Rideau Valley Conservation Authority
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Technical Memorandum

Date: February 1, 2012

Subject: **Analysis of Regulatory Flood Level on the Shoreline of Upper Rideau Lake, for the purposes of administering Ontario Regulation 174/06**

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Abstract

This memo provides a summary of the background information, simplifying assumptions and hydrologic and hydraulic analysis methods used to generate a reasonable estimate of the Regulatory (1:100 year) Flood Level for Upper Rideau Lake. As found earlier for other lakes, it was not possible to identify the approximate extent of lands that may be inundated under that water level, due to the limitations of available topographical information. This study supports the plotting of Regulation Limits Mapping for the Lake whenever topographic mapping of suitable scale and accuracy becomes available. Until then, the regulatory flood determination herein should be used in conjunction with site specific surveys and site visits to determine the extent of regulated areas, on a site-by-site, as-needed basis. The study area, consisting of the Upper Rideau Lake watershed is depicted in Figures 1 and 2.

The completed analysis meets or exceeds the standards for "approximate methods for estimating flood plains" as provided for in "Guidelines for Developing Schedules of Regulated Areas" (Conservation Ontario, 2005).

[1] The guidance and technical review provided by Bruce Reid are gratefully acknowledged.

Introduction

The development and site alteration control provisions of Ontario Regulation 174/06 apply in all areas within the RVCA area of jurisdiction meeting criteria set out in Ontario Regulation 97/04 (the so-called “generic regulation”), including areas that are adjacent to inland lakes and could be affected by flooding under 1:100 year flood conditions, or by erosion and slope failure processes. Over time, and as resources enable it, RVCA is working to complete its inventory of regulation limits mapping to explicitly delineate the areas that are subject to the regulation. Doing so will better inform the general public, landowners and RVCA staff as to where the regulations are in effect and are to be enforced.

There are numerous inland lakes in the RVCA area of jurisdiction for which there has been no previous attempt to define regulatory (1:100 year) flood levels and corresponding estimated flood lines. Upper Rideau Lake is one of the lakes that are subjected to artificial flow regulation and water storage function, and where the historical record of outflow discharge or annual maximum water level is insufficient for the use of statistical methods (single station frequency analysis). A three step process has been developed:

Step 1 – estimation of the 1:100 year flow at the lake’s outlet (Narrows Dam). Initially, flood flows at the outlets of all the lakes in the RVCA’s area of jurisdiction were estimated using a number of methods (RVCA, 2010). Various methods, borrowed from scientific research papers, handbooks and guideline documents, were applied and compared with a view to identifying a probable range of values for the 1:100 year discharge for each lake. The selection of a recommended 1:100 year discharge value for any particular lake (e.g., Upper Rideau Lake) would then be made through closer examination of all of the available streamflow and water level information that is available for that lake and its receiving stream, any site-specific analysis, and consideration of its natural runoff storage and release function (which depends on the lake’s area and the physical characteristics of its outlet).

Step 2 – computation of the lake level that corresponds with the 1:100 year flow at the lake’s outlet, using information about the physical characteristics of the lake’s outlet that determine it's hydraulic (flow) capacity, as well as the lake's runoff storage capacity. For Upper Rideau Lake, design drawings of the Narrows Dam were available.

Step 3 – estimated flood lines corresponding to the 1:100 year water surface elevation are then plotted using available topography of the shorelines around the lake. For most of the lakes in the RVCA area of jurisdiction, the best available topographic information is available in two formats:

- 1:10,000 scale OBM (Ontario Base Mapping) with a 5 m contour interval
- 10 m x 10 m Digital Elevation Model (DEM) compiled by MNR in 2006

Floodline plotting can be automated using computer programs and the DEM, or done manually by interpolating between the 5 metre contours. The two methods may yield differing results (in terms of the plotted position of the flood line in plan view), but neither line would be considered to more accurately reflect the true position of the flood line on the ground than the other. As found earlier for other lakes (RVCA, 2011a, 2011b), plotting the flood line using the DEM was not possible due to the limitations of available data. The resolution of the DEM (10x10m) is such that local topographic features at the scale of typical shoreline properties may not be accurately reflected in the DEM. Also, the stated vertical accuracy of the DEM is ±2.5 metres. Accordingly the flood lines estimated this way would only be a crude approximation, compared to the accuracy that has in the past been required for engineered flood line mapping. They may therefore not be suitable for RVCA regulation limits mapping purposes or for use in designating hazard lands for municipal zoning purposes.

Study Area

Upper Rideau Lake has a surface area of 1402 hectares and a shoreline length of 48.4 km. The catchment area draining to the lake is 152.9 km^2. Approximately 19% of the catchment area is covered by numerous lakes, big and small.

The watershed of Upper Rideau Lake is shown in Figure 1 (aerial photo base) and Figure 2 (DEM base). Ideally, regulation limits are to be produced for the entire shoreline of Upper Rideau Lake and adjacent low-lying areas based (in part) on the estimated flood lines for the 1:100 year water surface elevation. Narrows Dam obviously acts as the "hydraulic control" for lake levels during extreme runoff events and is therefore the downstream boundary of the study area. The Mill Pond Dam on County Road 10 (also known as the Main Street in Westport) is the upper limit of the study area.

The entire study area is within the Township of Rideau Lakes, Village of Westport, and Township of South Frontenac. There are a few, small clusters of settlement around the lake, as well as numerous lakeside cottages and rural residences. From the year 2004 to 2008 there were 41 development applications on Upper Rideau Lake.

Hydrological Analysis

Continuous water level records since 1977 are available upstream of Narrows Dam (02LA025); though no flow measurements are available. However, historical streamflow records on the Rideau River just downstream of Poonamalie Dam (02LA005), collected by Parks Canada since 1970, are available[2]. The water level data of the lake at Narrows Dam is of satisfactory quality. However, since the water level data is influenced by the dam operation, it is not suitable for deriving design flows without first converting them to a natural flow series, which appears to be cumbersome due to time-varying dam operation. Standard statistical analysis methods (frequency analysis) can not be used because of these limitations in the historical records.

As described in RVCA (2010), flood flows for Upper Rideau Lake outlet were previously computed using a number of methods, as follows (Table 1, Figure 3):

- FDRP regression (Ontario)
- FDRP regression (Eastern Ontario)
- FDRP regression (Northern Ontario)
- Gingras et al.'s equation (Region 2)
- Gingras et al.'s equation (Region 6)

[2] However the data is seasonal and has many gaps; moreover there is speculation about the effect of downstream dams on the rating curve. This data is therefore not suitable for performing a statistical analysis to derive reliable design floods (RVCA 2011a).

- Gingras et al.'s equation (Region 7)
- Gingras et al.'s equation (Ontario/Quebec)
- Mike11 long term simulation (1940 to 2007)
- Area-prorating using Rideau River flow at Carleton

Details of these methods and their computation are described in RVCA (2010), and are not repeated here. That analysis concluded that in general, and in the absence of more rigorous hydrologic analysis for any given lake, the 1:100 year discharge should be selected from amongst the range of values derived from the three "FDRP" regression equations, based on local considerations. In this examination of the Upper Rideau Lake situation, three site-specific estimates are available:

- Area-prorating using Rideau River flow at Poonamalie
- Genivar (2008) – based on data transposition from Kemptville
- RVCA (2007) – based on long term watershed simulation (Mike11)

Compared to the FDRP and Gingras et al's regression methods, these three studies are based on more site-specific information and are therefore considered more representative. The regression methods are therefore not considered any further.

The RVCA's Mike11 model has been applied on the whole Upper Rideau subwatershed. Details of the modeling methodology are available elsewhere (RVCA, 2007) and are not repeated here. Using this model, streamflow and water surface profiles were simulated on a continuous basis, with observed climatic data recorded at the Ottawa Airport from 1940 to 2007. Within this arrangement, the simulated flow and water level in the streams and lakes automatically captured temporal and spatial nuances of hydrologic response and hydrodynamic routing. Ignoring the first three years to avoid effects of initial conditions, the remaining 65 years of simulated flow data (1943 to 2007) at the outlet of Upper Rideau Lake (Narrows) were used for flood frequency analysis using the CFA program of Environment Canada (Pilon and Harvey, 1993). The flood quintiles derived from this analysis are listed in Table 1 and plotted in Figure 3.

The Mike11 model is currently the best tool available to RVCA. This kind of continuous modeling has many advantages as documented by various authors (e.g., Boughton and Droop, 2003; DEFRA, 2005). Advantages of this method over the traditional event-based methods are numerous and varied. The main advantage is the automatic accounting of antecedent moisture condition at every time step, which is taken into account in event based designs but in a rather arbitrary and/or conservative way. Integrated watershed models, like Mike11, can also account for the heterogeneity of basins, river and lake attenuation, varied response time of basins, water control structures and their operation policy. With the development of sophisticated watershed modeling techniques and increasing computer power, this method is now being increasingly used to estimate flows at ungaged basins where long-term climatic data is available.

The design flows estimated by the Mike11 model are considered to be the most defensible estimate, based on the following:

1. MacLaren (1979) estimated the 1:100 year flow of the Rideau River at Poonamalie (02LA005) at 143 cms from a frequency analysis performed on the Poonamalie Dam flow data for the period from 1945 to 1975[3]. This value was recently accepted by RVCA (2011a) as the most appropriate design flood for flood mapping purposes[4] of the Big Rideau Lake. Using area-prorating method, we estimate a 1:100 year flow at Narrows Dam at 29.0 cms. However, Watt et al. (1989) suggest that the area pro-rating method should be used only when the ratio of the drainage areas is between 0.5 and 2.0; in our case, it is 0.12. Moreover, if a lake or swamp lies between the ungauged site and gauging station, this method should not be used; instead, flood routing or 'reverse routing' is more appropriate. Considering the presence of extensive lake areas within the Upper Rideau basin, it appears that area pro-rating should not be used.

2. The Genivar (2008) estimate of 17.4 cms was based on data transposition from Kemptville Creek basin, a basin with different hydrologic settings

[3] The actual data was neither included in MacLaren (1979) nor could be found elsewhere.

[4] The rationale was that it gives values close to those obtained by RVCA's Mike11 model (RVCA 2007) and that there are perceived inaccuracies of the flow data collected at Poonamalie.

(absence of large lakes and flow regulation, for instance). Moreover, this method did not have any of the advantages of the continuous hydrologic modeling discussed above.

3. Mike11 modeling is the only method that accounted for the hydrologic routing through the lakes in this area. This is therefore considered superior to other estimates available at this time.

4. Finally, the volume of runoff required to raise the lake level to the estimated flood level (expressed as a depth of water over the entire catchment area of the lake), was compared with the magnitude of a 1:100 year snowmelt plus rain event over the catchment, as a check on the reasonableness of discharge prediction. The runoff volume required to raise the water level to the water level associated with the higher discharge estimates (30.0 or 17.4 cms) was found to be well in excess of any reasonable estimate of the runoff volume for a 1:100 year event.

Considering all information available and based on the considerations outlined above, it is recommended that the discharge estimates derived from the Mike11 long-term simulation be used as the most appropriate for flood risk determination on the shorelines of Upper Rideau Lake. The design flows are shown in Table 1.

The 1:100 year flow is 11.4 cms. This value was used in the hydraulic analysis to determine the corresponding computed water level, or the Regulatory Flood Level (RFL).

Data Used

Aerial Photo: The available DRAPE aerial photo was collected in May and June of 2008 for the entire RVCA area of jurisdiction. This high quality colored photo (Figure 1) clearly shows the rivers, creeks, land use, houses, buildings, roads, infrastructure, vegetation and other details.

Historic Aerial Photo: As shown in Figure 5, historical photos in this vicinity since the 1950s are available. These photos show lakeshore, watercourses and road layouts. These photos were helpful in gaining insight into the lake outlet, creek, the road crossing, and the surroundings.

DEM: The 10 x 10 m grid DEM was provided by MNR in 2006 (Figure 2). It has an accuracy of 1.5 m horizontally and 2.5 m vertically. Ideally, given a high enough quality of DEM, contour lines at 1 m intervals, and also corresponding to any specified elevation (e.g., 1:100 year flood elevation), can be generated from this DEM using GIS software to enable automated plotting of the flood line instead of more labour intensive interpolation between the 5 metre contours of the OBM maps.

Narrows Dam: This dam is situated at the downstream end of Upper Rideau Lake and is used to control the lake level and the outflow from the lake (Figures 4 and 6). This dam is operated by Parks Canada's Rideau Canal Office – with the view to achieve an optimum balance between different and often conflicting demands on the water. The 1975 drawings of this dam, prepared by J.D. Lee Engineering Limited (Figure 7), were obtained from Parks Canada and were used in our analysis. This dam is essentially a bridge fitted with stop logs for flow control. The bridge opening is 8.23 m wide and 2.33 m deep. The stop log section is under the bridge, with a sill level at 122.53 m. Fully opening up the bay by removing the stop logs during extreme flood events and thereby keeping the lake level within the 'flood control zone' (Figure 8) as described in Acres (1977, 1994) report is desirable; and it is our understanding that Parks Canada strives to do that. Therefore, in our hydraulic computation for flood events, we have assumed a fully opened dam to estimate the 1:100 year flood level.

Dam Operation Data: By operating the Narrows Dam, Parks Canada strives to keep the lake water level as close as possible to the 'rule curve' (Figure 9). However, given the variability of the hydrologic regime and water demands, this is not always possible; and the actual water level deviates from the rule curve. Records of the dam operation are kept by Parks Canada. Ten years of such data was used in the calibration and validation of our Mike11 model (RVCA 2007).

Water Level Data: Since 1977, continuous water level measurements of Upper Rideau Lake at Narrows (station 02LA025), just upstream of the dam, have been taken by Parks Canada. This information (Figure 8) has been utilized in the present study.

<u>Flow Data</u>: Since 1998, flow data of the Rideau River below Poonamalie Dam (station 02LA005) is being collected by Parks Canada. This data was used in the calibration and verification of the Mike11 model (RVCA 2007, 2011a).

Hydraulic Calculations

For a given estimate of the discharge, the headwater level is determined by the tailwater level (i.e. the water level downstream of the structure), and the hydraulic head required to overcome the energy losses associated with expansion and contraction of the flow and turbulent energy dissipation.

The tail water must generally be estimated beforehand. In this case, the 1:100 year flood level of 124.51 m downstream of the dam, calculated in a recent study (RVCA, 2011a), was used.

The physical dimensions of the dam were taken from the 1975 drawings obtained from Parks Canada (Figure 4). This dam configuration, along with associated lake levels, resembles several standard structures such as sluice gate, orifice, weir, brides, etc. with different empirical equations. We scrutinized these equations and finally found that the "bridge under sluice gate type pressure flow" (USACE, 2002) best suits our situation.

The flow Q for this kind of flow (see Figure 10) can be computed by the following equation (USACE, 2002).

$$Q = C_d A_{BU} \sqrt{2g} \left(Y_3 - \frac{Z}{2} + \frac{\alpha_3 V_3^2}{2g} \right)^{0.5}$$

where C_d is coefficient of discharge; A_{BU} is the net area of the bridge opening; g is the acceleration due to gravity (9.81 m^2/s); Y_3 and Z are defined in Figure 10. The upstream velocity head term ($\frac{\alpha_3 V_3^2}{2g}$) is usually small and has been (conservatively) neglected here.

From the bridge configuration and lake levels, C_d was (conservatively) estimated at 0.15 (Figure 10).

The hydraulic calculations indicate that an upstream head at 124.90 m will be necessary to pass the design flow of 11.4 cms, when the dam is fully open. This means that the head water will be about 4 cm above the low chord of the bridge, thus creating a pressure flow situation.

124.90 m can therefore be taken as the Regulatory Flood Level (RFL) for the Upper Rideau Lake for a design flow of 11.4 cms.

The recent Guidelines for Developing Schedules of Regulated Areas (Conservation Ontario, 2005) do not require accounting for wave rush-up on lakes that are less than 100 km^2 in surface area. Therefore such calculations were not performed for Upper Rideau Lake.

Summary of Conclusions from Hydrologic and Hydraulic Analyses

As mentioned earlier, Parks Canada strives to keep the dam fully opened during extreme flood events, and thus to keep the water level within the 'flood control zone' (124.19 to 124.73 m) as described in Acres (1994).

The regulatory flood level for Upper Rideau Lake is 124.90 metres above sea level (Figure 8), and is associated with a discharge of 11.4 cms at Narrows Dam, the present configuration of the dam and downstream lake level, and the assumption that the dam is fully open.

The RFL is slightly (0.04 m) above the lower chord of the bridge. This means that the bridge will experience pressure flow but not over topping. The top of the bridge and road will be well above this level (0.83 m).

We also observe that the RFL computed herein, is within the 1.0 m 'spill zone' defined by Acres (1994), about 0.17 m above the 'flood control zone', but well below (0.83 m) the higher limit of the spill zone (Figure 8). During large flood events, Parks Canada strives to keep the water level within the 'flood control zone' with an upper limit of 124.73 m. For larger flood (greater than the 1:100 year flood), the water level may be allowed to rise within the 'spill zone' with an upper limit of 125.73 m (surcharge level). Exactly how these zones were determined by Acres (1994) is not clear.

The regulatory flood level (124.90 m) can also be expressed relative to the range of water levels (123.67 to 124.82) observed over the last 33 years (Figure 8). According to the measurements, the annual high water levels have frequently exceeded the upper limit of the flood control zone (124.73 m), although only marginally. But they have always been lower than the RFL calculated here. The highest recorded water level was on April 30, 1980 and was 0.08 m lower than the RFL.

Flood Line Delineation and Regulation Limits

Ideally, once the Regulatory Flood Level is established, the plotting of 1:100 year flood lines or flood risk limits around the lake is a relatively straightforward matter. As previously noted, limitations of the available topographical information (the 10 x 10 m DEM received from MNR in 2006) did not allow accurate plotting of contour lines at 1 metre intervals or the estimated flood line at 124.90 metres above sea level. If this were not the case, the Regulation Limit line would then be plotted the prescribed 15 metres upland of the estimated flood line, wherever the extent of the flood hazard area limit is greater than the extent of wetlands or erosion and slope stability hazards.

However, because of the low horizontal resolution and stated vertical accuracy of the digital elevation model, it does not accurately represent the actual topography of shoreline properties, and the resulting estimated flood lines do not accurately identify areas that are affected by flooding under regulatory flood conditions and are, therefore, subject to the regulations.

Until topographic mapping or digital elevation models of better accuracy and resolution becomes available, identifying the boundaries of hazardous lands with reasonable confidence will require on-site inspections and/or aerial photograph interpretation if suitable imagery is available.

The Regulatory Flood Level of 124.90 metres above sea level should be used when assessing the safe access/egress and flood proofing aspects of development applications in the regulated area.

Regulation Policy Recommendations

Because of the large surface area of lakes (Upper Rideau and others) relative to its catchment area, the lake has a considerable flow attenuating effect during major runoff events. The runoff storage volume associated with inundated low-lying lakeshore properties is insignificant compared with the storage volume on the lake itself. It follows that the flood hydrograph attenuating function of the lake will not be significantly diminished by the minor loss of storage capacity that would be associated with typical shoreline development.

In general, therefore, development of shoreline properties will not have an adverse effect on the control of flooding provided the design of the development meets the following requirements:

1. The estimated regulatory flood level of 124.90 m.a.s.l. should be used in the design of any structures in the regulated area around Upper Rideau Lake. Any new structure (or addition to an existing structure) within the regulated area should be flood-proofed to prevent damage to the structure or its contents under 1:100 year flood conditions. The design of flood-proofing measures should include a minimum 30 cm freeboard above the regulatory flood level to provide an additional margin of safety, in consideration of uncertainties in the derivation of the regulatory flood level. The drawings submitted with the application should identify the proposed geodetic elevation of the structure and its foundation elements, and the flood proofing provisions in the design will be determined by the structure's relationship to the regulatory flood level.

2. Applications for approval of new residential buildings or additions that would enable an increase in the occupancy of existing residential buildings, in the regulated area will need to be accompanied by information on the access route to the building. Safe access to and egress from the site will be required under 1:100 year conditions. 30 cm (or less) of flood waters on access roads has typically been accepted as meeting

safe access requirements, where flow velocities are not significant. Topographic surveys of access routes may be required.

3. In general, lot grading and site alteration should be designed to minimize the need for importation fill from off-site, and in all cases shall be designed so as to ensure no degradation – and enhancement where possible – of the ecological integrity and water quality protection functions of the shoreline and riparian zone.

Closure

The hydrotechnical procedures used in this study to determine a regulatory flood level for Upper Rideau Lake conform to present day standards for flood hazard delineation, as set out in the MNR Natural Hazards Technical Guide (MNR, 2002). The computed flood elevations will be useful in the evaluation of applications for approval of development or site alteration in the regulated area and will also be of value in the flood forecasting and warning services of the RVCA.

The 1:100 year flood limits were not drawn due to the limitations of the available topographical information. In the absence of topographic mapping or digital elevation models of better accuracy and resolution, identifying the boundaries of hazardous lands with reasonable confidence will require on-site inspections and/or aerial photograph interpretation if suitable imagery is available.

It would be prudent for Parks Canada to continue to keep the water level as low as possible within the ‘flood control zone’ by appropriate dam operation during severe flood events (to the extent possible considering various demands on water management both upstream and downstream). This will ensure that the lake experiences only the lowest possible flood level associated with a 1:100 year flood event under a particular set of circumstances.

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8. Pilon, P. J., and Harvey, D. (1993). CFA – Consolidated Frequency Analysis version 3.1. Environment Canada, Surveys and Information Systems Branch, Ottawa, March 1993.

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13. RVCA (2010). Estimation of Design Flows for RVCA Lakes. Technical Memo, Rideau Valley Conservation Authority, Manotick, Ontario, November 2010.

14. RVCA (2011a). Analysis of Regulatory Flood Level on the Shoreline of Big/Lower Rideau Lake, for the purposes of administering Ontario Regulation 174/06. Technical Memo, Rideau Valley Conservation Authority, Manotick, Ontario, October 2011.

15. RVCA (2011b). Analysis of Regulatory Flood Level on the Shoreline of Bobs Lake, for the purposes of administering Ontario Regulation 174/06. Technical Memo, Rideau Valley Conservation Authority, Manotick, Ontario, October 2011.

16. USACE (2002). HEC-RAS – River Analysis System – Hydraulic Reference Manual version 3.1, US Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA, November 2002.

17. Watt, W. E. et al. (1989). Hydrology of Floods in Canada: A guide to Planning and Design. National Research Council Canada.

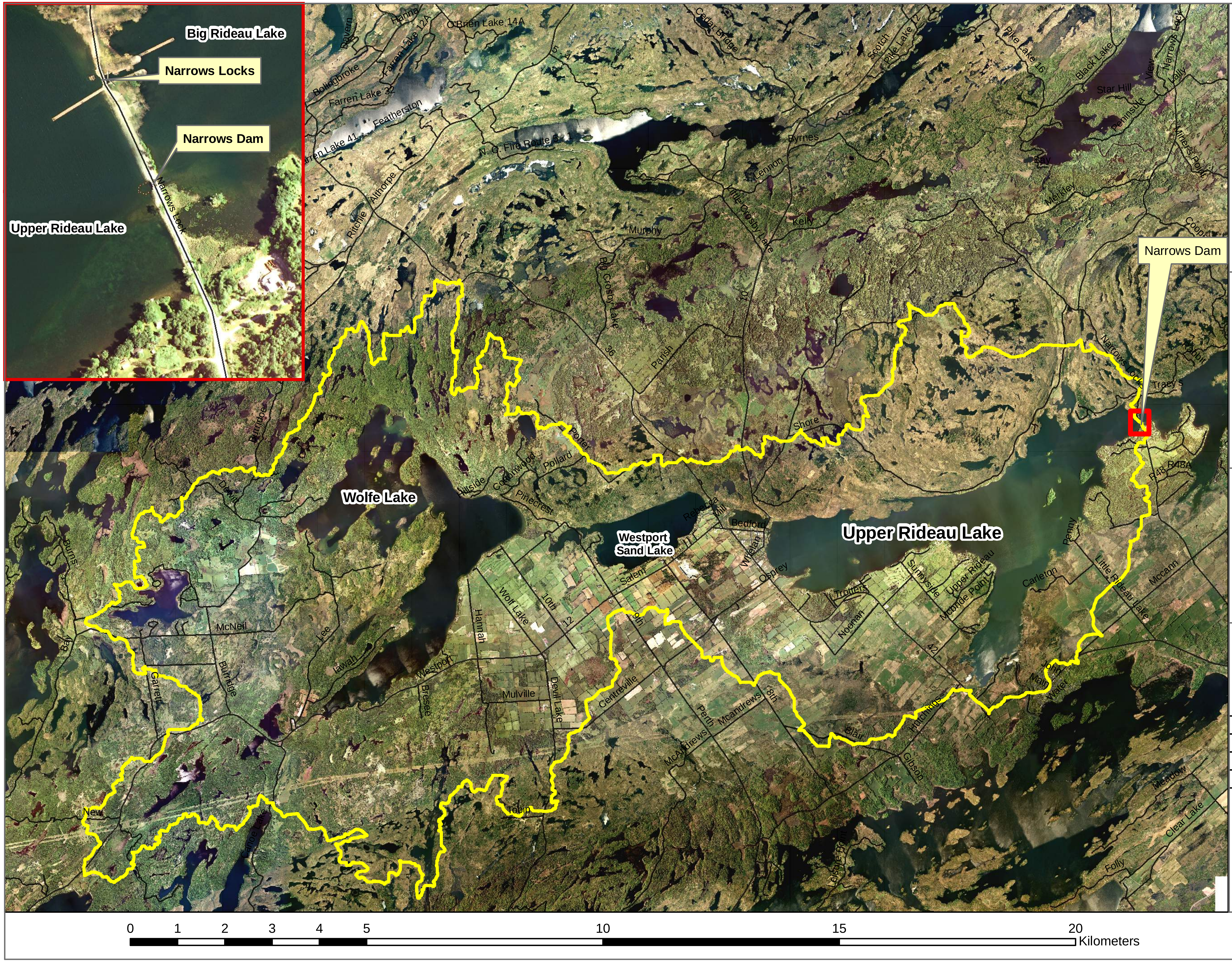
Table 1: Estimated Flood Flows at Narrows, Upper Rideau Lake Outlet

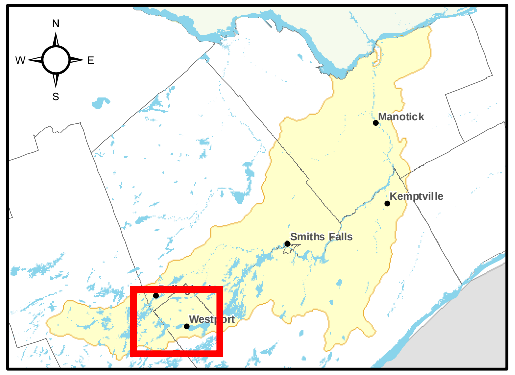
Return Period (years)	METHOD									
	Mike11[1]	FDRP[2]			Gingras et al.[3]				Area Pro-rating Method[4]	Genivar (2008)[5]
		Northern Ontario	Eastern Ontario	Ontario	Region 7	Region ON/QC	Region 2	Region 6		
	Flow (cms)									
2	5.23	13.81	26.24	12.91	27.89	26.58	48.50	8.07		9.70
5	6.70	19.79	29.77	18.55						12.50
10	7.75	23.89	31.80	22.42						13.90
20	8.81	27.90	33.58	26.22	60.10	53.66	91.98	15.95		15.10
50	10.30	34.58	38.12	32.57						16.50
100	11.40	39.91	41.47	37.64	74.98	65.81	109.12	20.26	29.00	17.40
200	12.70									
500	14.40									19.30
1000[5]										20.00
10000[5]										22.10
Summer/Fall PMF[6]										21.00
Spring PMF[7]										33.00

1. Mike11 output, using a Generalized Extreme Value Frequency Distribution
2. MNR (1986). Flood Plain Management in Ontario – Technical Guidelines.
3. Gingras, D., Adamowski, K., and Pilon, P.J. (1994) Regional Flood Equations for the Provinces of Ontario and Quebec. Water Resources Bulletin 30(1):55-67.
4. Area Pro-rating method using 1:100 year design flow at Poonamalie (drainage area 1250.92 km^2).
5. Frequency analysis with data based on hydrometric station 02LA006 (Kemptville) with correction factor of 02LA016 (Port Elmsley) -- **Caution:** consideration was given to the major reservoir effect from Narrows dam, this value should be taken as an inflow value for this dam & Use higher return period results with caution
6. Summer/Fall Probable Maximum Flood, generated by the summer/fall Probable Maximum Precipitation (PMP)
7. Spring Probable Maximum Flood, the maximum of either:
   a) PMF computer with the spring PMP and 1:100 yr snow accumulation, or
   b) PMF computed with the Probable Maximum Snow Accumulation and a 1:100 yr rainstorm
8. Spill Zone - encompasses all water levels which cause flood damage (Lower level of surcharge shown here)

Sources: RVCA (2010), ***Estimation of Design Flows for RVCA Lakes***
GENIVAR (2008), ***Hydrotechnical Study of the Rideau River Watershed***
ACRES (1994), ***Rideau Canal - Water Management Study***

Figure 1: Location Map





Legend

- Upper Rideau Lake Basin

Transportation

- Freeway
- Expressway / Highway
- Collector
- Local / Street

RIDEAU VALLEY CONSERVATION AUTHORITY

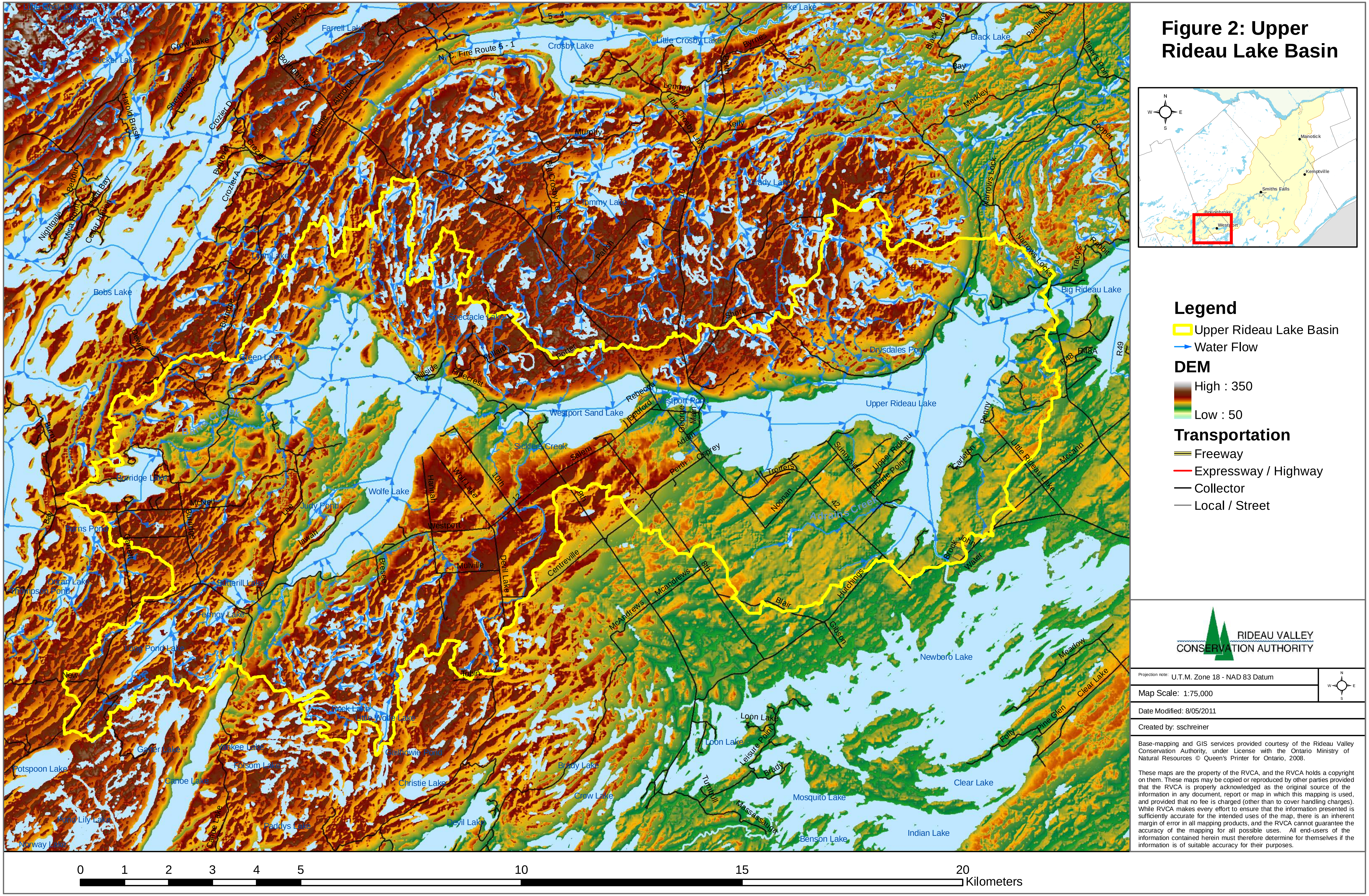
Projection note: U.T.M. Zone 18 - NAD 83 Datum

Map Scale: 1:75,000

Date Modified: 8/05/2011

Created by: sschreiner

Figure 2: Upper Rideau Lake Basin



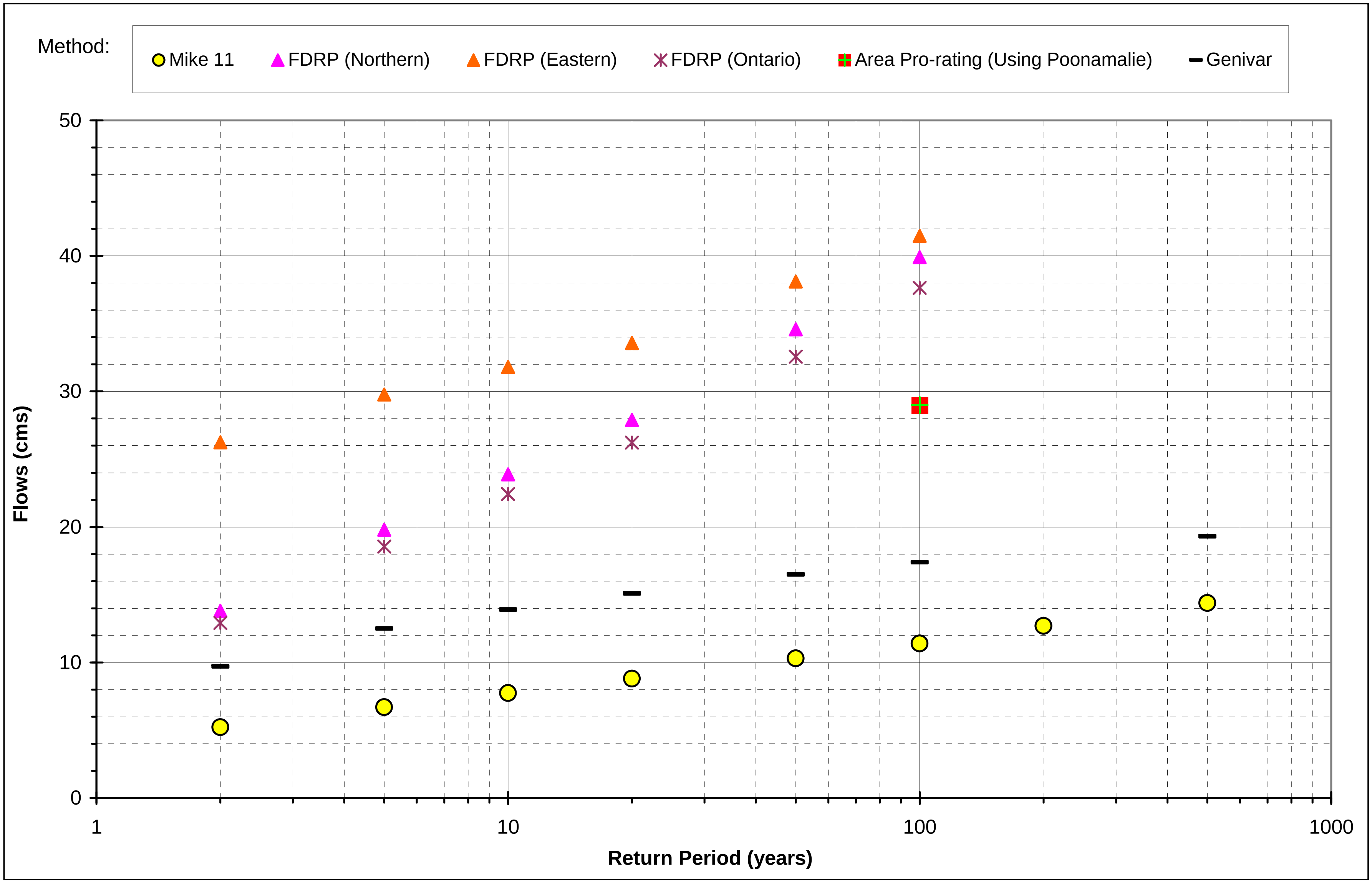


Figure 3: Estimated Flood Flows

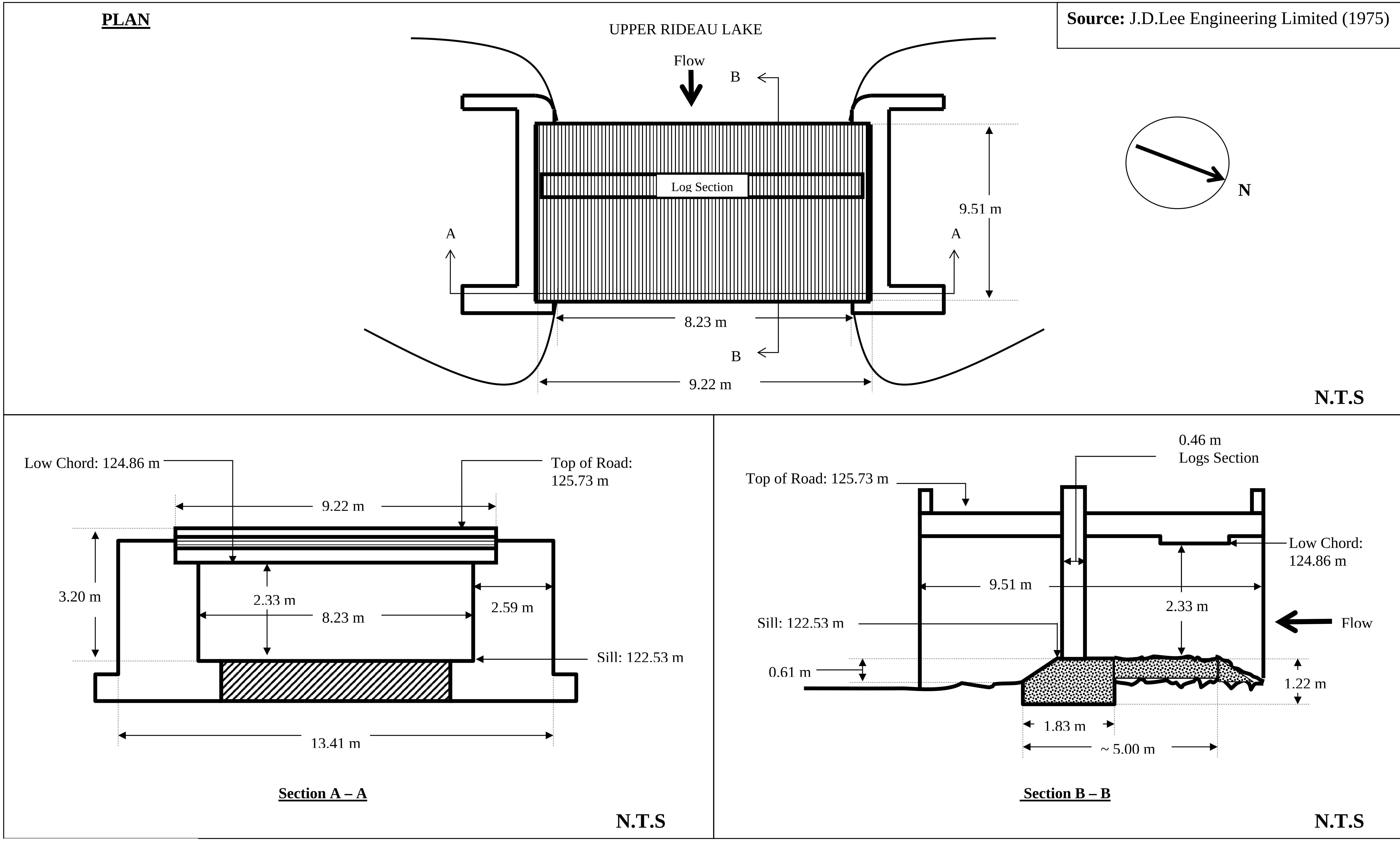
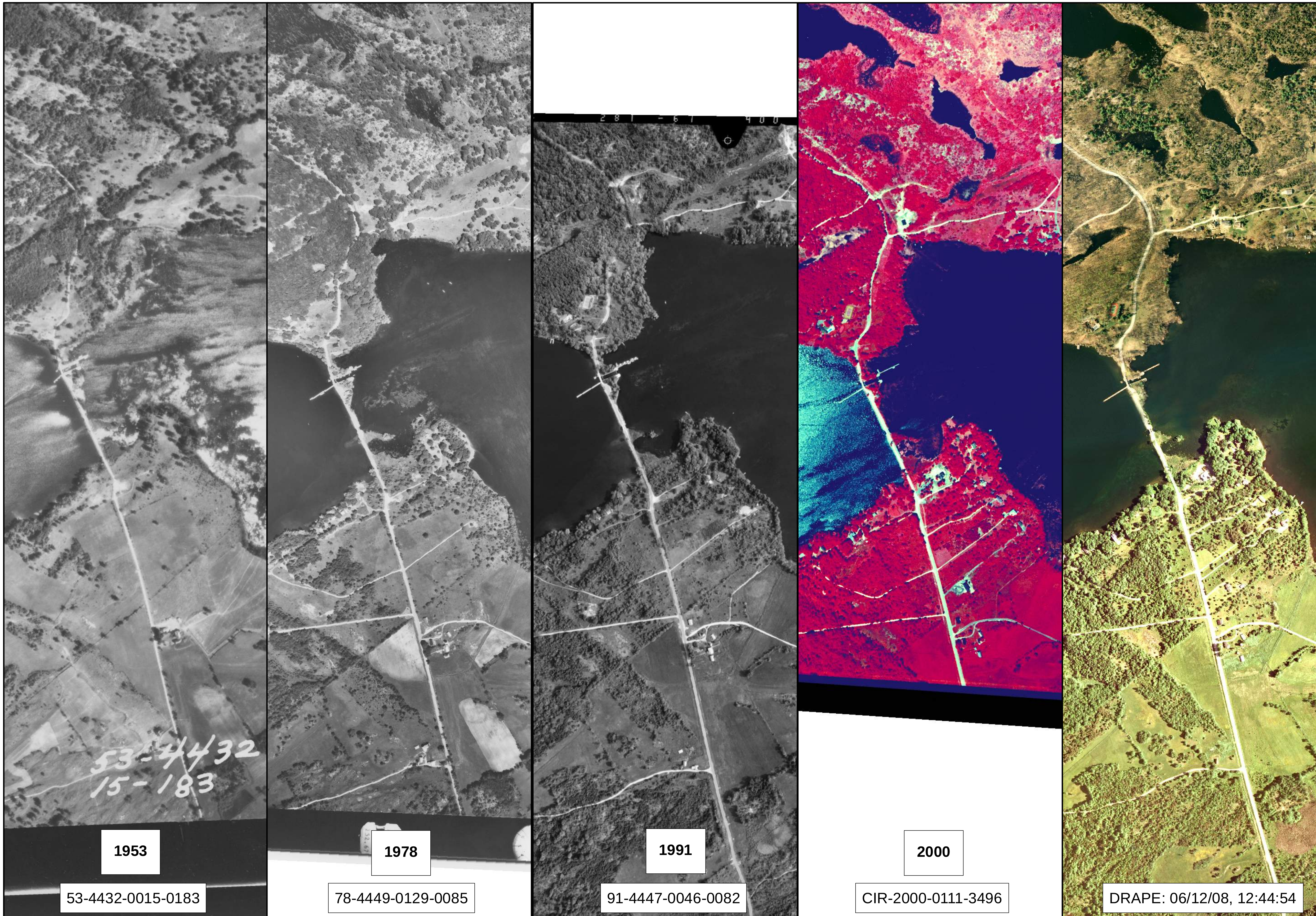


Figure 4: Narrows Dam

Figure 5: Upper Rideau Lake, Outlet, Historical Air Photos



0 200 400 800 1,200 1,600 2,000 Meters

RIDEAU VALLEY CONSERVATION AUTHORITY

Map Scale: 1:10,000

Projection note: U.T.M. Zone 18 - NAD 83 Datum

N W E S

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Modified by: dinnes	Date Modified: 5/11/2011 11:53:50 AM
Published by: apetit	Date Published: 5/26/2011

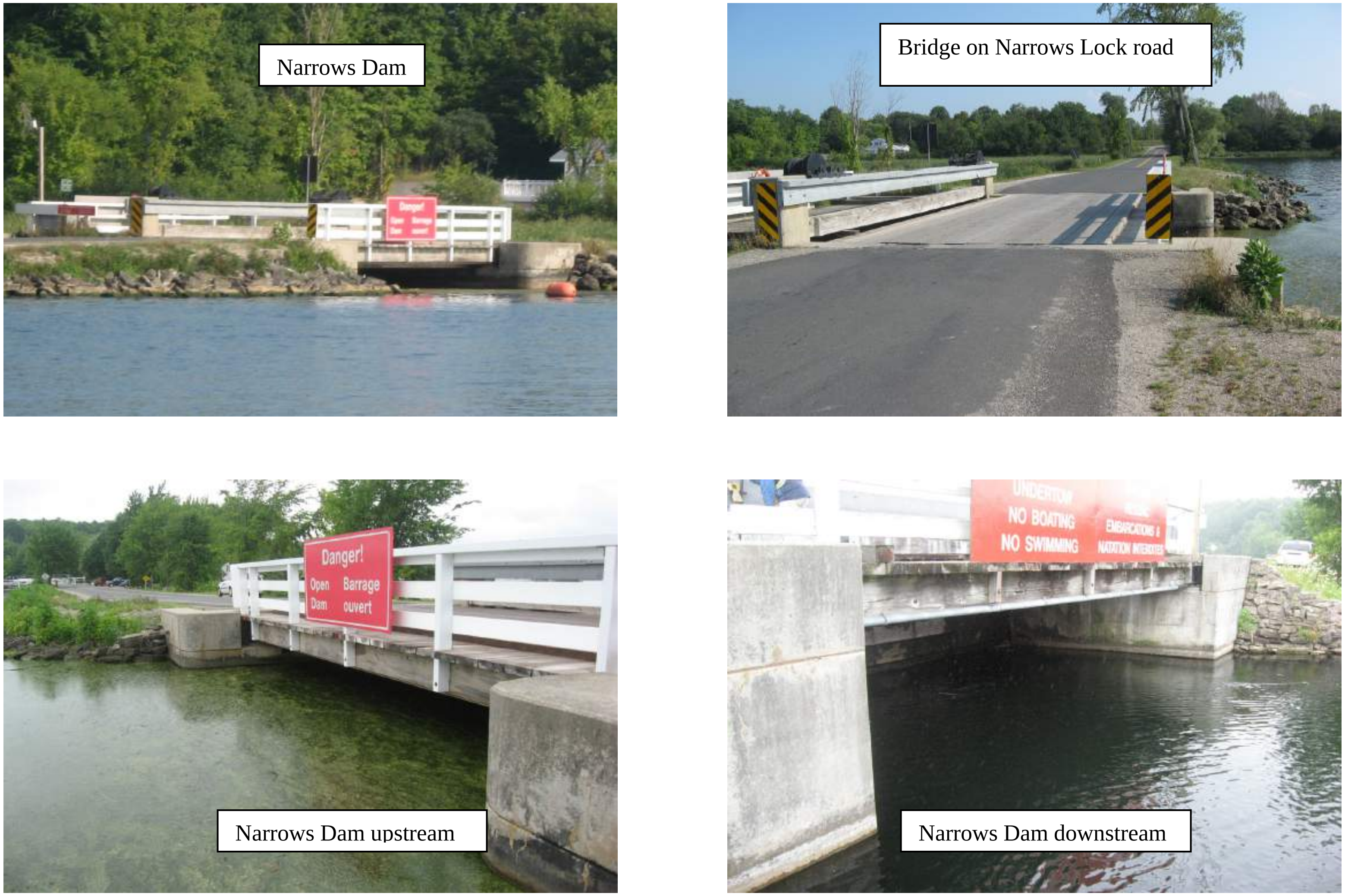

Figure 6: Narrows Dam Pictures (Taken July 2010 and September 2011)

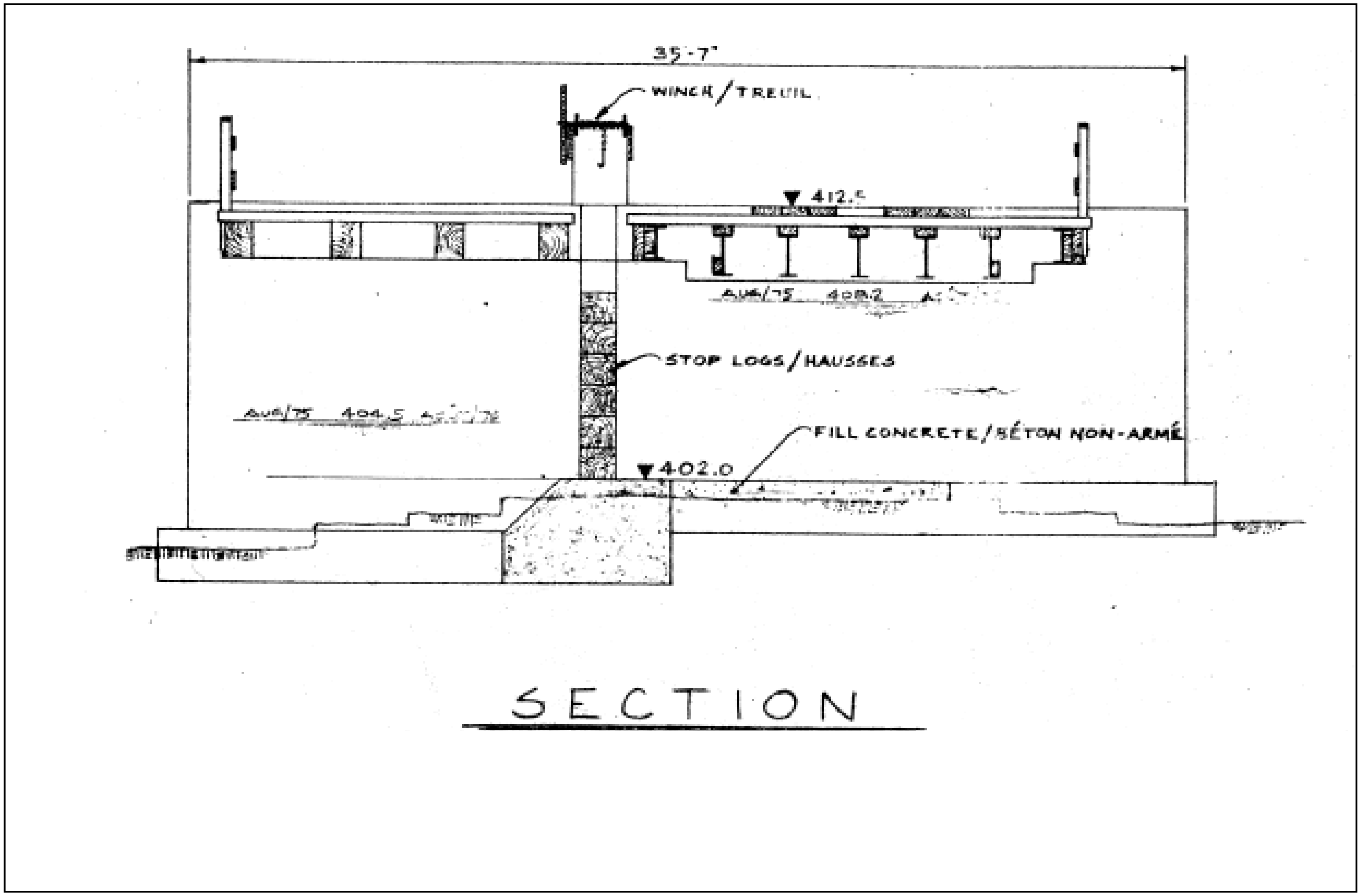

Figure 7: Typical Drawing of Narrows Dam by J. D. Lee Engineering Limited (1975)

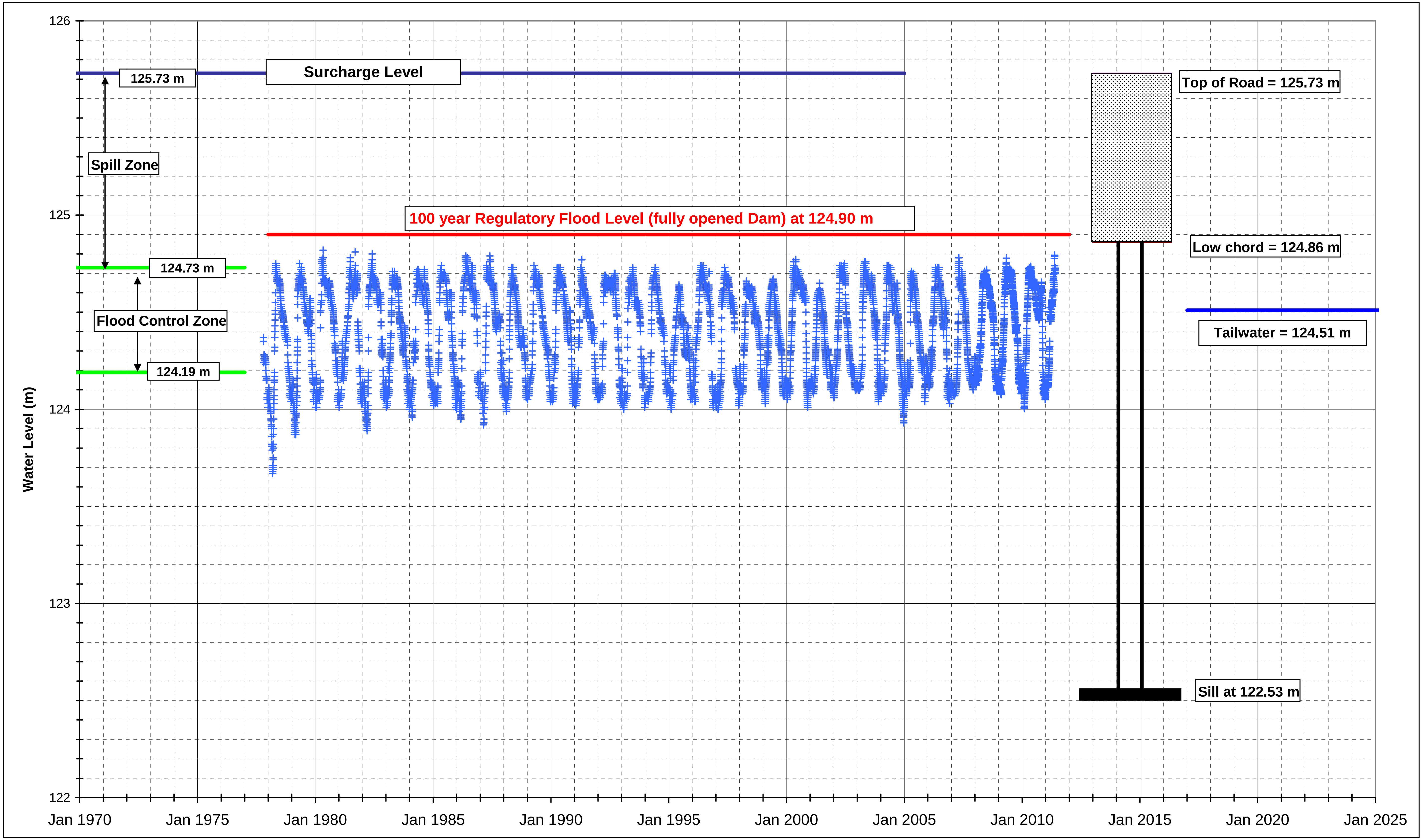

Figure 8: Water Level on Upper Rideau Lake at Narrows (Station ID: 02LA025)

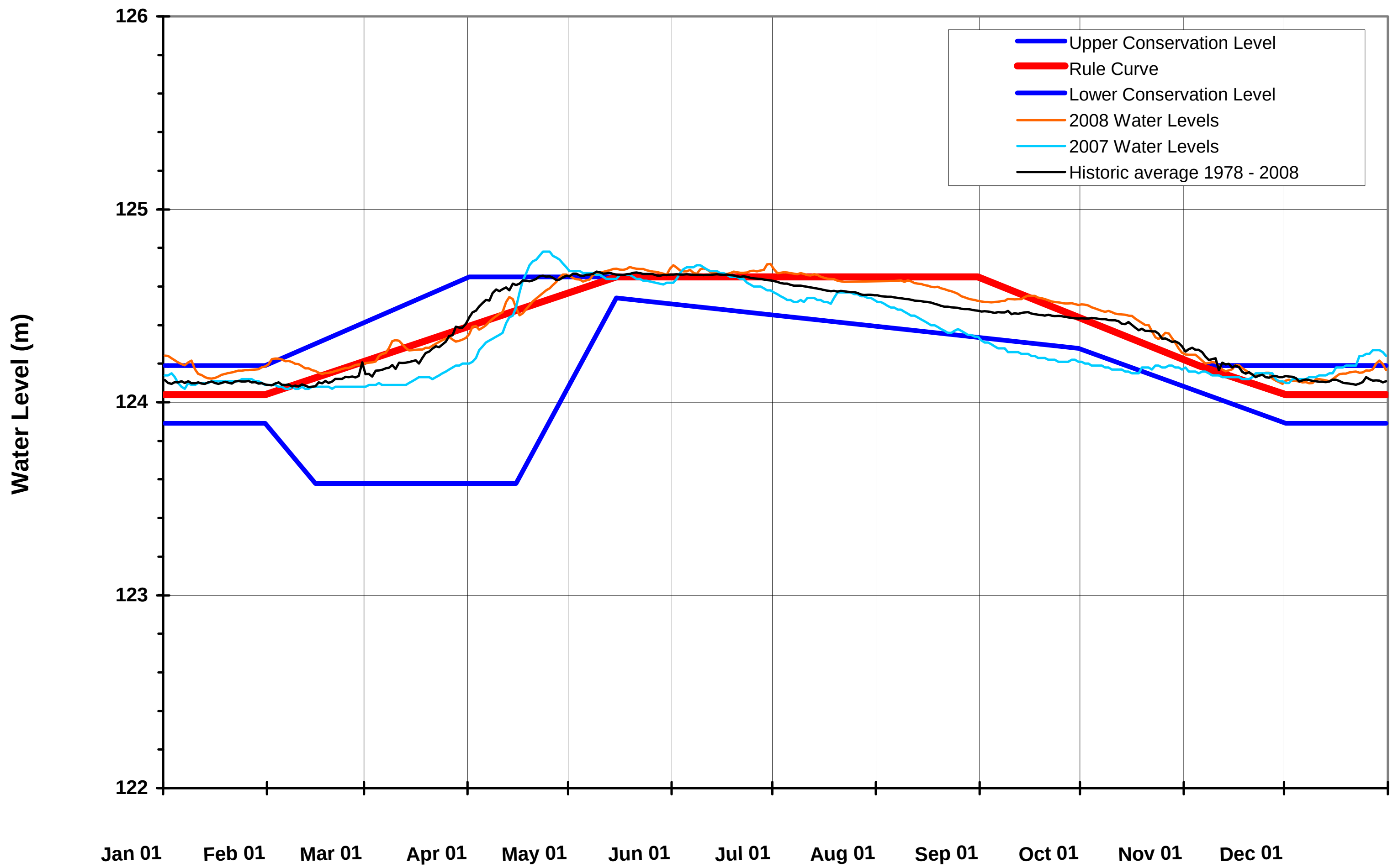

Figure 9: Rule Curve for Upper Rideau Lake

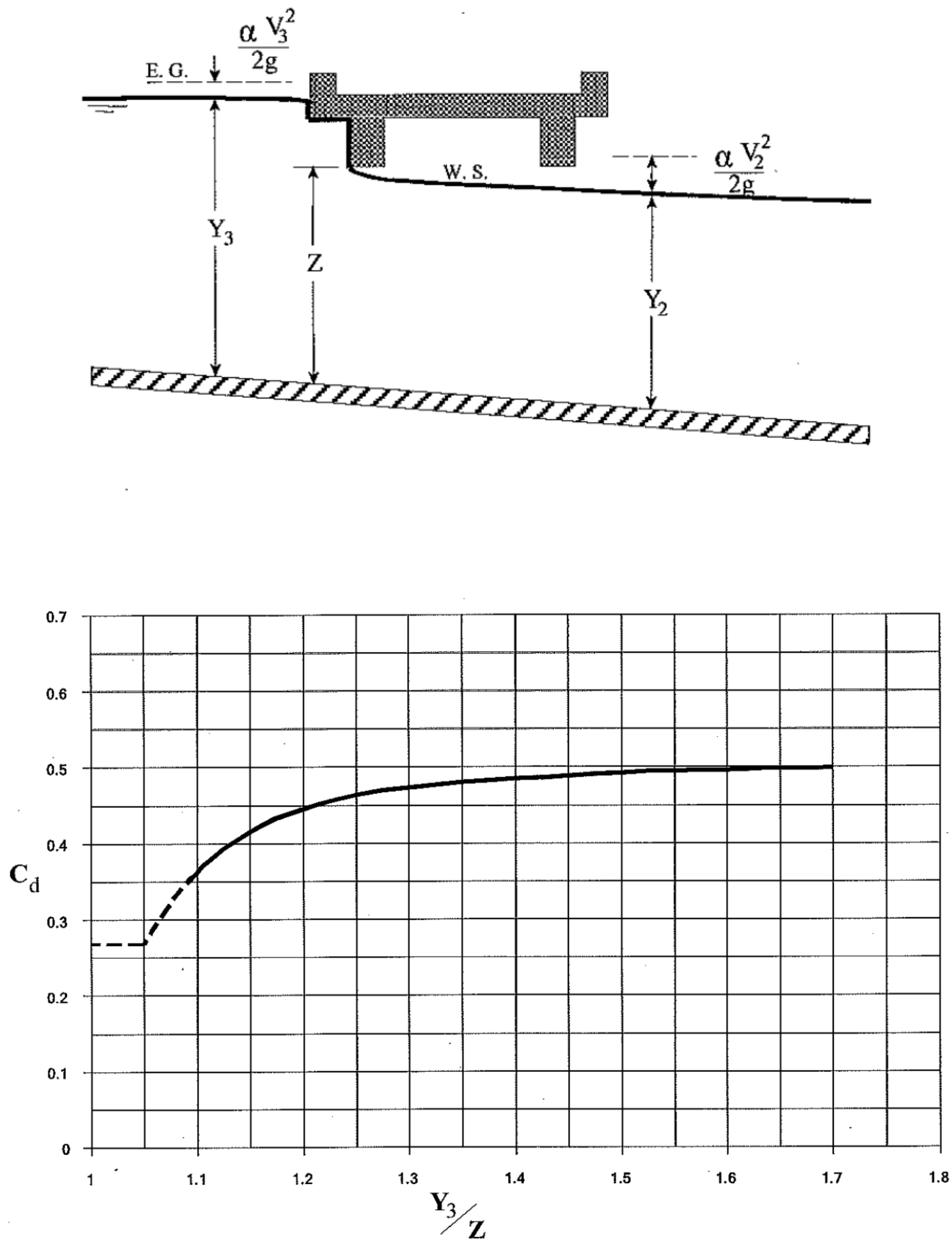

Figure 10: Bridge under Sluice Gate Type of Pressure Flow (after USACE, 2002)