DECISION MAKING SUPPORT SYSTEM FOR THE REGULATION OF THE OTTAWA RIVER BASIN

A CASE STUDY

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1. INTRODUCTION

Canada is blessed with plentiful water resources as it ranks fourth in the world for freshwater resources. Over the centuries, Canadian lakes and rivers have been used for various purposes including navigation and using the power of water for various industrial uses such as water mills that have been constructed since the 18th century. Waterpower for producing electricity started in Canada in the late 1800s with one of the first generating station built being located at Chaudière Falls on the Ottawa River. While dams had been built early in the development of Canada, larger dams for the purpose of flood control and river regulation were constructed essentially starting in the early part of the 20th century.

Over the course of the 20th century, further development of water resource infrastructures took place which included construction of more dams for water management purposes as well as larger hydropower developments to provide electricity for an increasing population.

The case study presented in this paper is related to the Ottawa River Basin, in particular to the technical work undertaken by the Ottawa River Regulation Planning Board (ORRPB) to ensure the integrated management of the flow from large reservoirs within the basin for the purpose of minimizing impacts of floods and droughts.

2. DESCRIPTION OF THE OTTAWA RIVER BASIN

2.1 Hydrography

From its source east of the Dozois Reservoir to its confluence with the St Lawrence River, the Ottawa River has a length of more than 1,130 km. The Ottawa River constitutes the principal tributary of the St. Lawrence River and for most of its length forms the boundary between the provinces of Ontario and Quebec. Its basin has a total area of 146,300 km^2, 65 percent of which is in Quebec and 35 per cent in Ontario.

The Ottawa River has a dense hydrographic network encompassing 19 tributaries of over 2,000 km^2 in area. On the Quebec side (left bank), major tributaries include the Gatineau, du Lièvre, Kipawa, and Rouge rivers. On the Ontario side (right bank), major tributaries include the Madawaska, Montréal, Blanche and Petawawa rivers (MDDELCC, 2015). The largest of the tributaries, both in terms of length and discharge volume is the Gatineau River.

The topography of the basin consists predominantly of a lowland area, largely situated in the Champlain plain, and two mountainous formations: the Laurentians on the left bank and the Algonquin dome on the right bank. Mont-Tremblant has the highest altitude (967.5 metres) and the minimum altitude within the lowlands is of approximately 40 metres.

A map of the basin is shown in Figure 1 which illustrates the watershed as well as major sub-watersheds that constitute the river basin.

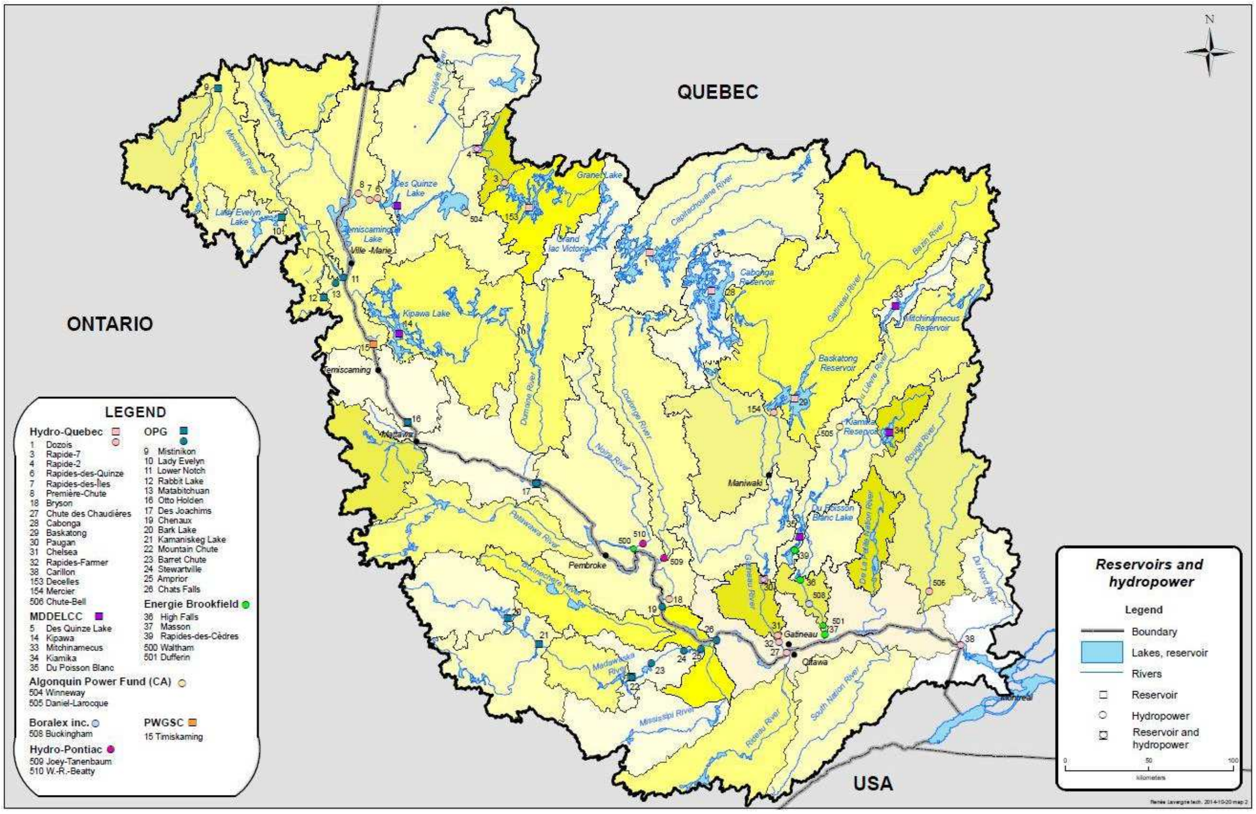

Figure 1. Map illustrating the Ottawa River Basin along with major sub-basins.

2.2 Dams/Reservoirs and Hydropower Generating Stations

The idea of using large natural lakes to store water took hold in the early twentieth century in connection with the requirement for a more uniform flow for navigation and power developments on the lower reaches of the river. This led to the construction of the Quinze, Timiskaming and Kipawa reservoirs, between 1911 and 1914, by the federal government. At that time, the Chaudière structure was the only hydropower plant on the river system.

Currently there are thirteen large reservoirs within the basin that each have usable capacities of more than 200 million cubic metres. These reservoirs, which combined have a total storage capacity of 12,115,000,000 m^3 (or 12,155 million m^3), are subject to integrated management under the ORRPB policies. Table 1 provides a list of these reservoirs along with their storage capacity, the year the reservoir was built, and the dam operator. Regulation of river flows is made possible by storing part of the river's natural runoff in these major reservoirs during spring and releasing it at other times during the year. The location of the principal reservoirs and hydro-electric generating stations is also illustrated on Figure 1.

In addition to these thirteen main reservoirs, another 14 smaller reservoirs also provide limited storage. Given the small storage capacity of these other reservoirs, they are not included in the Decision-Making Support System that is discussed in this paper.

Table 1. List of main reservoirs within the Ottawa River Basin.

River	Reservoir	Year Built	Dam Operator	Capacity (million m^3)
Ottawa	Dozois	1949	HQ	1,863
	Rapide 7	1941	HQ	371
	Quinze	1914	MELCC	1,308
	Timiskaming	1911	PSPC	1,217
	Des Joachims	1950	OPG	229
Montreal	Lady Evelyn	1925	OPG	308
Kipawa	Kipawa	1912	MELCC	673
Madawaska	Bark Lake	1942	OPG	374
Gatineau	Cabonga	1928	HQ	1,565
	Baskatong	1926	HQ	3,049
Lièvre	Mitchinamecus	1942	MELCC	554
	Kiamika	1954	MELCC	379
	Poisson Blanc	1930	MELCC	625

Note: HQ: Hydro-Québec
MELCC: Ministère de l'Environnement et de la Lutte contre les changements climatiques (Québec)
OPG: Ontario Power Generation
PSPC: Public Services and Procurement Canada

Hydropower generating stations have been constructed on the Ottawa River since the late 1800s. There are 43 hydropower generating stations located within the basin ranging in size from less than 1 MW to 753 MW with a total of over 4.200 MW (Canadian Hydropower Association, 2019). These hydropower stations represent a significant portion of the hydropower generation capacity for both Hydro-Québec and Ontario Power Generation. Other Independent Power Producers also own and operate hydropower stations within the basin. However, given the limited size of their reservoirs, they do not have a significant impact on minimizing impacts of floods and droughts in the river downstream.

2.3 ORRPB Structure

The Ottawa River Regulation Planning Board and Ottawa River Regulating Committee were established with the objective of ensuring integrated management of the principal reservoirs. Following a devastating flood in 1974, particularly in the Montreal region, the federal and provincial governments began to take steps to attempt to reduce the amount of damages incurred. Another large flood occurred in 1976, apparently increasing the efforts.

These efforts culminated with the signing of a **Canada-Quebec-Ontario Agreement Respecting Ottawa River Basin Regulation** (the Agreement), which established the Ottawa River Regulation Planning Board, the Ottawa River Regulating Committee (ORRC)and the Ottawa River Regulation Secretariat (ORRS). Various organizations that form this Planning Board include federal and provincial agencies as well as power utility companies, namely Hydro-Québec and OPG.

The role of the ORRPB is to ensure the integrated management of flows from the reservoirs listed in the Agreement and to formulate policies and criteria for their management. The Regulating Committee is tasked with enacting and formulating appropriate regulation and operational practices and procedures to ensure that operations of the principal reservoirs are carried out in accordance with the regulation policies and criteria adopted by the Planning Board. Finally, the Secretariat's role is to act as an executive arm of the Planning Board by collecting and analysing data; reporting and forecasting on hydrological conditions in the Ottawa River basin; developing and operating mathematical models to carry out the mandate of the Board; and maintaining the ORRPB website (http://www.ottawariver.ca/).

3. TECHNOLOGIES FOR INTEGRATED OPERATION OF GENERATING STATIONS AND RESERVOIRS

This section of the paper introduces the various aspects for the integrated operation of generating stations and reservoirs. This includes various steps from data acquisition (3.1), to meteorological (3.2) and hydrological modeling (3.3), and finally to implementation of a Decision-Making Support System for optimal operation of the reservoirs (3.4).

3.1 Data Acquisition

To run the various models used to assist in the management of the Ottawa River basin, a large amount of data is collected, verified, calculated and transmitted on an hourly, daily or weekly basis depending on the season.

Knowledge of water levels, discharges and snow conditions are essential to assessing basin hydrological conditions and forecasting the hydrologic response of the tributaries and the main stem of the Ottawa River. The location of hydrometric stations is illustrated on Figure 2.

In addition, meteorological data, particularly temperature and precipitation, are collected on a daily basis for use in the natural inflow forecasting model. The meteorological data available is captured from 151 meteorological stations located both within the watershed and at locations just outside of the basin. Similarly, snow survey data is measured at 79 stations within the basin. In addition to these stations, another 38 snow stations located outside of the basin are also used as part of the data analysis to describe current snow conditions in the basin. 10 GMON (Gamma MONitoring) stations are now available to better assess snowpack conditions. GMON are a new generation of sensors which gives snow water equivalent on a daily basis.

Among the data collected are the "declarations" by dam operators of their anticipated operation plan for each individual dam. These declarations of reservoir elevations or discharges represent the intent of the operators at each of the reservoirs and generating stations.

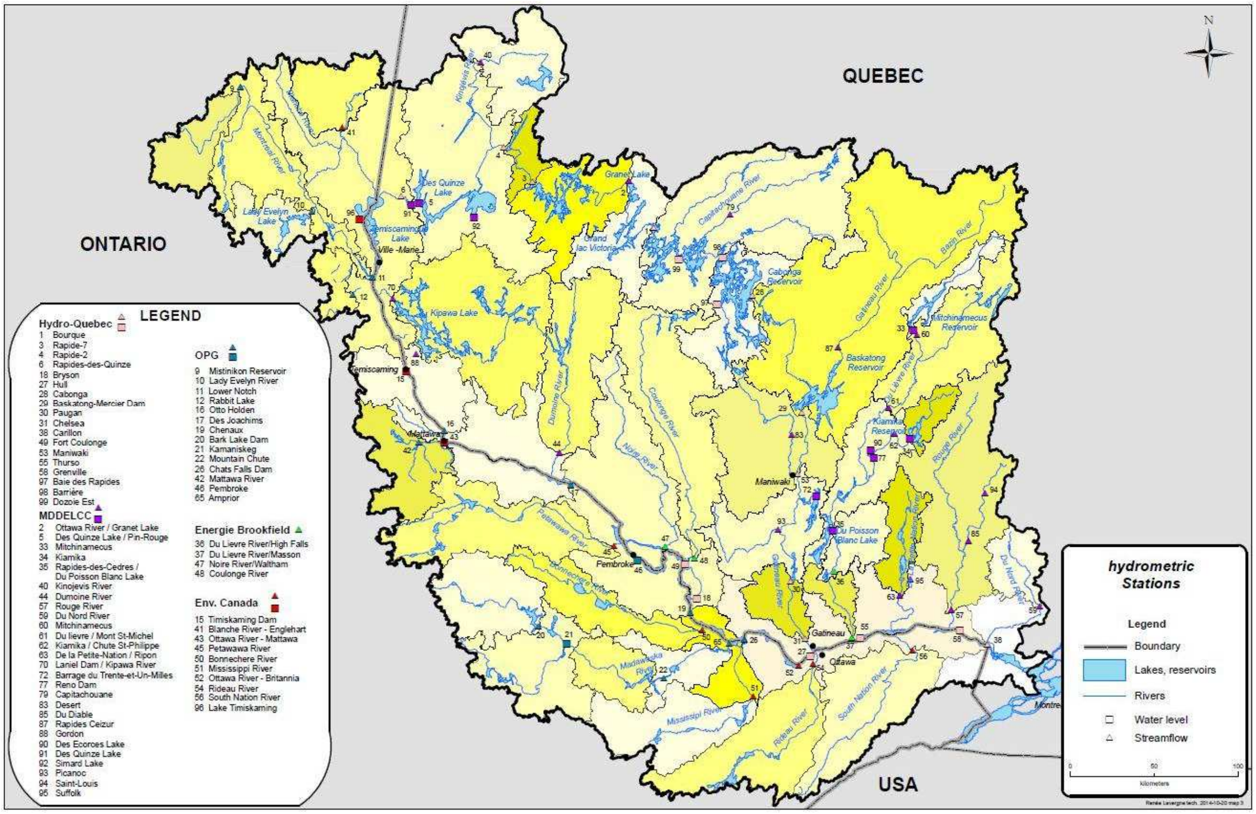

Figure 2. Location of hydrometric stations within the Ottawa River Basin.

The first step is to acquire data through real-time observations. Depending on the type of data, typically the ORRC's Members set up computerized systems to perform automatic data acquisition. The data are archived and transferred to the various tools that use them. There are four large categories of data:

a. Hydrological data include water levels, flows and water temperatures. Water levels in reservoirs are used to calculate storage, while levels in rivers are used to calculate flows through the use of rating curves. Flow data include turbine flows, spillage, and inflows. Water temperature data provide indirect information about the freeze-up and ice-melt conditions on the rivers and reservoirs.

b. Snow data include snowfall amount, snow density and snow water equivalent. The snow survey and GMON data from all partners are centralized and interpolated to produce basin averages which are adjusted in the hydrological model. Other sources of information about snow coverage are also consulted, but without necessarily being acquired formally (e.g., satellite images).

c. Meteorological data include data collected using a wide variety of conventional sensors employed in the network of synoptic meteorological stations. Since these data are inputs to the hydrological model, the main data are air temperature and measured precipitation, but also included relative humidity, atmospheric pressure and solar radiation. Lastly, data on wind speed and direction can help explain variations in measurements of reservoir water levels. Other sources of information, for example the radar imaging or Environment Canada’s Regional Deterministic Precipitation Analysis (RDPA), are also consulted without being formally collected, at least for now.

d. Electricity generation data, including the electricity (in MW) from the generating units in the plants, are used to calculate the turbine flows. This category also includes the data on floodgate openings, which are used to calculate spillage flows related to maneuvers at the facilities.

Data validation:

Once data acquisition is complete, the data must be validated. This step includes the following actions:

a. Detect missing data or outliers. When problems are discovered, the teams responsible for the equipment are contacted and repair and/or maintenance visits are planned. The validation team then follows up on those visits.
b. Correct missing data or outliers manually. Those corrections may be made daily or retroactively over a longer period.
c. Define the physical state of precipitations and separate the total amounts measured as rain and as snow (two inputs of the hydrological model).
d. Calculate the basin averages for the meteorological data and snow survey data, using the Kriging method of interpolation.
e. Calculate the inflows observed in the past few days by means of water balances or average measured flows.

Once the validation has been completed, the observed hydrological and meteorological data are ready to be used in the hydrological forecasting step. The only other input required in order to proceed with the forecast are the meteorological forecast scenarios.

3.2 Meteorological forecasting

The meteorological forecasting step is crucial because it is the source of a large part of the uncertainty inherent in any hydrological forecast. Every day, various model outputs are available to the meteorologist. Since each model “sees” the physical world in its own way, the forecast scenarios produced by different models are sometimes similar but may also sometimes be very different.

The current meteorological forecasting procedure is as follows:

a. Analysis of the current and past meteorological context. The meteorologist compares the output of the model with the observations from the previous day and the first six hours of the day.
b. Analysis of the future meteorological context. The meteorologist compares the output from the deterministic models—Canadian (GDPS and RDPS), American (GFS and NAM), and European (ECMWF)—as well as the North American Ensemble Forecast System (NAEFS).
c. Construction of meteorological scenarios. Based on the previous analysis, the weather grids will be modified to a resolution of 1° to obtain the most likely weather scenario for probability of

exceedance. Three grids—total precipitation, minimum temperature and maximum temperature—are modified, using the time-steps in the Canadian models, i.e., 6-hour time-steps for the first 48 hours and 12-hour time-steps for the following days. The type of precipitation is determined automatically based on a temperature threshold. Also during this step, depending on the level of certainty and the hydrological context, the meteorologist will decide on the forecast horizon, which can vary from 4 to 9 days.

d. Based on the grids, an interpolation is performed and the averages are calculated for all the watersheds. Lastly, to assess uncertainty, weather scenarios for 85% and 15% probability of exceedance are constructed based on daily spread of the 40 members of the ensemble forecast (NAEFS).

3.3 Hydrological forecasting

HSAMI is the operational hydrological model used within the ORRC. It was developed at Hydro-Québec (Bisson and Roberge, 1978) and is a global conceptual model that was modernized about 15 years ago (Fortin, 1999). The term “conceptual” means that the physical processes within the model are approximated using empirical relationships rather than the laws of physics. The term “global” means that the watershed is represented as a single, homogeneous spatial entity. Thus, the spatial variability of the processes is not explicitly taken into consideration. For example, a global model does not differentiate between rain that falls in the upstream portion and the downstream portion of the watershed. A global conceptual model is simpler but less demanding in terms of data entry and calculation time.

HSAMI uses the following inputs: daily minimum and maximum temperatures, rainfall and snowfall. Figure 3 shows the interactions between the different processes within HSAMI. Precipitation falls either on the ground or into the reservoir. Then, depending on soil saturation and ground frost conditions, the water may accumulate on the ground as snowpack, infiltrate vertically into the sub-surface soil or flow horizontally via the surface runoff hydrograph. With vertical infiltration, the water recharges the aerated zone and the saturated zone, and is then routed through the intermediate hydrograph and the base hydrograph, respectively. At the same time, the evapotranspiration process removes water from the snow cover, the soil surface, the vegetation and the surface of the reservoir and returns it into the atmosphere in the form of water vapour. Lastly, the natural inflows are defined by the sum of the three discharge hydrographs (surface, intermediate, and base). In HSAMI, the physical processes and their interactions are governed by parameters which are set during calibration of the model. HSAMI contains 23 parameters: 2 for evapotranspiration, 6 for processes involving snow, 3 for surface runoff, 7 for vertical infiltration, and 5 for horizontal flow.

Before it can be used in an operational setting, the model must be put through the calibration process, and the calibration must be done independently for each watershed. The purpose of the calibration is to ensure that the model reproduces the hydrological behaviour of a watershed as accurately as possible based on past observed data. To perform the calibration, daily series of minimum and maximum temperatures, precipitation (rain and snow) and calculated or measured inflows are taken over a common period are required.

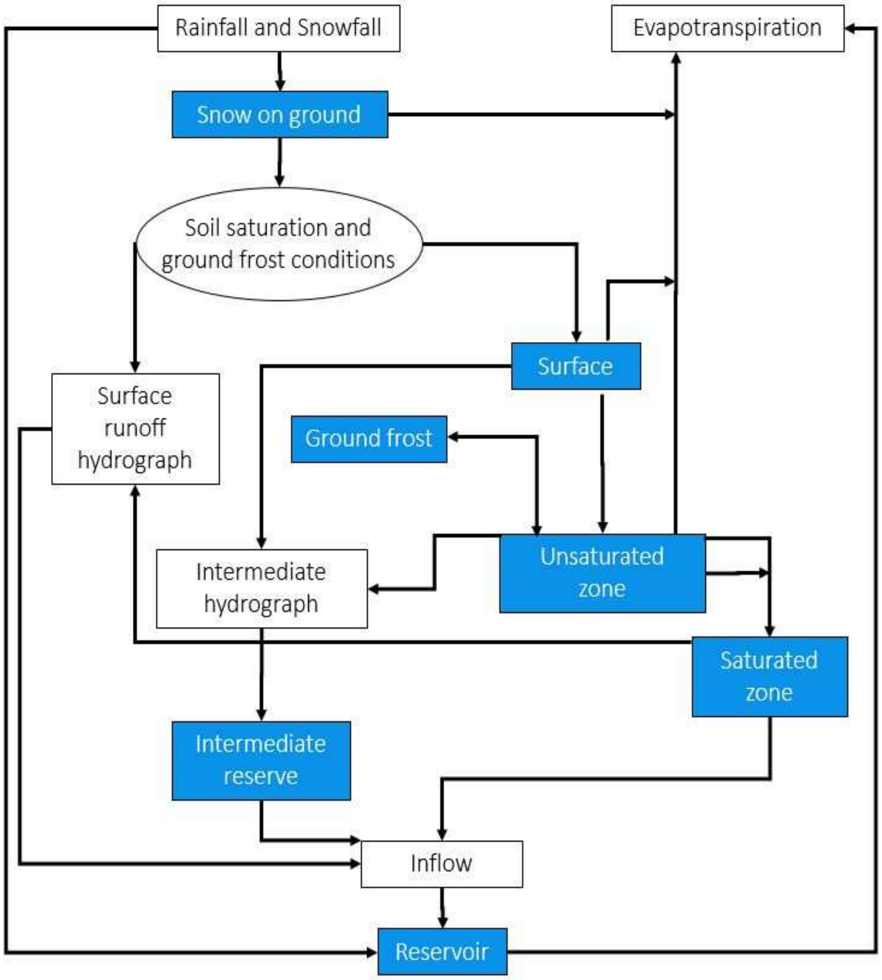

Figure 3. The HSAMI conceptual model (Fortin, 1999)

3.3.1 Calibration procedure for the hydrological model

Since HSAMI includes 23 parameters, they can be combined in thousands of ways. An iterative process is applied to find the best solution (best performance). The best solution is considered to be the combination of parameters that maximizes the Nash–Sutcliffe efficiency (NSE) coefficient on an annual basis.

$$C_N = 1 - \frac{\sum_{i=1}^{n} \quad \left(Q_{obs,i} - Q_{sim,i}\right)^2}{\sum_{i=1}^{n} \quad \left(Q_{obs,i+1} - \underline{Q}_{obs}\right)^2}$$

where:

$Q_{obs,i}$	is the inflow observed on day *i*
$Q_{sim,i}$	is the inflow simulated on day *i*
$Q_{obs,i+1}$	is the inflow observed on day *i+1*

$\bar{Q}_{obs}$ is the average inflow observed over the entire series

By definition, the NSE overemphasizes large inflows, which means that the model will be calibrated to reproduce the spring freshet as accurately as possible, to the detriment of, for example, low-water periods in summer or the rapid response following an autumn rainfall on saturated soil. However, other criteria may be used to calibrate the model to make it perform better under different conditions.

Calibration is an important exercise, because the behaviour of the model in operational mode will depend on it. Obviously, the better the quality of the data used for the calibration, the better the model will perform. The better the model is calibrated, the fewer manipulations the forecaster will be required to perform during the inflow forecasting procedure. Better calibration means (i) greater confidence in the forecast and (ii) shorter time required to produce the inflow forecast (see section 3.3.1).

At this point, everything is in place to enable production of the hydrological forecast—the heart of the process. The observed raw meteorological and hydrological data have been acquired, validated and interpolated to watershed scale. The deterministic meteorological prediction is ready, and it too has been brought to watershed scale. The calibrated hydrological model, the hydrologist's most important tool, is also ready, since all the data required for inputs has already been incorporated into it.

In an ideal world, the hydrologist would have a perfect model to work with that would reproduce the behaviour of a watershed exactly. That perfect model would itself be fed by data collected from an infinite network of measuring stations. In the ideal world, the hydrologist would have no work to do.

Obviously, reality is not ideal, and there are many sources of uncertainty: (i) the equations used in the hydrological model to reproduce the physics of a watershed are approximations; (ii) water level and flow measurements used to calculate observed inputs are sometimes missing and often noisy; (iii) the meteorological observations come from an insufficiently dense network of stations, which propagates spatial measurement errors during interpolation, thereby skewing the basin averages; and (iv) meteorological forecasting is not an exact science, particularly with longer forecast horizons. There are many sources of uncertainty, and the hydrologist's work consists mostly of comparing, evaluating, criticizing and integrating multiple sources of information before being able to produce the different inflow forecast scenarios.

In greater detail, the inflow forecasting procedure is as follows:

a. Quantify the evolution of the hydrometeorological situation. Quantify the differences between (i) the observed weather and the forecast made the previous day; (ii) the forecast made the previous day and the one made today; (iii) the series of inflows observed the previous day and today; and (iv) the observed inflows and the inflow forecast from the previous day, and (v) analyze the inflows of the previous few hours.
b. If necessary, verify and compare the meteorological forecast scenarios with the other model outputs. .
c. If necessary, when the observed inflow data appear to be incorrect, question the data validation team to identify potential undetected problems.
d. If necessary, search the historical database for events with similar conditions (observed inflow amounts, weather conditions, time of year, amount of snow on the ground, etc.). Similar hydrometeorological events help the hydrologist to better anticipate the hydrological reaction of a watershed to forecasted meteorological conditions.

e. Simulate the three inflow forecast scenarios with the aid of the hydrological model. The three scenarios are “low” (85% probability of exceedance), “medium” (50%) and “high” (15%).
f. If necessary, if the results of the simulation are unsatisfactory, adjust the forecast scenarios to obtain the desired results. Depending on the situation, the watershed and the hydrologist’s experience, the adjustments could involve:
    (i) modifications to observations or forecasts;
    (ii) a change in the date when the inflow forecast scenarios will merge with historical inflows;
    (iii) changes to the differences between the three scenarios (based on the noise in the initial conditions and/or the hydrometeorological uncertainty to come); and/or
    (iv) direct disturbance of the model’s state variables (e.g., reduction in snowpack or lowering of the water table elevation). All these adjustments to the model take time and therefore lengthen the total duration of the forecasting procedure. A well-calibrated model applied to a watershed with high-quality data will require fewer adjustments, and the forecast will be quicker to produce and have a higher level of confidence. Hence the importance of improving the network of measuring stations, the methods of calculating inflows, and the physical processes of the model and the techniques for calibrating it.

Since forecasting is used both to ensure the safety of the facilities and to optimize production, communication between all the stakeholders is essential. For example, it helps to be familiar with the condition of the measuring station network in order to be better able to judge the data and reduce the risk of being misled by outliers. In addition, the hydrologist may inform the hydrological system manager of the level of certainty/uncertainty for each watershed, which could influence the type of strategy to adopt. In the case of the ORRC, communicating the inflow forecasts for each sub-watershed, together with the level of certainty/uncertainty, is just as important, especially when protection of the public and facilities is involved.

3.4 Decision-Making Support System

This is a brief description of the HEC-ResSim model and its application in the operation planning of the Ottawa River system. For regulation planning of the Ottawa River system, the watershed model component of the HEC-ResSim model is omitted since the natural inflow forecasting model, HSAMI produced by Hydro-Quebec, is currently used. Output from the forecasting model HSAMI is fed into the HEC-ResSim model for use in the other two components, namely the flow routing and reservoir operation.

The model must be provided with a pre-specified operating plan (water levels or discharge declaration by operators) in order to route flows through storage reservoirs and eventually through river reaches.

The HEC-ResSim model was developed by the U.S. Army Corps of Engineers and is the next generation of model replacing the SSARR model. The SSARR model had been used by the ORRC ever since the creation of the ORRPB in 1983 and previously by the ‘ad hoc’ operating committee in the 1970’s but was replaced by the HEC-ResSim model in January of 2016.

3.4.1 The River System Model

This section gives a brief description of the parts of the HEC-ResSim model that are used for Ottawa River regulation, namely the channel and lake routing procedures and reservoir operation.

i) System Configuration

A schematic representation of the HEC-ResSim model for the Ottawa River basin is shown in Figure 4. As shown in the figure, the Ottawa River basin is conceptualized as forty-six watersheds that contribute runoff (or natural inflows) in specific locations along the physical river system. Starting in the headwater areas, natural inflows are routed and summed up along the physical river system, down to the basin outlet at Carillon dam.

For routing purposes, the physical river system is reduced to a set of interconnected stations of which there are three types. Transfer points are simply nodes in the system through which no routing is done. They typically serve to sum the flows from different branches of the river and as convenient point to introduce measured data. Flows are routed through the two remaining station types: reservoirs and reaches. Combinations of these three station types are linked together for the purpose of computer simulation.

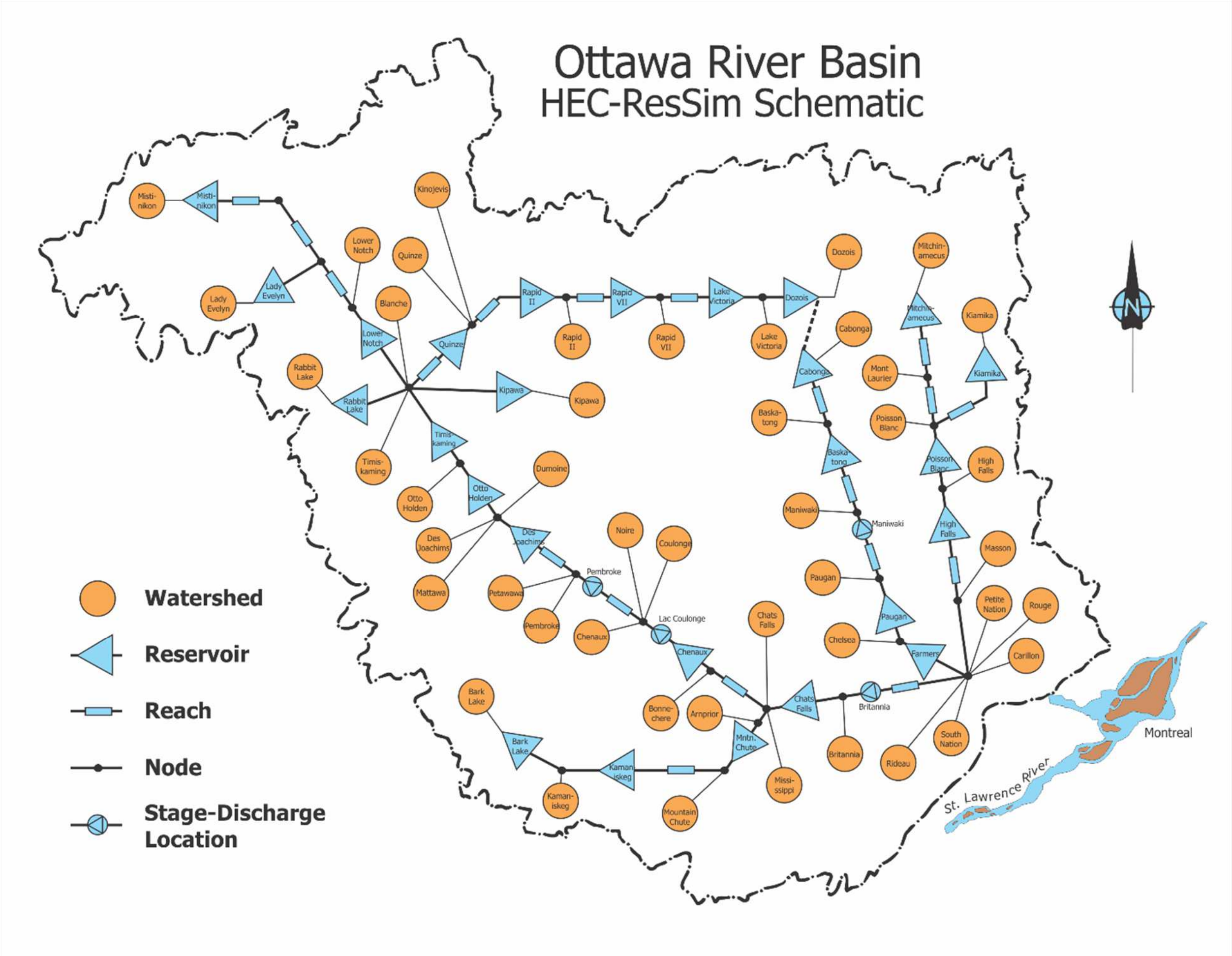

FIGURE 4. HEC-ResSim Schematic of the Ottawa River Basin.

ii) Channel Routing

Reaches are defined as sections of the river system where there is significant travel time (related to the modelling period) and where there is a routing effect on changes in discharge. The HEC-ResSim model uses a time-honoured method for streamflow routing that assumes that a reach is divided into a number of increments, each of which are considered to act as a small lake. For each phase or increment, the basic continuity equation is used in the form:

The basic routing method depends upon the equation of continuity manipulated to the form:

$$O_2 = \frac{I_m \quad O_1}{T_s + t/2} .t + O_1$$

Where:

O_2	the outflow at the end of the computation;
O_1	is the outflow at the beginning of computation;
t	is the time of the computation period;
I_m	is the mean inflow; and
T_s	is the time of storage

Time of storage is constant for the reach (each routing phase has the same Ts value) and is computed as a power function of discharge by the following equation:

$$T_s = KTS / Q^n$$

Where:

Ts	is the time of storage per increment in hours;
KTS	is a constant:
Q	is the discharge in cubic feet per second (option of using SI system);
n	is a coefficient usually between -1 and 1.

Outflow from each increment is used as inflow to the next downstream increment and the step by step procedure is completed for each increment for each time period.

The number of increments for a given length of channel may differ for different streams. In the Ottawa River system, satisfactory results were obtained by having increments of about 10 km.

The three routing parameters in the HEC-ResSim model are KTS, n and the number of phases and these vary upon the river reaches where KTS values range between 7 – 73 (median value of 13); n is typically 0.2 (varies between 0.18 – 0.5) and number of phases vary from 1 – 11 (median value of 4).

iii) Lake Routing

The routing of flow through natural lakes is based upon free flow conditions in which the lake outflow is determined by lake elevation and therefore by hydraulic head (rating curve). Routing is accomplished by an iterative solution of the storage continuity equation.

iv) Reservoir Operation

The HEC-ResSim model offers three methods of simulating reservoir operation. Free flow routing assumes that elevation outflow relationships are fixed and that outflow is determined by hydraulic head (rating curve). Routing is accomplished by an iterative solution of the storage continuity equation. If time of storage (Ts) values are input as a function of either flow or elevation, the initial estimate for the outflow is obtained from equation of storage continuity. Otherwise, the initial outflow (O2) is assumed to equal the outflow at the beginning of the period (O1). An outflow value (Qt) is then calculated using the storage equation given the elevation storage relationships that are entered into the computer in tabular form. The Qt value is then tested and the calculation is repeated until an acceptable outflow is obtained.

Manual control of reservoir outflow can be simulated by specifying discharge at particular points in time. Five variables can be controlled in this way: outflow, elevation, storage, change in elevation and change in storage.

The values specified may be evenly spaced throughout the simulation period or set sporadically at uneven intervals. The program uses linear interpolation in generating a value for each computational interval. Another option allows the user to specify an operating policy in terms of discharge as a function of reservoir elevation and inflow. If no specifications are made, outflow is computed equal to inflow. The specifications are met unless violations of reservoir characteristics occur.

For example:

a. the reservoir cannot be emptied below its lower bound;
b. discharge cannot exceed that obtained from the elevation discharge relationship of the control structure;
c. when the reservoir elevation exceeds the upper bound, outflow will be computed by free flow routing or the reservoir will pass inflow if no elevation discharge relationship (rating curve) is given.

v) Input of the Model

For the forecasting operations, the model requires the following input:

<u>Watershed discharges provided by the natural inflow forecasting model HSAMI</u>: The watershed discharges are converted to the HEC-ResSim model format and then referenced to transfer points. The forecasts used are generally the most probable (50% probability) but can be varied depending on the use (e.g. sensitivity analysis).

<u>Statements of future reservoir operating policy during the forecast period</u>: These statements are based on each agency's operating policy. The declarations of elevation or discharge represent the intent of the operators at each of the reservoirs and generating stations for the two forecast periods.

<u>Changes to bounds for reservoir levels and discharges or changes to any other constraints:</u> All constant or parametric input needed for the operation of the model is built in. The input includes the various physical and operating constraints, the curves that express storage elevation relationships of reservoirs, storage discharge relationships of spillways and channel characteristics.

vi) Initialization of Channel Routing

When the HEC-ResSim model is run it takes into consideration the previous six days of observed data including calculated inflows, discharges and levels in the system for computing channel routing.

vii) Output of the Model

The output consists of daily or weekly average discharges and water levels calculated at midnight for every daily or weekly period at every specified station applicable to the period of simulation. Note that levels are not provided for a transfer or reach station unless a stage discharge curve for that particular section of the river has been incorporated into the model database. The model currently has four stage-discharge curves, which allows for estimation of water levels at Pembroke, Lac Coulonge, Britannia and Maniwaki.

3.4.2 Sensitivity Analysis

The ORRC uses sensitivity analyses in various situations to check on the reaction of the system to inflows other than the standard 50% probability of exceedance. It is made possible by the ability of the natural inflow forecasting model to produce forecasts of various probabilities, both in terms of volume and peak.

The forecast used for the normal model runs of HEC-ResSim is based on volume and peak with a 50% probability for each inflow site. At times, depending on the situation, it may be useful to see what would happen if the inflows were higher or lower than normal. For example, if there were a particular part of the basin where there was concern that higher than normal inflows would result in a critical situation, the models could be run with a 15% forecast for that section and, perhaps, 50% for the rest of the system.

Sensitivity analysis is used in a wide variety of situations (flood/drought) and it has been the practice of the ORRC to use it whenever requested by the entire Committee or by a single agency concerned about one of their particular sub-systems. The results of sensitivity analysis are standard Short and Mid-Term HEC-ResSim and are made available to all member agencies. If after reviewing the results of a sensitivity analysis, one agency decides to modify its declarations, then HEC-ResSim is run again with the new proposed declarations, and the revised Short and Mid-Term HEC-ResSim results are made available.

3.4.3 Sharing of model results

All the models for the ORRC, with the exception of the natural inflow forecasting model, are currently run at the Secretariat. These models are run after the relevant data and forecasts are received from the participating agencies and the results are posted on the Ottawa River Regulation Secretariat FTP site. The format of the model results has been developed and refined over the years to satisfy the needs of the ORRC. Results of the HEC-ResSim Short-Term and Mid-Term models as well as any sensitivity analysis are posted on the ORRS FTP site. Also posted on the FTP site is a weekly report that summarizes the status of the basin.

Snow survey data from different agencies are compiled in a table and presented on a map of the basin indicating the snow cover in water equivalent and in terms of percentage of normal, all posted on the ORRS FTP site.

The results of the models are currently made available to all agencies represented on the Planning Board and the Great Lakes-St. Lawrence Study Office in Cornwall. However, the sensitivity analysis results are only available to the ORRC. This is mainly to ensure that outside agencies do not mis-interpret the output of these models.

The ORRS FTP server is an internet based communications system that allows uploading and downloading of files such as measured data, forecast and model result files. Access to the ORRS FTP server is limited to agencies involved in the regulation of the Ottawa River and those that use the model results for information purposes.

For most Agencies the short-term HEC-ResSim model is a very important tool for decision making. Indeed, for some, this model represents the only hydrologic forecast available. In order to review model results and facilitate planning within the Regulating Committee multiple conference calls are typically held during the freshet period. The Members discuss current and forecast conditions and determine appropriate reservoir management.

4. DISSEMINATION OF FORECAST RIVER CONDITIONS TO GOVERNMENT AGENCIES AND THE PUBLIC

The hydrological forecasts that are generated as part of the integrated management of the reservoirs are made available by the ORRC to governmental agencies that are involved in the issuance of flood-related messages and emergency response.

The Planning Board uses its website (www.ottawariver.ca) as the main tool for issuing hydrological forecasts to the public. Current and forecast conditions on the Ottawa River along with conditions at the major reservoirs in the system are available on the website. A general four-day forecast is also provided at key locations within the basin during the spring freshet period or other high water events.

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