

## **WORKSHOP SUMMARY PAPER**

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**Cumulative Impacts in the  
Great Lakes-St. Lawrence River Ecosystem**

**September 29-30, 1999  
Windsor, Ontario**

in support of the  
International Joint Commission's Water Use Reference

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Workshop Summary Paper  
Cumulative Impacts in the Great Lake - St. Lawrence River Ecosystem

## Table of Contents

|                                              |    |
|----------------------------------------------|----|
| I. Preface .....                             | 3  |
| II. Introduction. ....                       | 3  |
| III. Summary Response to Key Questions ..... | 4  |
| IV. Expert Presentations - Key Points .....  | 13 |

### Appendices

|                                                                                                                                                        |    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| A. A Literature Review of Cumulative Impacts in the<br>Great Lakes-St. Lawrence River Ecosystem From Factors<br>Affecting Water Levels and Flows ..... | 17 |
| B. Backgrounder - IJC Cumulative Impacts Workshop .....                                                                                                | 44 |
| C. List of Workshop Participants .....                                                                                                                 | 47 |
| D. Questions Asked of Workshop Experts .....                                                                                                           | 48 |
| E. Summary Notes - Participant Presentations .....                                                                                                     | 49 |
| F. Notes from Large Group Exercise .....                                                                                                               | 54 |

## **I. Preface**

This document presents the summary proceedings of an International Joint Commission-sponsored Workshop on Cumulative Impacts in the Great Lakes - St. Lawrence River Ecosystem (September 29-30, 1999 - Windsor, Ontario.) The workshop was conducted under the auspices of the Commission's reference on water consumption, diversion and other removals.

The proceedings were prepared by Douglas Cuthbert of Environment Canada and Dr. Michael J. Donahue of the Great Lakes Commission. These individuals were also responsible for the overall design and conduct of the workshop. Their role was to facilitate workshop discussion, record the opinions/observations of the invited experts, and organize this input into responses to specific questions posed by the Commission. All workshop participants were present in their personal and professional capacities. The statements presented in the proceedings are those of the authors and contributors, and do not necessarily represent those of their agency, the Commission's International Study Team, or the Commission itself.

The main body of the proceedings consists of an introductory statement, a consolidated response to each of several specific questions posed by the Commission, and a listing of key points gleaned from the statements of the assembled experts. Of primary interest to the Commission, Study Team and other readers is the response to the specific questions, as they contain findings and recommendations that can guide the balance of the reference as well as any resultant implementation efforts.

A detailed set of appendices offer the reader further support for, and documentation of the summary responses presented in the main body of the proceedings. Appendix A includes a detailed review and analysis of the environmental impact assessment literature as it relates to the reference. Other appendices provide background on the workshop; list of participants; list of key questions; summary notes from presentations; and notes from the workshop's large group exercise.

## **II. Introduction**

In February 1999, the governments of the United States and Canada presented the International Joint Commission with a reference on the consumption, diversion and removal of Great Lakes water. Prompted largely by a proposal for the bulk export of Lake Superior water, the reference stated the governments' concern that "current management principles and conservation measures may be inadequate to ensure the future sustainable use of our shared water." Specifically, the IJC was requested to develop recommendations on existing and potential consumptive uses and diversions (including exports); the cumulative effects of existing and potential diversions; and current laws and policies that affect the sustainability of water resources.

In August 1999, the IJC released an interim report to the governments titled "Protection of the Waters of the Great Lakes." In addition to presenting a series of interim recommendations to the governments, the IJC identified five areas for "special attention" prior to submitting its final report.

One such area entails “determining cumulative impacts of changes in Great Lakes levels that could be or are occasioned by current and future removals and consumptive use.” In response to this need, the IJC called for the design and conduct of an experts workshop for fact finding and recommendatory purposes. Ten experts ( five U.S., five Canadian) drawn from a variety of disciplines were joined by IJC Commissioners, staff and selected International Study Team members, to direct their attention to the cumulative impacts of past, present and possible future diversions and consumptive uses. In organizing the workshop, it was recognized that there are inherent uncertainties and unknowns, both scientific and political, that must be acknowledged as the expert analysis proceeded. Within that context, the workshop elicited a review of the state-of-the-art of impact assessment; a descriptive listing of what can and cannot be concluded about cumulative impacts; monitoring and research needs; current and desired capabilities of impact assessment methodologies; and key recommendations for the IJC and the governments to consider. The following is a summary of related discussions.

### **III. Summary Response to Key Questions**

#### **1) Cumulative Impacts of Past and Current Diversions and Consumptive Use**

- a) What can we conclude, with reasonable certainty, about the cumulative impacts (social, cultural, economic and environmental) of past and current changes, both with respect to absolute impacts of the changes, individually and cumulatively, and with respect to their redistributive effects?**

The Great Lakes hydrologic system is dynamic and highly complex. Levels and flows within the system are constantly fluctuating as they adapt to both natural and human-induced factors. Given both the fragility and intensive use of the system, even modest fluctuations can have pronounced social, cultural, economic and environmental impacts. These impacts can be either positive or negative, depending on the nature and direction of the fluctuation, location within the system, and the affected user groups.

While natural factors (e.g., climate conditions and events) are primarily responsible for historic fluctuations in levels and flows, human inventions (e.g., withdrawals, consumptive use, dredging, shoreline alteration) also impact social, cultural, economic and environmental characteristics of the system and its associated uses and user groups. These interventions are inherently cumulative: the impact of localized, small scale activities may be difficult to quantify on an individual basis but, collectively, can significantly alter the levels and flow regime and associated ecological conditions. The cumulative nature of these impacts becomes more pronounced as one proceeds downstream through the Great Lakes-St. Lawrence system.

The cumulative impacts associated with past and current change due to human activity – primarily withdrawals, consumptive use, dredging and channel/shoreline alterations – have been documented to varying degrees of precision. Most of these studies have been IJC initiatives assessing the impact of alternative lake level regulation plans. For example:

- ▶ Hydropower - Hydropower production has generally benefitted from natural conditions and human interventions (e.g., regulation plans) that provide comparatively high levels and flows needed to maximize power production. Low level and flow regime compromises production capability, and a determination of the cost of alternate sources of power

(replacement power) offers a means to quantify the cumulative impacts of actions that reduce levels and flows.

- ▶ Shipping - Commercial navigation on the Great Lakes-St. Lawrence systems is highly sensitive to fluctuations in levels and flows. Ports, harbors and channels throughout the system are routinely dredged to accommodate deep draft vessels which require literally every inch of available draft to maximize cargo capacity. Various studies have quantified the impact of water levels reductions by determining the associated reduction in cargo capacity and, hence, the reduction in cost efficiency of the cargo movement.
- ▶ Shoreline interests - Riparian interests are directly impacted by even very modest fluctuations in levels and flows. Short-term, seasonal and long-term fluctuations influence shoreline erosion, flooding and recession rates, although the extent of this relationship varies by shore type. Extensive studies of shoreline damage under various level and flow regimes have been carried out by comparing existing conditions with various lake level regulation schemes.
- ▶ Recreational Boating - Recreational boaters are impacted by even modest fluctuations and, particularly, under low level conditions in shallow draft harbors and marinas, and in parts of the system with naturally shallow characteristics. While no system-wide analysis has been conducted to date, site-specific studies have yielded some information by assessing impacts associated with alternate lake regulation plans.
- ▶ Fisheries - Natural fluctuations in levels and flows are considered an integral component of ecosystem processes, and are important to the health and productivity of the fishery. Sustained high or low lake level and flow regimes can alter near shore habitat and impact the nature and composition of the fishery in these areas. Studies to date have been largely qualitative.
- ▶ Wetlands - Coastal wetlands throughout the system are highly influenced by even modest fluctuations in levels and flows, and are considered primary indicators of the overall health of the system's aquatic environment. Quantitative studies have shown that Great Lakes wetlands are dependent on water-level fluctuations to maintain habitat diversity. Qualitative assessments to date have also found a relationship between the degree of fluctuation and the extent of coastal wetlands. An extended (or permanent) lowering of lake levels due to cumulative impacts could significantly alter the size and characteristics of such wetlands, although the extent and implications of that alteration have not been quantified or otherwise assessed on a system-wide basis.
- ▶ Water Quality - Water quality impacts associated with a change in the level and flow regime have been the focus of limited studies directed primarily at Lake Erie, and conducted for the International Joint Commission. While these studies only examined potential impacts associated with specific lake regulation options, they noted that potential impacts under certain low level and flow conditions might be found in the areas of hypolimnion volume, oxygen concentration, general lake quality, total phosphorus budget, near shore turbidity concentrations, Cladophora production, embayment water quality, and waste dispersion capability. It is also recognized that, under a low level regime, resultant pressures for dredging will pose the potential for increased rates of resuspension of toxic contaminants that have previously been deposited in bottom sediments.

- ▶ Native Americans/First Nations - The cumulative impact of withdrawals, consumptive use, diversion and export can have pronounced effects on the Native American/First Nations community from social, cultural, economic and environmental standpoints. A workshop participant noted that our current understanding of “aboriginal realities in the Basin” is limited and needs to be enhanced as water quantity management decisions are made, and decisionmaking processes developed.
- ▶ Additional Interests - Additional interests/interest areas potentially affected by the cumulative impact of withdrawals, consumptive use, diversion and export include water based-tourism and recreation (beyond recreational boating), agriculture, institutional (e.g., impact on treaties, regulation plans, local zoning ordinances) and social (e.g., public perception and reaction). Studies/ analyses in these areas have been limited to date.

Our ability to assess the cumulative impacts affecting the level and flow regime varies considerably from one action to the next. Several conclusions, however, can be made with certainty. Environmental and economic impacts associated with any such action have both localized and system-wide implications. Redistribution of these impacts – whether positive or negative – accumulates as one proceeds downstream through the Great Lakes-St. Lawrence system.

Experts agree that jurisdictions with management responsibility in the Great Lakes-St. Lawrence system lack an adequate decision-making framework to assess water use and removal proposals and, in particular, lack an ability to address cumulative impacts. To date, impact assessments have predominantly been linear interpolations of past experience. Assessments of water removal proposals, where they occur, have been hampered by the lack of relevant data and information, and typically have not addressed cumulative impact considerations on a system-wide basis.

Water use demands and conflicts – on both an intra and inter-basin scale – are expected to increase, given social, economic and demographic trends, as well as the prospective impact of climate change and variability on available water supplies. To anticipate, prevent or otherwise resolve such demands and conflicts, the existing management framework must be greatly enhanced – or a new one established – to generate scientifically sound and legally defensible water use decisions that respect ecological, social and economic considerations. Among others, the framework should have the following characteristics:

- ▶ A balance between control and adaptation. To varying degrees, human intervention can control the level and flow regime via regulation plans, infrastructure, system modifications and water supply and demand management. However, other factors beyond human control – such as climate change, isostatic rebound and precipitation patterns – must be accommodated. Thus, a management framework must be flexible and fully acknowledge risk, uncertainty and surprises associated with the Great Lakes-St. Lawrence system.
- ▶ Methodological rigor, and supporting data and information. Informed decisions on water use and removal proposals require a rigorous methodological framework supported by adequate data and information yielding environmental, social and economic dimensions of impact assessment. This data and information must be of sufficient breadth and detail to

quantify both localized and system-wide impacts associated with a removal proposal, and must also accommodate cumulative effects.

- ▶ Multi-jurisdictional, multi-sectoral and multi-disciplinary representation. The cumulative impacts associated with water use and removal practices and proposals have both local and system-wide dimensions and associated redistributed costs and benefits across environmental, social and economic dimensions. Thus, all affected governments must have a role in the management framework, affected sectors must have access to the decisionmaking process, and all relevant dimensions (i.e., disciplines) associated with water use and removal impacts must be considered.

Although an adequate decisionmaking framework for water management is found to be lacking, assessment tools are available to help assess the cumulative impact of current and prospective diversions, consumptive uses and other water removals. Such tools depend upon collaborative model building and adequate data and information. However, there are, and will always be limits to the capability of such tools, given uncontrollable and unknown factors, and all the uncertainties, surprises and complex non-linear interrelationships that are inherent in such a vast ecosystem. A few of these limitations are discussed in more detail below.

**b) What are we unable to conclude, either because the causal factors are insufficiently well understood, or because the cause and effect relationships are not well enough defined?**

Scientists and impact assessment experts agree that increased water withdrawals and associated reductions in water supplies carry the potential for significant detrimental impact to ecosystem integrity throughout the Great Lakes-St. Lawrence Basin, with impacts compounding as one moves downstream. It is also agreed that even modest changes in water withdrawals and supplies from individual, discrete actions have incremental and cumulative impacts on a localized and system-wide basis.

There is, however, a considerable degree of uncertainty associated with the nature, extent and severity of cumulative impacts. This uncertainty is generally found in three areas:

- ▶ We are unable to quantify – with any degree of precision – the ecological and economic impacts of most water withdrawals, consumptive uses and removals. Numerous studies to date – both localized and system-wide – suggest that adverse impacts are associated with even modest reduction in levels, flows and/or fluctuation range. Most of these studies, however, have focused on the evaluation of alternative lake regulation plans, as opposed to the individual and cumulative impacts of smaller scale withdrawals, consumptive uses and other removals. Further, with certain exceptions (e.g., commercial navigation, shoreline property, hydropower), such assessments have generally lacked methodological rigor and/or system-wide applicability, and are often qualitative in nature. In particular, impact assessment data and information is lacking with respect to fisheries productivity and composition; the extent and range of coastal wetlands; near-shore water quality; habitat; and biodiversity.
- ▶ It is difficult to verify causal relationships in light of other confounding factors affecting the physical, chemical and biological characteristics of the Basin's water resources. The Great

Lakes-St. Lawrence ecosystem is a highly dynamic one, and its ecological status at any given time is shaped by a multitude of factors, only some of which relate to water withdrawals, consumptive use or other removals. Climate change, for example, has pervasive yet still poorly documented impacts on water levels, flows, temperatures, precipitation patterns and storm events. Shoreline development patterns and, more generally, land use changes, have implications including altered runoff patterns, ground and surface water recharge, nutrient contaminant loadings and coastal processes. The introduction and establishment of aquatic nuisance species has had both localized and system-wide impacts upon water clarity, aquatic vegetation, aquatic species composition and nutrient/contaminant recycling, among others.

Due to these and other confounding factors, the causal relationships between a given water withdrawal, consumptive use or removal and observed changes in ecological status or economic use of the resource can be difficult to establish with precision.

- ▶ We cannot conclude that the characteristics of future water demand and usage will follow past patterns. Social, economic and demographic characteristics of the Great Lakes-St. Lawrence Basin are as dynamic as the resource itself. The Basin is experiencing continuing economic diversification, population shifts to coastal areas, and evolving water withdrawal and consumptive use practices. Further, Basin resources and residents are increasingly affected by external conditions and developments (e.g., climate change, globalized economy, prospective demand for interbasin water transfer/export) that have largely unknown implications for water resources demand and usage.

Enhanced ability to establish and quantify cause-effect relationships associated with discrete water withdrawal, consumptive use or other removal activities is a fundamental requirement for any decision support system facilitating informed water quantity management policy.

**c) What monitoring and research priorities might be recommended to governments to improve our ability to estimate social, cultural, economic and environmental impacts, with a special emphasis on ecological aspects?**

Experts identify numerous monitoring and research priorities that, if addressed, can help address limitations on our current ability to assess cumulative impacts across multiple areas. These priorities are briefly described below, organized for ease of reference under several categories.

- 1) Baseline Monitoring and Research. Data and information on the individual and cumulative impacts of water withdrawal, consumptive use and other removals is limited, given gaps in the breadth and continuity of baseline monitoring, and the sporadic nature of relevant research. The adequacy of any decision support system is fundamentally dependent upon such baseline activity. Key priorities include:
  - ▶ Ongoing monitoring and analysis of water use data (i.e., withdrawals, diversions, consumptive use, other removals) is needed on a jurisdiction, lake basin and usage category basis. The Great Lakes Commission-managed Great Lakes Water Use Data Base Repository attempts to fill this need, although its capabilities are currently less than satisfactory. It clearly needs reliable funding and jurisdictional commitment to provide accurate data, regular reports and meaningful trend analysis. A new analytical

component is needed to facilitate assessment of the individual and cumulative ecological and economic impacts associated with various water withdrawals.

- ▶ Near shore, close interval bathymetric and topographic mapping is needed throughout the basin to assess physical and ecological impacts of changes in levels, flows and fluctuations.
- ▶ At the water policy/management level, ongoing monitoring of water withdrawal permitting activity is needed as a additional means of assessing trends and new developments.
- ▶ Additional monitoring/understanding of groundwater in the Basin is needed in terms of resource status, use, surface/water interactions, sensitivity to surface water withdrawals and other uses, and ecological implication of changes from the individual and cumulative impacts of such uses.
- ▶ Social research is also needed to assess and respond to citizen reaction to the actual/prospective lowering of water levels. This will provide guidance in public policy decisionmaking and in the development/implementation of any decisionmaking institution or framework.

- 2) Decisionmaking Framework. Science-based monitoring and research concerning cumulative impacts must be complemented by policy/management research leading to the development of an effective decisionmaking framework for water quantity management. Key priorities include:

- ▶ A decision support system providing an effective framework for formulating and implementing water quantity management policies and programs is needed. Such a system must be multi-jurisdictional; inclusive; driven by scientific data; methodologically rigorous; socially acceptable; present and future oriented; and integrative. It must be flexible enough to accommodate uncertainty, yet rigid enough to yield decisions that are both scientifically sound and legally defensible.
- ▶ Current jurisdictional capabilities (i.e., staffing, finances, priority status) for the compilation and analysis of water use data need to be assessed in light of present and anticipated needs. Any new management regime ultimately developed to exercise decisionmaking authority will undoubtedly require a more comprehensive, consistent and timely approach to data gathering and analysis within and across all Basin jurisdictions.

- 3) Causal Relationships and Interactions. The dynamic nature of the Great Lakes-St. Lawrence system, coupled with the multiplicity of physical, chemical and biological processes affecting ecosystem status, challenge our ability to establish and characterize causal relationships between a given water use, its impact on levels, flows and fluctuations, and any observed changes in the ecosystem and economic uses thereof. While these challenges can never be fully overcome, additional research is nevertheless warranted in several areas, as follows:

- ▶ The relationship of water currents and flows to overall volume must be better understood.
- ▶ A relationship has been established between lowered water levels and the resuspension and redistribution of sediment, including the re-introduction of contaminants into the water column. However, this relationship (and associated magnitude and impact) needs to be better understood and quantified, both as it relates to current/anticipated natural processes and dredging practices.
- ▶ Climate change impacts on levels, flows and fluctuations within the Basin, as well as on ecological characteristics in general, warrant additional research. Unless such impacts are understood, they may distort or otherwise confound efforts to establish causal relationships between water use practices and the hydrology and ecology of the Basin.
- ▶ Additional research associated with the introduction, spread and impact of aquatic nuisance species is warranted at two levels. First, as with climate change, the presence of aquatic nuisance species has/will have a fundamental and pervasive impact on Basin ecology and, in particular, on species biodiversity. Understanding these impacts will reduce the aforementioned likelihood of distortion/confounding factors when causal relationships between water use practices and ecological and economic impacts are assessed.
- ▶ A better understanding of isostatic rebound and its current/prospective impacts on levels, flows and fluctuations is also needed for the reasons identified in the two preceding points.
- ▶ Generally speaking, monitoring and research efforts need to identify and respond to the synergistic affects of multiple water uses on levels, flows, fluctuations and associated ecological and economic impacts.
- ▶ Some experts noted that, although a framework driven by sound science is desirable, it will always have scientific limitations and, even if it were technically perfect, it could go only part way toward building the necessary consensus among all interests in the binational region. Water is, and always will be an issue involving differing cultural and heritage values, and will stir strong emotions among different groupings of people.

## 2) Cumulative Impact of Possible Future Changes

- a) **What can we conclude, with reasonable certainty, about the cumulative impacts (social, cultural, economic and environmental) of probable future changes, both with respect to absolute impacts of the changes, individually (i.e., removals, consumptive use changes and climate change) and cumulatively, and with respect to their redistributive effects?**

Conclusions drawn earlier relative to the cumulative impacts of past and current changes are also highly relevant as we assess the impacts of probable future changes. Experts agree, however, that efforts to characterize the future are rife with uncertainty – even over the short term – given

the nature and extent of emerging issues. Several developments are certain, even though our understanding of associated impacts is far from certain. For example,

- ▶ Climate change is a reality in the Great Lakes-St. Lawrence Basin. Even the more conservative general circulation models suggest a significant change in precipitation patterns, evapotranspiration and average temperature, all leading to gradual yet profound ecosystem impacts. Among others, likely outcomes include a pronounced reduction in levels and flows, changes in fluctuation patterns, increases in average lake temperatures, and changes in aquatic animal and plant species composition and location. These changes will be pervasive within and beyond the Great Lakes-St. Lawrence Basin.
- ▶ We know, with certainty, that the demand for Great Lakes-St. Lawrence water will increase over time, both within and beyond the Basin. This infers increasing water withdrawals and associated consumptive uses, and added pressure for both inter-basin diversions and other removals, including bulk export. While no such proposals on a large scale appear to be imminent at this time, some experts view this as inevitable. Paramount among these threats are prospective diversions to the southwest United States, where rapidly growing populations and economies in these generally water poor areas have also seen growing political power and influence, and in the midwest, given prospective agricultural irrigation demands. Also of concern are areas just outside the perimeter of the drainage basin where fast-growing communities are increasingly looking to the Great Lakes for municipal water supply. Finally, experts note that the bulk export of freshwater is a growing trend globally and, at this time, the Great Lakes-St. Lawrence Basin appears to be vulnerable to such activity.
- ▶ As with past and current changes in water use and consumption, probable future changes may have both localized and Basinwide impacts, and redistributive effects. As is now the case, the St. Lawrence River will integrate upstream impacts and, hence, bear the most pronounced ecological and economic consequences.
- ▶ We can also conclude, with certainty, that the future will bring ecosystem “surprises” that cannot presently be anticipated. Water use and demand characteristics are as dynamic as the natural system, and past patterns and practices are not necessarily a meaningful indication of probable futures. In sum, experts agree that we must “expect the unexpected.”

In discussions associated with possible future changes, experts reiterated the need for a flexible and adaptable decisionmaking framework for water quantity management. This mechanism needs to be guided by a vision shared by all Basin jurisdictions. It must be anticipatory and be able to adapt to surprises. Also, it must be able to nurture consensus among all parties, given social, cultural and value differences among jurisdictions (principally the United States and Canada.) It is important to note that the apparent absence of an imminent threat of a large scale diversion or bulk export proposal suggests that there is time to develop and implement such a mechanism in a rational and studied manner. However, the existence of many smaller scale withdrawals, consumptive uses and associated cumulative impacts offers a compelling argument for pursuing such a mechanism promptly and aggressively.

- b) Are there monitoring or research priorities that might be suggested which would reduce the degree of uncertainty in future projections and their estimated impacts?**

Experts agree that some level of uncertainty is inherent in any effort to develop projections of water use and associated impacts. Such uncertainty, however, can be minimized if adequate attention is given to the needs identified in the response to question 1c: baseline monitoring and research; research into the characteristics of an effective water use decision making framework; and enhanced understanding of causal relationships and impacts. In other words, monitoring and research priorities designed to enhance our capability to analyze the impacts of past and current diversions and consumptive uses will also enhance our capability to reduce uncertainties associated with the impacts of future projections.

Three areas are in need of special emphasis, however, if uncertainty is to be reduced. The first of these is improved understanding of causal relationships and/or interactions between the levels and flow regime and various physical, and biological processes or stressors with current or potentially pervasive impacts (e.g., isostatic rebound, climate change, aquatic nuisance species.) The second is an improved understanding of prospective water use demands and associated withdrawals and consumptive uses. Such understanding can be enhanced through monitoring of water withdrawals and usage; permit and reporting programs can be useful in accessing data and identifying trends. Finally, while technical uncertainties will always remain, experts agree that it would be helpful to establish a decision-making framework sensitive to differing social, economic and cultural characteristics and perspectives among all sectors of society affected by Basin water resources.

**c) In dealing with a future that may be very different from the past (e.g., warmer water may very fundamentally change things like Lake Erie overturning, and the progression of invasive species), how relevant are existing impact assessment methodologies?**

Impact assessment methodologies presently employed in the United States and Canada (and internationally) provide tools with which the cumulative environmental and economic impacts of water withdrawal and usage can be assessed, to some degree, both qualitatively and quantitatively. Impact analyses have been applied successfully in a variety of settings in the U.S. and, in Canada, the Canadian Environmental Assessment Act of 1995 has yielded both an operational policy statement and practitioner guide to facilitate broad and consistent application.

To maximize relevance to cumulative impact assessment needs in the Great Lakes-St. Lawrence Basin, experts agree that such methodologies must have a number of key characteristics. They must:

- ▶ provide a framework for multi-objective analysis;
- ▶ have objectives that are measurable;
- ▶ recognize that impacts have a synergistic effect;
- ▶ assess redistributed social and economic costs and benefits;
- ▶ recognize differing social, economic and cultural values and perspectives of affected parties;
- ▶ have a Basinwide scope and embrace an ecosystem approach to analysis;
- ▶ accommodate, rather than try to control or eliminate unpredictability;
- ▶ have a predictive capability, and a sensitivity to future outcomes when decisions are made;

- ▶ link physical, biological, social and economic dimensions of issues;
- ▶ recognize the interactions of distinct decisions, and how one may influence all others;
- ▶ provide for team-building, public consultations, and mechanisms for information exchange/ consensus building among sectors with differing view; and
- ▶ be broadly supported by the community(ies) in which they are to be applied.

Workshop participants recognized that, while existing methodologies have some relevance to impact assessment needs in the Great Lakes-St. Lawrence Basin, the above elements should be incorporated fully. The linearity that typifies most impact assessment methodologies to date was identified as a concern; an ecosystem approach recognizing uncertainty, unpredictability and impacts across all relevant disciplines/sectors is preferred. Also of concern is the unavailability of the data and information needed to realize the full potential of any methodology applied to the Great Lakes-St. Lawrence Basin.

**d) Should impact assessment methodologies take into account only individual proposals for removals or should they be based on a “global” approach that also takes into account the effects of an accumulation of such proposals?**

Impact assessment methodologies can, and must be applied on two levels. First, they should be capable of assessing - to the extent that available data and information will allow - the prospective impacts associated with a discrete proposal. Second, such methodologies must be able to assess the collective impact of multiple proposals. From a management/decision-making standpoint, this dual capability ensures that the impacts of small scale proposals – individually and collectively – are afforded a level of analysis and public policy evaluation that might otherwise only be directed at large scale proposals.

**3) What do governments need to know to understand and evaluate the impacts of a diversion or consumptive use proposal in light of cumulative impacts?**

(Organizer’s note: Workshop participants were presented with this third and final question as a means to capture any practical and pragmatic advice that would not otherwise have been generated by the pre-assigned questions.)

In formulating a strategy to address water withdrawal proposals and their prospective individual and cumulative impacts, governments are well advised to take several actions.

- ▶ As a matter of policy, governments are advised to acknowledge that even modest changes in levels, flows and fluctuations can have potentially significant adverse ecological and economic impacts.
- ▶ A comprehensive and multi-faceted decision-making process is warranted at the Basinwide, binational level to ensure that scientifically sound, socially responsible, economically justifiable, and legally defensible water use and management decisions can be made.
- ▶ Governments at all levels are advised to commit themselves to significantly enhanced support for the research, monitoring, data gathering, and analysis efforts that are fundamentally important components of a decision support system.

- ▶ Given uncertainties associated with future climate change, consumptive use, and possible pressures for removals, the precautionary approach recommended in the Commission's Interim Report was broadly supported. Toward this end, a "no regrets" approach might be adopted; a set of policies and programs that are well advised from ecological and economic standpoints irrespective of whether or not adverse impacts of climate change and water use demands -- both anticipated and unforeseen -- arise. Among others, this approach might feature enhanced data gathering and analysis, enhanced monitoring and research efforts, a formal decision-making framework, Basinwide water conservation programs, and a tracking/permitting program for water withdrawals applied uniformly throughout the Basin. Additionally, some participants suggested that such an approach might feature a bias toward keeping water in the basin and using it as efficiently as possible.

#### **IV. Expert Presentations - Key Points**

##### **A. Introductory Remarks**

Following introductory remarks by the workshop co-chairs and the lead IJC Commissioners, the workshop's Canadian co-chair, Mr. Cuthbert, summarized cumulative impacts work undertaken to date relating to the fluctuating Great Lakes water levels issue. He noted that considerable progress has been made over the years toward a systemic view of impacts. More recently, IJC boards have found it unwise and inconsistent to attempt to put dollar value assessments on beneficial and detrimental effects of changing water levels in the Great Lakes-St. Lawrence system. Mr. Cuthbert referred to the working paper on cumulative impacts/risk assessment which he had co-authored with Mr. Moulton for this IJC Reference study. He concluded that it seems quite certain that demands for the use of Great Lakes water will increase in the future, that climate will change, and that climate variability will continue to cause fluctuations in water levels and flows. However, it is not known with any certainty when or by how much water levels will change, the extent of some of the resulting impacts, or what resulting adaptations will occur in the natural and built environment. It is, however, virtually certain that lower water levels than those experienced over the past 30 years will occur. He noted that the impacts of declining levels would be, at least qualitatively, similar to those defined in the Task #5 Cumulative Impacts Working Paper associated with the reference.

##### **B. Expert Presentations on Impact Assessments Methodologies**

Messrs. Werick and Boulden led with presentations on the state and process of cumulative impact assessments in the United States and Canada.

Mr. Werick spoke on "shared vision planning" which he described as a management tool that deals with the imperfection in data and models by employing collaborative model building to achieve a balance between environmental quality, equity, economic prosperity and social well-being. Good water management should be based on drainage basins and should integrate ground and surface water, and water quality and quantity. It should also involve stakeholders and be multi-objective, multi-disciplinary and adaptive.

Speaking on the Canadian environmental assessment regime, Mr. Boulden (Environmental Assessment Board, Environment Canada) said that cumulative impacts can be assessed if the

assessments are kept simple by staying within monitoring systems, if additive effects are examined, and if assessments are undertaken in combination with other relevant projects or activities. This is being done in Canada under the Canadian Environmental Assessment Act of 1995 which provides for consideration of changes to social and economic conditions and cultural heritage.

### **C. Expert Presentations and Views on Cumulative Impacts**

Summary notes on these presentations are included in Annex E. Key points made by participants are as follows:

#### **Doug Wilcox, Great Lakes Science Center, U.S. Geological Survey.**

- ▶ Periodic water level variations are beneficial for wetlands and habitat in that they promote higher levels of biodiversity.
- ▶ Plant types sort themselves by water level sensitivities.
- ▶ No one has looked at the effects of very small lake level changes, although small water level regime reductions can potentially affect shallow wetland areas and impact on habitat, fisheries and wildlife.

#### **Jim Bruce, Global Change Strategies International, Inc.**

- ▶ If every country lives up to Kyoto obligations, double CO<sub>2</sub> conditions would be delayed a decade or two, but still occur in the latter half of the 21<sup>st</sup> century.
- ▶ All major climate change models indicate stronger and more prolonged El Nino events interspersed with fewer but strong La Ninas in a warming world.
- ▶ The climate may not change gradually or linearly.
- ▶ Under climate change conditions, lower Great Lakes water levels would result, exacerbated by greater consumptive use of water for irrigation, cooling and other purposes.
- ▶ Water quality conditions and ecosystem integrity are likely to suffer in a warming climate.
- ▶ More recent climate modeling work suggests that drier conditions, brought about by more frequent and severe El Nino events, are likely to migrate eastward to the upper Great Lakes resulting in decreased supplies regardless of the more general climate effects.

#### **Tom Coon, Department of Fisheries and Wildlife, Michigan State University**

- ▶ Fish species assemblages in the Great Lakes are likely to change in response to habitat changes associated with lake level regime changes.
- ▶ Efforts to eliminate or minimize lake level fluctuations are likely to have detrimental impacts on the entire fish assemblage of the Great Lakes and may result in declines of favored species.
- ▶ A long term drop in water level will not necessarily change the areal extent of wetlands - this depends on bathymetry as, over time, plants will respond by colonizing lake bottom that becomes closer to the lake surface.
- ▶ Impacts of diversions and consumptive uses are cumulative with impacts of land use decisions; many valuable habitats have been lost or modified as a result of dredging or filling in addition to water level changes.

#### **John Hall, Canadian Department of Fisheries and Oceans**

- ▶ Historical land use practices have reduced wetland areas by filling shallow coastal reaches, marshes and river mouths and restricting upland limits of wetlands.
- ▶ Once filled you can't get shallow water zones back.

- ▶ Will the response to lower lake levels be dredging and increased land available for development, or shoreline policy allowing newly exposed lake bottom to continue as part of the lake environment?
- ▶ Remaining Great Lakes wetlands are subject to a variety of stresses, one of which is water levels. "Stable" water levels and more regulation to limit highs and lows pushes wetlands toward monocultures.

#### **Norm Grannemann, U.S. Geological Survey**

- ▶ The Great Lakes region is characterized by strong groundwater/surface water interconnections with small direct groundwater discharges into the lakes and large indirect discharges supporting baseflow conditions in tributaries.
- ▶ Surface water and shallow groundwater divides are normally assumed to be coincident. This cannot be assumed to be the case for deep regional aquifers.
- ▶ Groundwater flow to streams and wetlands is critical for aquatic ecosystems.
- ▶ The many human activities that degrade or modify groundwater/surface water interconnections pose hazards to the Great Lakes ecosystem.

#### **Andrew Hamilton, Commission for Environmental Cooperation**

- ▶ Bulk removal of water by tanker would considerably increase Seaway traffic and operations, and further increase the potential for importation of exotic species.
- ▶ Address interactions in the system rather than impacts; maybe all we can do is manage our interactions with water and adapt our behaviour.
- ▶ Climate change will present a lot of surprises; prepare for them.

#### **Ronald Rossmann, Grosse Ile Research Station, U.S. Environmental Protection Agency**

- ▶ Great Lakes sediments contain contaminants derived from past activities that seriously degrade the environment.
- ▶ Decreasing water depths (no matter how small) will lead to increased erosion and resuspension of contaminated sediments in the nearshore zone.
- ▶ Dredging activities will increase with lower water levels, causing further potential for releases of contaminated sediments in the water and at disposal sites.

#### **Henry Regier, University of Toronto (retired)**

- ▶ Simulation models often exclude or "footnote" ecosystem complexities.
- ▶ Ecosystem linkages need to be defined to predict how systems respond, but responses are not always linear extrapolations of historical experiences. Ecosystem integrity depends on numerous non-linear processes.
- ▶ The August 10, Task 5 report places a strong, but not exclusive reliance on linear causality and simple aggregations of effects of stress.
- ▶ The connectedness within the Basin acts more strongly in a downstream than in an upstream direction.
- ▶ Uncertainty and unpredictability are conditions of life introducing complexities and non-linearities that will cause surprises.
- ▶ Past changes in the Great Lakes ecosystems are not reversible, ever! The goal might be to achieve a state of preferred ecosystem integrity that, if wisely selected, may be taken to possess ecosystem health and/or integrity.



## **APPENDIX A**

### **IJC Reference on Consumption, Diversions and Removals of Great Lakes Water**

#### **A Literature Review on Cumulative Impacts in the Great Lakes-St. Lawrence River Ecosystem From Factors affecting Water Levels and Flows**

October 15, 1999

Prepared by Michel Slivitzky  
in co-operation with The Great Lakes Commission

## 1. Introduction

This report responds to the mandate given, by the Canadian Section of the International Joint Commission, to the author working jointly with the Great Lakes Commission on a literature review resulting in the following products:

*A brief summary of key findings from the literature of the individual and cumulative impacts on the Great Lakes - St. Lawrence River ecosystem of any factors that may have affected Great Lakes- St. Lawrence River water levels and outflows to date, with expert opinion as to the quality of the technical assessments surveyed; and*

*A listing of methodologies or approaches that may be useful in assessing the individual and cumulative impacts on the Great Lakes - St. Lawrence River ecosystem of any future factors that may affect Great Lakes - St. Lawrence River water levels and outflows, with expert opinion on the validity of such methodologies surveyed.*

The following Section 2 will present the brief summary of findings, section 3 will examine methodologies that may be useful, section 4 will present some final remarks and section 5 (References), the complete list of all publications, brought to this author's attention. As it was impossible to review all of them in the available time frame, a preliminary scan, based on probable relevance to the current study and the mandate, determined an order of priorities for detailed review.

The exact terms of the mandate appear in Annex 1 at the end of this report. Annex 2 lists the Cumulative Impacts Matrix used in the current study and Annex 3 summarizes the author's notes on the documents reviewed in detail.

The Great Lakes Commission did a short search in four databases (Water Resources Abstract, Aquatic Sciences and Fisheries Abstracts, BIOSIS and NTIS) looking for papers on water diversions and Great Lakes. The abstracts from the resulting eleven citations are presented in Annex 4. From the examination of the abstracts of two reports (Loucks *et al.*, 1988 and David *et al.*, 1988) it is possible that some additional and pertinent information concerning impacts evaluations may be obtained.

Without going into a detailed analysis of the definition of cumulative impacts (some of the references in section 5 might bring further information on this subject), it might be useful to recall the ones presently used in the U.S. and Canada. The U.S. Council on Environmental Quality (1997) defines cumulative effects as :

*the impact of the environment which results from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions regardless of what agency or person undertakes such other action.*

and for Canada (Axys 1997, p.10):

*cumulative effect as: effects caused by a project under review in combination with other past, present and future human activities and cumulative effect assessment as: an estimate of the incremental impact of a proposed project and of the total impact after addition of the increment.*

Moreover, *A Synoptic Approach to Cumulative Impact Assessment: A Proposed Methodology*, (United States Environmental Protection Agency, 1992; also Annex 3) offers interesting information concerning ecological response to stress, ecosystem stability, a review of wetland functions, and the effect of wetland impacts. This report, however, primarily addresses inland wetlands.

## **2. A brief summary of key findings**

### **General remarks**

IJC study board reports have typically approached cumulative impact assessment from a relatively narrow point of view. The scope of previous impact assessments was limited to "regulation-type" scenarios of reducing water levels ranges and extreme levels. This "impacts" information base does not lend itself all that well to the current question of potential reduced levels regimes. All the references to the IJC and the IJC directives to the Study Board asked them to look at measures that could be taken to regulate the waters of the Great Lakes to reduce the extreme of stages that have been experienced in order to alleviate damages. Furthermore, a number of criteria are imposed on the possible regulation plans in terms of maximum/minimum levels and flows that would have to be preserved.

The possible impacted sectors of activities that should be looked at by the plans are also specified; these stayed more/less the same for most Study Boards from the late sixties to the early nineties. The impacts of various alternatives were derived by comparing a particular plan with a Basis of Comparison (BOC); one should not forget, however, that the BOC has already integrated the historical changes in the baseline (e.g., diversions, consumptive use, channel modifications) and that the measured/evaluated impacts are therefore incremental rather than cumulative.

Regulation was a necessary prerequisite, the extreme levels were the culprits, and the regulation scenarios adjusted the frequency and amplitudes of high and low waters to meet IJC criteria over long reference periods (70-100 years). This, in turn, increased the ranges of outflows, which increased the ranges of downstream levels. While for economic considerations (power, navigation, flooding) average annual values of loss/benefits may have a real life significance, for environmental impacts average values have no practical meaning because the impacts are most often felt in the extreme ranges. For instance, an increase/decrease in extremely high levels may affect fisheries recruitment and habitat depending on amplitude and season; a similar analysis can be made for extremely low waters. Furthermore, impacts are often very localized in space and it is difficult to draw attention to areas of maximum impact that have different significance in the different seasons.

When looking at the entire Great Lakes St.-Lawrence River System, the impacts are also different if we look at regulated lakes (Superior and Ontario) as opposed to unregulated lakes. On regulated lakes it is always possible to maintain the range of levels under existing (or modified) regulation plans with diminished water supplies; the effects on levels and flows, however, will be exacerbated in the downstream channels or unregulated lakes. Aggregation of impacts over space and time brings a fundamental danger; there are inherently winners and losers and cumulative impacts on some important parts of the ecosystem or the system biota may be underestimated. The relative importance of impacts at the basin scale and the specific and local issues implies a value judgement that will not show up in any aggregate compilation. Distribution of impacts is often more important than aggregation, and equity issues of who wins or who loses should be addressed. In that respect,

only the Levels Reference Study Board (1993) tried to address this issue and recognized the fallacies of trying to equate all impacts in economic terms, which is still somewhat prevalent.

In that context, the individual and cumulative impacts of any factors that may have affected Great Lakes-St. Lawrence River water levels and outflows to date are greatly dependent on the methodologies that were employed. Previous assessments were linear, with little if any identification of threshold sensitivities. While for some impacts the studies were able to derive quantitative losses and benefits, for others the reports were only able to provide qualitative assessments. An underlying assumption in some previous work is that, if we could not assess the impacts for whatever reason (lack of data, science, etc.), the impacts were viewed as insignificant. Such an assumption has little substantiation and should be challenged.

In the following paragraphs we summarize the methodologies as well as the type of impacts on the various interests. In so doing, we used the matrix proposed in the Task 5 Working Paper (Cuthbert and Moulton, 1999) and which is reproduced in Annex 2.

### **Hydropower**

The impacts are determined by comparing the magnitude and timing of the energy and power losses or gains to the power that would be generated under some BOC (Basis Of Comparison) with the power that could be generated under the various regulation plans, and evaluating the differences in term of cost of replacement power.

This is a classical approach used in all studies and the only items that varied are the inclusion/exclusion of energy and power, and the debatable definitions of the cost of replacement power which varies not only seasonally but from utility to utility. In that respect, the Levels Reference Study Board (1993) identified possible alternatives to replace energy and power losses, determined replacement cost for these alternatives, and identified the most likely replacement alternatives as a basis for determining the impacts of the plans.

### **Shipping**

The impact on commercial navigation was examined in all studies by applying a given pattern of shipments in the Great Lakes St.-Lawrence River System to the water levels under a BOC as compared to those which occurred under a regulation plan. In general, levels below the BOC reduce the water column available to a carrier on a given origin/destination route, while a higher water level may allow the vessel to load more tons per trip. The method employed aggregates the benefit/loss for commercial navigation for the system as a whole under each measure. The studies varied as to the pattern of shipment that was used and the reference periods.

It should be mentioned also that navigation losses could be eliminated by dredging deeper (where feasible) in harbours and connecting channels to offset the decrease in lake level. Some studies tried to calculate the costs of such dredging; however the environmental impacts of such activities specially when dealing with contaminated sediments received only cursory attention.

An area which received specific local attention is the evaluation of impacts of low waters on shipping in the Port of Montreal. Bergeron (1995), citing references from the industry (Canada Maritime, 1990), shows that a decrease of 30cm in level at Montreal brings a decrease of 2000 tons

in average loading per ship. In March 1989, daily variations in the levels at Montreal lead to a total decrease in loading of 1800 TEU and a loss of 3,6 M\$ for five container ships (Canada Maritime 1990). Detailed analysis of the methodology (*not available*) would have to be done to validate these findings and its applicability to the current study.

### **Shoreline interests**

The potential impacts, in dollar values, to shoreline property and agricultural lands due to reduction in the amount of beach erosion and flooding damages was estimated in all studies by comparing the estimated damages under existing conditions (BOC) and under a water level regulation scheme.

During the Levels Reference Study Board (1993) investigation, extensive studies of beach erosion processes were carried out to try to resolve the controversy focussed around the difference between long-term and short-term erosion. Overall, it was found that, for some shore types, recession rates are completely independent of lake levels and, for others, there is a direct although small, relationship between changes in lake level ranges and recession rate.

### **Recreational Boating**

Some studies (Levels Reference Study Board, 1993 and International Great Lakes Levels Board, 1973) looked at the impact of possible regulation scenarios on recreational boating and beaches. The 1973 study used a complex beach utility index for recreational beaches (based on beach carrying capacity and potential seasonal attendance for some 636 beaches in Canada and the United States) to compare BOC with different regulation scenarios (International Great Lakes Levels Board, 1973, Annex D, pages D-118/D-157) and evaluate the changes in terms of monetary gains due to the various regulation scenarios. For recreational boating, based on average changes in the mean lakes levels, the impacts were found to be negligible for the new regulation plans.

In the Levels Reference Study Board investigation, (1993), the study was confined to conducting site-specific investigations where detailed impacts information was gathered. The evaluation of impacts of fluctuating water levels on all recreational boaters who rent slips at publicly accessible marinas on the Great Lakes, the connecting channels and the St. Lawrence River was beyond the scope of the study (due to monetary and time constraints).

### **Fisheries**

The impact of various regulation plans on commercial fisheries was attempted in many studies. The International Great Lakes Levels Board (1973) study dealt mostly with the effects of lake levels regulation on fish stocks by looking at relationships between water levels and commercial catch in pounds. This approach was recognized as inadequate, and the study reverted to a qualitative assessment by polling the expertise of fishery biologists and administrators using a letter of inquiry.

Manny (1984; also Annex 3) looked at potential impacts of water diversions on fishery resources in the Great Lakes. Using the reports of the International Great Lakes Diversions and Consumptive Uses Study Board (1981), and the International Lake Erie Regulation Study Board (1981), this article examines the impacts of water withdrawals on fish from both an ecological and economic

perspective. Citing various references, he notes that, for example, in 1979 an estimated 1.2 billion fish larvae and 98 million juvenile and adult fish were drawn into the water intakes at the 90 power plants on the shore of the Great Lakes. Meador (1966; also Annex 3), after examining the results from five case studies presented in a 1995 symposium, concludes that these studies revealed important clues about the status of knowledge and the need for information related to ecological consequences of water transfer. Understanding fundamental ecological processes of managed fish species is crucial to future water transfer studies.

These two articles, which contain extensive bibliographies, may form a basis for an extensive review of the state of the art of impact assessment on fishery resources.

### **Wetlands**

Wetlands were used as the primary indicators of the overall health of the system's aquatic environment (Levels Reference Study Board, 1993, Annex 2, 238-264). The impacts upon wetlands of lake level regulation plans were assessed and research was oriented toward two goals: i) to better understand the response of wetland communities to fluctuations in water levels and ii) to apply this knowledge generally and speculate on the response of wetland plant communities to proposed water level regulation schemes. The environmental effects were evaluated based on quantitative and qualitative assessments; descriptive rather than numerical data were used to rate impacts as either positive, neutral or negative. It was found that fluctuations in water levels are important to maintain the extent of coastal marshes. The smaller the fluctuation in water levels, the smallest the extent of wetlands and the lower the habitat diversity (Wilcox *et al.*, 1992, Wilcox, 1995, Wilcox and Meeker, 1992). The environmental evaluation of all regulation plans found that environmental impacts of reduced fluctuations were negative on all lakes and connecting channels.

Fish association and wetlands subsystems were perceived by this study to be "integrative indicators" of the aquatic consequences of human activities in a river basin, including regulation. Such an approach treats the integrative indicator as a surrogate of the whole ecosystem and, if the surrogate manages to sustain its integrity under external stress, then the whole ecosystem is expected to do so. Such a working assumption should, however, be tested more than has been the case (Regier, 1999).

One should not forget also that changing water levels are just one stressor on wetland communities. Degradation comes in many forms and degrees of severity, and is far more difficult to quantify than loss of area. Documented examples of typical forms of degradation include: i) fragmentation, partial, filling and diking; ii) toxic substances in sediments of wetlands; iii) invasion by exotic species; iv) nutrient enrichment; and v) decrease in average area (Bedford, 1999). In that context, it becomes very difficult to make a realistic cumulative effect assessment.

### **Water Quality**

Water quality characteristics were examined in detail in only two studies (International Lake Erie Regulation Study Board, 1981 and International Great Lakes Diversions and Consumptive Uses Study Board, 1981); they included hypolimnion volume and oxygen resources, general lake water quality, total phosphorus budget and near-shore turbidity concentrations, *Cladophora* production, embayment water quality and waste dispersion capability.

Water quality evaluations were based on the water quality studies of the International Lake Erie Study Board and deal mostly therefore with Lake Erie, based on a one foot lowering of this lake. Very little pertinent information is therefore available for the other lakes. However, their conclusion is that "implementation of the 'maximum-effect' (Long Lake /Ogoki: 0 cms, Chicago: 246 cms, Welland 255 cms) diversion scenario would not significantly affect the lower lakes water quality". A summary of the impacts appear in Table 61 (International Lake Erie Regulation Study Board, 1981, p.147). Except for a reduction of turbidity (2% to 11%) and increase in Cladophora production (0.5% to 2.7%), all other impacts are negligible for the ranges of level variations resulting from implementation of the three regulation plans. The extent to which a similar approach might produce significant results for the range of variations that might be envisaged in the current Reference will have to be investigated in more detail.

#### **Other Interests**

The other interests, listed in Annex 2, such as Agriculture, Infrastructure, Native Americans/First Nations, Other Environment, Other Recreation, and Institutional and Social, were either combined in a qualitative way with other interests or received only passing attention in most of the studies.

### **3. Useful methodologies or approaches**

In this section, we first examine the various methodologies that can be implemented for assessing individual and cumulative impacts. We will then briefly examine the necessary conditions for implementing these methodologies. Finally, we look at how we should interpret these individual impacts and try to integrate the results.

The recent *Plan of Study for Criteria Review* (International St. Lawrence River Board of Control Study Team, 1999) examined the study scopes, data collection needs and evaluation for the Lake Ontario and St. Lawrence River and six areas of interest: i) Wetland/Environmental Interests; ii) Recreational Boating interests; iii) Coastal Zone Interests – Riparian Shore Property; iv) Commercial Navigation; v) Hydroelectric Power; and vi) Domestic, Industrial and Municipal Water Use. In that respect, it goes beyond the level of impacts assessment that appears in the Task 5 report (Cuthbert and Moulton, 1999); it outlines current state of art methodologies which would require implementation to make definitive progress in this area.

For economic interests (e.g., recreational boating; coastal zone interests and riparian shore property; commercial navigation; hydroelectric power; domestic, industrial and municipal water uses) they build and improve upon previous studies and, in particular, the Levels Reference Study (Levels Reference Study Board, 1993). They could be extended to the whole Great Lakes St.-Lawrence River Ecosystem and applied to systems which are not regulated. One aspect of domestic, industrial and municipal water uses that has not received sufficient attention, however, is the degradation of water quality in shallow areas under low water conditions and correspondingly increased water temperatures. Such impacts may be increased under reduced water supplies and should be addressed in future studies.

Concerning environmental impacts, the *Plan of Study* focuses on wetlands as an indicator of ecosystem integrity (International St. Lawrence River Board of Control Study Team, 1999, p.16):

*The biological effects of water level fluctuations in both lake and river are greatest in shallow water where even small changes in water level can result in conversion of a standing water environment to an environment in which sediments are exposed to the air; or vice versa. The localised effects of this change in the environment are most evident in the relatively immobile plant communities that occur in wetlands. In fact, the patterns of water level change are the driving force that determines the overall diversity and condition of wetland plant communities and the habitats they provide for a multitude of invertebrates, amphibians, reptiles, fish, birds, and mammals.*

While applied in the Study Plan to possible regulation scenarios, this approach can also be extended to other parts of the Great Lakes St.-Lawrence ecosystem. Special attention should be paid to cases when the lower levels are decreased, as may happen in unregulated lakes under decreased water supplies. Also, as mentioned previously, plants communities may be not the only indicators and fluctuating water levels are not the only stressors that affect wetland communities; water quality in shallow areas also plays an important part and care should be taken to ensure that associations of the state of wetland health reflect those possible associations. Fish stocks and the health of commercial fisheries have been associated in some studies with the quality of the wetlands. Unfortunately, most results have been of a very general qualitative type, and should be explored in more detail in the future.

The impacts of fluctuating water levels on the water quality of near-shore, shallow water areas has been investigated in some studies but neglected in the *Plan of Study*. Such impacts are important in areas of stagnant waters or areas where local water circulation is minimal. They may be particularly crucial in areas where contaminated sediments may be exposed to wave action during extreme low water level conditions. Some criteria have been proposed in the past and they should be looked at again; those criteria that reflect most the impacts on human uses of the resource and aquatic living resources should be retained for future studies.

All the methodologies we have just listed will need access to extensive information which, in most area of interest, are either completely missing or not up to date. Necessary efforts should be made, as mentioned in the *Plan of Study*, to acquire them so that the impact studies bring significant results. In particular, high resolution topographic and bathymetric data are a necessary prerequisite for evaluating the impacts of small changes in water levels.

Since human induced water withdrawals and diversions will have a maximum impact during periods of extreme low water, great care should be taken in defining appropriate Basis of Comparison (BOC) scenarios. As already mentioned, averages over a long reference period may have significance when looking at economic impacts. For environmental impacts, however, averages have no significance; amplitude and frequencies of extremes will affect how the system may or may not adapt. For some interests, the impacts are not linearly related to water levels. For instance, if the maximum level during the fish spawning season does not reach a critical level, fish will not be able to access this particular area and spawning will not occur.

The Great Lakes St.-Lawrence River basin has experienced two extensive periods (1932-1937 and 1962-1967) of very low water supplies. While reducing the effects of damages during periods of high levels, the impacts of withdrawals may be much more critical during such extended periods of natural low water supplies. The BOC therefore should be chosen accordingly so the various evaluations may point to the critical effects and areas. Furthermore, for a true cumulative impacts evaluation, the BOC should revert to pre-project conditions.

Notwithstanding the quality of the evaluations of all the individual impacts, there will inherently be losers and winners amongst the various interests, for the same interest and in the same region, and between regions, upstream and downstream. The evaluation framework should therefore be capable of handling such situations; trying to express everything in terms on monetary values will never satisfy all economic, environmental, and social interests and the question of equity will be of prime importance. The Levels Reference Study (Levels Reference Study Board, 1993, Annex 4) examined the various approaches and tried some criteria for measures evaluation; this is a subject that should receive more attention. For the final results to be socially acceptable to all stakeholders, the stakeholders should not only be involved in the final evaluation process but also be involved from the beginning in the choice of the various criteria and well as the evaluation instruments.

#### 4. Some final remarks

This review was limited to the impacts of changes in levels and flows. Future climate change, besides having a direct impact on flows and levels in this huge system, will also affect the temperatures of the waters in the system. Such changes in temperatures will necessarily impact all living resources (Regier *et al.*, 1990; and Annex 3) and should not be neglected in future impact assessments.

The St. Lawrence River downstream from Lake Ontario may be perceived as a "natural integrator" of cumulative impacts of all human activities in the some 800,000 square kilometres of the Great Lakes basin upstream and the impacts on the flows are not negligible. The fresh water inflow into the St.-Lawrence estuary, and its seasonal variability, plays a very important role in the productivity of this saline estuary-coastal ecosystem and any tampering on such ecosystems may have dangerous results in the future (Rozengurt, 1999).

Maybe we are pretentious in thinking that we can analyze all impacts of changes in water levels and flows in such a large ecosystem that extends from the middle of the North -American continent down to the estuary and Gulf of St.-Lawrence, or that such impacts may be manageable. Many uncertainties will necessarily remain, surprises are unavoidable and some actions may put us in a irreversible situation. One should not forget that a precautionary, no-regret approach is part of most risk analyses and most environmental impacts assessments should include it.

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**Annex 1**  
**A Literature Review on Cumulative Impacts**  
**in the Great Lakes-St. Lawrence River Ecosystem**  
**From Factors affecting Water Levels and Flows**

The Contractor, acting under the direction of the co-chairs of the Working Group on Cumulative Impacts and guidance as may be necessary from the co-directors of the Study Team and the lead Commissioners, shall work with the Great Lakes Commission on a joint literature review resulting in the following products:

A brief summary of key findings from the literature of the individual and cumulative impacts on the Great Lakes - St. Lawrence River ecosystem of any factors that may have affected Great Lakes- St. Lawrence River water levels and outflows to date, with expert opinion as to the quality of the technical assessments surveyed; and

A listing of methodologies or approaches that may be useful in assessing the individual and cumulative impacts on the Great Lakes - St. Lawrence River ecosystem of any future factors that may affect Great Lakes - St. Lawrence River water levels and outflows, with expert opinion on the validity of such methodologies surveyed.

The contractor shall be provided with an initial selection of relevant publications for the literature review.

The contractor shall attend and participate in a Cumulative Impacts Workshop being hosted by the International Joint Commission (IJC) in Windsor, Ontario on September 29 - 30, 1999 at which time it is expected that additional relevant publications will be brought to his attention.

Work on the contract shall commence on September 23, 1999. The contractor, together with the Great Lakes Commission, shall submit their findings in a joint report to the co-directors of the IJC's Study Team on Consumption, Diversion and Bulk Removal of Water by October 15, 1999.

The report shall be submitted in electronic form to:

pentlandr@ottawa.ijc.org and James.R.Hougnon@usace.army.mil

## Annex 2

### Cumulative Impacts Matrix

The impacts matrix presented herein is based on the *Methodology for Measures Evaluation* of the Levels Reference Study, Phase II, International Joint Commission and is taken from Cuthbert and Moulton (1999).

The following is an elaboration on the definition of interests used in the matrix.

*Shoreline* interests include implications of flooding, erosion, low water (shorewells, access) and changes in aesthetics of shoreline property.

*Hydropower* impacts are the loss of generation of electricity at plants on the connecting channels and St. Lawrence River, and the implications of this loss.

*Recreational Boating* impacts include the impacts on marinas, private docks, launch facilities, and boat owners and users.

*Shipping* impacts include the ship owners, the businesses that rely on shipping, the harbours and maintenance of the navigation channels and locks.

*Infrastructure* includes implications on water intakes and discharge facilities; bridge clearances; roadway embankments; weirs, dams, or culverts in tributary streams, etc.

*Fisheries* aspects include both the fish population and the commercial and recreational use of this population.

*Water Quality* impacts include both nearshore and mid-lake aspects.

*Native Americans/First Nations* includes impacts on their traditional life and on their communities.

*Wetlands* impacts include effects on the size and diversity of wetlands and on the many plants, animals, and birds that use the wetlands.

*Other Environment* includes implications for the environment not explicitly covered under Wetlands or Water Quality, including the lower reaches of the St. Lawrence River and the Gulf of St. Lawrence.

*Other Recreation* includes implications on tourism and recreation not covered under Recreational Boating.

*Agricultural* includes the impacts on farms and farm production from a change in lake levels. It does not include the direct impacts of climate change on farms.

*Institutional* includes implications on international treaties and agreements, IJC Orders of Approval, local zoning and land use ordinances, regulatory laws, etc.

*Social* includes implications on public perception and reaction.

### Annex 3

#### Notes for literature review

(in chronological order)

International Great Lakes Level Board, 1973, *Regulation of Great Lakes Water Levels*, a) Main report, b) Appendix D: Fish Wildlife and Recreation, c) Appendix E: Commercial Navigation, d) Appendix F: Power, December 1973.

Economic evaluation was carried out for commercial navigation and hydroelectric power using the well-established methods used by these interests for project evaluation and justification. Concerning the various shore properties interests, the study conducted surveys for estimating erosion and inundation damages, looked at marine structures (in terms of dredging costs), the water intakes and sewer outfalls (in terms of differences in pumping costs), recreational beaches (based on beach carrying capacity and potential seasonal attendance for some 636 beaches in Canada and the United States), and recreational boating (which were found of negligible impact for the new regulation plans).

Concerning environmental effects, the study looked at "ecological" effects (i.e. fisheries and wildlife, hygienic effects, aesthetic effects and social well being). While, for the last three sectors, evaluations were primarily of a qualitative nature, the study tried to quantify the impacts on wildlife using a numerical index which considered two known factors (maximum acreage of wildlife land in each lake and connecting channel and the percent of time these lands are inundated over the study period 1900-1967 at each level of operating range). For fisheries, the study dealt mostly with the effects of lake levels regulation on fish stocks by looking at relations between water levels and commercial catch in pounds; this approach was recognised to be inadequate and the study reverted to a qualitative assessment by polling the expertise of fishery biologists and administrators using a letter of inquiry.

International Lake Erie Regulation Study Board, *Lake Erie Water Level Study*, 1981: a) Main Report, b) Appendix F: Environmental Effects, July 1981.

Impacts are evaluated for three proposed regulation plans that have been developed for lowering the levels of Lake Erie by decreasing its outflow during periods of high water supply for the 77 year "study period" (January 1900 to December 1976). All three plans lower the maximum stage (5cm, 13cm and 33cm, Main Report, p102) and reduce the frequency of occurrence of high levels (Main Report, p.100), while slightly reducing the minimum stage and increasing the frequency of occurrence of low levels.

Environmental impacts are evaluated under three sub-headings: water quality, wildlife/wetlands and fish. The wildlife evaluation was largely qualitative. Some of the predicted impacts were based on the judgement of biologists familiar with Great Lakes wetlands, not on detailed scientific studies (Appendix F, p.64). For fish, the evaluation was based on available data. The identification of cause-effect relationships between water level changes and their impact on fish was based largely on inference and was therefore qualitative rather than quantitative" (Appendix F, p.125). For water quality characteristics, the following were evaluated: hypolimnion, near-shore turbidity, embayment dilution capacity, Cladophora production, water outfall dispersion, total

phosphorus budget, and general water quality. Table 56 (Main Report, p.140) summarizes the general approach for the evaluation of the impacts on water quality while table 61 (Main Report, p.147) summarizes the impacts. Except for a reduction of turbidity (2% to 11%) and increase in Cladophora production (0.5% to 2.7%) all other impacts are negligible for the ranges of level variations resulting from implementation of the three regulation plans. The extent to which a similar approach might produce significant results for the range of variations that might be envisaged in the current Reference will have to be investigated in more detail.

For the purpose of economic evaluation, the various interest were grouped into several major classifications (Main Report, p.171):

1. Coastal zone, including the effects of variation in water level and outflows on erosion and inundation of shoreline area (flood control and shore property), and the operation of water intakes (water supply). This also included the loss of agricultural land through erosion and inundation.
2. Power, including the impacts on the power facilities in the St. Marys, Niagara and St. Lawrence River.
3. Commercial navigation, including the impact throughout the Great Lakes – St. Lawrence Seaway System.
4. Recreational Beaches and Boating, including the impact on beaches and recreational boating throughout the lower Great Lakes and the St. Lawrence River basin.

1. Coastal Zone: The methodology to evaluate inundation used storm-water levels as an index of inundation damages. For the U.S., damage data were based on the survey of a four year period (1972-1976) while, for the Canadian portion, it was based on the Canada-Ontario Great Lakes Shore Damage Survey covering the period November 1972 to November 1973. For the Quebec portion of the St. Lawrence River, the 1974 and 1976 inundation events were used as the basis for inundation data. Storm-water stage damage curves were developed and calibrated based on the recorded levels of the survey periods and known damages.

Evaluation of impacts on coastal zone property was based on erosion damages to structures and loss of land through erosion. The methodology used a wave energy approach in the development of stage damage curves. For water intake facilities, the study considered the increased costs of electricity for pumping as they would increase with decreasing levels.

2. Power: The impacts were determined by comparing the power that would be generated under the BOC with the power that could be generated under each of the regulation plans, and evaluating the differences in term of cost of replacement power. This is a classical approach and the only items that are debatable are the definitions of the cost of replacement power, which varies not only seasonally but from utility to utility.
3. Commercial Navigation: The relationship between lake level and transportation cost is based on the allowable draft of shipping. In the Great Lakes St. Lawrence River System, allowable draft is limited by the depth of water in the harbours and the connecting channels between the lakes. When the depth in one part of the system is altered by a change in lake levels, the allowable draft (and therefore the loading of ships wishing to use that part of the

system at that time) may be affected. Any change in the loading capacity results in a change in the number of ship hours required to move a given volume of goods over that route, which in turn changes the total operating expenses involved. This reasoning forms the basis of a detailed calculation procedure which is applied on a monthly basis to each shipping route in the Great Lakes - St. Lawrence River trades. It should be mentioned also that navigation losses could be eliminated by dredging deeper (where feasible) in harbours and connecting channels to offset the decrease in lake level.

4. **Recreational Beaches and Boating:** The evaluation of impacts on recreational beaches was based on the assumption that altered lakes levels due to regulation change would generate changes in beach area. This was assessed on the basis of the beaches' ability to provide recreational opportunities and the dollar value associated with these opportunities.

Impacts on recreational boating were measured, for the U.S. only, from effects resulting from owners being prevented safe ingress/egress from boat slips or moorings due to insufficient depths. The method employed to calculate benefits and losses on recreational boating are explained in detail in three separate sections of Appendix G of the Main Report (*not available*).

International Great Lakes Diversions and Consumptive Uses Study Board, 1981, Great Lakes Diversion and Consumptive Uses, a) Main report, b) Annex G: Evaluation of Diversion Management Scenarios and Consumptive Water Use Projections, September 1981.

The methodologies used for impact evaluation are the ones developed by the International Lake Erie Regulation Study Board (1981) for use in both this study and its own study, and cover both the economic and the environmental impacts. Thirteen different diversion scenarios were selected for hydrologic review and a detailed economic review was directed to ten of them.

The major economic interests affected by variation of levels fall into four general groups: (1) coastal zone (inundation, erosion, water intakes, and marine structures), (2) beaches and boating, (3) hydro-electric power, and (4) navigation (transportation costs and dredging). The report presents benefits and costs for the four groups and the ten scenarios (tables 8-5, 8-6 and 8-7).

Environmental evaluation for this study covers the subjects of fisheries (alterations in near shore habitat, reductions in hypolimnion volume and changes in seasonal water level fluctuations), wildlife/wetland, and water quality. Water quality characteristics examined include hypolimnion volume and oxygen resources, general lake water quality, phosphorus and turbidity concentrations, Cladophora production, embayment water quality and waste dispersion capability. Out of the thirteen different diversion scenarios, only the "maximum-effect" diversion scenario (Long Lake /Ogoki: 0 cfs, Chicago: 246 cms, Welland 255 cms) was evaluated for environmental impacts as this scenario would have the greatest effect on levels and flows (page 8-28).

Because the environmental evaluation was limited to the use of existing information, the determination of cause-effect relationships between water level changes and the impacts on fish was based largely on inference and was qualitative rather than quantitative. In brief, information available was not sufficient to draw any definite conclusions. However the data available suggest

that the decrease in water levels would probably alter the shallow areas of the Great lakes in a way which would have a negative impact on fishery resources (page 8-33). Concerning the impacts on wetlands/wildlife, the study addressed mostly the impacts on fish and wildlife, the study concluded that, to analyze the possible effects of any diversion scenario, the efforts should be best directed toward a consideration of habitat alteration in the Great Lakes system, the areas most likely to be affected by lake level changes are the shallow water areas (nearshore zone) and wetland habitat in particular (IGLDCUSB, 1981; page 8-38). The water quality evaluation is based on the water quality studies of the International Lake Erie Study Board and deals mostly with Lake Erie, based on a one foot lowering of this lake. Very little pertinent information is available for the other lakes. However, their conclusion is that "implementation of the "maximum-effect" diversion scenario would not significantly affect the lower lakes water quality" (page 8-47).

This report also covered social effects (i.e. population growth, recreation, hunting, fishing, beach recreation/boating recreation), water quality, shore erosion and coastal flooding. The social impact assessments were mainly qualitative and concluded that implementation of the "maximum-effect" diversion scenario "should not produce significant social effects" (IGLDCUSB, 1981; page 8-53).

Evaluation of this study's conclusion on impacts of consumptive use is very difficult since they used various projections of future consumptive uses and never actually evaluated the impacts of the current uses at that time.

Manny, B.A., 1984, Potential impacts of water diversions on fishery resources in the Great Lakes, Fisheries, 9(5), October 1984.

Using the reports of the International Great Lakes Diversions and Consumptive Uses Study Board (1981) and the International Lake Erie Regulation Study Board (1981) this article examines the impacts of water withdrawals on fish from both an ecological and economic perspective.

Looking at impacts of temporary withdrawals of 2000 cms for cooling, and 140 cms consumptive use in 1975, the article cites various references and notes that, for example, in 1979 an estimated 1.2 billion fish larvae and 98 million juvenile and adult fish were drawn into the water intakes at the 90 power plants on the shore of the Great Lakes. The article also cites a number of specific studies on Lake Michigan and Lake Erie. The article concludes that water diversions represent a threat to fishery resources. It also cites observations from the two IJC's Boards studies that reductions in mean lake levels could cause permanent losses of wetland habitats that are valuable to fish and that such habitats are not readily re-established at lower lake levels.

International Joint Commission, 1985, *Great Lakes Diversion and Consumptive Uses*, January 1985.

The methodologies for impact analysis were reviewed in the Study Board report.

Project Management Team, 1989, *Living with the Lakes: Challenges and Opportunities*, a) Main Report, b) Annex D: The Great Lakes Ecosystem Perspective: Implications for Water Management, c) Annex F: Evaluation Instrument, July 1989.

The document (Annex F) lists in detail, for use in its Evaluation Framework, various types of impacts (positive and negative) under extreme high, extreme low and fluctuating water level baseline conditions both by Interest Groups and by Type of Environment for six Core Criteria and number of Operational Criteria. These are proposed for use in an Evaluation Instrument for recommending various courses of action to deal with the adverse consequences of fluctuating water levels. However, it offers no indication on how to actually measure the various impacts. Moreover, since they are very global, they offer little help in dealing with incremental impacts in changes in flows and levels.

Regier, H.A., Magnuson, J.C. and Coutant, C.C. (eds.), 1990, Proceedings of a Symposium on Effects of Climate Change on Fish, Transactions of the American Fisheries Society, 199(2), 173-392, March 1990.

Report of a symposium held September 14-15, 1988 during the annual meeting of the American Fisheries Society in Toronto, Ontario. Eighteen papers were presented that address various issues, such as impacts on temperature structures of the Great Lakes, oxygen concentration, thermal habitat and growth for various fish species.

United States Environmental Protection Agency, 1992, *A Synoptic Approach to Cumulative Impact Assessment: A Proposed Methodology*, Washington, DC. October 1992.

This documents begins by defining "impacts" as human generated actions or activities that, either by design or oversight, alter the characteristics of one or more ecosystems. *Cumulative impacts* are the sum of all individual impacts occurring over time and space, including those of the foreseeable future. *Effects* are the physical, chemical, and biological changes that result from an impact, including direct and indirect changes that can be removed in time and space. *Cumulative effects* are the sum of all changes resulting from cumulative impacts.

The document defines four synoptic indices for assessing cumulative impacts relative risk: function, values, functional loss, and replacement potential. It proposes a methodology for conducting a synoptic assessment and includes an extensive review of wetland functions and the effect of wetlands impacts.

An extensive bibliography is also included. This document is limited, however, to inland wetlands; some of the functions could in certain cases be transposed to riparian wetlands as on the Great Lakes shorelines.

Levels Reference Study Board, 1993, *Levels Reference Study- Great Lakes St. Lawrence River Basin*, a) Main Report, b) Annex 2: Land Use and Management, c) Annex 3: Existing regulation, System-wide regulation and crisis conditions, d) Annex 4: Principles, Evaluation, Integration and Implementation, March 1993.

Annex 4 presents an extensive analysis of the various approaches and methodologies used for the evaluation of measures. Four objectives were developed to support the goal statement (i.e., public participation, principles, short term support studies and measures evaluation). The first of these reflects a Study Board decision, while the remaining three are drawn from the IJC Directive. Study evaluation principles were developed as a guide to assist in decision making during the study. The study covered various methodologies for measure evaluation, and prepared a framework for impact analysis, impact assessment for various interests, and evaluation criteria to compare potential measures. These criteria were assembled into four groups: economic impact (benefit cost analyses and other economic and social impacts); environmental impact (ecological productivity and environmental purity); distribution of impacts (among affected regions and among affected interests); and, finally, the feasibility of the measures (technical, operational and legal and public policy).

Quantitative and qualitative assessments were carried out on the potential economic and environmental impacts of the various measures that were analysed. The economic impacts of regulation measures were assessed for riparian property, commercial navigation, recreational boating and hydropower. Wetlands were studied as indicators of the environmental effects of changes in water level regimes, while erosion studies determined possible changes in shore recession rates under reduced rates of water levels fluctuation. Land use and shoreline management measures were assessed by reviewing existing examples and conducting case studies.

Summaries of the methodologies used for the quantitative economic assessments appear in Annex 3 (pages 7-1 to 7-15). The impact on commercial navigation was examined by applying a given pattern of shipments in the Great Lakes St.-Lawrence River system to the water levels under the BOC as compared to those which occurred under a regulation plan. In general, levels below the BOC reduce the water column available to a carrier on a given origin/destination route, while a higher water level may allow the vessel to load more tons per trip. The method employed aggregates the benefit/loss for commercial navigation for the system as a whole under each measure.

The hydropower impacts determined the magnitude and timing of the energy and power losses or gains for the mainstem (St. Marys, Niagara and St. Lawrence rivers) hydro projects, due to various regulation scenarios, identified possible alternatives to replace energy and power losses, determined replacement cost for these alternatives, and identified the most likely replacement alternatives as a basis for determining the impacts of the plans.

In evaluating recreational boating, the study area included all United States and Canadian recreational boaters who rent slips at publicly accessible marinas on the Great Lakes the connecting channels and the St. Lawrence River. As evaluation of impacts of fluctuating water levels on all recreational boaters was beyond the scope of the study (due to monetary and time constraints); the study was confined to conducting site specific investigations where detailed impacts information was gathered.

The potential impacts, in dollar values, to shoreline property due to reduction in the amount of beach erosion and flooding damages was estimated by comparing the estimated damages under existing conditions (BOC) and under a water level regulation scheme. Extensive studies of beach erosion processes were carried out to try to resolve the controversy focussed around the difference between long-term and short-term erosion. Overall, it was found that, for some shore

types, recession rates are completely independent of lake levels, and that for others, there is a direct although small, relationship between changes in lake level ranges and recession rate.

Wetlands were used as the primary indicators of the overall health of the system's aquatic environment (Annex 2, 238-264). The impacts upon wetlands of lake level regulation plans were assessed. Research was oriented toward two goals: i) to better understand the response of wetland communities to fluctuation in water levels and ii) to apply this knowledge generally and speculate on the response of wetland plant communities to proposed water level regulation schemes. The environmental effects were evaluated based on qualitative assessments; descriptive rather than numerical data were used to rate impacts as either positive, neutral or negative. It was found that fluctuations in water levels are important to maintain the extent of coastal marshes. The smaller the fluctuation in water levels, the smallest the extent of wetlands. The environmental evaluation of all regulation plans found that environmental impacts were negative on all lakes and connecting channels.

Fish habitat impact assessment was limited to an evaluation of spawning habitat area and yellow perch reproduction in two sites in Saginaw Bay, Lake Huron, at three different water levels. (Annex 2, 267-276). It concludes that, although a relationship between water levels and reproductive success has been examined for a few species, there is little or nothing known about the effects of water levels fluctuations on most of the fishes in the Great Lakes.

Other interests, such as agriculture, commercial fishing, public infrastructure, riparian property, native North American communities and commercial and industrial facilities were not evaluated quantitatively, but qualitative assessments were undertaken which focussed primarily on characterising the interests and their responses to fluctuating levels. This qualitative information assisted study participants in weighing the suitability of measures during the evaluation process.

Bergeron, Luc, *Les niveaux extrêmes d'eau dans le Saint-Laurent: ses conséquences économiques et l'influence des facteurs climatiques*, Rapport présenté à Environnement Canada, Services Scientifiques, Direction de l'environnement atmosphérique, Région du Québec, Octobre 1995.

This report examines impacts of extreme high and low waters on a number of economic activities (shipping, recreational boating, water quality, infrastructures, agriculture and fisheries) in the Saint Lawrence River from Lake St. Louis downstream to Quebec City. The findings, while interesting (as the increase in recreational boating accidents during low water periods), are of such a general nature that the results could not be used to determine with accuracy the impacts of incremental changes in low water conditions.

The only exception is the evaluation of impacts of low waters on shipping in the Port of Montreal. Citing references from industry (Canada Maritime, 1990) it shows a decrease in loading of 114 TEU (twenty equivalent unit) for a decrease of 30cm in level at Montreal. Scott et al. (1989) mention that a decrease of 30cm in the port of Montreal brings a decrease of 2000 tons in average loading per ship. In March 1989, daily variations in the levels at Montreal lead to a total decrease in loading of 1800 TEU or 3,6 M\$ (Canada Maritime 1990).

Detailed analysis of the methodology would have to be done to validate these findings and their applicability to the current study.

Meador, M.R., 1996, Water Transfer Projects and the Role of Fisheries Biologists, Fisheries, 21(9), September 1996.

Transfers are accompanied by a variety of ecological concerns, including some related to commercial and recreational fisheries. Fisheries organisations and agencies often are called on to provide information regarding potential ecological consequences of water transfer projects, yet they frequently know relatively little about such effects. At the 1995 mid-year meeting of the Southern Division of the American Fisheries Society, held at Virginia Beach Virginia, the Warm Water Streams Commission sponsored a symposium on this subject. This paper provides an overview of the case studies presented at the symposium and a brief summary of the status of knowledge of ecological effects of water transfer projects and the role of fisheries biologists in these projects. The intents of this paper is to increase awareness of water transfer issues among fisheries biologists. More detailed technical information on the cases studies presented is published elsewhere.

After examining the results from five case studies, the paper concludes that these studies revealed important clues about the status of knowledge and the need for information related to ecological consequences of water transfer. Understanding fundamental ecological processes of managed fish species as they relate to all system components, including estuarine areas, can provide essential information for evaluating water transfer effects that is crucial to future water transfer studies.

This article contains an extensive bibliography, and may form a basis for an extensive review of the state of the art of impact assessment on fishery resources.

State of the Great Lakes 1997.

*Nothing pertinent for this review.*

An Updated Regulation Plan for the Lake Ontario – St. Lawrence River System, The International St. Lawrence River Board of Control, June 2, 1997.

Compares five regulation plans for Lake Ontario with Pre-Project conditions for eleven IJC criteria and a large number of "Interest Preference Indicators". *Nothing pertinent for this review.*

Water Management Implications of Global Warming: The Great Lakes St. Lawrence River Basin, USACE, IWR, Draft Report, May 1999.

Uses a Water Resources Impact Model (p. 27 and following) to evaluate the cumulative impacts of changes in water level and flows generated by various climate change scenarios on number of impacts.

For socio-economic impacts: hydropower (\$/yr.) value the references are IJC (1981) and IJC (1993a), for shoreline damages (\$/yr.) (IJC, 1993c) and Chao (1997– not referenced) for navigation (\$/ton). For environmental impacts two criteria are used: Fisheries – Cold Water

habitat (km<sup>3</sup>) (Chao and Koonce, 1993 – *not referenced*) and Wetland Area (m in elevation) (IJC, 1993).

Rozengurt, M.A., 1999, Running on entropy: the effect of water diversions on the estuary - coastal ecosystems, *Proceedings of the Nineteenth Annual American Geophysical Union HYDROLOGY DAYS*, August 16, 1999, Colorado State University, Fort Collins, Colorado, 369-389.

A seminal article on the effects of major water withdrawals and truncation and depletion of spring and annual runoff on estuary coastal ecosystems. Concludes that it is "time to focus on the limitation of river flow for withdrawals for it is the fresh water that forged and strengthened the critical link between rivers and bordering coastal seas over the past several thousand years."

Plan of Study for Criteria Review in the Order of Approval for Regulation of Lake Ontario – St. Lawrence River Levels and Flows, ISLRBC Study Team, September 17, 1999.

Contains very useful and interesting material for possible future studies of impact evaluation. Besides methodologies, covers in detail all of the data needs. Will be used for the second part of this review.

#### Annex 4

#### Abstracts from Great Lakes Commission's database search

Becker, N. and Easter, K.W., 1995. Water diversions in the Great Lakes basin analysed in a game theory framework, *Water Resources Management*, **9**(3), 221-242, 1995

Water diversions from the Great Lakes is a complex problem because the five lakes are a common property resource, since hydropower production and commercial navigation are a function of lake levels. Game theory is used to analyse the dependency among eight states and two provinces. The decisions concerning water diversion affect the state of the system in future periods and several scenarios with different restrictions on the lakes where diversions can be carried. This was done with respect to a one player (social planner), two players (U.S. versus Canada) and independent actions taken by states and provinces which can sum up to ten players. The results suggests that states do not divert water necessarily because they stand to gain but because they may lose more if they do not. This is a situation not unlike the prisoner's dilemma case.

Becker, N. and Easter, K.W., 1997, Water diversion from the Great Lakes: Is a co-operative approach possible? *International Journal of Water Resources Development*, **13**(1), 53-65, March 1997.

The concern about other states diverting water from the Great Lakes has prompted the Great Lakes states and provinces to adopt institutional arrangements that have effectively blocked any new diversions. Since the current arrangements do not allow diversions, important opportunities may be lost in the future. This article considers the possibility of 'economically desirable diversions' and how the gains should be allocated among the states and provinces to foster co-operation. The study shows that, in most cases, new institutional arrangements will be needed before agreements can be reached. Game theory is used to determine how coalitions may be formed to reach co-operative agreements for diversions. Five different lake diversion games are tried involving Lake Ontario, Lake Superior, Lake Erie, Lake Michigan-Huron, and finally, all the lakes together. Diversions from Lake Ontario may offer the best opportunity for co-operation since there are no inter-lake effects.

Butts, T. A. and Evans, R.L., 1980, *Aeration Characteristics of Flow Release Controls on Illinois Waterway Dams*, Illinois State Water Survey, Report No.: ISWS/CIR-145/80, 1980 73p.

The main stem of the Illinois Waterway, from Grafton at its confluence with the Mississippi River to Lockport below Chicago, consists of seven navigation locks and dams and attendant navigation pools. Each pool has historically experienced dissolved oxygen (D ) concentrations that fall below Illinois EPA water quality standards. The levels to which the DO falls in the pools are greatly influenced by the aerating characteristics the dams that form the pools. These aeration characteristics were studied to calibrate the dams with the British weir equation as a model, and to evaluate the effects of increased Lake Michigan diversion water on the dam aeration characteristics. The dam aeration coefficients derived varied significantly within a dam, depending on operation mode, and varied greatly between dams

David, M.H., Rosenthal, S.S., Loucks, E.D.; Joeres, E.F. and Potter, K.W., 1988, *Diversion of Great Lakes water, Part 2. Economic impacts*, UW-Madison Institute for Environmental Studies, IES-131,

1988, 73 pp (Also published as Wisconsin Univ.-Madison Sea Grant Inst. report no. WIS-SG-87-247).

The potential hydrologic and economic impacts of large-scale diversions of Great Lakes water are described in a pair of new reports jointly published by the UW Sea Grant Institute and the UW-Madison Institute for Environmental Studies. The team's four-year UW Sea Grant study involved the development of hydrologic and economic models to evaluate the effects of hypothetical water diversions ranging from 5,000 to 30,000 cubic feet per second (cfs) from Lakes Superior, Michigan-Huron and Erie. The first report, *Diversion of Great Lakes Water, Part 1: Hydrologic Impacts*, addresses the estimated effects of such diversions on lake levels and water flow. The second report, *Diversion of Great Lakes Water, Part 2: Economic Impacts*, assesses the monetary effects the hypothetical diversions would have on Great Lakes shipping and hydropower industries. Grant NA84A-A-D-00065. Also pub. as Wisconsin Univ.-Madison Sea Grant Inst. rept. no. WIS-SG-87-247. See also PB87-178620. Prepared in co-operation with Wisconsin Univ.-Madison. Sea Grant Inst. Sponsored by National Sea Grant Coll. Program, Rockville, MD.

Gonzalez, O.J., 1996, Formulating an ecosystem approach to environmental protection, *Environmental Management*, **20**(5), 597-605, Oct 1996

The U. S. Environmental Protection Agency (EPA) has embraced a new strategy of environmental protection that is place-driven rather than program-driven. This new approach focuses on the protection of entire ecosystems. To develop an effective strategy of ecosystem protection, however, EPA will need to: (1) determine how to define and delineate ecosystems and (2) categorise threats to individual ecosystems and priority rank ecosystems at risk. Current definitions of ecosystem in use at EPA are inadequate for meaningful use in a management or regulatory context. A landscape-based definition that describes an ecosystem as a volumetric unit delineated by climatic and landscape features is suggested. Following this definition, ecosystems are organised hierarchically, from mega-ecosystems, which exist on a continental scale (e.g., Great Lakes), to small local ecosystems. Threats to ecosystems can generally be categorised as: (1) ecosystem degradation (occurs mainly through pollution) (2) ecosystem alteration (physical changes such as water diversion), and (3) ecosystem removal (e.g., conversion of wetlands or forest to urban or agricultural lands). Level of threat (i.e., how imminent), and distance from desired future condition are also important in evaluating threats to ecosystems. Category of threat, level of threat, and "distance" from desired future condition can be combined into a three-dimensional ranking system for ecosystems at risk. The purpose of the proposed ranking system is to suggest a preliminary framework for agencies such as EPA to prioritise responses to ecosystems at risk.

Griffin, W.L., 1986, Great Lakes diversion: A legal perspective, The selected papers from the *Rawson Academy Of Aquatic Science National symposium, Canadian Waters: The State Of The Resource*, 1986, pp. 1-5, Can. Water Resour. J., **11**(2)

This paper gives a brief historical glance at some North American water diversions in a perspective of the United States law of "equitable apportionment" and of the international law of "equitable utilisation," examines Great Lakes diversion in the same perspective, and suggests an institutional structure to resist undesirable Great Lakes diversions.

Hartmann, H.C. 1990, Climate Change Impacts On Laurentian Great-Lakes Levels, *Climatic Change*, 1990, **17**(1), 49-67.

(no abstract was available).

Lee, D.H. and Southam, C.F., 1994, Effect and implications of differential isostatic rebound on Lake Superior's regulation limits, *Journal of Great Lakes Research*, **20**(2), 407-415, 1994

In 1902, U.S. federal authorities established water level limits for Lake Superior as part of the requirements permitting hydropower water diversions from the lake's outlet, the St. Marys River. The vertical datum to which these limits are referenced must be adjusted every 25 to 30 years due to differential isostatic rebound. Because crustal movement unequally changes the land-to-water relationship along Lake Superior's shoreline, the method by which the limits are established on a new datum could accelerate the natural effects of crustal movement with adverse effects on shoreline flood levels, navigation depths, and lake outflows. With the implementation of the new International Great Lakes Datum of 1985, a study was undertaken 1) to review the methods used to establish the limits on previous datums and 2) to quantify the changed land-to-water relationship between the limits established in 1902 and those referenced to the new datum.

Loucks, E.D., Joeres, E.F., Potter, K.W., David, M.H. and Rosenthal, S.S., 1988, *Diversion of Great Lakes water; Part 1. Hydrologic impacts*, UW-Madison Institute for Environmental Studies, IES-130, 1988, 73 pp (Also published as Wisconsin Univ.-Madison Sea Grant Inst. report no. WIS-SG-87-246), 72p., February 1987.

The report describes the findings of the Great Lakes water management study at the University of Wisconsin Sea Grant Institute. The study had the objective of developing a sound strategy for evaluating impacts caused by major water diversions if one were actually constructed. The evaluation strategy has two main components: hydrologic assessment and economic assessment. The report provides a detailed description of the recommended strategy for determining the hydrologic effects of diversions. These effects are expressed in terms of the amounts by which water levels and flows decrease. Both short-term and long-term impacts may be deduced.

Male J.W. and Soliman, K., 1978, *A Procedure To Determine Direct Diversions From Lake Michigan Illinois USA*, University of Illinois at Urbana-Champaign Water Resources Center Research UIUC-WRC-78-0137; W79-02523, 74p., October 1978.

Illinois diverts water from Lake Michigan to the Chicago River and Canal System in three primary ways: (1) diversions for municipal water supply, (2) storm water diverted away from the lake, and (3) direct diversions primarily for water quality purposes. The U.S. Supreme Court has ruled that the total average diversion must not exceed 3200 cfs. Since the storm-water diversion is uncontrollable, by reducing the amount necessary for direct diversion, the diversion available for municipal use can be increased. An optimisation procedure, utilising an efficient network algorithm, is developed to determine the average monthly flow rates at the three diversion points on Lake Michigan. The algorithm minimises the total amount diverted that is necessary to maintain the dissolved oxygen standard in the waterway system. The procedure is applied to evaluate direct diversion needs under existing conditions and after installation of ten instream aeration stations.

Stout, G.E. and Ackermann, W.C., 1974, *Hydrologic-Economic Feasibility Study on Precipitation Augmentation over the Great Lakes*, Illinois State Water Survey, Urbana. Sponsor: National Ocean Survey, Rockville, Md. Report No.: NOAA-74072251, 30p., March 1974.

Thirty-two million people live within the Great Lakes Region and depend heavily upon this resource for transportation, power production, water supply, and recreation. Large differences in lake levels create many social and economic problems. Every increase of one inch in water level permits an additional 110 tons of cargo on the freighters now in use and 225 tons on the larger vessels now under construction. A change in water level of one inch in Lake Michigan is equivalent to one-third of the diversion of water that is used for domestic and waste water dilution for the city of Chicago. The greatest benefit of the higher water levels is the energy producing capacity of the power industries. It was proposed that, through cloud seeding, one could recycle the evaporative water which occurs when polar and arctic air masses cross the open water surface directly into the lake. Benefits would be greatest during the period of low lake levels.

## APPENDIX B

Backgrounder: IJC Cumulative Impacts Workshop - September, 1999 for the Water Uses Reference

The Commission has provided the Co-directors of the Study Team with the following directions with respect to Task 1 - Cumulative Impacts - in the Second Phase Study Plan for the Water Uses Reference.

In reviewing what further work must be done on cumulative impacts, we must be careful to consider what is meant by this term. First, it refers to impacts on both levels and flows and on the total ecosystem (including its human components). Second, while it can and should be informed by the experience of the past, it is also forward-looking and future-oriented, focusing not on how hard the system can be pressed before it is damaged, but rather what must be done to avoid damage. In other words, it is a complement to the precautionary principle. Third, on the ecological plane, it represents more than a simple addition of the impacts of a certain number of withdrawals and removals, i.e. more than the sum of the individual changes. Fourth, it is a concept that must be seen and applied not independently but in the context of both natural fluctuations in water levels and fluctuations potentially arising from human-induced climate change.

Against this background, the Commission has reached the following conclusions:

- ▶ there are deficiencies in our abilities to assess the ecological impacts of water level changes;
- ▶ the Commission has recommended a five-year review of water use in the Great Lakes Basin and, accordingly, the Commission would like to recommend research priorities to governments so that cumulative impact assessment in, and government monitoring for, that review would be more meaningful;
- ▶ Bearing in mind the governments' request that the Commission consider in general terms such matters as potential effects on the environment and other interests of diversions and consumptive uses, we would also ask the Study Team to give special attention to determining cumulative impacts of changes in Great Lakes levels that could be or are occasioned by current and future removals and consumptive use; and to develop advice and information that the Commission might offer to governments on:  
(1) research priorities with an emphasis on ecological aspects of cumulative impact assessment; and (2) how the jurisdictions may evaluate the cumulative effects of any factors that may affect water levels in the Basin, or at least begin developing the questions that they should be asking;
- ▶ To help the Study Team in formulating its advice, the Commission would be prepared to support the conduct of a workshop to review and discuss these matters.

**Purpose**

The purpose of the Cumulative Impacts Workshop is to obtain advice on the foregoing matters that the Commission has asked the Study Team to address.

**Participation**

- ▶ In addition to the Co-chairs of the workshop, Doug Cuthbert and Michael Donahue, ten other experts in cumulative impacts, five from each country, will be selected by the Co-chairs of the workshop with the approval of the Co-directors of the Study Team, Commissioners and the Co-directors of the Study Team, and
- ▶ such Study Team and staff observers as the Co-directors of the Study Team consider necessary.

**Date, Location and Administrative Arrangements**

- ▶ The workshop will be held at a location in Windsor to be determined by the Co-chairs of the workshop, beginning at 1:00pm on September 29 and continuing until noon on September 30, 1999.
- ▶ Participants will be provided in advance of the workshop with such briefings and briefing materials as the Co-chairs of the workshop and the Co-directors of the Study Team decide should be provided to them. Any briefing materials provided to participants will include copies of the background section of this paper, the Commission's 1999 Interim Report to the governments on the Protection of the Waters of the Great Lakes and the Working Paper on Cumulative Impacts/Risk Assessment which was prepared for the Study Team during the first phase of the Reference. Briefing materials will, whenever possible, be sent to participants by e-mail.
- ▶ A one-hour telephone conference will be held with participants prior to the workshop to provide them with preparatory information and to stimulate thought. This telephone conference will be chaired by the Co-chairs of the workshop. The Co-chairs of the Commission and the Co-directors of the Study Team will be invited to participate in this conference.
- ▶ The International Joint Commission will, at the request of the Co-chairs of the workshop, engage contractors to assist the Co-chairs of the workshop with administrative tasks related to conducting the workshop, such as travel arrangements and accommodation for the experts, rental of suitable meeting space, and provision for a verbatim transcript of the workshop. The International Joint Commission will also, at the request of the Co-chairs of the workshop, engage agencies or organizations in each country to jointly assist in the identification of potential briefing materials. The cost of the workshop will be borne equally by the two sections of the Commission.

**Workshop Format and Agenda**

- ▶ The agenda for the workshop is attached.
- ▶ The Lead Commissioners or their designates will make welcoming and introductory as well as closing remarks.
- ▶ The Co-chairs of the workshop will act as co-facilitators.

- ▶ There will be a dinner for participants, probably at the hotel where the workshop is held.

**Reporting of Results**

- ▶ The Co-chairs of the workshop will, in addition to their duties as Co-chairs, act as Co-rapporteurs at the workshop and will prepare a report for the Co-directors of the Study Team on the workshop.
- ▶ All workshop participants, plus all members of the Study Team will have an opportunity to review and comment on the workshop report before it is finalized.
- ▶ The proceedings of the workshop will be recorded and a written verbatim transcript of those proceedings will be provided to each Co-director of the Study Team.

**APPENDIX C****List of Workshop Participants****CANADA****Experts**

Robert Boulden  
James Bruce  
John Hall  
Andrew Hamilton  
Henry Regier  
Michel Slivitzky  
(Literature Review)

**International Joint Commission**

Leonard Legault  
Murray Clamen  
Michael Veschler  
Tony Clarke

**Study Team**

Ralph Pentland  
Doug Cuthbert

**UNITED STATES**

Thomas Coon  
Norman Grannemann  
Ronald Rossman  
William Werick  
Doug Wilcox  
Erika Hieber  
(Workshop Proceedings)

Alice Chamberlain  
Gerry Galloway  
Jim Chandler  
Bruce Bandurski

Jim Hougnon  
Michael Donahue

**APPENDIX D****Questions Asked of Workshop Experts**

The following questions are posed to stimulate discussion. Participants should not feel constrained by the questions, and should feel free to offer any advice they deem appropriate as long as it is relevant to the purpose of the workshop.

**1. Cumulative Impacts of Past and Current Diversions and Consumptive Use**

- a) What can we conclude, with reasonable certainty, about the cumulative impacts (social, cultural, economic and environmental) of past and current changes, both with respect to absolute impacts of the changes, individually and cumulatively, and with respect to their redistributive effects?
- b) What are we unable to conclude, either because the causal factors are insufficiently well understood, or because the cause and effect relationships are not well enough defined?
- c) What monitoring and research priorities might be recommended to governments to improve our ability to estimate social, cultural, economic and environmental impacts, with a special emphasis on ecological aspects?

**2. Cumulative Impact of Possible Future Changes**

- a) What can we conclude, with reasonable certainty, about the cumulative impacts (social, cultural, economic and environmental) of probable future changes, both with respect to absolute impacts of the changes, individually (ie. removals, consumptive use changes and climate change) and cumulatively, and with respect to their redistributive effects?
- b) Are there monitoring or research priorities that might be suggested which would reduce the degree of uncertainty in future projections and their estimated impacts?
- c) In dealing with a future that may be very different from the past (eg. warmer water may very fundamentally change things like Lake Erie overturning, and the progression of invasive species), how relevant are existing impact assessment methodologies?
- d) Should impact assessment methodologies take into account only individual proposals for removals, or should they be based on a “global” approach that also takes into account the effects of an accumulation of such proposals?

**3. What Governments Need to Know**

- a) What do governments need to know to understand and evaluate the impacts of a diversion or consumptive use proposal in light of cumulative impacts?

(Note: Question 3 added during workshop.)



## APPENDIX E

### Summary of Participant's Presentations

#### Draft Summary Notes

as prepared by Erika Hieber, Institute for Water Research  
U.S. Army Corps of Engineers

**Mike Donahue and Doug Cuthbert** - Welcomed the participants to the Cumulative Effects Workshop and initiated introductions. All participants provided a brief introduction.

The floor was then turned over to the Commissioners for comments and remarks.

**Commissioner Len Legault** - Asked workshop participants to keep an open mind. He asked that the presenters address the questions provided to them before the workshop, but to also feel free to pose additional questions or provide additional information beyond the scope of the established questions.

**Commissioner Alice Chamberlain** - Recognized that the wide variety of expertise and knowledge of the presenters at the workshop would be fruitful to the information provided to the commissioners. The question of the removal of additional water from the Great Lakes will continue to be an issue, and the information presented at the workshop will be useful to include in the final report to the commissioners.

**Mike Donahue** - Provided an overview of the logistics for the workshop. Explained to the participants that the workshop was being recorded and that a written transcript would be prepared. Mike provided a brief overview of the sessions for the workshop. He also remarked that the information gathered at the workshop would feed into the recommendations to the study team for the "next step" as listed in the report.

**Doug Cuthbert** - Provided background on the cumulative impacts work completed to date. Provided an overview of the efforts completed by the Study Team. He explained the systematic evaluation of the environmental cumulative impacts and explained the difficulties in equating dollar figures to the anticipated impacts that would result from lake level changes. Doug also briefly mentioned the Lake Ontario study and the Lake Regulation Plan. He spoke of the importance of building an information base to develop an Environmental Impact Statement that represents the effects of changes in water levels. He explained the development of a cumulative effects matrix that provided information on the anticipated effects on various aspects related to the lakes. This information was based on assessments, as well as information collected from workshops and was sent for comment and review to individuals who represent the different aspects included in the matrix.

Doug stated that a change in future water demands seem certain. We also know that the climate is changing, and there is a need to determine what the correlation is between the climate change and additional lake withdrawals. It is difficult to predict when and how climate will influence lake levels. How will lower lake levels affect the ecosystem, and what are the implications to the environment?

**Bill Werick** – Discussed Cumulative Impact Process in the U.S. He provided his assumptions to managing cumulative impacts, stating that the goal should be sustainability and that management of the resources required the development of an analytical process. He went on to describe that multi-objective analysis was necessary in order to be a productive process and that the objectives needed to be measurable (quantifiable). There are likely to be conflicting views and implicit trade-offs that have some underlying value.

Impacts have a synergistic effect. Need to determine how the impacts interact with each other. Need to practice good water management. This can be accomplished by stakeholder involvement, multi-purpose, multi-objective planning, regional/basin view, multi-disciplinary team, understanding of relationship between surface and ground water, integration of water quality and quantity, and adaptive management.

Shared vision planning integrates the principles of good water management. It allows for the creation of a systems model that links to the various impacts. Shared vision encourages collaboration among stakeholders, as well as the development of an integrated model that is understandable to policy and decision-makers. It establishes a way to connect the issues of concern, and the need for public involvement and adaptability of recommendations

Using shared vision planning, including the development of an applicable simulation model for a system such as the Great Lakes, would (1) build the team, (2) build rigor, (3) provide result oriented research, (4), focus on critical issues, (5) dynamically integrate results, (6) facilitate sensitivity analyses, (7) improve communications among opposing views, and (8) provide a good framework for long-term management.

**Bob Boulden** - Spoke about the CEAA – Canadian Environmental Assessment Act of 1995. The Act defines environment to include effects to health, socio-economics, and welfare as well as biological and physical effects. Public education is needed in relation to cumulative impacts associated with lake levels. People need to be correctly informed on the actual needs and impacts, taking into account natural variations of the water levels. CEAA, Section 16 requires cumulative environmental impact assessment in combination with other projects or activities that have been or will be carried out. The following guidance has been developed to support the CEAA, (1) Operational Policy Statement, (2) Cumulative Effects Assessment Practitioners Guide, and (3) the Reference Guide for CEAA. Section 40 of CEAA establishes joint review panel to assess environmental effects (among Canadian jurisdictions or with the U.S.). Five year review of CEAA begins January 2000. Issues: definition of cumulative environmental impacts, scoping guidance, responsibilities of parties, feasibility of regional agreements, linkages to “harmonization agreements”. Bi-lateral agreements with provinces.

There is a UN ECE Convention on Environmental Impact Assessment in a Transboundary Context (not ratified by U.S. yet).

Boundary Waters Treaty Act of 1909– Proposed amendment would add licensing scheme for removal of water, including a prohibition for future diversions.

Ontario Water Resources Act prohibits withdrawals of more than 50,000 liters per day without a permit. They regularly review permit applications, and are grappling with cumulative effects.

Cumulative impacts can be and are being assessed. There are case studies and experiences to share. Jurisdictional cooperation and coordination are critical in facilitating assessments. Public education a continuing challenge.

Case Study – Alberta-Pacific Paper Mill. Cooperative Canadian-Alberta effort. He left a paper. Being used as a model for regulating cleanup.

**Doug Wilcox** – Provided primer on lake levels as they relate to the wetlands. Sampled along shore of Saginaw Bay during a period when the lake was receding after highs in the mid-1980s, exposing more shoreline. In addition to the lower lake levels, seiche events have also added affected short-term water levels. Showed which plants co-habit the same areas. Showed plant communities distribute themselves according to water-level history. Diversity occurred where ground was covered and uncovered most frequently. High and low levels each have a purpose. Later studies of Superior and Ontario showed that areas with more frequent fluctuations of inundation and dewatering had greater diversity. High lake levels caused die-off of dominant plant species; low lake levels allow reestablishment of a variety of wetland plants from the seed bank.

Also looking at long term fluctuations by studying ancient beach ridges that show where coast was. Some sites are wiped out (most recent site at progressively lower elevations survives). Sediment cores from beach ridge can show what lake levels were at the time. Results show 150 year cycle over the last 5000 years, with 30 year mini-cycles. Conclusion: Quantify what happened in past to forecast future. Long term levels show order of magnitude differences compared to withdrawals. Michigan done, Superior ongoing, Ontario soon, Erie we don't have, but do need. Shorter term cycles are not understood. No one has looked at the effects of small changes. His requests for studies of seiches has not been funded. Roger Gauthier (Detroit COE) has some detailed bathymetric maps, but we need more. Groundwater component needs to be studied. Isostatic rebound raises outlet with respect to the lake, raises lake levels. Does this balance withdrawals? What is really needed is a cross-discipline analysis, addresses exotics. Worked on restoration site at Metzger Marsh, found one year high followed with two years of low can recover a lot of plants.

**Jim Bruce** - Wanted to follow up on Bill and Doug's points. Showed graphs of 10,000 years – greenhouse gases 50% higher than ever in 10,000 years. Also agreed that climate models are pretty crude, but getting better as change becomes more pronounced. Said models predicted annual air surface temperatures well. Most climate models predict 0.5 to 1 meter lower. The Hadley Center model says no change (English). But these models are based on steady climate change. He thought we should consider another assumption. (What?) Later climate models show less increase in lake temperatures than earlier models did. What are ecosystem impact changes of warmer lakes? Climate Change will exacerbate ENSO swings. (Knutson and Manabe conclusion). Longer El Ninos with sharp short strong La Nina's. La Nina will give more precipitation, El Nino less in the western part of the basin. No correlation in lower lakes. Temperatures are higher in El Nino, lower in La Nina, so evaporation reinforces extra precipitation. 20% increase in number of days with > 2" of rain over the 20<sup>th</sup> century in the US, as predicted by Australians and others from CO<sub>2</sub> increases. That increases soluble reactive phosphorus concentrations. Higher lake temps and increased phosphorous runoffs are big concerns.

**Tom Coon** - Worked on investigating the fisheries of Lake Titicaca. He did fish studies and found that some species identified in previous expeditions had disappeared, while new species were currently inhabiting the lake because of changes in lake levels and lake temperatures. Most

important areas are coastal areas and main lake basins. The warm water fish located in the shallow areas of the bays and coastlines are linked more closely to wetlands than the open, colder water fish species. Land use changes and lake levels have eliminated lagoons, which connect coasts to the open water communities. Another change is in connecting waters. Loss of rapids in shallow water that are used for spawning and fry/juvenile development. Dredging or inundation has impacted the existence of these shallow areas. Loss of natural fluctuations has hurt wetlands.

In the open lake areas, hard to determine if there has been a loss in habitat quality, but climate change may cause problems. Most important impacts will be to coastal areas. Lower lake levels does not automatically hurt wetlands. The wetland vegetation just creeps down the shoreline and follows the receding water level. Zebra mussels clarified water column, allowing photosynthesis at deeper water levels. In turn, vegetation is becoming more prevalent in deeper waters. Need to have coastal maps of adequate detail to monitor vegetation and to make judgment calls on what is actually happening to the coastal environment. Advocated connecting data in a landscape management system. They know that wetlands are good for some species, but don't know what attribute it is. There are some undisturbed wetlands with diverse species, but we have not done a comparative study to show what it is these wetlands provide that produces more diverse and robust fish populations. How exactly does higher temperature affect thermodynamic actions in lakes?

Slight warming of Lake Erie could make a big difference. Two degrees centigrade warmer Ontario on April 1 changes time of stratification by an entire month. Important to have physical process models linked with habitat and biological models. Must also study near shore currents that re-distribute species. Merge these with socio-economic models.

**John Hall** – Project manager for fish and wildlife habitat restoration for Ontario. Responded to questions. When urbanization fills shallow areas, they do not get unfilled. That puts upper limit on restoration efforts. Restored wetlands are hugely expensive and not as effective as natural wetlands. If lake levels drop, does the uncovered bank become developable? Verified that regulation of Lake Ontario has created monoculture stands of vegetation and has hurt diversity. Need to look at frequency and time-shift of small variations in lake levels – makes a big difference in coastal species diversity. Need good bathymetry (but what scale?) Define what comprises the ecosystem. Need to develop a systems model in conjunction with stakeholder involvement to determine future planning needs.

**Norm Grannemann** – Groundwater conditions in the Great Lakes. Strong ground-surface interconnection, direct and indirect discharge, and a strong connection between groundwater and habitat – wetlands and maybe at the areas of direct discharge (direct means the water does not pass through a stream first). About 2,700 cfs in Lake Michigan, which has much higher discharge than any other lake. Most discharge in northern Lake Michigan, with coarse soils, high recharge, and steep elevation changes. Bigger component is indirect discharge, and it is accounted for in streamflow.

About half of the water flowing into Lake Erie is from indirect ground water sources while the other lakes receive about 75% from indirect ground water. For shallow water ground water, the boundaries are usually coincident with surface basin boundaries. But deep aquifers are different, and that means that changes in pumping can amount to diversions. Most consumptive use comes from groundwater. Groundwater paths are a mix of short, direct flows and long circuitous flows, and

this complicates the accounting, can affect wetlands (how?) Maybe 1 inch of 25 inches (tops) of Michigan recharge is from regional groundwater contributions.

**Andy Hamilton** – Important to look at the interactions within a system rather than the impacts. Should do systemic analysis. Must have a large enough framework to capture the entire system, realizing that when exploring the dynamic nature of the system we should expect some unknowns. In Churchill diversion we missed the mercury pollution issue. Prepare for a lot of surprises. Dissolved organic compound, clearer lakes, greater UV infiltration. Have to work together to develop these models.

Some things you don't need a computer for – e.g., what a local citizen would do in reaction to lower lake levels. Maybe all we can do is manage our interaction with water. Supported the idea of shared vision planning, though he might use a different phrase. We need to manage our interactions with water. The real options on what is done depend on how humans relate to the Great Lakes. We need to adapt our behavior. Did a three day visioning exercise with tribes (said they looked at pressures more than impacts). Many non-scientists involved in the process. It advanced the way they did river basin planning. Research needs: 1. Synthesis of individual effects collectively needs to be done not only with biological data but also socioeconomic information.. Use social science – why do people do what they do. If this use is encouraged, how do people change their behavior? He will write up his thoughts. Big point – it's an interaction between people and water.

**Ronald Rossmann** – Sediments: A reservoir of historic contamination of the environment. Sediments contain contaminants derived from past activities that seriously degraded the environment. If disturbed, problems associated with the contaminants will reappear. During low water, sediments are subject to natural erosion or removal for navigation. Erosion or dredging of sediment will release contaminants into the environment where they may bioconcentrate in the food chain. Prior to dredging the degree of sediment contamination must be determined for proper disposal of the dredged materials. During dredging, care must be taken not to release contaminated sediments into the water. This is difficult because contaminants usually are associated with the silt- and clay-sized fractions of sediment. Core samples collected from depositional areas of the Great Lakes show greatest contamination below the surface of the sediment, reflecting sediment deposition that occurred in the 1960's prior to enactment of the Clean Water and Clean Air Acts. A core from offshore of Batchawana Bay, Lake Superior showed mercury contamination levels to exceed 6 ppm in subsurface sediments. The core was collected from a location with a water depth of nearly 197 meters. Sediment contamination can be linked to biota contamination. Mercury concentrations in walleye were considerably higher in 1993 fish for all standardized lengths than for 1983, 1988, or 1989. This has been interpreted to be an impact of contaminated sediments.

**Henry Regier** – Brought a paper that describes links between hydrologic cycle and ecosystems. Cumulative effects assessment is "old hat" – don't need to reinvent the wheel. He discussed two approaches. Define linkages in ecosystem then predict how the system responds. Quasi-ecosystem approach links actions to users through ecosystem, but does not focus on the value of the ecosystem directly. Old fashioned linearity could not handle more than 3 degrees of interaction. The Green Book Corps of Engineers featured the prime economic impacts, put the rest in footnotes. First law of biology, under carefully controlled conditions, a living thing does anything it pleases. Ecosystem approach recognizes uncertainty and unpredictability. Simulation modelers keep it simple-stupid by excluding complexities from the models. Right brain model finds simplicities in constraints – thou shalt nots. Need to integrate logical, Procrustean ethics with ecosystem thinking.



## APPENDIX F

## Workshop Discussion Session Statements

Notes from Large Group Exercise

transcribed by Erika Hieber

**NOMINAL GROUP TECHNIQUE**

1. SILENT GENERATION OF IDEAS
  2. ROUND ROBIN PRESENTATION OF IDEAS
    - \*present or pass
    - \*concise
    - \*no critique
  3. GROUPING/CLARIFICATION
  4. CRITIQUE/MODIFY
  5. PTS. OF CONSENSUS/DIFFERENCE
- 

**CUMULATIVE IMPACTS OF PAST/CURRENT-DIVERSIONS AND CONSUMPTIVE USES****What CAN we conclude?**

- Lake levels continue to fluctuate and nature predominant factor
  - System itself is also fluctuating
  - System constantly adapting to changes
  - Redistributed social and economic costs and benefits
- 

**What CAN we conclude?**

- Net loss of habitat
  - Have freedom to make monitoring choices at various levels (fed. Government, regional, self)
  - Significant impacts on hydropower
  - Uneven benefits and costs between U.S. and Canada
  - Environmental as well as economic impacts
- 

**What CAN we conclude?**

- Natural range of water level fluctuations is likely greater than described in historic record
- Isostatic rebound will slowly continue to flood major portion of Great Lakes' shorelines
- Any change in volume of Great Lakes' waters will impact flows in the St. Lawrence River

- Ground water/surface water interactions need to be better quantified
-

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**What CAN we conclude?**

- Ground water divide is different than surface water divide in certain areas
  - Decision-making framework needs to have basin-wide and regional knowledge and information of cumulative effects.
  - Decision-making framework to address cumulative impacts does not exist
  - Humans re-acting to surprises rather than being pro-active
- 

**What CAN we conclude?**

- Human influences on climate affects water levels
  - Agencies (U.S. and Canada) unable to adequately evaluate cumulative impacts when making water permit decisions
  - Contaminated sediments have been and are being re-suspended by dredging
  - Impact assessment in the jurisdiction proposing a diversion will be different than the view of the jurisdiction(s) reacting to the proposal
- 

**What CAN we conclude?**

- Past withdrawals have encouraged and supported settlement of millions of people in Great Lakes Basin
  - Existing knowledge, data, and info to do cumulative effects assessment is satisfactory
  - Traditional knowledge less applicable today
- 

**What CAN we conclude?**

- Many will say that cumulative impacts are manageable
  - Have altered species composition of aquatic ecosystem (i.e., invasive species)
  - Any alteration of amplitude or frequency of water level fluctuates will impact wetlands
- 

**What CAN we conclude?**

- Have reasonable estimates of dredging and diversion
  - Big winners hydro-engineers companies that employ, and agencies that serve their interests
  - Limited amount of information on current impacts
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**What CAN we conclude?**

- Much is unpredictable.
  - Need to view as dynamic system
  - Humans are part of the system
  - Imposing a monistic, technocratic mind set is inherently unfair
  - In study of population dynamics cumulative impact calculations typically involve sequential products, not sums. (Loss of habitat involves power functions)
- 

**What CAN we conclude?**

- When we assess cumulative impacts need to be location specific as well as basin-wide
  - Can control diversions
  - Can influence consumptive use
  - Must adapt to climate change
  - Dealing with complex system
- 

**What CAN we conclude?**

- Filled in shallow riverine and coastal areas
  - With lower lake level, pressure to fill shallow areas will
  - Dredging will need to continue for operation of the system
- 

**What CAN'T we conclude?**

- What the actual total cumulative effects are
  - The extent to which climate change has affected current lake levels and interests
  - That the uncertain can be made certain
  - Without good bathymetric maps and groundwater data we cannot evaluate impacts on wetlands quantitatively
- 

**What CAN'T we conclude?**

- Magnitude of habitat loss
- Hard to distinguish effect of development and climate change on base flow and groundwater which constitutes large part of flow to the Lakes
- Long term implication of how the ecosystem will change due to ongoing introduction of exotic species

### **“On Break Ideas” - Unattributed**

- Research on social (non-market) and economic (market-based) values related to withdrawal and diversions
  - In making any decision on cumulative impacts on the environment, you must take into account the impact of that decision on other decisions on cumulative impact
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## **CUMULATIVE IMPACTS OF POSSIBLE FUTURE CHANGES**

### **Reasonably foreseeable**

#### **What DO we know?**

- Expect climate changes
  - Need to prepare for future external demands on G.L. water
  - Continuing shift of economic power to the southwest U.S.
  - Link area of water to human health and services
- 

#### **What DO we know?**

- Climate change will probably increase consumptive use
  - Increasing pressure in North America for water
  - St. Lawrence River as an integrator
  - It will be a challenge for U.S. and Canada to agree on the cumulative effects (due to social culture and value differences)
  - Expect the unexpected (there will be unknowns)
- 

#### **What DO we know?**

- Have time to make decision (no immediate need for decision)
  - Future proposals are inevitable
  - Ongoing issue
  - Need over-arching vision
- 

#### **What do we NEED to know?**

- Distributional consequences more important than aggregate (i.e., winners and losers)
  - How to make decisions using a socially acceptable decision-making framework
  - Future water needs as well as present uses and permit proposals
-



**What do we NEED to know?**

- Near shore bathymetric and topographic mapping (close interval)
  - Lake specific field studies of wetlands for lakes affected by withdrawals
  - Cross-disciplinary landscape ecology integration
  - Concentration of contaminants of concern in sediments that could be dredge
  - How to bring issues/decisions together via gaming theory or other multidisciplinary decision-making processes
  - How society performs
- 

**What do we NEED to know?**

- External demands for water in the future
  - Future dependencies on Great Lakes water
  - Tech advances that will take place- water dependent
  - Details and aspects of impacts of future water withdrawals
- 

**General Discussion**

- In conflicts, some one will wind up making a decision sooner or later. May not be result that anyone anticipated or possibly wanted
  - Native peoples are becoming involved in the cumulative effects assessment process to become part of decisions being made
  - Predictive models that take view of the entire system will assist in assessing cumulative impacts
  - IJC has been a world leader in informal, non-jurisdictional decision making
  - IJC should build on its successes and cumulative impact assessment efforts
  - We need a water allocation procedure (agreed to by jurisdictions)
  - Being "multidisciplinary" is the part of the problem
  - We need to be interdisciplinary and trans-disciplinary to come together
  - Also we need to be self-disciplinary
  - Diversions and consumptive uses have been driven by economic growth - but result in costs to others and detrimental affects to the natural environment
  - A lot has been done to understand diversions/consumption; need to better understand the range of uses and impacts, and how to improve the decision making process
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## **WHAT DO GOVERNMENTS NEED TO KNOW TO UNDERSTAND AND EVALUATE THE IMPACTS OF A DIVERSION OR CONSUMPTIVE USE PROPOSAL IN LIGHT OF CUMULATIVE IMPACTS?**

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### **Conclusions**

- Need to know impacts of our decisions on other decisions
  - Don't rely on miracles (no navigation, fusion power)
  - St. Lawrence River and gulf are the natural integrators of cumulative impacts
  - Pay attention to how the St. Lawrence responds
- 

### **Conclusions**

- Countries may get hung up, be challenged, on how to make decisions on water allocation due to different social values, softer issues
  - We have luxury of 20 years or so to follow "no regrets" idea on water use
  - How do we help get buy in to Great Lakes vision from society within and outside of the basin?
- 

### **Conclusions**

- Need to make a stronger case for water conservation and limits on water consumption
  - Water deficiencies in the St. Lawrence help make the above case
  - Should have bilateral (and trilateral native peoples) involved in the assessment, evaluation and, decision-making process for water use
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### **Conclusions**

- Need a reasonable, defensive decision making process (on water allocations) that society will accept
  - Cumulative impact methodologies haven't come to grips on the "integrated" side to make effective. Socially acceptable and future looking decisions
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### **Other ideas**

- Shouldn't discount future values (uncertain) when making current decisions
- Don't differentiate between climate change. Consumptive use and diversions need to be looked at when assessing cumulative impacts

- We can't do much to counteract climate change impacts- but can address adverse impacts, water use practices, and need for a socially/politically acceptable decision process