variability at reference sites. Effects-based approaches have developed from regional programs (e.g., NRBS, Moose River Basin) and from local Environmental Effects Monitoring (EEM) programs (i.e., pulp and paper and mining industries regulated under the *Fisheries Act*). A framework and implementation software (EcoAtlas-CE) have been developed for the Prairie and Northern Region, Environment Canada, as a demonstration project under the Northern Rivers Ecosystem Initiative. The vision is to provide an on-going and regional assessment of "accumulating" aquatic effects that integrates data, describes and assesses the data using consistent scientific principles, and presents data in a user-friendly public communication software tool for science-based, state-of-the environment reporting. This approach utilizes the extensive aquatic data and evaluation benchmarks that exist in Canada from multiple sources and jurisdictions. Water quantity (HYDAT), water quality (ACBIS, AB, SK, MB, PPWB), biological quality (EEM Program), and point source effluent quality (AB pulp mills; AB municipal sewage discharges) data sets populate the software to date.

This data and associated meta-data are accessible to the user for graphical display and download. The program also has an assessment function that uses the Canadian Water Quality Index as a benchmark to evaluate data sets. The results of the index calculations are displayed as “circles of water quality” in map layers. Biological data sets are also analyzed using a science-based, fully automated module where the data at “developed” sites are compared to reference sites and "effects" are represented by colored markers on the map. Accumulating effects can be assessed by comparing data sets to their respective benchmarks.

Observations/Recommendations:

- The software developed for Cumulative Effects Assessment could be used to determine the existing state of an aquatic system by drawing on both water quantity and point source quality data that will be available in the database.
- Cumulative Effects Assessment could also be used to predict how an aquatic ecosystem will be impacted by a new development by comparing the baseline data to data already in the program and pre-assessed benchmarks.
- Follow-up monitoring could be done using the same comparison-based design, and the data entered into the system to track changes and determine if impact predictions were accurate.

Session 4: Water Quality Monitoring Technologies and Methods - Innovations and Challenges

Chair: Tim Fletcher (Ontario Ministry of the Environment)
Thursday, October 17, 2002

Overview

Drinking water systems and aquatic ecosystems are vulnerable to a wide range of stressors and threats. In addition, recent events have raised concerns over the security of water infrastructure to terrorism threats. Given the wide range of existing and emerging threats, advances in water quality monitoring and detection technology are needed to effectively and efficiently identify risks to water quality from the source to the tap. A network needs to be put in place that lists the available technologies, laboratories capabilities and water quality monitors, as well what is being done and by whom. Clearly, there needs to be communication and collaboration among all sectors of water monitoring programs, including environmental pollution researchers, risk assessors, and the laboratories with the analytical capabilities. Laboratories need to become more than just data generators and processors in water quality monitoring programs and take a more active role in the decision-making process. Available and developing sensor technologies could facilitate water monitoring programs by providing low cost and rapid (or real-time) monitoring of both chemical contaminants and pathogens. The current science and technology of water quality monitoring sensors needs to move from the research and development stage to the implementation stage which will require collaboration by multiple stakeholders in the scientific, regulatory and industrial communities. New monitoring technologies provide the ability to incorporate early warning systems into water quality monitoring and will allow water managers to become more proactive, rather than reactive, in their approach to protecting aquatic ecosystems and drinking water supplies.

Observations/Recommendations:

- Advances in water quality monitoring technology and methods need to occur and be applied with experimental and operational programs.
- The development of sensor technology is an expensive undertaking that will require increased collaboration and partnerships, sometimes multi-national, to develop, test and implement.
- Water quality data generated by the increasing efficiency of water monitoring technology will require efficient analysis and interpretation in order for the benefits of technology to really have an impact on water management decisions. In response, laboratories may have to take on a more active role of providing advice and guidance to ensure that water quality data is provided to decision makers in a timely and effective manner.

Summary of Presentations:

Laboratory Support to Environmental Water Quality Monitoring Programs in Canada
Dave Warry (Environment Canada)

Laboratories are an integral component of a water quality monitoring program and can provide more than just data. Decisions based on the scientific information obtained from monitoring programs depend on the data generated by the laboratories used to support these programs. A number of questions have been raised along five theme issues that should be considered during the design of any multi-agency environmental monitoring program. The first theme is to identify the roles and capabilities of collaborators, whether they are from the federal, provincial, or private sector, in a monitoring program. The second theme is quality assurance and standardization which is essential for data comparability and credibility. The third theme is to understand the complexity of the monitoring program and the capability of laboratories to assess new issues. The fourth theme is to utilize research and development advances to assess emerging water quality issues without compromising the underlying integrity of the monitoring program. The development of new technology may result in more costly monitoring programs as well as the production of complex data sets that will require IT investments to ensure reliable data management. The fifth theme is for laboratories to look beyond just results output and look more towards forming partnerships to provide advice and collaborate with decision makers. These themes are linked, and making improvements to one theme area will often have a beneficial impact on one or more of the others.
Observations/Recommendations:

- The laboratory component of monitoring programs can provide more than just water quality data; it can provide interpretation of the results and help steer water managers and decision makers.
- Managers of science-based monitoring programs must be confident that the data being generated by the laboratories is relevant, appropriate and cost effective. One way to develop this confidence is to look at some of the laboratory-related issues that have contributed to the limitations of previous monitoring programs and ask how these limitations might be overcome.
- One of the key issues in Canada is that laboratory collaboration with water monitoring partners and decision makers needs to be improved. A network such as the U.S. National Environmental Methods Index could be developed so that water quality monitors are aware of the capabilities of Canadian laboratories.

Innovations in Micro-Analytical Systems for Water Quality Monitoring
Wayne Einfeld (Sandia National Laboratories)

Sandia National Laboratories and other research institutions are developing various micro-electromechanical-based (MEMS) sensor systems that offer efficient analytical capabilities in small, affordable packages. MEMS-based technologies have performance features that are very similar to laboratory-scale instruments traditionally used for water quality analyses with the added benefit of being compact and portable. These technologies are capable of nearly real-time water quality assessment and therefore, provide a monitoring tool that could be utilized as part of future early warning systems within municipal water distribution networks. The sensor systems used in this type of equipment are based on silicon micro-fabrication technologies much like that used for the production of micro-processors. Currently, a research prototype, hand-held gas chromatograph that has the potential to analyze volatile organic compounds in water has been developed. A field portable system that analyses for biotoxins and other high molecular weight compounds in water is currently being developed.
Observations/Recommendations:
- Technological breakthroughs in micro-analytical systems could make monitoring networks more efficient and affordable.
- The advent of new technologies such as MEMS raises the question of what should be monitored; the capability to monitor a parameter should not be a reason to monitor for it. Rather, monitoring programs need to ensure that the parameters monitored are pertinent to the monitoring program's objectives.

European Initiative on Sensors for Monitoring Water Quality
Susan Alcock (Cranfield Biotechnology Centre)

The European network on "Sensors for Monitoring Water Pollution", or SENSPOL, is working to develop practical applications for sensor systems that will aid in reducing water pollution. Sensor technologies can be used for rapid field assessments of pollution, including pollutant mixtures, which offers particular advantages for early warning systems within environmental monitoring programs. Currently, sensors are commercially available to measure parameters such as pH, temperature, acidity, dissolved oxygen concentrations, redox potential and conductivity. Sensors that measure biological effects, when used with analytical sensors, can provide additional, useful and complementary information on the quality of surface waters. It has been demonstrated that biosensors that are successful in the laboratory will also work in the environment and will be able to provide continuous information about the environment. As well, biosensors will be useful as screening, or early warning tools, for the presence of known or unknown chemical compounds (or mixtures) in the environment. Well-developed principles for sensing cover general toxicity, heavy metals, PAHs, BTEXs, nutrients, endocrine disrupting substances, emerging pollutants (biotoxins) and pathogens. There are enhanced sensor devices being developed that will be able to monitor several analytes simultaneously. Several types of sensors and related technologies could be adapted for screening contaminants in water, for example, toxicity sensors, molecularly imprinted polymers (MIPs) for detection of algal toxin (microcystin-LR), immunosensors for field-based quantification of herbicides, and an automated system for biological threats (e.g., bacteria, viruses and protozoans).
Observations/Recommendations:
- Sensor technology needs to be incorporated into research-based and operational water quality monitoring programs to ensure public safety from water contaminants. However, a bottleneck is evident in moving from concept to product.

- Bridging the technology implementation gap requires effective communication among researchers on environmental pollution, risk assessors, sensor developers, stakeholders, regulators and commercial companies that bring sensors to the market.

Monitoring for Waterborne Pathogens: Existing Techniques and Future Directions
Tom Edge (Environment Canada)

Changing social and environmental conditions are affecting the occurrence and prevalence of waterborne pathogens in aquatic ecosystems across Canada. Monitoring for waterborne pathogens currently involves using decades old technology and methods that in some cases do not adequately assess potential human health risks. Instead of attempting to directly measure the presence of many possible pathogens in drinking or recreational waters, efforts to monitor the microbial quality of water have largely focused on culture-based tests to detect the presence of fecal indicator bacteria such as total coliforms or *Escherichia coli.* While fecal indicator bacteria like *E. coli* are useful, there are waterborne human pathogens that do not originate from fecal pollution, and many other pathogens whose occurrence may not be reliably predicted by testing for fecal coliform bacteria (e.g., viruses and protozoa). New molecular techniques are being developed to detect specific waterborne pathogens such as polymerase chain reaction (PCR) assays. Advances in other fields such as antibody-based detection methods, gene probes, microfluidics, genomics and DNA microarray techniques are also leading to new approaches for assessing microbial water quality. Molecular techniques in the emerging field of microbial source tracking may also assist in determining whether fecal pollution and pathogens are coming from human or animal sources. While there are challenges in applying sensitive molecular techniques to complex environmental samples, there is a growing need to develop these techniques, and evaluate them as tools to enhance existing culture-based techniques for monitoring microbial water quality.
<u>Observations/Recommendations:</u>
- There is an urgent need to develop better waterborne pathogen monitoring tools to prevent waterborne disease outbreaks and enhance water quality management decisions.
- Future directions for waterborne pathogen monitoring research include: 1) the development of pathogen-specific detection tools; 2) improvement of microbial source tracking techniques; and 3) conducting studies to better understand the ecology of waterborne pathogens and the environmental risk factors leading to disease outbreaks.

Assessing Water Quality Using Remote Sensing
Robert Bukata (Environment Canada)

Remote sensing is a valuable technique for large-scale monitoring of inland and coastal water quality and can provide synoptic overviews of the spatial distribution of both physical and biophysical variables of water bodies. Although remote sensing of water quality has been available for the last three decades, in-land water quality monitoring from space is essentially absent from Canadian environmental monitoring protocols. Processed remote sensing data collected over natural waters is a valuable supplement to data routinely obtained from existing networks of ground-based water quality stations. Remote sensing uses the colour of in-land waters to determine water quality information such as the spatial distribution of co-existing chlorophyll concentrations, suspended inorganic matter, and dissolved organic matter within natural water bodies. Further applications of remote sensing include a suite of environmental issues and concerns such as primary productivity, eutrophication, presence and progression of deleterious algae, marine oil spills, aquatic habitats, plus a host of water quantity issues such as surface area, water level, water flow diversion, hydrology, and ice onset and break up. The science and technology of remote aquatic sensing is sound and now needs to find applications in water quality monitoring programs.

Observations/Recommendations:

- Time-series analysis of large-scale water quality change are integral to assessing the health status of environmental ecosystems for both humans and wildlife. Such time-series analyses are now a reality with remote sensing and should be incorporated into aquatic monitoring programs.
- The Canadian Space Agency has satellites in place that could use remote sensing to monitor water quality. Challenges (such as cost) exist between accessing and procuring existing satellite-based remote sensing water quality information for many agencies.

Session 5: Building Water Quality Knowledge Networks

Chair: Darrell Taylor (Nova Scotia Department of Environment and Labour)
Thursday, October 17, 2002

Overview

Monitoring networks vary in scope and scale from small watersheds managed at the local level to trans-boundary water systems managed at the national level. A common and key requirement of all monitoring networks is to clearly define specific questions to be answered. There are many tools presently available to assist in linking water quality monitoring networks. Data and information management capabilities are rapidly expanding with advances in information technology. The next step is to develop networks that increase sharing of existing water quality monitoring data. Ensuring consistent elements of programs, such as terminolgy and methodologies, will be key to ensuring success in linking networks in a meaningful way.

Observations/Recommendations:

- The preferred venue for sharing data is a web-based approach, which is both efficient and facilitates easy access to the data by all partners.
- In order to implement successful information sharing among the numerous jurisdictions in Canada, it will be important to have 1) stakeholders involved in the networking process, 2) one entity responsible for coordinating the networks, 3) and on-going financial support.
- There needs to be a consensus in Canada on what type of network of networks should be created. If access to compatible and comparable data is the chosen approach, then Canada might want to look at developing a framework such as the EUROWATERNET.
- Some sensitivities regarding public access to certain data may arise in putting together a network of networks, and will have to be respected.

Summary of Presentations:

Canada-Wide Water Quality Data Referencing Network

Isaac Wong (Environment Canada)

A Canada-wide Water Quality Data Referencing Network (CWQDRN) is currently under development through the support of Environment Canada's Canadian Information System for the Environment (CISE) program. The CWQDRN has been developed in cooperation with the CCME and federal, provincial and territorial jurisdictions, which have identified the need for such a network to be available on the Internet. Currently, various database methodologies and computer networks are used by federal, provincial and territorial environmental agencies to provide access to surface, ground and drinking water quality data. The CWQDRN is the first to demonstrate a nationally coherent and consistent approach for information access by departmental agencies having similar needs or interests. The initial phase of the data referencing network will point the way to access various existing data by providing information about the data (e.g., eta data), such as where, when and how they were collected, who owns them and how to access and use them. Subsequent access to these databases by users is optional, and the databases are left in the control of the owners of the data. Key features of the system include data inventory, data access via distributed system, data analysis, on-line mapping, dynamic graphing, decision support/expert systems, and water quality indicator results. The system is based on a multi-tiered client-server architecture with web, database and map servers. The second phase of the CWQDRN will act as part of a decision support system which will provide users with water quality data that may be used for trend analysis and to evaluate changes in aquatic ecosystems.

Red River Basin Decision Information Network (RRBDIN): A Network for Sharing Information, Data and Tools
Brian Fischer (Houston Engineering, Inc.)

The RRBDIN provides the framework from which the decision support system (DSS) is being developed. The DSS was an initiative that began in 1997 to improve water resource management following the Red River Basin flood. The conceptual idea was to develop a portal where all information, data and tools could be accessed and shared among the many different public and private entities involved in water management and flood preparedness. Most existing information systems in the Red River Basin have been designed by separate agencies to address their individual problems and requirements. Stand-alone systems result in 'Islands of Automation'. Advances in information technologies allow improved means of sharing and processing vital information. The DSS connects these "islands" and enables water management decisions and analyses to be performed by the community of stakeholders. The DSS is an interactive computer-based system which consists of databases, communication tools, models, documents, data, GIS, and other tools for specific application. The early concept for the RRBDIN included the identification and development of several complex applications or "tools", which utilized seamless geo-spatial data, to aid in emergency response planning and flood management. However, many of the early ideas were not technically feasible. The present, re-focused phase of the RRBDIN continues the early efforts to share information, but takes a more basic, practical approach building upon the lessons learned. Several new tools presently under development include geo-spatial data applications and a real-time data display for hydrologic, hydraulic, climate, weather and water quality data. The concept is that decisions about floodplain management, disaster relief and mitigation, and basic water management issues can be enhanced by properly organizing and making available this information within a web environment. The RRBDIN currently consists of a growing community of "Members" (individuals and organizations) that use, test, and direct the content of the evolving RRBDIN Internet Web Portal (http://www.rrbdin.org). The portal currently includes communication tools, a searchable list of organizations and points of contact, documents library, policies and procedures, web-mapping tool, and other information resources.

Observations/Recommendations:

- The vision for the RRBDIN is to continue to improve communications and foster participation and cooperation, especially internationally, and implement geo-spatial data for routine applications.
- For DSS to be successful, there needs to be participation, communication, and cooperation as well as one entity responsible for coordinating the system and financial support.

Watershed Assessment, Tracking & Environmental Results System (WATERS)
Thomas Dabolt (U.S. Environmental Protection Agency)

The U.S. EPA Office of Water has developed a data system to integrate water quality monitoring data, state reported water quality assessments, the status of total maximum daily loads (TMDLs) in conjunction with any associated legal obligations, and the environmental results associated with Clean Water Act Section 319 funding. The new system, the Watershed Assessment Tracking Environmental Results System (WATERS), integrates program databases using the National Hydrography Dataset (NHD) as the spatial framework. This integration, coupled with an EPA-internal web-based user interface, allowed the EPA Office of Water managers and staff to ask and answer numerous programmatic questions in support of assessment and monitoring activities. The NHD provides: 1) a rich cartographic feature content for making maps; 2) a stream addressing system for linking water-related information to the national drainage network; 3) upstream/downstream modeling along the drainage network; and 4) infrastructure for maintaining and enhancing the dataset.

The Finnish EUROWATERNET
Jorma Niemi (Finnish Environment Institute)

The EUROWATERNET is a monitoring network organized by the European Union Council of Ministers and involves nearly 30 countries, including Finland. National monitoring networks are designed and put in operation in EU Member Countries according to the Guidelines presented by the European Environment Agency. The individual national networks together comprise the EUROWATERNET monitoring network that is the first step towards common practices in monitoring water bodies at the European level. The EUROWATERNET aims to determine the quality and quantity of surface and ground waters in Europe, determine the degree of eutrophication, acidification and physical changes, control pollutant discharges, and look at the ecological quality. The Finnish EUROWATERNET monitoring network for inland waters was created according to the Guidelines presented by the European Environment Agency. The river network consists of 195 river sites analyzed for physical and chemical water quality variables (maximum 48 variables). The lake network consists of 253 lake sites situated in a total of 211 lake basins and five reservoirs, which together cover 61% of the lake area of the country. Both river and lake networks include old sites from existing national monitoring networks complemented with new sites. In addition, the network includes a total of 74 hydrological baseline sites used for the calculation of discharges and water levels for river and lake sites.
Observations/Recommendations:

- In the future, the EUROWATERNET monitoring network will be developed to meet the requirements set by the European Union Water Framework Directive (2000/60/EC).
- There needs to be a consensus in Canada on what type of network of networks should be created. If we want to have access to compatible and comparable data, then Canada should look at developing a framework such as the EUROWATERNET.

Session 6: Interpretation and Reporting - Getting Relevant Information Out

Chair: Serge Hébert (Ministère de l'Environnement du Québec)
Thursday, October 17, 2002

Overview

There are a number of good indices available for aggregating and reporting water quality data. One of the most important elements of any program that analyzes, aggregates and/or distributes information is the underlying principle that good comparable data in will mean good comparable information out. In Canada, environmental monitoring data has been collected by numerous Canadian agencies or jurisdictions since the 1950s, but these data are stored in databases that are not readily accessible. A Canada-wide water quality data referencing network is currently under development and should allow user friendly access to these data. The CCME has developed the Water Quality Index as a mathematical tool to aggregate water quality data. Lastly, two statistical programs, developed by the U.S. Geological Survey, to analyze and explain trends of constituents in water both temporally and spatially, were given as an example of how water quality monitoring data could be utilized to generate useful information.

Observations/Recommendations:

- The use of the CCME Water Quality Index by the different jurisdictions is not sufficient by itself. A framework needs to be put in place that will allow representative site selection, and define minimum sampling frequency and a core set of parameters for each type of site. The other option is to have a patchwork of water quality monitoring networks that may not be compatible among jurisdictions.

Summary of Presentations:

Analysis of Trends in Water Quality: Old Challenges, New Developments
Skip Vecchia (United States Geological Survey)

Innovative statistical techniques are needed to overcome challenges in the analysis of trends in the concentration of water constituents. Censoring for constituent concentrations below detection limits and non-normality of concentration data require non-parametric statistical techniques. Trend tests based on the seasonal Kendall's tau or von Belle statistics are well-suited for handling both censoring and non-normality because the techniques are based on rank transformations. Although non-parametric techniques are useful for detecting and comparing trends among many different constituents and many sampling locations, they are of limited use for explaining complex trends both spatially and temporally and for predicting changes in concentration as a result of changes in climate, land use, or hydrology. Parametric statistical models, though of limited use for highly censored data, are well-suited for explaining and predicting complex trends in constituent concentrations, such as total nitrogen or total phosphorus concentrations, that routinely exceed detection limits. Two relatively new parametric statistical models, developed by U.S. Geological Survey scientists, for analyzing trends in water-quality data are the SPARROW model (spatially referenced regressions of contaminant transport on watershed attributes) and the QWTREND model. The SPARROW model is used to analyze spatial trends in contaminant loads in relation to point and non-point sources, drainage-basin characteristics, and stream-channel characteristics. This model is particularly well-suited for making regional assessments of water quality on the basis of data from regional water-quality monitoring networks. The QWTREND model is a joint statistical time-series model for daily stream-flow and constituent concentration. This model is used to analyze complex temporal trends in stream-flow and constituent concentration at a fixed stream location. The model can be used to separate flow-related variability in concentration from trends caused by other factors, such as anthropogenic pollution, relate trends in concentration to trends in ancillary time-series data, such as fertilizer applications or livestock production, and develop efficient sampling designs to monitor temporal trends in water quality.

Providing Water Quality Information to Canadians
Joe Pomeroy (Environment Canada)

There is a lot of environmental data that has been collected by numerous Canadian agencies since the 1950s, which is stored in databases that are often not readily accessible. Presently, retrieval of the data is slow, generally requiring time to submit a request, and time to get the data package through the mail system. These nationally fragmented data-sets can become user friendly for both the generalist and specialist with the development of an on-line search package thatcan provide instant data in a variety of user-friendly formats. The first step to achieve such a system is a consistent cataloguing system for data-sets, and a knowledge of what the generalist user and specialist user may request. For the generalist, such a system would include a map-driven system where location is easily determined, and a selection of questions that they want answered, for example: Is the water good for making tea? or Can I swim in the bay down the road? Once a request is submitted, a series of web-services would then search the internet for those data-sets which hold the information. The service would then dynamically collate the data, producing an interpretative report that would be understandable to the user. The same process would occur for the specialist, except in this case the data request could be downloaded automatically to the desktop for further interpretation.
<u>Observations/Recommendations:</u>
- A reorganization of current data-sets may not be required if the data-sets were stored in more modern-flexible data management systems (e.g., SQLServer or Oracle).
- A standard system for cataloguing and geo-referencing would be required for each data-set to ensure availability in an efficient and timely manner.
- Ensuring the security of sensitive data for the respective owners can be readily achieved with appropriate certificates or passwords to access these holdings.

The CCME Water Quality Index
Bruce Raymond (P.E.I. Department of Fisheries & Aquaculture)
Pierre-Yves Caux (Environment Canada)

Reporting what is often complex information on water quality in a simple, understandable way to the public is a challenge. The CCME Water Quality Index (WQI) provides a tool to interpret complex water quality information for the public and to look at water quality across the country in a consistent manner. Many water quality parameters (e.g., acidity, fecal coliforms, dissolved oxygen) are combined and compared to provide a water quality ranking (good, average, poor) for individual water bodies. The actual parameters used are those which are important for the particular water body. The WQI incorporates Canadian Water Quality Guidelines so that comparisons can be made for different water uses (e.g., aquatic life, drinking water, and/or recreation). To test the Index on a broader scale, a pilot project was initiated in the Atlantic Region by Environment Canada, in partnership with the Atlantic Provinces. The CCME Water Quality Task Group is overseeing the project. The objective of the pilot is to test and fine-tune the application of the CCME WQI for the monitoring regimes and natural conditions found in the four Atlantic Provinces. This effort will allow for an easier application of the Index on a larger number of sites in the future and help provide guidance to other stakeholders wanting to apply the Index. A final report (March 2003) will describe the status of water quality in recent years, for multiple beneficial water uses (e.g., protection of aquatic life, recreation and source of drinking water) for a selection of water bodies. The water bodies selected cover watersheds having a wide range of land-use activities and levels of impairment, and are considered to be of special interest to Canadians. The number of sites selected for each jurisdiction is four to six, which allows considerable investment in testing, fine-tuning, and interpreting the application of the Index.

Observations/Recommendations:

- The Index is a powerful communication tool for the public and can also serve as an indicator of sustainable development.
- Some of the limitations of the WQI are: 1) it is sensitive to the quality of the data entered; 2) only general comparisons between jurisdictions are possible; 3) long-term trend analysis is not possible due to differing methodologies, detection limits, and QA/QC, and 4) there are information gaps, such as not enough temporal data or variables monitored.

Suggestions for Framework Development

Future Directions for Water Quality Monitoring by the CCME Jurisdictions
Brian Wilkes (Brian Wilkes and Associates)

In Canada, water quality data is being collected in a wide variety of programs and monitoring systems. The development of new monitoring science and techniques, and the willingness and technology to create efficient monitoring networks could significantly enhance the quantity and quality of information being generated. Better shared data systems could collectively strengthen the ability of jurisdictions to both understand and manage existing water quality issues. A strategy for a network for water quality monitoring would facilitate collaboration among the 14 jurisdictions and increase comparability in data-sets collected. However, a Canada-wide approach to environmental monitoring and reporting needs to avoid creating the impression that jurisdictions will be compared and judged.

Currently, the 14 jurisdictions in the CCME family conduct water quality monitoring to meet their own needs. National frameworks that are too prescriptive need to be avoided because jurisdictions require the flexibility to develop individual monitoring networks. The path to successfully create a network of water quality monitoring networks may be to implement new strategies and/or frameworks that promote broad agreement to principles, but that can also assist individual jurisdictions in implementing programs in their own way.

A number of suggestions have been made as to how frameworks could be set up to encompass the needs of all the jurisdictions. Two processes need to occur to facilitate the development of a Canada-wide water quality monitoring framework. The first step would be to set the stage for communication and collaboration among all stakeholders, which could start with the development of a steering committee, and resources committed to this within each CCME member government.

- It has been suggested that a steering committee of existing networks be founded to facilitate the development and eventual implementation of a Canada-wide water quality monitoring framework. This steering group would guide water quality monitoring practices and should include representatives from government, science and research, water treatment facility, and laboratory communities. Once established, the steering committee would need to set goals and objectives based on gaps/needs of common interest and/or benefits. Achievable realistic activities would then be developed along with a process for their implementation. The United States and Europe both have good examples showing how multiple jurisdictions can work together to implement a water quality monitoring network.
- Resource allocation needs to be planned and budgeted. Resources are not just new money to continue on-going projects, but also a time commitment from the people who sit at the CCME table to develop guidelines and frameworks. Collaboration could promote common measurements and variables being monitored, and similar analysis and reporting mechanisms across the country.

The second step would be to establish a timeframe and identifiable milestones that would facilitate the development of a framework for water quality monitoring in Canada.

- A more comprehensive evaluation of existing water quality monitoring programs needs to occur; there is a lot of information in the current inventory of water quality monitoring activities that could be used in creating future frameworks and water quality monitoring networks.

- An inventory of water quality monitoring tools and technologies needs to be taken to ensure that water quality monitoring programs are using the best available technologies and practices.
- Additional workshops may be necessary to bring together water quality monitoring practitioners from all sectors (government, science, research, development, water treatment facilities and decision-making communities) to develop a framework that will meet the needs of individual jurisdictions.
- A follow-up process should also be established to determine if the implemented strategy or frameworks are meeting the water quality monitoring needs in Canada.

Appendix 1 - Participants Questionnaire

Pre-Workshop Participant Questionnaire -- Consolidated Responses

The Monitoring Sub-Group of the CCME Water Quality Task Group invited workshop participants to share their views on water quality monitoring in Canada in advance of the workshop, through completion of a Pre-Workshop Participant Questionnaire. Questions were answered based upon participants' experience, perspective, and area of expertise. Responses received have been summarized below

1. The Canadian Council of Ministers of the Environment (CCME) has committed to *"link existing water quality monitoring networks to ensure Canadians have access to comprehensive information"*. What is your 'vision' of "linked water quality monitoring networks in Canada"?

- The initial task of linking water quality monitoring networks should be to improve communication from jurisdiction to jurisdiction. Sharing ideas and working together will facilitate the development of a national strategic plan for water quality monitoring and will help restore public confidence in our drinking and ambient water resources. Duplication of tasks is unnecessary and will be eliminated if communication lines are opened. All jurisdictions have a variety of expertise to contribute to this issue and should be called upon for action.

- Currently, we have extensive water quality data being collected in Canada by multiple organizations and across multiple jurisdictions. This information, and the way it is assessed, require integration to provide the information that Canadians want, and should be accessible through the Internet (e.g., available on the Green Lane, the CCME website, or a new website).

- A linked water quality monitoring network could be composed of many organizations and/or agencies, each of which may have unique needs and objectives, and would be responsible for their program and data. The linked network approach would be a user friendly system which would facilitate collaboration and cooperation on issues such as identifying priority parameters, sampling program design, field and laboratory protocol comparability, interpretation, reporting and data management. The network could include a set of Index stations (five to ten in each jurisdiction covering diverse geographic, ecological and hydrological regions). This system should facilitate comparability of data from different regions and jurisdictions within the network and the development of national reporting mechanisms.

- Water quality information needs to be linked to assessments of other indicators of aquatic health (e.g., biological) to establish the extent, magnitude, consistency, and acceptability of any changes. The information that Canadians want from a linked network is simple: where is monitoring being conducted, by whom, and most importantly, how is the water quality in the area that I live changing over time, how much has it changed, what components are changing, and should I be concerned?

- This approach should emphasize reduced costs and better information for decision-making. The U.S. National Water Quality Monitoring Framework provides a basis for this approach.

Eventually, the web-user would be able to access water quality data in summary or raw format from a GIS-mapped site for any water quality program. Regular meetings of Canadian water quality managers would be part of this vision.

2. What do you feel are some of the key steps that should be taken towards accomplishing this goal in the short, medium, and long term? (Include all pertinent areas, including science, policy, process, etc.)

Short-term steps:

- Start now to build better relationships and understanding among network managers.
- Provide links to other national information (e.g., CCME guidelines).
- Complete federal-provincial-territorial inventory of monitoring programs.
- Develop a national water quality monitoring working group to oversee a collaborative monitoring approach.
- Increased collaboration between water quality scientists.
- Continue development of new CCME Canadian Water & Sediment Quality Guidelines & refine old ones where necessary (e.g., turbidity).
- Draft a national agreement on water quality monitoring.
- Stop the territoriality of data access. Make government collected data available at no cost and in an electronic, user-friendly format to those who need to use it.
- Decide on the science-based framework that best assesses water quality and communicates this to Canadians.
- Implement a web portal where metadata and links to partner sites would be accessible to users.
- Each jurisdiction should identify five to ten stations, which would be part of a national water quality monitoring network.
- Form a National Committee, which would develop terms of reference for regional water quality monitoring teams. The National Committee would coordinate the assessment by federal, provincial and territorial departments of roles and responsibilities, and database needs, to ensure there are no overlaps or gaps.

Medium-term steps:

- Develop a national metadata dictionary.
- Evaluation and implementation of “new” water quality monitoring technologies.
- Identify a common set of variables to be measured and reported in a consistent manner across the country.
- Develop provincial or watershed-based working groups to develop a more localized approach to implementing a Canada-wide strategy.
- Pursue adequate support for monitoring programs in a long-term context.
- Improve CCME Water Quality Index (work on Version 2.0) using biology as well as chemistry.
- Ensure all data is georeferenced, develop standardized approach to data reporting (QA/QC, methods, reported units, etc.), and address funding issues.
- Check data for quality, or at least place a quality rating on the data.
- Agree on how the information will be distributed to Canadians (raw data? interpreted information? through the web? State of the Environment report?).
- Document methodological approaches within each jurisdiction: laboratory methodology, QA/QC, data analyses (descriptive statistics, temporal trends, etc.).

- Develop a communication strategy to ensure institutions, schools, industry and the general public know that water quality information is available in a variety of media types.
- Place more emphasis and resources on re-establishing and developing/strengthening joint federal-provincial agreements (as in the past); such programs are beneficial to all parties.
- Support research programs to evaluate existing waterborne pathogen monitoring tools, develop new ones, and obtain new knowledge on the occurrence of waterborne pathogens in targeted areas across Canada.

Long-term steps:

- Bring in other water quality information (i.e. municipal and regional studies), biological networks (*e.g.,* CABIN), ground water networks, etc.
- Ensure adequate support exists for monitoring programs and guideline development.
- Place validated & verified water quality data on the Internet in both provisional & finished data sets.
- Develop and manage a national web based system for data input and retrieval.
- Establish an agreement among agencies to continue monitoring at "index" sites to facilitate long-term reporting of trends in the Canadian environment and on the parameter list to compute Canadian Water Quality Index (CWQI) nationally.
- Implement a Canadian monitoring network financed by Environment Canada and operated by jurisdictions.
- Develop a national strategic plan or directive that jurisdictions can utilize to manage both drinking water and ambient water quality.
- Establish regional interdepartmental water monitoring teams nation wide.

3. What, in your view, are some of the barriers to achieving this CCME goal (i.e. "network of networks" concept) and/or your proposed steps identified above? (include list of knowledge, technology, process or policy gaps, etc.)

- The initial steps have been taken towards developing a common water policy involving all levels of government. Jurisdictions need to ensure that there is a better linkage between the collection of environmental information and the decision-makers who are developing policies on environmental quality. Institutional barriers and a lack of political will to coordinate this kind of information have been identified as key barriers. We must ensure that all jurisdictions feel that a national strategic plan, with the emphasis on information sharing and cooperation, would be sufficiently beneficial to them that they would be willing to contribute time, knowledge and resources. Individuals and organizations need to "*buy in*" to the idea that development and implementation of a national strategy will be beneficial (i.e. reduced costs and better information). Many workshop participants felt that a formal leader or champion should be identified to ensure that goals are being attained in a national context.

- The need for long-term, stable funding to address the decreased technical expertise and capacity, which has resulted from budget reductions, was identified as a common barrier. A number of technical and standardization issues were identified, including: the need for a common suite of field and laboratory protocols, the need for georeferenced data sets, the complexity of existing laboratory codes, and the need for metadata standards. QA/QC issues surrounding data collection, interpretation and reporting need to be resolved, as well as issues surrounding data ownership.

4. What potential *solutions/options/opportunities* do you see to overcoming these barriers to achieving the CCME Ministers' goal?

- Monitoring must be established as a high priority and funded accordingly. Federal-provincial agreements on water quality monitoring should be revisited, and long-term commitments from each jurisdiction are needed for a Canada-wide network to succeed. In order to facilitate partnerships and improve cooperation, jurisdictional roles and responsibilities should be clarified. Agencies need to be flexible in terms of their own requirements, in order to achieve and benefit from the national goals. The water quality monitoring community needs to show the link between the data and improved management practices. It is clear that some monitoring efforts disappear into databases and rarely emerge as new knowledge. We need to show how better monitoring leads to both better understanding and management of water quality.

- Canada can learn from the experiences of other multi-jurisdictional water quality monitoring networks. For example, the U.S. National Water Quality Monitoring Council (NWQMC), European Monitoring Tailor-Made (MTM) and EUROWATERNET, U.S. Methods and Data Comparability Board, and the U.S. State and Regional Council should all be studied by Canada. We should also consider developing a multi-national approach to facilitate information sharing so that we can build on the efforts of countries rather than duplicate them.

- This is an opportunity to showcase the usefulness of monitoring networks to Canadians. There must be an emphasis put on the reporting of current environmental conditions (i.e., water quality) to the public. This knowledge must also be communicated to decision makers such as managers, permit administrators, regulators and regional governments. Federal departments should form the backbone of the network and use their existing data to show that all departments have bought into the concept. Provincial members may have an easier time gaining senior approval to participate in a successful federal initiative, rather than joining an untested development process.

- Increased funding is needed not only to increase our monitoring and reporting efforts, but to also develop new waterborne research and monitoring tools and techniques. For example, there is a tremendous opportunity to apply advances in molecular and genomics techniques to develop better waterborne pathogen research and monitoring tools.

5. What do you see as the CCME's role in each of the proposed steps and opportunities above, and in which areas do you feel the CCME is best situated to focus its efforts?

- The CCME can provide much needed leadership, and be a catalyst in the development of better relationships, coordination, cooperation and understanding of how to link the networks. It is in a position to provide leadership and a forum for scientists, technologists, water quality managers, and policy-makers. The federal government does not have the mandate to acquire the bulk of the water quality data. Therefore, coordination with municipal, provincial, and territorial agencies is essential. The CCME is in a unique position to provide national interpretive tools, such as the Canadian Water Quality Index and the Canadian Water Quality Guidelines. Lastly the CCME could facilitate the development of national policies on water quality monitoring and the reactivation of federal-provincial agreements on water quality monitoring.

6. Please indicate briefly your expectations of this workshop:

- The primary expectation of the workshop was to meet other Canadian water quality monitoring practitioners and program managers to share knowledge, experience, and begin the process of establishing a national network. Part of this process was the development of a national (Federal-Provincial-Territorial) strategy for coordinated water quality monitoring and reporting in Canada. There was a common desire by many workshop participants to better understand the monitoring activities and programs in other jurisdictions, both within and outside Canada. Many people wanted to better understand and explore the CCME 'network of networks' proposal, how it might integrate with existing programs, and what the implications are to the individual jurisdictions.

Appendix 2 - Workshop Program

Tuesday, October 15, 2002

6:00 – 8:00 pm	Registration (Delta Vancouver Suites Hotel Lobby)
8:30 – 9:30 pm	Session Chairs Meeting (Delta Vancouver Suites Hotel - "WQM Office", Empire Suite)

DAY 1 - Wednesday, October 16, 2002

8:00 – 8:30 am	Registration
8:30 – 9:00 am	Welcome and Introduction
	Welcome from the Honourable Joyce Murray, Minister of Water, Land and Air Protection, British Columbia
	Workshop Objectives and Overview (Workshop Co-chairs: Rob Kent, Environment Canada, and Les Swain, BC Ministry of Water, Land and Air Protection)
9:00 – 9:45 am	**Setting the Stage** Session Chair: Rob Kent/Les Swain
9:00 - 9:15 am	CCME Water Action Plan (Jennifer Moore, CCME Water Coordination Committee Co-chair)
9:15 - 9:30 am	The Scope of the Challenge: Threats to Water Quality (John Lawrence, National Water Research Institute, Environment Canada)
9:30 - 9:45 am	Discussion
9:45 – 10:00 am	Health Break
10:00 – 11:45 am	**The Current State of Practice - Water Quality Monitoring in Canada** Session Chair: Dwight Williamson (Manitoba Conservation)
10:00 - 10:20 am	Overview of Current Water Quality Monitoring in Canada Based on the CCME Inventory (Brian Wilkes, Brian Wilkes & Associates Ltd.)
10:20 - 10:35 am	The Role of Monitoring & Surveillance in the 'Source to Tap' Multi-Barrier Approach – Finished Drinking Water Monitoring in Canada (Thon Phommavong, Saskatchewan Environment)

10:35 - 10:55 am	Water Quality Monitoring in Canadian Municipalities (Source to Tap) - An Example from the Greater Vancouver Regional District (Bob Jones, Greater Vancouver Regional District)
10:55 - 11:10 am	Community-based Environmental Monitoring in Canada: A Community Perspective (Jeff Borisko, Citizen's Environment Watch)
11:10 - 11:25 am	Developing Groundwater Monitoring Networks (Harvey Thorleifson, Geological Survey of Canada, Natural Resources Canada)
11:25 - 11:45 am	Panel Discussion
11:45 – 1:00 pm	Lunch
1:00 – 2:45 pm	**Designing Water Quality Monitoring Programs & Networks - Water Information Needs** Session Chair: Haseen Khan (Newfoundland and Labrador Department of Environment)
1:00 - 1:15 pm	Water Quality Monitoring in British Columbia (Les Swain, Ministry of Water, Land and Air Protection, British Columbia)
1:15 - 1:30 pm	Water Quality Monitoring Networks in Québec (Serge Hébert, Ministère de l'Environnement du Québec)
1:30 - 1:50 pm	A Framework For Collaborative Water Quality Monitoring (Charles A. Peters, United States Geological Survey)
1:50 - 2:05 pm	The Role of Research in Designing and Implementing Monitoring Programs – Experience from the Northern Rivers Basin Study and the Northern Rivers Ecosystem Initiative (Fred Wrona, National Water Research Institute, Environment Canada)
2:05 - 2:25 pm	Design of the Trend Network for Rivers and Streams in the National Water-Quality Assessment (NAWQA) Program (David K. Mueller, United States Geological Survey)
2:25 - 2:45 pm	Panel Discussion
2:45 – 3:00 pm	Health Break
3:00 – 4:30 pm	**Integrating Water Monitoring - Moving Beyond the Stovepipes** Session Chair: Pierre-Yves Caux (Environment Canada)
3:00 - 3:20 pm	Linking Health and Environment: Water Quality & Surveillance of Health Outcomes (Ray Copes, BC Ministry of Health Planning)

3:20 - 3:35 pm	Integrating Water Quality and Quantity Monitoring: Threats to Water Availability in Canada (Fred Wrona, National Water Research Institute, Environment Canada)
3:35 - 3:50 pm	Integrating Chemistry and Biology in Water Quality Monitoring in Manitoba (Dwight Williamson, Manitoba Conservation)
3:50 - 4:15 pm	Building an Aquatic Cumulative Effects Assessment (CEA) Framework From Integrated Environmental Effects Monitoring (Monique Dubé, National Water Research Institute, Environment Canada)
4:15 - 4:30 pm	Panel Discussion
4:30 – 4:45 pm	*Overview of Day 1 of Workshop & Setting the Stage for Day 2* (Rob Kent / Les Swain)

DAY 2 Thursday, October 17, 2002

8:00 – 8:30 am	Coffee, Juice and Muffins
8:30 – 8:45 am	Day 2 Introduction and Overview *(Rob Kent/Les Swain)*
8:45 – 10:45 am	**Water Quality Monitoring Technologies and Methods - Innovations and Challenges** Session Chair: Tim Fletcher (Ontario Ministry of Environment)
8:45 - 9:00 am	Laboratory Support to Environmental Water Quality Monitoring Programs in Canada (Dave Warry, National Water Research Institute, Environment Canada)
9:00 - 9:20 am	Innovations in Micro-analytical Systems for Water Quality Monitoring (Wayne Einfeld, Sandia National Laboratories, Albuquerque, NM)
9:20 - 9:45 am	European Initiative on Sensors for Monitoring Water Quality (Susan Alcock, Cranfield University, United Kingdom)
9:45 - 10:05 am	Monitoring for Waterborne Pathogens: Existing Techniques and Future Directions (Tom Edge, National Water Research Institute, Environment Canada)
10:05 - 10:20 am	Assessing Water Quality Using Remote Sensing (Robert P. Bukata, National Water Research Institute, Environment Canada)
10:20 -10:45 pm	Panel Discussion
10:45 – 11:00 am	Health Break

11:00 – 12:45 pm	**Data & Information Management - Building Water Quality Knowledge Networks** Session Chair: Darrell Taylor (Nova Scotia Department of the Environment and Labour)
11:00 - 11:15 am	Canada-Wide Water Quality Data Referencing Network (Isaac Wong, National Water Research Institute, Environment Canada)
11:15 - 11:35 pm	Red River Basin Decision Information Network (RRBDIN): A Network for Sharing Information, Data and Tools (Brian Fischer, Houston Engineering, Inc., St. Paul, Minnesota)
11:35 - 11:55 am	Watershed Assessment, Tracking & Environmental Results System (WATERS) (Thomas Dabolt, United States Environmental Protection Agency)
11:55 - 12:20 pm	The Finnish EUROWATERNET (Jorma Niemi, Finnish Environment Institute)
12:20 - 12:45 pm	Panel Discussion
12:45 – 1:45 pm	Lunch *Demonstration: Canada-Wide Water Quality Data Referencing System*
1:45 – 3:00 pm	**Interpretation and Reporting - Getting Relevant Information Out** Session Chair: Serge Hébert (Ministère de l'Environnement du Québec)
1:45 - 2:05 pm	Analysis of Trends in Water Quality: Old Challenges, New Developments (Skip Vecchia, United States Geological Survey)
2:05 - 2:25 pm	Providing Water Quality Information to Canadians (Joe Pomeroy, Environment Canada - Atlantic Region)
2:25 - 2:40 pm	The CCME Water Quality Index (Bruce Raymond, Prince Edward Island Department of Fisheries, Aquaculture and Environment, and Pierre-Yves Caux, National Guidelines and Standards Office, Environment Canada)
2:40 - 3:00 pm	Panel Discussion
3:00 – 3:15 pm	Health Break
3:15 – 4:45 pm	**Workshop Summary & Path Forward - Synthesis and Recommendations** Session Chair: Rob Kent/Les Swain

3:15 - 3:35 pm	Future Directions for Water Quality Monitoring by CCME Jurisdictions (Brian Wilkes, Brian Wilkes and Associates Ltd.)
3:35 - 4:30 pm	Interactive Discussion Observations on the Workshop, New Thoughts, and Take Home Messages Challenges, Opportunities, and Priorities Toward Better Linking Water Quality Monitoring Networks What can we do together? Next Steps and Path Forward
4:30 - 4:45 pm	Workshop Concluding Remarks (Rob Kent and Les Swain)

Appendix 3 - List of Participants

*Indicates presenter

Dave Trew
Alberta Environment

Kris Andrews
Liz Freyman
Vic Jensen
Gabi Matscha
Charles Newcombe
Narender Nagpal
Remi Odense
Robyn Roome
Les Swain*
Rodney Zimmerman
British Columbia Water, Land & Air Protection

Ray Copes*
British Columbia Health Planning

George Butcher
British Columbia Sustainable Development

Dwight Williamson*
Manitoba Conservation

Haseen Khan
Newfoundland & Labrador Environment

Don Fox
New Brunswick Environment & Local Government

Darrell Taylor
Nova Scotia Environment & Labour

Fred Fleischer
Tim Fletcher
Ontario Ministry of the Environment

Bruce Raymond*
Prince Edward Island Fisheries, Aquaculture & Environment

Serge Hébert*
Ministère de l'environnement du Québec

Murray Hilderman
Thon Phommavong*
Saskatchewan Environment & Resource Management

Nancy Gehlen
Canadian Council of Ministers of the Environment

Jennifer Moore*
CCME Water Coordination Committee
Environment Canada

Elaine McKnight
Marine Environment Branch
Environment Canada

Scott McDonald
Jean-Guy Zakrevsky
Meteorological Service of Canada
Environment Canada

Pierre-Yves Caux*
Paul Jiapizian
National Standards and Guidelines Office, Environment Canada

Don Andersen
Amanda Brady
Robert P. Bukata*
Lucretia Cullen
Simone de Rosemond
Monique Dube*
Tom Edge*
Robert Kent*
Émilie Larivière
Janine Murray
Dave Warry*
Isaac Wong*
Fred Wrona*
National Water Research Institute
Environment Canada

Pascale Groulx
National Water Issues Branch
Environment Canada

Bernard Rondeau
St. Lawrence Centre
Environment Canada

Joe Pomeroy*
Atlantic Region
Environment Canada

Scott Painter
Ontario Region
Environment Canada

Reg Dunkley
Kirk Johnstone
Beverly McNaughton
Andrea Ryan
Pacific and Yukon Region
Environment Canada

David Donald
Douglas Halliwell
Prairie and Northern
Environment Canada

Bonnie Antcliffe
Jim Gower
State of the Ocean
Fisheries and Oceans Canada

Marlow Pellatt
Parks Canada

Harvey Thorleifson*
Geological Survey of Canada

Jennifer Mercer
First Nations and Inuit Health Branch
Health Canada

Pat Brooks
Environmental Health Services
Department of Health & Social Services

Richard Carrier
Water Quality & Health Bureau

Scott Kirby
Pest Management Regulatory Agency
Health Canada

Francis Jackson
Bob Truelson
Indian and Northern Affairs

Judy Isaac-Renton
BC Centre for Disease Control

Daniel De Lisle
Canadian Space Agency

Bob Jones*
Water Quality Control Division
Greater Vancouver Regional District

Jeffrey Borisko*
Citizen's Environment Watch
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Brian Wilkes*
Brian Wilkes and Associates Ltd.

Thomas Dabolt*
US EPA Office of Water

Dave Mueller*
Charles Peters*
Skip Vecchia*
United States Geological Survey

Wayne Einfeld*
Sandia National Laboratories

Brian Fischer*
Houston Engineering, Inc.

Susan Alcock*
Cranfield Biotechnology Centre

Jorma Niemi*
Finnish Environment Institute