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Technical Memorandum

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Subject:	**Rideau River Hydrological Analysis for the Purposes of Flood Risk Mapping**
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Executive Summary

This report provides a summary of the hydrological analysis of the Rideau River from Poonamalie Dam to Rideau Falls and the derivation of design flows suitable for use in flood plain mapping. The analysis has been done in accordance with the technical guidelines set out under the Canada-Ontario Flood Damage Reduction Program (FDRP) (MNR, 1986), and the technical guide for the flood hazard delineation in Ontario (MNR, 2002) as laid out by the Ontario Ministry of Natural Resources. The 1:100 year flood lines that would be delineated using the design flows of this report would be suitable for use in the RVCA's regulation limits mapping (as per Ontario Regulation 174/06) and in municipal land use planning and development approval processes under the Planning Act.

Contents

1. Introduction

In 2012, the City of Ottawa and three conservation authorities (Mississippi, Rideau and South Nation) initiated a program for flood risk mapping within the boundary of the city. A four-year plan for mapping a number of high priority rivers and streams was made. As part of this program, the RVCA has identified 12 stream reaches, where the existing mapping would be updated or mapping will be created for the first time.

Historically, the Rideau River from Poonamalie Dam to the Rideau Falls has been segmented in to five reaches for flood mapping studies:

1) Rideau River (Hogs Back to Rideau Falls)
2) Rideau River (Hogs Back to Kars)
3) Rideau River (Kars to Burritts Rapids)
4) Rideau River (Burritts Rapids to Smiths Falls)
5) Rideau River (Smiths Falls to Poonamalie Dam)

The first three reaches are within the City of Ottawa and were therefore identified for updating under this program. Updating of the first reach (Hogs Back to Rideau Falls) has since been completed (RVCA 2016). The last reach (Smiths Falls to Poonamalie) was updated in 2010 (RVCA 2010). The middle three reaches are in need of updating and it was decided that a single, comprehensive hydrological analysis done for the entire Rideau River would be a logical approach. Once completed, flood flow quantiles derived from this study could then be used for mapping various reaches of the Rideau River. This hydrological analysis is documented here.

In a recent study on the lower most reach from Hags Back to Rideau Falls (RVCA 2016), it was found that the highest recorded water level at Carleton University gauge (60.35 m on 28 March 1976) was lower than the estimated 1:100 year flood level of 60.75 m. Furthermore, during subsequent studies on the upstream reaches (Hogs Back to Kars, and Kars to Burritts Rapids) (RVCA 2017a, 2017b), the same was found at Manotick gauge (81.01 m recorded vs. 81.80 m estimated flood level) and at Becketts Landing (86.76 m recorded vs. 87.31 m estimated flood level). Therefore, the 1:100 year flood is the appropriate mapping standard for the Rideau River.

2. Study Area

In this study, we analyze the hydrology of the whole Rideau River watershed, which is basically the whole RVCA jurisdiction except the East and West tributary areas which flow directly to the Ottawa River (Figures 1 and 2). Poonamalie is the location where the Rideau Lakes essentially morphs into the Rideau River. The entire length of the river downstream from Poonamalie to the Rideau Falls is analyzed here. The hydrology of the upstream lakes is not addressed here, but has been scrutinized in a number of past studies (RVCA 2012a, 2012b).

The Rideau River downstream of Poonamalie touches several municipalities:

- Township of Drummonds-North Elmsley,
- Town of Smiths Falls,
- Township of Montague,
- Township of Merrickville-Wolford,
- Township of North Grenville, and
- City of Ottawa.

3. Review of Previous Studies

Starting in the early seventies, different reaches of the Rideau River have been studied for the purposes of flood risk assessment. As shown in Figure 3, most of the reaches have been studied at least twice, with the third assessment currently on the go.

Methodology and analysis over the years have evolved as streamflow data has accumulated and computational technology improved. A chronological review of past studies is helpful in understanding (a) how the technical methodologies evolved, and (b) why the current analysis as presented in this report is justified.

Dillon (1972): Rideau River flood plain mapping from Ottawa River to Kars

The first flood mapping study of the Rideau River is that by Dillon (1972), which dealt with the reach from Kars to Rideau Falls. Using 56 years of streamflow data from the Rideau River at Ottawa (02LA004; located at Hurdman Bridge from 1911 to 1945 and then moved to Carleton University), a 'best fit' frequency curve was derived. The 1:100 year flow at this location was estimated as 26000 cfs (736.2 cms). Flows at other locations were also estimated, but the details were not documented. It was also mentioned that a 1:100 year rainfall generated much smaller flows than snowmelt-driven spring flows, but again the details were missing. The flood levels were computed using the 'standard step method' and about 200 cross-sections. No information about water control structures or their operation was included in this report. Flood risk lines were then plotted using contour maps. The role of ice in flooding was recognized; however ice-induced flooding was not investigated as ice cutting/blasting was considered successful in managing ice-induced flooding.

James F. MacLaren (1976): Report on Rideau River Floodline Mapping (Smiths Falls to Kars)

The next report on the Rideau River was conducted by James F. MacLaren (1976), with a focus on the reach from Kars to Smiths Falls. Flood frequency analysis was done using available streamflow data at Long Island (1949-1975; 27 years), Merrickville (1942-1975; 34 years) and Poonamalie (1944-1975; 32 years). The 1:100 year floods at these three locations were estimated at 14400, 5300 and 5000 cfs (407.8, 150.1 and 141.6 cms) respectively. Flows at other locations were computed by interpolating flows as a linear function of drainage area. The contribution of Kemptville Creek was estimated as 8600 cfs (243.5 cms) and was added at the confluence. The determination of the 1:100 year flood profile was based on two components. First, the headwaters upstream of water control structures were computed using the information provided by Rideau Canal Office. Second, the channel profiles upstream were computed using the RBACK computer model (developed by James F. MacLaren and based on standard step method). Flood lines were then plotted on photo-mosaic sheets.

James F. MacLaren (1979): Report on Rideau River Floodline Mapping (Smiths Falls to Poonamalie)

In this report, James F. MacLaren (1979) extended their 1976 mapping of the Rideau River from Smiths Falls to Poonamalie Dam. The flows estimated earlier in 1976 were used; headwaters at dams were computed from physical dimensions; and the flood levels were computed using the HEC-2 model. A calibration was performed that indicated that the water levels could be computed within 0.2 feet (6 cm), although the details were sketchy. Floodplain maps were then produced on photo-mosaic sheets.

James F. MacLaren (1983): Rideau River Floodline Mapping: Tributaries – Smiths Falls to Kars

The original 1976 mapping work was extended once again in 1983 to include major tributaries and is documented in James F. MacLaren (1983) report. Spring floods of nine tributaries were estimated by first estimating the mean annual flood as a function of watershed characteristics; and then estimating the design floods by multiplying the mean annual flood by a factor, which in turn was determined by a frequency analysis of the pooled data from a number of streams in this region. We may note that this method, although appropriate at that time considering available data and technology, was rather crude with many assumptions and approximations. Furthermore, uncalibrated HYMO models were used at representative tributaries to estimate the rainfall-generated summer flows. Comparing spring and summer floods, it was concluded that the spring floods are larger for the tributary basins investigated with area ranging from 4.0 to 50.9 square miles (10.3 to 131.8 km^2). Thereafter, the spring floods were used to calculate the flood levels.

The hydraulic computation was done using the HEC-2 model, and the floodplain plotted on phot-mosaic sheets.

Robinson (1984): Flood Risk Mapping of the Rideau River – Mooneys Bay to Rideau Falls

By the early eighties, it was felt that numerous changes in the watercourse and urban development had occurred to justify a new floodplain study of the Rideau River from Hogs Back to Rideau Falls. This was done by Robinson (1984) and it superseded the previous mapping of Dillon (1972). Both hydrologic and hydraulic computations were revised. By this time about 35 years of continuous streamflow record (1947 to 1982) at Carleton University gauge had accumulated. In 1977, Rideau Canal's operating policy of the Poonamalie Dam also changed; previously the objective was exclusively to maintain the summer navigation level, while after 1977 flood mitigation was added to as an additional objective. The post 1976 flows were adjusted 7% upward to offset the effect of Poonamalie Dam operation. Where instantaneous flows were not available during annual flood event, they were calculated by increasing the daily mean flow by 5.3% (this value was determined from available mean daily and instantaneous flow values when both were measured). Thus, for the first time for the Rideau River, adjustments for instantaneous values and dam operation were made to streamflow data before using them for flood mapping purposes[1]; afterwards, other investigators have adopted this approach as the most reasonable way to 'naturalize' the 'regulated' flow data of the Rideau River. Anyway, Robinson (1984) fitted a three parameter log-normal distribution to the adjusted flow data after excluding five low outliers, and estimated the 1:100 year flow as 654 cms. The HEC-2 model was used for hydraulic calculations and to determine the water surface profile, and the floodplain was plotted against a 1:2000 scale topography.

[1] During the Robinson (1984) study, several agencies, including the RVCA, Ministry of Natural Resources and Environment Canada, held in depth technical discussions about the best way to adjust the flow for man-made control, which resulted in this methodology. Since then, others have accepted this as a reasonable way to adjust flows and have used the same methodology, although using subsequently accumulated data.

In this methodology, the travel time from Poonamalie to Ottawa was not considered. Although the times of peak occurrences at Poonamalie are known, the times of the corresponding maxima of Poonamalie flood waves when they arrive at Ottawa are not known because of the large volumes of lateral inflows during flood events between the two locations from a drainage area twice the size of that above Poonamalie. Moreover, the 'desynchronized' flood peaks from areas of various size and shape make it difficult to isolate the effect of flow manipulation at Poonamalie on the hydrograph at Ottawa.

Dillon (1989): Rideau River Flood Risk Mapping Study – Mooney's Bay to Regional Road 6

This appears to be the first study within RVCA's jurisdiction to be done under the Canada-Ontario Flood Damage Reduction Program (FDRP) initiated in 1978. Adjustments at the Carleton gauge were made for instantaneous flows (6% increase) and for the Poonamalie Dam operation (5% increase of post-1976 peak flows) using Robinson's (1984) approach but with additional data. During the flood frequency analysis, the effect of discarding low outliers was investigated, and after discussions with Environment Canada staff, it was decided not to discard outliers since such a procedure has a tendency to make the data set an unrepresentative sample[2]. Four distributions from the CFA program were fitted to the 40 years (1947-1986) of data at the Carleton gauge, yielding estimates of the 1:100 year flood in the range from 597 to 678 cms, with an average of 629 cms which was only 4% lower than Robinson's (1984) estimate of 654 cms. Considering all, it was decided to continue using Robinson's (1984) estimate of 654 cms. Similar adjustments and frequency analysis were done on the Below Manotick gauge data (1948-1986). The same flow (654 cms) was used from Rideau Falls to the confluence of Jock River. The flow distribution along the East and West Branches at Manotick was determined from hydraulic (HEC-2) computation. The flows at Kars were determined using area prorating using Carleton and Below Manotick gauges (thus making it an extrapolation rather than interpolation); and then the flows between Manitick and Kars were estimated based on linear distance along the river. Once the flows were estimated, the HEC-2 model was setup and run to calculate water surface profiles, and the floodplain lines were plotted on 1:2000 scale topographic maps (made from 1:8000 scale aerial photography) with 1.0 m contour lines and 0.5 m interpolated auxiliary contour lines.

[2] This illustrates the subjectivity in hydrological analysis and partly explains the variation of estimated flood magnitudes from study to study. Fortunately, most of the time, differences arising from such subjectivities are relatively small and inconsequential in the overall scheme of things. Moreover, typical measurement error and uncertainty associated with streamflow data are usually larger and more intractable. Therefore, slightly erring on the side of conservatism usually gives reasonable and pragmatic result.

Robinson (2003): Rideau River Floodline Mapping – Regional Road 6 to Burritts Rapids – General Report

This project to map the Rideau River from Kars to Burritts Rapids was commissioned in 1992 and the final report by Robinson (2003) was preceded by a number of interim reports. Different methodologies were tried and many challenges faced; but at the end, the approach based on flood frequency analysis at gauge locations and flow transposition – first advocated by Robinson (1984) and followed by Dillon (1989) – was adopted. A frequency analysis of the streamflow data from 1948 through 1989 at Below Manotick gauge was done, and the three parameter log-normal (3PLN) distribution was selected for conservatism and also for consistency with past studies. It is not clear if the data at the Ottawa gauge was revised. However, it appears that the flood quantiles at Ottawa and Below Manotick were used for estimating the flows at upstream locations by area pro-rating (thus making it an extrapolation rather than interpolation). The details of the hydrological calculations are scattered in various interim reports, but a 1993 report (Robinson, 1993) contains the summary. At the end, however, design flows from Dillon (1989), which were really taken from Robinson (1984), were finally chosen for flood mapping purposes. The estimated flows were then used in the HEC-2 model for water profile computation. Floodplain was plotted on 1:2000 and 1:5000 scale topographical maps.

RVCA (2016): Rideau River Flood Risk Mapping from Hogs Back to Rideau Falls

This is one of the projects initiated in 2012 as part of the City-RVCA program, and is now complete. The reach of the Rideau River from Hogs Back to Rideau Falls has been updated. In regard to hydrology, RVCA (2016) has essentially followed the Robinson (1984) methodology, but with additional data accumulated over the last 30 years. This methodology was the result of inter-agency consultation and served well over the years. The streamflow data at the Ottawa or Carleton University gauge from 1947 to 2012 was analyzed. First, all daily mean flows were converted to instantaneous flows. Adjustments (about 11%) for the Poonamalie Dam operation were then made following the original Robinson (1984) methodology. Finally, a frequency analysis of the instantaneous flow series was carried out using the CFA3 program (Pilon and Harvey, 1993) and the flood quantiles for various return periods determined. The flows were about 1.5% lower than those determined by Robinson (1984). These flood flows were then fed into a HEC-RAS model to compute the regulatory flood level (RFL). The floodplain lines were plotted using high accuracy LIDAR topography.

From the above review, several observations can be made about the progression of hydrological analysis of the Rideau River as it relates to flood risk mapping.

a) First, the scope and rigor of the methodology changed with accumulated data and available computational technology.
b) The need for using instantaneous flow was recognized early on, and a method to compute them from daily mean flow by simple correlation has been widely used and accepted.
c) When a long enough record was available, a single station flood frequency analysis was usually done to compute flood quantiles at gauge locations. When a long enough record was not available, the record was sometimes extended by transposing flows from gauges with longer records.
d) The appropriateness of using 'naturalized flow', as opposed to 'regulated flow' for flood mapping was recognized. This was later formally stated in FDRP and Hazard Guidelines (MNR 1986, 2002)[3]. Both guidelines advocate using the naturalized flow as opposed to the

[3] Excerpt from FDRP (MNR, 1986): In flood frequency analysis of peak flows, the initial assumption is made that floods are natural events that can be described by a particular probability distribution. If man has imposed his will upon a stream in such a way as to affect peak flows, then they are no longer natural events and no distribution is applicable. Thus, the first step in undertaking a frequency analysis is the conversion of regulated stream flows to natural conditions. This is achieved by removing the effect of regulatory installations, such as dams and diversions, if they have a significant influence on the flood peak. If their influence is small, however, conversion is not required, but it is always necessary to estimate their effect prior to judging the significance thereof.

Excerpt from Hazard Guidelines (MNR, 2002): In flood frequency analysis of peak flows, the initial assumption is made that floods are random and independent events that can be described by a particular probability distribution. If a stream is regulated sufficiently to affect the resulting peak flows, then they are no longer random and independent events; a probability distribution which assumes randomness and independence is not applicable. The first step in undertaking frequency analysis is to determine the influence of regulation on the streamflows. If necessary, the conversion of regulated streamflows to natural conditions is achieved by removing the effect of dams and diversions. … Downstream of the culvert or bridge, the natural flood line should be used for delineating the flood hazard, making no allowance for the temporary upstream ponding.

regulated flow when there is a significant difference between them. In the case of Rideau River downstream of Poonamalie Dam, the difference between regulated and naturalized flows was found to be substantial – in the order of 6 to 14% (see Tables 1 and 2). It was, therefore, decided quite early on that the naturalized flows would be used for the purposes of flood hazard mapping.

e) Robinson (1984) first introduced a methodology to adjust the Carleton gauge data for the Poonamalie dam operation. This had the blessing of all agencies involved in the FDRP program including Environment Canada, Ministry of Natural Resources, and RVCA, and, was readily accepted at later times by all subsequent investigators.

f) Flow division among branches (e.g., around Manotick Island; just upstream of Rideau Falls) is generally done by assuming a flow split at a bifurcation point and then matching the water surface profiles at the junction. This used to be manually implemented in HEC-2 models, but can now be done automatically in HEC-RAS models.

g) Flow transposition from gauge locations to other locations was done by either area pro-rating or linear interpolation based on distance. In the earlier years, James F. MacLaren (1976) used a linear function of area. Later studies used an exponential function for certain locations, where the exponent was determined from known gauge locations (Robinson 1984; Dillon 1989; RVCA 2016), and then used linear interpolation between the locations that were determined through area pro-rating.

h) Inflows from major tributaries (e.g., the Jock River and Kemptville Creek) were estimated by flood frequency analysis when a long enough streamflow record was available. Otherwise, cruder approximations were used.

i) A consensus around the methodology for hydrological analysis for flood mapping purposes has been formed over the last four decades.

This has been a consequence of accumulated data, available technology and inter-agency consultation.

4. Current Methodology

Based on the review of past studies, we conclude that the Robinson (1984) methodology is still, by common consent as well as by technical reasoning, the most appropriate for the Rideau River. We have therefore decided not to deviate from it in any significant way.

Our methodology for estimating flood quantiles along the Rideau River, therefore, consists of the following components:

- Estimating and using instantaneous flows.
- Converting 'regulated flows' to 'naturalized flows' by using the Robinson (1984) methodology.
- Testing streamflow data for suitability for flood frequency analysis (homogeneity, independence, randomness, and trend).
- Using standard flood frequency analysis where long enough streamflow record is available (gauge locations) to estimate flood quantiles.
- Using area pro-rating to transpose flood quantiles from gauge locations to other locations.
- Using the hydraulic model (HEC-RAS) to determine the flow split where multiple branches are present

Once we settled on this approach, the available streamflow data and watershed characteristics determined to a large extent – as we shall see later in the report – the eventual outcome of this analysis, i.e., the flood quantiles. This, in fact, left little room for subjectivity on part of the analyst.

5. Hydrological Analysis

5.1 Streamflow Data Availability

Available streamflow records along the Rideau River from Poonamalie to Rideau Falls and major tributaries are listed in Table 1; gauge locations are shown in Figure 2. The record at Ottawa (02LA004; Carleton University; or Hurdman Bridge before 1965) is the longest. The new gauge above Rideau Falls (02LA027) is just a few years old and has not been used in this report. Ownership and operating responsibility of the gauges have been assumed by several agencies over the years; the Ottawa (02LA004), Jock (02LA007) and Kemptville (02LA006) gauges are operated by Water Survey of Canada (WSC) using WSC standard, while the Manotick (02LA012), Merrickville (02LA011) and Poonamalie (02LA005) gauges are operated by Parks Canada using a separate standard[4].

5.2 Instantaneous Flow

Flood damage and thus flood risk are usually associated with the maximum flood flow or the instantaneous flow; that is why MNR (1986, 2002) recommends using instantaneous flows for flood risk mapping. Historically, however, records of only the daily mean flows are kept most of the time, although sometimes (often in recent years) both the mean daily and instantaneous flows are available. In such cases, there is a need to extend the record of instantaneous flow and this can usually be done by correlating the instantaneous flow to the daily mean flow. This is usually the first step in organizing the streamflow data for flood frequency analysis.

We have determined the correlation between mean daily and instantaneous flows for the following gauge locations:

- Rideau River At Ottawa (02LA004)
- Rideau River Below Manotick (02LA012)
- Rideau River Below Merrickville (02LA011)
- Jock River Near Richmond (02LA007)
- Kemptville Creek Near Kemptville (02LA006)

[4] In an email on 21 October 2015, Parks Canada staff confirmed that they operate their gauges in a fashion that is suitable for their operational needs including navigation.

Tables 2(a-e) and Figures 4(a-e) show numerical values and correlation graphs for these five locations. A simple linear or parabolic equation sufficed to get a good correlation between the daily mean and instantaneous flow, with a correlation coefficient (R^2) value usually above 0.98. The instantaneous flows were found to be about 2-8% more than the mean daily flows on the average.

5.3 Adjustment for Poonamalie Dam

The flow of the Rideau River is controlled by Parks Canada (Rideau Canal Office) at the Poonamalie Dam, about 6 km upstream of Smiths Falls. Before 1977, the objective of Rideau Canal's operating policy of the Poonamalie Dam was exclusively to maintain the summer navigation level. After 1977 flood mitigation was added as an objective; therefore, the downstream flows were artificially reduced (regulated). Starting around 1991, Park Canada changed the Poonamalie Dam operating policy to manage fisheries needs and to hold back water to be released later for ice flushing during spring time[5]. The effect of this change in operational policy is reflected in the increase in peak flows (Figure 5a-c).

The Robinson (1984) methodology of adjusting or naturalizing 'regulated' flows is again adopted here. Previously, it was applied to the data for the Ottawa (02LA004) and Below Manotick (02LA012) gauges; now, having sufficiently long flow records, we have also applied it to the Below Merrickville (02LA011) data.

Adjusting Ottawa (02LA004) Data

Most recently, in dealing with the most downstream reach of the Rideau River (Hogs Back to Rideau Falls), RVCA (2015) has adjusted the Ottawa gauge data. This analysis is still valid and we have taken this analysis *in toto* and reproduced it in Table 2a.

As described in RVCA (2015), an analysis of the relationship between the gauges at Ottawa (02LA004) and at Poonamalie or above Smith Falls (02LA005) was conducted to determine if an adjustment of Ottawa flows was required as had been done by

[5] This was communicated to us by Parks Canada staff via an email on 23 October 2015. This seems to roughly coincide with the Rideau Canal Water Management Study (Acres International Limited, 1994).

Robinson (1984). Figure 3a shows the ratio between the Rideau above Smith Falls and Rideau at Ottawa, the average ratio for three periods, and the annual peaks for the Rideau at Ottawa gauge. Distinct changes in ratio occur in 1977 and 1991. Robinson (1984) increased the flows in the period between 1977 and 1982 by 7% to recognize and account for the effect of a change in operating practice at the Rideau Canal's Poonamalie Dam that was implemented after the 1976 flood event. After that event (the highest flow on record for this study area), the Rideau Canal undertook to attempt to minimize releases out of Lower Rideau Lake while the downstream reaches of the Rideau River were approaching or at their peak. However, it was, and still is, well understood that there is only a limited capacity in the reservoir lakes of the Rideau Waterway that can be used to achieve in this "flood abatement" benefit. It has never been demonstrated that any downstream flood abatement benefits can be achieved during extreme spring flood events by this kind of dam operation. The recorded flows since 1977 were therefore adjusted before being used in flood frequency analysis to remove the effect of artificial regulation. In other words, the adjusted flows are an estimate of what might have been experienced in Ottawa if the Rideau Canal not adopted its practice of attempting to control releases from Lower Rideau Lake at the Poonamalie Dam.

RVCA's (2016) analysis showed three distinct dam operation periods: 1970-1976, 1977-1990 and 1990-2012. Figure 5a shows the range of ratios between flows above Smith Falls to flow at the Rideau at Ottawa gauge. An increase in the ratio from 1991-2012 of 10.84% relative to 1977-1990 was found, and as a result the flow peaks for 1977-1990 were increased by 11% to offset the reduced flow from the Poonamalie Dam. The final flow series is presented in Table 2a, and is considered representative of the current operating practice of Parks Canada[6].

Adjusting Below Manotick (02LA012) Data

The same Robinson (1984) methodology was used to adjust the Below Manotick (02LA0012) data. Here we have now 34 years of data, which is sufficient for statistical analysis. First, the instantaneous flow data was computed and organized (Table 2b). The

[6] In a meeting between RVCA and Parks Canada staff on 12 March 2015, the current operating policies for the dams along the Rideau Canal was clarified and confirmed by Parks Canada staff. During flood events, Parks Canada fully opens the dams and allows 'free flowing' condition at all structures.

adjustment factor was found to be 16% after comparing the Manotick data to Poonamalie data (Figure 5b). The instantaneous flow series was adjusted upwards by 16% before conducting the statistical analysis.

Adjusting Below Merrickville (02LA011) Data

The same procedure was followed to adjust the Below Merrickville (02LA0011) data, where we have 35 years of data. The instantaneous flow data was computed and organized (Table 2c). The adjustment factor was found to be 12% after comparing the Merrickville data to Poonamalie data (Figure 5c). The instantaneous flow series was adjusted upwards by 12% before conducting the statistical analysis.

5.4 Statistical Tests of Streamflow Data

Using the instantaneous peak flow records that were compiled statistical tests were conducted using the Consolidated Frequency Analysis 3.1 (CFA 3.1) Software Package by Environment Canada (Pilon and Harvey, 1993). According to standard hydrologic theory (e.g., Stedinger et al. 1993; McCuen 2003), these criteria should usually be satisfied before using the data for statistical analysis:

- The data were generated by a random process;
- Individual values are independent;
- The time series is stationary; and
- Sampling is from a homogeneous population.

Four tests were carried out on the data using the Consolidated Frequency Analysis (CFA 3.1) Software Package by Environment Canada. The software analyses the data for independence, trend, randomness and homogeneity using the following tests:

- Spearman Rank Order Serial Correlation Coefficient Test for Independence,
- Spearman Rank Order Correlation Coefficient Test for Trend,
- Runs Above and Below the Median for General Randomness, and
- Mann-Whitney Split Sample Test for Homogeneity.

The software analyses the four attributes at a five percent and one percent level of significance, which also means that the associated attribute is true 95% (five percent significance) or 99% (one percent significance) of the time. The details of the statistical analysis are given in Appendix A. The main conclusion is that the annual peak flows at each gauge are suitable for flood frequency analysis, since, barring a couple of minor exceptions, the gauge data were found to be independent, without trend, homogeneous and random at a 1% or 5% level. More specifically all gauges except the Carleton/Ottawa gauge were found to pass the independence and randomness test which are the attributes of most concern according to the Hazard Guidelines (MNR, 2002).

5.5 Flood Frequency Analysis

After necessary adjustments to the streamflow data have been made, single station flood frequency analysis was performed at two gauge locations on the Rideau River (Below Manotick and Below Merrickville). Frequency analyses at the other two locations (Ottawa and Poonamalie) are already available from recent reports (RVCA 2010, 2016). Single station frequency analysis was also done for two major tributaries (Jock River near Richmond and Kemptville Creek near Kemptville), where long term data is available.

Consolidated Frequency Analysis 3.1 (CFA_3), a widely used program from Environment Canada (Pilon and Harvey, 1993), was used for the frequency analysis (as well as the statistical tests described above). The annual maximum instantaneous flow values were input to the program for the following four gauges:

- Rideau River Below Manotick (02LA012)
- Rideau River Below Merrickville (02LA011)
- Jock River Near Richmond (02LA007)
- Kemptville Creek Near Kemptville (02LA006)

CFA program fits four frequency distributions to flood data:

- Generalized Extreme Value (GEV),
- Three-Parameter Lognormal (3PLN),
- Log Pearson Type III (LP3), and
- Wakeby (WBY).

The CFA output files, showing the details of both statistical and frequency analyses, for these four gauges are included in Appendix B. Plots of the four distributions were plotted together for each location (Figures B.1 to B.5 in Appendix B) and the ‘best fit’ distribution was chosen largely based on visual matching with data points and, to a lesser extent, by examining the computed statistics[7]. No attempt was made to identify or exclude outliers, since such practices, in our opinion, may fail to faithfully represent the measured data.

For the locations on the Rideau River (Below Manotick and Below Merrickville), the Generalized Extreme Value (GEV) was found to fit the data best and at the same time remain above the data points and thus slightly on the conservative side (so as not to underestimate the flow at the higher end). The same distribution (GEV) was found to fit the Ottawa data (RVCA, 2016). The estimated flows at Manotick and Merrickville are about 13.7% and 29.3% lower than previous estimates. We consider our estimates better suited for flood mapping purposes because we used recent data of better quality.

For the tributaries (Jock and Kemptville), the WAKEBY distribution was found to fit the data well and without significant conservatism. This was deliberately done to avoid overestimating the tributary flows; it thus allowed a higher (conservative) flow to remain in the Rideau River (for which the mapping will be done)[8]. The 1:100 year flows are 21.9% and 10.5% lower than previous estimates, which can be attributed mainly to the frequency distribution chosen and, to a lesser degree, the length of data record.

Table 3 compares the flood quantiles calculated during the current study and the last estimates used for flood mapping purposes. Figures 6(a-e) present the same information in graphical form.

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[7] There is considerable debate about how to find a balance between mathematical sophistication of flood frequency analysis and the inevitable error and uncertainty of data. Engineers and hydrologists tasked with practical problem are generally in favor of avoiding excessive emphasis on mathematical manipulation in view of the large uncertainty of hydrological data collected in the field. For example, Stedinger et al. (1993), in a state-of-the-art review (Chapter 18 of the Handbook of Hydrology edited by D. R. Maidment, 1993), states: “Probability plots are extremely useful for visually revealing the character of a data set. Plots are effective way to see what the data look like and to determine if fitted distributions appear consistent with the data. Analytical goodness-to-fit criteria are useful for gaining an appreciation for whether the lack of fit is likely to be due to sample-to-sample variability, or whether a particular departure of the data from a model is statistically significant. In most cases several distributions will provide statistically acceptable fits to the available data so that goodness-of-fit tests are unable to identify the “true” or “best” distribution to use. Such tests are valuable when they can demonstrate that some distributions appear inconsistent with the data.”

[8] We do not recommend that the flood flows for the Jock and Kemptville Creek estimated here be used for any other purposes – including and especially for flood risk mapping along these tributaries. A separate and independent analysis would be necessary for such projects.

The flood quantiles recommended for flood mapping purposes are tabulated in Table 4. These values will be used in future hydraulic modeling along the Rideau River for flood risk mapping.

5.6 Flow Transposition by Area Pro-Rating

Once the flood quantiles at gauge locations are estimate by flood frequency analysis (as described above), then we have to estimate flood quantiles at other ungauged locations. This is necessary because hydraulic models of long rivers, to be accurate, generally need flows at more locations – not just the gauge locations. Known flows from gauged locations are therefore transposed to ungauged locations.

Flow transposition by area pro-rating is a popular method. The general form of area pro-rating is:

$$\left(\frac{Q_1}{Q_2}\right) = \left(\frac{A_1}{A_2}\right)^k \qquad \text{(Equation 1)}$$

where

Q_1 is the flow at the first location;

Q_2 is the flow at the second location;

A_1 is the drainage area of at the first location;

A_2 is the drainage area at the second location; and

k is an exponent for the reach, empirically determined from the data.

The value of k for natural watersheds is in the range of 0.70 to 0.80. For a regulated watershed, it assumes different values. For any pair of gauge locations, the value of k can obviously be calculated, if flows and drainage areas are known.

For the three reaches of the Rideau River (in between four gauges), Equation 1 was used to calculate the k value as follows:

- Ottawa to Manotick [k = 2.03]
- Manotick to Andrewsville [k = 1.73]
- Andrewsville to Poonamalie [k = 0.72]

These k values were calculated using the 1:100 year flood quantiles listed in Table 4 and in Figures 7 and 8. Similarly, k values were also calculated for floods quantiles with other return periods, as listed in Table 5.

Since the Jock River and Kemptville Creek are within the Rideau River watershed, Equation 1 can be expected to apply to the following gauge combinations:

- Rideau at Ottawa and Jock near Richmond [k = 0.72]
- Rideau at Ottawa and Kemptville near Kemptville [k = 0.90]

The k values within brackets are again for the 1:100 years flows; values for other events are listed in Table 5. These values are close to those expected in natural watersheds.

We observe that Poonamalie flow has been influenced the most by the dam and are substantially lower than what one would expect to be its the natural value (somewhere near the Jock-Ottawa or Kemptville-Ottawa lines in Figure 7. This same is true for the Andrewsville and Manotick flows, but to an incrementally lower degree; this reflects the gradual recovery of the flows to natural or unregulated values downstream from Poonamalie Dam. The magnitude of k – essentially the slope of the flow-area curve – depends on the lateral flow contribution within a river reach; the more the lateral inflow the higher the value of k. The large lateral inflows from Kemptville, Stevens and other creeks explain the high value of k in the reach between Andrewsville and Manotick (Figure 8). Likewise, inflows from Jock River and dense urbanization explain the even larger k value downstream of Manotick.

Equation 1 was once used earlier by Dillon (1989), and they found a k value of 1.27 for the reach between Manotick and Ottawa. This value, considerably lower than our value of 2.03, can be attributed to lower urbanization at that time and shorter flow record.

We used Equation 1, along with the appropriate exponent (k) value from Table 5, for estimating flood quantiles at key locations along the Rideau River for flood mapping purposes (Table 6 and Figure 9). These flows are recommended for use in hydraulic (HEC-RAS) modeling supporting flood risk delineation.

6. Conclusions and Recommendations

1) An extensive review of the all previous hydrological work associated with flood risk mapping along the Rideau River has been completed. It appears that a consensus around the methodology for hydrological analysis for flood mapping purposes has been formed over the last four decades. This has been a consequence of accumulated data, available technology and inter-agency consultation.
2) The appropriateness of using 'naturalized flow', as opposed to 'regulated flow' for flood mapping was recognized (which was later formally stated in provincial guidelines). In the case of Rideau River downstream of Poonamalie Dam, the difference between regulated and naturalized flows was found to be substantial. It was, therefore, decided quite early on that the naturalized flows would be used for the purposes of flood hazard mapping.
3) Robinson (1984) first introduced a methodology to adjust the Carleton gauge data for the Poonamalie Dam operation. This had the blessing of all agencies involved in the FDRP program including Environment Canada, Ministry of Natural Resources, and RVCA, and, at later times, of all subsequent investigators.
4) Based on earlier studies and available data, we have devised a methodology centered on the Robinson (1984) methodology and other practices that evolved over the years. We believe this is consistent with past studies and congruent with available data and modern-day technology. It also meets applicable provincial guidelines (MNR, 2002).
5) We recommend that the flood quantiles calculated using our methodology and presented in Tables 4 and 6 be used for flood mapping purposes along the Rideau River.

7. Closure

The hydrological analysis documented in this report generally conforms to present day standards for flood hazard delineation, as set out in the MNR's Natural Hazards Technical Guide (MNR, 2002). The flood quantiles derived during this study are suitable for flood risk mapping purposes along the Rideau River from Poonamalie to Rideau Falls. Floodplain and regulation limit lines based on these flood quantiles would be suitable for use in the RVCA's regulation limits mapping (as per Ontario Regulation 174/06) and in municipal land use planning and development approval processes under the Planning Act.

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Table 1 Hydrometric Gauge Information.

Location	Station ID	Water Level		Flow		Owner	Comments
		Start	End	Start	End		
Rideau River Above Rideau Falls	02LA027	2010	2015			WSC	Short record, not used.
Rideau River at Ottawa (Carleton University)	02LA004	2002	2014	1933	2014	WSC	
Rideau River below Manotick (Long Island)	02LA012			1980	1996	WSC	
Rideau River below Manotick (Long Island)	02LA012	1997	2014	1997	2014	PC	Parks Canada Operated
Rideau River below Merrickville (Andrewsville)	02LA011			1979	1996	WSC	
Rideau River below Merrickville (Andrewsville)	02LA011			2003	2014	PC	Parks Canada Operated
Rideau River above Smiths Falls (Poonamalie)	02LA005			1970	1996	WSC	
Rideau River above Smiths Falls (Poonamalie)	02LA005	2003	2014	1997	2014	PC	Parks Canada Operated
Jock River Near Richmond (Moodie Drive)	02LA007	2002	2014	1969	2014	WSC	
Kemptville Creek Near Kemptville (County Road 18)	02LA006	2002	2014	1969	2014	WSC	

Table 2A Rideau River Flow at Ottawa (02LA004).

Year	Annual Max Daily Flow (m^3/s)	Max Instantaneous Flow (m^3/s)	Inst/Daily Ratio	Estimated Instantaneous Flow (m^3/s)	Final Instantaneous Flow Series (m^3/s)	Flow increased by 11% (m^3/s)	Final Flow Series (m^3/s) (Input to CFA)
1947	538			560.26	560.26		560.26
1948							
1949	379			392.75	392.75		392.75
1950	447			462.80	462.80		462.80
1951	419			433.67	433.67		433.67
1952	379			392.75	392.75		392.75
1953	331			344.73	344.73		344.73
1954	405			419.26	419.26		419.26
1955	493			511.54	511.54		511.54
1956	351			364.60	364.60		364.60
1957	133			159.16	159.16		159.16
1958	306			320.19	320.19		320.19
1959	413			427.48	427.48		427.48
1960	532			553.71	553.71		553.71
1961	193			213.27	213.27		213.27
1962	323			336.85	336.85		336.85
1963	442			457.57	457.57		457.57
1964	109			138.03	138.03		138.03
1965	146			170.72	170.72		170.72
1966	215			233.57	233.57		233.57
1967	311			325.08	325.08		325.08
1968	377			390.73	390.73		390.73
1969	328			341.77	341.77		341.77
1970	442			457.57	457.57		457.57
1971	496	513	1.03		513.00		513.00
1972	535	578	1.08		578.00		578.00
1973	447	464	1.04		464.00		464.00
1974	396			410.04	410.04		410.04
1975	394	413	1.05		413.00		413.00
1976	583	597	1.02		597.00		597.00
1977	467	473	1.01		473.00	525.03	525.03
1978	487	527	1.08		527.00	584.97	584.97
1979	403	423	1.05		423.00	469.53	469.53
1980	385	421	1.09		421.00	467.31	467.31
1981	435	446	1.03		446.00	495.06	495.06
1982	397	435	1.10		435.00	482.85	482.85
1983	224	246	1.10		246.00	273.06	273.06
1984	385	398	1.03		398.00	441.78	441.78
1985	265	276	1.04		276.00	306.36	306.36
1986	223	256	1.15		256.00	284.16	284.16
1987	334	353	1.06		353.00	391.83	391.83
1988	247	273	1.11		273.00	303.03	303.03
1989	251	276	1.10		276.00	306.36	306.36
1990	259	264	1.02		264.00	293.04	293.04
1991	311	326	1.05		326.00		326.00
1992	270	282	1.04		282.00		282.00
1993	508	514	1.01		514.00		514.00
1994	331	338	1.02		338.00		338.00
1995	263	269	1.02		269.00		269.00
1996	232	243	1.05		243.00		243.00
1997	441	448	1.02		448.00		448.00
1998	451	458	1.02		458.00		458.00
1999	436	448	1.03		448.00		448.00
2000	244	245	1.00		245.00		245.00
2001	356	366	1.03		366.00		366.00
2002	188	222	1.18		222.00		222.00
2003	238	249	1.05		249.00		249.00
2004	167	199	1.19		199.00		199.00
2005	427	437	1.02		437.00		437.00
2006	215	218	1.01		218.00		218.00
2007	259	262	1.01		262.00		262.00
2008	478	493	1.03		493.00		493.00
2009	220	254	1.15		254.00		254.00
2010	234	237	1.01		237.00		237.00
2011	350.85			364.45	364.45		364.45
2012	214.03			232.67	232.67		232.67

Source: RVCA (2015) Rideau River Flood Risk Mapping from Hog's Back to Rideau Falls

Table 2B Rideau River Flow Below Manotick (02LA012).

Year	Annual Max Daily Flow (m³/s)	Max Instantaneous Flow (m³/s)	Inst/Daily Ratio	Estimated Instantaneous Flow (m³/s)	Final Instantaneous Flow Series (m³/s)	Flow increased by 15.87% (m³/s)	Final Flow Series (m³/s) (Input to CFA)
1981	298.00	312.00	1.0470		312.00	361.51	361.51
1982	296.00	303.00	1.0236		303.00	351.09	351.09
1983	163.00	200.00	1.2270		200.00	231.74	231.74
1984	243.00	247.00	1.0165		247.00	286.20	286.20
1985	178.00	183.00	1.0281		183.00	212.04	212.04
1986	159.00	186.00	1.1698		186.00	215.52	215.52
1987	236.00	253.00	1.0720		253.00	293.15	293.15
1988	187.00	210.00	1.1230		210.00	243.33	243.33
1989	173.00	183.00	1.0578		183.00	212.04	212.04
1990	192.00	197.00	1.0260		197.00	228.26	228.26
1991	231.00	235.00	1.0173		235.00		235.00
1992	195.00	210.00	1.0769		210.00		210.00
1993	342.00	347.00	1.0146		347.00		347.00
1994	250.00	261.00	1.0440		261.00		261.00
1995	203.00	206.00	1.0148		206.00		206.00
1996	173.00	173.00	1.0000		173.00		173.00
1997	299.80	299.96	1.0005		299.96		299.96
1998	306.47			311.57	311.57		311.57
1999	282.42	288.65	1.0221		288.65		288.65
2000	197.70	199.00	1.0066		199.00		199.00
2001	230.63	230.74	1.0005		230.74		230.74
2002	144.78	150.45	1.0392		150.45		150.45
2003	186.51	195.04	1.0457		195.04		195.04
2004	124.23	136.00	1.0947		136.00		136.00
2005	274.33	278.00	1.0134		278.00		278.00
2006	175.48	179.93	1.0254		179.93		179.93
2007	185.67	187.72	1.0110		187.72		187.72
2008	335.60	340.00	1.0131		340.00		340.00
2009	164.01	166.00	1.0121		166.00		166.00
2010	177.37	185.63	1.0466		185.63		185.63
2011	238.15	242.78	1.0194		242.78		242.78
2012	151.04	153.00	1.0130		153.00		153.00
2013	157.13	157.00	0.9992		157.00		157.00
2014	327.85	330.20	1.0072		330.20		330.20

Table 2C Rideau River Below Merrickville (02LA011).

Year	Annual Max Daily Flow (m^3/s)	Max Instantaneous Flow (m^3/s)	Inst/Daily Ratio	Estimated Instantaneous Flow (m^3/s)	Final Instantaneous Flow Series (m^3/s)	Flow increased by 12.30% (m^3/s)	Final Flow Series (m^3/s) (Input to CFA)
1980	119.00	125.00	1.0504		125.00	140.38	140.38
1981	129.00	134.00	1.0388		134.00	150.48	150.48
1982	114.00	118.00	1.0351		118.00	132.51	132.51
1983	110.00	119.00	1.0818		119.00	133.64	133.64
1984	123.00	128.00	1.0407		128.00	143.74	143.74
1985	85.20	94.10	1.1045		94.10	105.67	105.67
1986	89.80	99.10	1.1036		99.10	111.29	111.29
1987	97.20	101.00	1.0391		101.00	113.42	113.42
1988	85.20	98.20	1.1526		98.20	110.28	110.28
1989	74.80	77.40	1.0348		77.40	86.92	86.92
1990	74.60	83.80	1.1233		83.80	94.11	94.11
1991	116.00	120.00	1.0345		120.00		120.00
1992	124.00	169.00	1.3629		169.00		169.00
1993	151.00	157.00	1.0397		157.00		157.00
1994	119.00	126.00	1.0588		126.00		126.00
1995	133.00	142.00	1.0677		142.00		142.00
1996	106.00	118.00	1.1132		118.00		118.00
1997							
1998							
1999							
2000							
2001							
2002							
2003	89.07	102.20	1.1474		102.20		102.20
2004	84.23	96.12	1.1411		96.12		96.12
2005	149.10	157.16	1.0540		157.16		157.16
2006	115.63	121.20	1.0481		121.20		121.20
2007	92.83	99.00	1.0665		99.00		99.00
2008	154.45	156.50	1.0133		156.50		156.50
2009	80.92	85.68	1.0589		85.68		85.68
2010	93.46	96.12	1.0285		96.12		96.12
2011	138.59	141.32	1.0197		141.32		141.32
2012	64.07	65.93	1.0290		65.93		65.93
2013	68.61	72.92	1.0628		72.92		72.92
2014	168.77	173.00	1.0251		173.00		173.00

Table 2D Jock River Near Richmond (02LA007).

Year	Annual Max Daily Flow (m^3/s)	Max Instantaneous Flow (m^3/s)	Inst/Daily Ratio	Estimated Instantaneous Flow (m^3/s)	Final Flow Series (m^3/s) (Input to CFA)
1970	121.00	125.00	1.0331		125.00
1971	112.00	116.00	1.0357		116.00
1972	136.00			140.30	140.30
1973	119.00			122.82	122.82
1974	79.30			82.01	82.01
1975	122.00	123.00	1.0082		123.00
1976	137.00	140.00	1.0219		140.00
1977	117.00			120.77	120.77
1978	133.00	148.00	1.1128		148.00
1979	114.00			117.68	117.68
1980	103.00			106.37	106.37
1981	108.00	111.00	1.0278		111.00
1982	75.50			78.10	78.10
1983	49.80			51.68	51.68
1984	118.00	120.00	1.0169		120.00
1985	59.10			61.24	61.24
1986	62.00	65.00	1.0484		65.00
1987	79.20	80.90	1.0215		80.90
1988	63.10	64.80	1.0269		64.80
1989	63.60			65.87	65.87
1990	65.90			68.24	68.24
1991	78.80	82.80	1.0508		82.80
1992	72.20	74.00	1.0249		74.00
1993	142.00	145.00	1.0211		145.00
1994	66.20	67.50	1.0196		67.50
1995	54.90	55.60	1.0128		55.60
1996	50.00			51.89	51.89
1998	124.00	126.00	1.0161		126.00
1999	135.00	136.00	1.0074		136.00
2000	44.70	46.50	1.0403		46.50
2001	100.00	107.00	1.0700		107.00
2002	40.60	43.30	1.0665		43.30
2003	51.80	56.40	1.0888		56.40
2004	41.00	43.30	1.0561		43.30
2005	125.00	127.00	1.0160		127.00
2006	42.20	44.10	1.0450		44.10
2007	57.00	57.80	1.0140		57.80
2008	115.00	122.00	1.0609		122.00
2009	50.50	51.30	1.0158		51.30
2010	54.90	56.60	1.0310		56.60
2011	78.30	80.60	1.0294		80.60
2012	53.70	55.00	1.0242		55.00
2013	68.30	70.80	1.0366		70.80
2014	103.00	105.00	1.0194		105.00

Note: 2014 data is provisional data that has not been quallity assured or quality checked.

Table 2E Kemptville Creek Near Kemptville (02LA006).

Year	Annual Max Daily Flow (m^3/s)	Max Instantaneous Flow (m^3/s)	Inst/Daily Ratio	Estimated Instantaneous Flow (m^3/s)	Final Flow Series (m^3/s) (Input to CFA)
1970	69.70	72.20	1.0359		72.20
1971	76.50	78.20	1.0222		78.20
1972	80.10	81.60	1.0187		81.60
1973	53.50			54.54	54.54
1974	56.90	59.20	1.0404		59.20
1975	47.30	47.60	1.0063		47.60
1976	72.80	74.20	1.0192		74.20
1977	79.30	80.10	1.0101		80.10
1978	64.80	66.50	1.0262		66.50
1979	49.50	50.30	1.0162		50.30
1980	55.60			56.66	56.66
1981	57.50			58.58	58.58
1982	73.00	73.70	1.0096		73.70
1983	31.30	32.40	1.0351		32.40
1984	55.30	55.80	1.0090		55.80
1985	31.80	33.20	1.0440		33.20
1986	42.50	43.20	1.0165		43.20
1987	48.60	49.60	1.0206		49.60
1988	39.10	40.50	1.0358		40.50
1989	35.00			35.83	35.83
1990	41.70	43.00	1.0312		43.00
1991	41.40	42.20	1.0193		42.20
1992	33.40			34.21	34.21
1993	68.20	68.70	1.0073		68.70
1994	54.70	55.90	1.0219		55.90
1995	24.00			24.70	24.70
1996	34.00			34.82	34.82
1997	58.40	59.20	1.0137		59.20
1998	59.00	59.70	1.0119		59.70
1999	56.90	58.00	1.0193		58.00
2000	38.70	39.90	1.0310		39.90
2001	51.90	52.40	1.0096		52.40
2002	25.70	26.40	1.0272		26.40
2003	39.30	39.80	1.0127		39.80
2004	29.20	30.10	1.0308		30.10
2005	64.10	65.30	1.0187		65.30
2006	28.20	28.50	1.0106		28.50
2007	29.80	30.20	1.0134		30.20
2008	66.50	67.40	1.0135		67.40
2009	27.60	28.00	1.0145		28.00
2010	31.10	31.80	1.0225		31.80
2011	53.00			54.03	54.03
2012	30.50	31.00	1.0164		31.00
2013	28.00	29.40	1.0500		29.40
2014	76.72	78.00	1.0167		78.00

Note: 2014 data is provisional data that has not been quallity assured or quality checked.

Table 3 Estimated Flood Quantiles in cms

		Rideau River at Ottawa (02LA004)		Rideau River Below Manotick (02LA012)		Rideau River Below Merrickville (02LA011)		Jock River Near Richmond (02LA007)		Kemptville Creek Near Kemptville (02LA006)	
Return Period (year)	Annual Probability of Exceedence (%)	Robinson (1984)	RVCA (2015)†	Dillon (1989)	RVCA (2015)	MacLaren (1976)	RVCA (2015)	PSR (2004)	RVCA (2015)	RVCA (2007)	RVCA (2015)
1.003	99.7		62.70		98.00		44.90		42.20	14.60	14.80
1.05	95.2		174.00		140.00		72.00		44.00	26.20	26.10
1.25	80		268.00		180.00	59.46	95.00		53.50	36.80	33.00
2	50		369.00	255.00	230.00	79.29	120.00	91.00	84.70	49.50	48.20
5	20	513.00	475.00	327.00	292.00	96.28	148.00	123.00	125.00	64.30	67.20
10	10	552.00	529.00	372.00	330.00	110.43	162.00	142.00	140.00	73.00	75.50
20	5		572.00	414.00	364.00	124.59	174.00	160.00	147.00	80.70	80.70
50	2	626.00	617.00	466.00	406.00	141.58	186.00	181.00	151.00	90.10	84.80
100	1	654.00	644.00	504.00	435.00	150.08	194.00	196.00	153.00	96.80	86.60
200	0.5		667.00		463.00		200.00		153.00	103.00	87.80
500	0.2		691.00		497.00		207.00		154.00	111.00	88.60
Data Span		1947-1982	1947-2012	1948-1986	1981-2014	1916-1976	1980-2014	1970-2003	1970-2014	1970-2007	1970-2014
Distribution Used		3PLN	GEV	3PLN	GEV	Lognormal	GEV	LP3	WKY	3PLN	WKY

Note:

GEV - Generalized Extreme Value

3PLN - 3 Parameter Lognormal

LP3 - Log Pearson Type III

WKY - Wakeby

† Source: RVCA (2015) Rideau River Flood Risk Mapping from Hogs Back to Rideau Falls

Table 4 Estimated Flood Quantiles to be Used for Flood Mapping.

		Rideau River at Ottawa (02LA004)	Rideau River Below Manotick (02LA012)	Rideau River Below Merrickville (02LA011)	Rideau River Above Smith Falls (02LA005)	Jock River Near Richmond (02LA007)	Kemptville Creek Near Kemptville (02LA006)
Return Period (year)	Annual Probability of Exceedence (%)	Discharge (m^3/s)	Discharge (m^3/s)	Discharge (m^3/s)	Discharge (m^3/s)	Discharge (m^3/s)	Discharge (m^3/s)
2	50	369.00	230.00	120.00	53.00	84.70	48.20
5	20	475.00	292.00	148.00	100.00	125.00	67.20
10	10	529.00	330.00	162.00	117.00	140.00	75.50
20	5	572.00	364.00	174.00	128.00	147.00	80.70
50	2	617.00	406.00	186.00	135.00	151.00	84.80
100	1	644.00	435.00	194.00	140.00	153.00	86.60
200	0.5	667.00	463.00	200.00	145.00	153.00	87.80
350††	0.3	680.00	480.00	204.00	148.00	154.00	88.00
500	0.2	691.00	497.00	207.00	150.00	154.00	88.60
Drainage Area (km^2)		3809	3138	1967	1250	526	411
Data Span		1947-2012	1981-2014	1980-2014	1970-2010	1970-2014	1970-2014
Frequency		GEV	GEV	GEV	Manual Fit †††	WAKEBY	WAKEBY

Note:

GEV - Generalized Extreme Value

3PLN - 3 Parameter Lognormal

LP3 - Log Pearson Type III

WKY - Wakeby

† Source: RVCA (2016) Rideau River Flood Risk Mapping from Hogs Back to Rideau Falls

†† 350 year flood quantile was estimated by graphical interpolation

††† Manual fit on Mike11-generated data. See RVCA (2012a).

Note: We do not recommend that the flood flows for the Jock and Kemptville Creek estimated here be used for any other purposes – including and especially for flood risk mapping along these tributaries. A separate and independent analysis would be necessary for such projects.

Table 5 Calculated "k" Exponents That Are Used In the Flow Transposition Equation in Order to Determine the Flows at Different Locations.

Return Period (Years)	Rideau River at Ottawa (02LA004) and Rideau River Below Manotick (02LA012)	Rideau River Below Manotick (02LA012) and Rideau River Below Merrickville (02LA011)	Rideau River Below Merrickville (02LA011) and Rideau River Above Smith Falls (02LA005)	Rideau River at Ottawa (02LA004) and Jock River Near Richmond (02LA007)	Rideau River at Ottawa (02LA004) and Kemptville Creek Near Kemptville (02LA006)
2	2.44	1.39	1.80	0.74	0.91
5	2.51	1.45	0.86	0.67	0.88
10	2.44	1.52	0.72	0.67	0.87
20	2.33	1.58	0.68	0.69	0.88
50	2.16	1.67	0.71	0.71	0.89
100	2.03	1.73	0.72	0.73	0.90
200	1.88	1.80	0.71	0.74	0.91
350	1.80	1.83	0.71	0.75	0.92
500	1.70	1.87	0.71	0.76	0.92

Table 6 Estimated Flood Quantile for HEC-RAS Modelling.

River	Reach	Cross-Section ID	Return Period (Year)								
			500 Yr	350 Yr	200 Yr	100 Yr	50 Yr	20 Yr	10 Yr	5 Yr	2 Yr
Rideau River	USManotick	29000	460.45	445.42	430.18	405.32	379.23	341.25	310.13	275.21	217.30
Rideau River	USManotick	28727	460.84	445.80	430.53	405.64	379.52	341.50	310.35	275.39	217.44
Rideau River	USManotick	27870	462.68	447.54	432.18	407.14	380.87	342.64	311.35	276.24	218.09
Rideau River	USManotick	26830	466.75	451.39	435.84	410.45	383.86	345.19	313.58	278.12	219.51
Rideau River	USManotick	26060	466.86	451.49	435.94	410.53	383.94	345.26	313.64	278.17	219.55
Rideau River	USManotick	25110	467.26	451.88	436.30	410.87	384.24	345.51	313.86	278.36	219.69
Rideau River	USManotick	24165	469.44	453.94	438.26	412.64	385.83	346.87	315.05	279.37	220.45
Rideau River	USManotick	23130	470.37	454.81	439.09	413.39	386.51	347.45	315.55	279.79	220.77
Rideau River	USManotick	21765	473.44	457.72	441.85	415.89	388.76	349.36	317.22	281.21	221.84
Rideau River	USManotick	20890	473.63	457.90	442.02	416.04	388.91	349.48	317.33	281.29	221.91
Rideau River	DS Manotick	15350	497.00	480.00	463.00	435.00	406.00	364.00	330.00	292.00	230.00
Rideau River	DS Manotick	13730	657.69	640.69	622.65	594.65	563.56	517.39	476.08	422.43	318.38
Rideau River	DS Manotick	6615	682.85	671.51	658.30	634.94	607.76	562.77	520.06	466.75	362.77
Rideau River	DS Manotick	0	691.00	680.00	667.00	644.00	617.00	572.00	529.00	475.00	369.00

River	Reach	Cross-Section ID	Return Period (Year)								
			500 Yr	350 Yr	200 Yr	100 Yr	50 Yr	20 Yr	10 Yr	5 Yr	2 Yr
Rideau River	Kars to BR	29822.51	243.76	234.98	226.59	213.21	198.64	178.26	162.20	146.08	121.61
Rideau River	Kars to BR	29405	243.76	234.98	226.59	213.21	198.64	178.26	162.20	146.08	121.61
Rideau River	Kars to BR	26880	259.74	250.39	240.88	226.12	210.24	188.09	170.79	153.45	127.49
Rideau River	Kars to BR	23675	262.61	253.15	243.44	228.43	212.31	189.84	172.32	154.77	128.54
Rideau River	Kars to BR	21545	264.77	255.23	245.36	230.16	213.87	191.16	173.47	155.75	129.32
Rideau River	Kars to BR	18720	278.83	268.79	257.89	241.45	223.99	199.70	180.93	162.13	134.39
Rideau River	Kars to BR	15855	282.27	272.10	260.95	244.20	226.45	201.78	182.74	163.67	135.62
Rideau River	Kars to BR	13635	284.84	274.58	263.24	246.26	228.29	203.33	184.09	164.83	136.54
Rideau River	Kars to BR	12665	380.50	369.59	358.03	339.76	319.84	290.46	265.60	237.38	188.58
Rideau River	Kars to BR	10150	389.51	378.15	366.19	347.19	326.59	296.26	270.70	241.72	191.89
Rideau River	Kars to BR	6305	396.05	384.37	372.11	352.59	331.49	300.46	274.39	244.86	194.28
Rideau River	Kars to BR	2605	412.33	399.82	386.82	365.98	343.63	310.86	283.52	252.63	200.19
Rideau River	Kars to BR	1700	458.75	443.82	428.65	403.94	377.98	340.18	309.20	274.42	216.71
Rideau River	Kars to BR	1050	460.39	445.37	430.12	405.27	379.18	341.21	310.10	275.18	217.28
Rideau River	Kars to BR	290	460.69	445.65	430.39	405.51	379.40	341.40	310.26	275.32	217.39

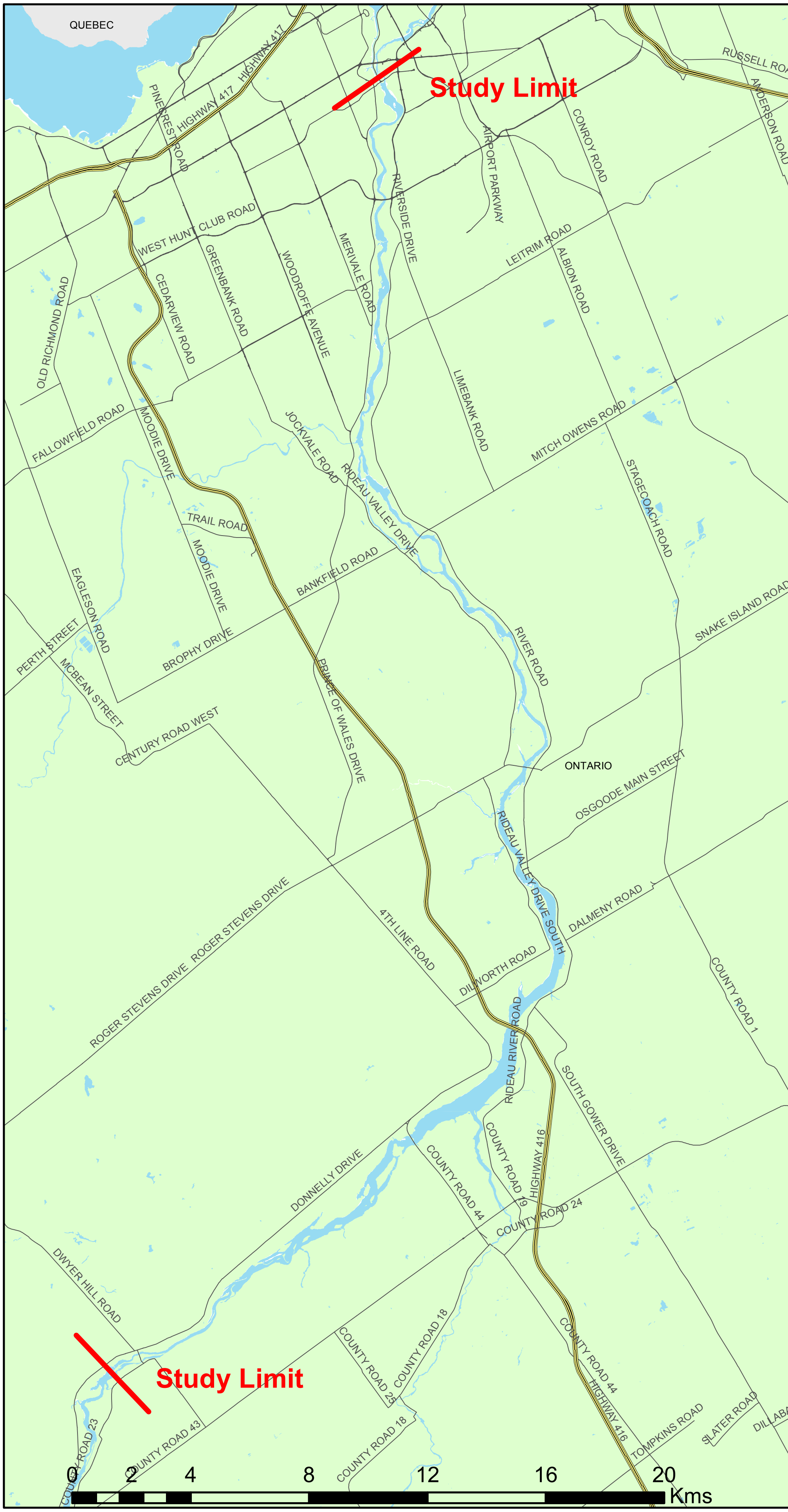

Figure 1 Study Area

1:200,000

Projection Note: NAD 1983 UTM Zone 18N

Created by: SNolan

Date Modified: 10/27/2015

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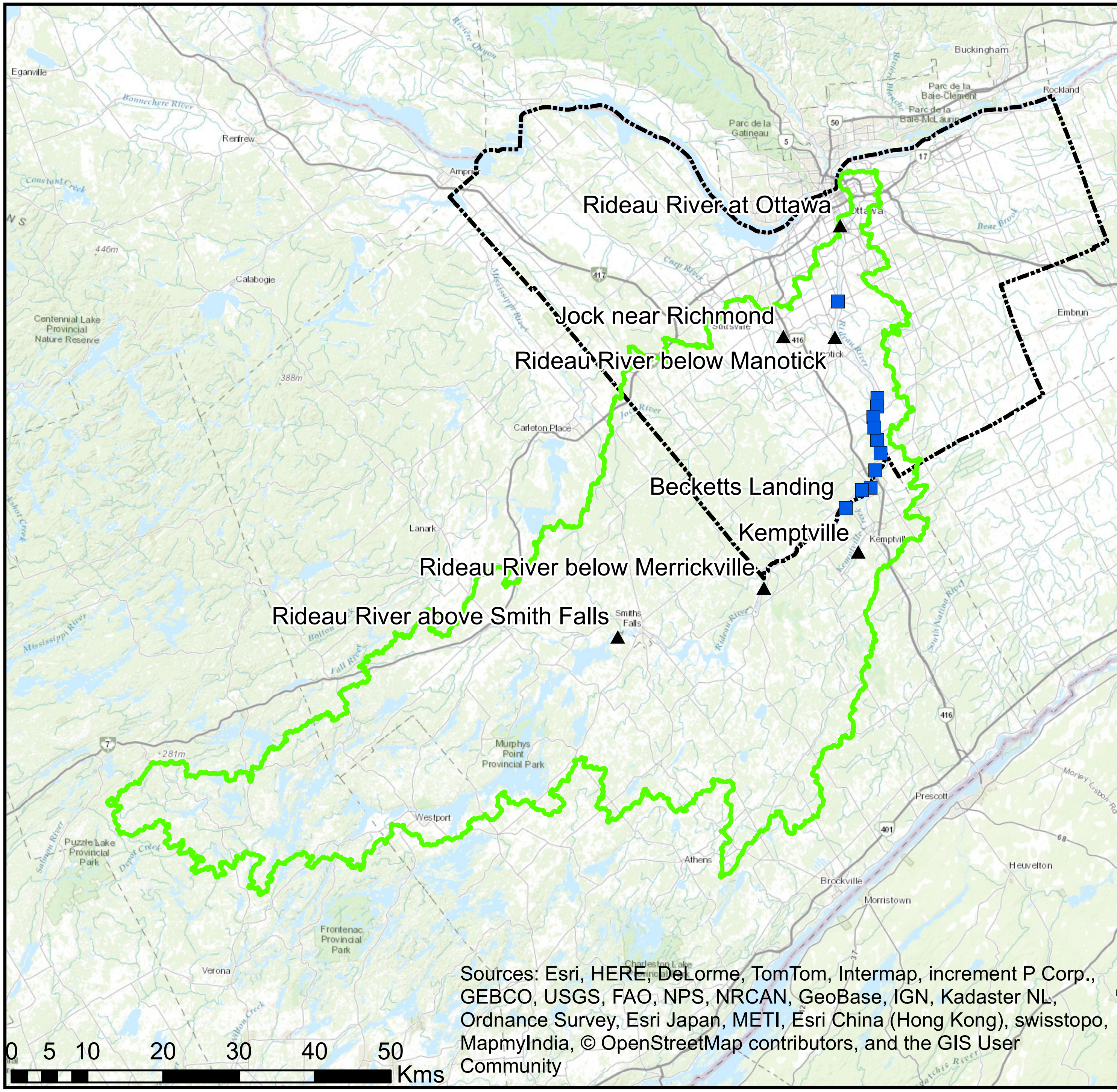


Figure 2 Hydrometric Data Availability

Legend

- Flood Damage Centres
- Gauges
- Rideau River Watershed
- City of Ottawa Boundary

RIDEAU VALLEY CONSERVATION AUTHORITY

1:750,000

Projection Note: NAD 1983 UTM Zone 18N

File Path: \\RVCASTORAGE1\rvcahydrology\M800_City\Rideau_HBtoKars_M800_200_020_204\RideauHydrology Report\Maps_V2_SN\Figure 2 Hydrometric Data Availability.mxd

Created by: SNolan

Date Modified: 10/26/2015 4:57:04

Figure 3 Previous Flood Risk Mapping Studies on the Rideau River

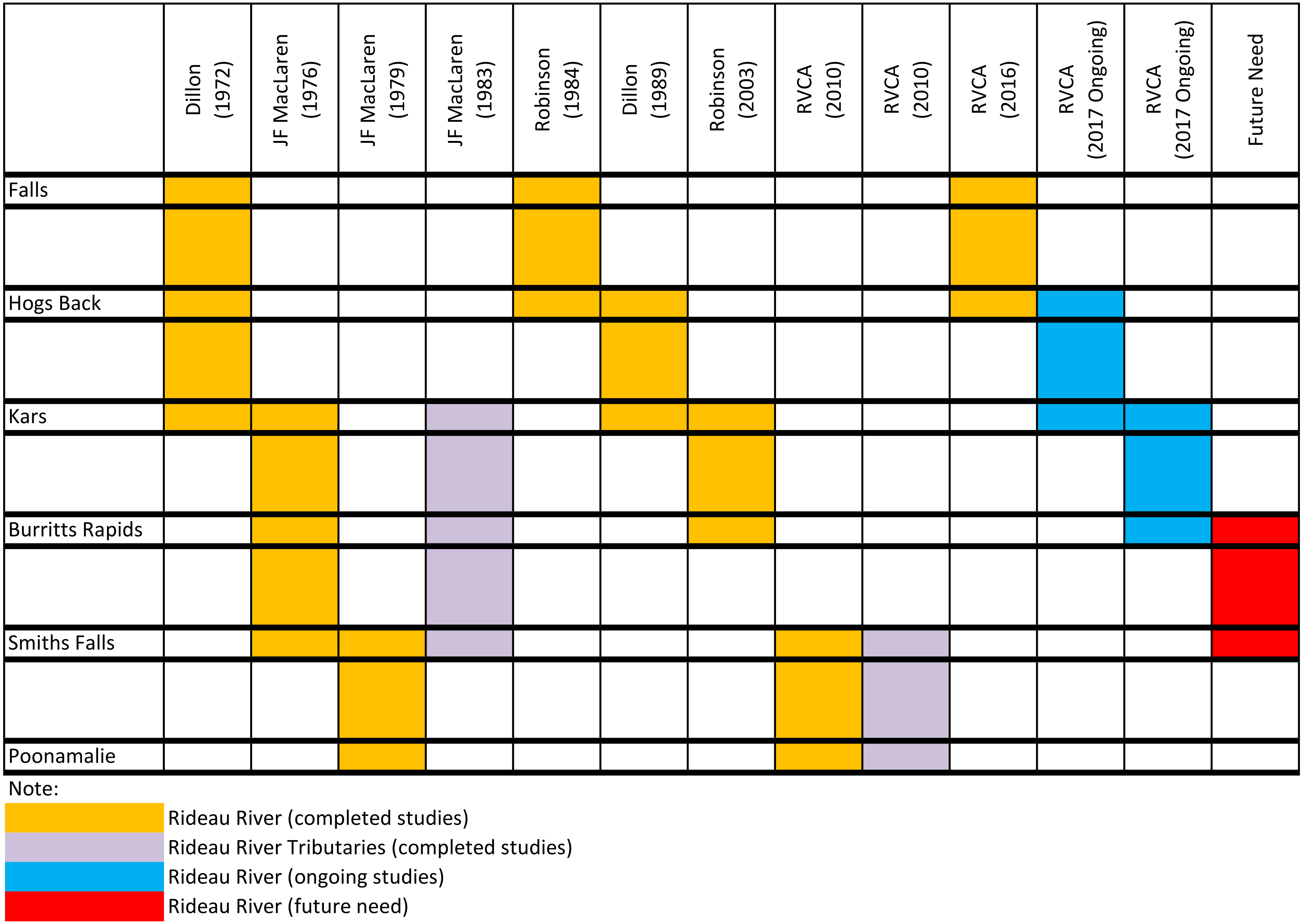
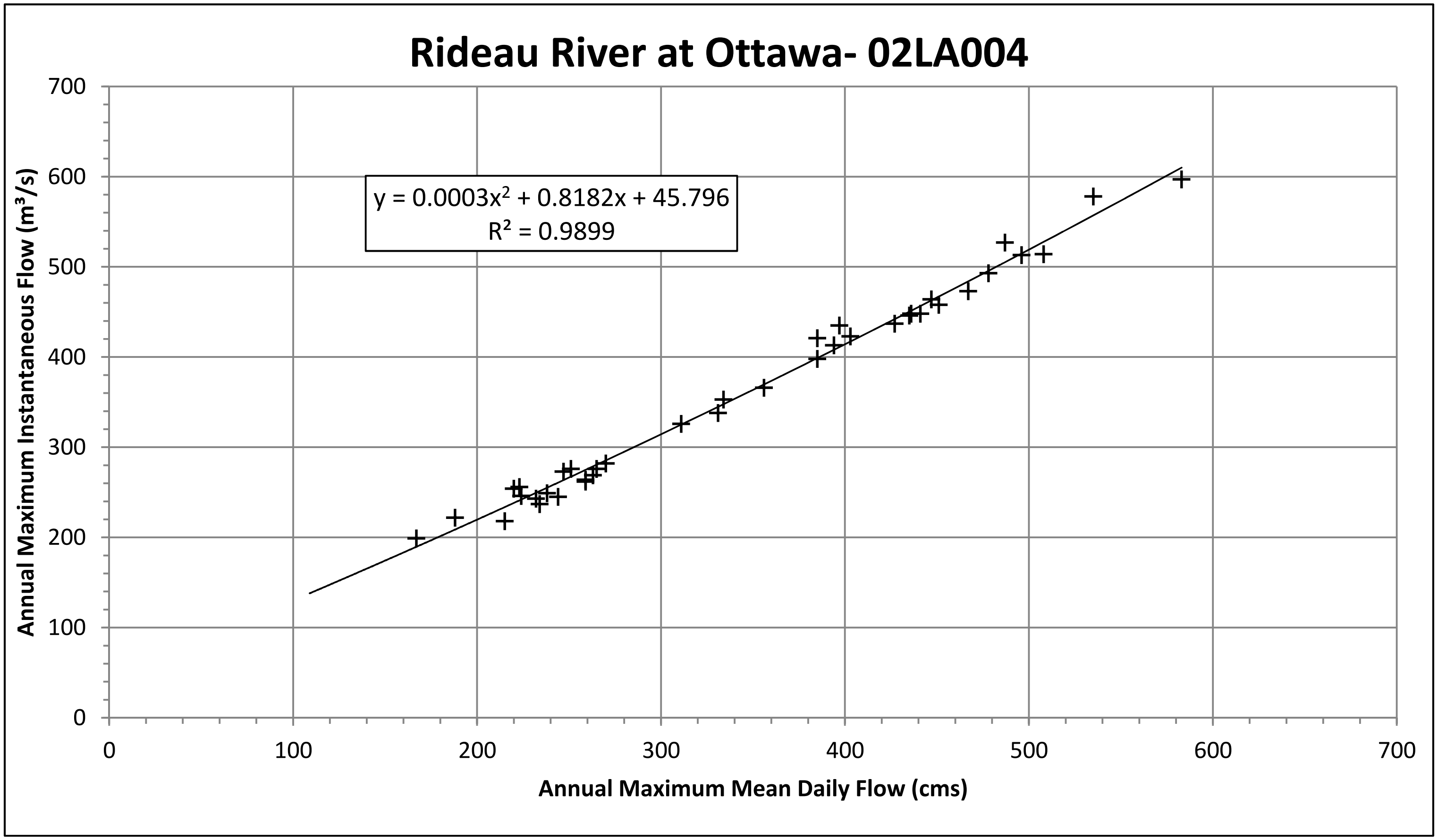


Figure 4A Relationship Between the Annual Maximum Mean Daily Flow and the Annual Maximum Instantaneous Flow for the Rideau River at Ottawa (02LA004) Stream Gauge.



Source: RVCA (2015) Rideau River Flood Risk Mapping from Hogs Back to Rideau Falls

Figure 4B Relationship Between the Annual Maximum Mean Daily Flow and the Annual Maximum Instantaneous Flow for the Rideau River Below Manotick (02LA012) Stream Gauge.

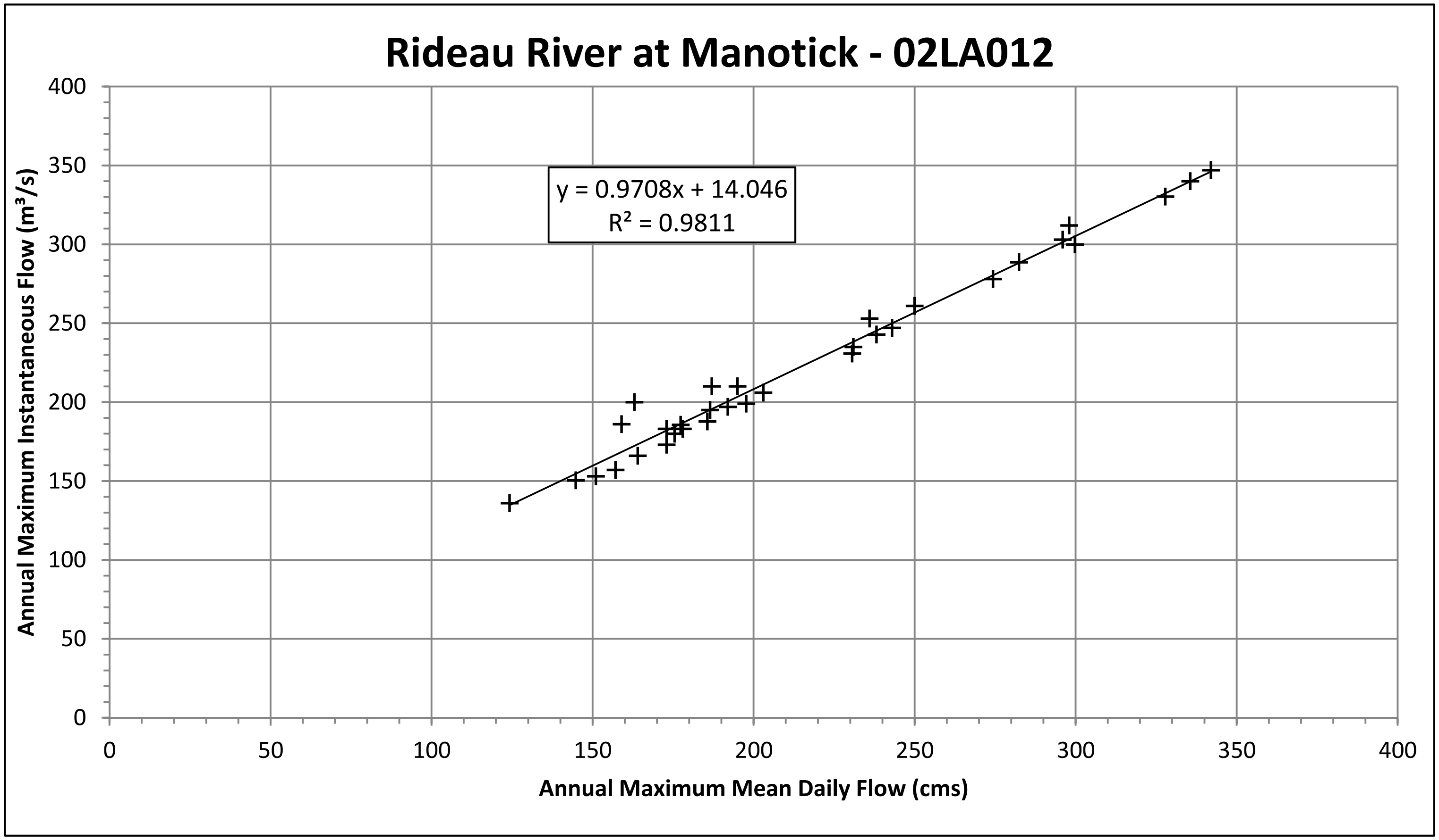


Figure 4C Relationship Between the Annual Maximum Mean Daily Flow and the Annual Maximum Instantaneous Flow for the Rideau River Below Merrickville (02LA011) Stream Gauge.

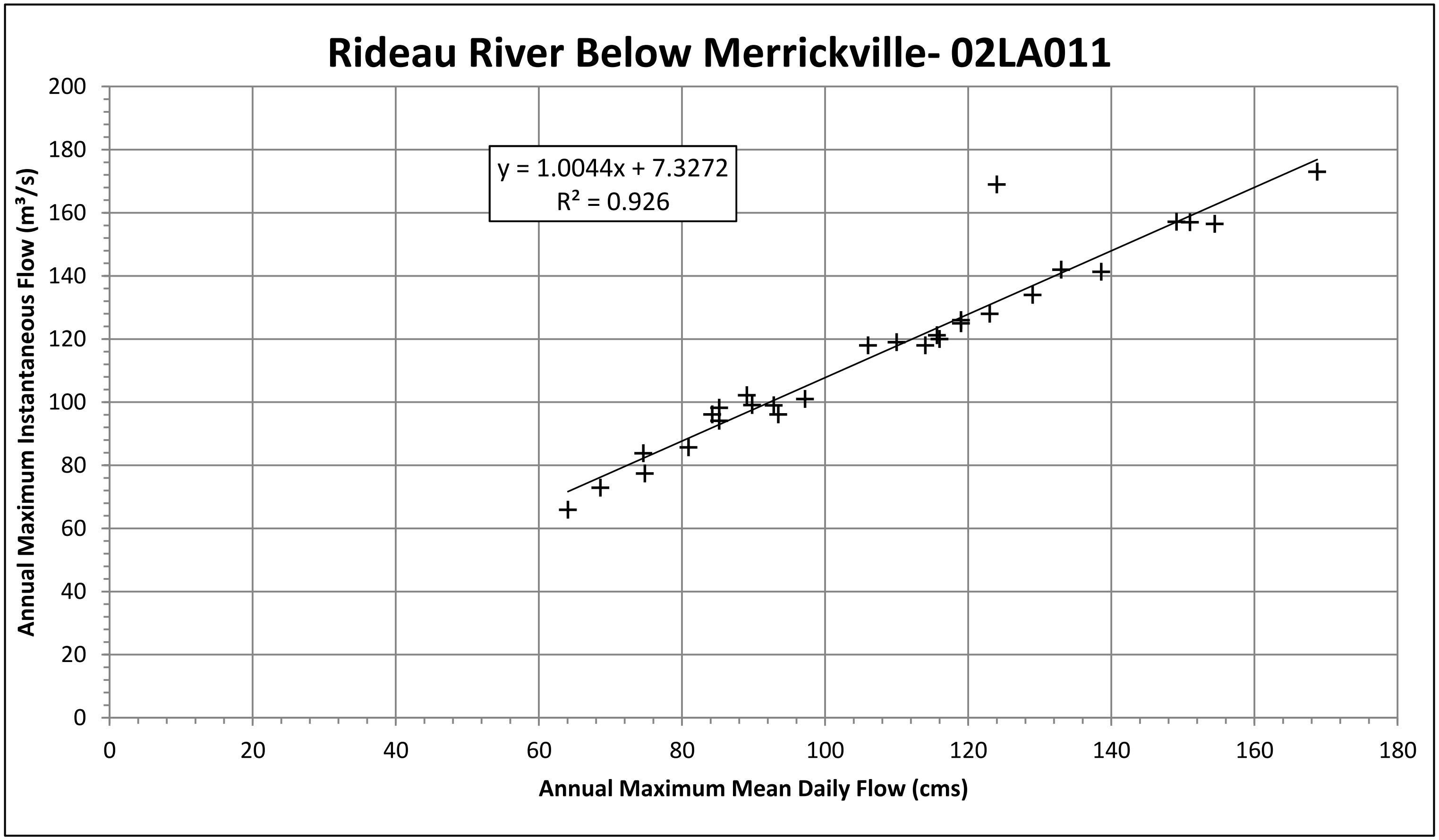


Figure 4D Relationship Between the Annual Maximum Mean Daily Flow and the Annual Maximum Instantaneous Flow for the Jock River Near Richmond (02LA007) Stream Gauge.

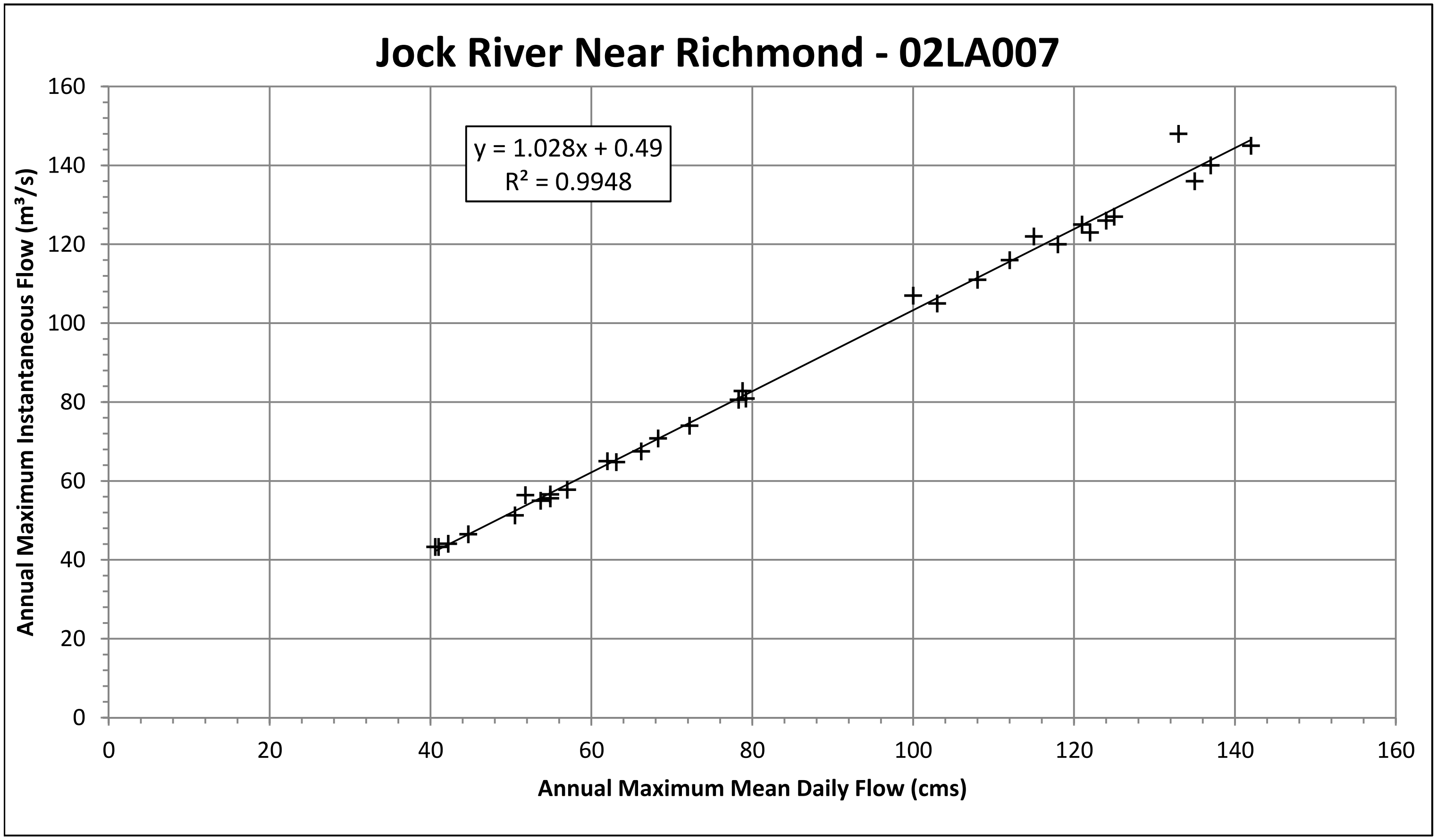


Figure 4E Relationship Between the Annual Maximum Mean Daily Flow and the Annual Maximum Instantaneous Flow for the Kemptville Creek Near Kemptville (02LA006) Stream Gauge.

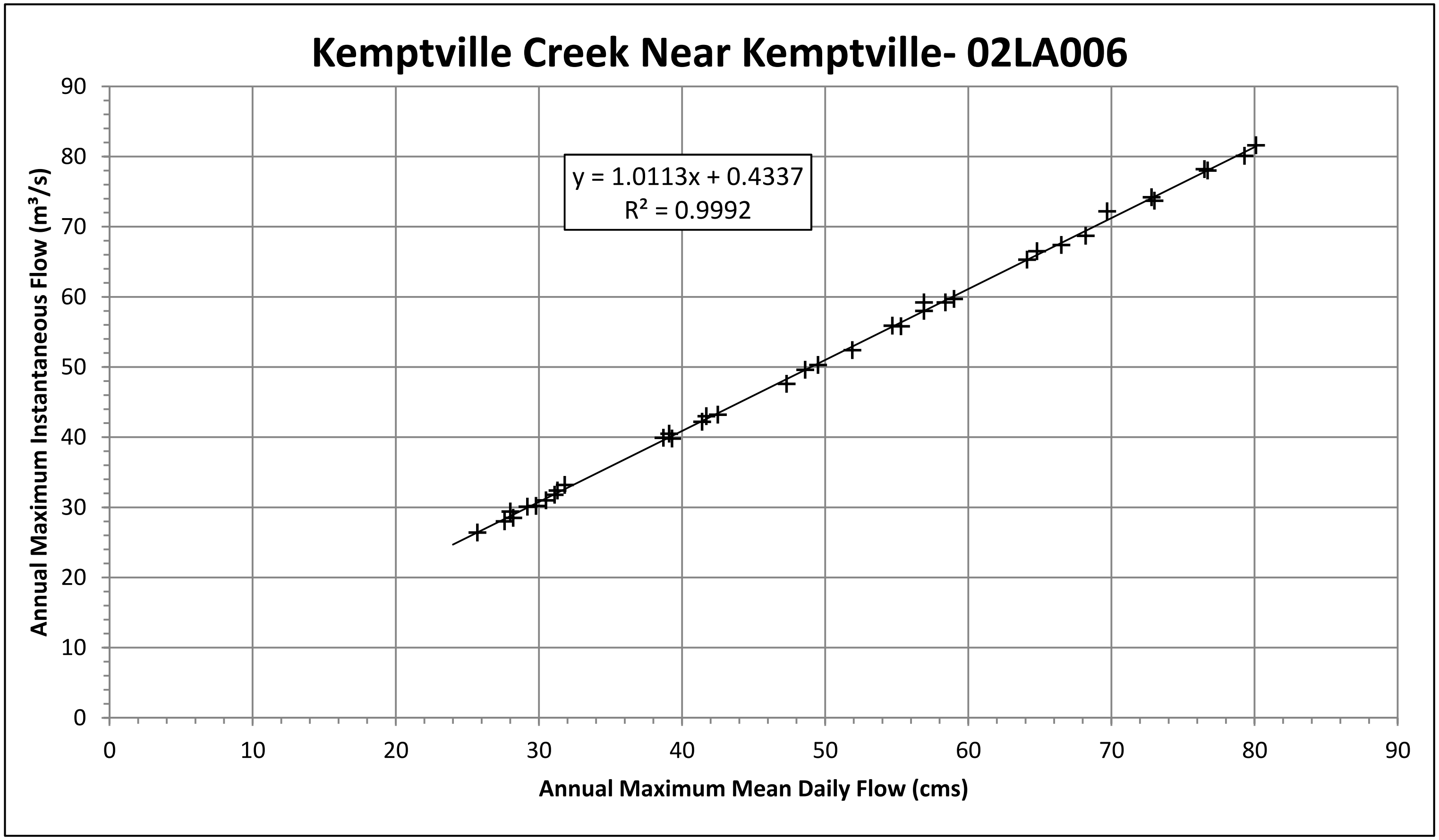
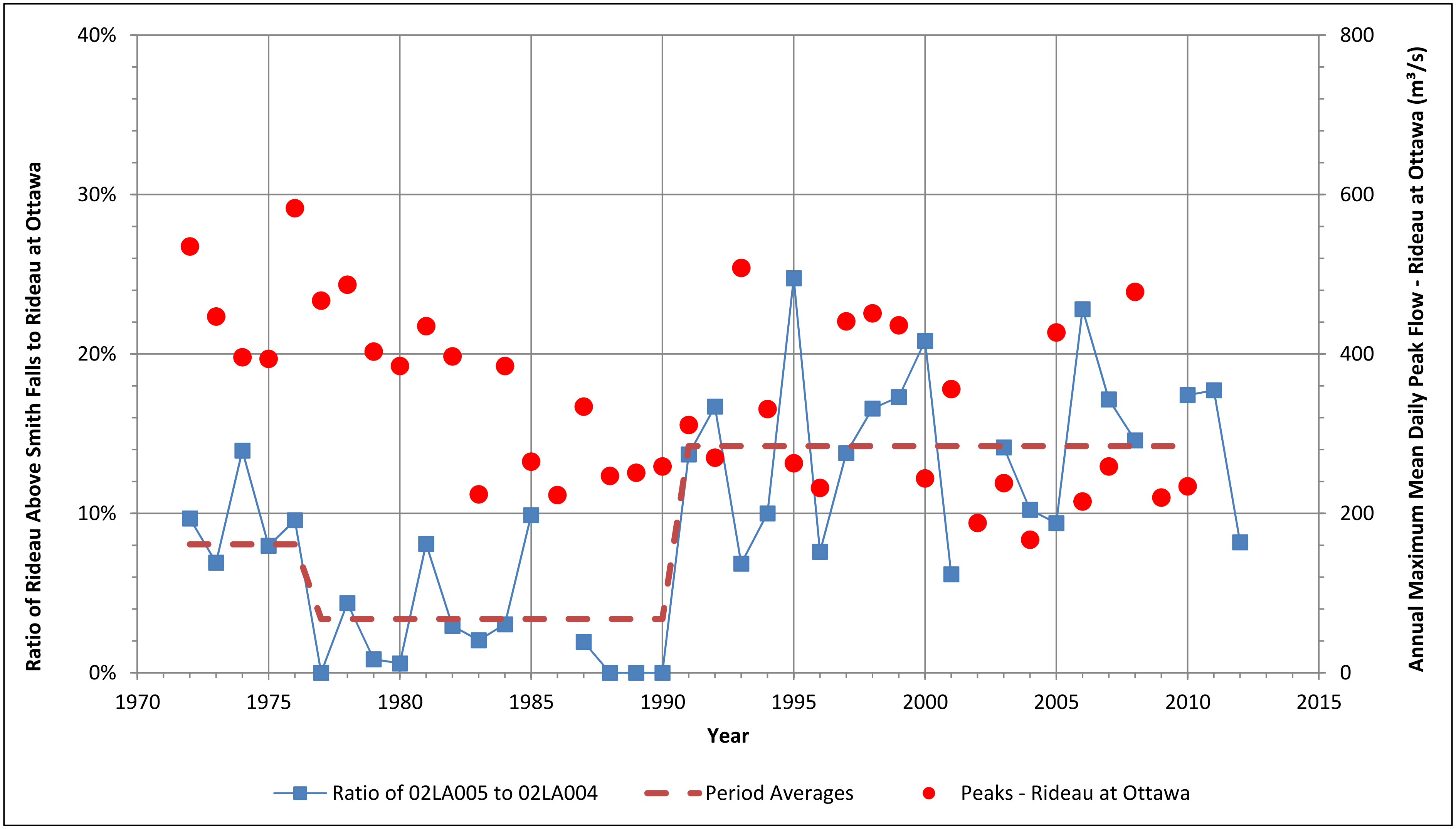


Figure 5A Variation of Flow Between the Stream Gauges at Rideau River Above Smith Falls (02LA005) and the Rideau River at Ottawa (02LA004).



Source: RVCA (2015) Rideau River Flood Risk Mapping from Hogs Back to Rideau Falls

Figure 5B Variation of Flow Between the Stream Gauges at Rideau River Above Smith Falls (02LA005) and the Rideau River Below Manotick (02LA012).

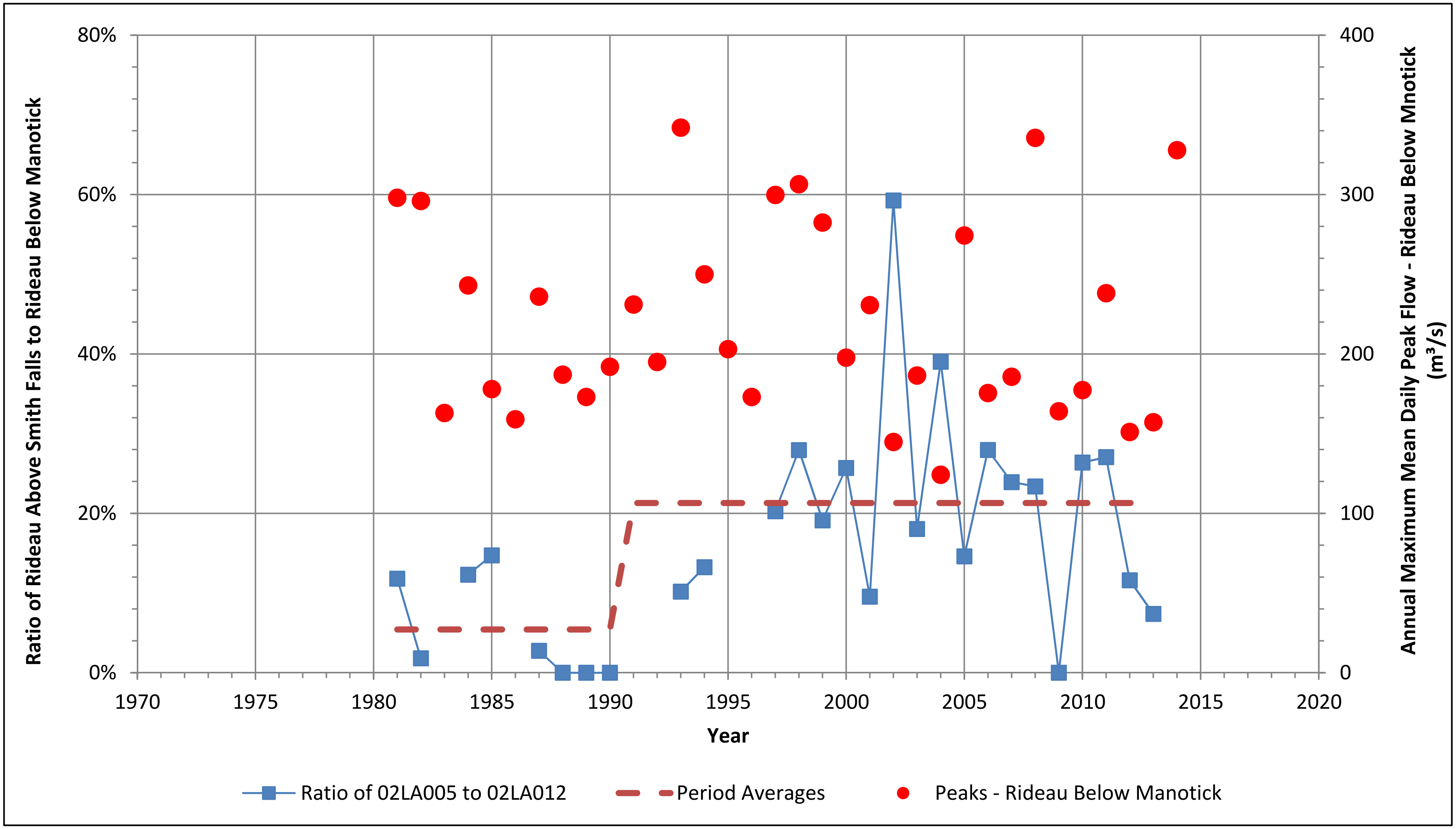


Figure 5C Variation of Flow Between the Stream Gauges at Rideau River Above Smith Falls (02LA005) and the Rideau River Below Merrickville (02LA011).

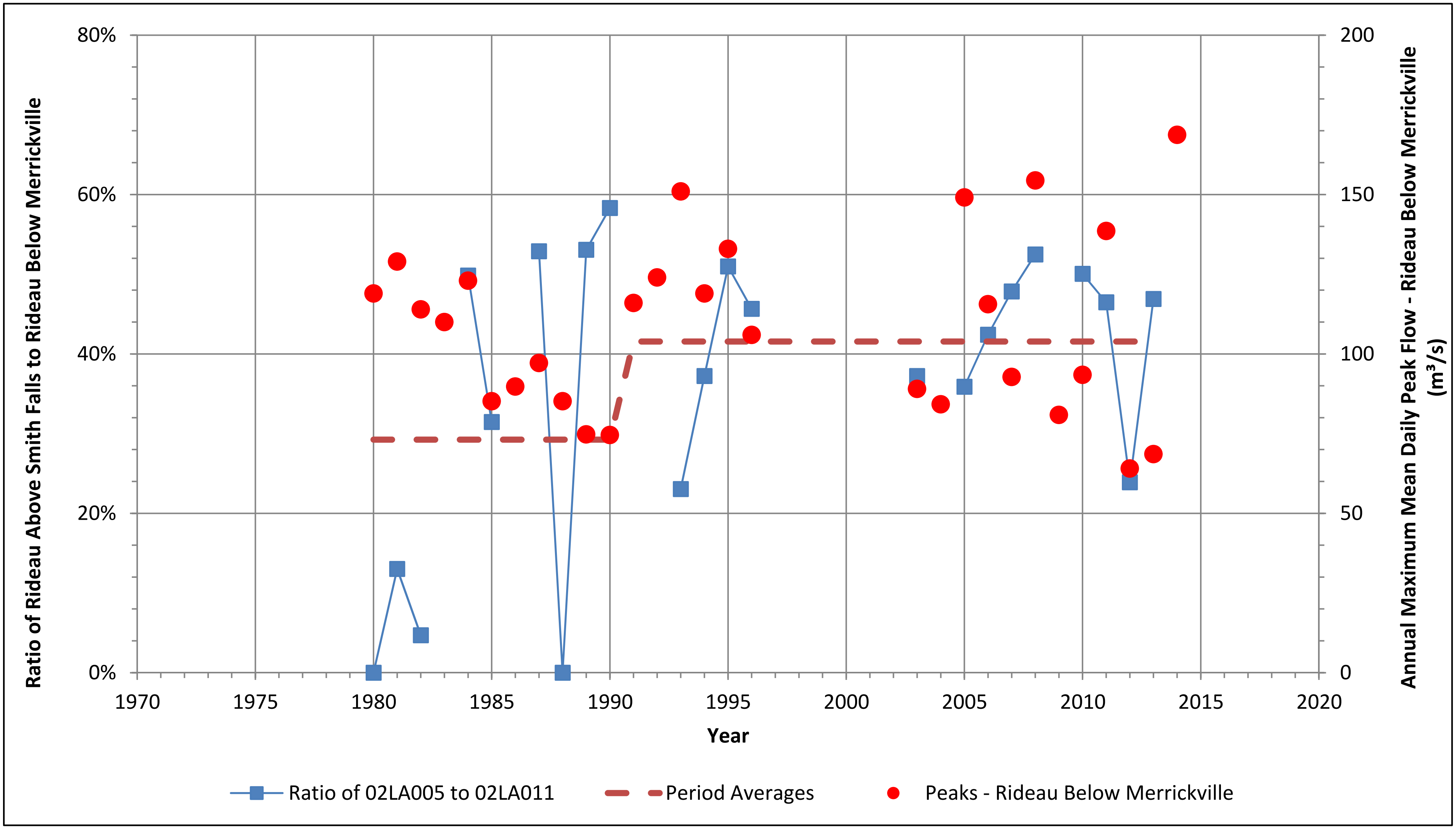
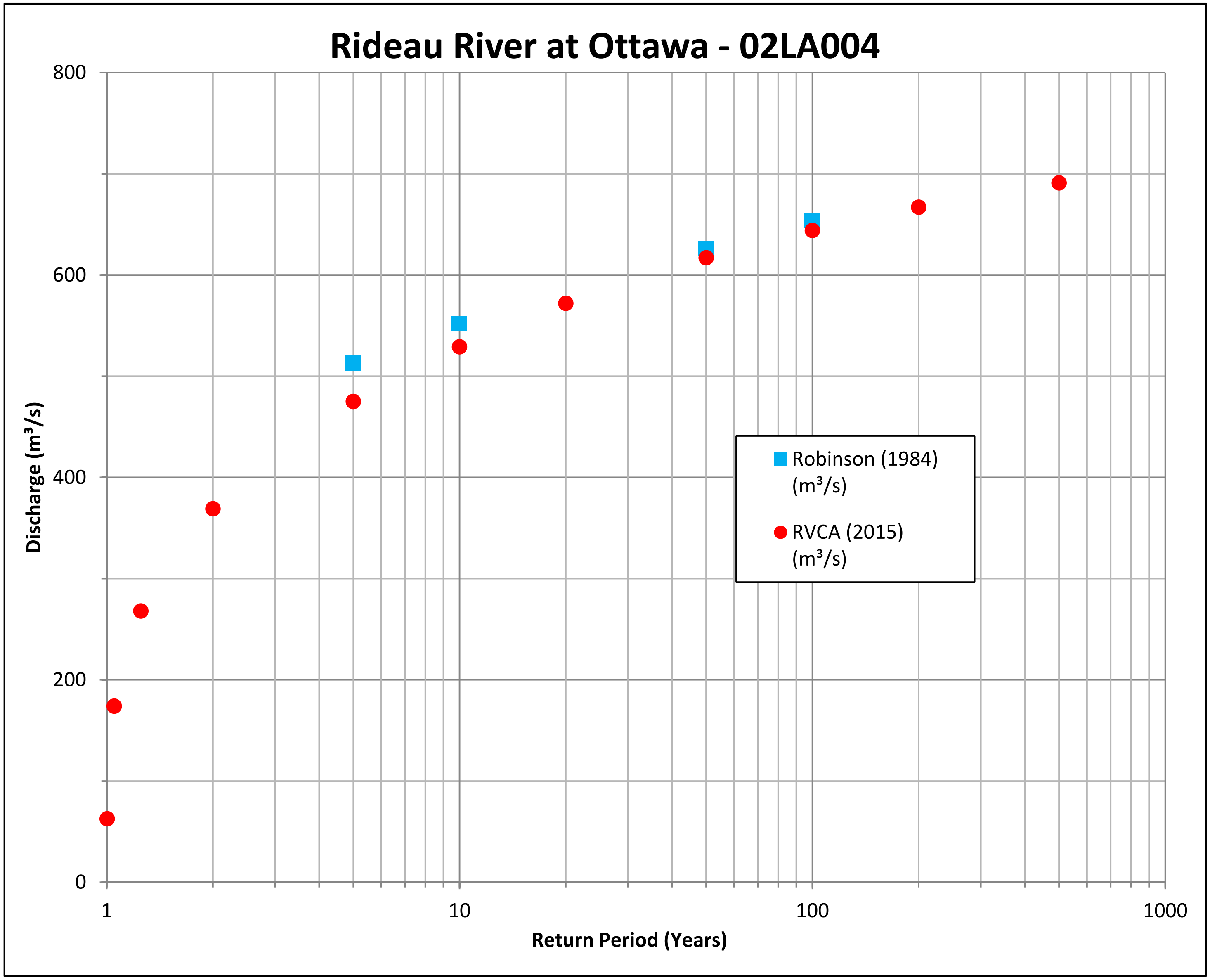


Figure 6A Estimated Flood Flows for the Rideau River at Ottawa (02LA004) Stream Gauge.



Source: RVCA (2015) Rideau River Flood Risk Mapping from Hogs Back to Rideau Falls

Figure 6B Estimated Flood Flows for the Rideau River Below Manotick (02LA012) Stream Gauge.

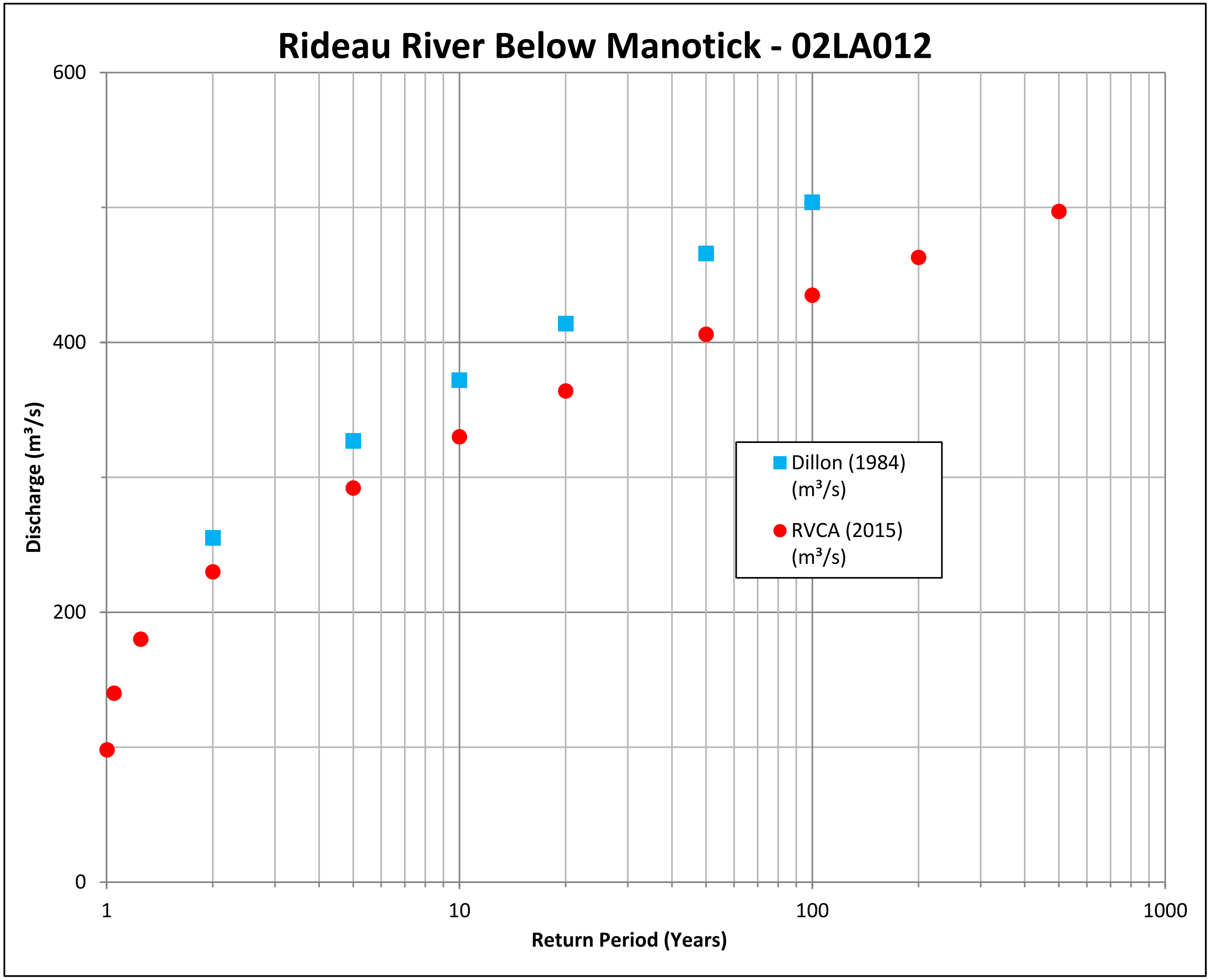


Figure 6C Estimated Flood Flows for the Rideau River Below Merrickville (02LA011) Stream Gauge.

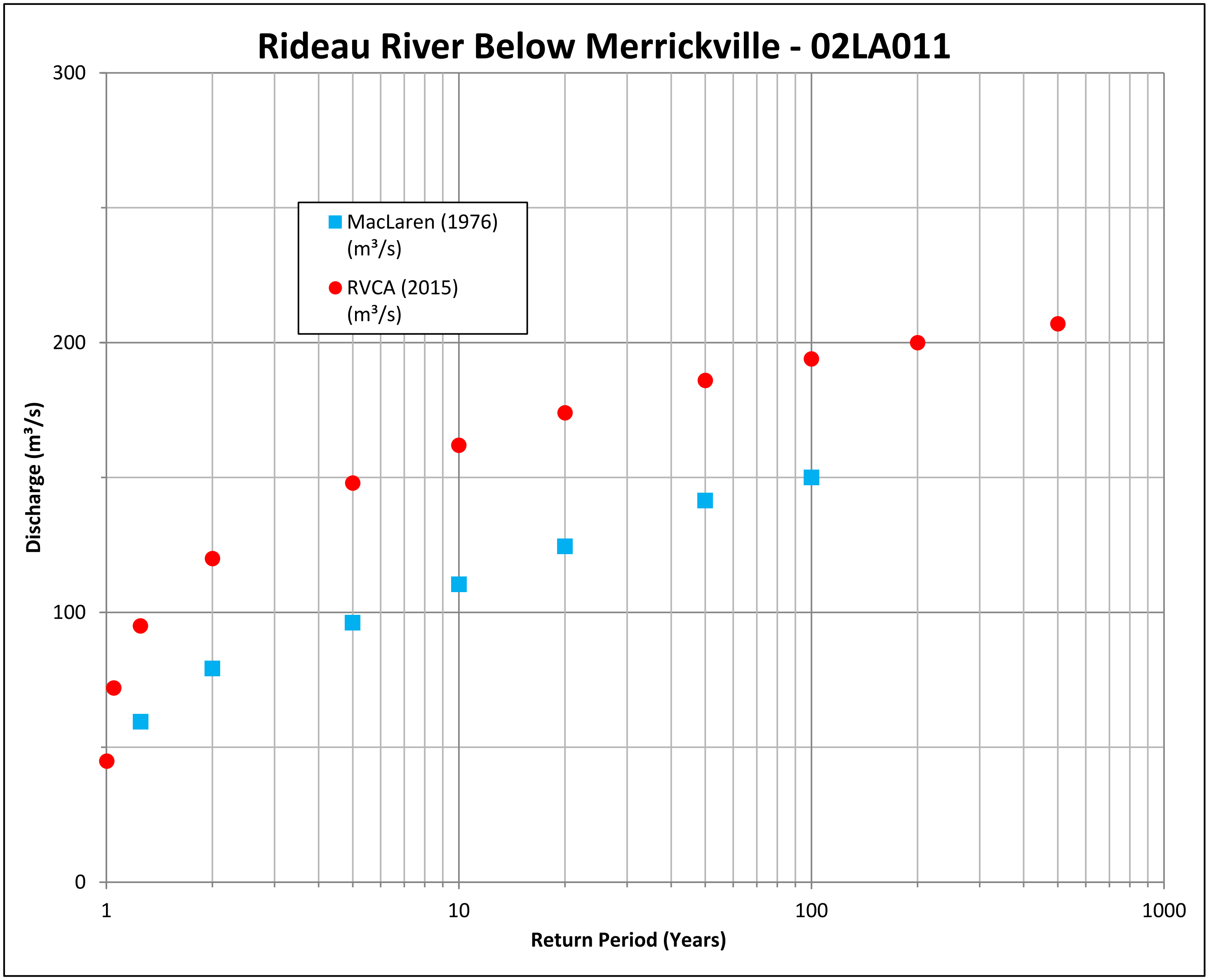


Figure 6D Estimated Flood Flows for the Jock River Near Richmond (02LA007) Stream Gauge.

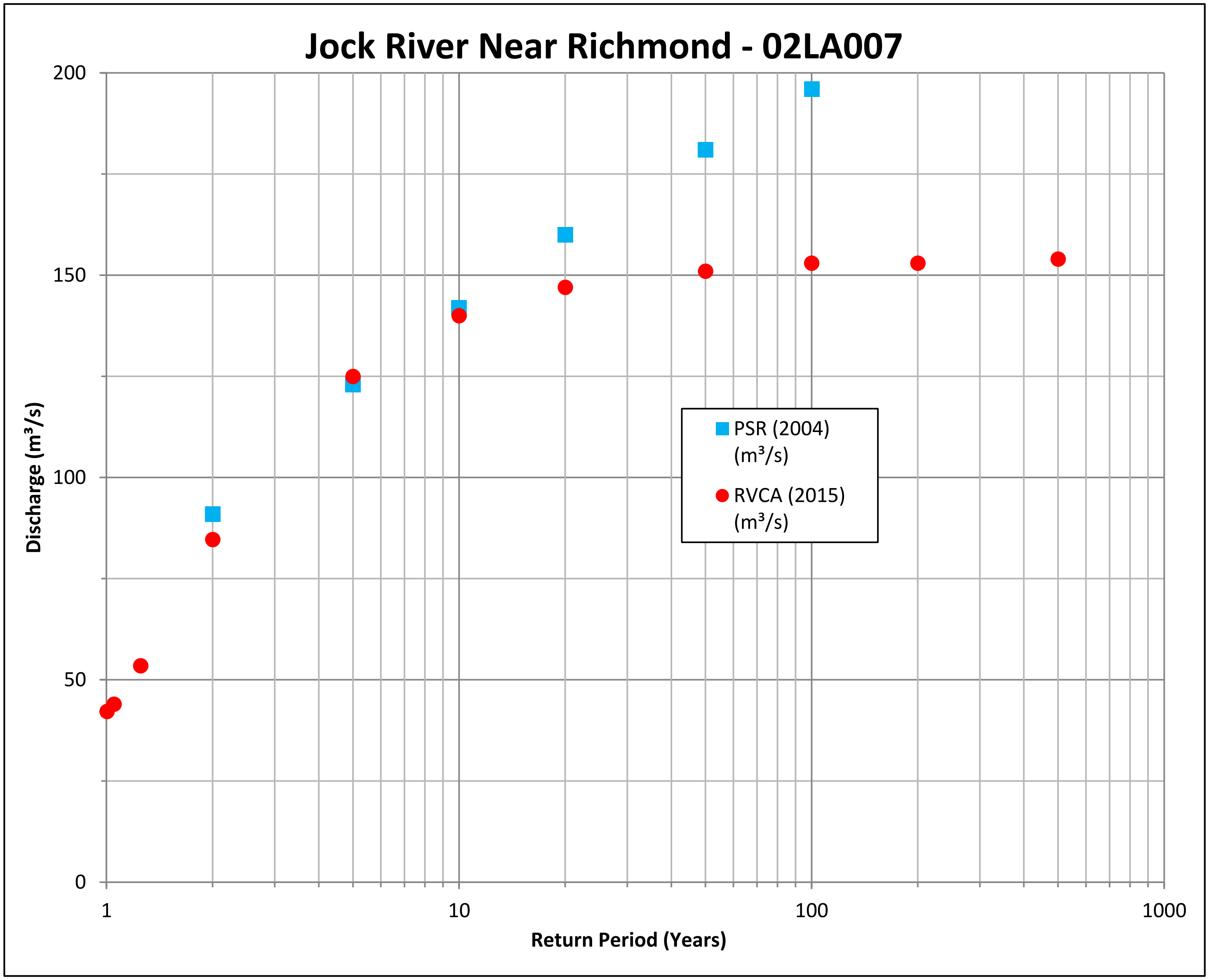


Figure 6E Estimated Flood Flows for the Kemptville Creek Near Kemptville (02LA006) Stream Gauge.

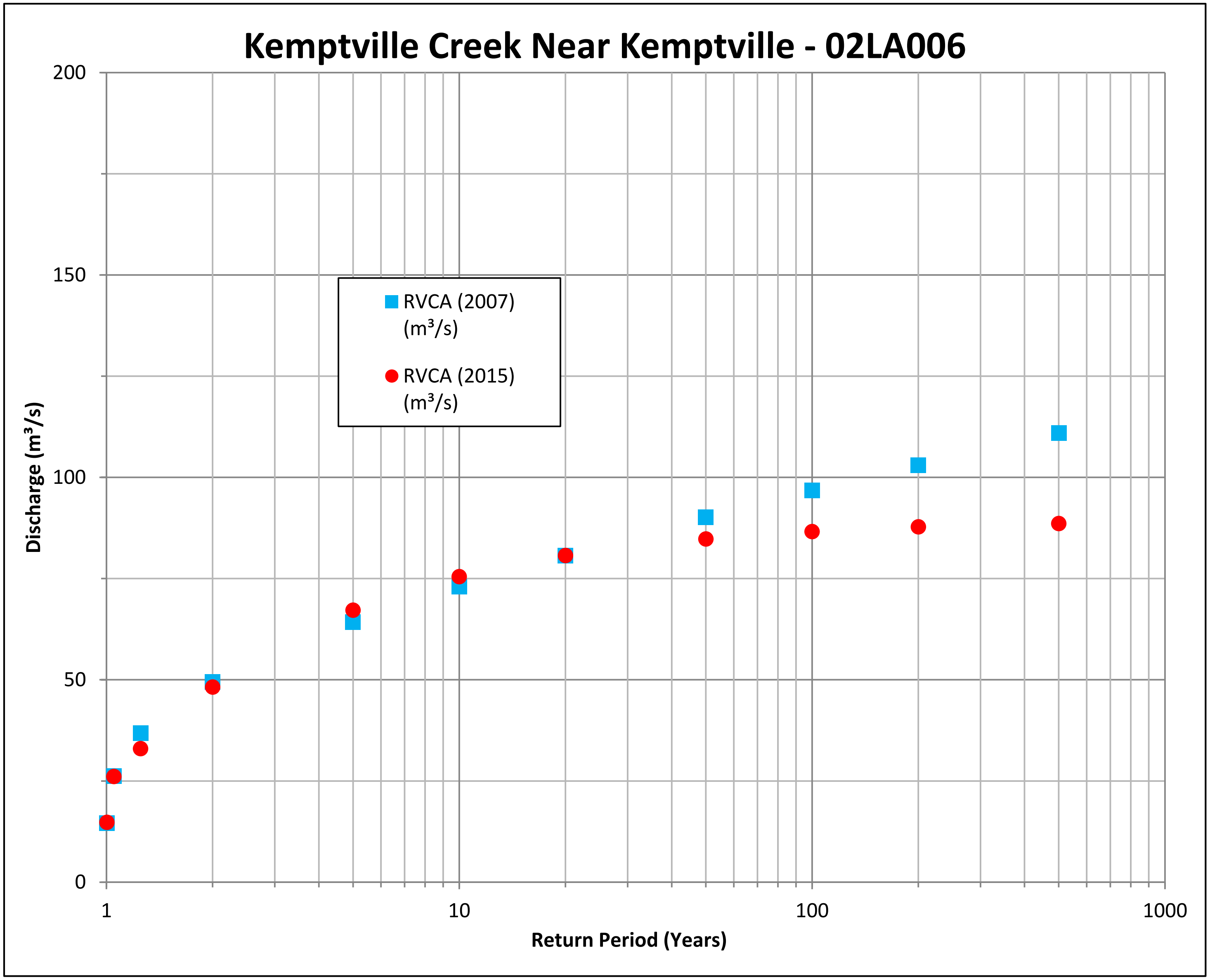
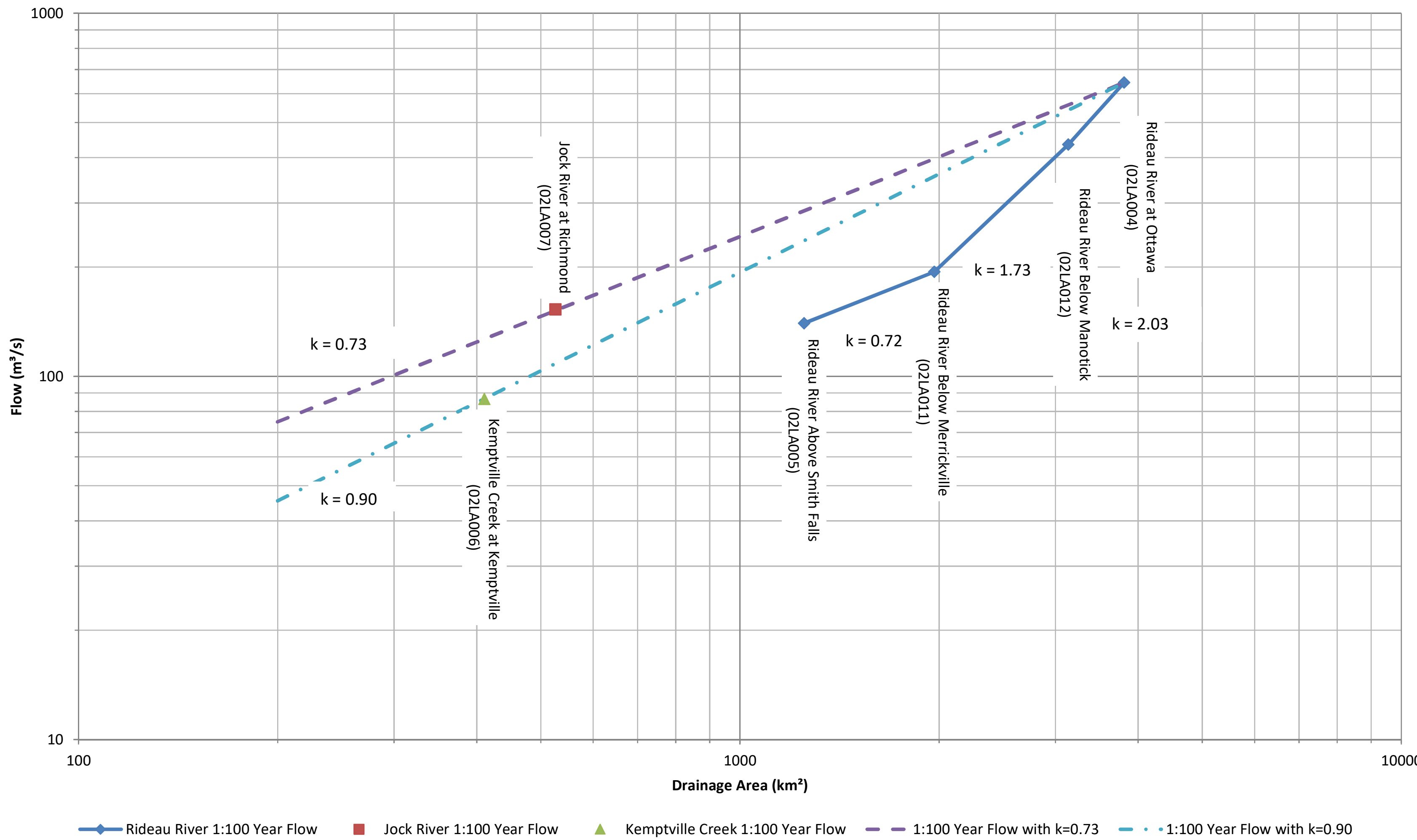
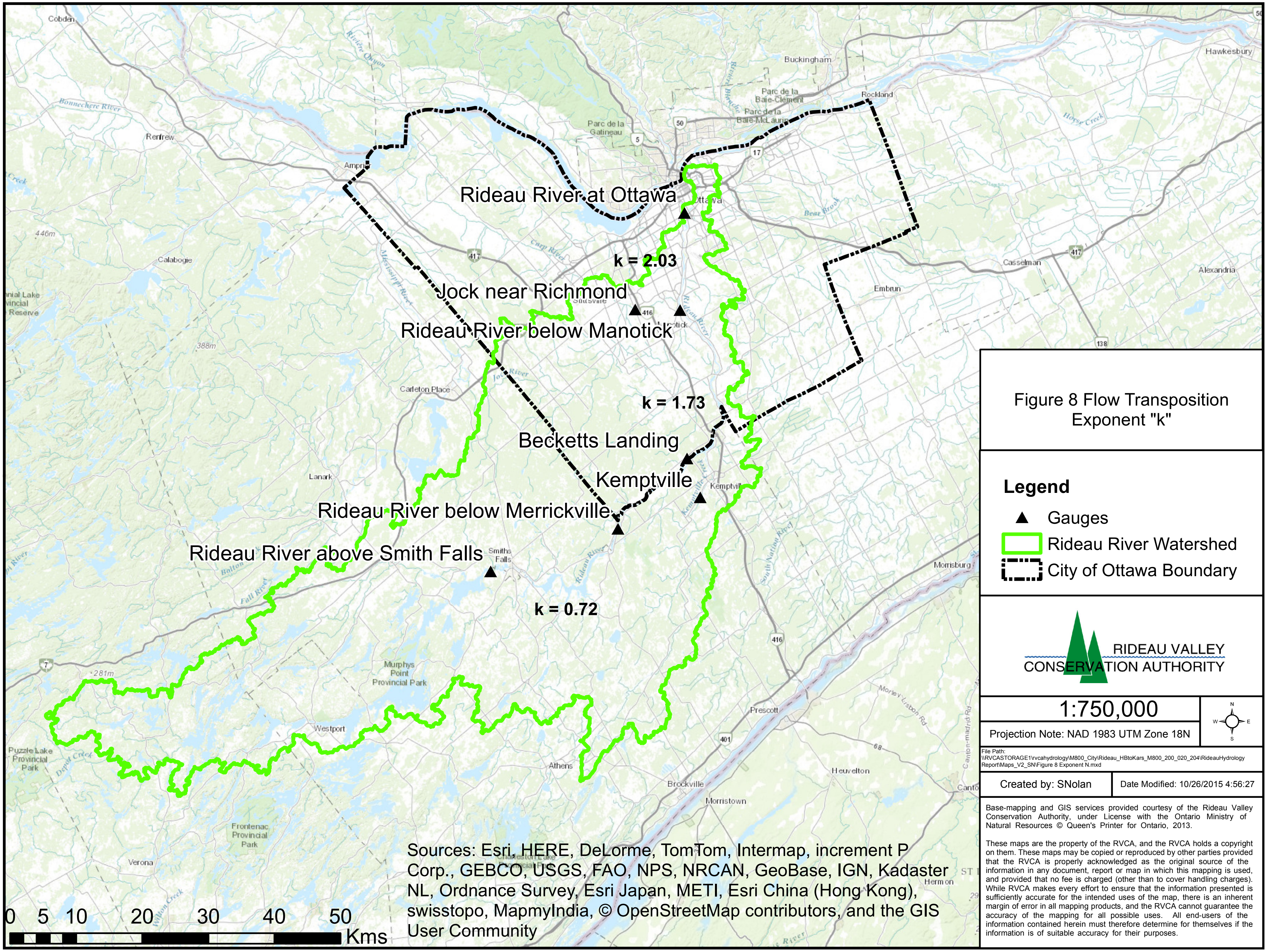


Figure 7 The Calculated Exponent "k" Between Stream Gauges for the Flow Transposition Equation





Rideau River at Ottawa
k = 2.03
Jock near Richmond
Rideau River below Manotick
k = 1.73
Becketts Landing
Kemptville
Rideau River below Merrickville
Rideau River above Smith Falls
k = 0.72
Figure 8 Flow Transposition Exponent "k"
Legend
Gauges
Rideau River Watershed
City of Ottawa Boundary
RIDEAU VALLEY CONSERVATION AUTHORITY
1:750,000
Projection Note: NAD 1983 UTM Zone 18N
Created by: SNolan
Date Modified: 10/26/2015 4:56:27
0 5 10 20 30 40 50 Kms
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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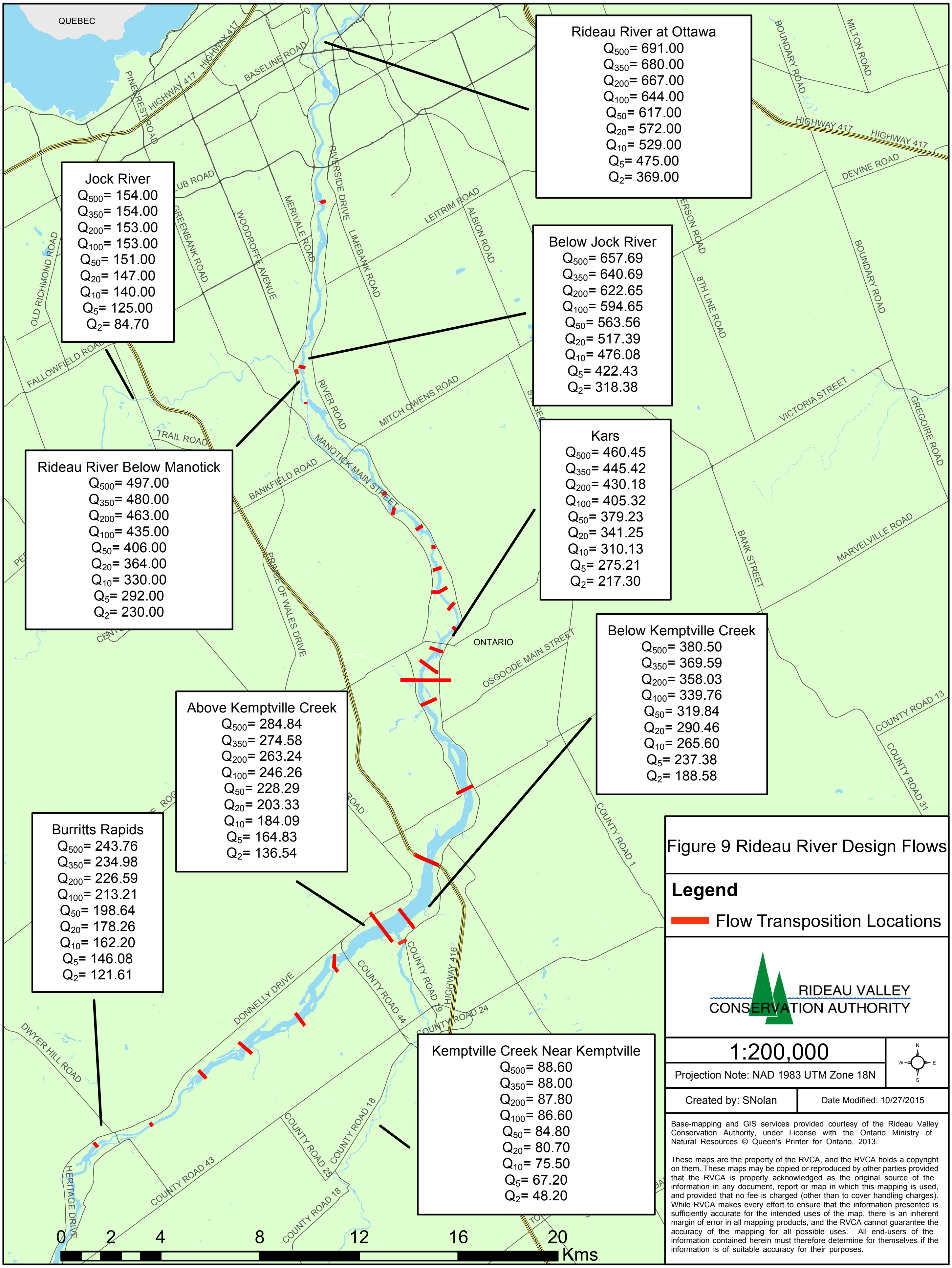

Figure 9 Rideau River Design Flows
Legend
Flow Transposition Locations
RIDEAU VALLEY CONSERVATION AUTHORITY
1:200,000
Projection Note: NAD 1983 UTM Zone 18N
Created by: SNolan
Date Modified: 10/27/2015
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Rideau River at Ottawa
Q_{500}= 691.00
Q_{350}= 680.00
Q_{200}= 667.00
Q_{100}= 644.00
Q_{50}= 617.00
Q_{20}= 572.00
Q_{10}= 529.00
Q_{5}= 475.00
Q_{2}= 369.00
Jock River
Q_{500}= 154.00
Q_{350}= 154.00
Q_{200}= 153.00
Q_{100}= 153.00
Q_{50}= 151.00
Q_{20}= 147.00
Q_{10}= 140.00
Q_{5}= 125.00
Q_{2}= 84.70
Below Jock River
Q_{500}= 657.69
Q_{350}= 640.69
Q_{200}= 622.65
Q_{100}= 594.65
Q_{50}= 563.56
Q_{20}= 517.39
Q_{10}= 476.08
Q_{5}= 422.43
Q_{2}= 318.38
Rideau River Below Manotick
Q_{500}= 497.00
Q_{350}= 480.00
Q_{200}= 463.00
Q_{100}= 435.00
Q_{50}= 406.00
Q_{20}= 364.00
Q_{10}= 330.00
Q_{5}= 292.00
Q_{2}= 230.00
Kars
Q_{500}= 460.45
Q_{350}= 445.42
Q_{200}= 430.18
Q_{100}= 405.32
Q_{50}= 379.23
Q_{20}= 341.25
Q_{10}= 310.13
Q_{5}= 275.21
Q_{2}= 217.30
Below Kemptville Creek
Q_{500}= 380.50
Q_{350}= 369.59
Q_{200}= 358.03
Q_{100}= 339.76
Q_{50}= 319.84
Q_{20}= 290.46
Q_{10}= 265.60
Q_{5}= 237.38
Q_{2}= 188.58
Above Kemptville Creek
Q_{500}= 284.84
Q_{350}= 274.58
Q_{200}= 263.24
Q_{100}= 246.26
Q_{50}= 228.29
Q_{20}= 203.33
Q_{10}= 184.09
Q_{5}= 164.83
Q_{2}= 136.54
Burritts Rapids
Q_{500}= 243.76
Q_{350}= 234.98
Q_{200}= 226.59
Q_{100}= 213.21
Q_{50}= 198.64
Q_{20}= 178.26
Q_{10}= 162.20
Q_{5}= 146.08
Q_{2}= 121.61
Kemptville Creek Near Kemptville
Q_{500}= 88.60
Q_{350}= 88.00
Q_{200}= 87.80
Q_{100}= 86.60
Q_{50}= 84.80
Q_{20}= 80.70
Q_{10}= 75.50
Q_{5}= 67.20
Q_{2}= 48.20
QUEBEC
ONTARIO
HIGHWAY 417
BASELINE ROAD
PINECREST ROAD
OLD RICHMOND ROAD
FALLOWFIELD ROAD
GREENBANK ROAD
WOODROFFE AVENUE
MERIVALE ROAD
RIVERSIDE DRIVE
LIMEBANK ROAD
LEITRIM ROAD
ALBION ROAD
BOUNDARY ROAD
MILTON ROAD
DEVINE ROAD
8TH LINE ROAD
VICTORIA STREET
GREGOIRE ROAD
MITCH OWENS ROAD
RIVER ROAD
MANOTICK MAIN STREET
BANKFIELD ROAD
TRAIL ROAD
PRINCE OF WALES DRIVE
BANK STREET
MARVELVILLE ROAD
OSGOODE MAIN STREET
COUNTY ROAD 13
COUNTY ROAD 31
COUNTY ROAD 1
COUNTY ROAD 19
COUNTY ROAD 44
HIGHWAY 416
COUNTY ROAD 24
DONNELLY DRIVE
DWYER HILL ROAD
HERITAGE DRIVE
COUNTY ROAD 43
COUNTY ROAD 25
COUNTY ROAD 18
0 2 4 8 12 16 20 Kms

Appendix A

Statistical Analysis of Streamflow Data

Statistical Analysis of Streamflow Data

When analyzing historical flow data, it is important to ensure that the data is suitable for statistical analysis before using it. In order to keep a consistent approach with the previous flood risk studies on the Rideau River, four tests were carried out on the data using the Consolidated Frequency Analysis (CFA 3.1) Software Package by Environment Canada (Pilon and Harvey, 1993). The software analyses the data for independence, trend, randomness and homogeneity using the following tests;

- Spearman Rank Order Serial Correlation Coefficient Test for Independence
- Spearman Rank Order Correlation Coefficient Test for Trend
- Runs Above and Below the Median for General Randomness
- Mann-Whitney Split Sample Test for Homogeneity

The software analyses the four attributes at a five percent and one percent level of significance, which also means that the associated attribute is true 95% (five percent significance) or 99% (one percent significance) of the time.

The Spearman Rank Order Serial Correlation Coefficient Test for Independence and the Spearman Rank Order Correlation Coefficient Test for Trend are said to be non-significant when the T value produced by the test is less than the Students T value. For the Runs Above and Below the Median for General Randomness and the Mann-Whitney Split Sample Test for Homogeneity the test is said to be non-significant when the Z value calculated by the test is greater than the standard Z value or when the U value calculated by the test is less than the standard U value.

The attributes that are the most important in relation to a hydrological analysis are randomness and independence since the regulating effect of water control structures should be mitigated before a statistical analysis is conducted (MNR, 2002).

When looking at the results four out of the five stations are not significantly non-random at a five percent level and while the Rideau River near Ottawa gauge is not significantly non-random at a one percent level. Four out the five stations also showed that at a five percent level there is no significant dependence with Rideau River near

Ottawa failing both the five percent and one percent levels. This may be due to the Rideau River at Ottawa gauge having a lot longer data span than the other gauges which would mean it has a greater number of lower flows compared to high flows. This might make it seems like the flow at the gauge is relying on another variable when in reality we know it is just the nature of the natural system to have more low flows than high flows.

When examining the trend, it can be seen that one out of the five stations do not have significant trend at a five percent level while two out of five have significant trend at a one percent level. This trend is not of concern because the gauge locations are on natural systems where the annual maximum peak flow tends to occur during the spring freshet which tends to have similar characteristics each year.

Only one station passed the homogeneity test at a five percent level while one out of the five stations failed at a one percent level. This is also not concerning due to the fact that it is known that the Kemptville gauge has not been moved and that the dataset has been sampled from the same stream.

It is found after analyzing the data that the flow records are suitable for flood frequency analysis without any further adjustments.

Table A1 Test Results for Independence and Trend for the Annual Maximum Instantaneous Flow Data Sets for Various Locations.

Location	Independence			Trend		
	5% Level	1% Level	Students T	5% Level	1% Level	Students T
02LA004 - Rideau River Near Ottawa	Significant T = 1.671	Significant T = 2.389	2.83	Significant T = 1.999	Not Significant T = 2.658	2.341
02LA012 - Rideau River Below Manotick	Not Significant T = 1.696	Not Significant T = 2.454	0.503	Significant T = 2.038	Not Significant T = 2.741	2.6
02LA011 - Rideau River Below Merrickville	Not Significant T = 1.708	Not Significant T = 2.485	0.392	Not Significant T = 2.052	Not Significant T = 2.771	1.044
02LA007 - Jock River at Richmond	Not Significant T =1.225	Not Significant T = 2.423	1.225	Significant T = 2.019	Significant T = 2.700	3.598
02LA006 - Kemptville Creek Near Kemptville	Not Significant T = 1.683	Not Significant T = 2.420	1.194	Significant T = 2.018	Significant T = 2.697	3.626

Table A2 Test Results for Randomness and Homogeneity for the Annual Maximum Instantaneous Flow Data Sets for Various Locations.

Location	Randomness			Homogeneity		
	5% Level	1% Level	Z	5% Level	1% Level	U or Z
02LA004 - Rideau River Near Ottawa	Significant Z = 1.960	Not Significant Z = 2.575	2.268	Significant Z = -1.645	Not Significant Z = -2.326	Z = -2.323
02LA012 - Rideau River Below Manotick	Not Significant			Significant U = 96.0	Not Significant U = 77.0	U = 86
02LA011 - Rideau River Below Merrickville	Not Significant			Not Significant U = 66	Not Significant U = 51	U = 87
02LA007 - Jock River at Richmond	Not Significant Z = 1.960		1.22	Significant Z = -1.645	Not Significant Z = -2.326	Z = -2.3
02LA006 - Kemptville Creek Near Kemptville	Not Significant Z = 1.960		1.22	Significant Z = -1.645	Significant Z = -2.326	Z = -2.327

Appendix B

CFA Input and Output Files

CFA Input File (Rideau River at Ottawa – 02LA004)

```
02LA004
Rideau River at Ottawa -Inst77-91 +11 (1947-2012)
65         3830
65      Number of Observations
3830    Area
02LA004     1947      4    560.3
02LA004     1949     03    392.8
02LA004     1950     04    462.8
02LA004     1951     04    433.7
02LA004     1952     04    392.8
02LA004     1953     03    344.7
02LA004     1954     04    419.3
02LA004     1955     04    511.5
02LA004     1956     04    364.6
02LA004     1957     03    159.2
02LA004     1958     03    320.2
02LA004     1959     04    427.5
02LA004     1960     04    553.7
02LA004     1961     03    213.3
02LA004     1962     04    336.8
02LA004     1963     03    457.6
02LA004     1964     04    138.0
02LA004     1965     12    170.7
02LA004     1966     03    233.6
02LA004     1967     04    325.1
02LA004     1968     03    390.7
02LA004     1969     04    341.8
02LA004     1970     04    457.6
02LA004     1971     04    513.0
02LA004     1972     04    578.0
02LA004     1973     03    464.0
02LA004     1974     04    410.0
02LA004     1975     04    413.0
02LA004     1976     03    597.0
02LA004     1977     03    525.0
02LA004     1978     04    585.0
02LA004     1979     03    469.5
02LA004     1980     03    467.3
02LA004     1981     02    495.1
02LA004     1982     04    482.9
02LA004     1983     03    273.1
02LA004     1984     04    441.8
02LA004     1985     03    306.4
02LA004     1986     05    284.2
02LA004     1987     03    391.8
02LA004     1988     03    303.0
02LA004     1989     03    306.4
02LA004     1990     03    293.0
02LA004     1991     04    326.0
02LA004     1992     04    282.0
02LA004     1993     04    514.0
02LA004     1994     04    338.0
02LA004     1995     01    269.0
02LA004     1996     01    243.0
02LA004     1997     04    448.0
02LA004     1998     03    458.0
02LA004     1999     04    448.0
02LA004     2000     04    245.0
02LA004     2001     04    366.0
02LA004     2002     04    222.0
02LA004     2003     03    249.0
02LA004     2004     03    199.0
02LA004     2005     04    437.0
02LA004     2006     12    218.0
02LA004     2007     04    262.0
02LA004     2008     04    493.0
02LA004     2009      5    254.0
02LA004     2010     03    237.0
02LA004     2011     03    364.4
02LA004     2012     03    232.7
```

CFA Output File (Rideau River at Ottawa – 02LA004)

```
          --- SPEARMAN TEST FOR INDEPENDENCE ---

02LA004          Rideau River at Ottawa -Inst77-91 +11 (1947-2012)
ANNUAL MAXIMUM DAILY FLOW SERIES  1947 TO 2012  DRAINAGE AREA =  3830.000

SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =  .341    D.F.= 61
                   CORRESPONDS TO STUDENTS T = 2.830
                CRITICAL T VALUE AT 5% LEVEL = 1.671        SIGNIFICANT
                    -    -    -    -  1%   -   = 2.389        SIGNIFICANT

Interpretation: The null hypothesis is that the correlation is zero.

At the 1% level of significance, the correlation is significantly
different from zero. That is, the data display highly significant
serial dependence.



       --- SPEARMAN TEST FOR TREND ---

02LA004          Rideau River at Ottawa -Inst77-91 +11 (1947-2012)
ANNUAL MAXIMUM DAILY FLOW SERIES  1947 TO 2012  DRAINAGE AREA =  3830.000

SPEARMAN RANK ORDER CORRELATION COEFF =  .283    D.F.= 63
            CORRESPONDS TO STUDENTS T = 2.341
         CRITICAL T VALUE AT 5% LEVEL = 1.999        SIGNIFICANT
             -    -    -    -  1%   -   = 2.658    NOT SIGNIFICANT

Interpretation: The null hypothesis is that the serial(lag-one) correlation
                is zero.

At the 5% level of significance, the correlation is significantly
different from zero, but is not so at the 1% level of significance.  That is,
the trend is significant but not highly so.



       --- RUN TEST FOR GENERAL RANDOMNESS ---

02LA004          Rideau River at Ottawa -Inst77-91 +11 (1947-2012)
ANNUAL MAXIMUM DAILY FLOW SERIES  1947 TO 2012  DRAINAGE AREA =  3830.000

THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN (RUNAB) = 24
      THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) = 32
      THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) = 32

(NOTE: Z IS THE STANDARD NORMAL VARIATE.)

For this test, Z =  2.268
Critical Z value at the 5% level = 1.960                SIGNIFICANT
Critical Z value at the 1% level = 2.575            NOT SIGNIFICANT

Interpretation: The null hypothesis is that the data are random.

At the 5% level of significance, the null hypothesis is rejected,
but not so at the 1% level of significance.  That is,
the data are significantly non-random, but not highly so.
```

--- MANN-WHITNEY SPLIT SAMPLE TEST FOR HOMOGENEITY ---

02LA004 Rideau River at Ottawa -Inst77-91 +11 (1947-2012)
ANNUAL MAXIMUM FLOW SERIES 1947 TO 2012 DRAINAGE AREA= 3830.000

SPLIT BY TIME SPAN, SUBSAMPLE 1 SAMPLE SIZE= 32
SUBSAMPLE 2 SAMPLE SIZE= 33

(NOTE: Z IS THE STANDARD NORMAL VARIATE.)
For this test, Z = -2.323
CRITICAL Z VALUE AT 5% SIGNIFICANT LEVEL = -1.645 SIGNIFICANT
- - - - 1% - - = -2.326 NOT SIGNIFICANT

Interpretation: The null hypothesis is that there is no
location difference between the two samples.

At the 5% level of significance, there is a significant difference
in location, but not so at the 1% level. That is, the
location difference is significant, but not highly so.

WSC STATION NO=02LA004
WSC STATION NAME=Rideau River at Ottawa -Inst77-91 +11 (1947-2012)

MONTH (1)	YEAR (2)	DATA (3)	ORDERED (4)	RANK (5)	PROB. (6) (%)	RET. PERIOD (7) (YEARS)
4	1947	560.300	597.000	1	.92	108.667
3	1949	392.800	585.000	2	2.45	40.750
4	1950	462.800	578.000	3	3.99	25.077
4	1951	433.700	560.300	4	5.52	18.111
4	1952	392.800	553.700	5	7.06	14.174
3	1953	344.700	525.000	6	8.59	11.643
4	1954	419.300	514.000	7	10.12	9.879
4	1955	511.500	513.000	8	11.66	8.579
4	1956	364.600	511.500	9	13.19	7.581
3	1957	159.200	495.100	10	14.72	6.792
3	1958	320.200	493.000	11	16.26	6.151
4	1959	427.500	482.900	12	17.79	5.621
4	1960	553.700	469.500	13	19.33	5.175
3	1961	213.300	467.300	14	20.86	4.794
4	1962	336.800	464.000	15	22.39	4.466
3	1963	457.600	462.800	16	23.93	4.179
4	1964	138.000	458.000	17	25.46	3.928
12	1965	170.700	457.600	18	26.99	3.705
3	1966	233.600	457.600	19	28.53	3.505
4	1967	325.100	448.000	20	30.06	3.327
3	1968	390.700	448.000	21	31.60	3.165
4	1969	341.800	441.800	22	33.13	3.019
4	1970	457.600	437.000	23	34.66	2.885
4	1971	513.000	433.700	24	36.20	2.763
4	1972	578.000	427.500	25	37.73	2.650
3	1973	464.000	419.300	26	39.26	2.547
4	1974	410.000	413.000	27	40.80	2.451
4	1975	413.000	410.000	28	42.33	2.362
3	1976	597.000	392.800	29	43.87	2.280
3	1977	525.000	392.800	30	45.40	2.203
4	1978	585.000	391.800	31	46.93	2.131
3	1979	469.500	390.700	32	48.47	2.063
3	1980	467.300	366.000	33	50.00	2.000
2	1981	495.100	364.600	34	51.53	1.940
4	1982	482.900	364.400	35	53.07	1.884
3	1983	273.100	344.700	36	54.60	1.831
4	1984	441.800	341.800	37	56.13	1.781
3	1985	306.400	338.000	38	57.67	1.734
5	1986	284.200	336.800	39	59.20	1.689
3	1987	391.800	326.000	40	60.74	1.646
3	1988	303.000	325.100	41	62.27	1.606

3	1989	306.400	320.200	42	63.80	1.567
3	1990	293.000	306.400	43	65.34	1.531
4	1991	326.000	306.400	44	66.87	1.495
4	1992	282.000	303.000	45	68.40	1.462
4	1993	514.000	293.000	46	69.94	1.430
4	1994	338.000	284.200	47	71.47	1.399
1	1995	269.000	282.000	48	73.01	1.370

WSC STATION NO=02LA004
WSC STATION NAME=Rideau River at Ottawa -Inst77-91 +11 (1947-2012)

MONTH	YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
(1)	(2)	(3)	(4)	(5)	(6) (%)	(7) (YEARS)
1	1996	243.000	273.100	49	74.54	1.342
4	1997	448.000	269.000	50	76.07	1.315
3	1998	458.000	262.000	51	77.61	1.289
4	1999	448.000	254.000	52	79.14	1.264
4	2000	245.000	249.000	53	80.67	1.240
4	2001	366.000	245.000	54	82.21	1.216
4	2002	222.000	243.000	55	83.74	1.194
3	2003	249.000	237.000	56	85.28	1.173
3	2004	199.000	233.600	57	86.81	1.152
4	2005	437.000	232.700	58	88.34	1.132
12	2006	218.000	222.000	59	89.88	1.113
4	2007	262.000	218.000	60	91.41	1.094
4	2008	493.000	213.300	61	92.94	1.076
5	2009	254.000	199.000	62	94.48	1.058
3	2010	237.000	170.700	63	96.01	1.042
3	2011	364.400	159.200	64	97.55	1.025
3	2012	232.700	138.000	65	99.08	1.009

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
02LA004 Rideau River at Ottawa -Inst77-91 +11 (1947-2012)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	370.968	116.142	.313	.005	2.229
LN X SERIES	5.862	.343	.059	-.599	2.886
L-MOM RATIO	370.968	67.216	.181	-.001	.039

X(MIN)= 138.000 TOTAL SAMPLE SIZE= 65
X(MAX)= 597.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 131.416 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA L - MOMENTS

DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)= .7803E+03
GEV PARAMETERS: U= 327.54 A= 118.463 K= .262

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	62.7
1.050	.952	174

1.250	.800	268
2.000	.500	369
5.000	.200	475
10.000	.100	529
20.000	.050	572
50.000	.020	617
100.000	.010	644
200.000	.005	667
500.000	.002	691

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
02LA004 Rideau River at Ottawa -Inst77-91 +11 (1947-2012)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	370.968	116.142	.313	.005	2.229
LN X SERIES	5.862	.343	.059	-.599	2.886
LN(X-A) SERIES	10.280	.004	.000	-.001	2.228

X(MIN)= 138.000 TOTAL SAMPLE SIZE= 65
X(MAX)= 597.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 131.416 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A=-28760.350 M=10.280 S= .004

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	53.2
1.050	.952	178
1.250	.800	273
2.000	.500	371
5.000	.200	469
10.000	.100	520
20.000	.050	562
50.000	.020	610
100.000	.010	642
200.000	.005	671
500.000	.002	707

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
02LA004 Rideau River at Ottawa -Inst77-91 +11 (1947-2012)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	370.968	116.142	.313	.005	2.229
LN X SERIES	5.862	.343	.059	-.599	2.886

X(MIN)= 138.000 TOTAL SAMPLE SIZE= 65
X(MAX)= 597.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 131.416 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT M= 646.3
LP3 PARAMETERS: A= -.2146 B= 2.840 LOG(M)= 6.471
M = 646.3

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	81.1
1.050	.952	174
1.250	.800	270
2.000	.500	376
5.000	.200	476
10.000	.100	521
20.000	.050	553
50.000	.020	583
100.000	.010	599
200.000	.005	611
500.000	.002	623

FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
02LA004 Rideau River at Ottawa -Inst77-91 +11 (1947-2012)

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	370.968	116.142	.313	.005	2.229
LN X SERIES	5.862	.343	.059	-.599	2.886
L-MOM RATIO	370.968	67.216	.181	-.001	.039

X(MIN)= 138.000   TOTAL SAMPLE SIZE= 65
X(MAX)= 597.000   NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 131.416   NO. OF ZERO FLOWS= 0

THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

M= 152.315 A= 170.173 B= 2.62 C= -399.217 D= -.314
DISTRIBUTION IS UPPER BOUNDED AT E= .7217E+03

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	154
1.050	.952	179
1.250	.800	255
2.000	.500	373
5.000	.200	478
10.000	.100	528
20.000	.050	566
50.000	.020	605
100.000	.010	628
200.000	.005	646
500.000	.002	665

CFA Input File (Rideau River Below Manotick – 02LA012)

```
02LA012
Rideau River Below Manotick
34   3120
34      Number of Observations
3120    Area
02LA012     1981       2    361.51
02LA012     1982       4    351.09
02LA012     1983       5    231.74
02LA012     1984       4     286.2
02LA012     1985       3    212.04
02LA012     1986       5    215.52
02LA012     1987       3    293.15
02LA012     1988       3    243.33
02LA012     1989       3    212.04
02LA012     1990       3    228.26
02LA012     1991       4       235
02LA012     1992       3       210
02LA012     1993       4       347
02LA012     1994       4       261
02LA012     1995       1       206
02LA012     1996       4       173
02LA012     1997       4    299.96
02LA012     1998       4    311.57
02LA012     1999       4    288.65
02LA012     2000       4       199
02LA012     2001       4    230.74
02LA012     2002       6    150.45
02LA012     2003       3    195.04
02LA012     2004       1       136
02LA012     2005       4       278
02LA012     2006      12    179.93
02LA012     2007       4    187.72
02LA012     2008       4       340
02LA012     2009       4       166
02LA012     2010       3    185.63
02LA012     2011       3    242.78
02LA012     2012       3       153
02LA012     2013       4       157
02LA012     2014       4     330.2
```

CFA Output File (Rideau River Below Manotick – 02LA012)

```
        --- SPEARMAN TEST FOR INDEPENDENCE ---

  02LA012          Rideau River Below Manotick
  ANNUAL MAXIMUM DAILY FLOW SERIES  1981 TO 2014  DRAINAGE AREA =  3120.000

  SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =  .090    D.F.= 31
                     CORRESPONDS TO STUDENTS T =  .503
                  CRITICAL T VALUE AT 5% LEVEL = 1.696    NOT SIGNIFICANT
                      -    -    -    -  1%   -   = 2.454    NOT SIGNIFICANT

  Interpretation: The null hypothesis is that the correlation is zero.

  At the 5% level of significance, the correlation is not significantly
  different from zero.  That is, the data do not display significant
  serial dependence.



        --- SPEARMAN TEST FOR TREND ---

  02LA012          Rideau River Below Manotick
  ANNUAL MAXIMUM DAILY FLOW SERIES  1981 TO 2014  DRAINAGE AREA =  3120.000

  SPEARMAN RANK ORDER CORRELATION COEFF =  .418    D.F.= 32
              CORRESPONDS TO STUDENTS T = 2.600
           CRITICAL T VALUE AT 5% LEVEL = 2.038        SIGNIFICANT
               -    -    -    -  1%   -   = 2.741    NOT SIGNIFICANT

  Interpretation: The null hypothesis is that the serial(lag-one) correlation
                  is zero.

  At the 5% level of significance, the correlation is significantly
  different from zero, but is not so at the 1% level of significance.  That is,
  the trend is significant but not highly so.



        --- RUN TEST FOR GENERAL RANDOMNESS ---

  02LA012          Rideau River Below Manotick
  ANNUAL MAXIMUM DAILY FLOW SERIES  1981 TO 2014  DRAINAGE AREA =  3120.000

  THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN (RUNAB) = 19
        THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) = 17
        THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) = 17
  Range at 5% level of significance: 12. to 24.    NOT SIGNIFICANT

  Interpretation: The null hypothesis is that the data are random.

  At the 5% level of significance, the null hypothesis cannot be
  rejected. That is, the sample is significantly random.
```

--- MANN-WHITNEY SPLIT SAMPLE TEST FOR HOMOGENEITY ---

02LA012 Rideau River Below Manotick
ANNUAL MAXIMUM FLOW SERIES 1981 TO 2014 DRAINAGE AREA= 3120.000

SPLIT BY TIME SPAN, SUBSAMPLE 1 SAMPLE SIZE= 17
SUBSAMPLE 2 SAMPLE SIZE= 17

MANN-WHITNEY U =	86.0	
CRITICAL U VALUE AT 5% SIGNIFICANT LEVEL =	96.0	SIGNIFICANT
- - - - - 1% - - =	77.0	NOT SIGNIFICANT

Interpretation: The null hypothesis is that there is no location difference between the two samples.

At the 5% level of significance, there is a significant difference in location, but not so at the 1% level. That is, the location difference is significant, but not highly so.

WSC STATION NO=02LA012
WSC STATION NAME=Rideau River Below Manotick

MONTH (1)	YEAR (2)	DATA (3)	ORDERED (4)	RANK (5)	PROB. (6) (%)	RET. PERIOD (7) (YEARS)
2	1981	361.510	361.510	1	1.75	57.000
4	1982	351.090	351.090	2	4.68	21.375
5	1983	231.740	347.000	3	7.60	13.154
4	1984	286.200	340.000	4	10.53	9.500
3	1985	212.040	330.200	5	13.45	7.435
5	1986	215.520	311.570	6	16.37	6.107
3	1987	293.150	299.960	7	19.30	5.182
3	1988	243.330	293.150	8	22.22	4.500
3	1989	212.040	288.650	9	25.15	3.977
3	1990	228.260	286.200	10	28.07	3.563
4	1991	235.000	278.000	11	30.99	3.226
3	1992	210.000	261.000	12	33.92	2.948
4	1993	347.000	243.330	13	36.84	2.714
4	1994	261.000	242.780	14	39.77	2.515
1	1995	206.000	235.000	15	42.69	2.342
4	1996	173.000	231.740	16	45.61	2.192
4	1997	299.960	230.740	17	48.54	2.060
4	1998	311.570	228.260	18	51.46	1.943
4	1999	288.650	215.520	19	54.39	1.839
4	2000	199.000	212.040	20	57.31	1.745
4	2001	230.740	212.040	21	60.23	1.660
6	2002	150.450	210.000	22	63.16	1.583
3	2003	195.040	206.000	23	66.08	1.513
1	2004	136.000	199.000	24	69.01	1.449
4	2005	278.000	195.040	25	71.93	1.390
12	2006	179.930	187.720	26	74.85	1.336
4	2007	187.720	185.630	27	77.78	1.286
4	2008	340.000	179.930	28	80.70	1.239
4	2009	166.000	173.000	29	83.63	1.196
3	2010	185.630	166.000	30	86.55	1.155
3	2011	242.780	157.000	31	89.47	1.118
3	2012	153.000	153.000	32	92.40	1.082
4	2013	157.000	150.450	33	95.32	1.049
4	2014	330.200	136.000	34	98.25	1.018

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
02LA012 Rideau River Below Manotick

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	238.193	64.036	.269	.402	2.431
LN X SERIES	5.438	.270	.050	-.014	2.401
L-MOM RATIO	238.193	36.970	.155	.110	.054

X(MIN)= 136.000 TOTAL SAMPLE SIZE= 34
X(MAX)= 361.510 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 113.498 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA L - MOMENTS

DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)= .9603E+03
GEV PARAMETERS: U= 208.59 A= 58.602 K= .078

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	98.0
1.050	.952	140
1.250	.800	180
2.000	.500	230
5.000	.200	292
10.000	.100	330
20.000	.050	364
50.000	.020	406
100.000	.010	435
200.000	.005	463
500.000	.002	497

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
02LA012 Rideau River Below Manotick

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	238.193	64.036	.269	.402	2.431
LN X SERIES	5.438	.270	.050	-.014	2.401
LN(X-A) SERIES	5.271	.319	.060	-.097	2.453

X(MIN)= 136.000 TOTAL SAMPLE SIZE= 34
X(MAX)= 361.510 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 113.498 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= 33.997 M= 5.271 S= .319

FLOOD FREQUENCY REGIME

RETURN	EXCEEDANCE	FLOOD

PERIOD	PROBABILITY	
1.003	.997	115
1.050	.952	148
1.250	.800	183
2.000	.500	229
5.000	.200	288
10.000	.100	327
20.000	.050	363
50.000	.020	408
100.000	.010	443
200.000	.005	476
500.000	.002	521

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
02LA012 Rideau River Below Manotick

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	238.193	64.036	.269	.402	2.431
LN X SERIES	5.438	.270	.050	-.014	2.401

X(MIN)= 136.000 TOTAL SAMPLE SIZE= 34
X(MAX)= 361.510 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 113.498 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT M= .1819E+08
LP3 PARAMETERS: A= -.6273E-02 B= 1798. LOG(M)= 16.72
M = .1819E+08

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	109
1.050	.952	147
1.250	.800	184
2.000	.500	230
5.000	.200	288
10.000	.100	323
20.000	.050	355
50.000	.020	394
100.000	.010	423
200.000	.005	451
500.000	.002	487

FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION

02LA012 Rideau River Below Manotick

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	238.193	64.036	.269	.402	2.431
LN X SERIES	5.438	.270	.050	-.014	2.401
L-MOM RATIO	238.193	36.970	.155	.110	.054

X(MIN)= 136.000 TOTAL SAMPLE SIZE= 34

X(MAX)= 361.510 NO. OF LOW OUTLIERS= 0

LOWER OUTLIER LIMIT OF X= 113.498 NO. OF ZERO FLOWS= 0

THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

M= 73.874 A= 80.020 B= 37.45 C= -302.950 D= -.399

DISTRIBUTION IS UPPER BOUNDED AT E= .4568E+03

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	82.7
1.050	.952	147
1.250	.800	180
2.000	.500	227
5.000	.200	297
10.000	.100	336
20.000	.050	365
50.000	.020	393
100.000	.010	409
200.000	.005	420
500.000	.002	431

CFA Input File (Rideau River Below Merrickville – 02LA011)

```
02LA011
Rideau River Below Merrickville
29     1920
29        Number of Observations
1920      Area
02LA011   1980     3              140.38
02LA011   1981     2              150.48
02LA011   1982     4              132.51
02LA011   1983     5              133.64
02LA011   1984     4              143.74
02LA011   1985     3              105.67
02LA011   1986     5              111.29
02LA011   1987     4              113.42
02LA011   1988     3              110.28
02LA011   1989     5              86.92
02LA011   1990     12             94.11
02LA011   1991     4              120.00
02LA011   1992     4              169.00
02LA011   1993     4              157.00
02LA011   1994     4              126.00
02LA011   1995     1              142.00
02LA011   1996     4              118.00
02LA011   2003     3              102.20
02LA011   2004     5              96.12
02LA011   2005     4              157.16
02LA011   2006     12             121.20
02LA011   2007     4              99.00
02LA011   2008     4              156.50
02LA011   2009     4              85.68
02LA011   2010     3              96.12
02LA011   2011     3              141.32
02LA011   2012     3              65.93
02LA011   2013     4              72.92
02LA011   2014     4              173.00
```

CFA Output File (Rideau River Below Merrickville – 02LA011)

```
       --- SPEARMAN TEST FOR INDEPENDENCE ---

 02LA011          Rideau River Below Merrickville
 ANNUAL MAXIMUM DAILY FLOW SERIES  1980 TO 2014  DRAINAGE AREA =  1920.000

 SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =  .078    D.F.= 25
                   CORRESPONDS TO STUDENTS T =  .392
                CRITICAL T VALUE AT 5% LEVEL = 1.708    NOT SIGNIFICANT
                    -    -   -   -  1%   -   = 2.485    NOT SIGNIFICANT

 Interpretation: The null hypothesis is that the correlation is zero.

 At the 5% level of significance, the correlation is not significantly
 different from zero.  That is, the data do not display significant
 serial dependence.



       --- SPEARMAN TEST FOR TREND ---

 02LA011          Rideau River Below Merrickville
 ANNUAL MAXIMUM DAILY FLOW SERIES  1980 TO 2014  DRAINAGE AREA =  1920.000

 SPEARMAN RANK ORDER CORRELATION COEFF =  .197    D.F.= 27
            CORRESPONDS TO STUDENTS T = 1.044
         CRITICAL T VALUE AT 5% LEVEL = 2.052    NOT SIGNIFICANT
             -    -   -   -  1%   -   = 2.771    NOT SIGNIFICANT

 Interpretation: The null hypothesis is that the serial(lag-one) correlation
                 is zero.

 At the 5% level of significance, the correlation is not significantly
 different from zero. That is, the data do not display significant
 trend.



       --- RUN TEST FOR GENERAL RANDOMNESS ---

 02LA011          Rideau River Below Merrickville
 ANNUAL MAXIMUM DAILY FLOW SERIES  1980 TO 2014  DRAINAGE AREA =  1920.000

 THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN (RUNAB) = 11
       THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) = 14
       THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) = 14
 Range at 5% level of significance: 10. to 20.    NOT SIGNIFICANT

 Interpretation: The null hypothesis is that the data are random.

 At the 5% level of significance, the null hypothesis cannot be
 rejected. That is, the sample is significantly random.
```

--- MANN-WHITNEY SPLIT SAMPLE TEST FOR HOMOGENEITY ---

02LA011 Rideau River Below Merrickville
ANNUAL MAXIMUM FLOW SERIES 1980 TO 2014 DRAINAGE AREA= 1920.000

SPLIT BY TIME SPAN, SUBSAMPLE 1 SAMPLE SIZE= 14
SUBSAMPLE 2 SAMPLE SIZE= 15

MANN-WHITNEY U =	87.0	
CRITICAL U VALUE AT 5% SIGNIFICANT LEVEL =	66.0	NOT SIGNIFICANT
- - - - - 1% - - =	51.0	NOT SIGNIFICANT

Interpretation: The null hypothesis is that there is no location difference between the two samples.

At the 5% level of significance, there is no significant location difference between the two samples. That is, they appear to be from the same population.

WSC STATION NO=02LA011
WSC STATION NAME=Rideau River Below Merrickville

MONTH (1)	YEAR (2)	DATA (3)	ORDERED (4)	RANK (5)	PROB. (6) (%)	RET. PERIOD (7) (YEARS)
3	1980	140.380	173.000	1	2.05	48.667
2	1981	150.480	169.000	2	5.48	18.250
4	1982	132.510	157.160	3	8.90	11.231
5	1983	133.640	157.000	4	12.33	8.111
4	1984	143.740	156.500	5	15.75	6.348
3	1985	105.670	150.480	6	19.18	5.214
5	1986	111.290	143.740	7	22.60	4.424
4	1987	113.420	142.000	8	26.03	3.842
3	1988	110.280	141.320	9	29.45	3.395
5	1989	86.920	140.380	10	32.88	3.042
12	1990	94.110	133.640	11	36.30	2.755
4	1991	120.000	132.510	12	39.73	2.517
4	1992	169.000	126.000	13	43.15	2.317
4	1993	157.000	121.200	14	46.58	2.147
4	1994	126.000	120.000	15	50.00	2.000
1	1995	142.000	118.000	16	53.42	1.872
4	1996	118.000	113.420	17	56.85	1.759
3	2003	102.200	111.290	18	60.27	1.659
5	2004	96.120	110.280	19	63.70	1.570
4	2005	157.160	105.670	20	67.12	1.490
12	2006	121.200	102.200	21	70.55	1.417
4	2007	99.000	99.000	22	73.97	1.352
4	2008	156.500	96.120	23	77.40	1.292
4	2009	85.680	96.120	24	80.82	1.237
3	2010	96.120	94.110	25	84.25	1.187
3	2011	141.320	86.920	26	87.67	1.141
3	2012	65.930	85.680	27	91.10	1.098
4	2013	72.920	72.920	28	94.52	1.058
4	2014	173.000	65.930	29	97.95	1.021

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
02LA011 Rideau River Below Merrickville

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	121.434	28.575	.235	-.016	2.545
LN X SERIES	4.771	.248	.052	-.490	3.062
L-MOM RATIO	121.434	16.664	.137	.002	.056

X(MIN)= 65.930 TOTAL SAMPLE SIZE= 29
X(MAX)= 173.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 62.710 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA L - MOMENTS

DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)= .2365E+03
GEV PARAMETERS: U= 109.98 A= 29.824 K= .236

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	44.9
1.050	.952	72.0
1.250	.800	95.0
2.000	.500	120
5.000	.200	148
10.000	.100	162
20.000	.050	174
50.000	.020	186
100.000	.010	194
200.000	.005	200
500.000	.002	207

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
02LA011 Rideau River Below Merrickville

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	121.434	28.575	.235	-.016	2.545
LN X SERIES	4.771	.248	.052	-.490	3.062
LN(A-X) SERIES	7.883	.011	.001	-.003	2.540

X(MIN)= 65.930 TOTAL SAMPLE SIZE= 29
X(MAX)= 173.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 62.710 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT A= .2772E+04
3LN PARAMETERS: A= 2772.283 M= 7.883 S= .011

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	41.9
1.050	.952	73.5
1.250	.800	97.4
2.000	.500	122
5.000	.200	146
10.000	.100	158
20.000	.050	168
50.000	.020	180
100.000	.010	187
200.000	.005	194
500.000	.002	203

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
02LA011 Rideau River Below Merrickville

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	121.434	28.575	.235	-.016	2.545
LN X SERIES	4.771	.248	.052	-.490	3.062

X(MIN)= 65.930 TOTAL SAMPLE SIZE= 29
X(MAX)= 173.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 62.710 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT M= 191.8
LP3 PARAMETERS: A= -.1372 B= 3.542 LOG(M)= 5.257
M = 191.8

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	42.9
1.050	.952	71.9
1.250	.800	97.4
2.000	.500	123
5.000	.200	147
10.000	.100	157
20.000	.050	165
50.000	.020	172
100.000	.010	176
200.000	.005	180
500.000	.002	183

FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
02LA011 Rideau River Below Merrickville

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	121.434	28.575	.235	-.016	2.545
LN X SERIES	4.771	.248	.052	-.490	3.062
L-MOM RATIO	121.434	16.664	.137	.002	.056

X(MIN)= 65.930 TOTAL SAMPLE SIZE= 29
X(MAX)= 173.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 62.710 NO. OF ZERO FLOWS= 0

THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

M= 55.436 A= 36.400 B= 7.93 C= -119.969 D= -.390
DISTRIBUTION IS UPPER BOUNDED AT E= .2118E+03

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	56.4
1.050	.952	69.4
1.250	.800	95.6
2.000	.500	120
5.000	.200	148
10.000	.100	163
20.000	.050	175
50.000	.020	186
100.000	.010	192
200.000	.005	197
500.000	.002	201

CFA Input File (Jock River Near Richmond – 02LA007)

```
02LA007
Jock River at Richmond
44      559
44      Number of Observations
559     Area
02LA007   1970     4     125.00
02LA007   1971     4     116.00
02LA007   1972     4     140.30
02LA007   1973     3     122.82
02LA007   1974     3     82.01
02LA007   1975     4     123.00
02LA007   1976     4     140.00
02LA007   1977     3     120.77
02LA007   1978     4     148.00
02LA007   1979     3     117.68
02LA007   1980     3     106.37
02LA007   1981     2     111.00
02LA007   1982     4     78.10
02LA007   1983     3     51.68
02LA007   1984     4     120.00
02LA007   1985     3     61.24
02LA007   1986     5     65.00
02LA007   1987     3     80.90
02LA007   1988     3     64.80
02LA007   1989     3     65.87
02LA007   1990     3     68.24
02LA007   1991     4     82.80
02LA007   1992     4     74.00
02LA007   1993     4     145.00
02LA007   1994     4     67.50
02LA007   1995     1     55.60
02LA007   1996     2     51.89
02LA007   1998     3     126.00
02LA007   1999     4     136.00
02LA007   2000     2     46.50
02LA007   2001     4     107.00
02LA007   2002     4     43.30
02LA007   2003     3     56.40
02LA007   2004     3     43.30
02LA007   2005     4     127.00
02LA007   2006     4     44.10
02LA007   2007     4     57.80
02LA007   2008     4     122.00
02LA007   2009     4     51.30
02LA007   2010     3     56.60
02LA007   2011     3     80.60
02LA007   2012     3     55.00
02LA007   2013     4     70.80
02LA007   2014     4     105.00
```

CFA Output File (Jock River Near Richmond – 02LA007)

```
          --- SPEARMAN TEST FOR INDEPENDENCE ---

 02LA007          Jock River at Richmond
 ANNUAL MAXIMUM DAILY FLOW SERIES  1970 TO 2014  DRAINAGE AREA =  559.0000

 SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =  .190    D.F.= 40
                   CORRESPONDS TO STUDENTS T = 1.225
                CRITICAL T VALUE AT 5% LEVEL = 1.684    NOT SIGNIFICANT
                    -    -    -    -  1%   -   = 2.423    NOT SIGNIFICANT

 Interpretation: The null hypothesis is that the correlation is zero.

 At the 5% level of significance, the correlation is not significantly
 different from zero.  That is, the data do not display significant
 serial dependence.



       --- SPEARMAN TEST FOR TREND ---

 02LA007          Jock River at Richmond
 ANNUAL MAXIMUM DAILY FLOW SERIES  1970 TO 2014  DRAINAGE AREA =  559.0000

 SPEARMAN RANK ORDER CORRELATION COEFF =  .485    D.F.= 42
            CORRESPONDS TO STUDENTS T = 3.598
         CRITICAL T VALUE AT 5% LEVEL = 2.019        SIGNIFICANT
             -    -    -    -  1%   -   = 2.700        SIGNIFICANT

 Interpretation: The null hypothesis is that the serial(lag-one) correlation
                 is zero.

 At the 1% level of significance, the correlation is significantly
 different from zero. That is, the data display highly
 significant trend.



       --- RUN TEST FOR GENERAL RANDOMNESS ---

 02LA007          Jock River at Richmond
 ANNUAL MAXIMUM DAILY FLOW SERIES  1970 TO 2014  DRAINAGE AREA =  559.0000

 THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN (RUNAB) = 19
       THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) = 22
       THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) = 22

 (NOTE: Z IS THE STANDARD NORMAL VARIATE.)

 For this test, Z =  1.220
 Critical Z value at the 5% level = 1.960           NOT SIGNIFICANT

 Interpretation: The null hypothesis is that the data are random.

 At the 5% level of significance, the null hypothesis cannot be
 rejected. That is, the sample is significantly random.
```

--- MANN-WHITNEY SPLIT SAMPLE TEST FOR HOMOGENEITY ---

02LA007 Jock River at Richmond
ANNUAL MAXIMUM FLOW SERIES 1970 TO 2014 DRAINAGE AREA= 559.0000

SPLIT BY TIME SPAN, SUBSAMPLE 1 SAMPLE SIZE= 22
SUBSAMPLE 2 SAMPLE SIZE= 22

(NOTE: Z IS THE STANDARD NORMAL VARIATE.)
For this test, Z = -2.300
CRITICAL Z VALUE AT 5% SIGNIFICANT LEVEL = -1.645 SIGNIFICANT
- - - - 1% - - = -2.326 NOT SIGNIFICANT

Interpretation: The null hypothesis is that there is no location difference between the two samples.

At the 5% level of significance, there is a significant difference in location, but not so at the 1% level. That is, the location difference is significant, but not highly so.

WSC STATION NO=02LA007
WSC STATION NAME=Jock River at Richmond

MONTH (1)	YEAR (2)	DATA (3)	ORDERED (4)	RANK (5)	PROB. (6) (%)	RET. PERIOD (7) (YEARS)
4	1970	125.000	148.000	1	1.36	73.667
4	1971	116.000	145.000	2	3.62	27.625
4	1972	141.440	141.440	3	5.88	17.000
3	1973	123.760	140.000	4	8.14	12.278
3	1974	82.470	136.000	5	10.41	9.609
4	1975	123.000	127.000	6	12.67	7.893
4	1976	140.000	126.000	7	14.93	6.697
3	1977	121.680	125.000	8	17.19	5.816
4	1978	148.000	123.760	9	19.46	5.140
3	1979	118.560	123.000	10	21.72	4.604
3	1980	107.120	122.000	11	23.98	4.170
2	1981	111.000	121.680	12	26.24	3.810
4	1982	78.520	120.000	13	28.51	3.508
3	1983	51.790	118.560	14	30.77	3.250
4	1984	120.000	116.000	15	33.03	3.027
3	1985	61.460	111.000	16	35.29	2.833
5	1986	65.000	107.120	17	37.56	2.663
3	1987	80.900	107.000	18	39.82	2.511
3	1988	64.800	105.000	19	42.08	2.376
3	1989	66.140	82.800	20	44.34	2.255
3	1990	68.540	82.470	21	46.61	2.146
4	1991	82.800	80.900	22	48.87	2.046
4	1992	74.000	80.600	23	51.13	1.956
4	1993	145.000	78.520	24	53.39	1.873
4	1994	67.500	74.000	25	55.66	1.797
1	1995	55.600	70.800	26	57.92	1.727
2	1996	52.000	68.540	27	60.18	1.662
3	1998	126.000	67.500	28	62.44	1.601
4	1999	136.000	66.140	29	64.71	1.545
2	2000	46.500	65.000	30	66.97	1.493
4	2001	107.000	64.800	31	69.23	1.444
4	2002	43.300	61.460	32	71.49	1.399
3	2003	56.400	57.800	33	73.76	1.356
3	2004	43.300	56.600	34	76.02	1.315
4	2005	127.000	56.400	35	78.28	1.277
4	2006	44.100	55.600	36	80.54	1.242
4	2007	57.800	55.000	37	82.81	1.208
4	2008	122.000	52.000	38	85.07	1.176
4	2009	51.300	51.790	39	87.33	1.145
3	2010	56.600	51.300	40	89.59	1.116

3	2011	80.600	46.500	41	91.86	1.089
3	2012	55.000	44.100	42	94.12	1.063
4	2013	70.800	43.300	43	96.38	1.038
4	2014	105.000	43.300	44	98.64	1.014

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
02LA007 Jock River at Richmond

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	89.109	33.585	.377	.239	1.770
LN X SERIES	4.417	.392	.089	-.088	1.795
L-MOM RATIO	89.109	19.292	.217	.079	-.058

X(MIN)= 43.300 TOTAL SAMPLE SIZE= 44
X(MAX)= 148.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 28.498 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA L - MOMENTS

DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)= .3231E+03
GEV PARAMETERS: U= 74.61 A= 31.130 K= .125

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	13.3
1.050	.952	37.4
1.250	.800	59.3
2.000	.500	85.8
5.000	.200	117
10.000	.100	136
20.000	.050	152
50.000	.020	171
100.000	.010	183
200.000	.005	195
500.000	.002	209

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
02LA007 Jock River at Richmond

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	89.109	33.585	.377	.239	1.770
LN X SERIES	4.417	.392	.089	-.088	1.795
LN(X-A) SERIES	4.078	.548	.134	-.245	1.952

X(MIN)= 43.300 TOTAL SAMPLE SIZE= 44
X(MAX)= 148.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 28.498 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= 21.427 M= 4.078 S= .548

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	34.5
1.050	.952	45.1
1.250	.800	58.6
2.000	.500	80.5
5.000	.200	115
10.000	.100	141
20.000	.050	167
50.000	.020	204
100.000	.010	233
200.000	.005	264
500.000	.002	308

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
02LA007 Jock River at Richmond

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	89.109	33.585	.377	.239	1.770
LN X SERIES	4.417	.392	.089	-.088	1.795

X(MIN)= 43.300 TOTAL SAMPLE SIZE= 44
X(MAX)= 148.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 28.498 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT M= 151.5
LP3 PARAMETERS: A= -.3725 B= 1.621 LOG(M)= 5.021
M = 151.5

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	10.0
1.050	.952	32.2
1.250	.800	60.2
2.000	.500	93.0
5.000	.200	122
10.000	.100	133
20.000	.050	140
50.000	.020	146
100.000	.010	148
200.000	.005	150
500.000	.002	151

FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
02LA007 Jock River at Richmond

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	89.109	33.585	.377	.239	1.770
LN X SERIES	4.417	.392	.089	-.088	1.795
L-MOM RATIO	89.109	19.292	.217	.079	-.058

X(MIN)= 43.300 TOTAL SAMPLE SIZE= 44
X(MAX)= 148.000 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 28.498 NO. OF ZERO FLOWS= 0

THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

M= 42.148 A= -35.382 B= 3.29 C= -147.245 D=-1.013
DISTRIBUTION IS UPPER BOUNDED AT E= .1540E+03

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	42.2
1.050	.952	44.0
1.250	.800	53.5
2.000	.500	84.7
5.000	.200	125
10.000	.100	140
20.000	.050	147
50.000	.020	151
100.000	.010	153
200.000	.005	153
500.000	.002	154

CFA Input File (Kemptville Creek Near Kemptville - 02LA006)

```
02LA006
Kemptville Creek Near Kemptville
45      411
45     Number of Observations
411     Area
02LA006     1970       4 72.20
02LA006     1971       4 78.20
02LA006     1972       4 81.60
02LA006     1973       3 54.54
02LA006     1974       4 59.20
02LA006     1975       4 47.60
02LA006     1976       3 74.20
02LA006     1977       3 80.10
02LA006     1978       4 66.50
02LA006     1979       3 50.30
02LA006     1980       3 56.66
02LA006     1981       2 58.58
02LA006     1982       4 73.70
02LA006     1983       3 32.40
02LA006     1984       4 55.80
02LA006     1985       3 33.20
02LA006     1986       3 43.20
02LA006     1987       3 49.60
02LA006     1988       3 40.50
02LA006     1989       3 35.83
02LA006     1990       3 43.00
02LA006     1991       4 42.20
02LA006     1992       4 34.21
02LA006     1993       4 68.70
02LA006     1994       4 55.90
02LA006     1995       3 24.70
02LA006     1996       2 34.82
02LA006     1997       4 59.20
02LA006     1998       3 59.70
02LA006     1999       4 58.00
02LA006     2000       4 39.90
02LA006     2001       4 52.40
02LA006     2002       4 26.40
02LA006     2003       3 39.80
02LA006     2004       3 30.10
02LA006     2005       4 65.30
02LA006     2006      12 28.50
02LA006     2007       4 30.20
02LA006     2008       4 67.40
02LA006     2009       4 28.00
02LA006     2010       3 31.80
02LA006     2011       3 54.03
02LA006     2012       3 31.00
02LA006     2013       4 29.40
02LA006     2014       4 78.00
```

CFA Output File (Kemptville Creek Near Kemptville – 02LA006)

```
          --- SPEARMAN TEST FOR INDEPENDENCE ---

02LA006          Kemptville Creek Near Kemptville
ANNUAL MAXIMUM DAILY FLOW SERIES  1970 TO 2014  DRAINAGE AREA =  411.0000

SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =  .181    D.F.= 42
                   CORRESPONDS TO STUDENTS T = 1.194
                CRITICAL T VALUE AT 5% LEVEL = 1.683    NOT SIGNIFICANT
                    -    -    -    -  1%   -   = 2.420    NOT SIGNIFICANT

Interpretation: The null hypothesis is that the correlation is zero.

At the 5% level of significance, the correlation is not significantly
different from zero.  That is, the data do not display significant
serial dependence.



          --- SPEARMAN TEST FOR TREND ---

02LA006          Kemptville Creek Near Kemptville
ANNUAL MAXIMUM DAILY FLOW SERIES  1970 TO 2014  DRAINAGE AREA =  411.0000

SPEARMAN RANK ORDER CORRELATION COEFF =  .484    D.F.= 43
            CORRESPONDS TO STUDENTS T = 3.626
         CRITICAL T VALUE AT 5% LEVEL = 2.018        SIGNIFICANT
             -    -    -    -  1%   -   = 2.697        SIGNIFICANT

Interpretation: The null hypothesis is that the serial(lag-one) correlation
                is zero.

At the 1% level of significance, the correlation is significantly
different from zero. That is, the data display highly
significant trend.



          --- RUN TEST FOR GENERAL RANDOMNESS ---

02LA006          Kemptville Creek Near Kemptville
ANNUAL MAXIMUM DAILY FLOW SERIES  1970 TO 2014  DRAINAGE AREA =  411.0000

THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN (RUNAB) = 19
      THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) = 22
      THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) = 22

(NOTE: Z IS THE STANDARD NORMAL VARIATE.)

For this test, Z =  1.220
Critical Z value at the 5% level = 1.960           NOT SIGNIFICANT

Interpretation: The null hypothesis is that the data are random.

At the 5% level of significance, the null hypothesis cannot be
rejected. That is, the sample is significantly random.
```

--- MANN-WHITNEY SPLIT SAMPLE TEST FOR HOMOGENEITY ---

02LA006 Kemptville Creek Near Kemptville
ANNUAL MAXIMUM FLOW SERIES 1970 TO 2014 DRAINAGE AREA= 411.0000

SPLIT BY TIME SPAN, SUBSAMPLE 1 SAMPLE SIZE= 22
SUBSAMPLE 2 SAMPLE SIZE= 23

(NOTE: Z IS THE STANDARD NORMAL VARIATE.)
For this test, Z = -2.327
CRITICAL Z VALUE AT 5% SIGNIFICANT LEVEL = -1.645 SIGNIFICANT
- - - - 1% - - = -2.326 SIGNIFICANT

Interpretation: The null hypothesis is that there is no
location difference between the two samples.

At the 1% level of significance, the hypothesis of no location
difference between the samples is rejected.

WSC STATION NO=02LA006
WSC STATION NAME=Kemptville Creek Near Kemptville

MONTH (1)	YEAR (2)	DATA (3)	ORDERED (4)	RANK (5)	PROB. (6) (%)	RET. PERIOD (7) (YEARS)
4	1970	72.200	81.600	1	1.33	75.333
4	1971	78.200	80.100	2	3.54	28.250
4	1972	81.600	78.200	3	5.75	17.385
3	1973	54.540	78.000	4	7.96	12.556
4	1974	59.200	74.200	5	10.18	9.826
4	1975	47.600	73.700	6	12.39	8.071
3	1976	74.200	72.200	7	14.60	6.848
3	1977	80.100	68.700	8	16.81	5.947
4	1978	66.500	67.400	9	19.03	5.256
3	1979	50.300	66.500	10	21.24	4.708
3	1980	56.660	65.300	11	23.45	4.264
2	1981	58.580	59.700	12	25.66	3.897
4	1982	73.700	59.200	13	27.88	3.587
3	1983	32.400	59.200	14	30.09	3.324
4	1984	55.800	58.580	15	32.30	3.096
3	1985	33.200	58.000	16	34.51	2.897
3	1986	43.200	56.660	17	36.73	2.723
3	1987	49.600	55.900	18	38.94	2.568
3	1988	40.500	55.800	19	41.15	2.430
3	1989	35.830	54.540	20	43.36	2.306
3	1990	43.000	54.030	21	45.58	2.194
4	1991	42.200	52.400	22	47.79	2.093
4	1992	34.210	50.300	23	50.00	2.000
4	1993	68.700	49.600	24	52.21	1.915
4	1994	55.900	47.600	25	54.42	1.837
3	1995	24.700	43.200	26	56.64	1.766
2	1996	34.820	43.000	27	58.85	1.699
4	1997	59.200	42.200	28	61.06	1.638
3	1998	59.700	40.500	29	63.27	1.580
4	1999	58.000	39.900	30	65.49	1.527
4	2000	39.900	39.800	31	67.70	1.477
4	2001	52.400	35.830	32	69.91	1.430
4	2002	26.400	34.820	33	72.12	1.387
3	2003	39.800	34.210	34	74.34	1.345
3	2004	30.100	33.200	35	76.55	1.306
4	2005	65.300	32.400	36	78.76	1.270
12	2006	28.500	31.800	37	80.97	1.235
4	2007	30.200	31.000	38	83.19	1.202
4	2008	67.400	30.200	39	85.40	1.171
4	2009	28.000	30.100	40	87.61	1.141
3	2010	31.800	29.400	41	89.82	1.113
3	2011	54.030	28.500	42	92.04	1.087

3	2012	31.000	28.000	43	94.25	1.061
4	2013	29.400	26.400	44	96.46	1.037
4	2014	78.000	24.700	45	98.67	1.013

FREQUENCY ANALYSIS - GENERALIZED EXTREME VALUE DISTRIBUTION
02LA006 Kemptville Creek Near Kemptville

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	50.146	16.934	.338	.239	2.086
LN X SERIES	3.856	.352	.091	-.170	1.987
L-MOM RATIO	50.146	9.812	.196	.070	-.001

X(MIN)= 24.700 TOTAL SAMPLE SIZE= 45
X(MAX)= 81.600 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 18.120 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA L - MOMENTS

DISTRIBUTION IS UPPER BOUNDED AT (U+A/K)= .1576E+03
GEV PARAMETERS: U= 42.86 A= 16.048 K= .140

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	10.8
1.050	.952	23.5
1.250	.800	35.0
2.000	.500	48.6
5.000	.200	64.6
10.000	.100	73.8
20.000	.050	81.9
50.000	.020	91.1
100.000	.010	97.3
200.000	.005	103
500.000	.002	109

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
02LA006 Kemptville Creek Near Kemptville

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	50.146	16.934	.338	.239	2.086
LN X SERIES	3.856	.352	.091	-.170	1.987
LN(X-A) SERIES	3.932	.326	.083	-.141	1.977

X(MIN)= 24.700 TOTAL SAMPLE SIZE= 45
X(MAX)= 81.600 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 18.120 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= -3.527 M= 3.932 S= .326

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	17.3
1.050	.952	26.1
1.250	.800	35.3
2.000	.500	47.5
5.000	.200	63.6
10.000	.100	74.0
20.000	.050	83.7
50.000	.020	96.1
100.000	.010	105
200.000	.005	115
500.000	.002	127

FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
02LA006 Kemptville Creek Near Kemptville

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	50.146	16.934	.338	.239	2.086
LN X SERIES	3.856	.352	.091	-.170	1.987

X(MIN)= 24.700 TOTAL SAMPLE SIZE= 45
X(MAX)= 81.600 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 18.120 NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

DISTRIBUTION IS UPPER BOUNDED AT M= 93.69
LP3 PARAMETERS: A= -.2125 B= 3.217 LOG(M)= 4.540
M = 93.69

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	10.4
1.050	.952	22.7
1.250	.800	35.7
2.000	.500	50.6
5.000	.200	65.2
10.000	.100	72.0
20.000	.050	77.0
50.000	.020	81.8
100.000	.010	84.5
200.000	.005	86.6
500.000	.002	88.7

FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
02LA006 Kemptville Creek Near Kemptville

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	50.146	16.934	.338	.239	2.086
LN X SERIES	3.856	.352	.091	-.170	1.987
L-MOM RATIO	50.146	9.812	.196	.070	-.001

X(MIN)= 24.700 TOTAL SAMPLE SIZE= 45
X(MAX)= 81.600 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 18.120 NO. OF ZERO FLOWS= 0

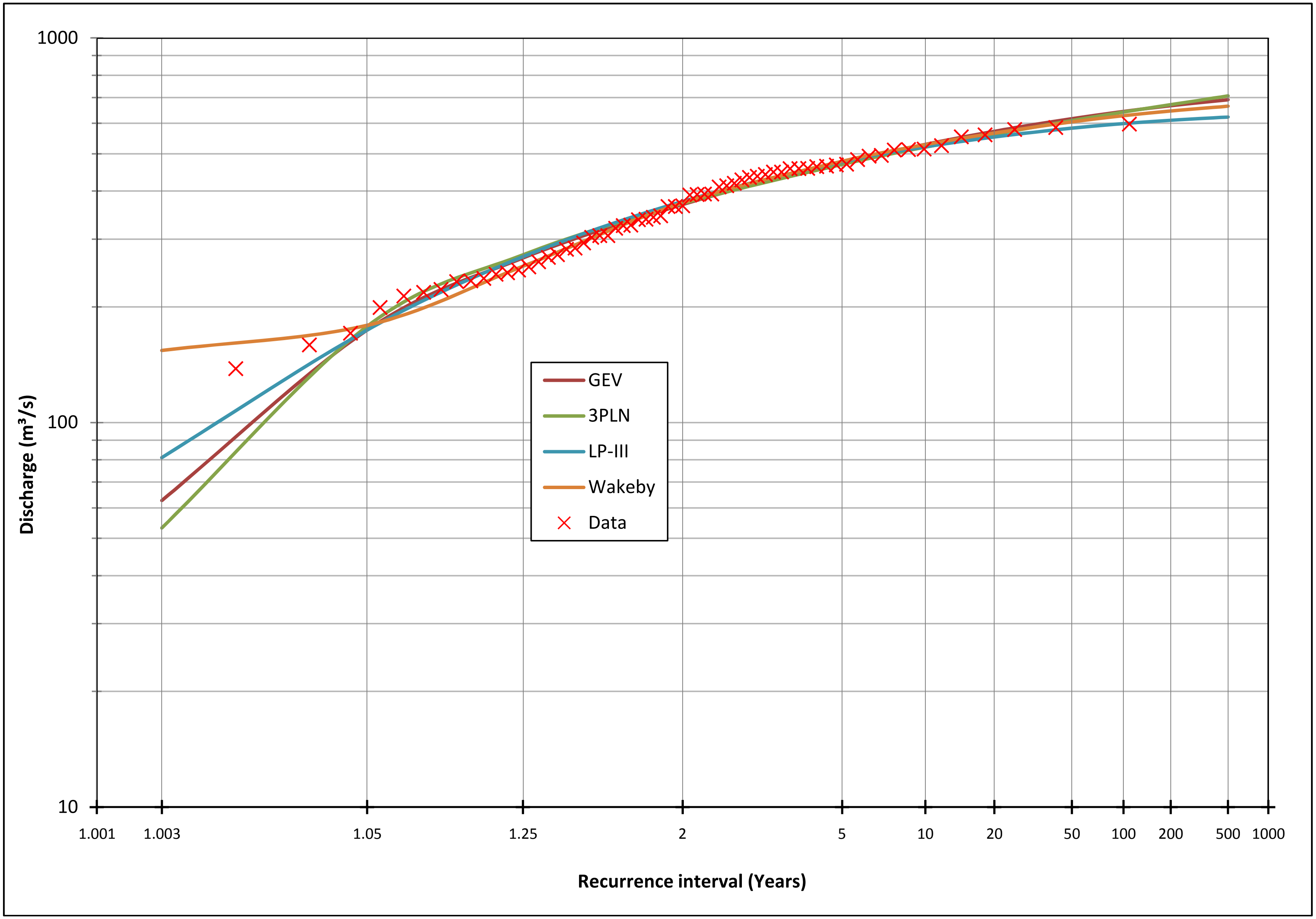
THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA L-MOMENTS

M= .000 A= 23.958 B=317.12 C= -65.733 D= -.665
DISTRIBUTION IS UPPER BOUNDED AT E= .8969E+02

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	.997	14.8
1.050	.952	26.1
1.250	.800	33.0
2.000	.500	48.2
5.000	.200	67.2
10.000	.100	75.5
20.000	.050	80.7
50.000	.020	84.8
100.000	.010	86.6
200.000	.005	87.8
500.000	.002	88.6

Figure B1 Frequency Analysis Distributions from CFA_3.1 for the Rideau River at Ottawa Stream Gauge.



Source: RVCA (2015) Rideau River Flood Risk Mapping from Hog's Back to Rideau Falls

Figure B2 Frequency Analysis Distributions from CFA_3.1 for the Rideau River Below Manotick Stream Gauge.

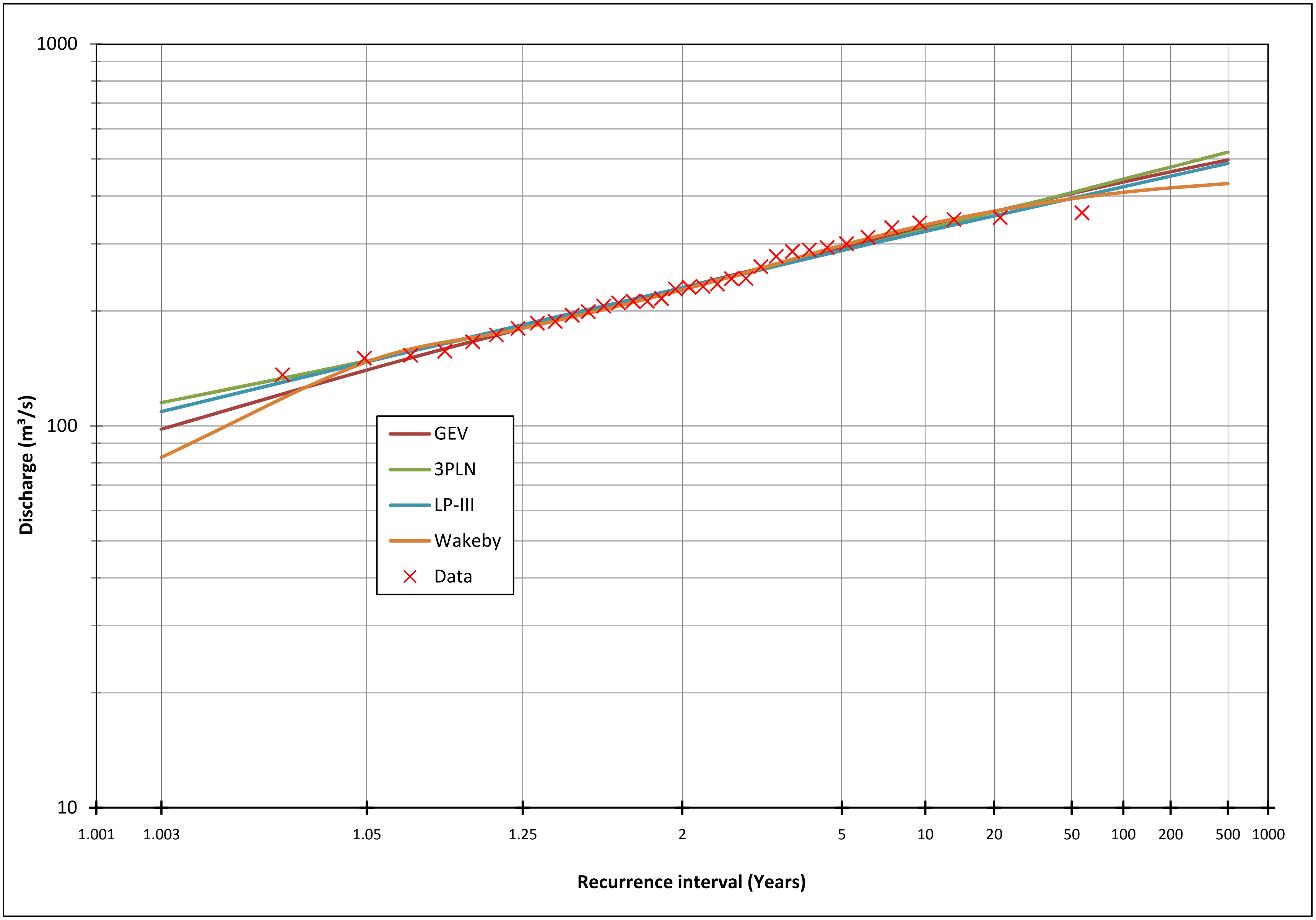


Figure B3 Frequency Analysis Distributions from CFA_3.1 for the Rideau River Below Merrickville Stream Gauge.

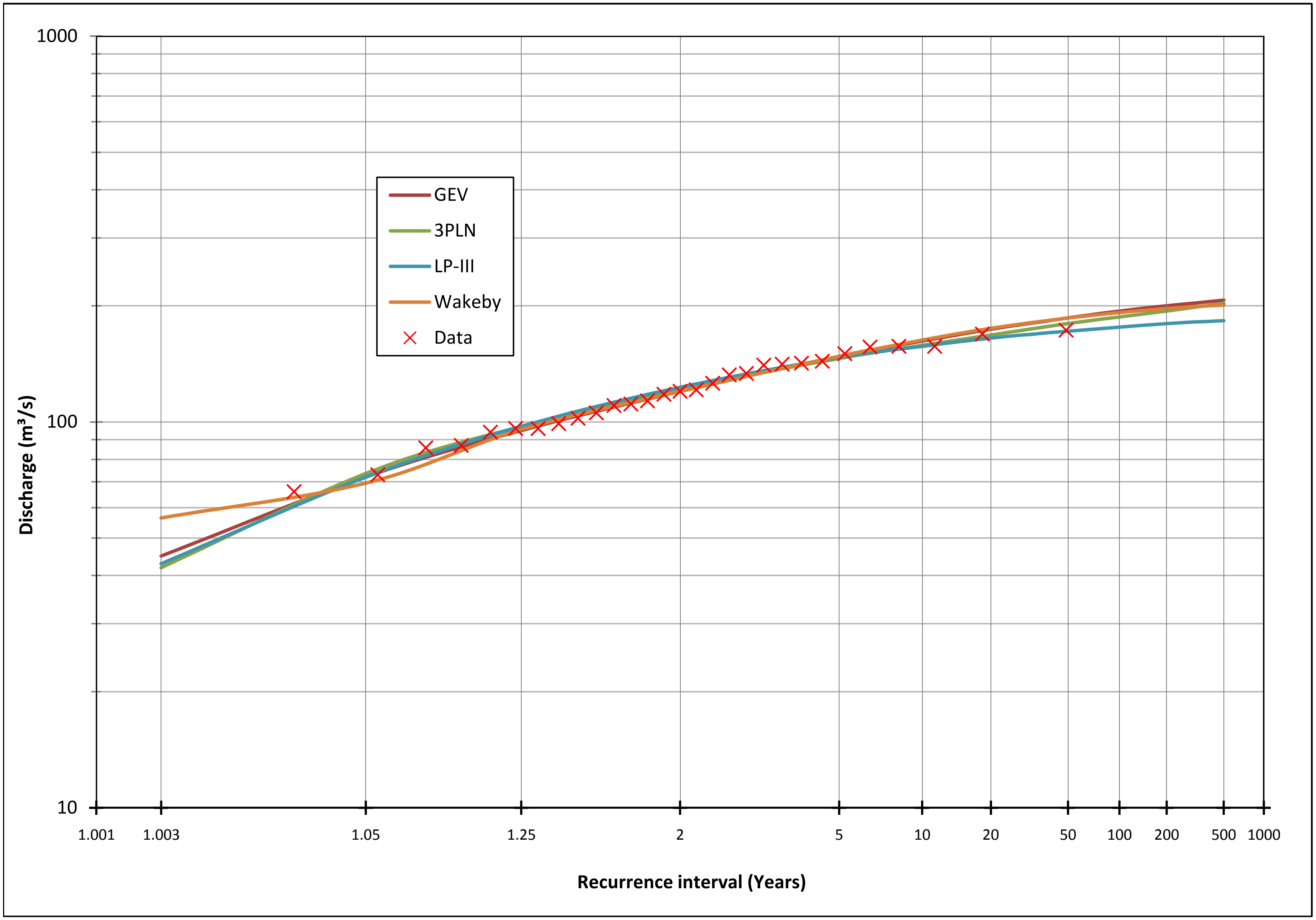


Figure B4 Frequency Analysis Distributions from CFA_3.1 for the Jock River Near Richmond Stream Gauge.

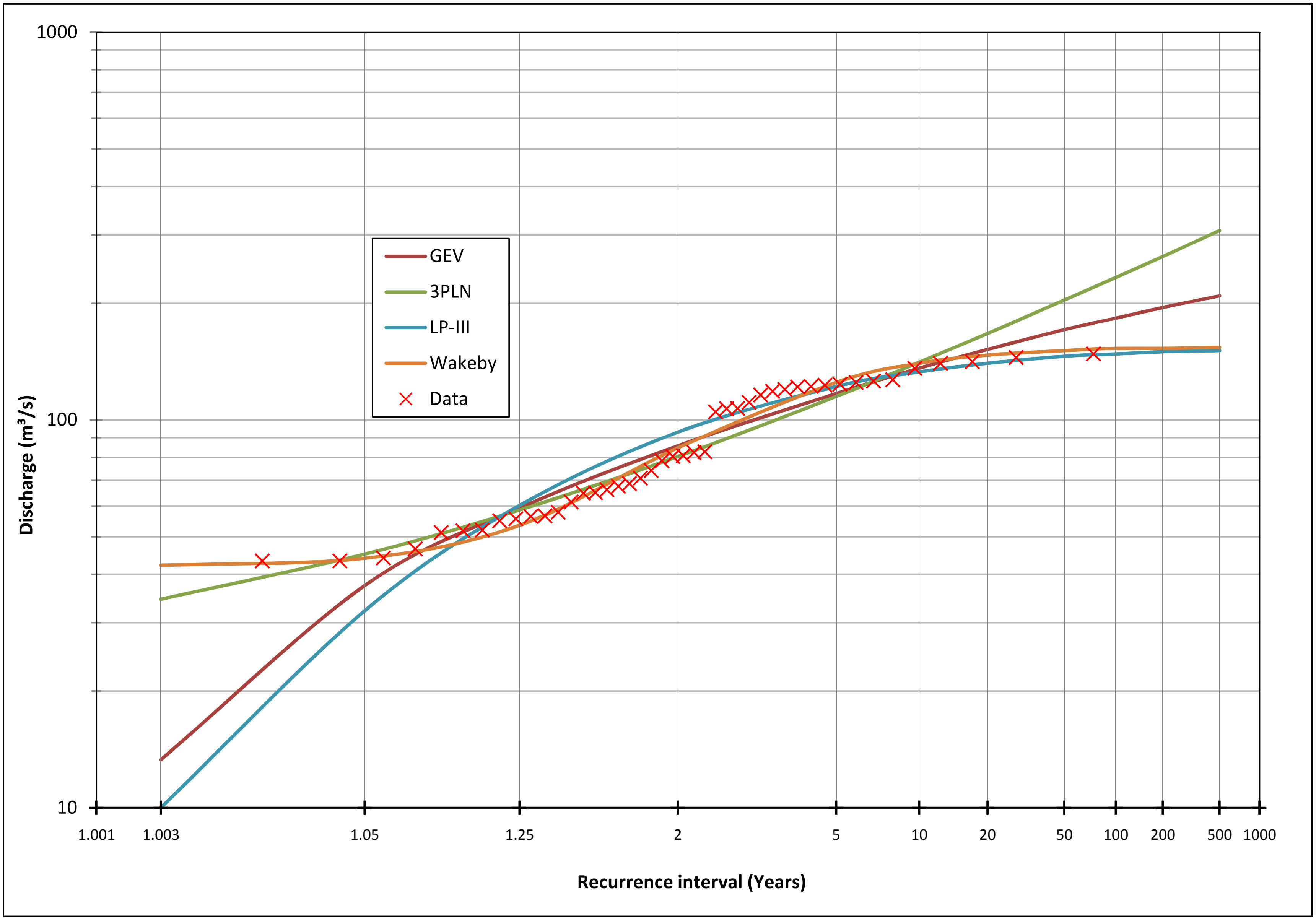


Figure B5 Frequency Analysis Distributions from CFA_3.1 for the Kemptville Creek Near Kemptville Stream Gauge.