Lake Ontario Regulation Plan C: Local-Basin Approach

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1) INTRODUCTION

Lake Ontario is the lowest lake of the Great Lakes cascading system in North America (Graph 1). Currently, the lake is regulated by the International St. Lawrence River Board of Control (www.istrbc.org) under Regulation Plan 1958 D. Since the plan's inception, the lake has experienced several extremely high and low (inflow) supply events. As a result, the plan outflow had to be deviated in order to control the lake level and outflow within a desirable range. The recorded lake outflow and level is referred to as "Plan 58D with Deviation" (Plan 1958DD) outflow and level.

Because of the need for deviations in the current plan to handle extreme inflow events, and to better accommodate a greater range of interests, a review of the existing regulation plan was initiated in 2000. Plan C (Local-Basin Approach) was one of a number of plans that were presented to the International Lake Ontario–St. Lawrence River Study Board in early 2005. The final version of the plan was submitted to the Board in August 2005. (A full description of the Study Board is available at the International Joint Commission-IJC web site: www.ijc.org).

Graph 1

2) OBJECTIVES

Plan C was developed to enhance the current environmental, social and economical benefits in Lake Ontario and the St. Lawrence River System. The design of the plan is guided by the following general water management and environmental objectives:

a) Water Management Objectives:
   i) Maintain a planned outflow ranging from 5000 m^3/s to 9500 m^3/s, and a lake level ranging from 74.15 m. to 75.37 m. Any outflow or level outside of these ranges may cause significant social and economical loss to various users of the system. A brief review of the historical record indicates that the most practical lake level range is from 74.00 m. to 75.70 m.
   ii) The planned outflow should be stable, predictable, and able to react to the change of supply condition quickly.

b) Environmental Objectives:
   i) Increase the current wetland and biodiversity of the lake by expanding the current lake level range; this may cause significant loss to the current users of this lake-river system, and is not considered in Plan C.

   or

   ii) Enhance the current wetland and biodiversity by regulating the lake level as close to its local-basin supply (Local Natural Flow Regime) as possible; this enhancement may not have any negative impact to the current users of this lake-river system, and is the basis of design for the Local-Basin Approach.

3) LAKE ONTARIO (INFLOW) SUPPLY REVIEW:

Plan C attempts to meet the plan design objectives based on Lake Ontario's supply characteristic. Lake Ontario's supply comes from two sources: local-basin supply and upstream supply (Lake Erie outflow):

a) The local-basin supply (Figure 1) is unregulated and natural, and has high seasonal variation. The local natural flow enhances the biodiversity and ecosystem health of the lake (under the local natural flow regime). A near-natural lake level fluctuation (or the natural cycle of the lake) can be generated from the local-basin supply pattern, however, local-basin supply makes up about 15% of the Lake Ontario's total supply (Figure 2), and is relatively unpredictable and inaccurate as a predictor of total supply (Figures 3 & 4).

Lake Ontario Quarter Monthly Supply Summary (1900-2000)

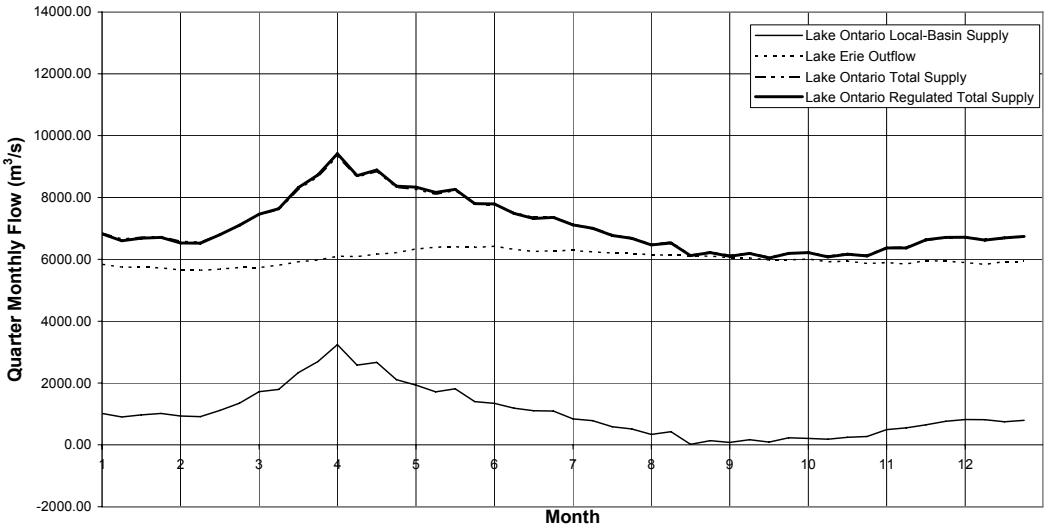

Figure 1

Lake Ontario Average Annual Supply Summary (1900-2000)

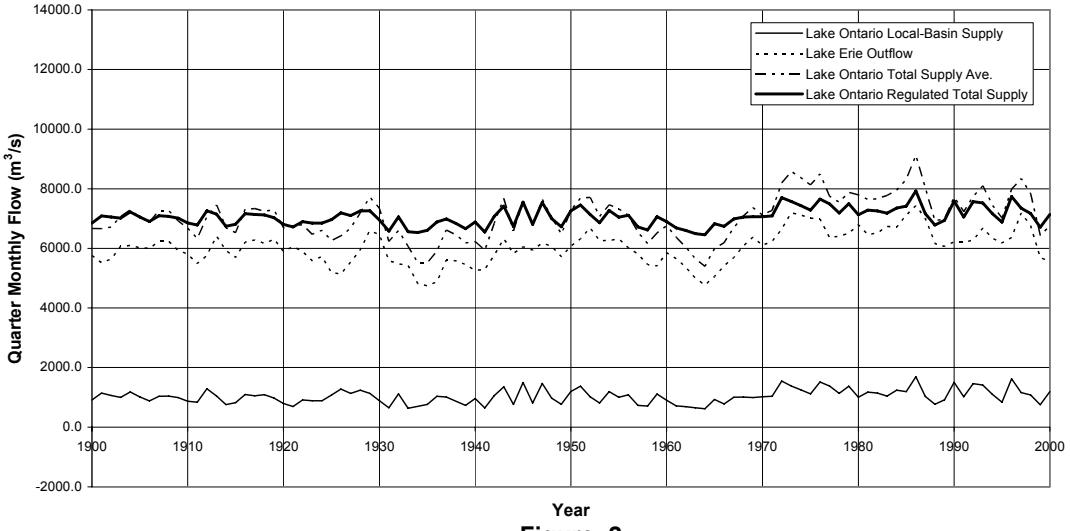

Figure 2

Lake Ontario Inflow (Supply) (1962 - 1964)

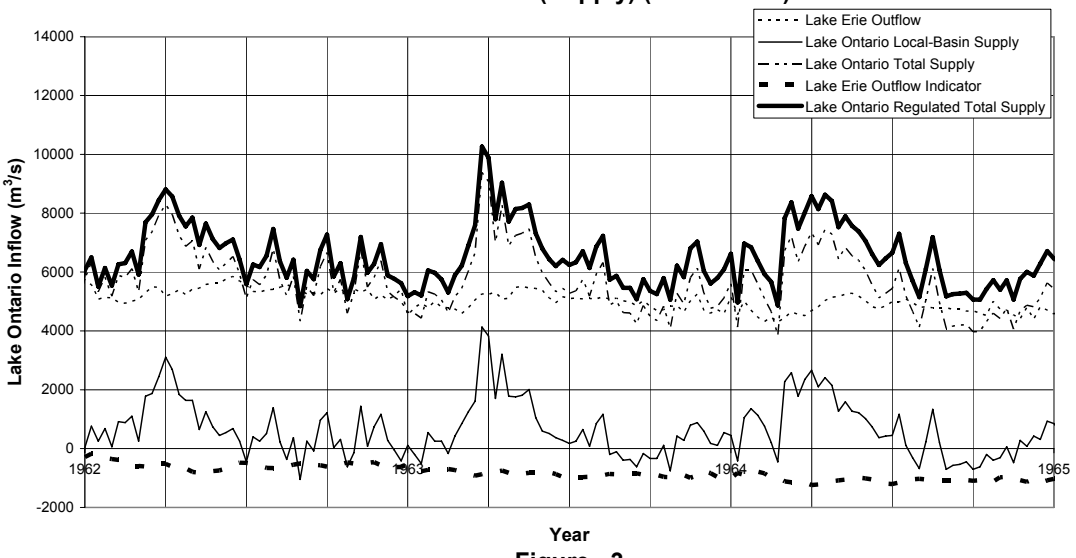

Figure 3

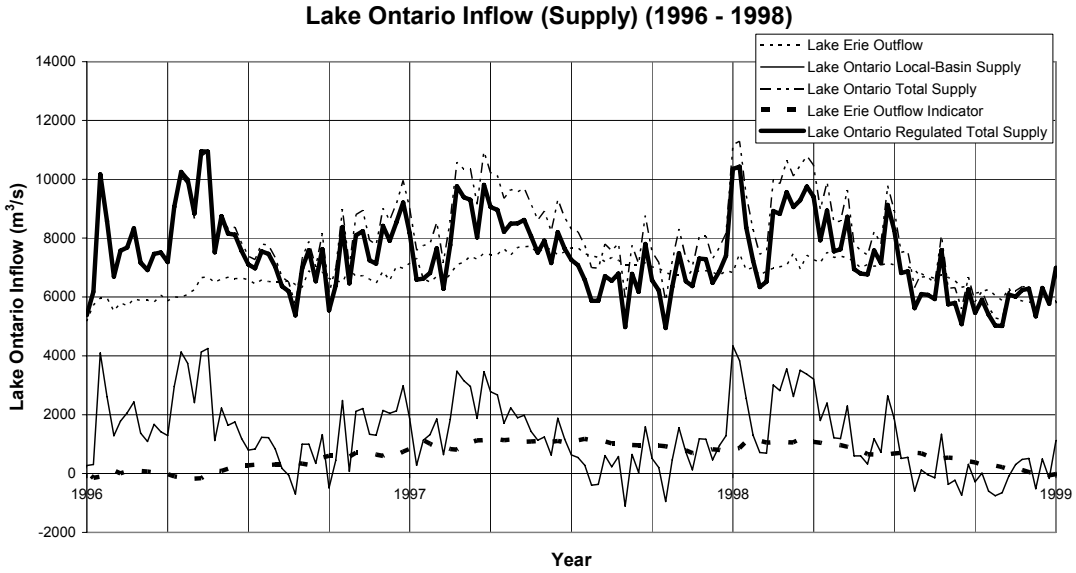

Figure 4

b) Lake Erie Outflow (Figure 2) is measured at several controlled sites and makes up around 85% of Lake Ontario's total supply. Lake Erie Outflow is accurate, stable and predictable (Figures 3 & 4). Although the outflow has small seasonal variations (Figure 1), the natural flow pattern of the outflow is altered with the presence of the series of large lakes upstream.

c) Lake Ontario Total Supply is the combination of Lake Ontario Local-Basin Supply and Lake Erie Outflow. It retains both the natural flow pattern of the local-basin supply and its large natural seasonal variation (Figure 1), however, the total supply is relatively unstable and unpredictable (Figures 3 & 4), and the average annual total supply (Figure 2) is impacted by Lake Erie outflow variation.

4) **METHODOLOGY**

Plan C (Local-Basin Approach) uses the following four basic components to regulate Lake Ontario to as close to its natural local-basin flow pattern as possible, while maintaining the lake level and outflow within the desirable ranges for environmental, social and economic interests:

a) Weighted Lake Erie Outflow Indicator:
Plan C splits Lake Erie Outflow into two flows; Weighted Lake Erie Normal Outflow (Figure 5) and Weighted Lake Erie Outflow Indicator (Figures 3 & 4).

The Weighted Lake Erie Normal Outflow is the long term Lake Erie seasonal outflow (from 1900 to 2000), and is the portion of Lake Erie Outflow to be stored in Lake Ontario and regulated by the Basic Rule Curve. The remaining portion of Lake Erie Outflow (the Weighted Lake Erie Outflow Indicator) by-passes Lake Ontario and is directly added to or subtracted from the Basic Rule Curve Plan Flow of Lake Ontario. It is not considered in the Basic Rule Curve regulation of Lake Ontario. Therefore, the change of Lake Erie Outflow supply condition will have minimal impact on the lake level, and the lake can be regulated as close to its natural local-basin flow pattern as possible.

Weighted Lake Erie Outflow Indicator = Lake Erie Outflow
– Weighted Lake Erie Normal Outflow

Plan C: Weighted Upstream Normal Supply (Weighted Lake Erie Normal Outflow)

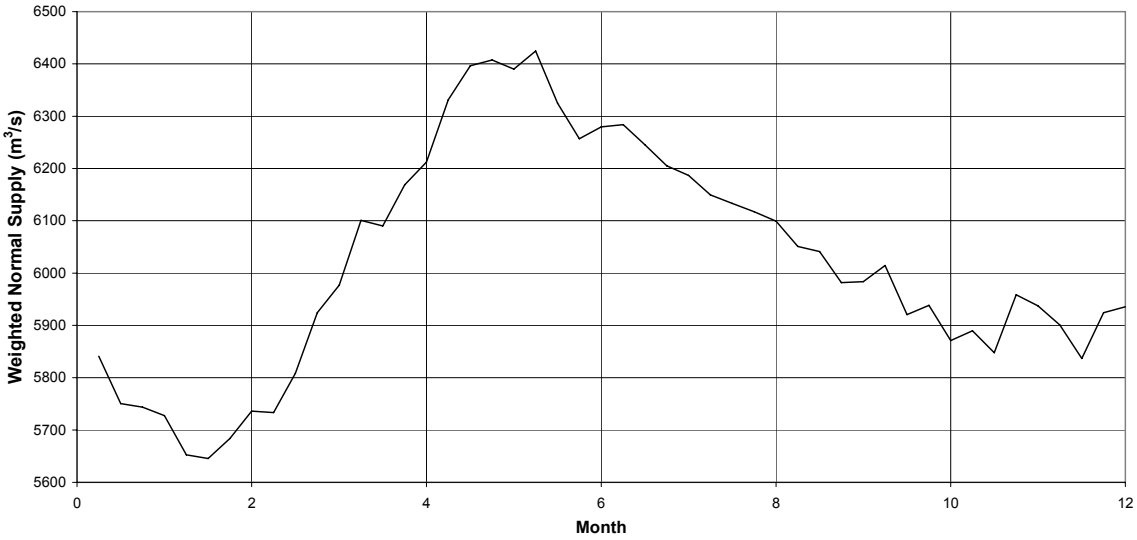

Figure 5

b) b) Basic Rule Curve (Figure 6):

The Total Supply to be regulated by the Basic Rule Curve is called the Lake Ontario Regulated Total Supply (Figures 1, 2, 3 & 4). It is equal to the Lake Ontario Total Supply minus the Weighted Lake Erie Outflow Indicator. The Lake Ontario Regulated Total Supply has a similar flow pattern to the Lake Ontario Local-Basin Supply in terms of seasonal flow variations (Figures 1, 3 & 4) and in terms of average annual flow variations (Figure 2). Therefore, with the Lake Ontario Regulated Total Supply and the Basic Rule Curve, the plan is able to regulate the lake close to the natural flow pattern of the Lake Ontario Local-Basin Supply, while the range of the lake level is governed by the range of the Lake Ontario Regulated Total Supply. This resulting flow pattern is similar to the Local-Basin Supply (Figure 2).

Basic Rule Curve Plan Flow = (7000 + 2050 * (Lake Level – 74.8)) m^3/s

Plan C: Basic Rule Curve

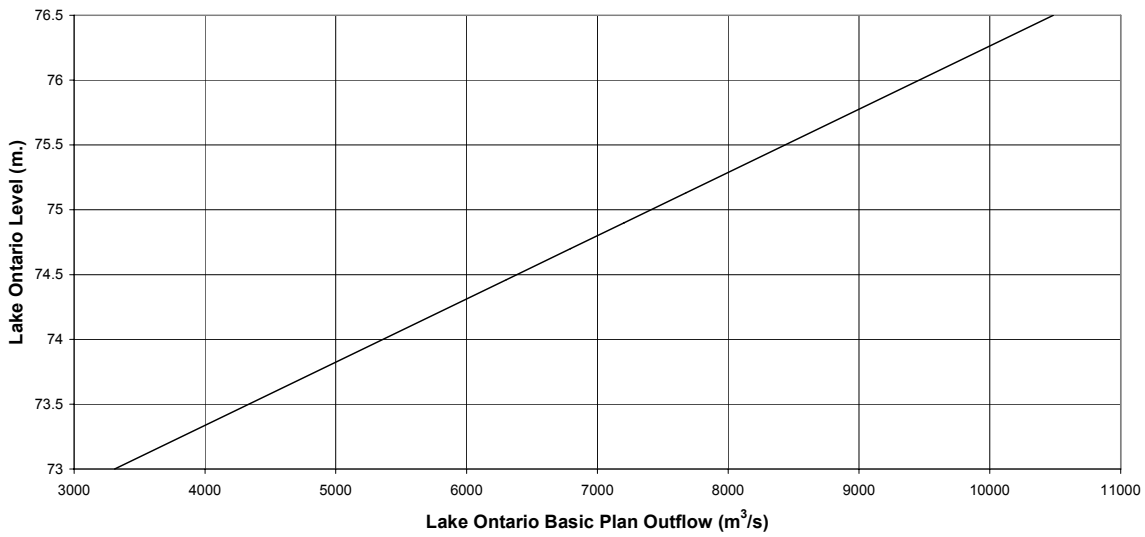

Figure 6

c) Seasonal Flow Adjustment:
The plan uses the seasonal flow adjustment (Figure 7) to modify the seasonal outflow of the lake and balance the benefits of all interests within Lake Ontario and the St. Lawrence River System. The adjustment was derived from the evaluation results (Tables 1 & 2) of the plan by the trial and error method.

Plan C: Seasonal Flow Adjustment

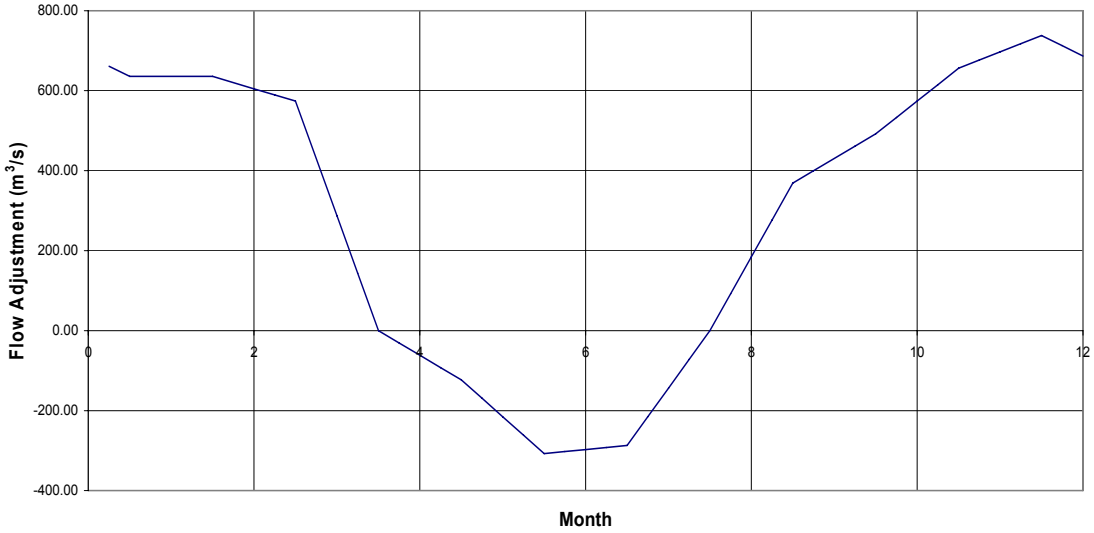

Figure 7

d) Estimated Outflow Capacity:
Plan C also uses the estimated outflow capacity of the river (Figure 8) to limit the maximum plan outflow throughout the season. The estimated outflow capacity of the river was derived from the historical Lake Ontario outflow and the Lake Ontario & St. Lawrence River levels under ice cover and open channel (ice free) conditions.

Plan C: Estimated Maximum Lake Ontario-St. Lawrence River Outflow Capacity

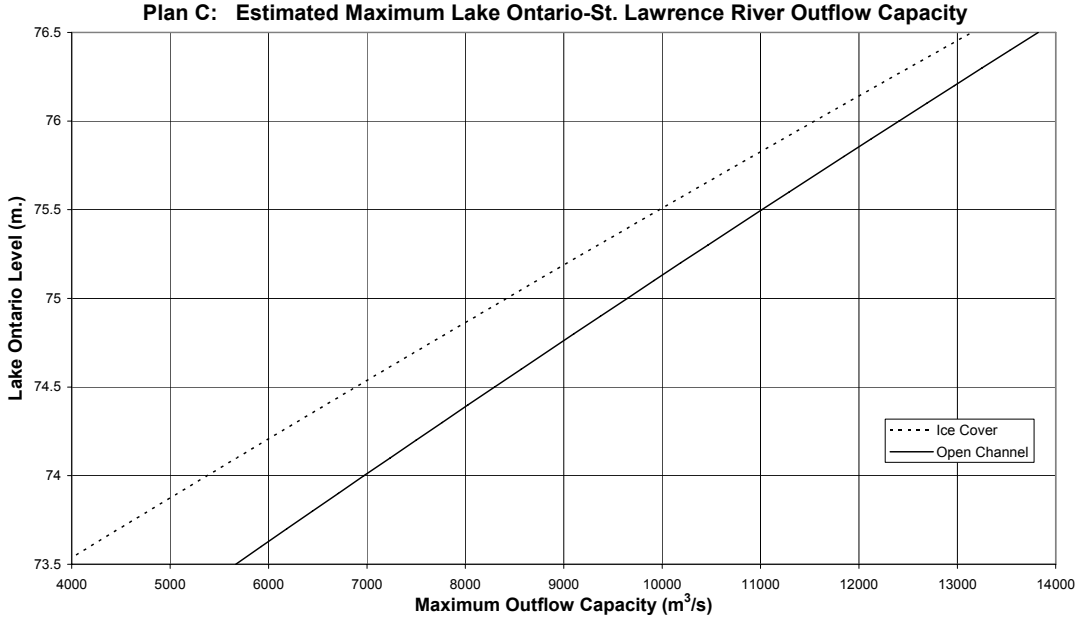

Figure 8

The plan outflow from Plan C is the sum of the Weighted Lake Erie Outflow Indicator (Upstream Supply Indicator), the Basic Rule Curve Plan Flow, and the Seasonal Flow Adjustment. The outflow is limited by the estimated outflow capacity of the river and various constraints defined by the Study Board (Annex 3 of Reference 2).

5) **RESULTS**

All proposed plans were evaluated with the Study Board's "Shared Vision" evaluation model. The economic evaluation for the candidate plans is shown in Table 1, and the environmental performance evaluation for the plans is shown in Table 2.

Plan C provides balanced economical benefits to all users of the lake-river system, and has the highest total economical benefit of $8,000,000/yr. The plan has a very small economic loss of $10,000 for commercial navigation on Lake Ontario. Environmentally, Plan C has a good meadow marsh rating of 1.29, but poor wetland bird (Least Battern, Virginia Rail & Black Tern) and muskrat ratings.

Table 1 – Economic Evaluation

The table below shows the economic benefits or losses of each of the candidate plans for the interest as compare to Plan 1958DD

Net Benefits for Five Plans (millions of U.S. dollars, average annual)

	A	B	C	D	E
Total	$7.52	$6.48	$8.00	$6.52	-$12.30
COASTAL	-$0.62	-$1.11	$0.40	$0.32	-$25.96
Ontario	-$0.36	-$0.60	$0.27	$0.25	-$23.12
Shore Protection Maintenance	-$0.23	-$0.49	$0.26	$0.27	-$12.98
Erosion to Unprotected Developed Parcels	-$0.13	-$0.10	$0.01	-$0.02	-$0.29
Flooding	-$0.01	-$0.01	$0.00	-$0.01	-$9.85
Upper St. Lawrence River	**$0.00**	**$0.00**	**$0.00**	**$0.00**	-$1.56
Flooding	**$0.00**	**$0.00**	**$0.00**	**$0.00**	-$1.56
St. Lawrence	-$0.25	-$0.51	$0.14	$0.07	-$1.27
Flooding	-$0.22	-$0.47	$0.02	-$0.02	-$1.21
Shore Protection Maintenance	-$0.03	-$0.04	$0.11	$0.09	-$0.07
COMMERCIAL NAVIGATION	**$0.41**	**$2.20**	**$1.22**	**$2.31**	**$4.13**
Ontario	-$0.04	-$0.02	-$0.01	-$0.01	-$0.01
Seaway	$0.53	$2.28	$1.20	$2.35	$4.15
Montreal down	-$0.08	-$0.06	$0.02	-$0.03	$0.00
HYDROPOWER	$3.50	$5.97	$4.59	$1.82	$14.16
NYPA-OPG	$3.51	$4.16	$1.35	$1.04	$10.23
Hydro Quebec	-$0.01	$1.81	$3.24	$0.78	$3.93
RECREATIONAL BOATING	$4.23	**-$0.58**	$1.80	$2.04	**-$4.64**
Above Dam	$2.21	-$0.62	$0.39	$0.52	-$5.91
Ontario	$1.29	-$0.64	$0.21	$0.13	-$5.03
Alex Bay	$0.89	-$0.05	$0.14	$0.32	-$0.86
Ogdensburg	$0.01	$0.00	$0.01	$0.01	-$0.09
Lake St. Lawrence	$0.02	$0.06	$0.03	$0.06	$0.07
Below Dam	$2.02	$0.04	$1.41	$1.53	$1.27
Lac St. Louis	$1.13	$0.17	$0.82	$0.77	$0.78
Montreal	$0.70	-$0.02	$0.44	$0.58	$0.41
Lac St. Pierre	$0.19	-$0.10	$0.15	$0.17	$0.08
M&I	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
SL One time infrastructure costs	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
LSL Water Quality Investments	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**

Notes on Table 1:

1. Results are based on the historical supply sequence (from 1900 to 2000).
2. Result for Plans A, B, D & E is adopted from Ripple Effects-Volume 12 (reference 1).
3. Plan E is not a candidate plan, the plan represents the natural flow condition.

Table 2 – Environmental Performance Evaluation

The table shows the performance Indicator of each of the candidate plans as compared to Plan 1958DD. The numbers indicate whether a plan is better or worse than 1958DD.

	Environmental Performance Indicators	A	B	C	D	E
Ontario	Wetland Meadow Marsh Community	1.02	1.44	1.29	1.17	1.56
	Low Veg 18C - spawning habitat supply	0.89	0.95	0.93	0.94	0.88
	High Veg 24C - spawning habitat supply	1.05	1.00	1.02	1.01	1.08
	Low Veg 24C - spawning habitat supply	1.00	1.02	0.99	1.00	1.11
	Northern Pike - YOY recruitment	1.02	1.00	1.02	1.05	1.03
	Largemouth Bass - YOY recruitment	0.94	0.98	0.98	0.97	0.96
	Least Bittern (IXEX) - reproductive index	0.88	1.04	0.80	0.95	1.13
	Virginia Rail (RALI) - reproductive index	0.96	1.11	0.84	0.99	1.15
	Black Tern (CHNI) - reproductive index	1.03	1.12	0.85	1.01	1.16
	Yellow Rail (CONO) - preferred breeding habitat	0.96	1.01	0.99	0.98	1.01
	King Rail (RAEL) - preferred breeding habitat	1.05	1.10	1.01	1.03	1.27
Upper R	Low Veg 18C - spawning habitat supply	1.01	1.01	0.99	1.01	1.04
	High Veg 24C - spawning habitat supply	1.03	1.01	1.01	1.02	1.02
	Low Veg 24C - spawning habitat supply	1.01	1.01	1.00	1.01	1.04
	Northern Pike - YOY recruitment	1.05	1.03	1.00	1.01	1.06
	Largemouth Bass - YOY recruitment	0.99	1.00	1.00	1.00	1.00
	Northern Pike - YOY net productivity	4.02	2.08	1.10	1.17	4.08
	Virginia Rail (RALI) - reproductive index	1.16	1.27	1.32	1.31	1.33
	Muskrat (ONZI) – house density in drowned river mouth wetlands	1.42	4.39	0.81	1.73	37.25
Lower River	Golden Shiner - suitable feeding habitat area	1.00	1.00	0.90	1.00	1.03
	Wetlands fish - abundance index	0.87	0.90	0.74	0.84	0.97
	Migratory wildfowl - habitat area	1.03	1.03	1.00	0.97	1.00
	Least Bittern - reproductive index	1.03	1.06	1.03	1.00	1.06
	Virginia Rail (RALI) - reproductive index	0.94	0.97	1.00	1.06	1.00
	Migratory wildfowl – productivity	1.06	1.00	1.00	1.00	1.03
	Black Tern (CHNI) - reproductive index	0.84	0.77	0.97	1.00	0.77
	Northern Pike (ESLU) - reproductive area	0.97	0.94	0.87	0.94	0.94
	Frog sp. - reproductive habitat surface area	0.87	0.87	1.03	1.03	0.94
	Eastern Sand Darter (AMPE) - reproductive area	1.10	1.03	1.19	1.13	1.06
	Spiny Softshell Turtle (APSP) – reproductive habitat surface area	1.03	1.06	1.06	1.03	1.03
	Bridle Shiner (NOBI) - reproductive habitat surface area	1.00	0.97	1.03	1.00	1.03
	Muskrat (ONZI) - surviving houses	1.04	0.88	1.12	0.96	0.80
	Percentage "good" scores for each plan	9%	22%	13%	16%	34%
	Overall Environmental Index	1.06	1.35	1.03	1.10	4.04

Notes to Table 2:

1. Figures reflect the impact relative to Plan 1958-DD expressed as ratio, where 1 represents no change from 1958-DD (black), >1.00 represents an improvement relative to 1958-DD (blue), and <1.00 represents a deterioration relative to 1958-DD (red).
2. Results are based on the historical supply sequence (from 1900 to 2000).
3. Result for Plans A, B, D & E is adopted from Ripple Effects-Volume 12.

Water Management Review:

A brief water management review of Lake Ontario's outflow and level during the extreme (high & low) supply condition was conducted for Plan C. The review reveals that:

1. With the weighted upstream-supply indicator, Plan C is able to forecast and react to the change of the upstream-supply condition ahead of regulation plans from Plan 1958-DD (Figures 10 & 11).

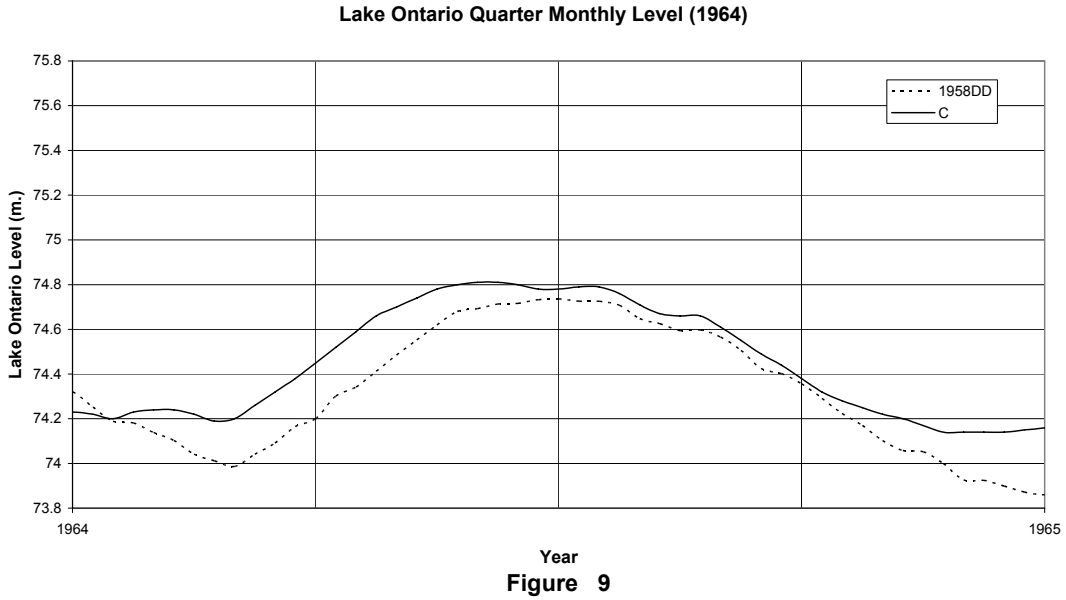

Figure 9

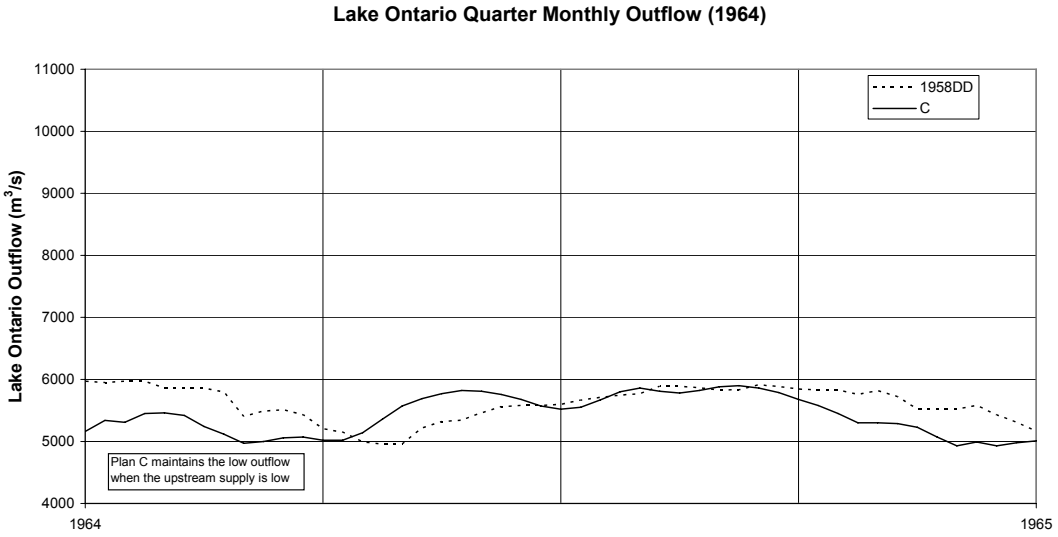

Figure 10

2. During the extreme low-supply condition, Plan C attempts to reduce the impact of drought conditions on the lake by keeping the lake level relatively high (as shown in Fig. 9) and the outflow within a relatively narrow range (Figures 10).

3. During the extreme high-supply condition, Plan C lowers the lake level prior to the winter (Figure 12). The lower lake level prior to the winter reduces the risk of an excessively high lake level in the following summer.

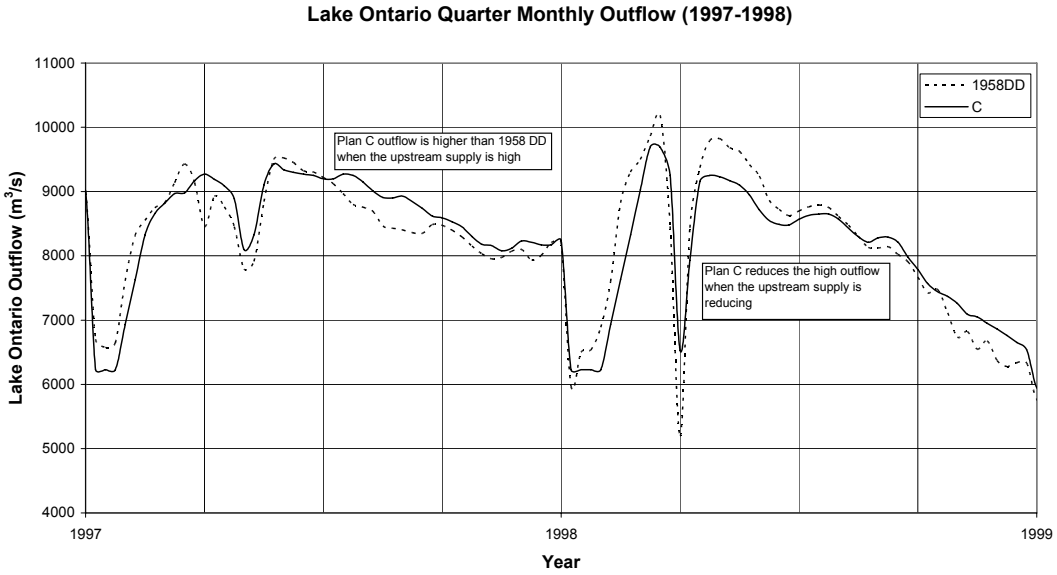

Figure 11

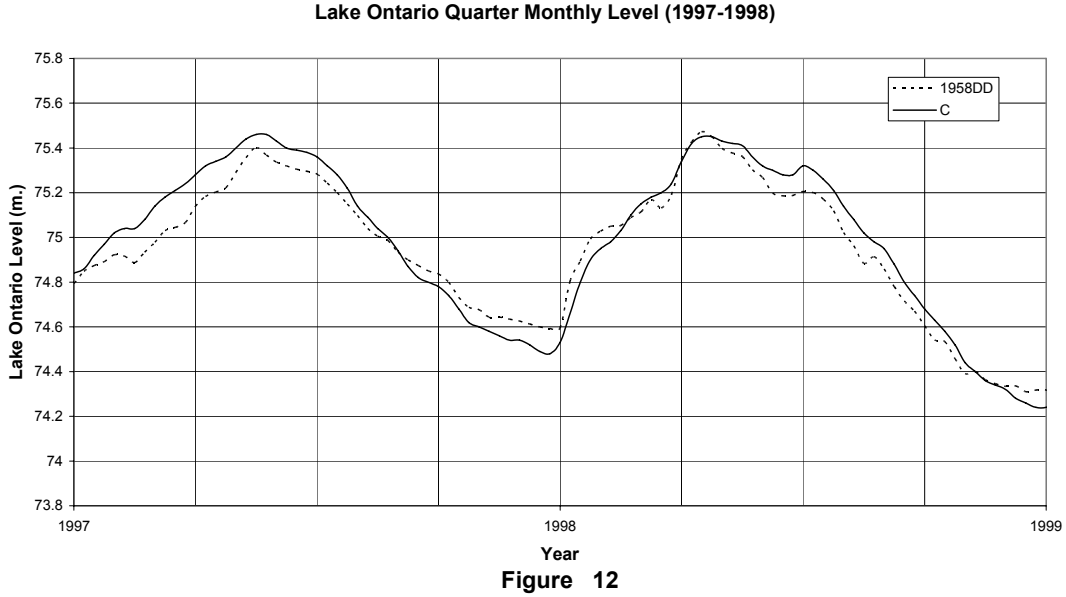

Figure 12

6) **CONCLUSION**

Plan C is able to regulate Lake Ontario close to its natural local-basin flow pattern and control the lake level and outflow within desirable ranges. Plan C has a relatively good meadow marsh rating as shown in Table 2 (the meadow marsh is one of the indicators for the biodiversity and ecosystem health of the lake). The plan is able to balance the benefits for all interests, including environmental interest.

The weighted upstream-supply indicator of the plan is able to forecast and react to the upstream-supply condition much earlier than traditional level-based regulation plans. Therefore, the plan is able to minimize the impact of the extreme supply (due to the climate change) on the lake.

ACKNOWLEDGEMENTS

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