

# **INTERNATIONAL UPPER GREAT LAKES STUDY BOARD**

## **ORGANIZATIONAL AND OPERATIONAL GUIDELINES FOR THE BASIN HYDROLOGY NBS/ NTS CLIMATE CHANGE TECHNICAL WORKING GROUP**

### **GENERAL GUIDELINES AND INFORMATION**

The Technical Working Groups (TWGs) are formed by the Board in consultation with the IJC. The TWGs are organized under specific tasks which fulfill the mandate of the IJC to undertake the studies required to provide the Commission with the information it needs to evaluate options for regulating levels and flows in the Upper Great Lakes system in order to benefit affected interests and the system as a whole in a manner that conforms to the requirements of the Treaty, and the Board shall be guided by this mandate in pursuing its studies. These studies include:

1. Examining physical processes and possible ongoing Lake Huron outflow and St. Clair River changes and their impacts on levels of Lake Michigan and Huron. Additionally, depending on the nature and extent of these changes and impacts, recommending and evaluating potential remedial options;
2. Reviewing the operation of structures controlling Lake Superior outflow in relation to impacts of such operations on water levels and flows, and consequently affected interests;
3. Assessing whether changes to the Order or regulation plan are warranted to meet contemporary and emerging needs, interests and preferences for managing the system in a sustainable manner; and
4. Evaluating any options identified to improve the operating rules and criteria governing the system.

Specific Tasks Teams (TTs) are the Lake Huron Outflow/ St. Clair River Task Team and Lake Superior Regulation Task Team (See attached “IUGLS Organization – Task Team Framework”). The following TWGs are established under the two Task Teams to provide the expert and technical support to deliver the Study:

#### **I. Lake Huron Outflow/ St. Clair River Task Team:**

1. Data Verification, Reconciliation, Collection and Monitoring;
2. Hydraulic Modeling; and
3. Sediment Studies.

## II. Lake Superior Regulation Task Team:

1. Municipal, Domestic and Industrial Water Uses;
2. Commercial Navigation;
3. Eco-System;
4. Coastal Zone;
5. Hydropower; and
6. Recreational Boating and Tourism

## III. Other TWGs which serve one or both TTs:

1. Basin Hydrology: to address net basin supply (NBS), net total supplies (NTS) and climate change issues for both Task Teams;
2. Plan Evaluation: directly linked to the Lake Superior Regulation Task Team, but could peripherally be connected to the Lake Huron Outflow/ St. Clair River Conveyance Task Team;
3. Mitigation Issues: directly linked to the Lake Huron Outflow/ St. Clair River Task Team, but could peripherally be connected to the Lake Superior Regulation Task Team.

The individuals appointed to the TWGs provide the Study Team and the International Joint Commission their expertise and support in their personal and professional capacity and not as representatives of their agencies or employers. The Board provides guidance to the TWGs directly and through the Study Co-Managers. Each TWG should, whenever possible, be composed of equal numbers of members from the U.S. and Canada, and there shall in all cases be at least one member from each country. Each TWG will have two co-Leads, one from each country. All reports of TWGs shall include any dissenting or different views within the group.

Study Board and PIAG members will be apprised of the activities of the TWG by the Task Team Co-Chairs and specifically by TWG co-Leads for those in which they have an expertise in the subject being evaluated by that TWG.

TWG members are committed to work with their specific group as a team in advising on the issues and delivering the work with which the group is tasked.

The co-Leads of each TWG, working in close liaison with the Study Managers and the TWG members are expected to provide leadership and guidance in planning and delivering the work of their TWG as defined by the Study Board Work Plan. The co-Leads will organize meetings and

conference calls; draft work plans; draft terms of reference and provide cost estimates for required work; identify suppliers and sources; draft documentation for contracts; prepare written reports on completed work; and coordinate with other TWGs.

Each TWG is expected to confirm its annual Work Plans and deliverables with the Board and Study Managers. Funding for the activities of each TWG, in accordance with its approved Work Plan, will be provided by the appropriate section of the Commission, in accordance with applicable government procedures and requirements.

Work that may be undertaken by other government agencies will be on the basis of well-identified products and deliverables, with timelines and itemized costs associated with the tasks. Such work may be according to a formal agreement, contract or memorandum of understanding as the case may justify. Such agreements will be concluded by the appropriate section of the Commission, in accordance with applicable government procedures and requirements.

Each TWG will submit a semi-annual activity report listing activities completed and products created during the reporting period in time to provide input to the Board's semi-annual Progress Report. The TWG will also submit a semi-annual report on expected deliverables that will be generated during the next period.

Each TWG should also keep abreast of the activities of the Board, TTs and other TWGs to ensure consistency in Board general procedures and guidelines, and to ensure best integration of the results of these groups towards the ultimate objectives of the Board and IJC.

## **SPECIFIC INFORMATION AND TASKS**

### Net Basin and Net Total Supplies

There are two approaches commonly used to estimate NBS. The first approach, which is called the component method, derives NBS using a water balance of the components of the hydrological cycle. The second method, called the residual method, is more indirect and is based on change in storage of the lake. As part of the scope of work, consideration should be given to investigate alternate techniques for estimating components of the hydrologic cycle. These include but not limited to grid or mesh based modelling, employing Regional Climate model as tool to deliver NBS, etc.

With the component method, NBS is computed as the precipitation occurring over the lake plus runoff to the lake from the surrounding basin, plus groundwater, plus condensation on the lake surface minus evaporation from the lake surface. Runoff to the lake by the surrounding watershed is a composite of flow from measured tributaries and estimated, ungauged tributaries. It is important to note that the runoff when measured by conventional stream gauges would reflect all upstream impacts on the available water supply including any upstream diversions, consumptive use or changes due to land use. Estimation of contribution of water from ungauged tributaries within the local basin should also take into account upstream diversions and consumptive use. The groundwater

component is not quantitatively included in most analyses of balance within the Great Lakes basin. Computing NBS by the component method requires an estimation of overlake precipitation, evaporation and condensation, which are not directly measured but can be derived using various models. For example, precipitation over the Great Lakes is typically estimated based on interpolated point measurement data from inland stations. The uncertainty associated with the estimation of overlake precipitation and evaporation has been estimated to range from 15 to 60%.

An alternative approach for estimating NBS is through what is termed “reverse routing” or the residual method. Reverse routing is a mass balance of streamflow entering and leaving the system plus or minus any changes in storage on the local lake. Recorded amounts of the diversions into and out of the lake, and estimates of consumptive use can be factored in when calculating the net basin supply. For Lakes Michigan-Huron, NBS by this method is computed as the change in volume of water in storage on Lakes Michigan-Huron plus the outflow through the St. Clair River, plus out-going diversions and consumptive use, minus the outflow from Lake Superior. Outflow from Lakes Michigan-Huron is derived using hydraulic ratings which correlate water levels and river flow. The inflow from Lake Superior, through the St. Marys River is determined as the summation of recorded flows through each of the different structures at Sault Ste Marie. Ideally, the change in water storage in a lake is determined by knowing the surface area at various elevations; however in the case of Lakes Michigan-Huron a constant lake surface area is used. Rating equations are subject to error usually less than 5% of the flow value, while the stage or elevation of the lake is an average reading of a number of representative water level gauges within the combined lake system. Determining the lake-wide average level is subject to measurement error, and readings over a period of two days from a network of gauges are used to determine lake-wide end-of-month levels.

Care must be taken when comparing estimates of NBS derived using the component or residual method due to the different way diversions and consumptive use may be handled in the computation. Any analysis or comparison of NBS values must take these differences or limitations into account. For example, the interpretation of trend analysis of NBS series needs to reflect upon the possible shifting patterns of consumptive uses and land use within the entire basin and the quality/quantity of available source data over time. A water balance over the local basin would be required to accurately account for components of the system, namely precipitation, runoff, groundwater, diversions, consumptive use and evaporation, recalling that either measured or model-derived estimates of runoff should represent human-impacted runoff for the tributary basins. A separate analysis of each component is also required to better understand what may be changing and why within the hydrological cycle.

The net total supply (NTS) to Lakes Michigan-Huron is the amount of water over unit time that is being supplied to the lake from the local basin, basically its NBS, and outflow from Lake Superior. NTS could be derived using both the residual and component methods. Once again, care must be taken when dealing with diversions into or out of the basin, namely the Long Lac, Ogoki and Chicago Diversions. When performing water

balance study, one can either include the diversions as tributary inflow and outflow, or as separate components in the derivation of their values for NBS and NTS. Consistency is critical in the determination of NBS and NTS taking into consideration their intended use.

Outflows from Lake Superior are included in the estimate of the Lakes Michigan-Huron NTS which has influence on their levels. The outflows from Lake Superior have been fully regulated since 1921, with changes in the regulation policy being implemented over time. An adjustment for the variation in regulation policy is required to create series that facilitate analysis for patterns and trends.

Should NTS to Lakes Michigan-Huron be increasing or decreasing over recent time, there would have been a corresponding change in water levels. Changes to the characteristics of the outlet could also influence the lake's response to changes in NTS. Outflow from Lakes Michigan-Huron is governed by the lake level at the outlet. The NTS and the amount of water taken from the lake by diversions and consumptive use over the time period impact upon the levels of Lakes Michigan-Huron, and consequently influence the downstream river conditions and flows of the St. Clair River.

Effort is required to obtain improved estimates of outflow and inflow via diversions and consumptive use over the basins. These estimates will be of use to improve estimates of NBS and NTS for the system and to enhance knowledge of the water budget within the system. These data would also be used to assess their impacts on upper Great Lakes water levels and outflows. Changes in the amount and timing of these diversions and consumptive uses need to be analyzed as well to look for trends over time and to ensure that they have been appropriately reflected in the estimate of supplies to the lakes during the last 100 years.

A modeling environment that mathematically depicts water balance, the hydrological cycle, lake response and hydraulic routing is required to describe the causal relationship amongst the physical conditions of the system, as well as hydrometeorological factors and their feedback effects. A water balance or hydrological model is required for the Lakes Michigan-Huron and Lake Erie basins to establish net input to the lakes that Upper Lakes reflect impacts of diversions, consumptive uses, overlake precipitation and evaporation, gauged and ungauged tributary runoff to estimate NBS and NTS. Lakes must be connected via hydrodynamic models that can adequately reflect historical as well as current conditions.

One modeling effort of particular interest is the on-going activities in support of the Coordinated Great Lakes Regulation and Routing Model (CGLRRM) (CCBGLHHD, 2004). The model was designed to test the performance of various Lake Superior regulation plans and was not designed to recreate historical water levels. This model computes average monthly levels and outflows for the upper Great Lakes system through Lake Erie, given historical or simulated water supplies and using existing or modified regulation plans. A limitation of the utility of the existing model for the proposed study

of the St. Clair River is that a constant physical Lakes Michigan-Huron water level to outflow relationship is assumed to apply for the entire simulation period, although the effects of ice and aquatic weed-growth resistance on flow can vary with time. The model can not progressively reflect channel modifications or changes to diversions and consumptive use losses that have occurred discretely or continuously over time. As well, computational methods are not able to “reflect short-term hydrodynamic effects such as wind setup, ice jams, etc.” An assessment should be performed to establish if shorter computational time periods are required and what modifications to the model are required to enhance its capabilities for analytical purposes of the study.

The CGLRRM is a rather simple hydrological “routing” model and is useful for generating water levels and flow data for the upper lakes under various assumptions such as Lake Superior’s pre-project outlet conditions, the present or other outflow regulation plans, or the addition of Lakes Michigan-Huron and/or Lake Erie outflow regulation. Since it is a water-balance model, it can evaluate the impacts on lake levels due to diversions and consumptive uses given net basin supply. The eventual modeling environment should be designed to allow a simulation that accurately reflects historical and potential future physical and climatic conditions as well as scenario playing to establish response sensitivity to existing or hypothetical conditions. An important limitation may lie in the lack of historical data that may be available upon which to condition models.

A number of modeling activities are required. Some of these include:

- Investigate abilities and suitability of the CGLRRM or other available models for this overall effort. Define modifications or approaches that should be undertaken to develop a modeling environment/system that suitably represents the physical system using appropriate time domains. Undertake modifications to the CGLRRM or other available models that would be suitable to achieve the desired system. This system would be used to facilitate modeling within the study.
- Improve upon the estimation of ungauged tributary inflows, overlake precipitation and lake evaporation, subsequently revising estimates, as required, to improve their accuracy and reliability.
- Review for accuracy and consistency and update, if required, water level and flow data used in computation of NBS and NTS. Review the approaches to computing NBS for each major basin to ensure factors such as diversions and consumptive use are consistently reflected in the estimates. Develop consistent NBS and NTS series as input to the modeling system and for analytical purposes.
- Review of historical NBS and NTS and their component and residual parts for patterns over time.
- Trend and shift analyses of water levels, NBS, water cycle components, etc. should be performed if visible patterns are discernable.

## Climate Change

The climate of the upper Great Lakes basin has a great impact on the requirements and effectiveness of the Lake Superior outflow regulation plan. Net basin supply is a function of climate. Over the long term, the net basin supply received limits the amount of water that can be stored in or released from a lake. The net basin supply has had historical variations on many timescales. Periods of higher and lower water supplies will undoubtedly occur in the future due to the natural variation in climate, with and without the effects of anthropogenic increases of greenhouse gases in the atmosphere. To design a regulation plan that would be more useful under a wider range of supplies, consideration would be given to generating hydrological sequences based on the statistical properties of existing historical supply using, for example, a stochastic approach as was done in the International Lake Ontario – St. Lawrence River Study.

A qualitative assessment of changes due to demographic and other possible factors, such as consumptive uses, would be made to illustrate how such changes may affect water supplies and related hydrological factors. Alternative basin supplies could then be routed through the hydraulic model to determine the impacts on levels and flows.

Lake Superior Regulation Plan 1977-A was developed and tested using 1900-1986 historical water supplies to Lake Superior and the downstream lakes, adjusted to certain assumptions concerning water diversions and outlet conditions of the downstream lakes. Since 1986, more extreme supplies have been recorded. These include the rapid decline in the water supplies in 1987-1988, the very high supplies of the mid-1990s, and the very low supplies that began in the late 1990s and have continued through current times. Among the first steps in this study would be the review and updating of the historical water supplies through to the most recent available year and defining other basic parameters in the modeling environment such as diversions, outlet conditions, and ice and aquatic growth impacts on flows. Some of this work may have to be revisited if it is found that significant changes in the St. Clair River flow capacity have occurred in recent decades.

Climatic factors contribute to the variability in the levels of the Upper Great Lakes. The utility of observed time series of lake levels has been enhanced by the use of a 50,000-year stochastically generated time series of net basin supply having statistical characteristics similar to those of the observed time series. This is a useful method for synthesizing time series of net basin supply to test the robustness and performance of a regulation plan under a wide array of plausible supply conditions. These series can also be applied for calculating the frequency of exceedence of various lake levels under scenarios corresponding to experimental outflow regulation plans. Work done for the International Lake Ontario – St. Lawrence River Study would be directly applicable here. In that study the equivalent of 50,000 years of NBS sequences for each of the upper lakes were generated and routed to create the NTS series for Lake Ontario. These data could be used directly in the Upper Lakes Study.

Additional analyses would also be undertaken making use of, and possibly extending, the application of climate change general circulation models (GCM) to estimate future supplies to the Great Lakes. The future supply scenarios that were generated for the

upper lakes as part of the International Lake Ontario – St. Lawrence River Study could be directly applied for this study, but consideration should also be given to generating new scenarios based on more current GCM and Regional Circulation Model (RCM) results should they be available. RCMs provide potentially higher resolution output, which may be more physically representative of the Great Lakes geography, leading to more accurate results, however at the time of the Lake Ontario – St. Lawrence River Study, even these models did not account for lake-atmosphere interactions.

Rather than assessing variability as depicted by general circulation models (GCM), it might be more fruitful to attempt to gain greater understanding of the long-term variability of the past, whose modes might be extended into the future. This includes the relationship between climatic variables and lake levels at time scales from a few years to a few decades and an understanding of the manifestations and causes of common variability of climate and lake levels at timescales of a few years to several decades. The long-term modes of variability involve regimes of wet-cold, wet-warm, dry-cold, and dry-warm conditions, which are connected to large-scale, persistent atmospheric circulation patterns. These circulation anomalies have been characterized by teleconnection indices, such as El Niño Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), the Pacific Decadal Oscillation (PDO), and others. Empirical matching of combinations of the magnitudes and phases of these indices with the precipitation-temperature regime of the Great Lakes region could be carried out, leading to enhanced physical understanding of the causes of teleconnections between the climate of the Great Lakes region and foci of oceanic forcing. Scenarios of net basin supply can be generated by extension of observed net basin supply through stochastic synthesis of a long time series, and also through reconstruction of paleo-levels. Baedke and Thompson (2000) reconstructed high stand levels of Lake Michigan over the past 4700 years, which may be useful in assessing historical net basin supply, and input into a hydraulic routing model. They have demonstrated that a 150- to 160-year cycle in lake levels exists concurrently with a 30-to 33-year cycle, both of which they believe to be related to climatic factors. A similar reconstruction is pending for Lake Superior levels.

These various methods will be investigated to provide the best scenario to model future climate variability and change, and therefore not all of these approaches will be adopted in the study. The selected climate-related studies would be coordinated with hydraulic and hydrological studies, with the outputs from the climate studies being used as input to hydrological models, as well as channel routing and lake regulation models. The water levels and flows resulting from the various regulation plans and climate scenarios will be evaluated using the approach developed in the study to assess impacts on the resource groups.