Rideau Valley Conservation Authority
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Technical Memorandum

Date: February 14, 2012

Subject: **Analysis of Regulatory Flood Level on the Shoreline of Bobs 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 Bobs 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 Bobs 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).

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. Bobs 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 (Bolingbroke 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, 2010a). 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., Bobs 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 Bobs Lake, design drawings of the Bolingbroke 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, 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.

This report supersedes an earlier version dated October 18, 2011 and approved by the RVCA Board of Directors on October 27, 2011.

Study Area

Bobs Lake has a surface area of 2878 hectares and a shoreline length of 215 km. The catchment area draining to the lake is 358.63 km^2.

The study area includes the watershed of Bobs Lake as shown in Figure 1 (aerial photo base) and Figure 2 (DEM base). Ideally, regulation limits are to be produced for the entire shoreline of Bobs Lake and adjacent low-lying areas based (in part) on the estimated flood lines for the 1:100 year water surface elevation. Bolingbroke 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 entire study area is within the townships of Tay Valley and South Frontenac. There is no major centre of settlement around the lake, but many (≈150) lakeside cottages and rural residences.

Hydrological Analysis

There are historical streamflow records on the Tay River just downstream of Bolingbroke Dam (02LA017) since 1998 collected by Parks Canada. However the data is seasonal and has many gaps. This data is not therefore of sufficient length and quality to perform statistical analysis to derive design floods. Continuous water level data of the lake at Bolingbroke (02AL023) since 1978 is available from Parks Canada, and 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 (2010a), flood flows for Bobs 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)

- 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 (2010a), 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 Bobs Lake situation, three site-specific estimates are available:

- FENCO (1981) – based on snowmelt
- Genivar (2008) – based on data transposition
- RVCA (2007) – based on long term 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 and area pro-rating methods are therefore not considered any further.

In a subsequent study on Tay River Basin (RVCA, 2010b), the Mike11 flows were found to be better than FENCO (1981) and Genivar (2008) estimates and the most suitable for flood mapping purposes[1].

This inference was drawn mainly based on the superiority of continuous modeling, 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

[1] The RVCA Board, in its December 16, 2010 meeting, approved this report and adopted the Mike11 flows as the best suited for flood mapping purposes.

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 ungauged basins where long-term climatic data is available.

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 Bobs Lake. The design flows are shown in Table 2.

The flows listed in Table 2 have been used in the hydraulic analysis to determine the corresponding computed water levels.

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.

Bolingbroke Dam: This dam is situated at the downstream end of Bobs Lake and is used to control the lake level and the outflow from the lake. 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 1983 as-built drawing of this dam was obtained from Parks Canada and was used in our analysis. The main bay is 3.03 m wide and fitted with stop logs (Figure 4) and a sill level at 159.21 m. It also has two flash boards (8.26 and 12.16 m wide, and at an elevation of 162.58 m) for passing flood flows. 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 6) 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 Bolingbroke Dam, Parks Canada strives to keep the lake water level as close as possible to the 'rule curve' (Figure 7). 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 1978, continuous water level measurements of Bobs Lake just upstream of the dam (station 02LA023 at Bolingbroke), have been taken by Parks Canada. This information (Figure 6) has been utilized in the present study.

Flow Data: Since 1998, flow data of the Tay River at Bolingbroke (station 02LA017, downstream of Bolingbroke Dam) is being collected by Parks Canada. However this data has gaps (Figure 8). We have not directly used this data in flood level computation; however, this data was used in the verification of the Mike11 model which was used to estimate the design flows.

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 (see Figure 4).

The tail water must generally be estimated beforehand. In this case, there was a large drop (2 m) downstream of the dam and steep channel further downstream; therefore, the flow could be considered independent of the tail water.

The physical dimensions of the dam were taken from the 1983 as-built drawings obtained from Parks Canada (Figure 4).

The rating curve of the dam, i.e., the relationship between the upstream water level and the flow passing through the dam, was constructed using the physical dimensions of the dam and standard broad-crested weir flow equation (Bos, 1990):

$$Q = \frac{2}{3} C_d C_v \sqrt{\frac{2}{3} g} b h^{1.5}$$

where C_d and C_v are the discharge and approach velocity coefficients; g is the acceleration due to gravity (9.81 m^2/s); b is the width of the weir; and h is the height of the upstream water level above the weir crest level. This equation applies to the central stop log bay (when all logs are out) as well as to side spill sections of the Bolingbroke Dam. The coefficients C_d and C_v were estimated to be 0.93 based on the weir configuration and 1.0 for an assumed negligible velocity head far upstream.

Figure 9 shows the rating curves for the entire structure as well as for the central bay and side sections. In these calculations, it was assumed that all logs are taken out.

The hydraulic calculations are summarized in Table 2. It indicates that the 1:100 year flood level in Bobs Lake is 163.07 m above mean sea level. The computed water levels corresponding to flow with other return periods are also listed, all under the assumption that all logs are taken out.

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 Bobs 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' (161.66 to 162.87 m) as described in Acres (1994).

The regulatory flood level for Bobs Lake is 163.07 metres above sea level (Figure 6), and is associated with a discharge of 47.3 cms at Bolingbroke Dam, the present configuration of the dam and downstream channel, and the assumption that all logs are taken out. This level is 0.49 m (19⅓ inches) above the overflow section level and 0.15 m (6 inches) below the lower level of the platform.

We also observe that the RFL is within the 1.0 m 'spill zone' defined by Acres (1994), about 0.20 m (8 inches) above the 'flood control zone', but well below (0.80 m or 31½ inches) the higher limit of the spill zone (Figure 6). During large flood events including and up to the 1:100 year flood, Parks Canada strives to keep the water level within the 'flood control zone' with an upper limit of 162.87 m. For larger floods (greater than the 1:100 year flood), the water level may be allowed to rise within the 'spill zone' with an upper limit of 163.87 m. Exactly how these zones were determined by Acres (1994) is not clear.

The RFL (163.07 m) can also be expressed relative to the range of water levels (161.10 to 163.05) observed over the last 33 years (Figure 6). According to the measurements, the water level approached this limit very closely (within the range of measurement error) twice during this period. Strictly speaking, these incidents (approaching or exceeding this level) are a result of dam manipulation and, if desired, could be avoided by keeping them down by removing stop logs. This also highlights that the actual water level at the lake is a manifestation of incoming flow and time-varying dam operation, whereas the water levels listed in Table 2 are based on incoming flow and a static operating condition (i.e., no logs). From the observed data, it appears that Parks

Canada has been doing a good job of keeping the water level down and therefore the lake free of flood risk.

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 lines. 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 (163.07 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 Bobs Lake relative to its catchment area and the presence of many other lakes (altogether covering about 12% of the catchment), 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 163.07 m.a.s.l. should be used in the design of any structures in the regulated area around Bobs 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 the regulatory flood level for Bobs 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 could not be 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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Senior Water Resources Engineer

References:

1. Acres (1977). Study of the Operation of the Rideau-Cataraqui System. Report submitted to Rideau Canal, Parks Canada by Acres Consulting Services Limited, Niagara Falls, Canada, March 1977.

2. Acres (1994). Rideau Canal Water Management Study. Report submitted to Canadian heritage Parks Service by Acres International Limited, Canada, June 1994.

3. Bos, M. G. (1990). Discharge Measurement Structures. ILRI Publication 20, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands, 401 pp.

4. Boughton, W. and Droop, O. (2003). Continuous simulation for design flood estimation – a review. Environmental Modelling and Software 18:309-318.

5. Conservation Ontario (2005). Guidelines for Developing Schedules of Regulated Areas. Conservation Ontario and Ministry of Natural Resources, October 2005.

6. DEFRA (2005). National river catchment flood frequency method using continuous simulation. R&D Technical Report FD2106/TR, UK Department for Environment, Food and Rural Affairs, September 2005.

7. FENCO (1981). Tay River Flood Plain Mapping. Report prepared for Rideau Valley Conservation Authority by FENCO Consultants Limited, Toronto, May 1981.

8. Genivar (2008). Hydrotechnical study of the Rideau River Watershed, Final Report. Prepared for Parks Canada by Genivar Ontario Limited, Ottawa, August 2008.

9. 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.

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

11. MMAH (2005). 2005 Provincial Policy Statement. Ontario Ministry of Municipal Affairs and Housing, Queen's Printer, Toronto, Ontario, 2005.

12. MNR (1986). Flood Plain Management in Ontario – Technical Guidelines. Ontario Ministry of Natural Resources, Conservation Authorities and Water Management Branch, Toronto.

13. MNR (2002). Technical Guide – River & Stream systems: Flooding Hazard Limit. Ontario Ministry of Natural Resources, Water Resources Section, Peterborough, Ontario, 2002.

14. RVCA (2007). Rideau River Watershed Modeling Using Mike11, Draft Report, Rideau Valley Conservation Authority, Manotick, Ontario, March 2007.

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

16. RVCA (2010b). Tay River Flood Risk Mapping from Christie Lake to Glen Tay. Technical Memo, Rideau Valley Conservation Authority, Manotick, Ontario, December 2010.

Table 1: Estimated Flood Flows at Bobs Lake Outlet

Return Period (years)	SOURCE / METHOD										
	Mike11[1]	FDRP[2]			Gingras et al.[3]				Area Pro-rating [4]	Genivar[5]	Fenco[6]
		Northern Ontario	Eastern Ontario	Ontario	Region: 7	Region: ON/QC	Region: 2	Region: 6			
2	23.00	23.27	55.19	23.73	62.47	50.00	81.31	13.90		23.10	
5	29.90	33.23	68.42	33.22						29.60	
10	34.30	40.04	76.55	39.60						33.10	
20	38.40	46.70	83.99	45.79	130.01	97.31	144.53	26.66		36.00	
50	43.50	58.40	93.54	56.21						39.20	
100	47.30	67.79	100.50	64.44	157.84	118.01	167.70	33.38	110.71	41.40	20.25
200	51.10										
500	56.00									45.90	
1000 [7]										47.50	
10,000 [7]										52.60	
Summer PMF										78.00	
Spring PMF										98.00	

1. Mike11 output, using a Log Pearson Type 3 Frequency Distribution.
2. MNR (1986). Flood Plain Management in Ontario – Technical Guidelines. Ontario Ministry of Natural Resources, Conservation Authorities and Water Management Branch, Toronto.
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 streamflow measurements from the gauge: Rideau River at Carleton University (Station ID 02AL004; drainage area 3830 km2).
5. Genivar (2008) output, using 3 parameter Log normal Distribution based on data from Kemptville hydrometric station (02LA006) with correction factor of Port Elmsley (02LA016).
6. Fenco (1981) estimates, based on modeling (HYMO and HEC-2) of a 2 day 100 year snowmelt event with saturated antecedent moisture content conditions (AMC III) at Perth.
7. Use with caution, these events as they are considered to be extrapolated beyond reasonable limits.

Sources: RVCA (2010): Estimation of Design Flows for RVCA Lakes.
Fenco (1981): Tay River Flood Plain Mapping.
Genivar (2008): Hydrotechnical Study of the Rideau River Watershed.

Table 2: Computed Water Levels of Bobs Lake

Return Period	Flow	Computed Water Surface Elevation
years	cms	m
2	23.00	162.05
5	29.90	162.59
10	34.30	162.75
20	38.40	162.87
50	43.50	162.99
100	47.30	163.07
200	51.10	163.15
500	56.00	163.24

Note: Assuming all logs are taken out

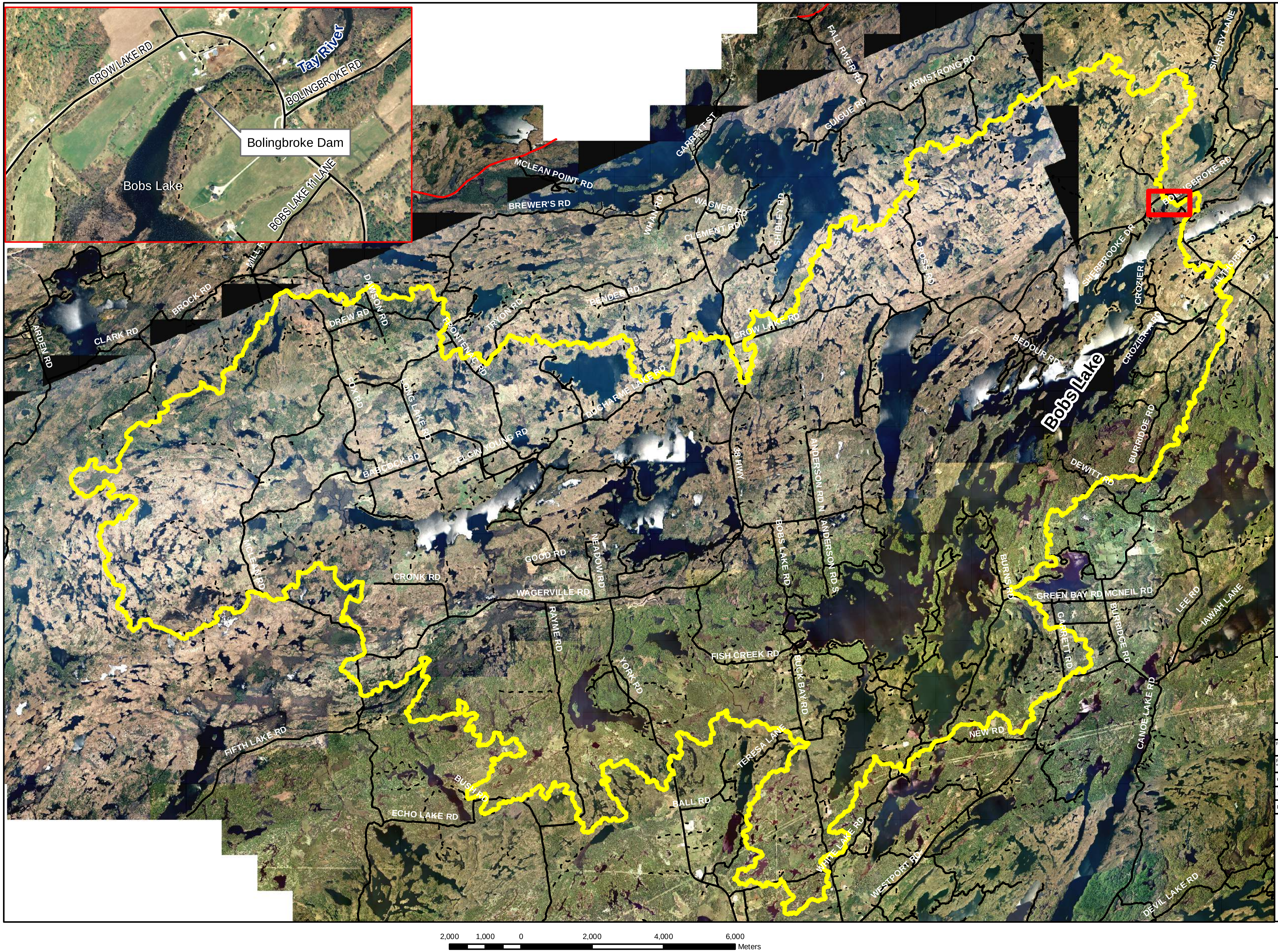
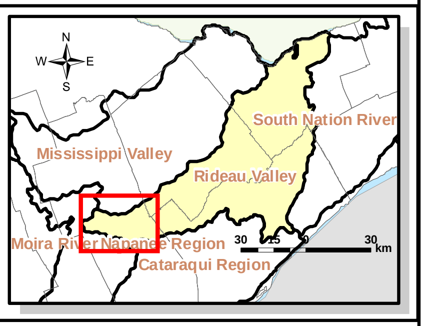


Figure 1: Location Map of Bobs Lake



Legend

Watershed

- Bobs Basin

Transportation

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

RIDEAU VALLEY CONSERVATION AUTHORITY

Map Scale: 1:100,000

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

File Location:
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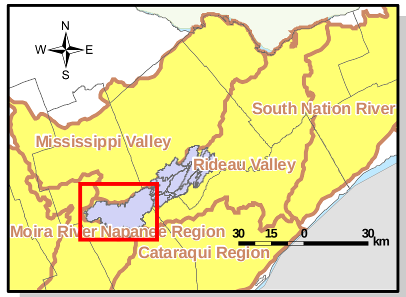
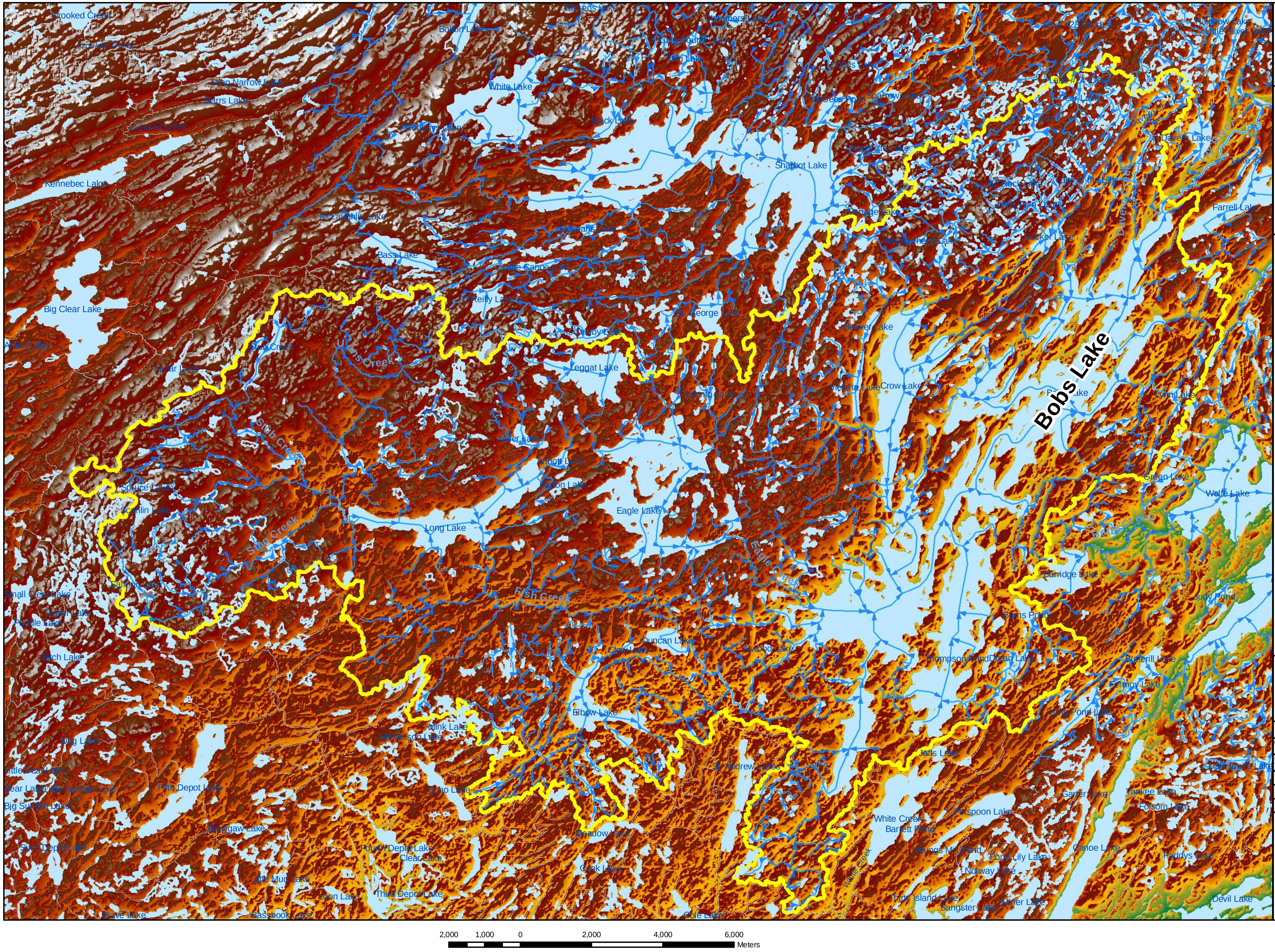
Figure2: Bobs Lake Basin





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Map Scale: 1:100,000

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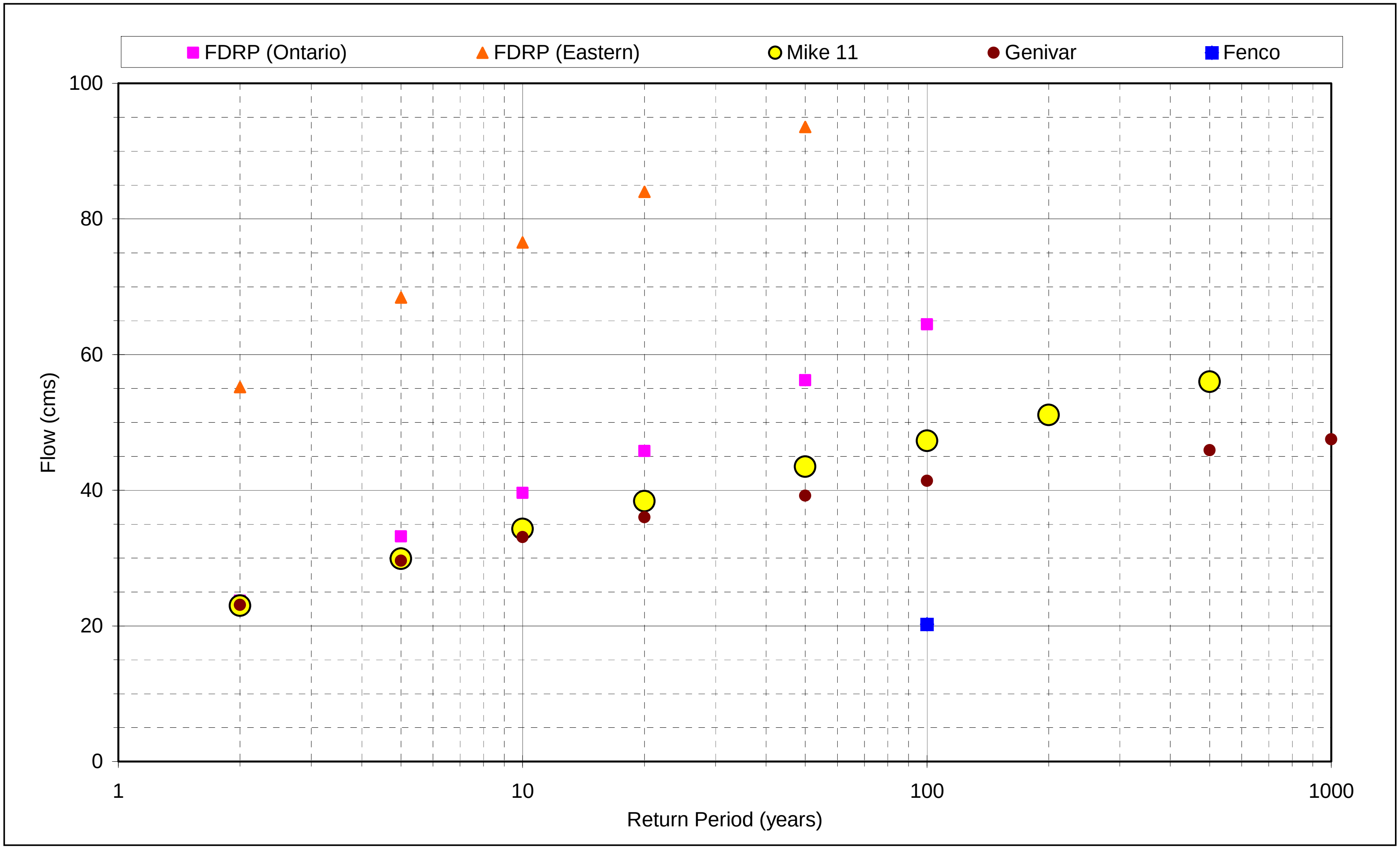


Figure 3: Estimated Flood Flows

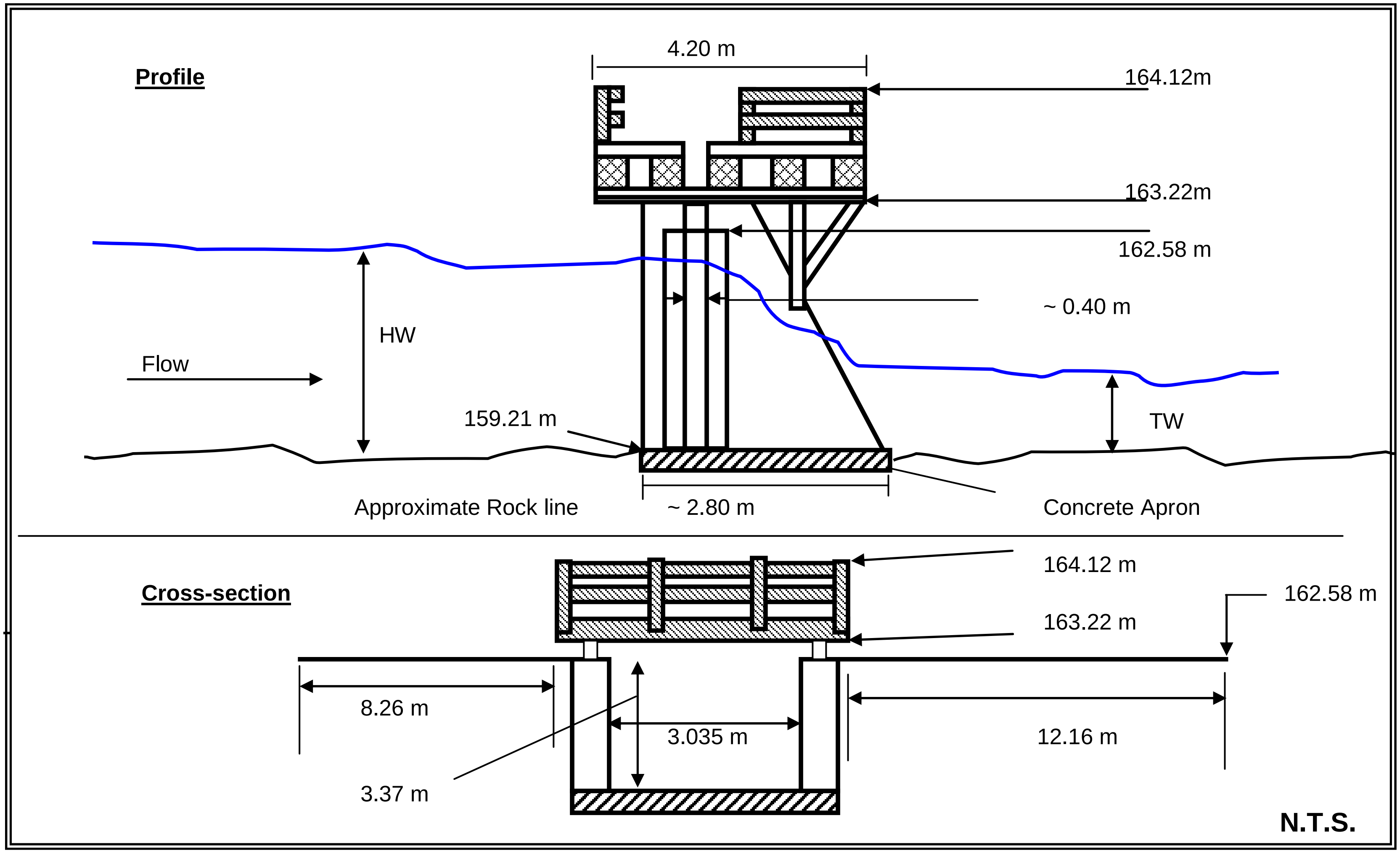
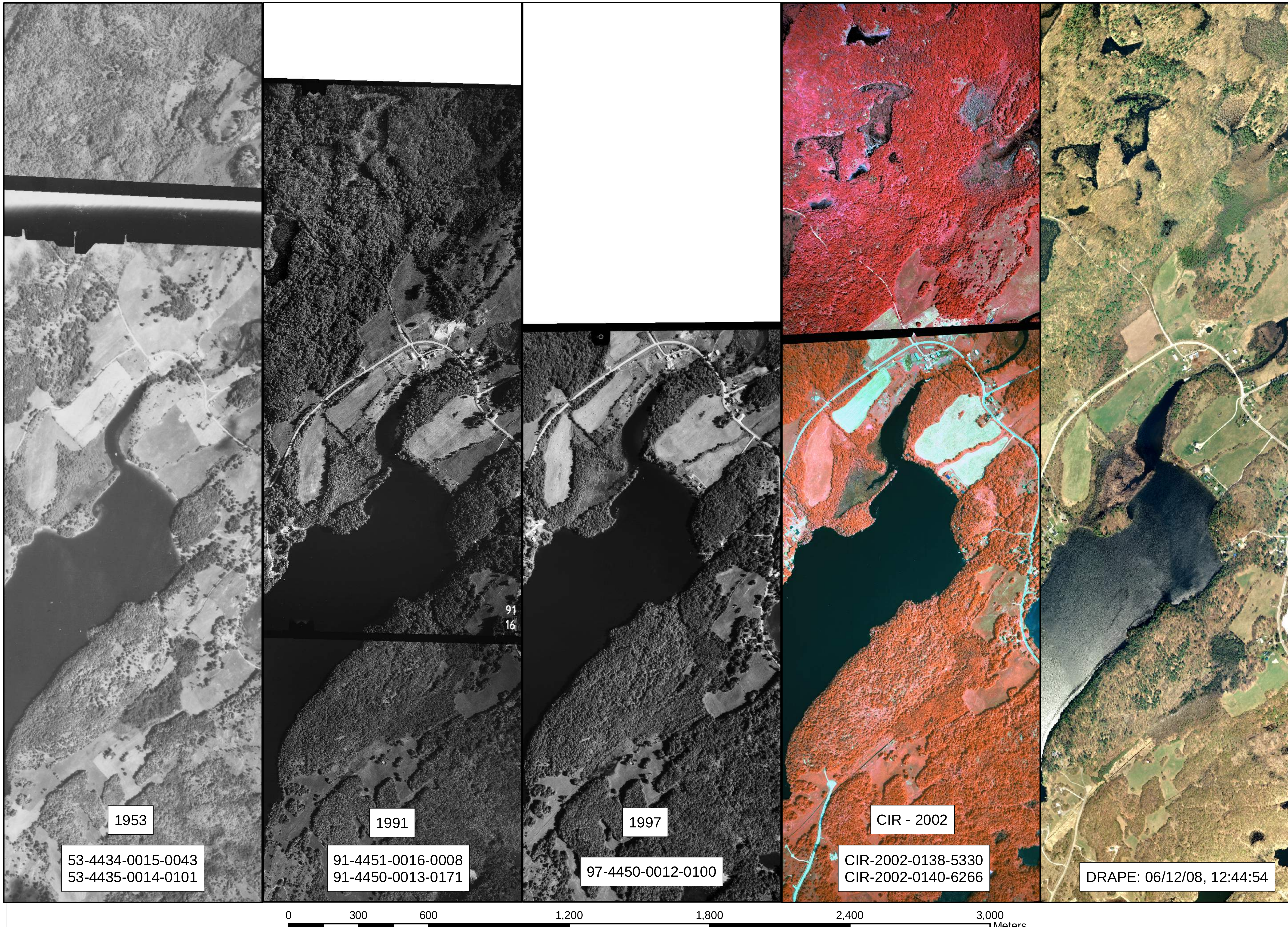


Figure 4: Bolingbroke Dam (Drawn after Parks Canada Plan of existing Dam, 1983)

Figure 5: Bobs Lake Outlet, Historical Air Photos



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Map Scale: 1:15,000

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

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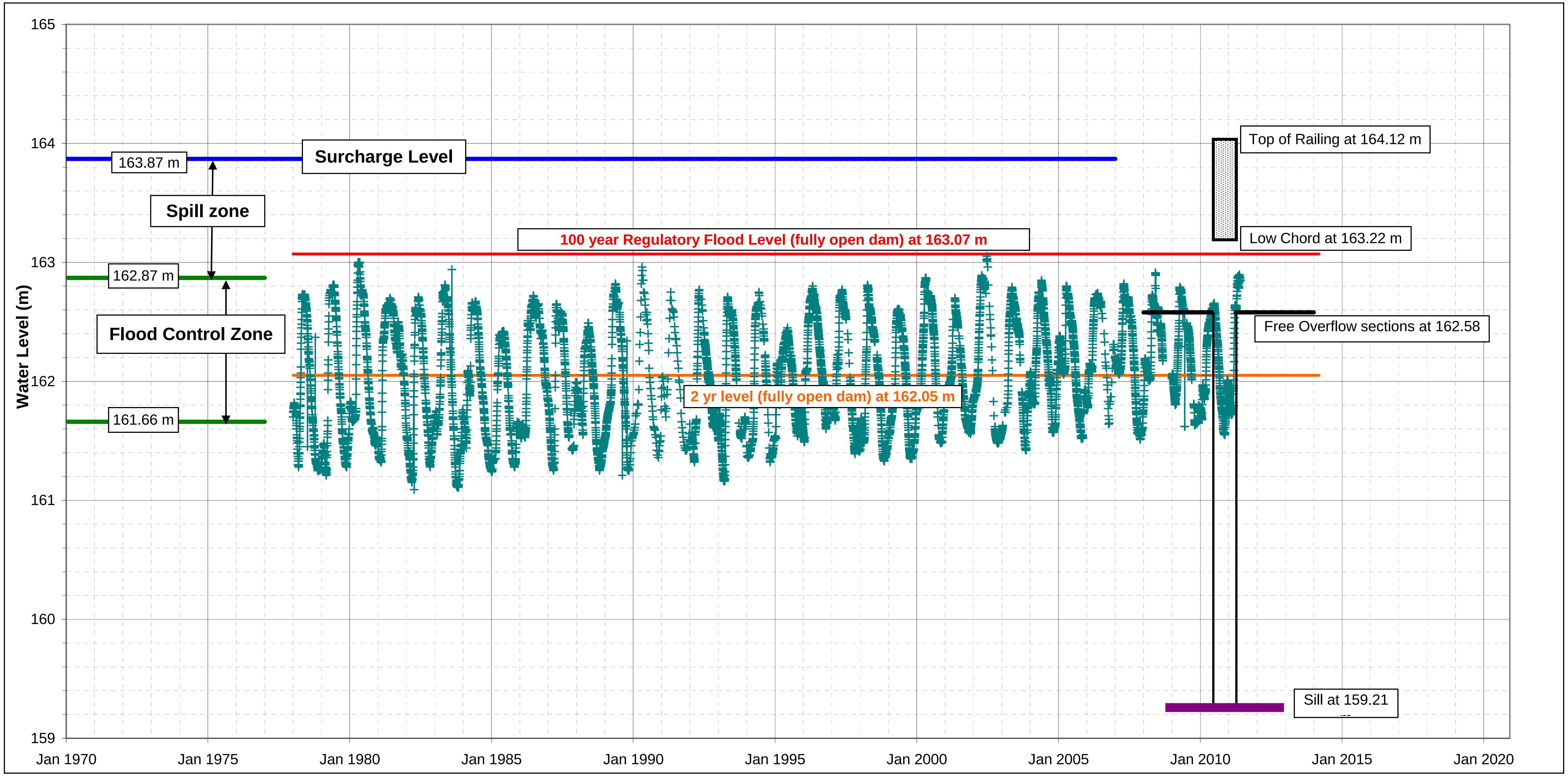


Figure 6: Water Level of Bobs Lake at Bolingbroke (02LA023)

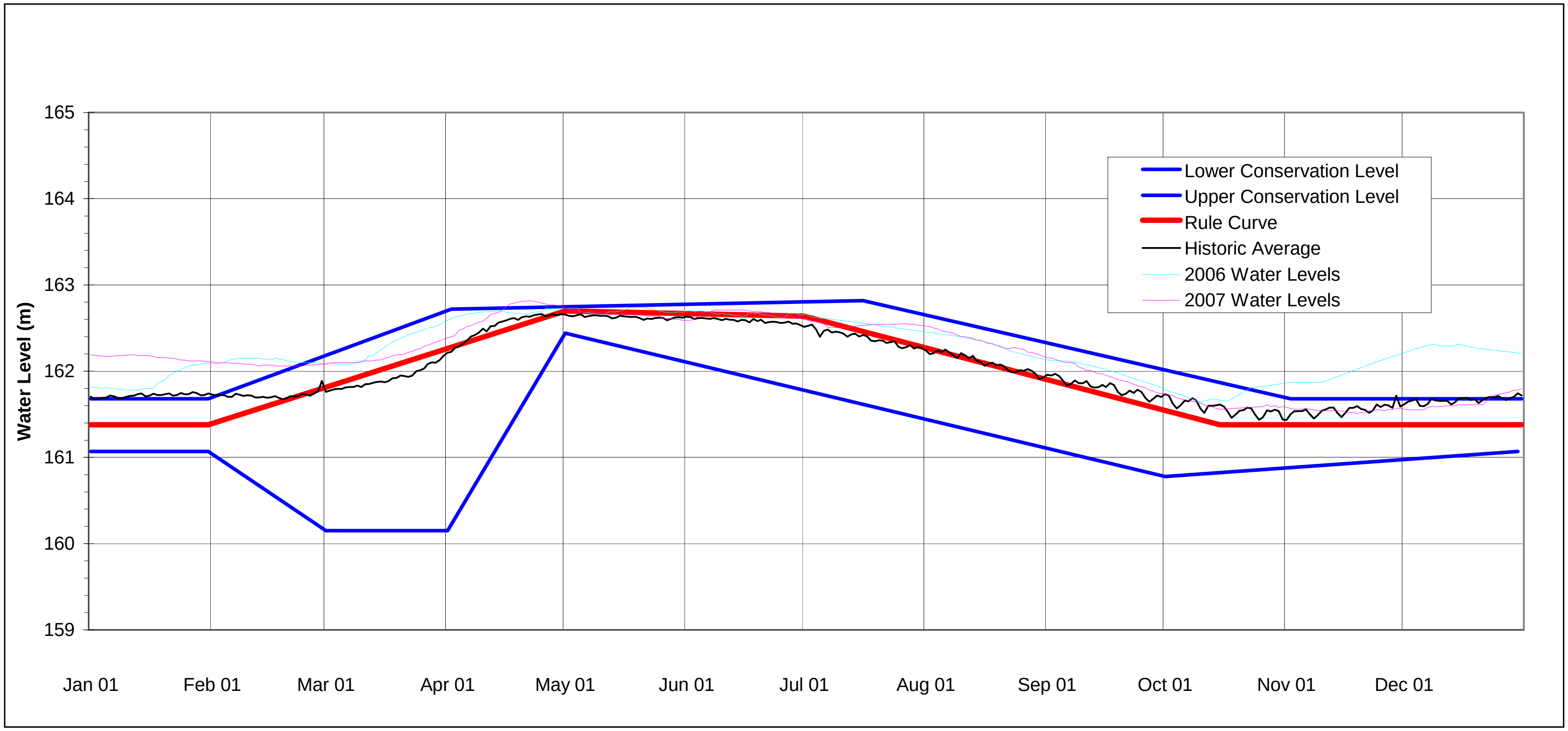
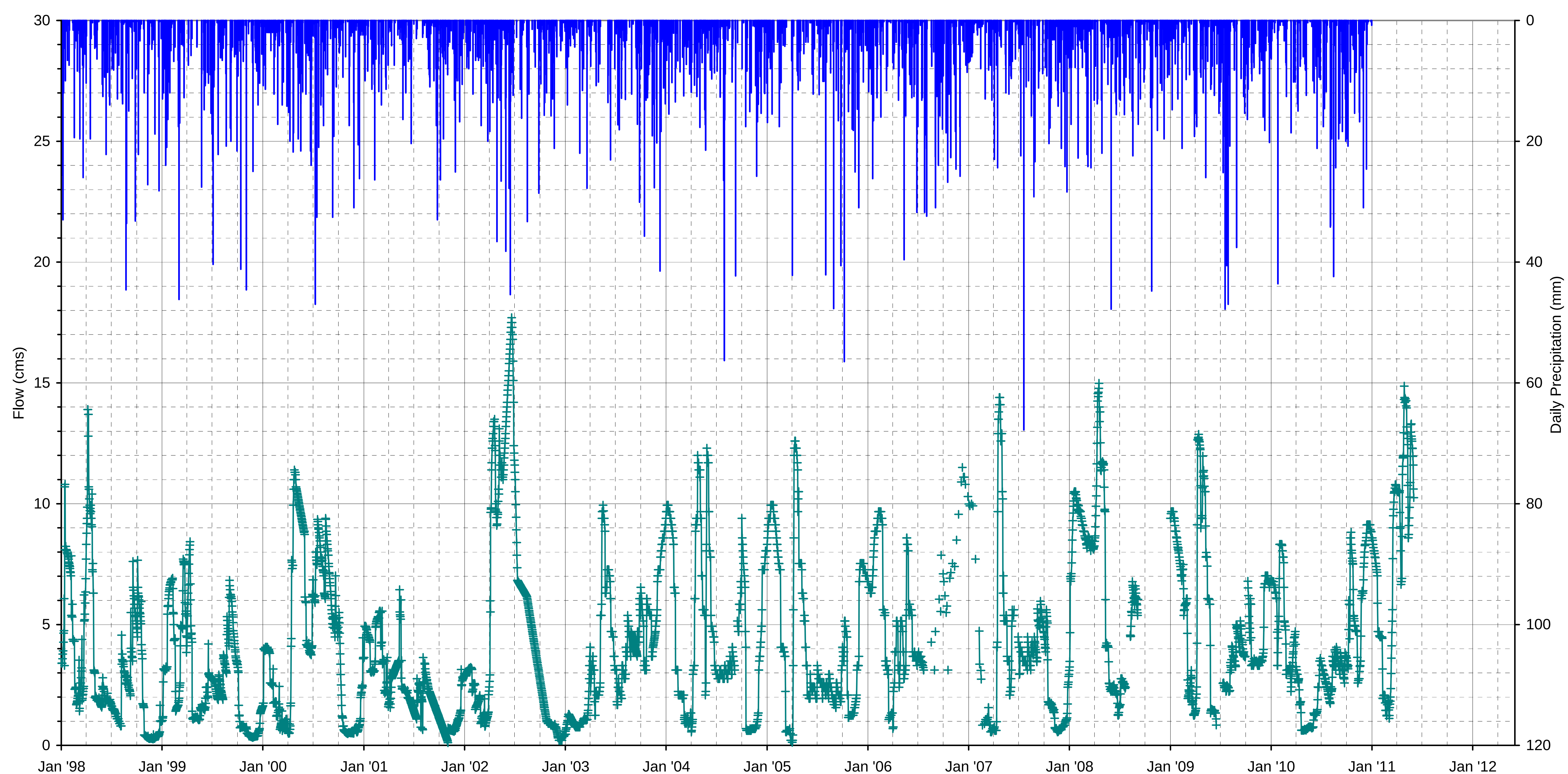


Figure 7: Rule Curve for Bobs Lake



Note : Godfrey Station ran from 1984 to 2003 and was discontinued, the remaining data until December 2005 is adjusted from other stations using the MNR: Climate Data Gap Filling project. The data from January 2006 to December 2010 is from the Ottawa airport station (6106000).

Figure 8: Flow of TAY @ Bolingbroke (02LA017) and precipitation data from Godfrey (Station ID: 610285) and Ottawa Airport (Station ID: 6106000)

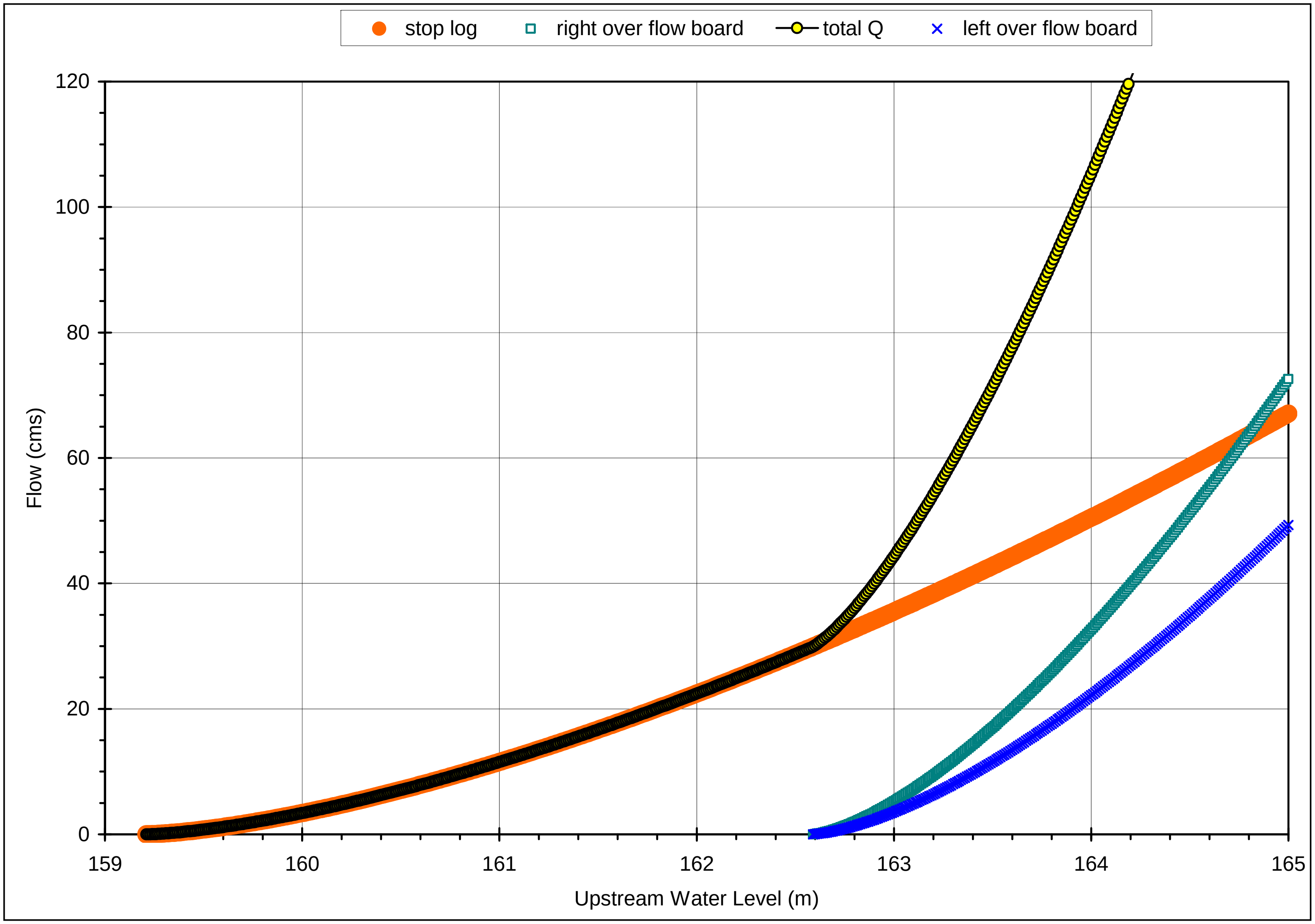


Figure 9: Stage - Discharge Relationship at Bolingbroke Dam