



CHARACTERISATION OF NATURAL FLOW REGIMES AND ENVIRONMENTAL FLOWS EVALUATION IN NEW BRUNSWICK



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LIST OF ACRONYMS AND SYMBOLS

A2	Climate scenario
ABF	Aquatic base flow
CRCM	Canadian regional climate model
CGCM	Coupled global climate model
GEV	Generalized extreme value distribution
IPCC	Intergovernmental panel on climate change
MAF	Mean annual flow
MLE	Maximum likelihood estimates
MMF	Mean monthly flow
Q_{50}	Median flow
Q_{90}	90% flow
SRES	Special report on emission scenarios
WAL	Water availability lower target
WAU	Water availability upper target

a, b	Regression constants
DA	Drainage area
F(x)	Cumulative function
k, σ , μ	GEV distribution parameters
QF	High flow
QL	Low flow
Q_T	Discharge at return period T
R ²	Coefficient of determination
RMSE	Root mean squared error
T	Return period
α, β, γ	Weibull distribution parameters

ABSTRACT

River hydrology is a key component in river engineering, river restoration, river resources planning as well as in the functioning of river ecosystems. As such, hydrological analyses play an important role not only in water resources projects but also in fish habitat and instream flow studies. The present study focused on flow metrics that best describe the natural flow regime and the hydrological characteristics of rivers within New Brunswick. In total, 54 hydrometrics stations were selected for the analysis and parameters describing flow availability included, among others, the mean annual flow, median flow as well as mean monthly flows. A flow duration analysis was also conducted for each station to estimate the probability of exceedance of different flows throughout the year. Extreme events are also important in hydrology and these were studied by conducting a high and low flow frequency analyses. Following the frequency analysis, regional regression equations were calculated between many flow metrics and drainage basin area. Following the characterization of the flow regime, environmental flows were calculated and assessed for the studied rivers. The concept of environmental flow relates to the quantity of water required in rivers to sustain an acceptable level of living conditions for aquatic biota at various phases of their development. For many agencies, environmental flow methods are essential in environmental impact assessments and in the protection of important fisheries resources. This part of this study deals with the evaluation of hydrologically based environmental flow methods within the New Brunswick. In total, four hydrologically based environmental flow methods were compared using data from the selected stations across the region: the 25% mean annual flow, the Q_{50} method, the 70% Q_{50} method and the Q_{90} flow duration method. The study provided a range of potential environmental flows on a monthly basis as well as potential water availability.

RÉSUMÉ

L'hydrologie des cours d'eau joue un rôle important dans l'aménagement et la restauration des rivières, dans l'utilisation des ressources hydriques ainsi que dans le fonctionnement des écosystèmes aquatiques. Alors, les analyses hydrologiques jouent un rôle important non seulement dans les projets de ressources hydriques, mais aussi pour l'habitat du poisson et l'évaluation du débit réservé. Première partie de cette étude se concentrera sur les paramètres hydrologiques qui décrivent le mieux le débit et le régime naturel hydrologique des cours d'eau du Nouveau-Brunswick. Au total, 54 stations hydrométriques ont été choisies pour l'analyse des caractéristiques hydrologiques décrivant la disponibilité en eau, entre autres, le débit moyen annuel, le débit médian ainsi que les débits mensuels moyens. Une analyse de débit classé a également été réalisée pour chaque station afin d'estimer la probabilité de dépassement des différents débits tout au long de l'année. Les évènements extrêmes sont également importants en hydrologie et ils ont été étudiés par une analyse de fréquence des débits de crues et des débits faibles. Suite à l'analyse de fréquence, des équations de régression régionales ont été calculées entre de nombreux paramètres de débits vs superficie des bassins versant. La protection des rivières contre l'impact du retrait d'eau est un problème récurrent de gestion des ressources hydriques. La seconde partie de cette étude porte sur les différentes méthodes de calcul pour évaluer le débit réservé. Au total, trois méthodes de calcul ont été comparées en utilisant les stations sélectionnées à travers le Nouveau-Brunswick. Elles sont : la méthode du 25% du débit moyen annuel qui génère un haut niveau de protection, la méthode 70%Q₅₀ qui fournit des niveaux adéquats de protection et la méthode Q₉₀ qui génère une faible protection du débit réservé. La présente étude montre l'importance du régime d'écoulement hydrologique, en particulier en ce qui a trait à la composante du débit de base, comme un facteur déterminant dans le niveau de protection de débit réservé.

1. INTRODUCTION

River hydrology and environmental flows are key components in water resources management in New Brunswick for a variety of activities, e.g., river engineering, river restoration, water resources planning, the functioning of river ecosystems, etc. As such, many facets of our daily lives depend on water. Water security is becoming increasing important not only for fish habitat and fisheries management but also for the protection of water quality, quantity and the sustainability of water supplies in the province of NB.

The present study will focuses on describing the natural flow regime of rivers for the province of New Brunswick as well as calculating environmental flows or instream flows. Environmental flows are the amount of water which is required in rivers, and which is not available for withdrawal, to sustain aquatic life or any other important river processes, e.g., maintaining river morphology, dilution of effluents, etc. The understanding of the natural flow regimes, water availabilities and environmental flows are key components in the overall water management within a specific region. A study of the natural flow regime provides essential information pertaining to water availability on both time and space whereas environmental flows provides information of water which could potentially be available for withdrawal. The analysis was conducted using specific flow metrics and with as much hydrometric data as possible (54 hydrometric stations). As such, this study will focus on flow metrics that best describes the natural flow regime and hydrologic characteristics of rivers. Flow characteristics, such as the mean annual flow (MAF, water availability), mean monthly flows (distribution of flows within the year) as well as flow duration characteristics (temporal distribution of water availability) will be studied for each hydrometric station. Regional characteristics of flow metrics will be studied in order to estimate resources availability for ungauged basins in New Brunswick.

Following the characterization of flow availability and the timing of events, the study will then focus on extreme events (i.e., high and low flows). Peak flows, bankfull discharge (important for channel shape and form) and low flows will be analyzed using frequency analysis. For example, high flows are important for the design of hydraulic structure as well as dam safety whereas low flows are important for drinking water quality, dilution processes as well as other water use during low flow periods. The frequency of low flows is particularly important to assess water availability and potential volumes for water extraction during low flow events.

Following the description of the natural flow regime, the study will quantify environmental flows for each river system using commonly used approaches. For this part of the study, four commonly used environmental flow methods will be considered:

- 1) Fixe percentages of the mean annual flow (e.g., 25% MAF),
- 2) Median monthly flow method Q_{50}
- 3) 70% of median monthly flow method 70% of Q_{50} and
- 4) Q_{90} flow duration method.

Studies have shown the importance of river hydrology and ecology where they have described many key components of the natural flow regime. The province of New Brunswick has relatively abundant water resources. This was recently pointed out by Environment Canada (2009): In Atlantic Canada, the presence of large rivers and relatively low Environmental flow studies have received more attention over the past decades as a result of a growing awareness for the protection of the environment as well as increased water demands. As such, several studies have been undertaken with the objectives of evaluating river flows and environmental flow requirements (Caissie and El-Jabi, 1995a; Dunbar et al., 1998; Tharme, 2003; Caissie and Robichaud, 2009). The complexity of environmental flow studies is highly dependent on specific objectives, data availability, and the resources requiring protection including the magnitude of projects (Beecher, 1990; Annear et al., 2004; Linnansaari et al., 2013). For example, Annear et al. (2004) described the environmental flow evaluation process as a five riverine components (i.e., hydrology, geomorphology, biology, water quality and connectivity) as well as a public involvement and legal/institutional components. Linnansaari et al. (2013) provided an overview of environmental flow methods applied in different provinces across Canada as well as some methods and approaches applied internationally. As outlined in these studies, various methods are available in the literature to conduct environmental flow studies and they have generally been classified into different categories (IEC Beak Consultants Ltd., 1985; Tharme, 2003; King et al., 2003; Acerman and Dunbar, 2004). In the present study, we will group environmental flow methods into four categories: 1) hydrologically-based methods, 2) hydraulic methods, 3) habitat preference methods and 4) holistic approaches / framework. In additions, various environmental flow methods can be found in each of these categories. For instance, Tharme (2003) identified over 200 different assessment methods world-wide.

Among the different environmental flow methods, the habitat preference methods are considered to be the most complex methods for assessing flow requirements of aquatic species (Bovee, 1982; Stalnaker et al., 1995). However, this approach is also the most difficult and expensive to apply. Flows are generally selected where the habitat preference is maximized for single or multiple species. Over the years, habitat preference methods have been identified with many problems as well as lacking validation studies, especially when linking predicted “usable” habitat to population densities or the productive capacity of rivers (Hudson et al., 2003).

The hydraulic methods involve analyzing some hydraulic features of a specific segment of a watercourse (Hamilton and Kosakoski, 1982). This approach assumes a direct relation between hydraulic characteristics (e.g., area or wetted perimeter) and fish habitat. For example, this approach assumes that a 20% reduction in wetted perimeter would result in a 20% reduction in available habitat. Environmental flows by hydraulic methods are generally applied for specific habitat types (e.g., riffles) and environmental flow targets are selected where key habitat attributes (e.g., wetted perimeter) decreases more rapidly as a function of discharge (Hamilton and Kosakoski, 1982).

Hydrologically-based assessment methods are considered to be the simplest method, as they mostly rely on historic streamflow data and do not require any field work water demand means that the threat to water availability was ranked as low (below 10%). According to this study, the province of New Brunswick has ample water to meet different

demands even at the sub-drainage area level. Nevertheless, the timing of low flows is particularly problematic where water becomes deficit during certain periods of the year (e.g., summer period and during winter period, particularly in northern New Brunswick). During these deficit periods, the demand for water (e.g., water supplies, irrigation, etc.) often exceeds the amount available in rivers. Such deficit periods can become even more problematic when considering environmental flow needs.

2. BACKGROUND

The first step in most hydrological studies is the characterization of the flow regime. Studies have shown that the natural flow regime plays a key role in the functioning of river ecosystems (Poff et al., 1997) and where the natural flow regime is recognized as a key ecological component worth protecting. In the study of river flow regimes many hydrologic indices have been calculated. For instance, some studies have identified indicators of hydrologic alteration (Olden and Poff, 2003), which characterized the structure of the flow regime and its variability. These indices are used during hydrologic studies as well as environmental flow evaluations. For example, Richter et al. (1996) identified 66 flow indices when looking at hydrologic alteration issues. Olden and Poff (2003) identified 171 flow variables whereas Monk et al. (2007) described over 200 indices. With so many indices, some studies have attempted to reduce these indices to include only those that are most relevant of these hydrologic characteristics, i.e., those that best represent the river hydrology (Daigle et al. 2011; Monk et al. 2011). In water management, the study of flow regimes is often influenced by water use and withdrawal. As such, these components also need to be considered and assessed, as well as environmental flow requirements.

Studies are showing that water withdrawal demands from rivers (e.g. irrigation, hydroelectric, drinking water, etc.) are currently increasing world-wide (Postel et al., 1996). Such water withdrawals can affect the flow regime as well as fish habitat and aquatic life in many ways. The extraction of water can affect the ability of a stream to dilute contaminants as well as impacting the thermal regime (Caissie, 2006). Therefore, the scarcity of water, especially during low flows and droughts, can result in a direct conflict between the protection of aquatic habitat and water use. This requires water resources and fisheries managers to rely on good data and understanding of water availability, hydrologic regimes as well as important fisheries requiring protection. For the Department of Fisheries and Oceans, environmental flow methods are essential in environmental impact assessments and in the protection of important fisheries, as it pertains to the application of the Fisheries Act. The demand for water is expected to increase in the future and it is estimated that over 50% of the total accessible runoff is already being used worldwide (Postel et al., 1996). To address these issues, the concept of environmental flows (or instream flows) was developed among hydrologists, engineers, biologists, and water resource managers (Tennant, 1976; Wesche and Rechard, 1980; Annear et al., 2004). The concept of environmental flows relates to the quantity of water required in rivers to sustain an acceptable level of life of aquatic biota at various phases of their development. Environmental flow requirements can also include other instream uses such as recreational activities, navigation and others.

(Wesche and Rechard, 1980). As such, hydrologically-based methods rely on the assumption that if the river discharge and the hydrologic character of a river are protected, then aquatic biota within the river ecosystem will also be protected. The concept of protecting the hydrologic character of a river is also promoted in the natural flow paradigm (Poff et al., 1997); which suggests that protecting the flow regime should also protect the river ecosystem. The environmental flow assessment becomes a matter of determining, how far can we depart from the natural flow regime (through water extraction and modifications) without impacting too much the river ecosystem? Historically, some hydrologically-based instream flow methods have been applied as “minimum flow” where everything above a given discharge is “fair game” for water extractions. This often resulted in a “flatlined” streamflow hydrograph which had a significant impact on rivers (Annear et al. 2004). Currently, most would agree that any well applied methods (including hydrologically-based methods) should be done with the consideration of streamflow variability and the hydrologic regime in order to maintain some level of ecosystem integrity (Poff et al. 1997).

Historically within the Maritime Provinces (New Brunswick, Prince Edward Island and Nova Scotia), a derivative of the Tennant method, i.e., the 25% Mean Annual Flow (MAF) method was used as the environmental flow target to assess water withdrawal projects. The 25% MAF was not necessarily set unilaterally but was used as a guiding principle during the environmental flow assessment. The concept was that when a river discharge is above the 25% MAF, then some level of water extraction or modification would be permitted. However, when the river discharge was below the 25% MAF or any other environmental flow targets, no pumping or diversion should occur and the river should regain its natural flow regime. Accordingly, flows below environmental flow targets represent “hands-off” flows. Over the past decades, some studies have been carried out to evaluate environmental flow methods within the Maritime Provinces (Caissie and El-Jabi 1995a; Caissie and El-Jabi 1995b; Caissie and El-Jabi, 2003; Caissie et al. 2014). These studies included environmental flow methods used historically in New Brunswick as well as other potential methods, particularly those of neighboring provinces or states (e.g. New England states and Quebec). Studies demonstrated that both the 25% MAF method as well as the Q_{50} (median flow applied on a monthly basis) seemed to provide adequate environmental flow protection in the context of the hand-off flows for the Maritime Provinces. In addition, these studies showed that the 25% MAF method was best for ungauged basins (better regional equations), as the Q_{50} method showed relatively high spatial variability and high variability as a function of drainage basin size (Caissie and El-Jabi 1995b). This was especially true for the Q_{50} during low flow months (July to September). Nevertheless, the Q_{50} method could be applied in many cases, provided that good flow data was available. Following these studies, some provinces (e.g., New Brunswick and Prince Edward Island) used 70% of Q_{50} as environmental flows; however, this approach was only recently evaluated (Caissie et al. 2014). In the application of the 70% Q_{50} method, particularly in New Brunswick and Nova Scotia, the baseflow of rivers plays an important role in the level of environmental flow protection. In practice, regardless of the environmental flow method used, environmental flows below 10% MAF are considered too low and such flows should be avoided (Tennant 1976; Caissie and El-Jabi 2003).

In the present study, the natural flow regime will be described followed by the application of potential environmental flow approaches in New Brunswick. As such, a range of

potential methods will be applied rather than specific methods, as these result are required to estimate potential water availability. Notably, for specific projects the selection of a particular method should be done on a project by project basis with a thorough understanding of the site and fisheries requiring protection. Within the present study the term water availability can refer to the total water volume or discharge of a river system or the water available for withdrawal. The water availability in the context of water available for withdrawal (or off-stream uses) represents the excess water above the environmental flow requirement. Accordingly, the term water availability will at times referred to the “water available for withdrawal”.

3. MATERIALS AND METHODS

3.1 Data and study region

The hydrological analysis was carried out using historical data from 54 hydrometric stations of which 51 are located in New Brunswick (Figure 1). In order to enhance the quality of the regional analysis, three stations located outside the province of New Brunswick were also included: two stations located in Quebec and one station located in Nova Scotia. All data used in this study were collected from the HYDAT database using HYDAT version 1.0 (April 15, 2014). Data extracted included daily discharge data as well as extreme values, i.e., annual maximum and minimum daily discharges data.

3.2 Natural flow regimes

3.2.1 Water availability

The water availability was characterized using the mean annual flow (MAF), the mean monthly flow (MMF) and a flow duration analysis. The mean annual flow provides valuable data on the water availability (total volume of water) for the given river whereas the mean monthly flow provides information on the distribution of the total water on a seasonal basis (winter, spring, summer etc.). A flow duration analysis was also conducted for each hydrometric station. This analysis provides information on the time that specific flows were exceeded within a given time period. A flow duration analysis is a non-parametric cumulative distribution function of daily discharges. It consists of ranking flows from the highest to the lowest values and then calculating their respective frequencies. A flow duration curve can be constructed by plotting the ranked flows against the calculated frequencies and corresponding flows of different frequencies (or percentiles) can thereafter be determined (e.g., 50% or median flow Q_{50} , 90% or Q_{90} , etc.). In the present study, the flow duration analysis was carried out using a program in R, which makes the necessary calculation using Environment Canada (HYDAT) flow data.

3.2.2 Frequency analysis

A frequency analysis was carried for each station to estimate high and low flows of different recurrence intervals. The maximum and minimum daily discharges by year was extracted from the HYDAT database and fitted to the generalized extreme value (GEV) distributions for both high and low flows. In the case of low flows, the 2 and 3-parameter Weibull distribution were also used for comparative purposes. The MLE (maximum likelihood estimates) method was used for estimating the parameters for all distributions.

The CDF for the distributions are given by the following equations:

GEV distribution:

$$F(x) = \exp \left\{ - \left[1 + k \left(\frac{x - \mu}{\sigma} \right)^{-1/k} \right] \right\} \quad (1)$$

where k , σ and μ are shape, scale and location parameters, respectively.

Weibull distribution:

$$F(x) = 1 - \exp \left[- \left(\frac{x - \gamma}{\beta} \right)^\alpha \right] \quad (2)$$

where α , β and γ are shape, scale and location ($\gamma \equiv 0$ yields to 2 parameter Weibull distribution) parameters, respectively.

The relation between the CDF (i.e., $F(x)$) and the recurrence interval, T , used in high flow hydrology is given by the equation:

$$F(x) = 1 - \frac{1}{T} \quad (3)$$

and for low flows by:

$$F(x) = \frac{1}{T} \quad (4)$$

Following the frequency analysis, an analysis of high and low flow periods (both magnitude and timing) was also carried out using a running average for a 30-day period (mean of 30 days). This analysis essentially provides information on high and low flows period throughout the year. In this analysis, the spring high flow period was studied as well as both winter and summer low flows.

3.2.3 Regionalization

Characteristics of floods and low flows differ from one drainage basin to another and results of single station analysis are only applicable to gauged streams. As many water resource projects are undertaken within ungauged basins, there is a requirement for the development of regional equations. Regional regression analysis consists of establishing a relationship between flow metrics (mean flows, high and low flows, etc.) and physiographic parameters describing the basin. With the discharge as the dependent variable and the physiographic factors as the independent variables (in this case, drainage area), a regression was performed in order to evaluate the parameters of the following equation:

$$Q_T = aDA^b \quad (5)$$

where, a and b are regression constants, DA is the drainage area (km^2) and Q represents the flow (annual flows, high or low flows for different recurrence intervals, m^3/s). In the present study, the parameters a and b were calculated using nonlinear regression.

3.3 Environmental flow assessment

In the present study, the following hydrologically based environmental flow methods were used:

- 25% mean annual flow (MAF) method;
- Median monthly flow (Q_{50}) method;
- 70% Q_{50} method;
- 90% flow duration method.

25% mean annual flow (MAF) method

The 25% MAF method is a fixed percentage of MAF method which have been inspired on Tennant approach (Tennant 1976). Others studies have also described fix percentage of MAFs, e.g. Reiser et al., 1989; Caissie and El-Jabi 1995a. The 25% Mean Annual Flow (MAF) states that the minimum flow required to maintain aquatic life, regardless of season or species is the 25% mean annual flow. As this approach has been used in the Maritime Provinces in the past, it will be used in the present study as well for comparison purposes.

Median monthly flow (Q_{50}) and 70% Q_{50} method

The median monthly flow (Q_{50}) method was developed for the New England region by the US Fish and Wildlife Service - USFWS (1981) with the basic assumption that the median monthly flow (flow available 50% of the time each month) should be able to sustain or protect fish populations as these species have evolved to maximize their fitness to such habitat and flow conditions at different times of year. This method will be applied and, as in the USFWS (1981), the Q_{50} for the month of August will be used as the Aquatic Base Flow (ABF). A variant of the Q_{50} method is the 70% Q_{50} , which was applied within some of the Maritime Provinces (Caissie et al. 2014). For instance, this method has been applied in New Brunswick as well as in the province of Prince Edward Island.

90% flow duration method

This method, similar to the Q_{50} method, uses daily flow duration data for every month of the year for the period of record. Based on the Northern Great Plains Resource Program - NGPRP (1974), flow recommendations are expressed in terms of minimum monthly flow. The recommended flow for each month is the one that equaled or exceeded 90% of the time (90th percentile or Q_{90}) in a flow duration analysis. This environmental flow method has been applied mostly in the prairie region and has been shown not to be applicable within the Maritime Provinces for most month of the year (Caissie et al. 2014). However, this approach could potentially be applied during high flow months and, as such, will be tested under this condition.

Climate change impact

A climate change impact is also provided using the Canadian regional climate model, CRCM 4.2.3. The CRCM4.2.3 time-slice simulation for 1961-2100 is driven by CGCM3, following IPCC "observed 20th century" scenario for years 1961-2000 and the Special Report on Emissions Scenarios (SRES) A2 for years 2001-2100 over the North-American domain (AMNO) with a 45-km horizontal grid-size mesh (El-Jabi et al., 2010).

4. RESULTS AND DISCUSSION

Mean annual flow (MAF) and mean monthly flow (MMF)

The 54 stations are plotted on a map of New Brunswick (Figure 1) and some of their relevant characteristics are presented in Table 1. The number of years of record varies between 11 and 93 with a mean value of 39 years. The smallest drainage basin corresponds to Narrows Mountain Brook at 3.89 km^2 whereas the largest river corresponds to the Saint John River at Fort Kent at 14700 km^2 . The mean annual flow varied between $0.098 \text{ m}^3/\text{s}$ (Narrow Mountain Brook) and $279 \text{ m}^3/\text{s}$ (Saint John River at Fort Kent) for these rivers. In order to study the temporal characteristics of flow (e.g., within the year flow distribution), the mean monthly flow for each hydrometric station was computed. Table 2 and Table 3 show the mean monthly and the normalized mean monthly flows from January to December for each 54 stations. Table 3 shows that the high flow month is April (mean = $63.6 \text{ L s}^{-1} \text{ km}^{-2}$) followed by May (mean = $54.4 \text{ L s}^{-1} \text{ km}^{-2}$); however, results also showed that the variability was higher in May (Std. Dev. = $20.5 \text{ L s}^{-1} \text{ km}^{-2}$). Winter low flow occurred mainly in February in New Brunswick with a mean normalized flow of $11.7 \text{ L s}^{-1} \text{ km}^{-2}$. The summer low flows showed slightly lower values than in winter with a mean normalized flow of $8.8 \text{ L s}^{-1} \text{ km}^{-2}$ in September (Table 3). It should be pointed out that summer low flows were somewhat similar between July ($11.1 \text{ L s}^{-1} \text{ km}^{-2}$), August ($9.4 \text{ L s}^{-1} \text{ km}^{-2}$) and September ($8.8 \text{ L s}^{-1} \text{ km}^{-2}$). In New Brunswick the mean overall normalized flow was calculated at $23.0 \text{ L s}^{-1} \text{ km}^{-2}$. As such, the winter high monthly flows generally represent over 200% the mean annual flow whereas the summer low flow month (September) typically represents 38% of the mean annual flow.

A box plot of the New Brunswick mean monthly flow curve is presented in Figure 2. This figure shows both the mean and median monthly flow as well as the corresponding variability. Results show that the median monthly flow was close to the mean but slightly lower. The variability was low during low flow months ($2.6 \text{ L s}^{-1} \text{ km}^{-2}$ in August) and higher during the spring high flows (e.g., $20.5 \text{ L s}^{-1} \text{ km}^{-2}$ in May). A histogram plot of monthly flows for each station are also given in Appendix B.

Flow duration analysis

The flow duration analysis provides information on the percentage of the time that flows are equaled or exceeded, such as flows that correspond to 50% and 90% of the time (i.e., Q_{50} and Q_{90}). A flow duration analysis was carried out for each hydrometric station in New Brunswick. Results for some flows are presented in Table 4. This table show that the median flow (Q_{50}) varied from $0.045 \text{ m}^3/\text{s}$ (01AL004) to $136 \text{ m}^3/\text{s}$ (01AD002) for New Brunswick. Previous studies have showed that the Q_{50} generally corresponds to approximately half of the mean annual flow (Leopold 1994, Caissie 2006b). The mean

annual flow (MAF) is also presented in Table 4 and results show that the median flows varied between 27% (Bass R.) and 57% (Lepreau R.) of the MAF, with an average value of 48%. Therefore, in New Brunswick median flows (Q_{50}) were approximately 50% of the MAF on average, as reported in previous studies. The Q_{90} , representing low flows, was also calculated for each station by province (Table 4). Values of Q_{90} varied between $0.011 \text{ m}^3/\text{s}$ (01AL004) and $43.6 \text{ m}^3/\text{s}$ (01AD002). Similar to the Q_{50} , a comparison was carried out between the Q_{90} and the MAF. Notably, the Q_{90} is a low flow value that represents on average approximately 17% of the MAF. The Q_{50} for the month of August, also known at the Aquatic Base Flow (ABF), was calculated as it is used during some environmental flow studies. The Q_{50} (Aug) varied between $0.022 \text{ m}^3/\text{s}$ (01AL004) and $104.5 \text{ m}^3/\text{s}$ (01AD002). Individual flow duration curves for each station are provided in Appendix B.

With the single station flow duration analysis results, a regional flow duration curve was calculated for New Brunswick, as shown in Figure 3. In this figure the flows are expressed as discharge per unit area (L/s per km^2 ; $\text{L s}^{-1} \text{ km}^{-2}$). This figure shows flows corresponding to different percentage (from 0% to 100%) on the flow duration curve, as well as flow variability using a box plot representation. The normalized flow duration curve showed flows between $577 \text{ L s}^{-1} \text{ km}^{-2}$ at 0% and $0.838 \text{ L s}^{-1} \text{ km}^{-2}$ at 100%. The normalized Q_{50} was calculated at $11.3 \text{ L s}^{-1} \text{ km}^{-2}$. The flow variability increased for lower flows, particularly for percentages higher than 80% (Q_{80}). The flow variability was also slightly high at 0% (Std Dev = 245). The mean and median values in the regional flow duration curve were very close. The normalized mean annual flow was calculated $23.0 \text{ L s}^{-1} \text{ km}^{-2}$ (see above) and this flow corresponds to a flow that is exceeded 28% of the time on the flow duration curve (Figure 3). This means that the flows in New Brunswick Rivers are generally below the mean annual flow for 72% of the time.

Flow frequency

Results of the 54 single station high and low flow frequency analyses are provided in Table 5 and Table 6, for recurrence intervals of 2, 5, 10, 20, 50 and 100 years for high flows and 2, 5, 10, 20 and 50 years for low flows. Individual flow frequency curves are also presented in Appendix A. For the Saint John River at Fort Kent, which has the largest drainage area (14700 km^2), the 2-year flood and drought was estimated to be $2352 \text{ m}^3/\text{s}$ and $31.7 \text{ m}^3/\text{s}$, respectively, using GEV distribution. These correspond to the highest estimated 2-year flood and drought in New Brunswick. Conversely, the lowest estimated 2-year flood (GEV) and drought (GEV) was at Narrows Mountain Brook (drainage area of 3.89 km^2) and values were $1.18 \text{ m}^3/\text{s}$ and $0.006 \text{ m}^3/\text{s}$, respectively. For all 54 stations, the corresponding Anderson-Darling (AD) statistics are presented in Table 7. The Anderson-Darling statistics provides a mean of comparing the goodness-of-fit of different distribution functions. In the case of high flows, GEV distribution was used exclusively because the GEV provided a good fit for all stations. In the case of low flows, results of AD statistics favored GEV over 2-parameter Weibull(2p) or the 3-parameter Weibull(3p) most of the time (Table 7). In fact, over 87% (47/54) of the low flows favored the GEV distribution, followed by 11% (6/54) for the Weibull(2p) and 2% (1/54) for the Weibull(3p) distribution function. The high and low flow frequency curves for each station are also given in Appendix B.

Flow characteristics by station (fact sheet)

Following the analysis of high and low flow frequencies, a fact sheet was prepared to show a summary of results for each station (see Figure 4 for the Southwest Miramichi River example; see Appendix B for results of all other stations). In fact, Figure 4 shows the different flow characteristics for the Southwest Miramichi River at Blackville (01BO001). This figure shows the flow duration analysis (top left panel) followed by a time series of mean daily discharge for each day of year and corresponding variability (top right panel). The time series of mean daily discharge (Qmean) represents the mean discharge value for each day of the year (mean of day 1, 2, 3... 365, etc.) while STDmean represent the variability around the mean. This figure shows the high and low flow periods are in synchrony with the corresponding variability (STDmean). The two bottom panels represent the high (left panel) and low flow (right panel) frequency analysis. These panels also inform on the type of distribution used in the fitting of the high and low flows (e.g., GEV).

Regional flow characteristics

Following the single station analysis some regional flow characteristics were analyzed. For example, Figure 5 shows the average daily discharge time series for all stations in New Brunswick. In this figure, daily runoff characteristics (mm) are presented rather than discharge values to compare flows of the various rivers within the province. This figure shows high variability in runoff among rivers, particularly in spring and late autumn. Winter low flows as well as a mid-winter thaw period (towards the end of January and early February) are clearly evident from this analysis. The winter low flow period was generally between January 31 (day 31) and March 2 (day 61) and this low flow period was followed by the high spring flows (peaked around May 1; day 121; Figure 5). The summer low flow period generally extended between August 23 (day 235) and September 17 (day 260; Figure 5). A high flow period was also observed in autumn, generally between October 28 (day 301) and December 12 (day 346) followed by slightly lower flows.

The above time series analysis was followed by a characterization of high and low flows (both timing and magnitude) based on a 30-day average flow period. The objective of using a 30-day average flow period was to eliminate or minimize short-term flow variability. As such, a 30-day flow period will better reflect both high and low flow magnitude and timing. Results from this analysis revealed that the timing of the spring high flow period was generally bi-modal (Figure 6a) where high flows were within two categories, i.e., peak flows that occurred before and after day 115 (April 25). When studying high flow magnitude (30-day mean) vs. timing, results showed that earlier spring high flows tended to be of lower magnitude, and vice versa (Figure 6b). For instance, peak flows occurring around April 15 (day 105) were generally close to $70 \text{ m}^3/\text{s}$ (based on the regression line) whereas peak flows occurring around May 10 (day 130) were generally $93 \text{ m}^3/\text{s}$ (i.e., representing an increase of $23 \text{ m}^3/\text{s}$).

The timing of summer and winter low flows are shown in Figure 7. From these results, it is clear that most stations ($35/54 = 65\%$) experience their summer low flow over a very short period, within a 10-day period, i.e., between August 28 (day 240) and September 7 (day 250; Figure 7a). In terms of winter low flows, a few stations experienced their winter low flows in January (between day 10 and 20); however, most of the winter low flows were noted to occur between February 9 (day 40) and March 11 (day 70; Figure 7b), i.e. over a 30-day period. No significant relationships were observed between the magnitude and the timing of both summer and winter low flows.

A cluster analysis was performed on the timing of high and low flows to determine if any patterns emerged as a function of latitude within the province. For both winter and summer low flows, no specific patterns were evident; however, in the case of the timing of spring high flow two distinctive groups were observed from the analysis (Figure 8). This figure shows that two distinct groups were identified and typically represented northern and southern rivers. Figure 9 shows the location of each station within the two groups, and this figure shows that the first group represents northern stations whereas the second group represents southern stations. These results clearly show that there was a north / south gradient in terms of spring high flow timing. A few exceptions were noted from the cluster analysis, i.e. rivers in the south (north) that were identified part of the northern (southern) group (e.g. station 01BV007, 01BU004 and 01AL003).

Based on this cluster analysis, the daily discharge time series analysis was recalculated for both northern and southern rivers and results are presented in Figure 10. The darker black line within this figure represents all stations analyzed together for comparison purposes, as calculated above (see Figure 5). Figure 10 shows that the northern stations have lower winter low flows and that the spring high flows generally occurred later (peak flows generally occurred around May 5; day 125). This is most likely due to snowmelt condition in the north which resulted in a greater spring flow (more snow accumulation) and which occurred later in the season (colder condition than in the south). For the southern stations, the winter low flows were generally higher and the spring peak flows generally occurred earlier, around April 20 (day 110), i.e., 15 days earlier compared to the northern stations. In fact, the southern part of the province often experiences warmer condition in winter and more precipitation falls in the form of rain in comparison to the north. When comparing the summer low flows, both the northern and southern stations showed similar timing and magnitude and lowest low flows occurred around September 5 (day 248). The autumn high flow period was more important for southern stations than for northern stations.

Regional flow characteristic was also investigated for the mean annual flow (MAF). A cluster analysis of the mean annual flow and latitude was carried out and results are presented in Figure 11. From this cluster analysis, two major group emerged with most stations falling within group 1 and a few stations (i.e., 8 stations) falling within group 2. A closer look at these two groups revealed that the average normalized mean annual flow for group 1 was $21.6 \text{ L s}^{-1} \text{ km}^{-2}$ whereas the average normalized mean annual flow of group 2 was $31.6 \text{ L s}^{-1} \text{ km}^{-2}$. As such, stations within group 2 tend to have a greater mean annual flow (greater water availability) by almost 46% or $10 \text{ L s}^{-1} \text{ km}^{-2}$. The location of stations

within the two groups is shown in Figure 12. This figure shows that the stations in group 2 are generally along the Bay of Fundy and have correspondingly greater mean annual flows. These results are consistent with the fact that the southern part of the province receives slightly higher amounts of precipitation (close to an additional 200 mm compared to the rest of the province), as reported in previous studies (e.g., Caissie and Robichaud 2009).

In order to estimate flow for ungauged basins regional regression equations were calculated for various flows (i.e., mean annual flow, median flow – Q_{50} and ABF – Q_{50} for August). Figure 13a shows the relation between the MAF and the drainage area (DA) for all stations within the province. Regression equations are also provided in Table 8 for these flows as well as for high and low flows (i.e., frequency analysis). It was noted that regression equation between the mean annual flow (MAF) and drainage area (DA) showed a high coefficient of determination ($R^2=0.99$) indicating a high correspondence between these variables as well as a similar behavior for small and large rivers. Similar to the MAF, the regression equation for Q_{50} vs. drainage area (DA) showed a very high level of association between these variables with a R^2 of 0.99 (Figure 13b). The regional regression equation between Q_{50} for August (ABF) and drainage area showed a R^2 of 0.97, slightly lower than previous variables.

In order to estimate high and low flows for ungauged basins, regional regression equations were also calculated. The estimated regression equations are presented in Table 8 (see also Appendix A) along with their corresponding coefficients of determination (R^2) and root mean squared error (RMSE). For the regional regression equations, R^2 varied between 0.956 and 0.996 for high flows and between 0.799 and 0.875 for low flows. It should be noted that the regression parameters were calculated using a genetic algorithm. It is also important to note that the regression equations were developed for a specific range of drainage basin sizes and should not be applied outside those ranges (ranges are provided in Table 8).

Environmental flow assessment

Following the flow characterization within the province of New Brunswick, different environmental flows methods were applied to assess potential instream flow requirement and corresponding water availability for withdrawal. In fact, when assessing water available for human consumption it is important to also consider environmental flows as this water will be essentially reserved for fish habitat, thus not available for off-stream use. In the present study, only hydrologically-based environmental flow methods were considered because of the data availability and their wide application in a regional context. However, in practice when evaluating specific projects other environmental flow approaches can also be considered part of the analysis. Table 9 shows results of typical environmental flows methods used in New Brunswick, and results are shown for all analyzed stations in this study. Results are presented for the 25% mean annual flow method (25% MAF) as well as the median flow (Q_{50}) for August. A variant of the Q_{50} , i.e. 70% Q_{50} was also provided for the month of August as well as the flow exceeded 90% of the time (Q_{90}) for August as well. It should be noted that most flow duration approaches (Q_{50}

and Q_{90}) methods are applied on the monthly basis; however, this table shows only the results for the month of August (which represents among the lowest flow month). In Table 9, normalized flow values (discharge per unit area) are presented to compare results among stations. For instance, the 25% MAF method show a mean environmental flow value of $5.78 \text{ L s}^{-1} \text{ km}^{-2}$ for the province. This flow is available 73% of the time on the provincial flow duration curve (Figure 3). The provincial normalized mean annual flow was calculated at $23.0 \text{ L s}^{-1} \text{ km}^{-2}$ (see section on Mean annual flow and mean monthly flow, above). The 25% MAF ranged between $4.46 \text{ L s}^{-1} \text{ km}^{-2}$ (01AH005) and $9.83 \text{ L s}^{-1} \text{ km}^{-2}$ (01BV006; Table 9). The Q_{50} for August showed an average value of $5.32 \text{ L s}^{-1} \text{ km}^{-2}$ which is similar, but slightly lower, than the average 25% MAF ($5.78 \text{ L s}^{-1} \text{ km}^{-2}$; Table 9). In fact, $5.32 \text{ L s}^{-1} \text{ km}^{-2}$ represents a mean flow for the province which is 23% of the MAF (i.e., 23 % of $23.0 \text{ L s}^{-1} \text{ km}^{-2}$). The Q_{50} environmental flows varied between $1.47 \text{ L s}^{-1} \text{ km}^{-2}$ (01AK007) and $10.4 \text{ L s}^{-1} \text{ km}^{-2}$ (01BV005), i.e. slightly more variable than the 25% MAF. When comparing the Q_{50} to the 25% MAF it was noted that the site variability was higher for the Q_{50} . This variability is also reflected in the standard deviation (Std. Dev.) for the Q_{50} method at $2.26 \text{ L s}^{-1} \text{ km}^{-2}$ compared to $1.13 \text{ L s}^{-1} \text{ km}^{-2}$ for the 25% MAF (Table 9). Expressed in a coefficient of variation ($Cv = \text{Std}/\text{Mean}$), these values would represent 20% (25 MAF) and 42% (Q_{50}). Notably, the variability in the Q_{50} is almost twice that of the 25% MAF. The 70% Q_{50} showed a lower mean value for the province at $3.73 \text{ L s}^{-1} \text{ km}^{-2}$ (this represents 16% MAF of $23.0 \text{ L s}^{-1} \text{ km}^{-2}$). The 70% Q_{50} environmental flows varied between $1.03 \text{ L s}^{-1} \text{ km}^{-2}$ (01AK007) and $7.31 \text{ L s}^{-1} \text{ km}^{-2}$ (01BV005). The lowest environmental flows were observed with the Q_{90} method with a mean provincial value of $2.28 \text{ L s}^{-1} \text{ km}^{-2}$ (i.e., only 9.9% of MAF or $23.0 \text{ L s}^{-1} \text{ km}^{-2}$). The Q_{90} environmental flows varied between $0.24 \text{ L s}^{-1} \text{ km}^{-2}$ (01AK007) and $5.17 \text{ L s}^{-1} \text{ km}^{-2}$ (01BK004). As shown in previous studies the Q_{90} method should not be applied during low flow periods, as environmental flows would be too low (Caissie et al. 2014). Similarly, the 70% Q_{50} method should be applied with caution and with good data as above low values $1.30 \text{ L s}^{-1} \text{ km}^{-2}$ represents only 6% of MAF. Notably, any environmental flows below the 10% MAF is considered too low and such not be used (Tennant 1976; Caissie and El-Jabi 2003; Caissie et al. 2014).

Mean normalized flow values by month for each environmental flow method are presented in Figure 14a. This figure shows that the mean monthly flows vary between $63.6 \text{ L s}^{-1} \text{ km}^{-2}$ (April) and $8.8 \text{ L s}^{-1} \text{ km}^{-2}$ (September) for the province of New Brunswick. The mean environmental flow for each month is also presented in this figure. For instance, environmental flows vary between $2.1 \text{ L s}^{-1} \text{ km}^{-2}$ in September (Q_{90} method) to $50.1 \text{ L s}^{-1} \text{ km}^{-2}$ in April (Q_{50} method). It is clear from this figure that all potential environmental flow methods may not apply throughout the year. For instance, during high flow months less restrictive methods could be applied because of high water conditions. Similarly, during low flow months, some methods should not be applied as the environmental flows would be too low to protect fish habitat and important fisheries. As such, a suite of potential methods have been suggested in Table 10 in order to assess potential environmental flows and corresponding water availability. It should be noted that the selection of these methods (as lower and upper targets) are only for the purpose of assessing water availability (in the present study). In fact, the selection of environmental flow methods can

be site/project specific and could be somewhat different based on a variety of other criteria (e.g., type and importance of specific species, size of the river, size of the project, etc.). In the present study, the 70% Q_{50} was proposed as the potential lower target in winter whereas the Q_{50} method was suggested for the upper target. In spring and during the high flow period, the 25% MAF (lower target) and Q_{90} methods (upper target) were suggested as environmental flows. In summer, both the 70% Q_{50} (lower) and 25% MAF (upper) were proposed whereas in autumn the 25% MAF (lower) and the Q_{50} (upper) were proposed (see Table 10).

Based on the upper and lower targets identified in Table 10, Figure 14b shows potential range of environmental flow targets for New Brunswick on a monthly basis and compared to the Mean Monthly Flow (MMF). This figure shows that the upper environmental flow target could be in the range of $5.8 \text{ L s}^{-1} \text{ km}^{-2}$ (summer) to $10-17 \text{ L s}^{-1} \text{ km}^{-2}$ (winter and autumn). The lower target was less variable and generally between $3.6 \text{ L s}^{-1} \text{ km}^{-2}$ (summer) and $5-8 \text{ L s}^{-1} \text{ km}^{-2}$ (winter and spring) with a mean overall value of $5.5 \text{ L s}^{-1} \text{ km}^{-2}$. It should be noted caution is warranted in summer months as environmental flows approach $3.6 \text{ L s}^{-1} \text{ km}^{-2}$ in August and September (i.e., flow representing close to 16% of MAF). During these low flow months, high spatial variability can influence environmental flows, and site specific baseflow component can also influence environmental flows (Caissie et al. 2014). Moreover, environmental flows lower than the 10% MAF should be selected as such flows are considered too low for adequate protection of important fisheries.

With the above suggested monthly environmental flow targets it was possible to calculate the corresponding water availability for withdrawal, which is simply the difference between the mean monthly flow and the environmental flow targets. Notably, the water availability for withdrawal represents the excess water above the environmental flow targets which can be used for off-stream use. Figure 15a presents the water availability (i.e., for withdrawal) for New Brunswick for each month based on the lower and upper environmental flow targets. For example, in January and February the water availability was calculated at between $4.3 \text{ L s}^{-1} \text{ km}^{-2}$ and $7.0 \text{ L s}^{-1} \text{ km}^{-2}$ depending on the selected environmental flow targets. Water availability for withdrawal becomes higher between March and June with value generally exceeding $10 \text{ L s}^{-1} \text{ km}^{-2}$ and reaching as high as $58 \text{ L s}^{-1} \text{ km}^{-2}$ (April). Water availability was lowest in summer (July-September) with values between $3 \text{ L s}^{-1} \text{ km}^{-2}$ and $6 \text{ L s}^{-1} \text{ km}^{-2}$ (Figure 15a). Figure 15b provides information related to the percentage of time the Mean Monthly Flows (MMF) is available on the flow duration curve, as the MMF represents long-term flow conditions. For instance, the MMF was calculated to be available between 27% (Feb and Aug) and 38% (Apr) of the time. At these percentages, the water available for withdrawal (values presented in Figure 15a) would be guaranteed on the long-term. In fact, the water available for withdrawal identified in Figure 15a (e.g., $4.3 \text{ L s}^{-1} \text{ km}^{-2}$ or $7.0 \text{ L s}^{-1} \text{ km}^{-2}$; for the month of January) are related to the availability of the MMF. As an example, when the MMF is available during the month of January (29% of the time) and the lower environmental flow target is selected (i.e., $6.1 \text{ L s}^{-1} \text{ km}^{-2}$; Figure 14b), then $7.0 \text{ L s}^{-1} \text{ km}^{-2}$ would be available for water withdrawal. Similarly, if the upper environmental flow target was selected ($8.8 \text{ L s}^{-1} \text{ km}^{-2}$; Figure 14b) and the MMF was available, then this would permit a water withdrawal of $4.3 \text{ L s}^{-1} \text{ km}^{-2}$. Figure 15b

provides information on the percentage of time that water available for withdrawal is present when the MMF is also available (i.e., long-term conditions). However, it is important to note that if the required water withdrawal was less than the values in Figure 15a, then water would be available for a higher percentage of time. For example, if the lower environmental flow target was selected for January (i.e., $6.1 \text{ L s}^{-1} \text{ km}^{-2}$; Figure 14b) and the water withdrawal required was only $0.6 \text{ L s}^{-1} \text{ km}^{-2}$ (requiring a river flow of $6.7 \text{ L s}^{-1} \text{ km}^{-2}$ to meet this demand), then this flow would be available 65% of the time (analysis based on the January flow duration curve).

Figure 16 shows important flow metrics in relation to high and low flow frequencies from a regional perspective (i.e., using regional equations) and for small / large rivers. For instance, peak flows for small basins are much higher per drainage area than peak flows for large rivers. Regional regression equations also show that small rivers showed higher low flows (per drainage area) compared to larger rivers. The flow metrics provided in Figure 16 are the MAF, 25% MAF, Q_{90} (May) and 70% Q_{50} (Sep). This figure shows that the MAF, Q_{90} flow for May and 25% MAF are within the range of high and low flows; however, the 70% Q_{50} (Sep) can be within the range of the 2-year flow low, especially for small basins. This approach needs to be applied with caution in the province of New Brunswick, as environmental flows approaching the 2-year low flow may not fully protect environmental conditions within the rivers.

Figure 17 shows an example of fact sheets provided in Appendix B, which calculates, for each analyzed station the MMF, flow by different environmental flows method (top left), suggested environmental flow targets (top right) and corresponding water availabilities for withdrawal (bottom left), as well as the occurrence of the MMF on the flow duration curve (bottom right).

Climate change impact

Figure 18 shows the climate change effect on mean monthly flows for the 2070-2100 time slice using A2 scenario. The analysis show that MMF in New Brunswick would most likely increase by 0.8-4% towards the end of this century.

5. CONCLUSION

The present study focused on flow metrics that best describe the natural flow regime and streamflow characteristics for rivers in New Brunswick. Also, water availability as well as water availability for withdrawals were calculated when considering a range of environmental flow targets. The study showed that rivers in New Brunswick generally provide around $23.0 \text{ L s}^{-1} \text{ km}^{-2}$ (normalized Mean Annual Flow - MAF) and this flow is exceeded approximately 28% of the time. As such, New Brunswick Rivers experience below MAF for 78% of the time. The median flows were approximately 50% of MAF. The water availability throughout the province is similar, with the exception of rivers along the Bay of Fundy, which have slightly higher flows per drainage area. Rivers in the northern part of the province generally experience lower winter flows and higher spring peak flows

compared to river in the south. Peak flows for northern rivers also occur later in the season and generally of greater magnitude than the south. In summer, the timing of low flows was very similar throughout the province with over 65% of low flow events occurring between August 28 and September 7. Low flow frequencies on a regional basis showed more variability (lower R^2) than high flows. Following the characterization of the flow regime, environmental flows were calculated and assessed for the studied rivers. The concept of environmental flow relates to the quantity of water required in rivers to sustain an acceptable level of living conditions for rivers ecosystems. In total, four hydrologically based environmental flow methods were applied across the Province: the 25% mean annual flow, the Q_{50} method, the 70% Q_{50} method and the Q_{90} flow duration method. Based on these four hydrologically based methods, a range of monthly flow target was proposed to assess potential water availability (Table 10). Some caution was pointed out when applying the 70% Q_{50} method, as low summer environmental flow targets was observed using this approach (e.g., $3.7 \text{ L s}^{-1} \text{ km}^{-2}$; Aug; Figure 14b) for the province wide analysis. Careful examination of site specific results should be done in order not to have environmental flows below 10% MAF. Also, it is well documented in the literature that Q_{50} show more spatial variability as well as a greater variability with drainage basin size than the MAF. As such, good data are required on specific rivers when this approach is used.

Based on long-term conditions (namely the Mean Monthly Flows), water availability for withdrawal was calculated between $4.3 \text{ L s}^{-1} \text{ km}^{-2}$ and $12.1 \text{ L s}^{-1} \text{ km}^{-2}$ in winter (Jan-Mar) followed by values between $38 \text{ L s}^{-1} \text{ km}^{-2}$ and $60 \text{ L s}^{-1} \text{ km}^{-2}$ in April and May (Figure 15). The month of June showed water availability close to $13 \text{ L s}^{-1} \text{ km}^{-2}$ whereas summer low flow months (July-Sep) showed values between $3 \text{ L s}^{-1} \text{ km}^{-2}$ and $6 \text{ L s}^{-1} \text{ km}^{-2}$ depending on the environmental flow targets. Autumn water availabilities were generally between $7 \text{ L s}^{-1} \text{ km}^{-2}$ and $19 \text{ L s}^{-1} \text{ km}^{-2}$. These water availabilities withdrawal are generally available between 27% and 38% of the time based on flow duration data. Overall New Brunswick Rivers showed water availability for withdrawal between $12.5 \text{ L s}^{-1} \text{ km}^{-2}$ and $17.6 \text{ L s}^{-1} \text{ km}^{-2}$ (mean of all months) depending on the environmental flow target. Based on the overall river water availability for the province ($23.0 \text{ L s}^{-1} \text{ km}^{-2}$) these values represent 54% and 76 % of the total available river discharge.

In conclusion, regardless of the method used for environmental flow assessment, the analysis should always be carried out with the consideration of as many riverine components as possible. The assessment should focus on protecting the river ecosystem as a whole using the best available knowledge of both biotic and abiotic conditions. As pointed out in this study, the river hydrology and corresponding base flow conditions are key factors in environmental flow assessments and extremely important in the protection of rivers' ecosystems.

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Table 1. Analyzed hydrometric stations in New Brunswick

Station ID	Station Name	DA (km ²)	Period of Record	N	MAF (m ³ /s)
01AD002	Saint John River at Fort Kent	14700	1927-2012	86	279.2
01AD003	Saint Francis River at outlet of Glasier Lake	1350	1952-2012	61	25.6
01AF003	Green River near Riviere-Verte	1150	1963-79, 1981-1993	30	26.4
01AG002	Limestone River at Four Falls	199	1968-1993	26	3.64
01AG003	Aroostook River near Tinker	6060	1975-2010	36	114.4
01AH005	Mamozekek River near Campbell River	230	1973-1990	18	4.1
01AJ003	Meduxnekeag River near Belleville	1210	1968-2010	43	25.2
01AJ004	Big Presque Isle Stream at Tracey Mills	484	1968-2010	43	9.82
01AJ010	Becaquimec Stream at Coldstream	350	1974-2011	38	7.6
01AJ011	Cold Stream at Coldstream	156	1974-1993	20	3.16
01AK001	Shogomoc Stream near Trans Canada Highway	234	1919-40, 1944-2012	91	4.99
01AK005	North Nashwaak Stream near Royal Road	26.9	1966-1993	28	0.54
01AK007	Nackawic River near Temperance Vale	240	1968-2010	43	4.94
01AK008	Eel River near Scott Siding	531	1974-1993	20	10.5
01AL002	Nashwaak River at Durham Bridge	1450	1962-2010	49	35.8
01AL003	Hayden Brook near Narrows Mountain	6.48	1971-1993	23	0.177
01AL004	Narrows Mountain Brook near Narrows Mountain	3.89	1972-2010	39	0.098
01AM001	Northwest Oromocto River at Tracy	557	1963-2010	48	12.3
01AN001	Castaway Brook near Castaway	34.4	1972-81, 1983-1993	21	0.874
01AN002	Salmon River at Castaway	1050	1974-2012	39	22
01AP002	Canaan River at East Canaan	668	1926-40, 1963-2011	64	13.5
01AP004	Kennebecasis River at Apohaqui	1100	1962-2011	50	25.5
01AP006	Nerepis River at Lepreau	293	1976-1993, 2009-2010	20	6.94
01AQ001	Lepreau River at Lepreau	239	1919-2011	93	7.32
01AQ002	Magaguadavic River at Elmcroft	1420	1917-32, 1943-2011	85	33.5
01AR006	Dennis Stream near Saint Stephen	115	1967-2012	46	2.78
01AR008	Bocabec River above Tide	43	1967-1979	13	1.095
01BC001	Restigouche River below Kedgwick River	3160	1963-2010	48	68.4
01BE001	Upsalquitch River at Upsalquitch	2270	1919-32, 1944-2010	81	41.1
01BJ001	Tetagouche River near West Bathurst	363	1923-33, 1952-1994	54	7.65
01BJ003	Jacquet River near Durham Centre	510	1965-2011	47	10.7
01BJ004	Eel River near Eel River Crossing	88.6	1968-1983	16	2.11
01BJ007	Restigouche River above Rafting Ground Brook	7740	1969-2010	42	163.4
01BK004	Nepisiquit River near Pabineau Falls	2090	1958-1974	17	45.2
01BL001	Bass River at Bass River	175	1966-1990	25	3.16
01BL002	Southwest Caraquet River at Burnsville	173	1970-2010	41	3.64
01BL003	Tracadie River at Murphy Bridge Crossing	383	1971-2011	41	8.36
01BO001	Southwest Miramichi River at Blackville	5050	1919-32, 1962-2012	65	118.1
01BO002	Renous River at McGraw Brook	611	1966-1994	29	14.7
01BO003	Barnaby River below Semiwagan River	484	1973-1994	22	9.68
01BP001	Little Southwest Miramichi River at Lyttleton	1340	1952-2010	61	33.1
01BP002	Catamaran Brook at Repap Road Bridge	28.7	1990-2010	21	0.637
01BQ001	Northwest Miramichi River at Trout Brook	948	1962-2010	49	21.6
01BR001	Kouchibouguac River near Vautour	177	1931-32, 1970-1994	27	3.74
01BS001	Coal Branch River at Beersville	166	1964-2011	47	3.69
01BU002	Petitcodiac River near Petitcodiac	391	1962-2011	50	8.07
01BU003	Turtle Creek at Turtle Creek	129	1963-2010	48	3.61
01BU004	Palmer's Creek near Dorchester	34.2	1967-1985	19	0.934
01BV005	Ratcliffe Brook below Otter Lake	29.3	1961-1971	11	0.995
01BV006	Point Wolfe River at Fundy National Park	130	1964-2011	48	5.11
01BV007	Upper Salmon River at Alma	181	1968-1978	11	7.05
01BD002	Matapedia en Amont de la Rivière assemetquagan, QC	2770	1970-91, 1995, 1997	25	57.7
01DL001	Kelley River at Eight Mile Ford, NS	63.2	1970-96, 1999-2011	40	1.85
01BF001	Nouvelle au Pont, QC	1140	1965-2000	36	25.9

DA : Drainage area, N : number of years , MAF : Mean annual flow

Table 2. Mean monthly flows (m³/s) in New Brunswick

Station ID	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
01AD002	101	75.1	110	744	923	294	183	152	136	199	252	173
01AD003	10.2	7.96	9.61	63.1	89.3	25.6	14.6	13.3	10.7	15.4	21.1	16.4
01AF003	9.57	8.78	9.43	53.6	99.8	27.9	17.2	14.7	13.2	21.8	22.6	16.5
01AG002	1.39	1.54	3.18	12.9	6.69	2.83	1.82	1.83	1.82	3.06	3.48	3.17
01AG003	57.3	51.9	77.6	409	246	87.3	54.6	47.9	41.1	92.6	117	90.8
01AH005	1.34	1.39	2.04	11.4	12.3	4.25	2.93	2.26	1.97	2.55	3.24	2.93
01AJ003	14.5	12.4	26.7	91.4	44.9	18.6	10.8	8.3	7.9	17.7	26.8	25
01AJ004	5.61	4.91	9.52	36.4	16.8	6.92	4.55	3.13	3.31	6.82	10	10
01AJ010	4.3	2.89	7.42	25	12.6	5.37	3.64	3.24	3.08	6.41	9.39	7.84
01AJ011	1.94	1.57	3.37	9.84	4.72	2.55	1.33	1.64	1.35	2.99	3.53	3.04
01AK001	3.81	2.94	4.73	16.6	9.63	3.71	1.84	1.22	1.26	2.72	5.52	5.93
01AK005	0.259	0.328	0.544	1.81	0.891	0.373	0.201	0.201	0.208	0.436	0.602	0.594
01AK007	2.7	2.24	5.74	18.3	7.76	2.98	1.61	1.49	1.47	3.68	5.94	5.4
01AK008	5.63	5.64	11.3	35.7	18	9.37	4	3.85	3.18	7.74	10.8	10.9
01AL002	21.4	16.9	30.6	109	75.9	28.7	17.4	13.6	14.7	27	41.2	36.9
01AL003	0.107	0.0882	0.122	0.515	0.412	0.149	0.0857	0.0665	0.0686	0.147	0.18	0.18
01AL004	0.0563	0.0433	0.0875	0.342	0.181	0.0691	0.045	0.0348	0.0352	0.0722	0.114	0.104
01AM001	9.32	9.28	17.2	38.1	18.5	8.53	4.52	3.26	2.82	7.63	14.1	14.6
01AN001	0.547	0.489	1.02	2.52	1.49	0.784	0.45	0.472	0.292	0.7	0.884	0.833
01AN002	13.8	10.7	27.4	73.2	36.4	17.2	10.2	8.35	6.48	15.5	24.2	21.1
01AP002	9.49	7.18	17.3	43.9	21.2	8.3	5.35	4.27	4.53	10.8	15.2	14
01AP004	23.5	20.3	37	64.2	38.3	16.8	10.6	7.74	7.93	17.7	30	31.6
01AP006	4.5	4.48	11.1	20	8.46	4.9	2.14	2.48	1.83	6.09	8.42	9
01AQ001	7.16	5.61	8.94	17.3	10.3	4.73	2.69	2.61	3.1	6.14	9.84	9.4
01AQ002	27.7	24	38.4	88.7	55	25.8	15.2	12.2	12.4	23.1	37.9	41.9
01AR006	2.11	1.93	4.26	7.37	3.83	1.74	0.828	0.787	0.862	2.1	3.5	4.1
01AR008	0.953	0.971	1.38	2.48	1.78	0.743	0.324	0.321	0.4	0.899	1.21	1.69
01BC001	24.2	19	22.4	151	245	69	47	37.6	33.7	54.2	65.8	48.9
01BE001	14.9	11.2	13.2	94.1	154	50.7	26	19	17.5	26	37	27.3
01BJ001	2.51	1.94	2.72	19.4	31.9	8.11	3.58	3.04	2.42	4.7	6.18	5
01BJ003	3.23	2.43	3.76	29.5	42	9.98	5.46	4.73	3.88	7.48	8.55	6.67
01BJ004	0.461	0.426	0.696	5.53	9.36	1.74	0.876	0.753	0.906	1.56	1.39	1.34
01BJ007	58.2	45.5	53.4	370	613	167	109	86.7	74.6	117	147	111
01BK004	21.5	16.8	15.5	63.6	181	63.6	27.8	24.4	24	29.5	38.8	33.8
01BL001	0.709	1.07	1.56	11.5	9.66	2.26	1.13	1.34	0.745	2.52	3	2.37
01BL002	1.64	1.48	2.04	10.5	9.78	3.72	2.13	1.8	1.41	2.66	3.46	2.99
01BL003	4	3.23	4.76	24.8	22.6	8.29	4.81	4.02	3.02	5.26	7.89	7.54
01BO001	61.9	50	76.4	329	300	105	63.1	55	51.2	89.9	127	107
01BO002	6.08	7.14	8.29	40.6	45	13.9	6.4	5.44	6.03	11	13.7	12.5
01BO003	4.05	3.79	7.28	37	20.6	8.68	3.86	3.37	2.55	7.04	9.22	8.84
01BP001	15.9	13	18.9	74.3	101	36.6	19.9	17.6	15.9	24	31.5	27.7
01BP002	0.315	0.199	0.352	1.8	1.61	0.508	0.371	0.283	0.206	0.554	0.797	0.641
01BQ001	8.94	8.2	12.5	59	63.6	19.5	11.3	10.9	8.47	15.9	21.6	18.5
01BR001	1.92	1.9	3	12.8	8.81	3.67	1.84	1.38	1.22	2.4	3.28	3.21
01BS001	2.09	1.75	4.51	12.8	6.52	2.58	1.61	1.18	0.972	2.62	4.12	3.61
01BU002	5.9	4.99	12	24.3	12.2	5.24	3.33	2.26	2.28	5.79	9.13	9.34
01BU003	2.68	2.43	4.5	10.4	7.06	2.46	1.22	0.797	0.816	2.3	4.28	4.45
01BU004	0.715	0.736	1.26	2.02	1.55	0.631	0.459	0.343	0.354	0.85	1.16	1.13
01BV005	0.656	0.814	0.851	2.22	1.81	0.551	0.454	0.51	0.506	0.903	1.34	1.32
01BV006	3.79	3.07	6.05	11.2	8.37	3.46	2.39	1.95	2.29	5.21	7.2	6.31
01BV007	4.31	4.7	6.42	13.6	15.7	5.43	4.21	2.72	2.82	6.77	8.6	9.25
01BD002	19.4	21.1	19.6	97.6	251	79.3	36.7	28.8	24.9	40.9	37.7	32
01DL001	1.76	1.6	2.8	4.04	2.24	1.05	0.769	0.724	0.727	1.55	2.52	2.45
01BF001	7.45	6.41	6.67	36	110	38.5	16.8	13	14.5	23.5	22.8	14.4

Table 3. Normalized mean monthly flows in New Brunswick (L/s/km²)

Station ID	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
01AD002	6.9	5.1	7.5	50.6	62.8	20.0	12.4	10.3	9.3	13.5	17.1	11.8
01AD003	7.6	5.9	7.1	46.7	66.1	19.0	10.8	9.9	7.9	11.4	15.6	12.1
01AF003	8.3	7.6	8.2	46.6	86.8	24.3	15.0	12.8	11.5	19.0	19.7	14.3
01AG002	7.0	7.7	16.0	64.8	33.6	14.2	9.2	9.2	9.2	15.4	17.5	15.9
01AG003	9.5	8.6	12.8	67.5	40.6	14.4	9.0	7.9	6.8	15.3	19.3	15.0
01AH005	5.8	6.0	8.9	49.6	53.5	18.5	12.7	9.8	8.6	11.1	14.1	12.7
01AJ003	12.0	10.2	22.1	75.5	37.1	15.4	8.9	6.9	6.5	14.6	22.1	20.7
01AJ004	11.6	10.1	19.7	75.2	34.7	14.3	9.4	6.5	6.8	14.1	20.7	20.7
01AJ010	12.3	8.3	21.2	71.4	36.0	15.3	10.4	9.3	8.8	18.3	26.8	22.4
01AJ011	12.4	10.1	21.6	63.1	30.3	16.3	8.5	10.5	8.7	19.2	22.6	19.5
01AK001	16.3	12.6	20.2	70.9	41.2	15.9	7.9	5.2	5.4	11.6	23.6	25.3
01AK005	9.6	12.2	20.2	67.3	33.1	13.9	7.5	7.5	7.7	16.2	22.4	22.1
01AK007	11.3	9.3	23.9	76.3	32.3	12.4	6.7	6.2	6.1	15.3	24.8	22.5
01AK008	10.6	10.6	21.3	67.2	33.9	17.6	7.5	7.3	6.0	14.6	20.3	20.5
01AL002	14.8	11.7	21.1	75.2	52.3	19.8	12.0	9.4	10.1	18.6	28.4	25.4
01AL003	16.5	13.6	18.8	79.5	63.6	23.0	13.2	10.3	10.6	22.7	27.8	27.8
01AL004	14.5	11.1	22.5	87.9	46.5	17.8	11.6	9.0	9.1	18.6	29.3	26.7
01AM001	16.7	16.7	30.9	68.4	33.2	15.3	8.1	5.9	5.1	13.7	25.3	26.2
01AN001	15.9	14.2	29.7	73.3	43.3	22.8	13.1	13.7	8.5	20.3	25.7	24.2
01AN002	13.1	10.2	26.1	69.7	34.7	16.4	9.7	8.0	6.2	14.8	23.0	20.1
01AP002	14.2	10.7	25.9	65.7	31.7	12.4	8.0	6.4	6.8	16.2	22.8	21.0
01AP004	21.4	18.5	33.6	58.4	34.8	15.3	9.6	7.0	7.2	16.1	27.3	28.7
01AP006	15.4	15.3	37.9	68.3	28.9	16.7	7.3	8.5	6.3	20.8	28.7	30.7
01AQ001	30.0	23.5	37.4	72.4	43.1	19.8	11.3	10.9	13.0	25.7	41.2	39.3
01AQ002	19.5	16.9	27.0	62.5	38.7	18.2	10.7	8.6	8.7	16.3	26.7	29.5
01AR006	18.3	16.8	37.0	64.1	33.3	15.1	7.2	6.8	7.5	18.3	30.4	35.7
01AR008	22.2	22.6	32.1	57.7	41.4	17.3	7.5	7.5	9.3	20.9	28.1	39.3
01BC001	7.7	6.0	7.1	47.8	77.5	21.8	14.9	11.9	10.7	17.2	20.8	15.5
01BE001	6.6	4.9	5.8	41.5	67.8	22.3	11.5	8.4	7.7	11.5	16.3	12.0
01BJ001	6.9	5.3	7.5	53.4	87.9	22.3	9.9	8.4	6.7	12.9	17.0	13.8
01BJ003	6.3	4.8	7.4	57.8	82.4	19.6	10.7	9.3	7.6	14.7	16.8	13.1
01BJ004	5.2	4.8	7.9	62.4	106.0	19.6	9.9	8.5	10.2	17.6	15.7	15.1
01BJ007	7.5	5.9	6.9	47.8	79.2	21.6	14.1	11.2	9.6	15.1	19.0	14.3
01BK004	10.3	8.0	7.4	30.4	86.6	30.4	13.3	11.7	11.5	14.1	18.6	16.2
01BL001	4.1	6.1	8.9	65.7	55.2	12.9	6.5	7.7	4.3	14.4	17.1	13.5
01BL002	9.5	8.6	11.8	60.7	56.5	21.5	12.3	10.4	8.2	15.4	20.0	17.3
01BL003	10.4	8.4	12.4	64.8	59.0	21.6	12.6	10.5	7.9	13.7	20.6	19.7
01BO001	12.3	9.9	15.1	65.1	59.4	20.8	12.5	10.9	10.1	17.8	25.1	21.2
01BO002	10.0	11.7	13.6	66.4	73.6	22.7	10.5	8.9	9.9	18.0	22.4	20.5
01BO003	8.4	7.8	15.0	76.4	42.6	17.9	8.0	7.0	5.3	14.5	19.0	18.3
01BP001	11.9	9.7	14.1	55.4	75.4	27.3	14.9	13.1	11.9	17.9	23.5	20.7
01BP002	11.0	6.9	12.3	62.7	56.1	17.7	12.9	9.9	7.2	19.3	27.8	22.3
01BQ001	9.4	8.7	13.2	62.2	67.1	20.6	11.9	11.5	8.9	16.8	22.8	19.5
01BR001	10.8	10.7	16.9	72.3	49.8	20.7	10.4	7.8	6.9	13.6	18.5	18.1
01BS001	12.6	10.5	27.2	77.1	39.3	15.5	9.7	7.1	5.9	15.8	24.8	21.7
01BU002	15.1	12.8	30.7	62.1	31.2	13.4	8.5	5.8	5.8	14.8	23.4	23.9
01BU003	20.8	18.8	34.9	80.6	54.7	19.1	9.5	6.2	6.3	17.8	33.2	34.5
01BU004	20.9	21.5	36.8	59.1	45.3	18.5	13.4	10.0	10.4	24.9	33.9	33.0
01BV005	22.4	27.8	29.0	75.8	61.8	18.8	15.5	17.4	17.3	30.8	45.7	45.1
01BV006	29.2	23.6	46.5	86.2	64.4	26.6	18.4	15.0	17.6	40.1	55.4	48.5
01BV007	23.8	26.0	35.5	75.1	86.7	30.0	23.3	15.0	15.6	37.4	47.5	51.1
01BD002	7.0	7.6	7.1	35.2	90.6	28.6	13.2	10.4	9.0	14.8	13.6	11.6
01DL001	27.8	25.3	44.3	63.9	35.4	16.6	12.2	11.5	11.5	24.5	39.9	38.8
01BF001	6.5	5.6	5.9	31.6	96.5	33.8	14.7	11.4	12.7	20.6	20.0	12.6
Mean	13.1	11.7	20.2	63.6	54.4	19.3	11.1	9.4	8.8	17.8	24.6	23.0
Std. Dev.	6.3	6.1	11.1	12.7	20.5	4.7	3.1	2.6	2.8	5.6	8.5	9.6

Table 4. Various annual flow characteristics of selected stations (m³/s)

Station ID	DA (km ²)	MAF	Q ₅₀	Q ₅₀ (Aug)	Q ₉₀
01AD002	14700	279.2	136	104.5	43.6
01AD003	1350	25.6	12.3	8.22	3.91
01AF003	1150	26.4	13.5	11.9	4.994
01AG002	199	3.64	1.82	1.465	0.66
01AG003	6060	114.4	55.9	30.45	17.3
01AH005	230	4.1	2	1.845	0.6064
01AJ003	1210	25.2	11.4	5.38	2.71
01AJ004	484	9.82	4.65	2.46	1.33
01AJ010	350	7.6	3.57	1.94	0.8708
01AJ011	156	3.16	1.71	1.17	0.4304
01AK001	234	4.99	2.48	0.695	0.477
01AK005	26.9	0.54	0.234	0.11	0.036
01AK007	240	4.94	1.7	0.524	0.204
01AK008	531	10.5	5.4	2.92	1.18
01AL002	1450	35.8	18.7	9.7	6.01
01AL003	6.48	0.177	0.088	0.057	0.031
01AL004	3.89	0.098	0.045	0.022	0.011
01AM001	557	12.3	5.95	1.785	0.7921
01AN001	34.4	0.874	0.454	0.425	0.125
01AN002	1050	22	10.6	4.96	2.79
01AP002	668	13.5	5.76	1.835	0.8195
01AP004	1100	25.5	14.1	5.18	3.601
01AP006	293	6.94	3.05	1.77	0.5289
01AQ001	239	7.32	4.19	1.76	0.9087
01AQ002	1420	33.5	19.9	9.48	5.66
01AR006	115	2.78	1.36	0.266	0.16
01AR008	43	1.095	0.609	0.149	0.108
01BC001	3160	68.4	34.3	26.65	12.5
01BE001	2270	41.1	18.4	15	7.16
01BJ001	363	7.65	2.92	2.145	0.906
01BJ003	510	10.7	4.03	3.04	1.33
01BJ004	88.6	2.11	0.776	0.613	0.218
01BJ007	7740	163.4	80	65.1	29.9
01BK004	2090	45.2	23.8	17.7	11.3
01BL001	175	3.16	0.845	0.549	0.17
01BL002	173	3.64	1.97	1.49	0.8464
01BL003	383	8.36	4.53	3.01	1.874
01BO001	5050	118.1	63.25	42.3	25.3
01BO002	611	14.7	6.945	4.07	2.34
01BO003	484	9.68	3.85	3.365	0.9578
01BP001	1340	33.1	17.5	13.45	6.94
01BP002	28.7	0.637	0.292	0.126	0.07
01BQ001	948	21.6	10.1	7.37	3.6
01BR001	177	3.74	1.81	1.41	0.597
01BS001	166	3.69	1.56	0.488	0.3365
01BU002	391	8.07	3.52	1.43	0.6701
01BU003	129	3.61	1.73	0.592	0.422
01BU004	34.2	0.934	0.464	0.308	0.099
01BV005	29.3	0.995	0.549	0.43	0.17
01BV006	130	5.11	2.88	1.465	0.6395
01BV007	181	7.05	3.85	2.11	1
01BD002	2770	57.7	29	24.9	10.5
01DL001	63.2	1.85	1.03	0.432	0.167
01BF001	1140	25.9	11.8	11.6	3.96

**Table 5. Results of flood frequency analysis for different recurrence intervals
(m³/s)**

Station ID	Name	QF2	QF5	QF10	QF20	QF50	QF100
01AD002	Saint Johhn River at Fort Kent	2352	3006	3368	3671	4006	4222
01AD003	Saint Francis River at outlet of Glasier Lake	198.1	271.6	321.5	370.3	434.9	484.4
01AF003	Green River near Riviere-Verte	219.8	300.9	349.9	393.7	446.1	482.3
01AG002	Limestone River at Four Falls	33.2	42.44	49.29	56.49	66.79	75.32
01AG003	Aroostook River near Tinker	961.3	1240	1409	1561	1744	1870
01AH005	Mamozekel River near Campbell River	40.01	55.42	66	76.44	90.39	101.2
01AJ003	Meduxnekeag River near Belleville	240.8	340	413.2	489.6	598.3	687.8
01AJ004	Big Presque Isle Stream at Tracey Mills	95.35	134.5	164.7	197.4	245.8	287.2
01AJ010	Becaquimec Stream at Coldstream	80.26	117.1	145.8	177	223.5	263.6
01AJ011	Cold Stream at Coldstream	33.72	50.17	62.88	76.66	97.1	114.6
01AK001	Shogomoc Stream near Trans Canada Highway	36.67	49.3	57.92	66.4	77.67	86.34
01AK005	North Nashwaak Stream near Royal Road	6.191	8.796	10.78	12.91	16.02	18.66
01AK007	Nackawic River near Temperance Vale	52.29	73.86	91.03	110.1	139	164.5
01AK008	Eel River near Scott Siding	70.1	89.57	100.6	110	120.7	127.6
01AL002	Nashwaak River at Durham Bridge	326	481.3	603	736.4	936.7	1110
01AL003	Hayden Brook near Narrows Mountain	1.9	3.016	3.904	4.887	6.384	7.699
01AL004	Narrows Mountain Brook near Narrows Mountain	1.18	1.699	2.15	2.685	3.566	4.401
01AM001	Northwest Oromocto Rriver at Tracy	121.8	175.5	223.1	280.6	377	470.1
01AN001	Castaway Brook near Castaway	8.475	11.29	13.04	14.63	16.58	17.97
01AN002	Salmon River at Castaway	197.5	239	262.1	281.3	302.7	316.5
01AP002	Canaan River at East Canaan	146.5	186.4	208.2	226.3	246.1	258.7
01AP004	Kennebecasis River at Apohaqui	230.9	324.1	392.1	462.3	561.2	641.8
01AP006	Nerepis River at Lepreau	85.54	126.7	166.4	217.4	309.7	405.4
01AQ001	Lepreau River at Lepreau	61.79	92.98	121.9	158.1	221.5	285.1
01AQ002	Magaguadavic River at Elmcroft	218.2	297.7	360.4	429.5	534.1	625.4
01AR006	Dennis Stream near Saint Stephen	24.25	34.15	42.17	51.16	65.07	77.48
01AR008	Bocabec River above Tide	10.76	16.69	21.66	27.41	36.61	45.08
01BC001	Restigouche River below Kedgwick River	584.4	783.5	914.8	1040	1202	1323
01BE001	Upsalquitch River at Upsalquitch	344.2	466.7	545.5	619.4	712.6	780.8
01BJ001	Tetagouche River near West Bathurst	72.5	98.38	116.2	133.9	157.5	175.9
01BJ003	Jacquet River near Durham Centre	114	148.1	170.2	191	217.5	237
01BJ004	Eel River near Eel River Crossing	26.74	35.12	41	46.91	54.95	61.28
01BJ007	Restigouche River above Rafting Ground Brook	1365	1827	2155	2486	2940	3300
01BK004	Nepisiquit River near Pabineau Falls	355.9	517.9	623.4	723.5	851.2	945.7
01BL001	Bass River at Bass River	39.05	54.18	66.27	79.71	100.3	118.4
01BL002	Southwest Caraquet River at Burnsville	31.54	45.31	55.59	66.41	81.99	94.94
01BL003	Tracadie River at Murphy Bridge Crossing	62.75	85.65	102.4	119.9	144.5	164.7
01BO001	Southwest Miramichi River at Blackville	854.2	1076	1195	1292	1398	1463
01BO002	Renous River at McGraw Brook	131.8	184.5	225.4	269.8	335.9	392.7
01BO003	Barnaby River below Semiwagan River	96	130.7	154.8	178.8	211.2	236.5
01BP001	Little Southwest Miramichi River at Lyttleton	228.7	336.8	428.7	536	709.4	870.9
01BP002	Catamaran Brook at Repap Road Bridge	6.521	9.307	11.24	13.15	15.74	17.75
01BQ001	Northwest Miramichi River at Trout Brook	183.3	265.7	329.2	397.7	499	585.6
01BR001	Kouchibouguac River near Vautour	36.05	46.78	53.74	60.3	68.63	74.76
01BS001	Coal Branch River at Beersville	44.91	58.7	67.11	74.68	83.79	90.14
01BU002	Petitcodiac River near Petitcodiac	88.87	110.5	120.9	128.7	136.3	140.6
01BU003	Turtle Creek at Turtle Creek	37.93	54.43	66.33	78.53	95.56	109.3
01BU004	Palmer's Creek near Dorchester	12.3	17.88	21.82	25.77	31.18	35.45
01BV005	Ratcliffe Brook below Otter Lake	12.37	19.84	25.27	30.88	38.76	45.17
01BV006	Point Wolfe River at Fundy National Park	63.2	88.01	104.5	120.4	141	156.5
01BV007	Upper Salmon River at Alma	81.66	114.9	139.5	165.1	201.6	231.6
01BD002	Matapedia en Amont de la Rivière assemetquagan, QC	432.3	547.9	625.9	701.8	801.5	877.5
01DL001	Kelley River at Eight Mile Ford, NS	18.05	24.84	30.54	37.15	47.71	57.44
01BF001	Nouvelle au Pont, QC	255.9	335.3	380.8	419.9	464.6	494.1

Table 6. Results of daily droughts frequency analysis for different recurrence intervals (m³/s)

Station ID	Name	QL2	QL5	QL10	QL20	QL50
01AD002	Saint Johhn River at Fort Kent	31.7	23.9	20.4	17.9	15.2
01AD003	Saint Francis River at outlet of Glasier Lake	3.38	2.54	2.19	1.94	1.69
01AF003	Green River near Riviere-Verte	3.05	2.23	1.87	1.61	1.34
01AG002	Limestone River at Four Falls	0.439	0.317	0.252	0.199	0.139
01AG003	Aroostook River near Tinker	3.16	0.98	0.452	0.215	0.082
01AH005	Mamozekel River near Campbell River	0.452	0.353	0.311	0.28	0.248
01AJ003	Meduxnekeag River near Belleville	1.32	0.751	0.517	0.347	0.177
01AJ004	Big Presque Isle Stream at Tracey Mills	0.789	0.489	0.352	0.247	0.138
01AJ010	Becaquimec Stream at Coldstream	0.477	0.329	0.263	0.213	0.162
01AJ011	Cold Stream at Coldstream	0.226	0.141	0.102	0.0733	0.043
01AK001	Shogomoc Stream near Trans Canada Highway	0.278	0.153	0.105	0.0705	0.0373
01AK005	North Nashwaak Stream near Royal Road	0.013	0.00854	0.00685	0.00568	0.00456
01AK007	Nackawic River near Temperance Vale	0.0646	0.0297	0.0178	0.0109	0.00575
01AK008	Eel River near Scott Siding	0.648	0.354	0.229	0.136	0.0425
01AL002	Nashwaak River at Durham Bridge	3.82	2.98	2.63	2.39	2.14
01AL003	Hayden Brook near Narrows Mountain	0.0227	0.0176	0.0151	0.0132	0.0111
01AL004	Narrows Mountain Brook near Narrows Mountain	0.00604	0.00324	0.00203	0.00113	0.000214
01AM001	Northwest Oromocto Rriver at Tracy	0.307	0.0801	0.0329	0.014	0.00464
01AN001	Castaway Brook near Castaway	0.0742	0.0511	0.0413	0.0341	0.0268
01AN002	Salmon River at Castaway	1.88	1.43	1.26	1.14	1.02
01AP002	Canaan River at East Canaan	0.42	0.271	0.213	0.172	0.132
01AP004	Kennebecasis River at Apohaqui	2.53	1.81	1.51	1.28	1.04
01AP006	Nerepis River at Lepreau	0.217	0.116	0.0743	0.0462	0.0218
01AQ001	Lepreau River at Lepreau	0.424	0.186	0.108	0.0641	0.0326
01AQ002	Magaguadavic River at Elmcroft	3.3	2.12	1.63	1.27	0.906
01AR006	Dennis Stream near Saint Stephen	0.0562	0.0209	0.0109	0.00581	0.00258
01AR008	Bocabec River above Tide	0.0392	0.0124	0.00579	0.00279	0.00108
01BC001	Restigouche River below Kedgwick River	9.52	7.73	6.91	6.29	5.64
01BE001	Upsalquitch River at Upsalquitch	5.41	4.18	3.65	3.25	2.85
01BJ001	Tetagouche River near West Bathurst	0.689	0.511	0.437	0.384	0.33
01BJ003	Jacquet River near Durham Centre	0.994	0.754	0.646	0.565	0.481
01BJ004	Eel River near Eel River Crossing	0.159	0.115	0.0974	0.0851	0.073
01BJ007	Restigouche River above Rafting Ground Brook	23.5	18.1	15.6	13.5	11.3
01BK004	Nepisiquit River near Pabineau Falls	8.93	7.77	7.32	7	6.69
01BL001	Bass River at Bass River	0.091	0.0502	0.033	0.0205	0.00786
01BL002	Southwest Caraquet River at Burnsville	0.684	0.544	0.473	0.415	0.351
01BL003	Tracadie River at Murphy Bridge Crossing	1.51	1.2	1.07	0.974	0.879
01BO001	Southwest Miramichi River at Blackville	18.7	14.5	12.6	11.1	9.53
01BO002	Renous River at McGraw Brook	1.35	0.929	0.753	0.624	0.494
01BO003	Barnaby River below Semiwagan River	0.55	0.391	0.328	0.283	0.238
01BP001	Little Southwest Miramichi River at Lyttleton	5.02	3.77	3.2	2.77	2.32
01BP002	Catamaran Brook at Repap Road Bridge	0.0396	0.0275	0.0223	0.0186	0.0148
01BQ001	Northwest Miramichi River at Trout Brook	2.58	2.11	1.91	1.76	1.62
01BR001	Kouchibouguac River near Vautour	0.426	0.305	0.247	0.202	0.153
01BS001	Coal Branch River at Beersville	0.207	0.144	0.116	0.0953	0.0736
01BU002	Petitcodiac River near Petitcodiac	0.387	0.264	0.216	0.181	0.148
01BU003	Turtle Creek at Turtle Creek	0.311	0.241	0.21	0.187	0.163
01BU004	Palmer's Creek near Dorchester	0.042	0.0241	0.0168	0.0115	0.0063
01BV005	Ratcliffe Brook below Otter Lake	0.0756	0.0498	0.0397	0.0325	0.0256
01BV006	Point Wolfe River at Fundy National Park	0.311	0.204	0.162	0.133	0.104
01BV007	Upper Salmon River at Alma	0.537	0.354	0.279	0.225	0.172
01BD002	Matapedia en Amont de la Rivière assemetquagan, QC	8.83	6.72	5.77	5.05	4.31
01DL001	Kelley River at Eight Mile Ford, NS	0.0748	0.0468	0.0346	0.0254	0.0159
01BF001	Nouvelle au Pont, QC	2.94	2.14	1.77	1.48	1.19

Table 7. Anderson-Darling statistics

Station ID	High flows GEV	Low flows		
		GEV	Weibull(2p)	Weibull(3p)
01AD002	0.261	0.145	0.923	0.19
01AD003	0.176	0.263	1.391	0.375
01AF003	0.324	0.782	0.963	0.881
01AG002	0.156	0.182	0.335	0.222
01AG003	0.154	0.614	0.351	1.01
01AH005	0.352	0.426	0.609	3.97
01AJ003	0.398	0.53	0.599	4.74
01AJ004	0.318	0.186	0.214	0.211
01AJ010	0.275	0.205	0.318	0.283
01AJ011	0.193	0.119	0.19	0.128
01AK001	0.289	0.274	0.895	0.379
01AK005	0.392	0.143	0.79	0.22
01AK007	0.426	0.594	0.632	1.8
01AK008	0.299	0.514	0.641	0.615
01AL002	0.169	0.349	1.47	0.362
01AL003	0.445	0.333	0.416	0.384
01AL004	0.232	0.55	7.92	2.38
01AM001	0.275	0.356	0.425	4.34
01AN001	0.229	0.532	0.674	0.472
01AN002	0.271	0.414	1.65	0.396
01AP002	0.234	0.407	1.24	0.939
01AP004	0.19	0.158	0.51	0.171
01AP006	0.382	0.185	0.522	0.227
01AQ001	0.239	0.919	0.522	0.569
01AQ002	0.492	0.203	0.709	0.316
01AR006	0.185	0.787	0.482	0.658
01AR008	0.259	0.509	0.533	4.63
01BC001	0.298	0.178	0.648	0.212
01BE001	0.299	0.167	1.16	0.413
01BJ001	0.183	0.173	1.106	0.21
01BJ003	0.151	0.196	0.579	0.245
01BJ004	0.331	0.187	0.6	3.86
01BJ007	0.2	0.172	0.264	0.177
01BK004	0.285	0.206	1.08	0.259
01BL001	0.156	0.398	0.456	0.411
01BL002	0.283	0.243	0.26	0.244
01BL003	0.228	0.277	1.06	0.523
01BO001	0.326	0.259	0.576	0.296
01BO002	0.322	0.396	0.658	0.431
01BO003	0.28	0.102	0.58	0.167
01BP001	0.26	0.248	0.712	0.407
01BP002	0.377	0.193	0.443	0.217
01BQ001	0.274	0.405	1.51	0.659
01BR001	0.584	0.204	0.264	0.244
01BS001	0.354	0.269	0.442	0.316
01BU002	0.269	0.212	1.07	0.534
01BU003	0.157	0.21	0.828	0.298
01BU004	0.202	0.211	0.338	3.46
01BV005	0.195	0.255	0.537	0.339
01BV006	0.301	0.285	1.27	0.362
01BV007	0.25	0.167	0.423	0.214
01BD002	0.697	0.196	0.454	0.228
01DL001	0.245	0.216	0.286	0.204
01BF001	0.261	0.337	0.46	0.408

Note : Distributions used in bold

Table 8. Regional regression equations for mean, median, high and low flows(3.89 km² < DA < 14700 km²)

Mean & median flow	$Q_{MAF} = 0.0354 DA^{0.9363}$	RMSE = 3.13	R ² = 0.995
	$Q_{50} = 0.0197 DA^{0.9229}$	RMSE = 2.37	R ² = 0.989
	$Q_{ABF} = 0.0073 DA^{0.9888}$	RMSE = 2.95	R ² = 0.967
High flow	$QF_2 = 0.2724 DA^{0.9448}$	RMSE = 26.0	R ² = 0.996
	$QF_5 = 0.4511 DA^{0.9180}$	RMSE = 42.8	R ² = 0.993
	$QF_{10} = 0.6378 DA^{0.8942}$	RMSE = 60.6	R ² = 0.989
	$QF_{20} = 0.8898 DA^{0.8690}$	RMSE = 83.5	R ² = 0.982
	$QF_{50} = 1.3712 DA^{0.8339}$	RMSE = 122.5	R ² = 0.970
	$QF_{100} = 1.8944 DA^{0.8065}$	RMSE = 159.3	R ² = 0.956
Low flow	$QL_2 = 0.00481 DA^{0.9195}$	RMSE = 2.08	R ² = 0.875
	$QL_5 = 0.00370 DA^{0.9172}$	RMSE = 1.81	R ² = 0.840
	$QL_{10} = 0.00334 DA^{0.9114}$	RMSE = 1.64	R ² = 0.824
	$QL_{20} = 0.00302 DA^{0.9080}$	RMSE = 1.49	R ² = 0.813
	$QL_{50} = 0.00279 DA^{0.8989}$	RMSE = 1.33	R ² = 0.799

Table 9. Specific normalized environmental flows (L/s/km²)

Station ID	25% MAF	Q ₅₀ (Aug)	70%Q ₅₀ (Aug)	Q ₉₀ (Aug)
01AD002	4.75	6.39	4.48	2.56
01AD003	4.74	5.71	4.00	2.41
01AF003	5.74	8.78	6.15	4.55
01AG002	4.57	6.18	4.33	3.01
01AG003	4.72	4.41	3.08	1.58
01AH005	4.46	6.96	4.87	3.08
01AJ003	5.21	3.54	2.48	0.88
01AJ004	5.07	4.30	3.01	1.74
01AJ010	5.43	4.20	2.94	1.36
01AJ011	5.06	5.11	3.58	1.58
01AK001	5.33	2.74	1.91	0.93
01AK005	5.02	2.38	1.67	0.55
01AK007	5.15	1.47	1.03	0.24
01AK008	4.94	4.04	2.83	1.29
01AL002	6.17	5.83	4.08	2.83
01AL003	6.83	6.48	4.54	3.40
01AL004	6.30	4.11	2.88	1.29
01AM001	5.52	2.30	1.61	0.44
01AN001	6.35	7.09	4.97	2.35
01AN002	5.24	3.77	2.64	1.82
01AP002	5.05	1.73	1.21	0.53
01AP004	5.80	4.18	2.93	2.32
01AP006	5.92	2.75	1.93	0.53
01AQ001	7.66	5.02	3.51	1.15
01AQ002	5.90	5.70	3.99	2.28
01AR006	6.04	2.20	1.54	0.35
01AR008	6.37	3.49	2.44	0.35
01BC001	5.41	8.20	5.74	4.32
01BE001	4.53	6.17	4.32	3.38
01BJ001	5.27	4.77	3.34	2.18
01BJ003	5.25	5.16	3.61	2.27
01BJ004	5.95	5.63	3.94	2.35
01BJ007	5.28	8.02	5.61	4.50
01BK004	5.41	8.13	5.69	5.17
01BL001	4.51	1.85	1.29	0.46
01BL002	5.26	7.86	5.50	5.08
01BL003	5.46	7.70	5.39	5.01
01BO001	5.85	7.50	5.25	3.86
01BO002	6.01	5.34	3.73	2.19
01BO003	5.00	3.58	2.51	1.19
01BP001	6.18	8.88	6.22	4.54
01BP002	5.55	3.66	2.56	1.36
01BQ001	5.70	6.45	4.51	3.02
01BR001	5.28	5.52	3.86	2.44
01BS001	5.56	2.64	1.85	1.19
01BU002	5.16	2.31	1.61	0.93
01BU003	7.00	3.95	2.77	2.49
01BU004	6.83	4.82	3.38	1.32
01BV005	8.49	10.44	7.31	3.17
01BV006	9.83	8.38	5.87	2.39
01BV007	9.74	9.50	6.65	2.77
01BD002	5.21	8.27	5.79	4.48
01DL001	7.32	3.76	2.63	0.98
01BF001	5.68	8.18	5.73	4.78
Mean	5.78	5.32	3.73	2.28
Std. Dev.	1.13	2.26	1.58	1.42

Table 10. Potential environmental flow targets by seasons

Month	Season	Lower target	Upper target
Jan			
Feb	Winter	70% Q ₅₀	Q ₅₀
Mar			
Apr			
May	Spring	25% MAF	Q ₅₀
Jun			
Jul			
Aug	Summer	70% Q ₅₀	25% MAF
Sep			
Oct			
Nov	Autumn	25% MAF	Q ₅₀
Dec			

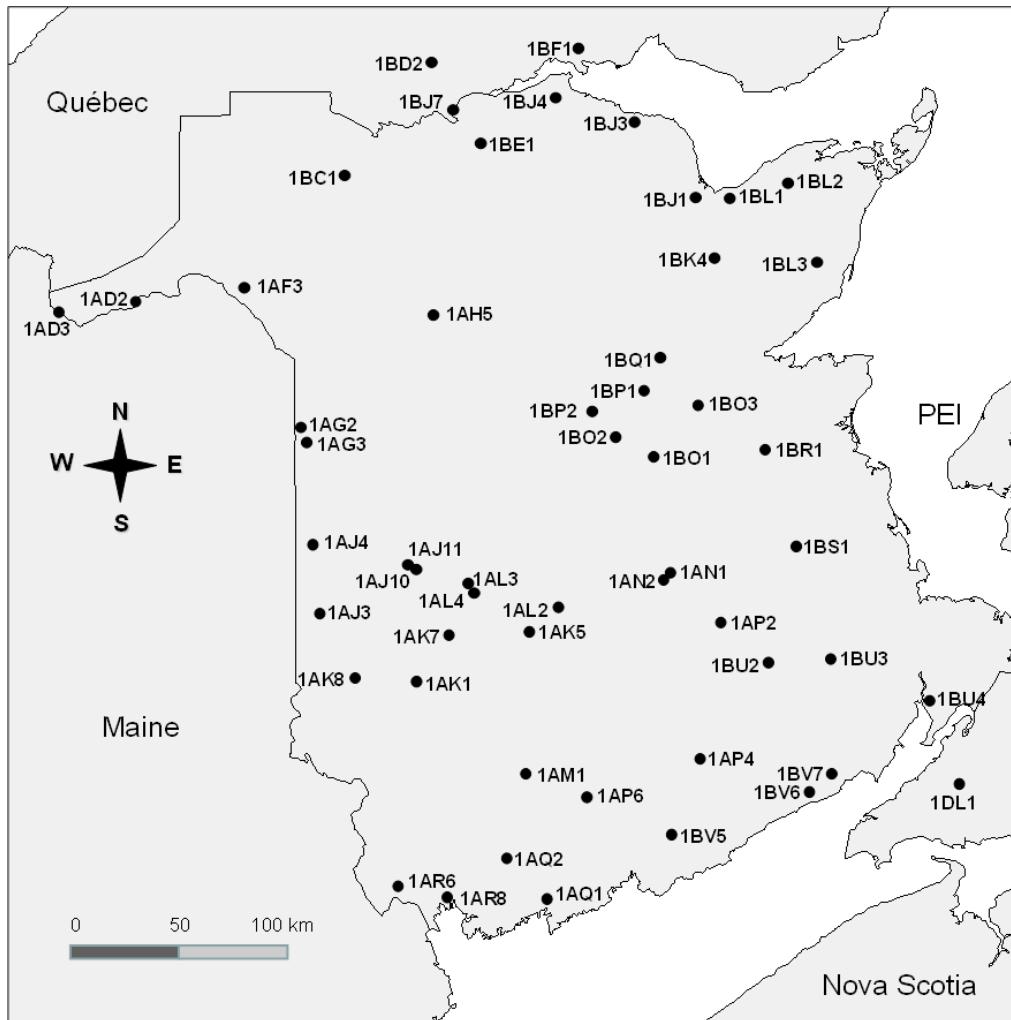


Figure 1. Location of selected hydrometric stations in New Brunswick (54 stations).

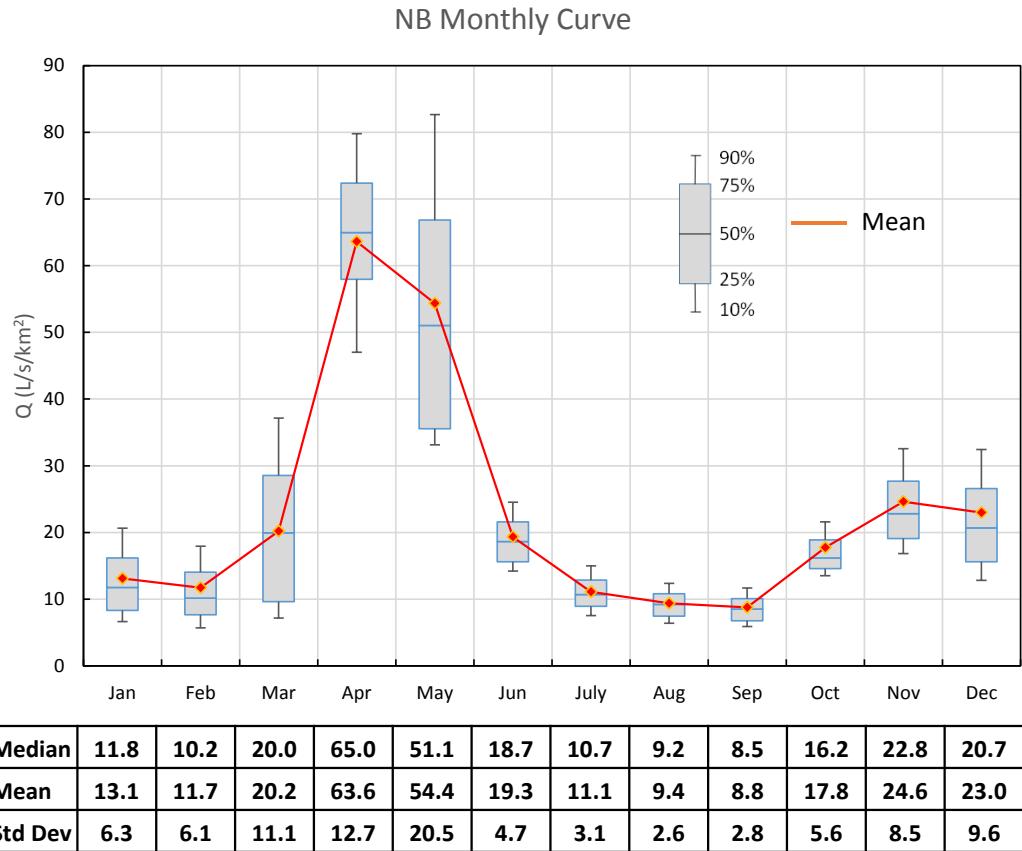


Figure 2. Box plot of New Brunswick normalized mean monthly flows

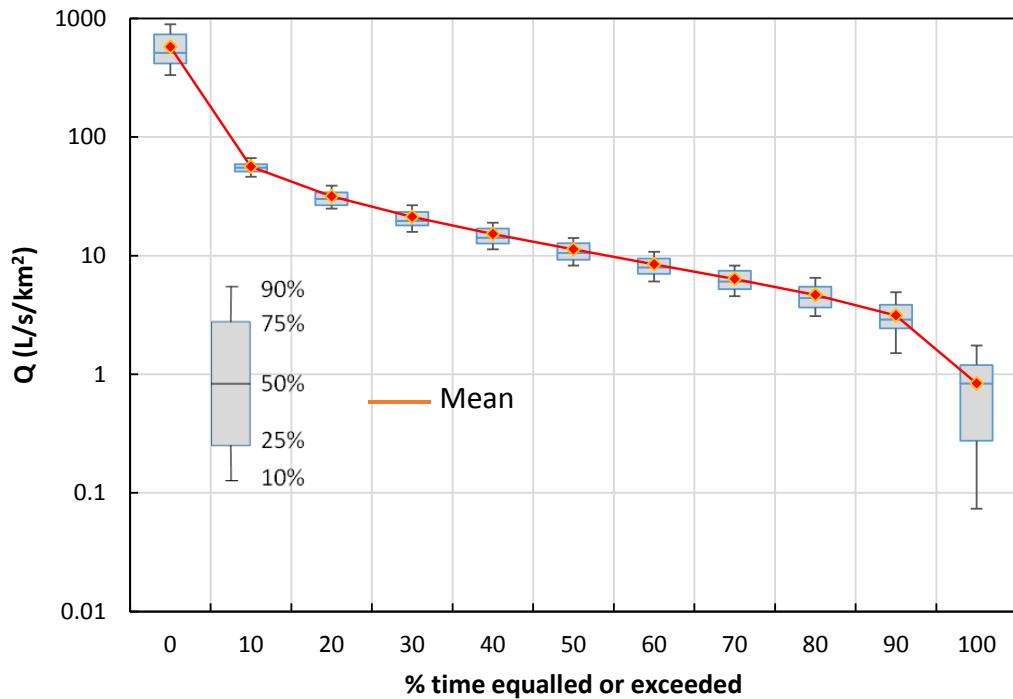
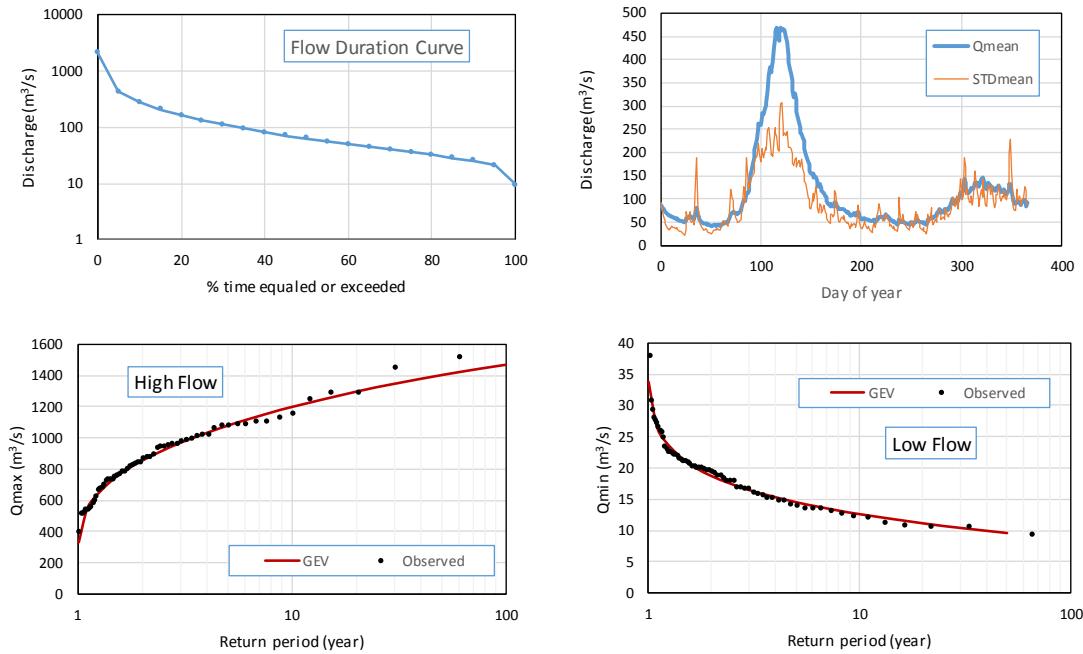


Figure 3. New Brunswick flow duration curve

Median	513	55.3	30.1	19.7	14.1	10.5	7.98	6.08	4.40	2.89	0.836
Mean	577	56.2	31.5	21.2	15.2	11.3	8.48	6.37	4.65	3.14	0.838
Std Dev	245	9.45	7.10	5.47	4.16	3.24	2.58	2.02	1.58	1.23	0.673

Figure B.38 : Southwest Miramichi River at Blackville (01BO001)

Station ID	01BO001	Mean annual flow (MAF)	118.1 m ³ /s
Latitude	46°44'09" N	Median annual flow (Q_{50})	63.25 m ³ /s
Longitude	65°49'32" W	Q_{50} (Aug)	37.9 m ³ /s
Drainage area	5050 km ²	70% Q_{50} (Aug)	26.53 m ³ /s
Period of record	1919-32,1962-2012 (65 years)	Q_{90} (Aug)	19.5 m ³ /s

**Figure 4. Fact sheet for single station analysis: example for the Southwest Miramichi River at Blackville**

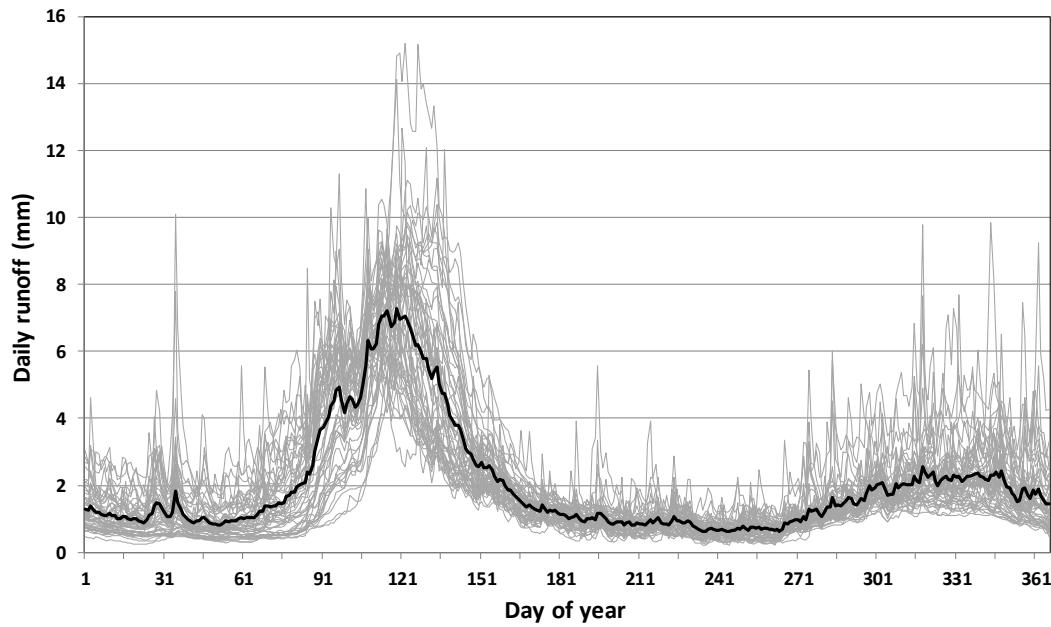


Figure 5. Average of daily runoff characteristics for all stations analyzed in New Brunswick (darker line represents the mean of all stations).

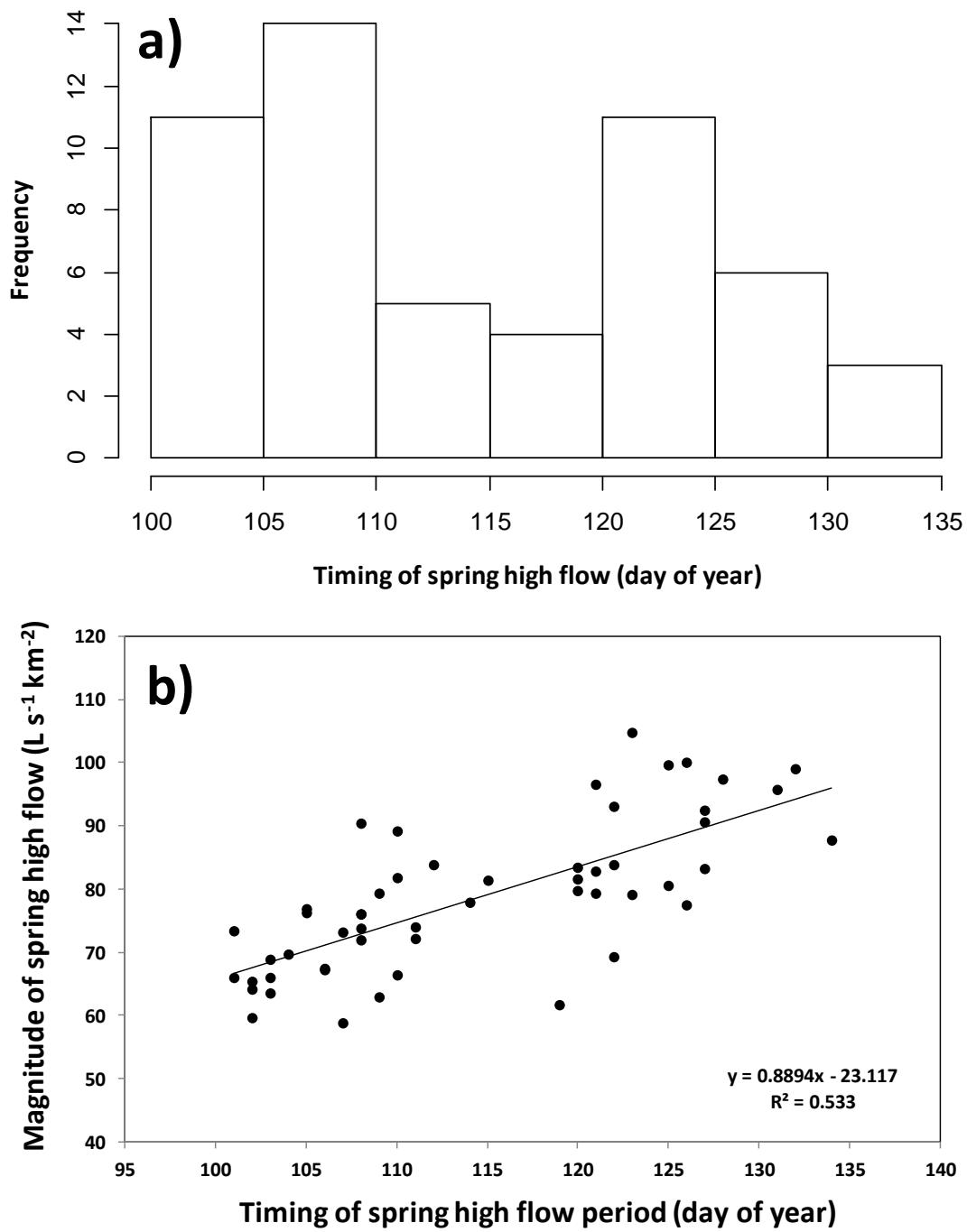


Figure 6. Results of high flow magnitude (30-day average) vs. timing (day of year) for all stations analyzed in New Brunswick

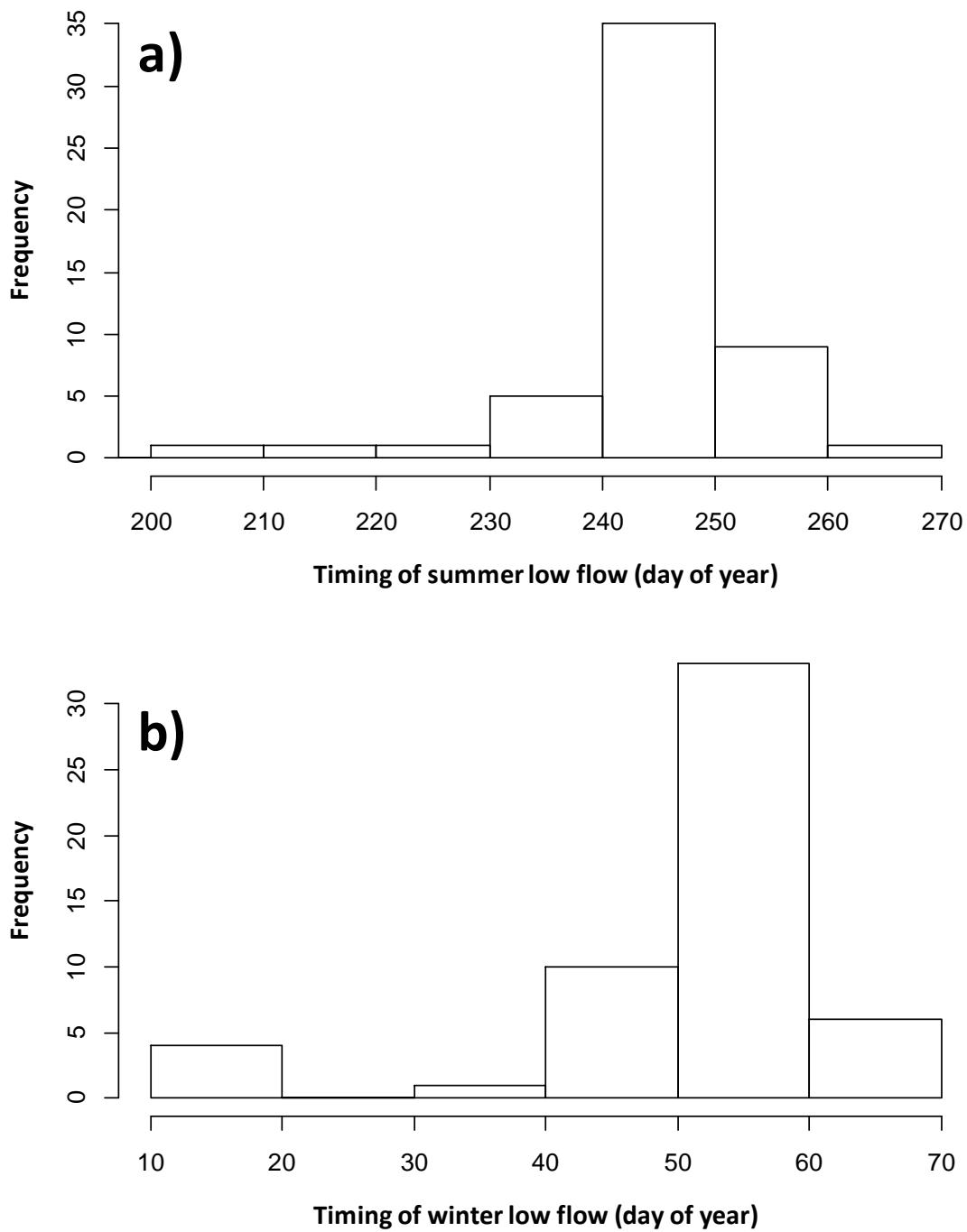


Figure 7. Results of summer and winter low flow timing (for a 30-day average flow condition) for all stations analyzed in New Brunswick

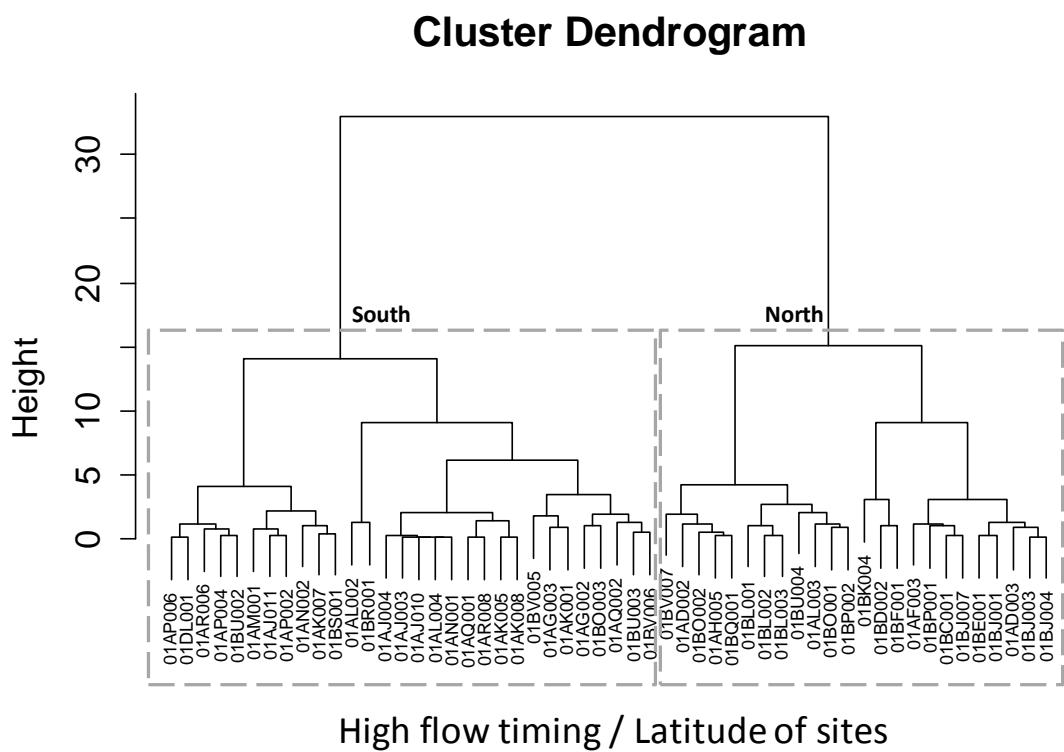


Figure 8. Results of a cluster analysis for the timing of spring high flow (30-day period) and latitude of each site in New Brunswick. Gray box identify two distinct groups, i.e. northern and southern rivers

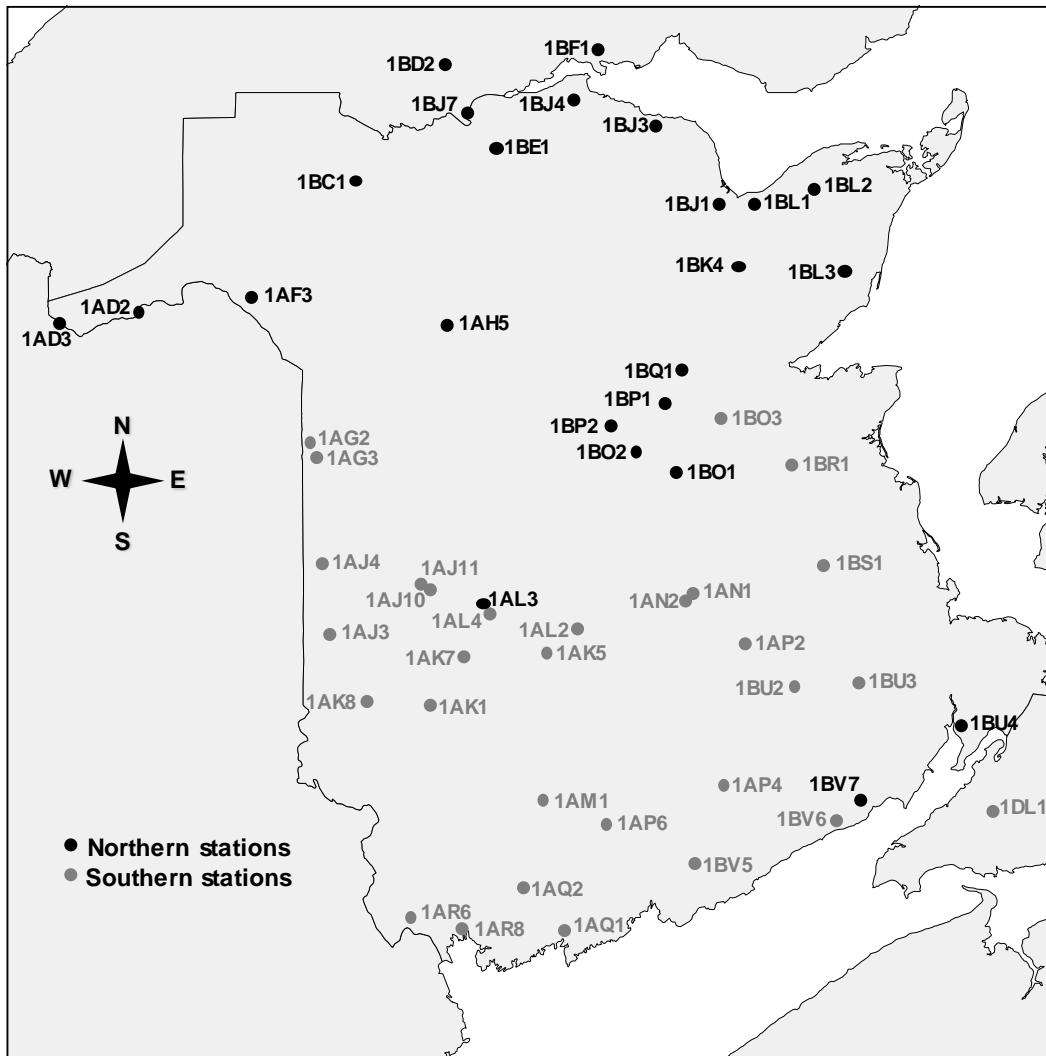


Figure 9. Location of stations within each group of the cluster analysis for the timing of spring high flow (30-day period) and latitude in New Brunswick

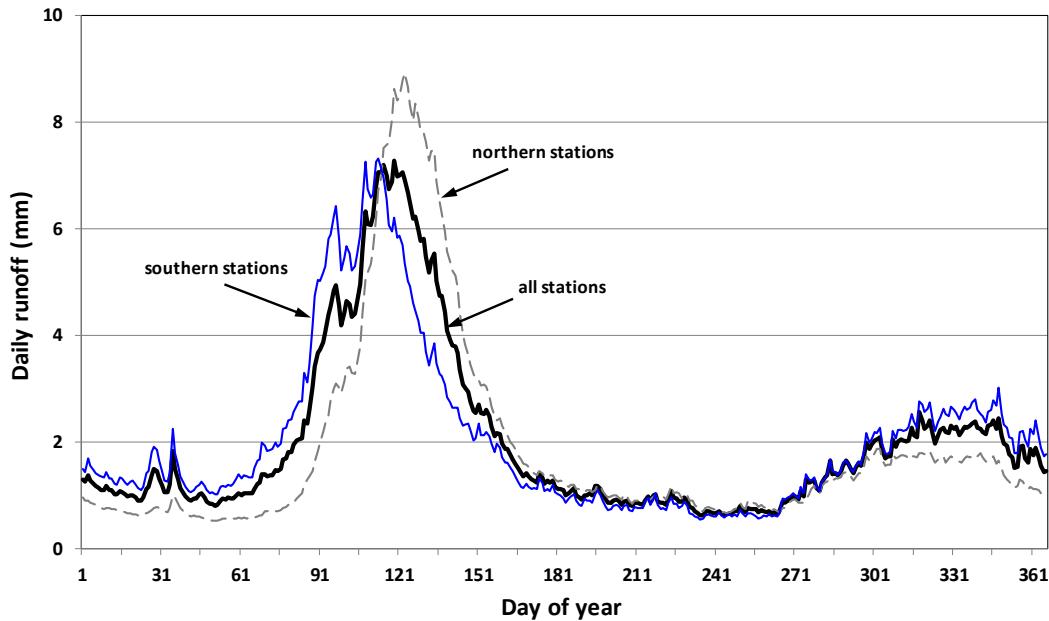


Figure 10. Average of daily runoff characteristics for northern and southern rivers identified in the cluster analysis. Darker black line represents the average of all stations in New Brunswick (i.e. same data as in Figure 5 above).

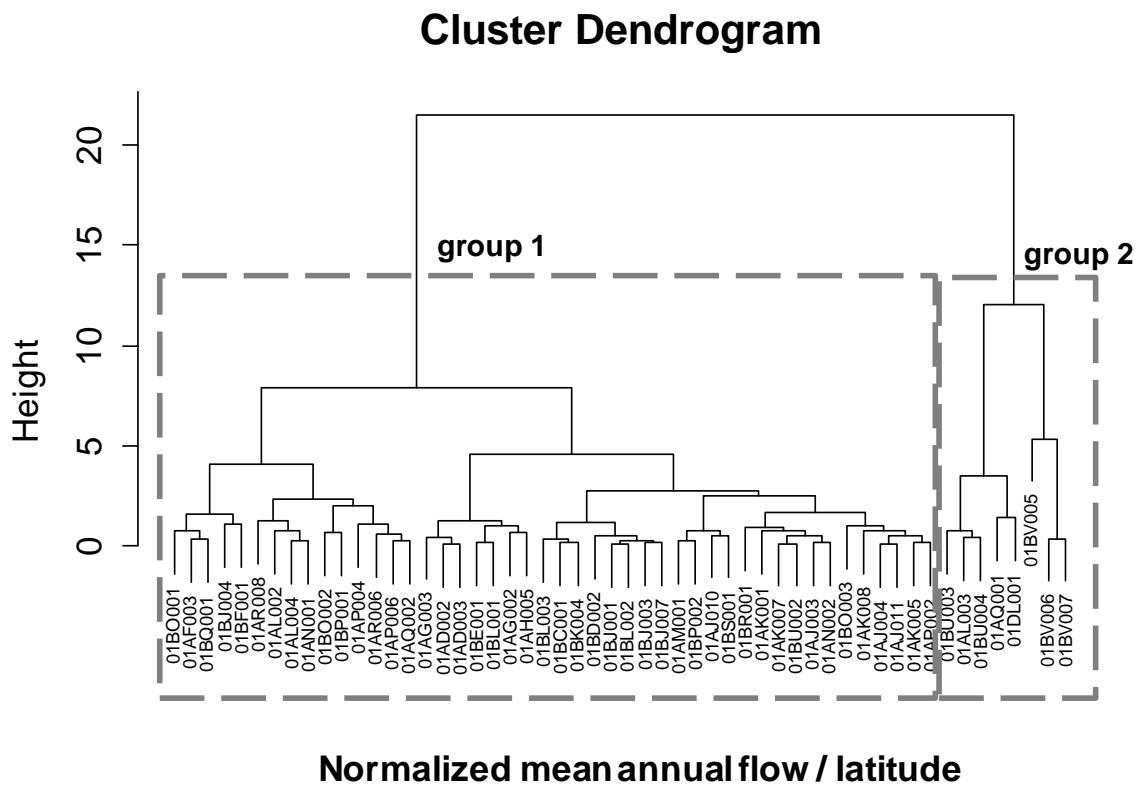


Figure 11. Results of a cluster analysis for the normalized mean annual flow ($\text{L s}^{-1} \text{ km}^{-2}$) and latitude for New Brunswick rivers

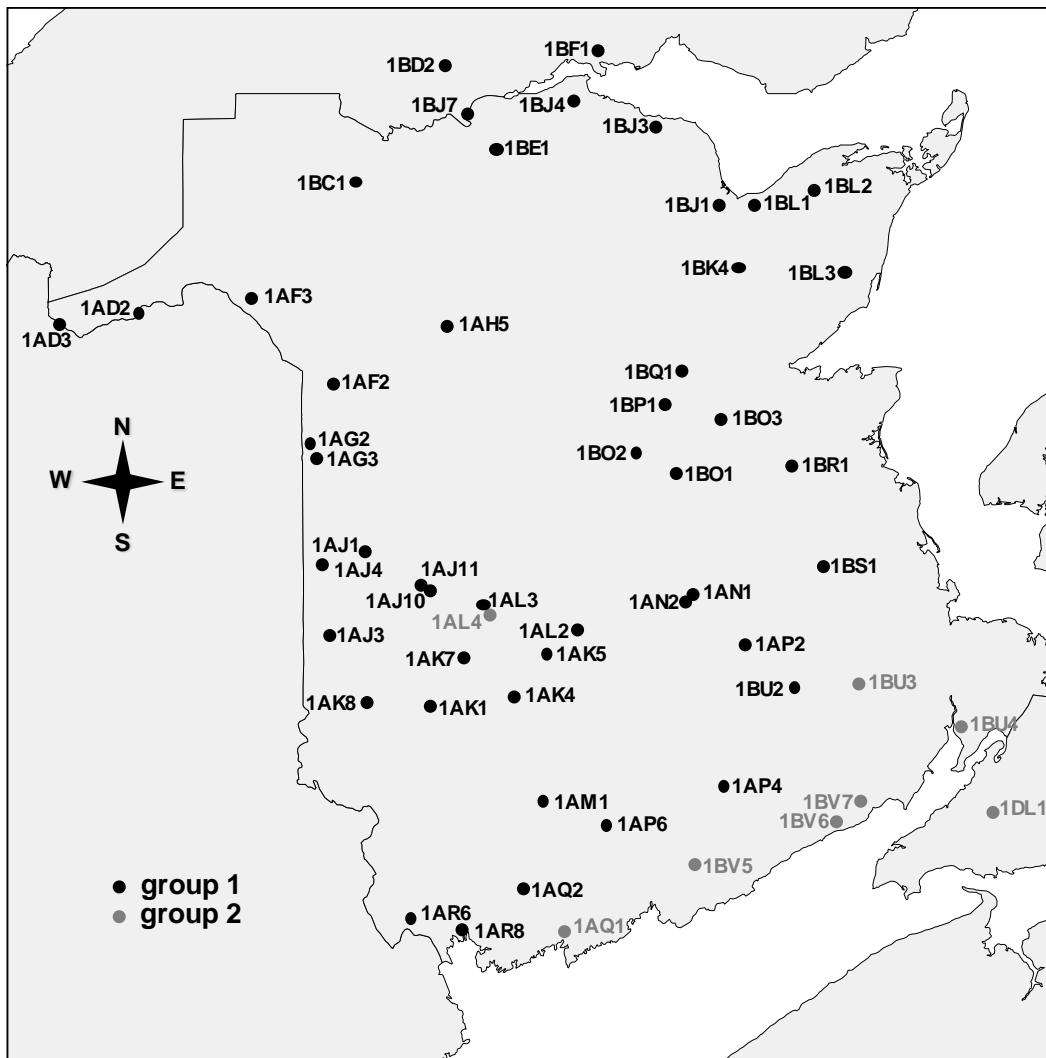


Figure 12. Location of stations within each group of the cluster analysis for the normalized mean annual flow ($\text{L s}^{-1} \text{ km}^{-2}$) and latitude for New Brunswick rivers

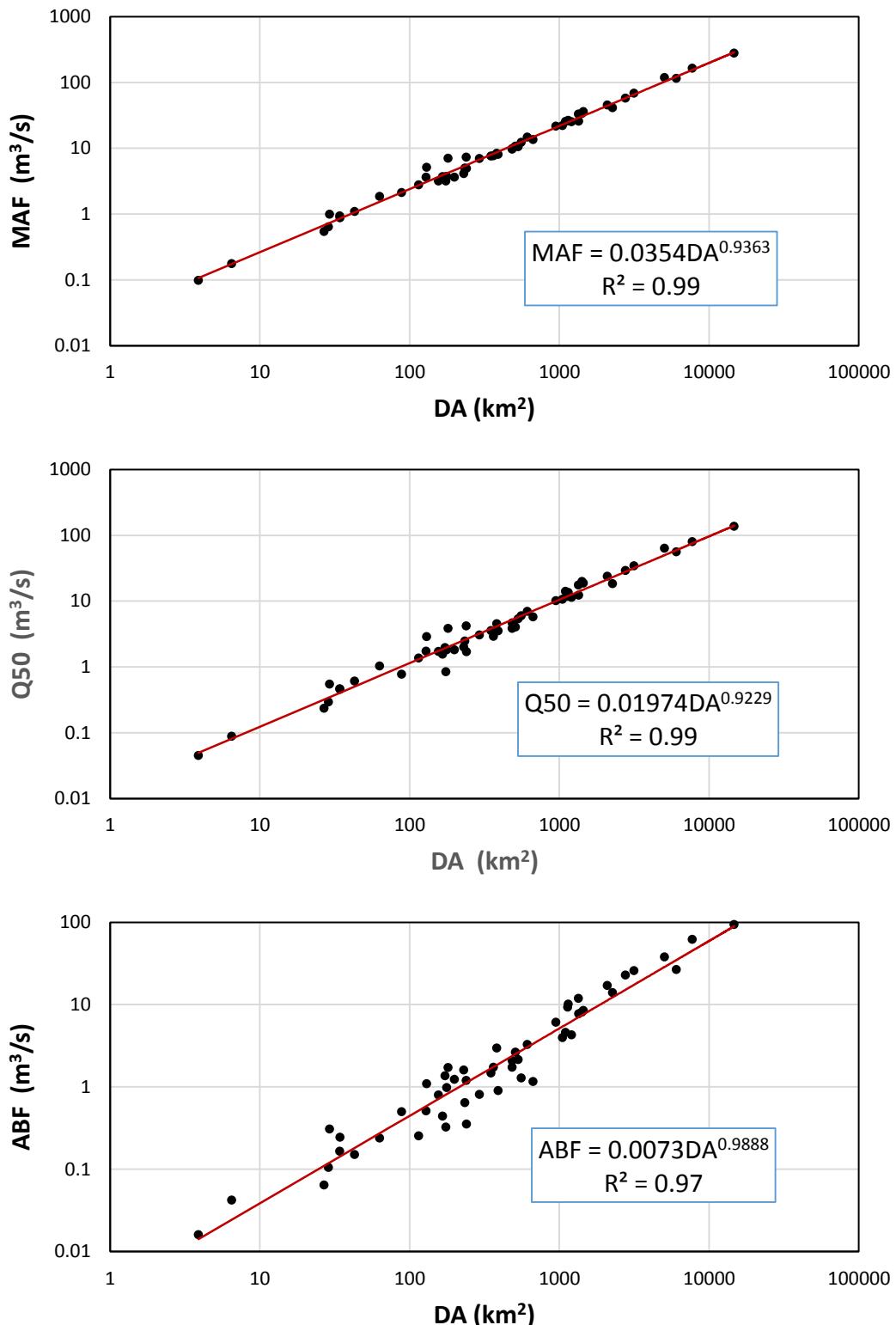


Figure 13. Regionalized flows for New Brunswick a) Mean annual flow (MAF)
b) Median flow (Q₅₀) c) ABF (Q₅₀ for August)

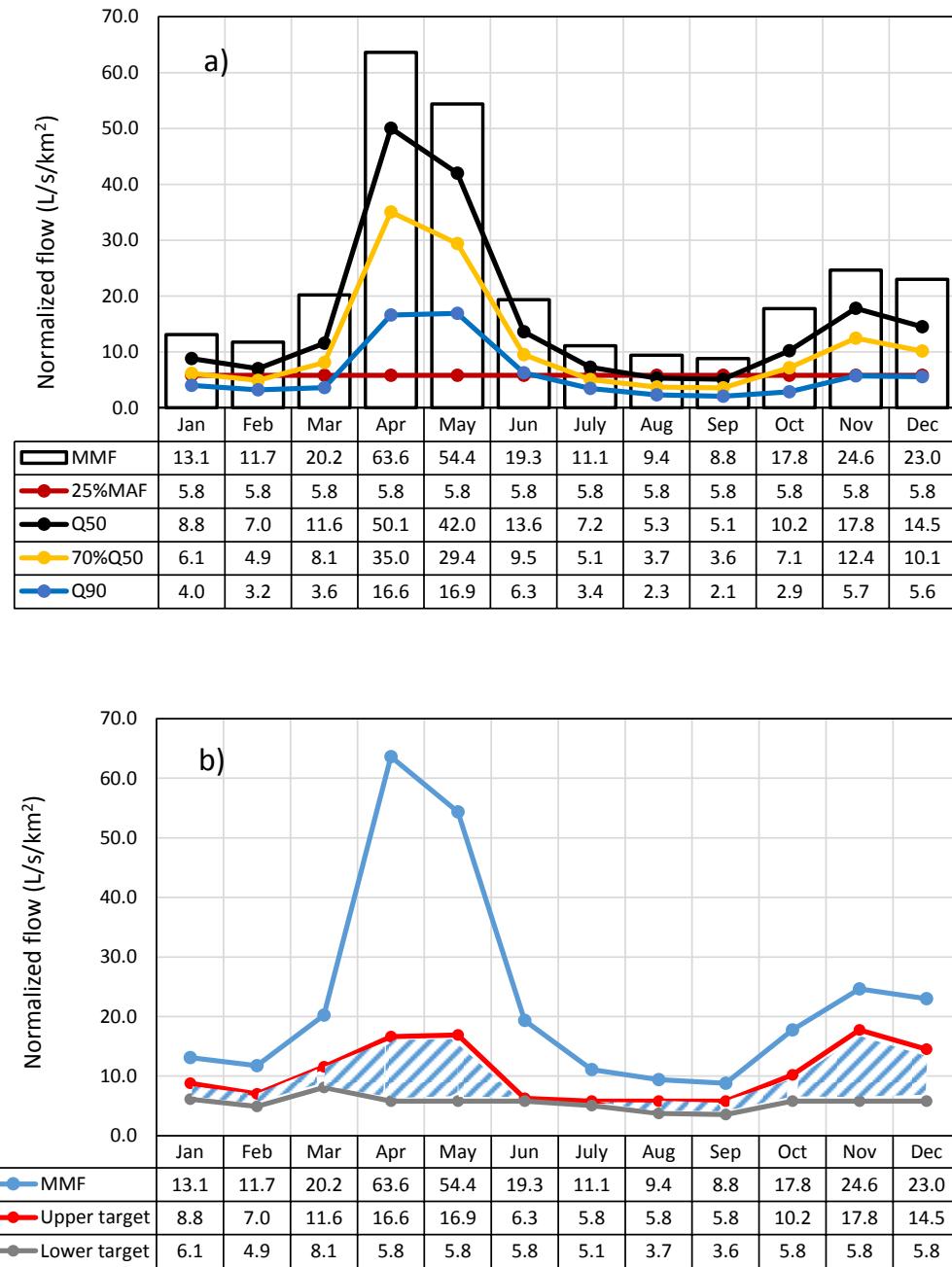


Figure 14. Mean monthly flows (MMF) and a) various environmental flows b) potential environmental flow target for New Brunswick

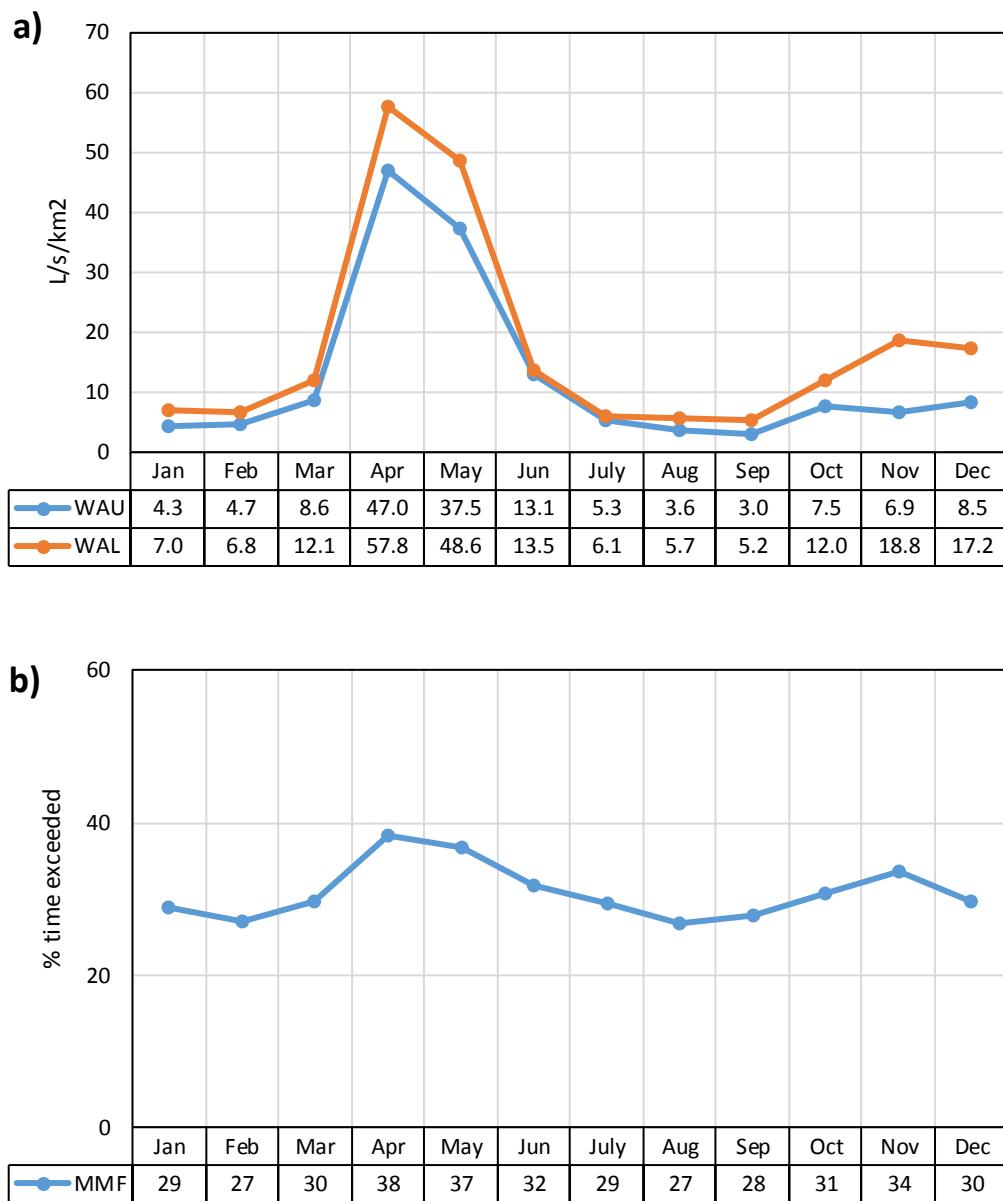


Figure 15. Normalized monthly flow water availability and the exceedance probability of mean monthly flow a) water availability b) occurrence of MMF

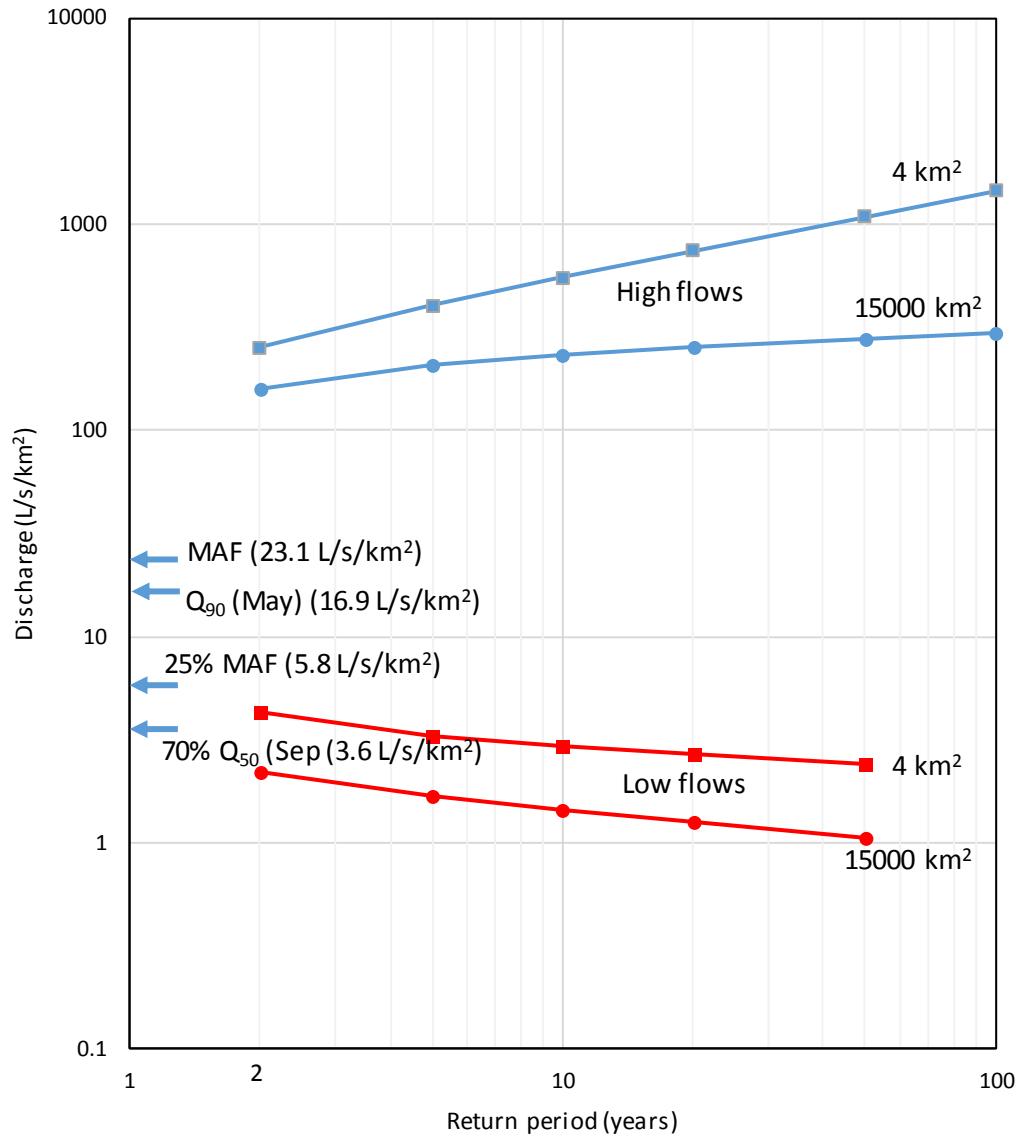


Figure 16. Summary of discharge regimes in New Brunswick

Figure B.38 : Southwest Miramichi River at Blackville (01BO001) (Continued)



Figure 17. Environmental flow fact sheet for Southwest Miramichi River at Blackville

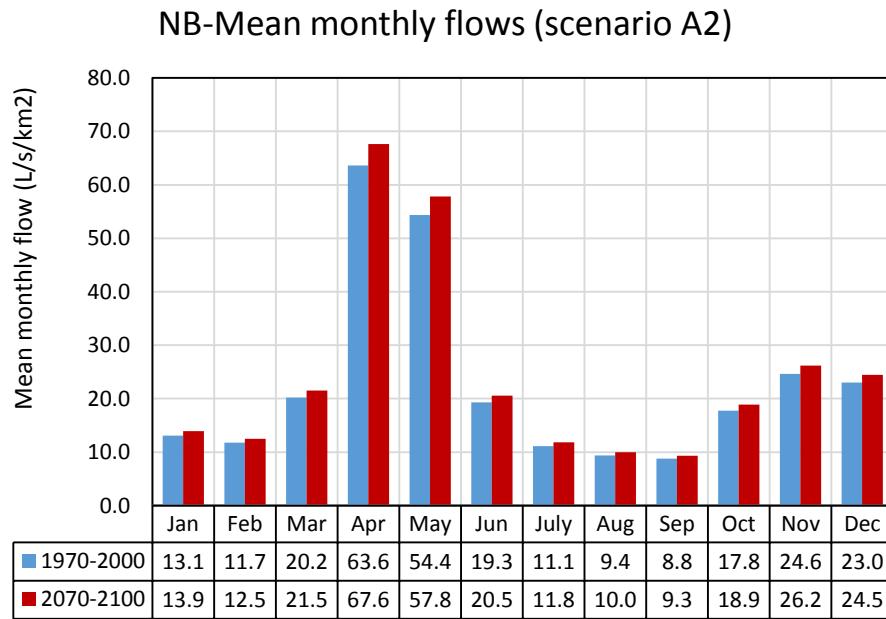
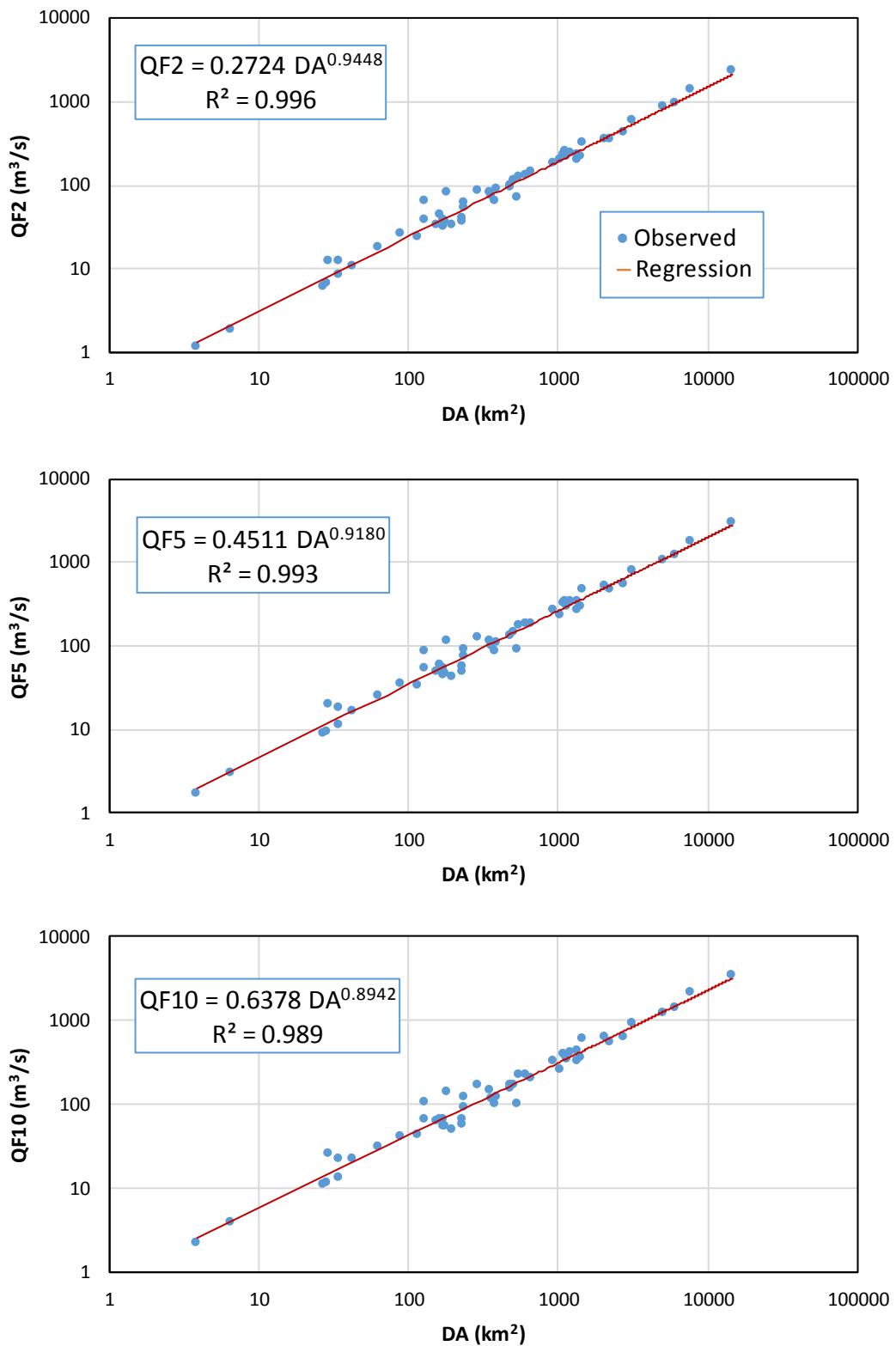


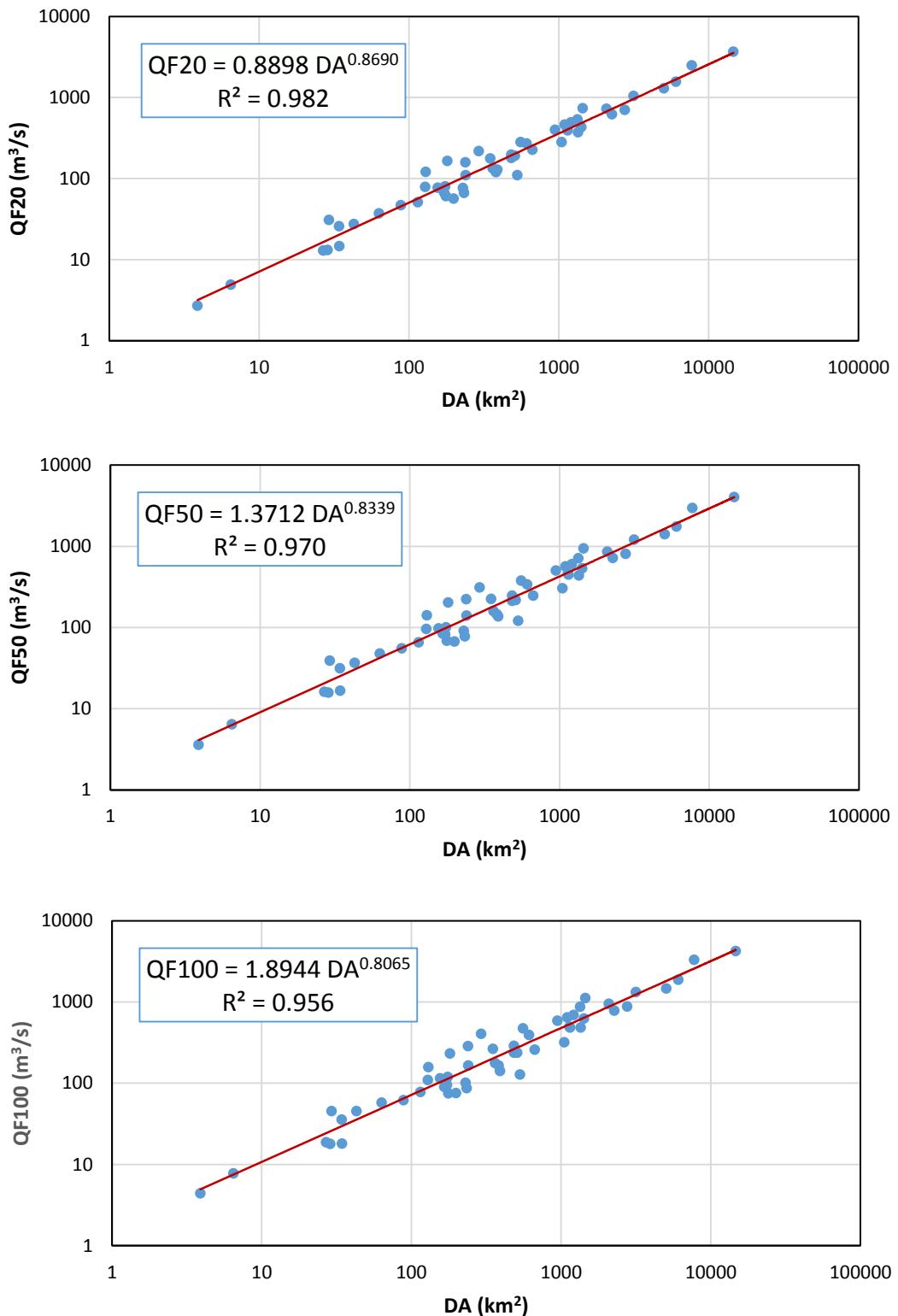
Figure 18. New Brunswick mean monthly flows using climate change scenario A2

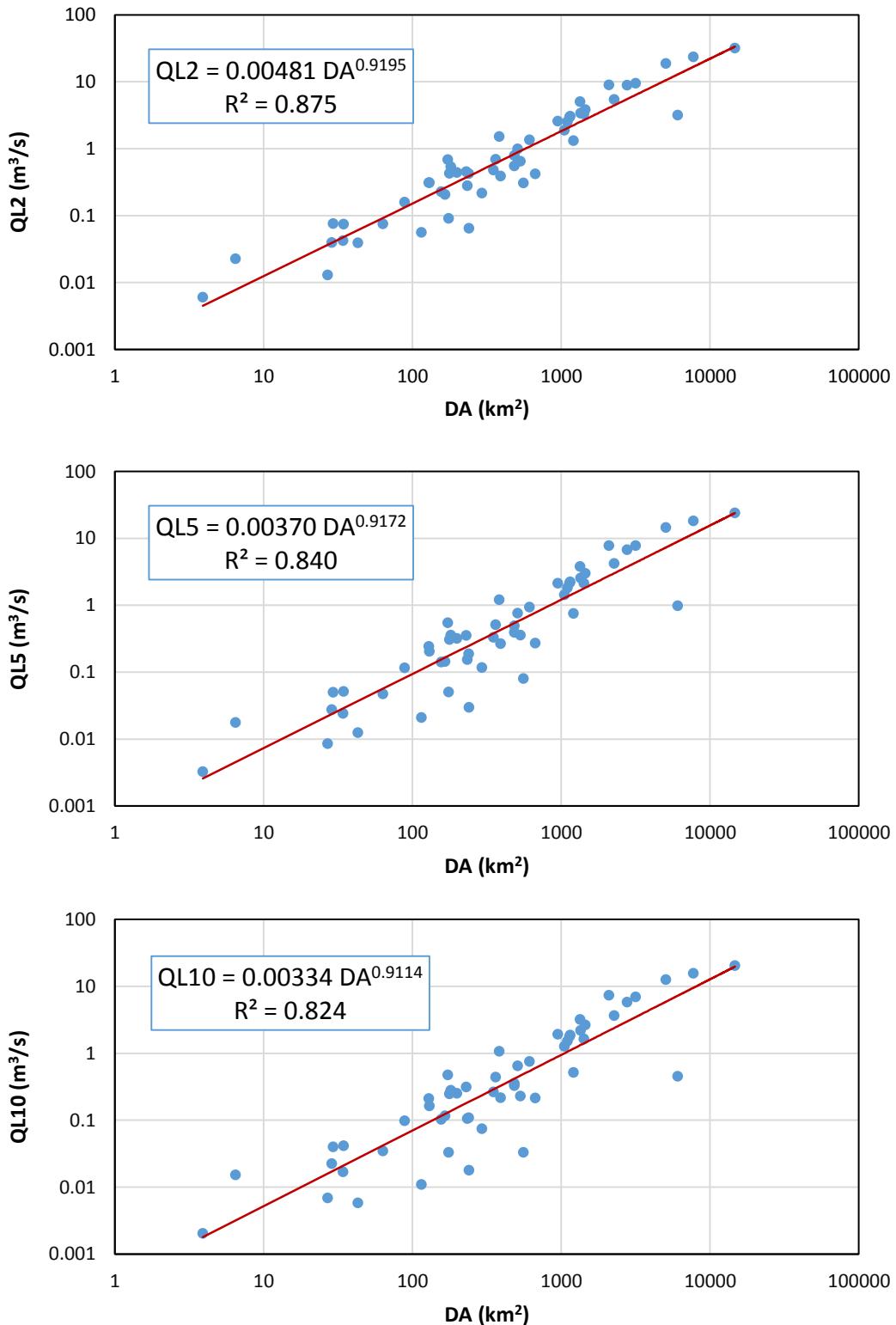
APPENDIX A

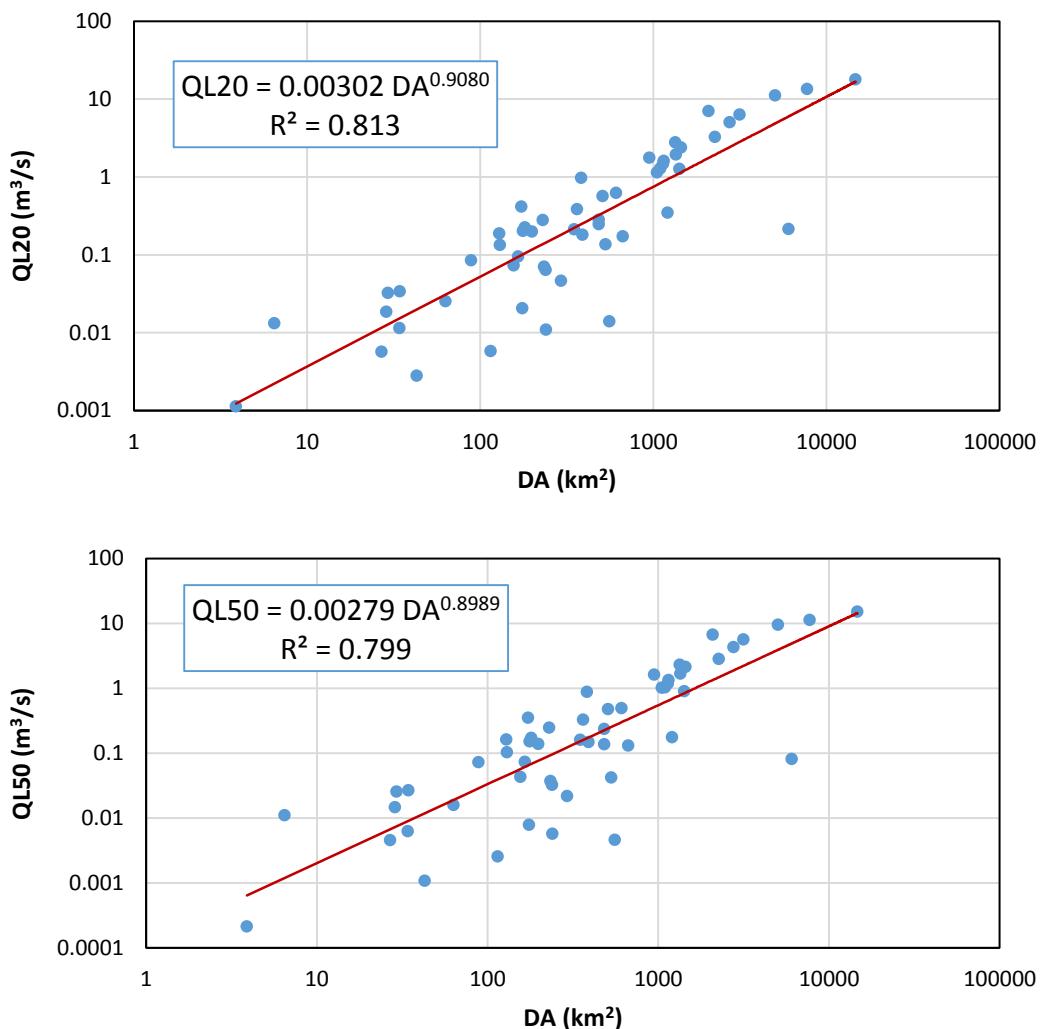
Regional discharge vs drainage area curves for New Brunswick

- **High flow (QF2, QF5, QF10, QF20, QF50, QF100)**
- **Low flow (QL2, QL5, QL10, QL20, QL50)**









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APPENDIX B

Fact-sheets by station in New Brunswick

Flow characteristics

- **Flow duration curve**
- **Monthly discharge**
- **Flood frequency curve**
- **Drought frequency curve**

Environmental flows

- **Mean monthly flows**
- **Environmental flow targets**
- **Water availability**
- **Occurrence of MMF**

Figure B.1 : Saint Johhn River at Fort Kent (01AD002)

Station ID	01AD002	Mean annual flow (MAF)	279.2 m ³ /s
Latitude	47°15'29" N	Median annual flow (Q ₅₀)	136 m ³ /s
Longitude	68°35'45" W	Q ₅₀ (Aug)	94 m ³ /s
Drainage area	14700 km ²	70%Q ₅₀ (Aug)	65.8 m ³ /s
Period of record	1927-2012 (86 years)	Q ₉₀ (Aug)	37.7 m ³ /s

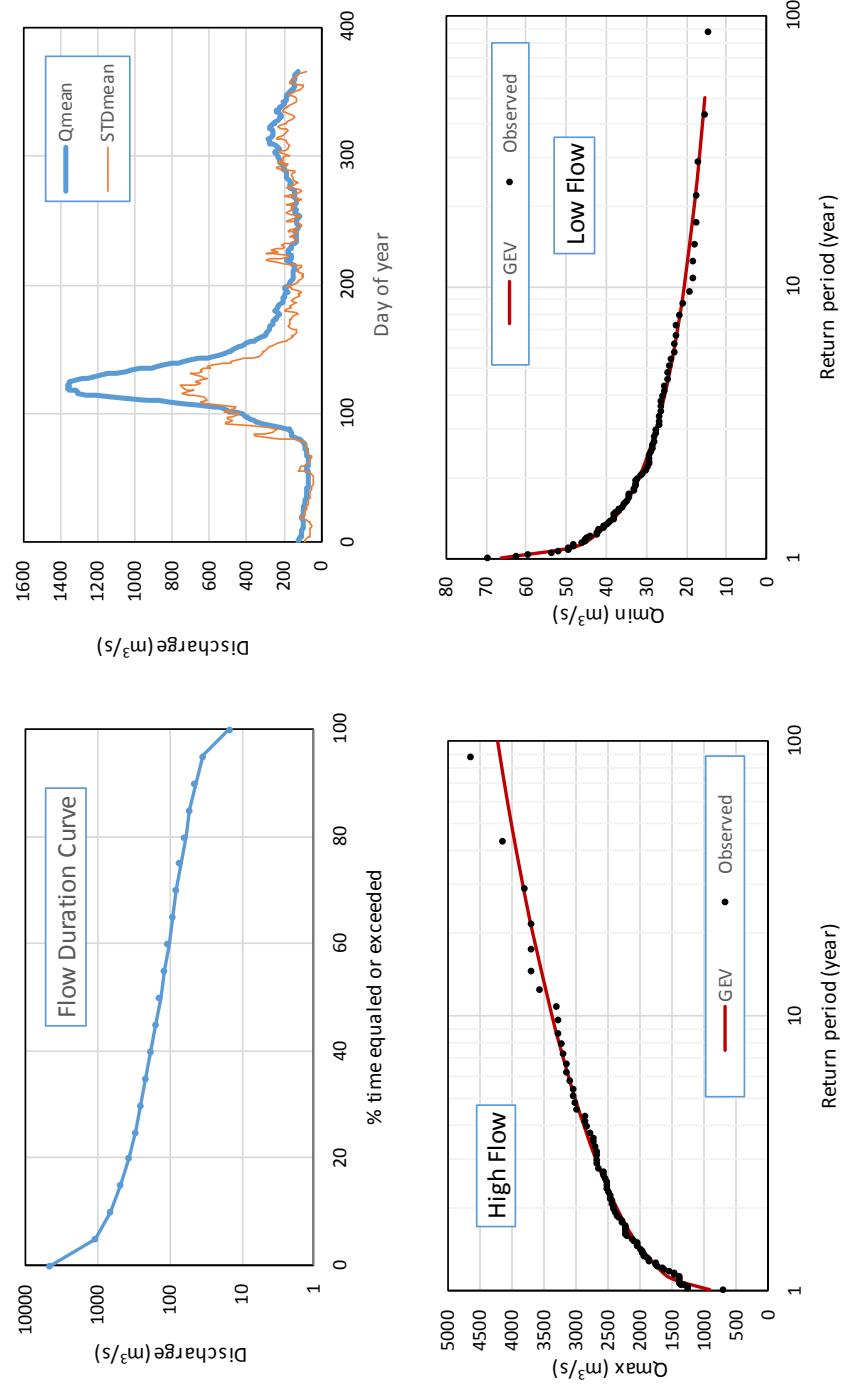


Figure B.1 : Saint Johnn River at Fort Kent (01AD002) (Continued)

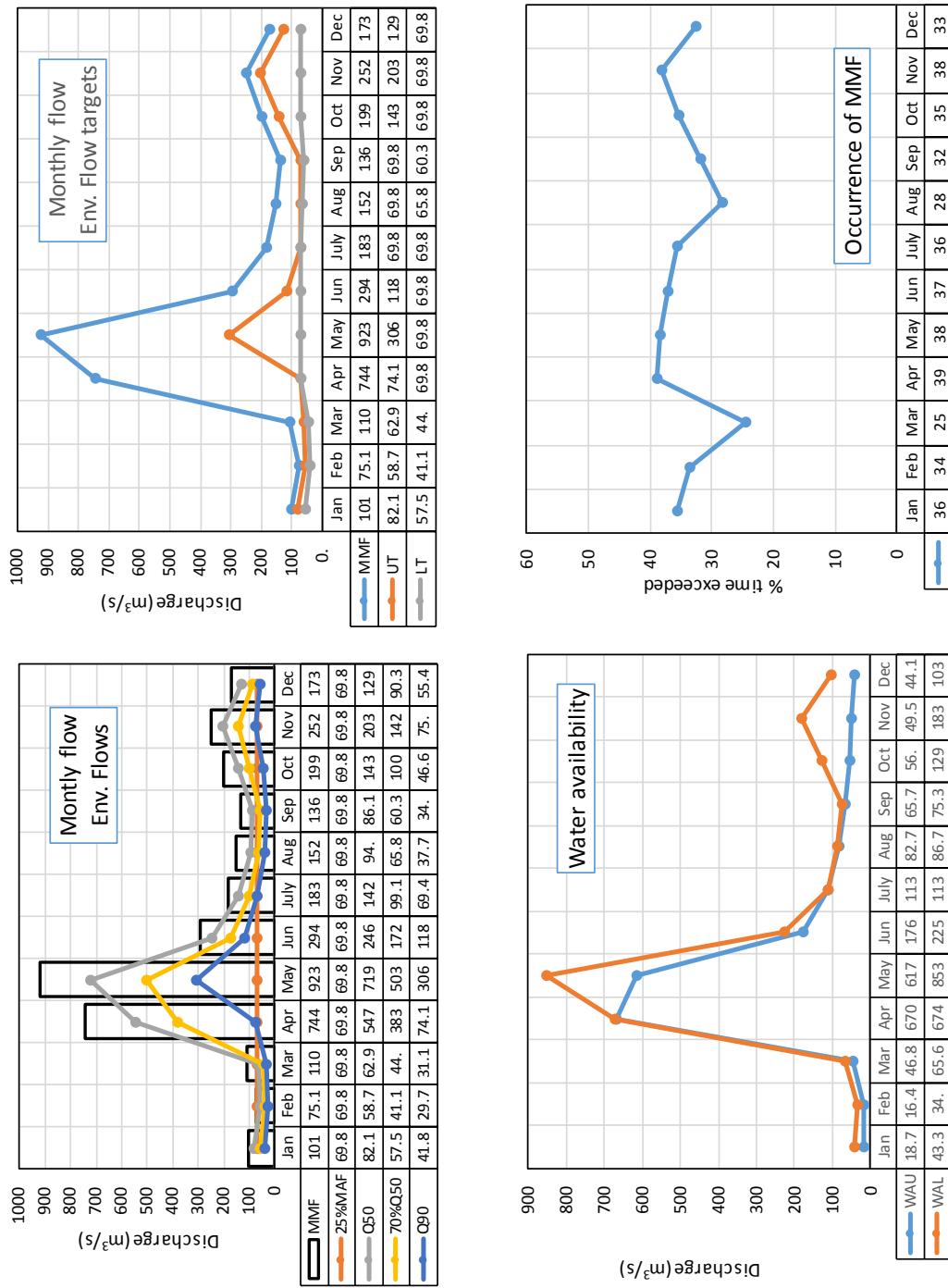


Figure B.2 : Saint Francis River at outlet of Glasier Lake (01AD003)

Station ID	01AD003	Mean annual flow (MAF)	25.6 m ³ /s
Latitude	47°12'23" N	Median annual flow (Q ₅₀)	12.3 m ³ /s
Longitude	68°57'20" W	Q ₅₀ (Aug)	7.71 m ³ /s
Drainage area	1350 km ²	70%Q ₅₀ (Aug)	5.397 m ³ /s
Period of record	1952-2012 (61 years)	Q ₉₀ (Aug)	3.26 m ³ /s

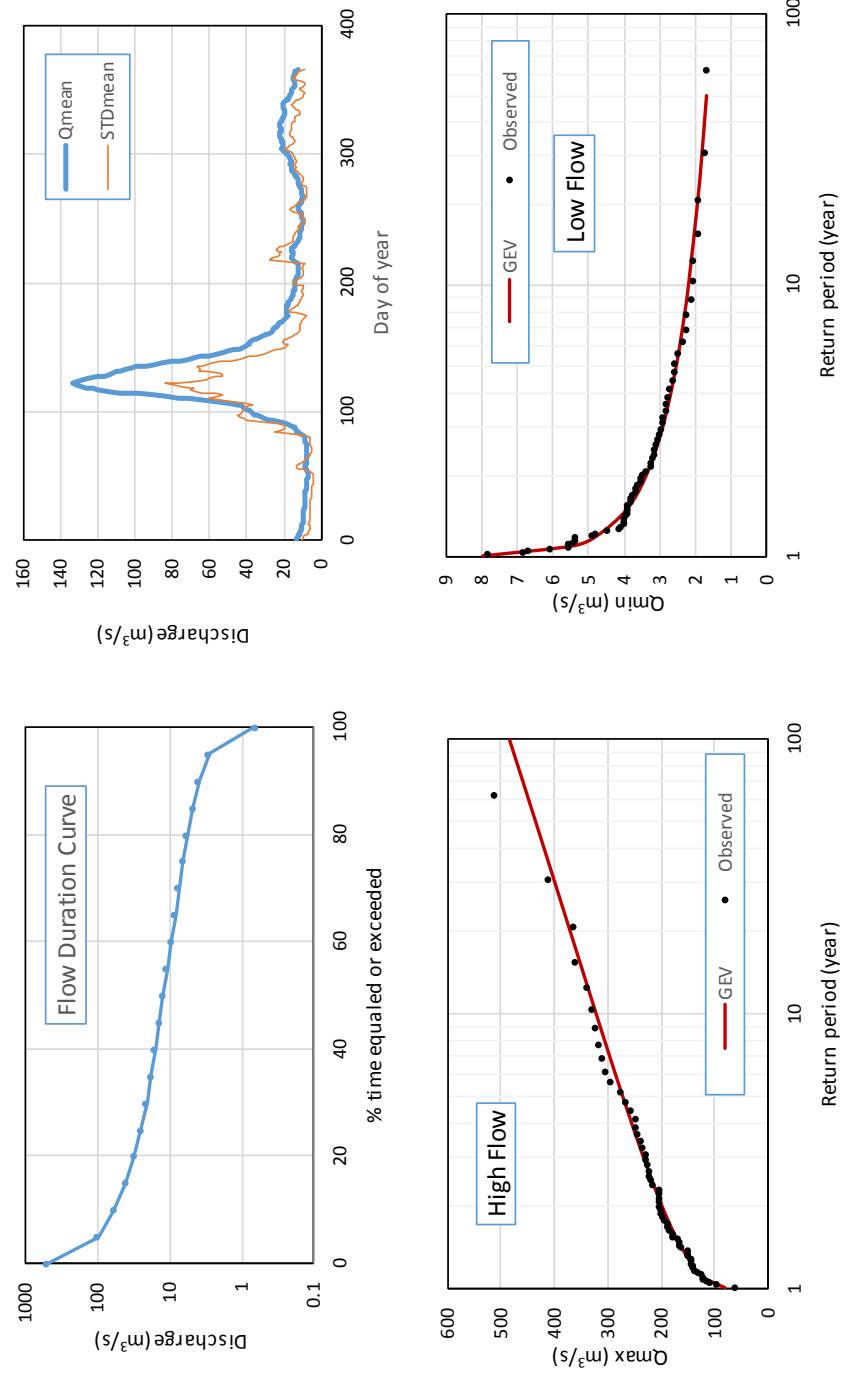


Figure B.2 : Saint Francis River at outlet of Glacier Lake (01AD003) (Continued)

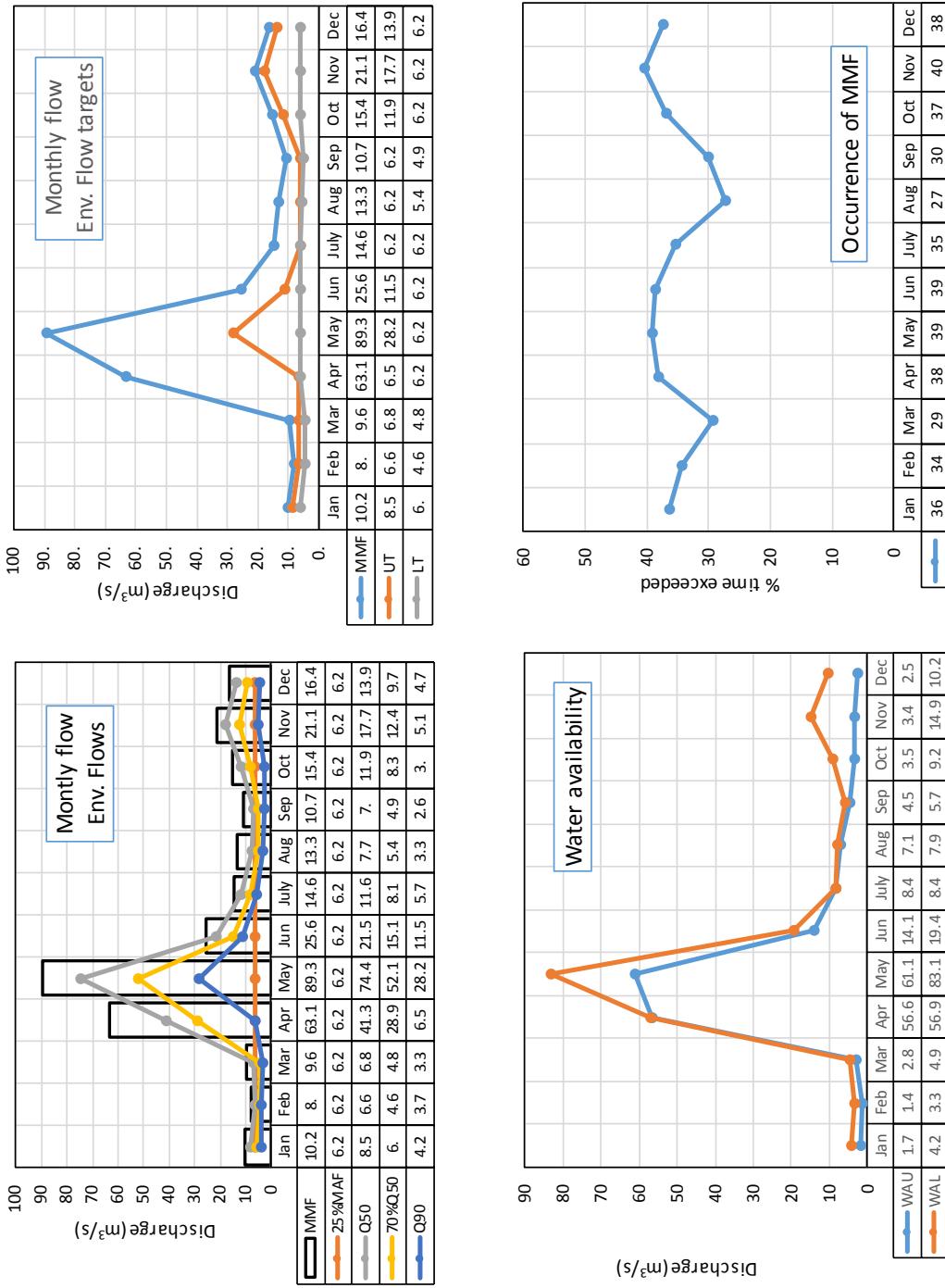


Figure B.3 : Green River near Rivière-Verte (01AF003)

Station ID	01AF003	Mean annual flow (MAF)	26.4 m ³ /s
Latitude	47°20'06" N	Median annual flow (Q ₅₀)	13.5 m ³ /s
Longitude	68°08'06" W	Q ₅₀ (Aug)	10.1 m ³ /s
Drainage area	1150 km ²	70%Q ₅₀ (Aug)	7.07 m ³ /s
Period of record	1963-79,1981-1993 (30 years)	Q ₉₀ (Aug)	5.237 m ³ /s

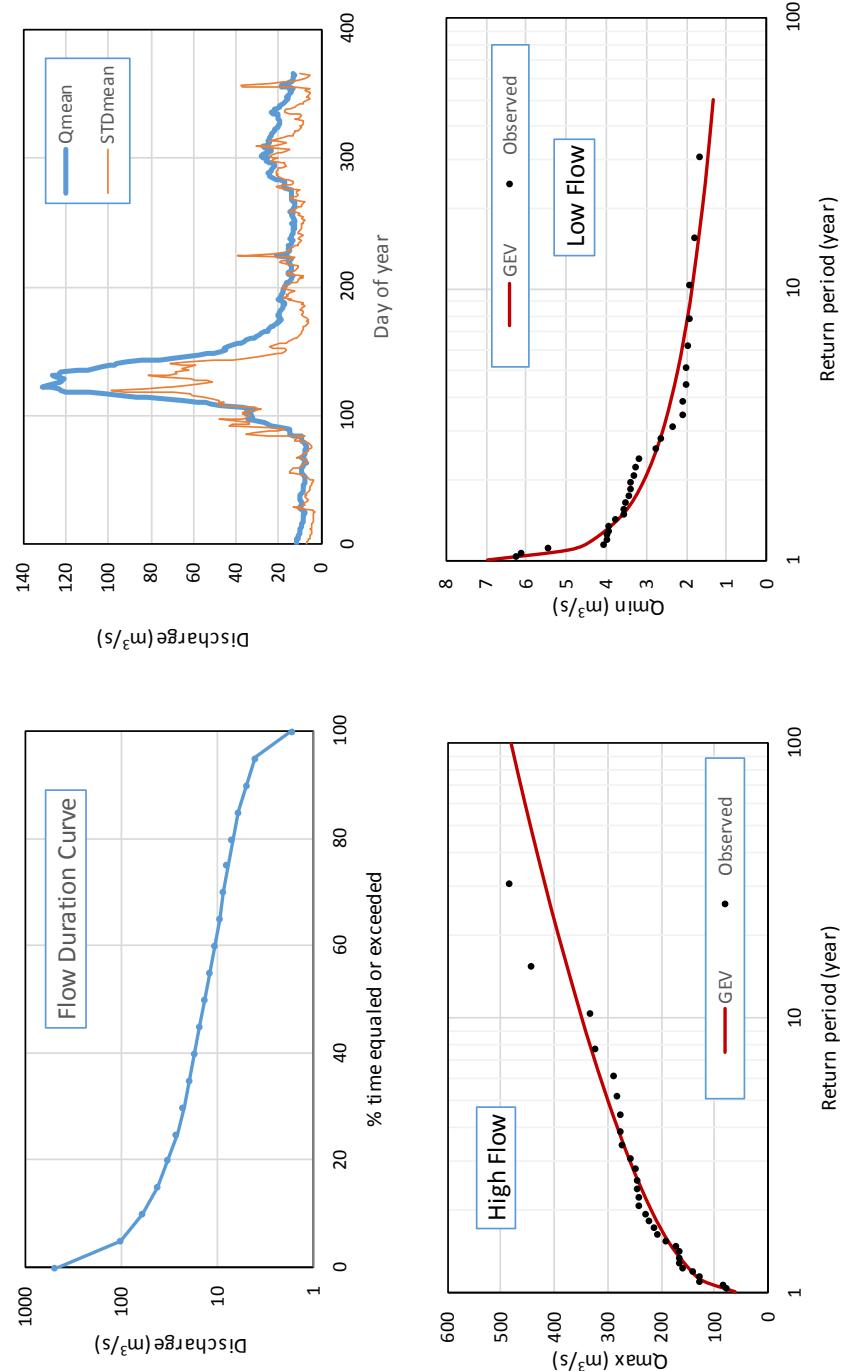


Figure B.3 : Green River near Riviere-Verte (01AF003) (Continued)

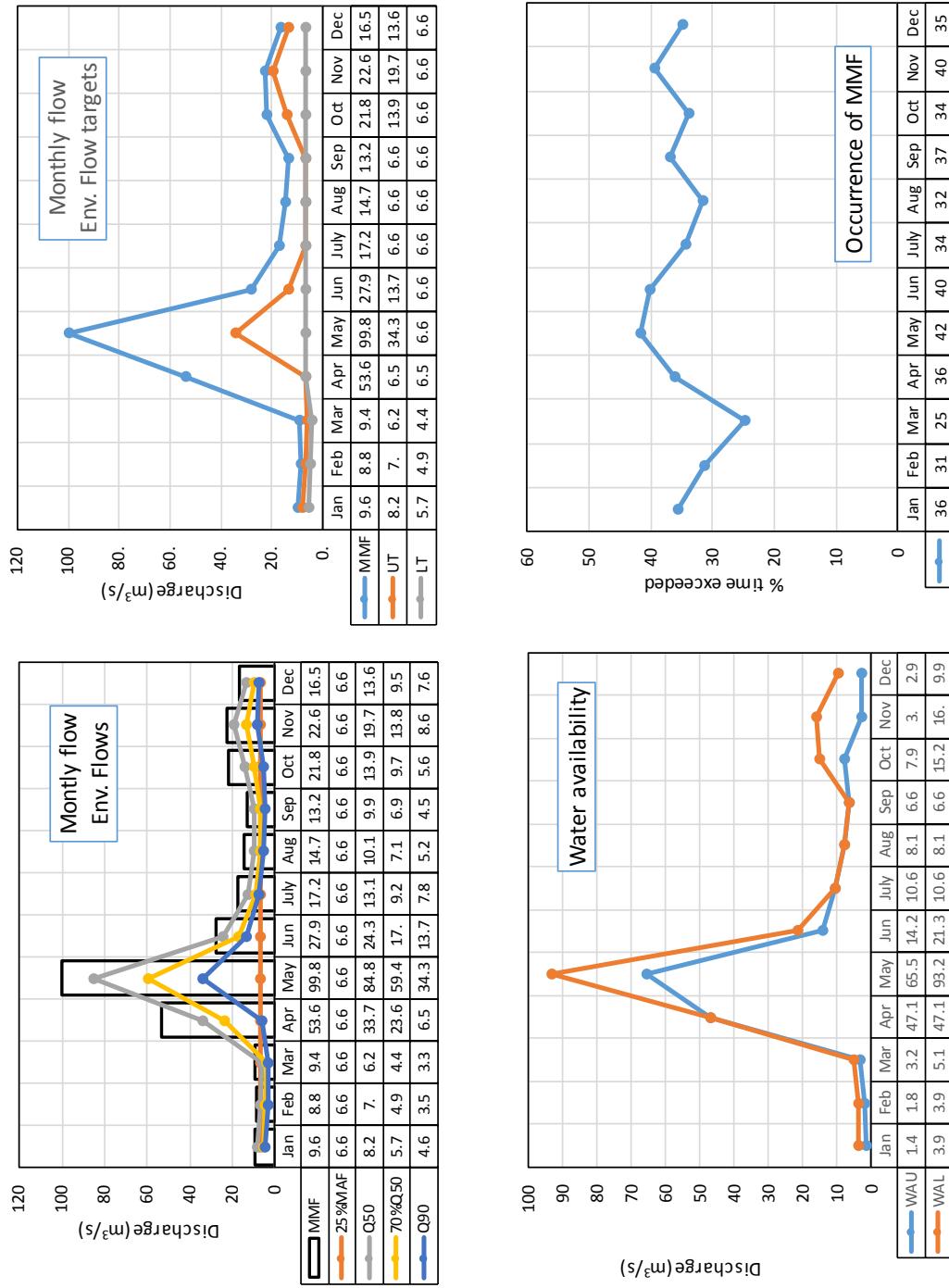


Figure B.4 : Limestone River at Four Falls (01AG002)

Station ID	01AG002	Mean annual flow (MAF)	3.64 m ³ /s
Latitude	46°49'42" N	Median annual flow (Q ₅₀)	1.82 m ³ /s
Longitude	67°44'35" W	Q ₅₀ (Aug)	1.23 m ³ /s
Drainage area	199 km ²	70%Q ₅₀ (Aug)	0.861 m ³ /s
Period of record	1968-1993 (26 years)	Q ₉₀ (Aug)	0.599 m ³ /s

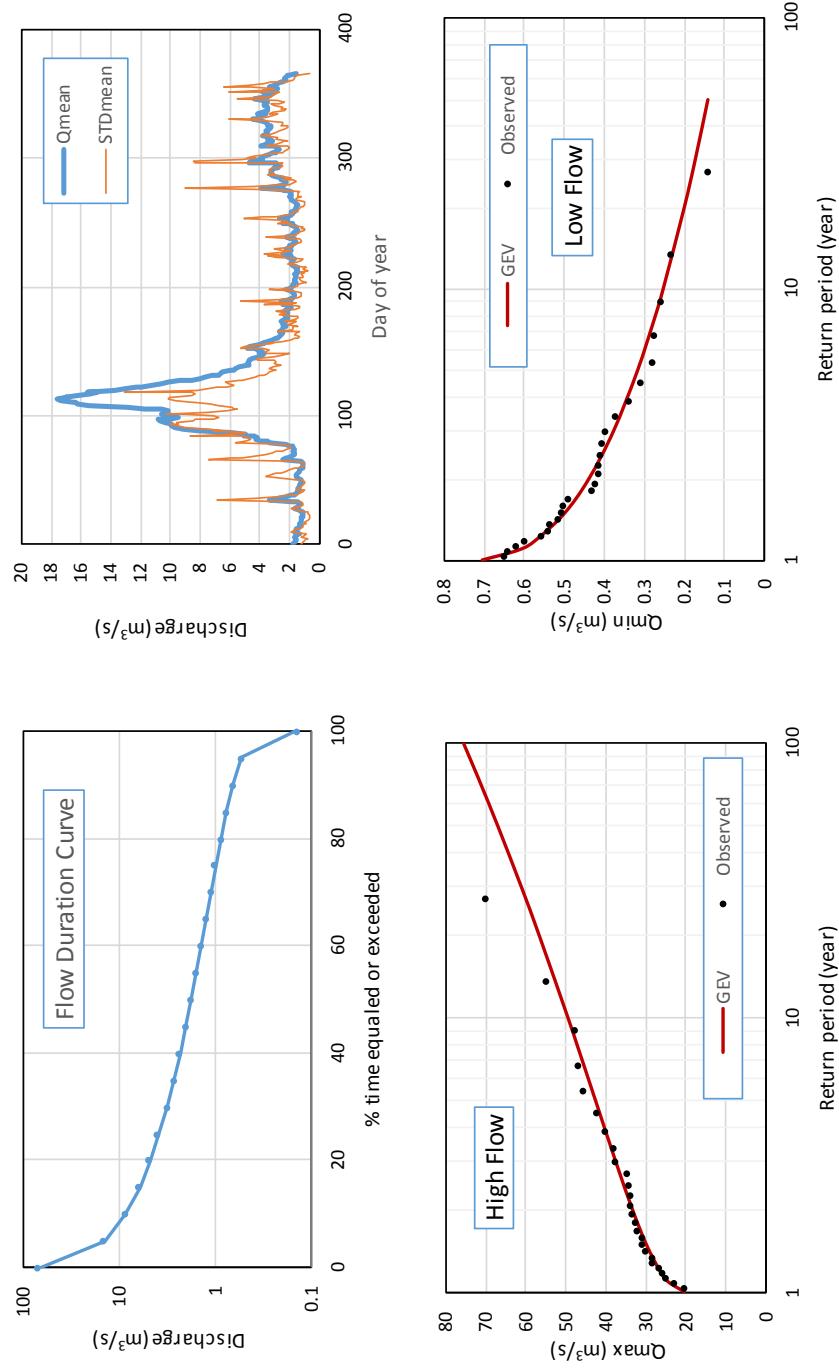


Figure B.4 : Limestone River at Four Falls (01AG002) (Continued)

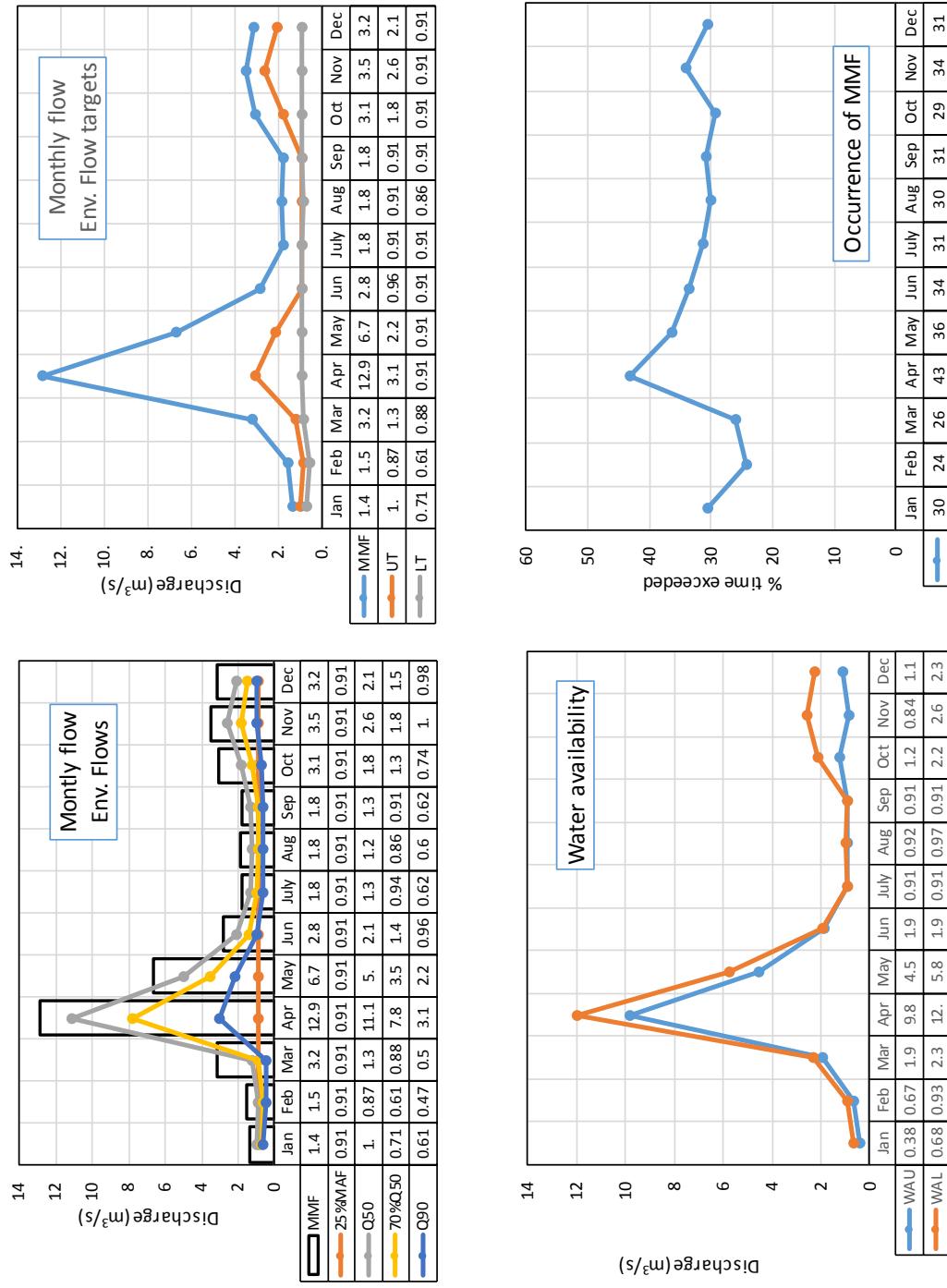


Figure B.5 : Aroostook River near Tinker (01AG003)

Station ID	01AG003	Mean annual flow (MAF)	114.4 m ³ /s
Latitude	46°48'58" N	Median annual flow (Q ₅₀)	55.9 m ³ /s
Longitude	67°45'07" W	Q ₅₀ (Aug)	26.7 m ³ /s
Drainage area	6060 km ²	70%Q ₅₀ (Aug)	18.69 m ³ /s
Period of record	1975-2010 (36 years)	Q ₉₀ (Aug)	9.59 m ³ /s

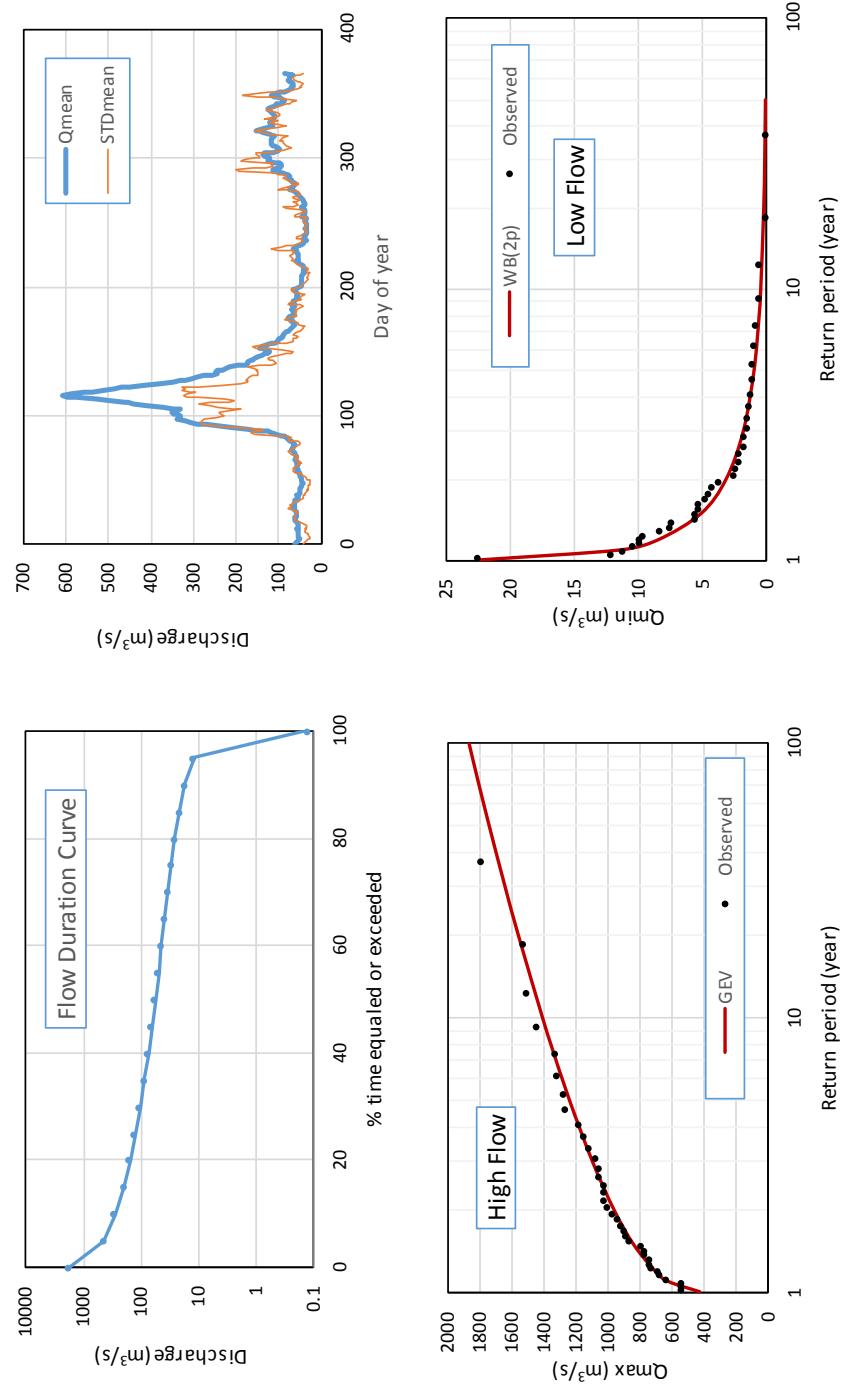


Figure B.5 : Aroostook River near Tinker (01AG003) (Continued)

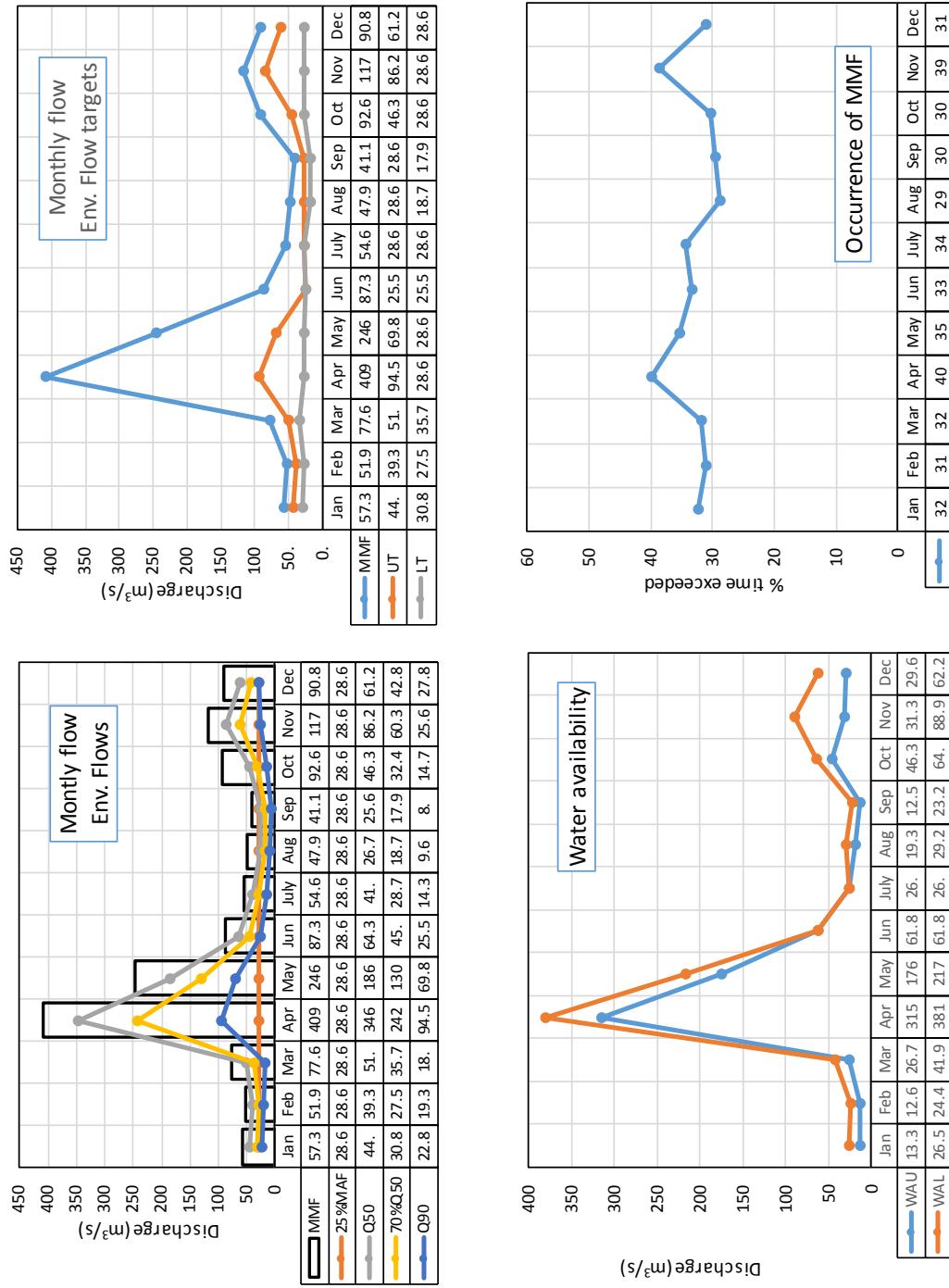


Figure B.6 : Mamozekek River near Campbell River (01AH005)

Station ID	01AH005	Mean annual flow (MAF)	4.1 m ³ /s
Latitude	47°15'03" N	Median annual flow (Q ₅₀)	2 m ³ /s
Longitude	67°08'32" W	Q ₅₀ (Aug)	1.6 m ³ /s
Drainage area	230 km ²	70%Q ₅₀ (Aug)	1.12 m ³ /s
Period of record	1973-1990 (18 years)	Q ₉₀ (Aug)	0.7091 m ³ /s

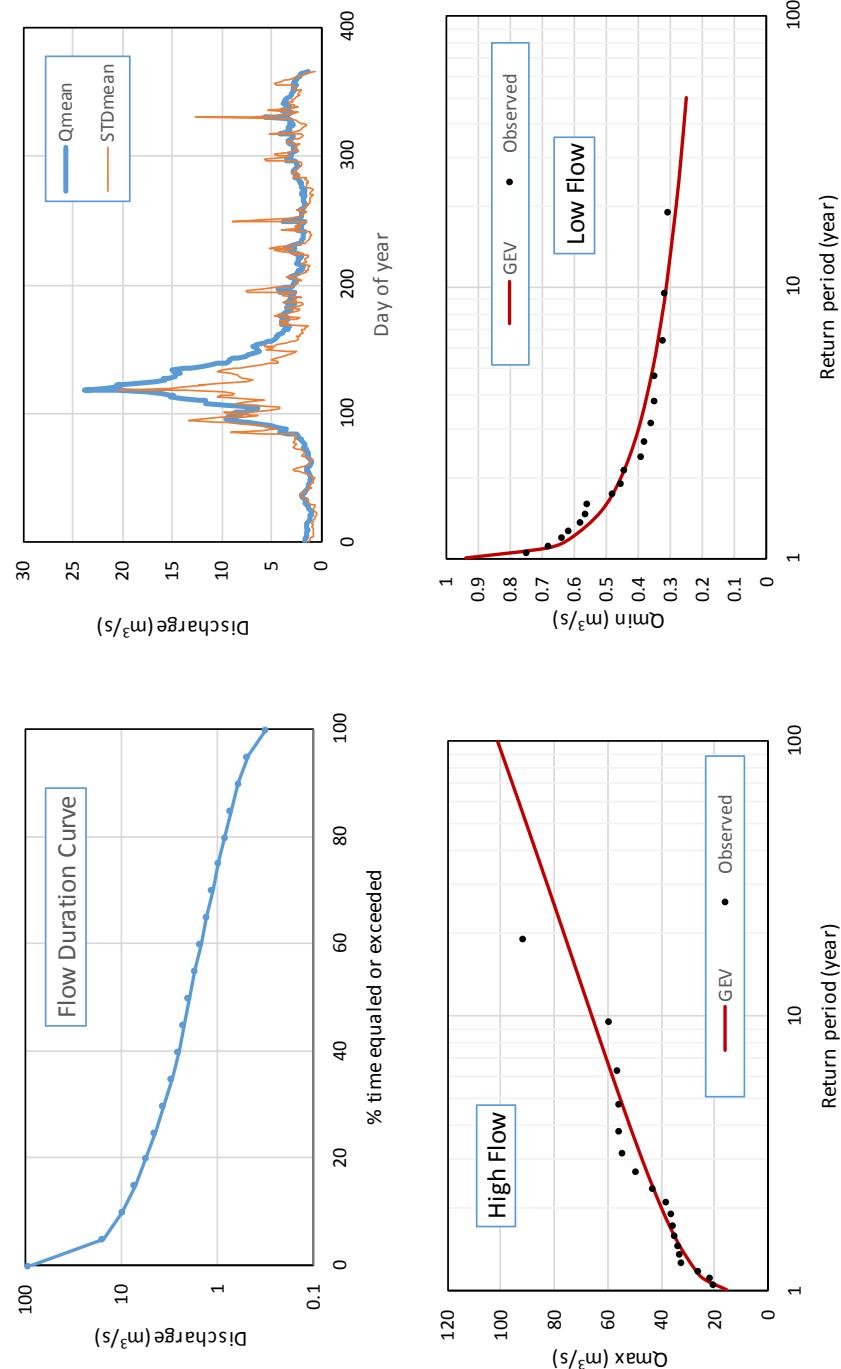


Figure B.6 : Mamozekek River near Campbell River (01AH005) (Continued)

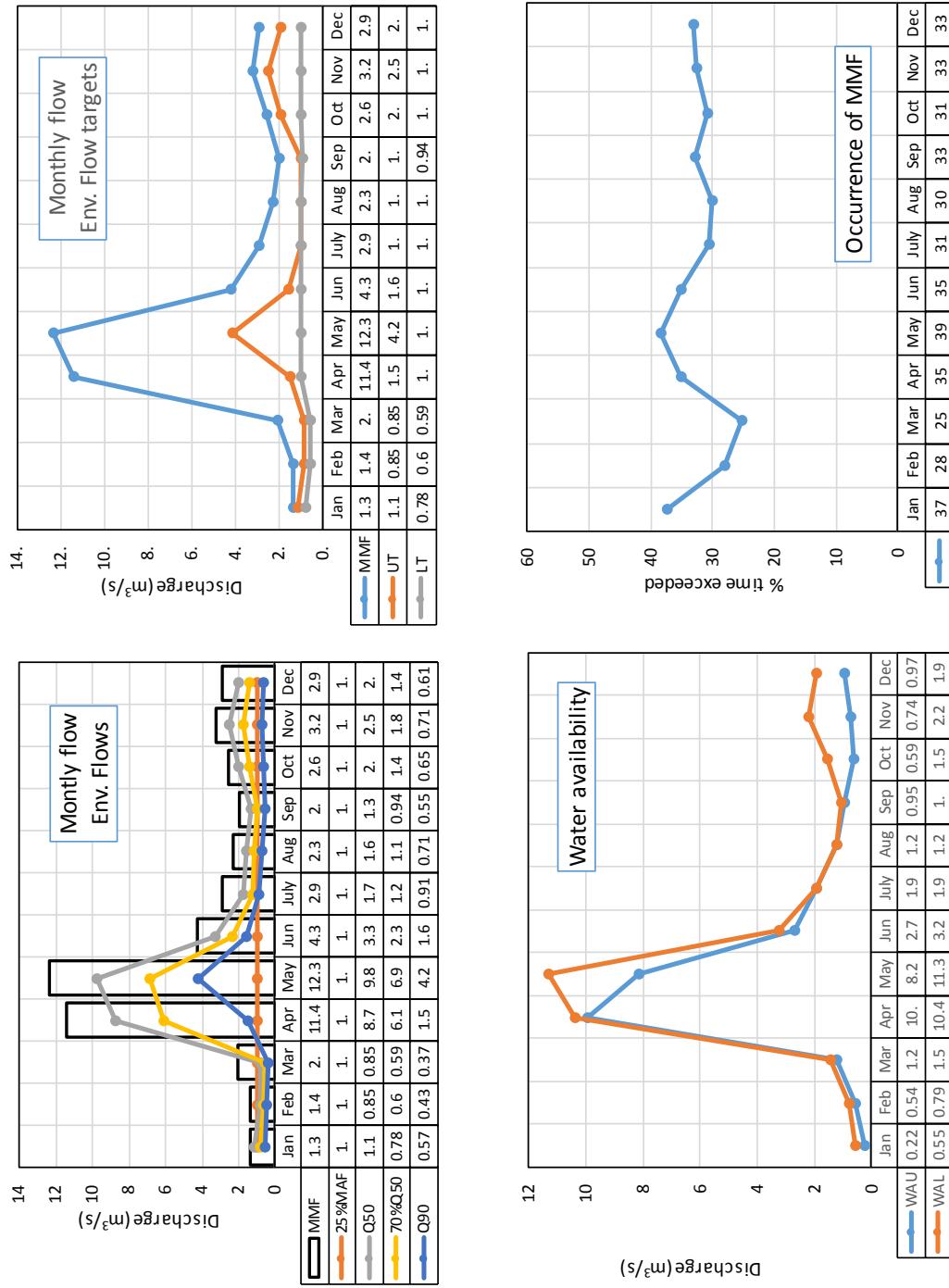


Figure B.7 : Meduxnekeag River near Belleville (01AJ003)

Station ID	01AJ003	Mean annual flow (MAF)	25.2 m ³ /s
Latitude	46°12'58" N	Median annual flow (Q ₅₀)	11.4 m ³ /s
Longitude	67°43'40" W	Q ₅₀ (Aug)	4.28 m ³ /s
Drainage area	1210 km ²	70%Q ₅₀ (Aug)	2.996 m ³ /s
Period of record	1968-2010 (43 years)	Q ₉₀ (Aug)	1.06 m ³ /s

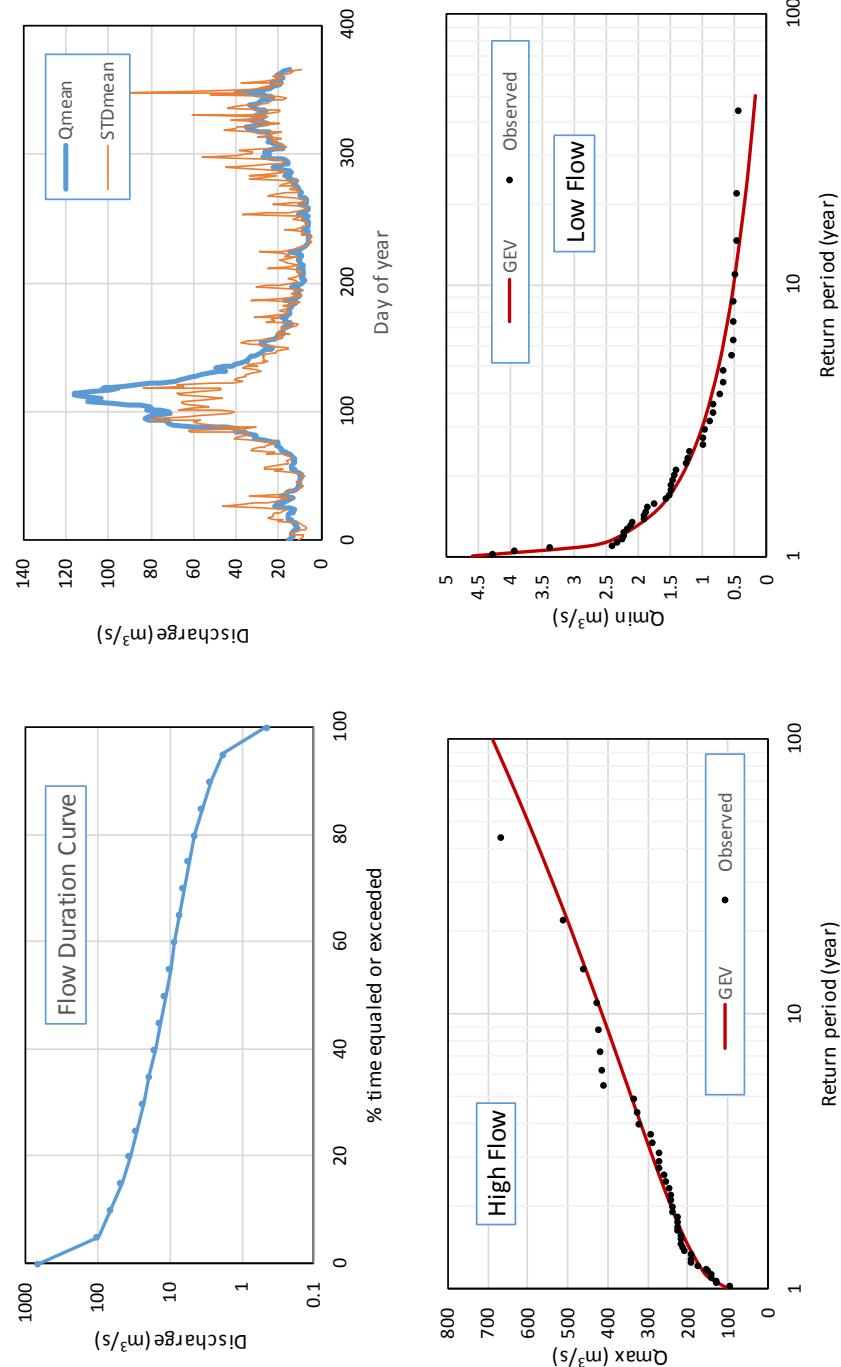


Figure B.7 : Meduxnekeag River near Belleville (01AU003) (Continued)

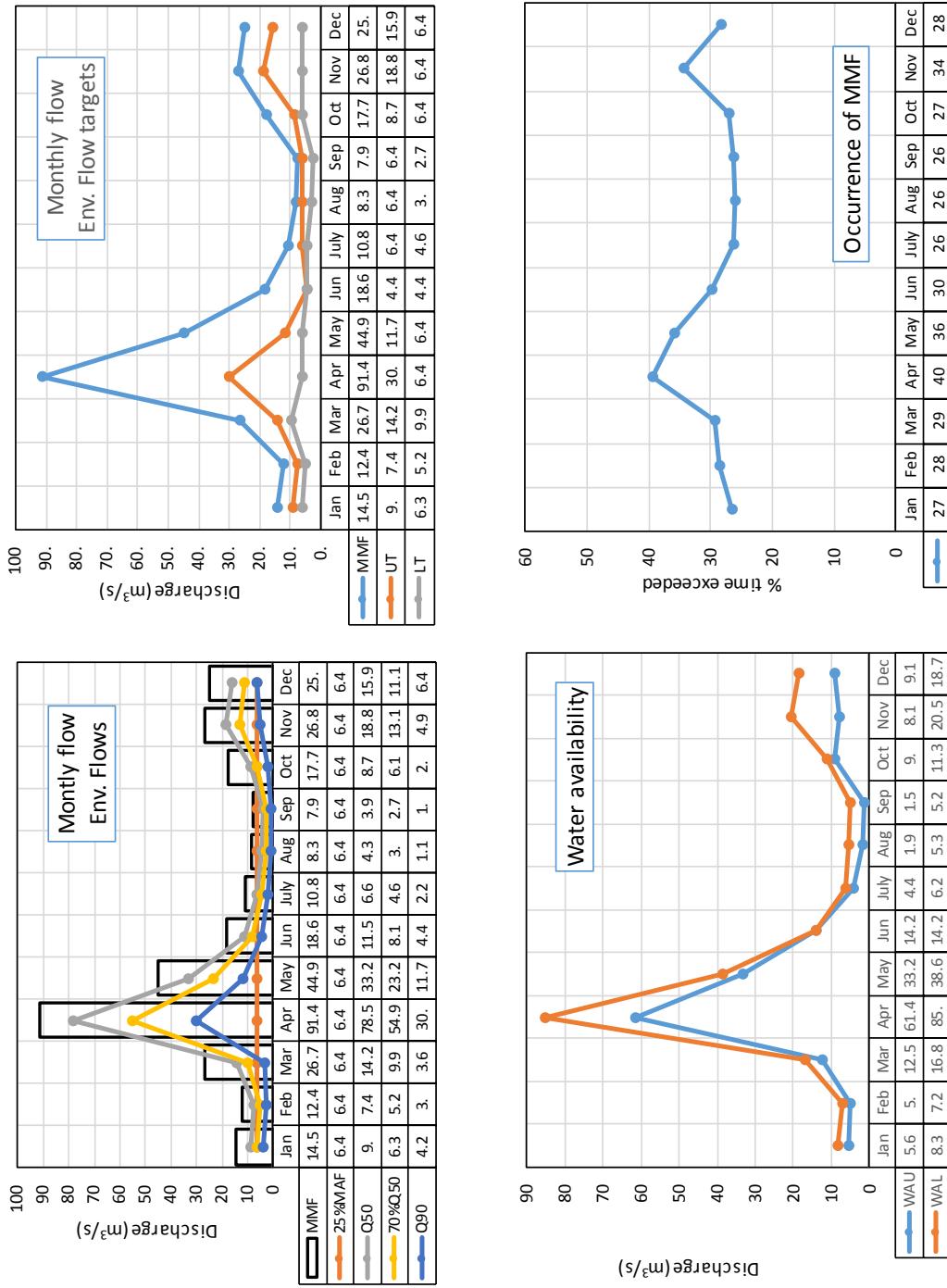


Figure B.8 : Big Presque Isle Stream at Tracey Mills (01AJ004)

Station ID	01AJ004	Mean annual flow (MAF)	9.82 m ³ /s
Latitude	46°26'18" N	Median annual flow (Q ₅₀)	4.65 m ³ /s
Longitude	67°44'18" W	Q ₅₀ (Aug)	2.08 m ³ /s
Drainage area	484 km ²	70%Q ₅₀ (Aug)	1.456 m ³ /s
Period of record	1968-2010 (43 years)	Q ₉₀ (Aug)	0.841 m ³ /s

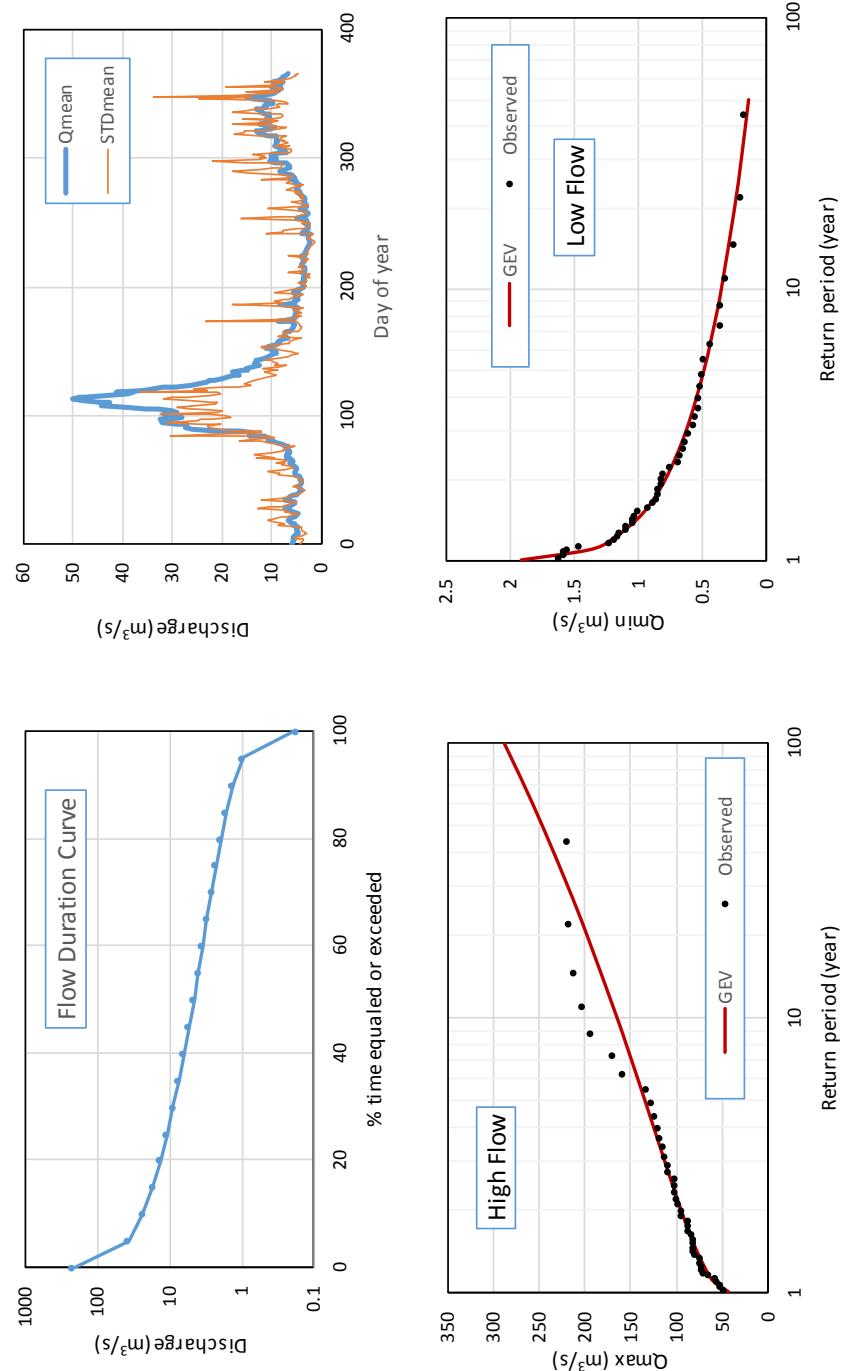


Figure B.8 : Big Presque Isle Stream at Tracey Mills (01AJ004) (Continued)

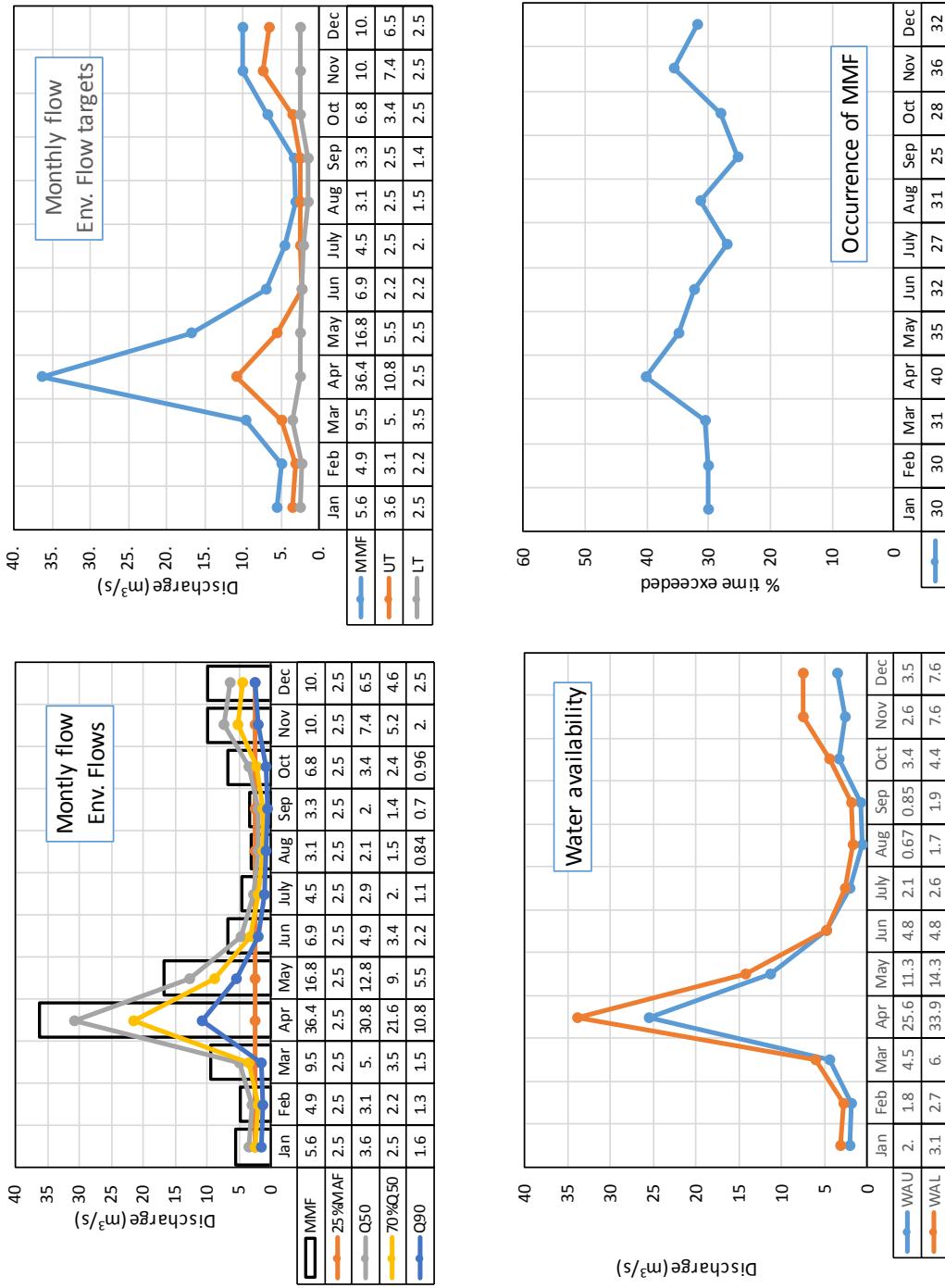


Figure B.9 : Becaquimec Stream at Coldstream (01AJ010)

Station ID	01AJ010	Mean annual flow (MAF)	7.6 m ³ /s
Latitude	46°20'27" N	Median annual flow (Q ₅₀)	3.57 m ³ /s
Longitude	67°27'54" W	Q ₅₀ (Aug)	1.47 m ³ /s
Drainage area	350 km ²	70%Q ₅₀ (Aug)	1.029 m ³ /s
Period of record	1974-2011 (38 years)	Q ₉₀ (Aug)	0.477 m ³ /s

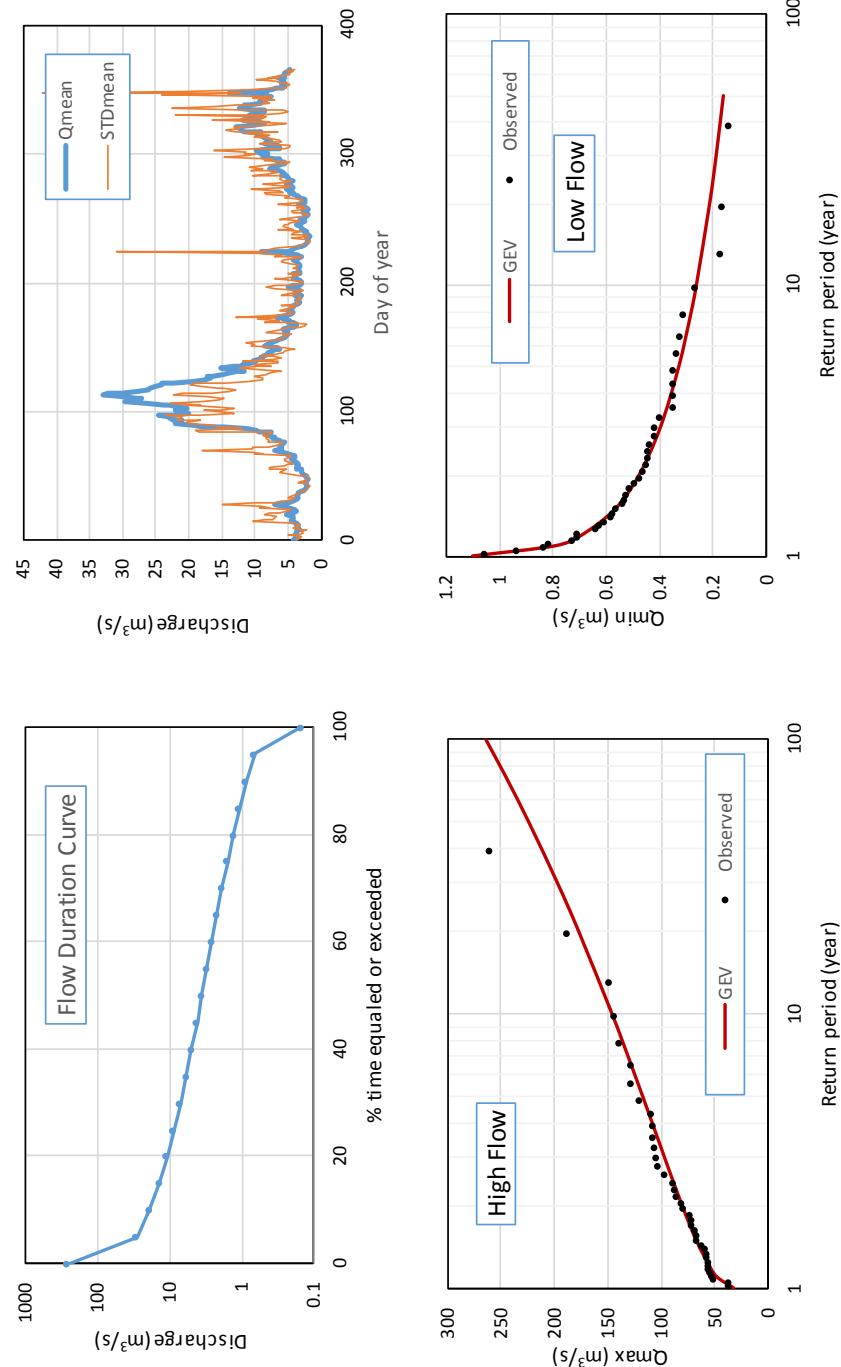


Figure B.9 : Becaquimec Stream at Coldstream (01AJ010) (Continued)

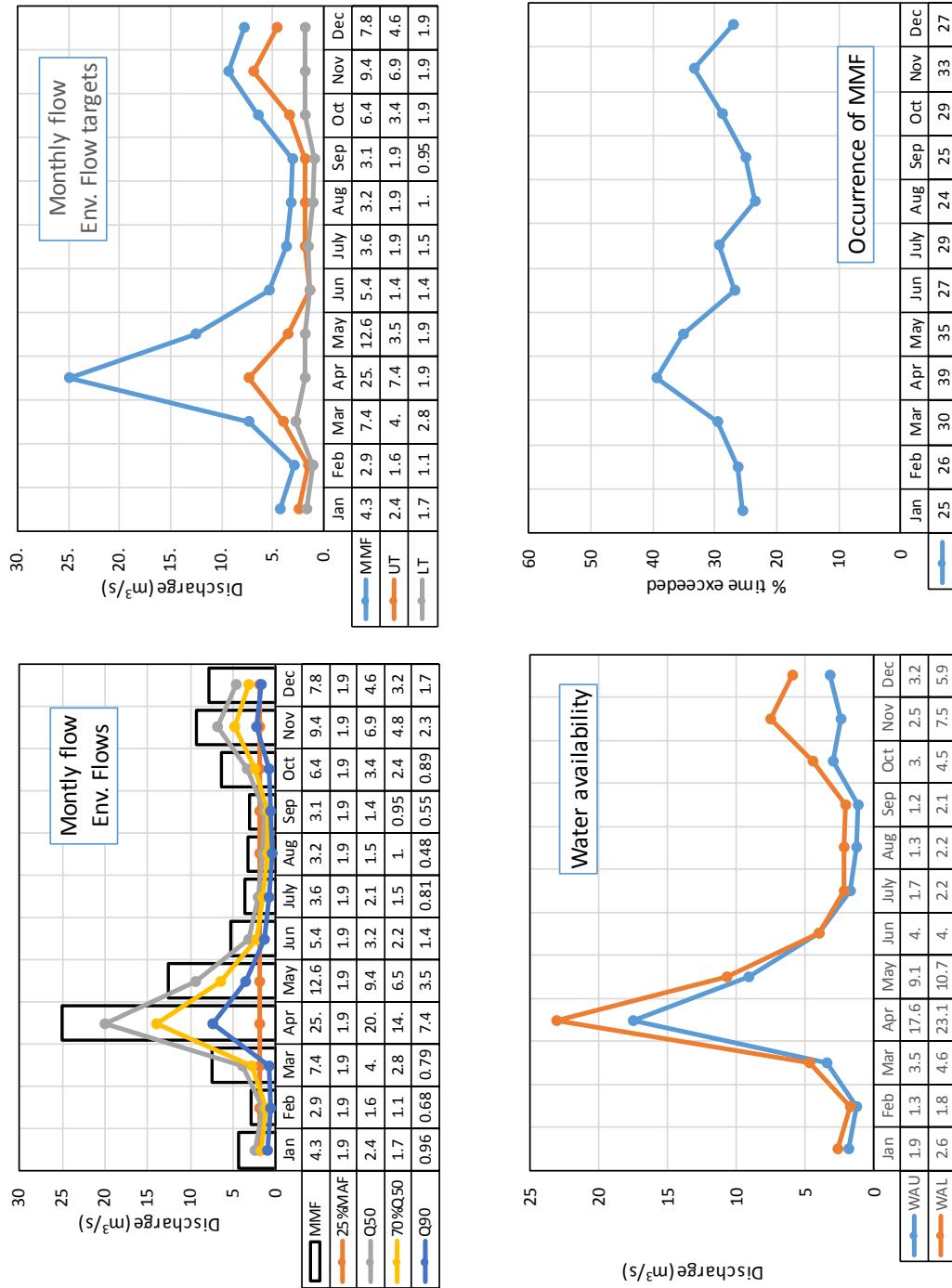


Figure B.10 : Cold Stream at Coldstream (01AJ011)

Station ID	01AJ011	Mean annual flow (MAF)	3.16 m ³ /s
Latitude	46°20'32" N	Median annual flow (Q ₅₀)	1.71 m ³ /s
Longitude	67°28'09" W	Q ₅₀ (Aug)	0.797 m ³ /s
Drainage area	156 km ²	70%Q ₅₀ (Aug)	0.5579 m ³ /s
Period of record	1974-1993 (20 years)	Q ₉₀ (Aug)	0.2459 m ³ /s

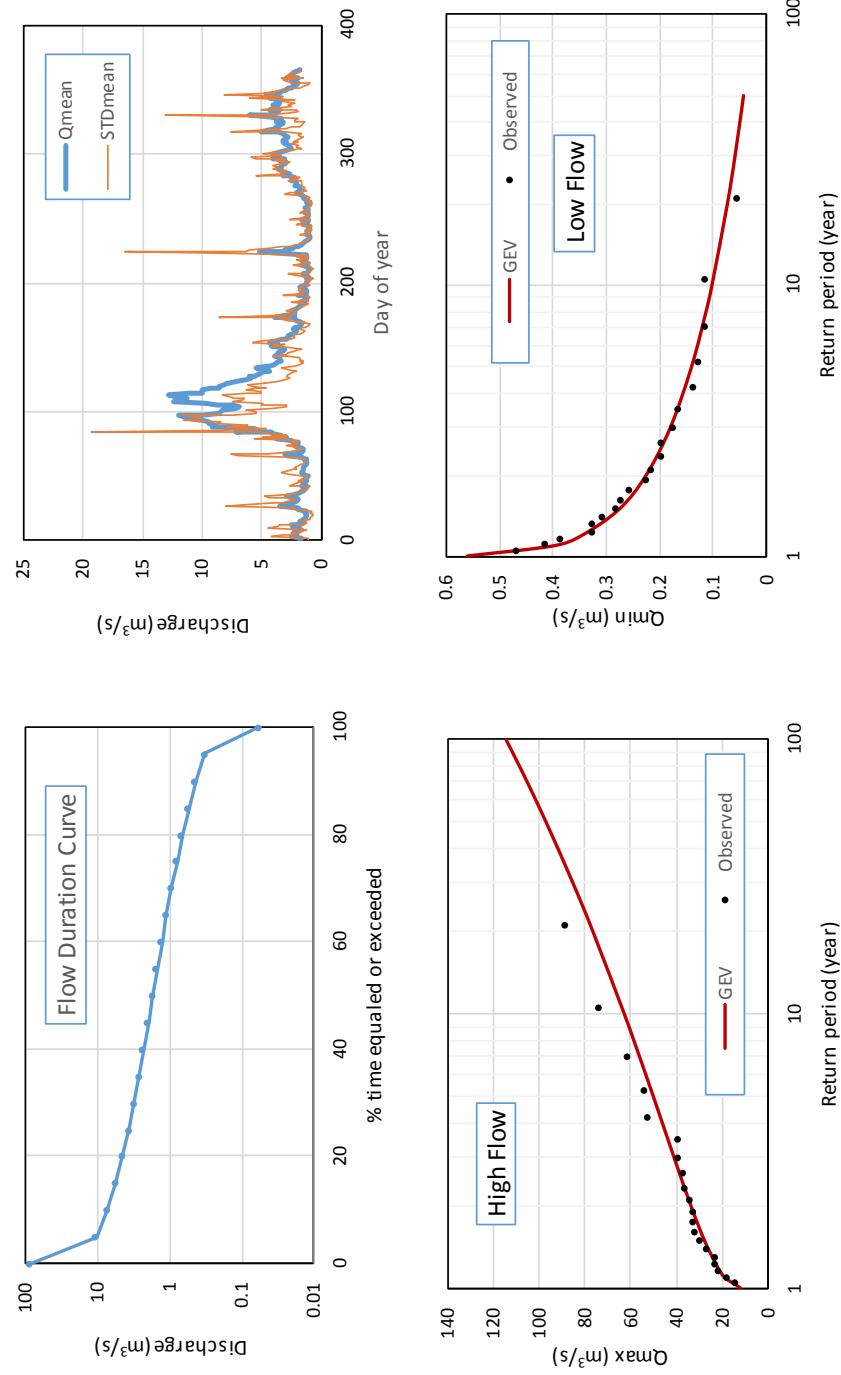


Figure B.10 : Cold Stream at Coldstream (01AJ011) (Continued)

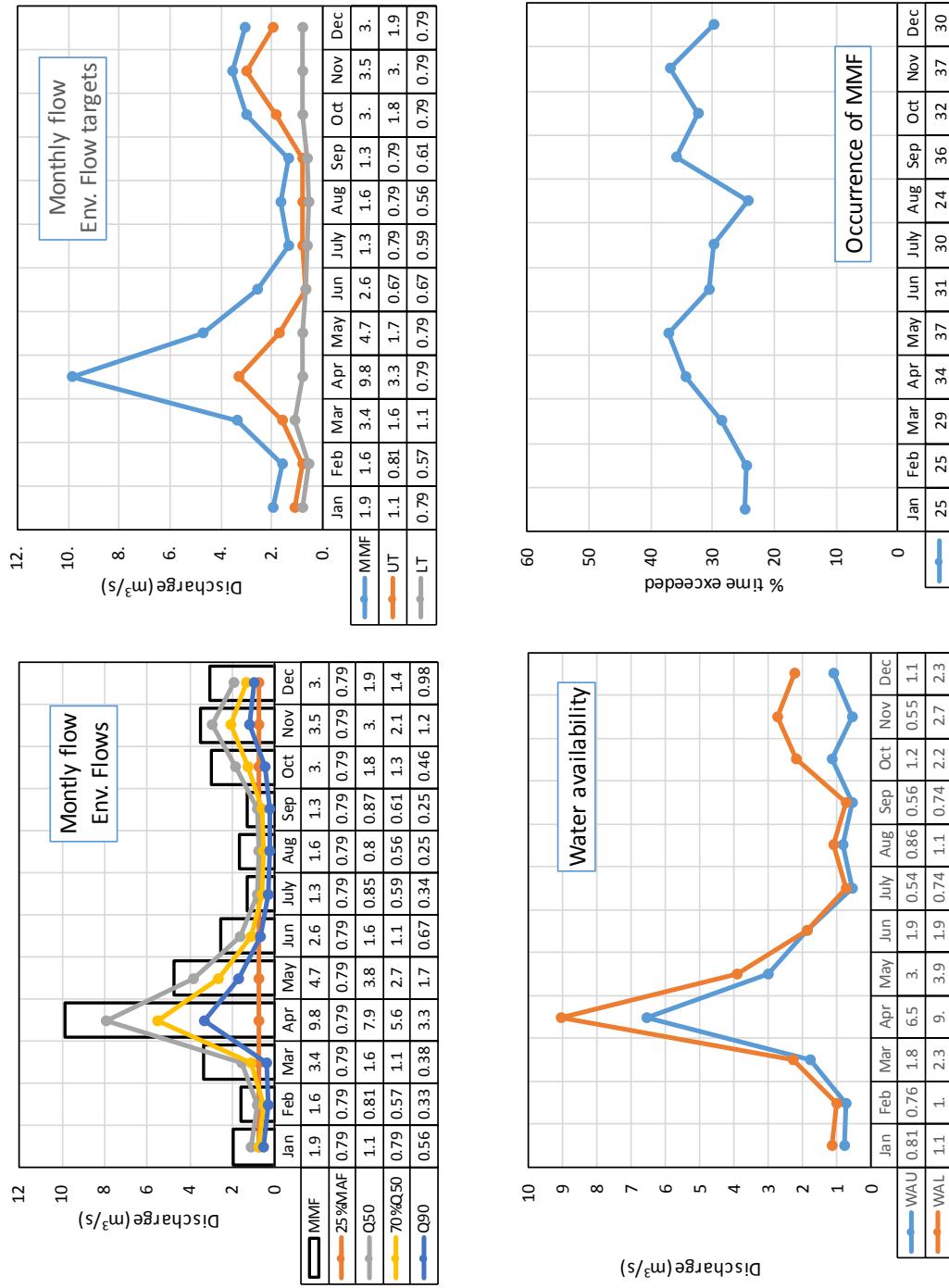


Figure B.11 : Shogomoc Stream near Trans Canada Highway (01AK001)

Station ID	01AK001	Mean annual flow (MAF)	4.99 m ³ /s
Latitude	45°56'36" N	Median annual flow (Q ₅₀)	2.48 m ³ /s
Longitude	67°19'13" W	Q ₅₀ (Aug)	0.64 m ³ /s
Drainage area	234 km ²	70%Q ₅₀ (Aug)	0.448 m ³ /s
Period of record	1919-40,1944-2012 (91 years)	Q ₉₀ (Aug)	0.218 m ³ /s

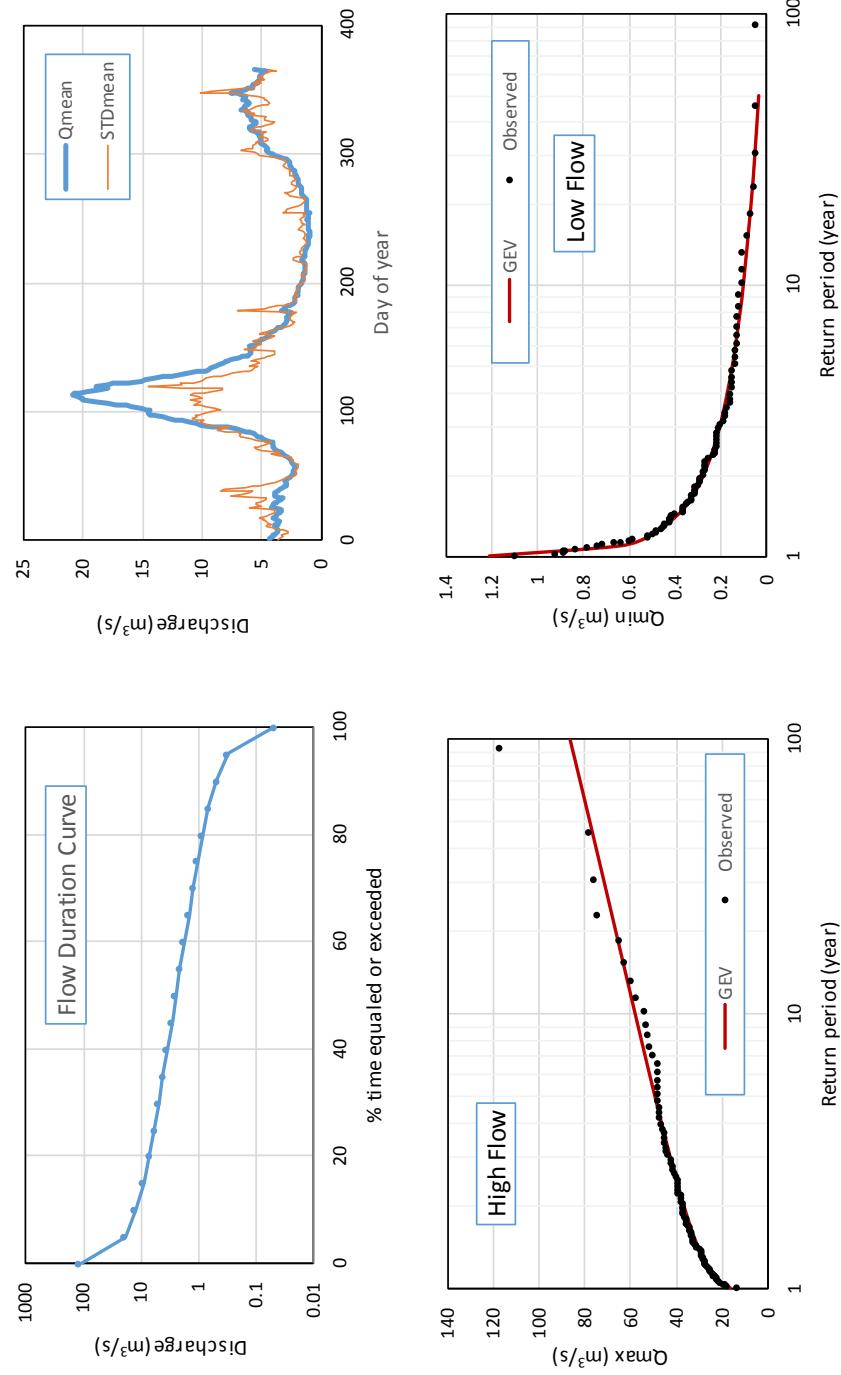


Figure B.11 : Shogomoc Stream near Trans Canada Highway (01AK001) (Continued)

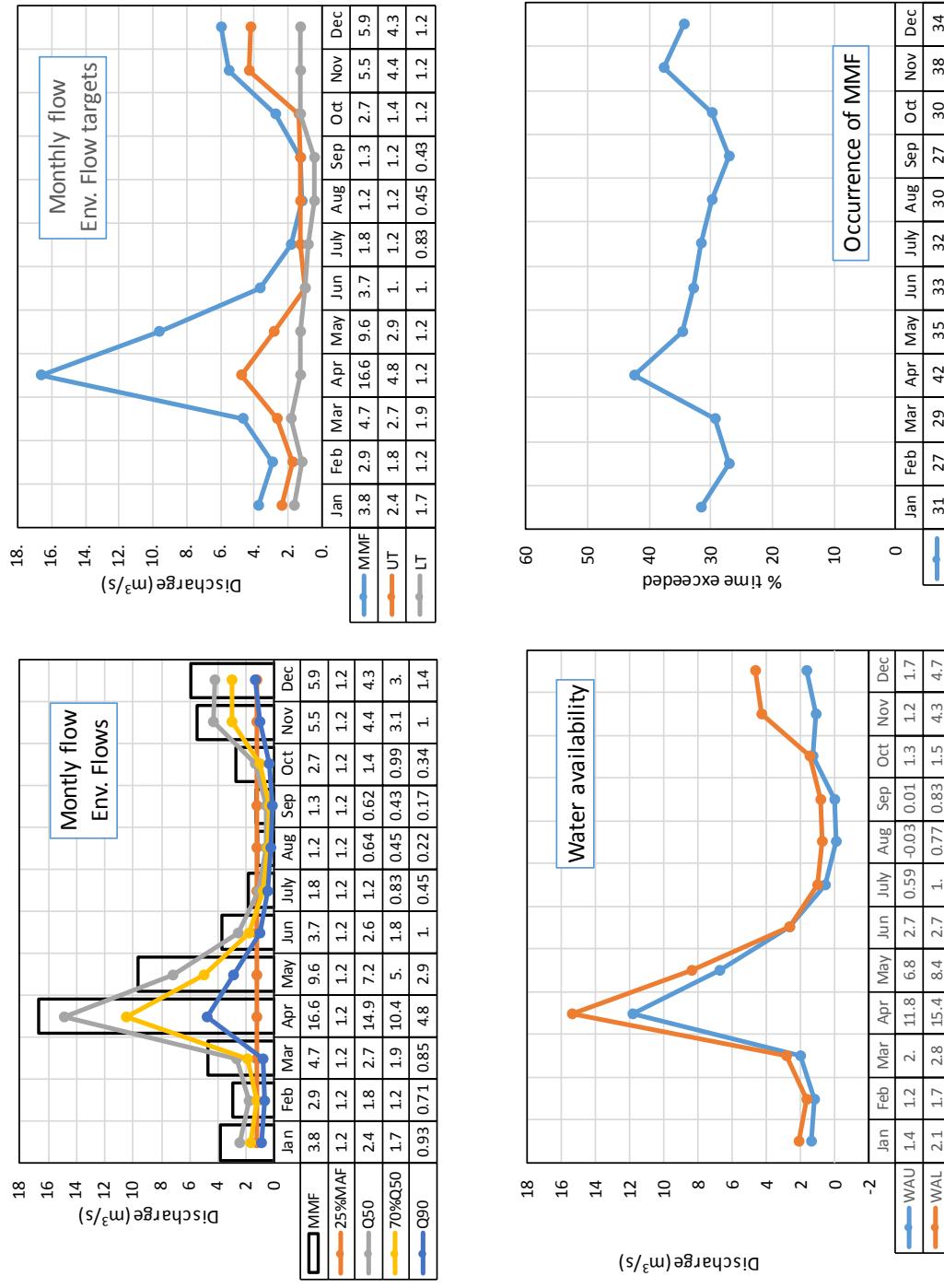


Figure B.12 : North Nashwaak Stream near Royal Road (01AK005)

Station ID	01AK005	Mean annual flow (MAF)	0.54 m ³ /s
Latitude	46°02'06" N	Median annual flow (Q ₅₀)	0.234 m ³ /s
Longitude	66°42'05" W	Q ₅₀ (Aug)	0.064 m ³ /s
Drainage area	26.9 km ²	70%Q ₅₀ (Aug)	0.0448 m ³ /s
Period of record	1966-1993 (28 years)	Q ₉₀ (Aug)	0.0147 m ³ /s

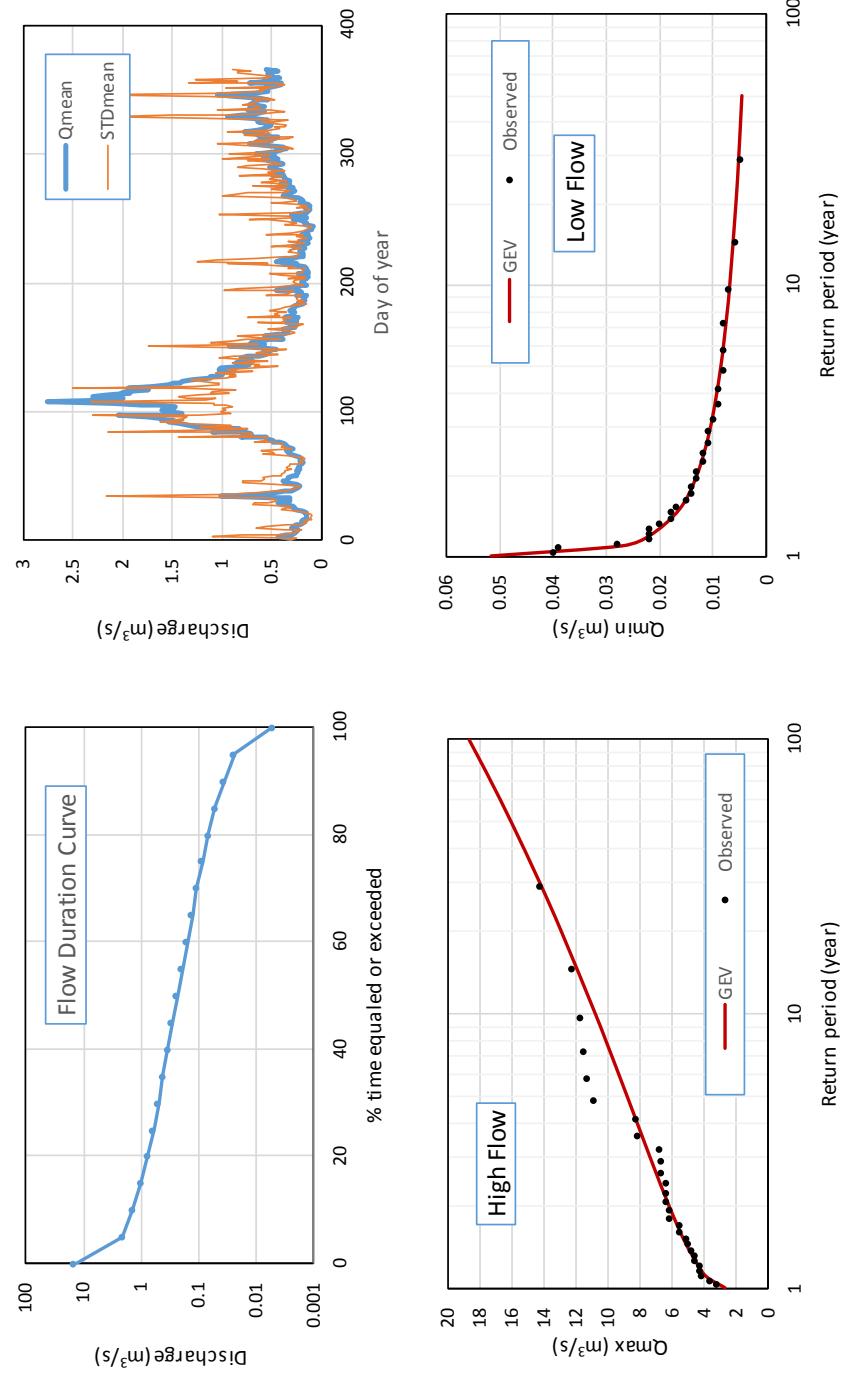


Figure B.12 : North Nashwaak Stream near Royal Road (01AK005) (Continued)

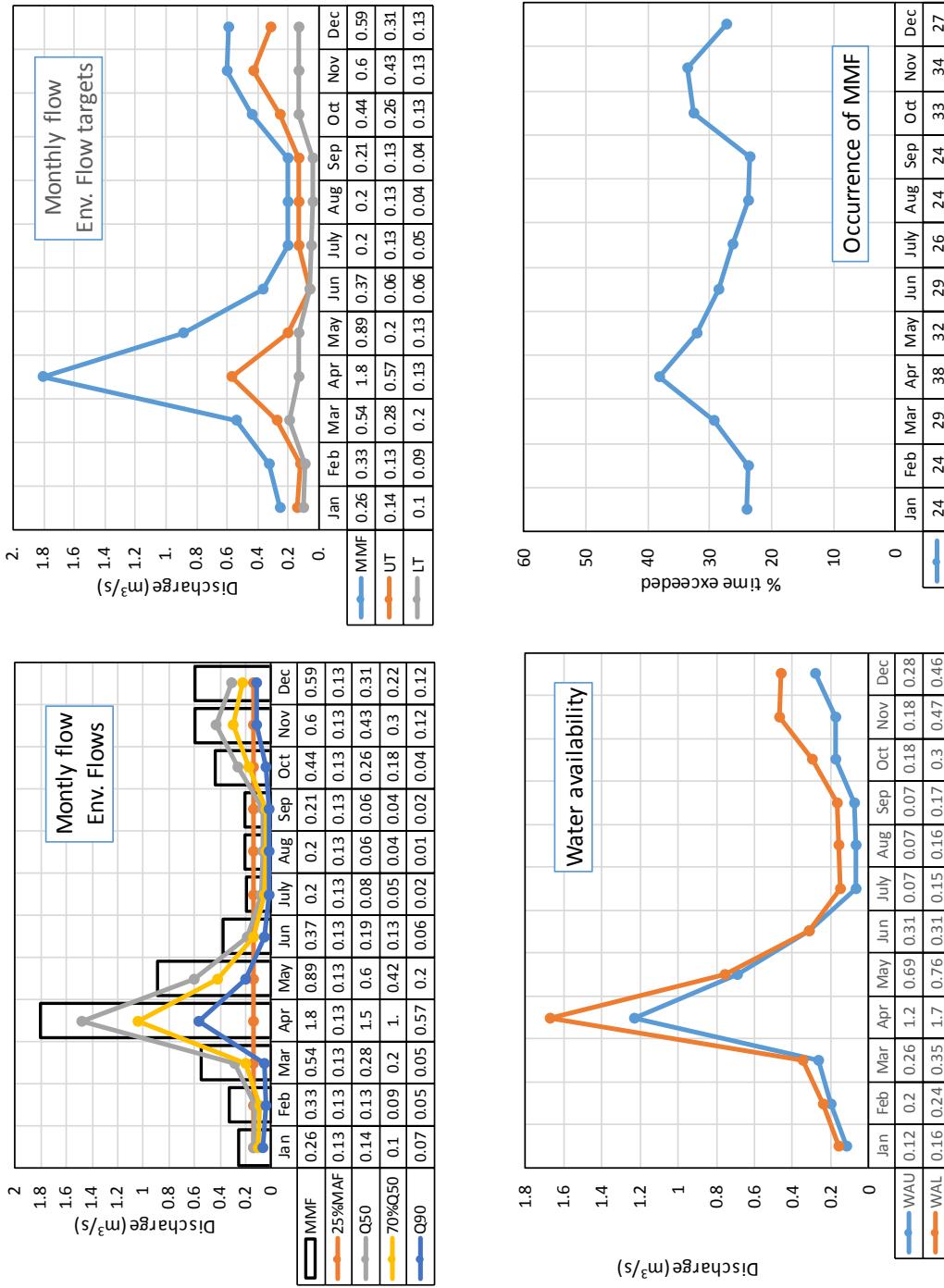


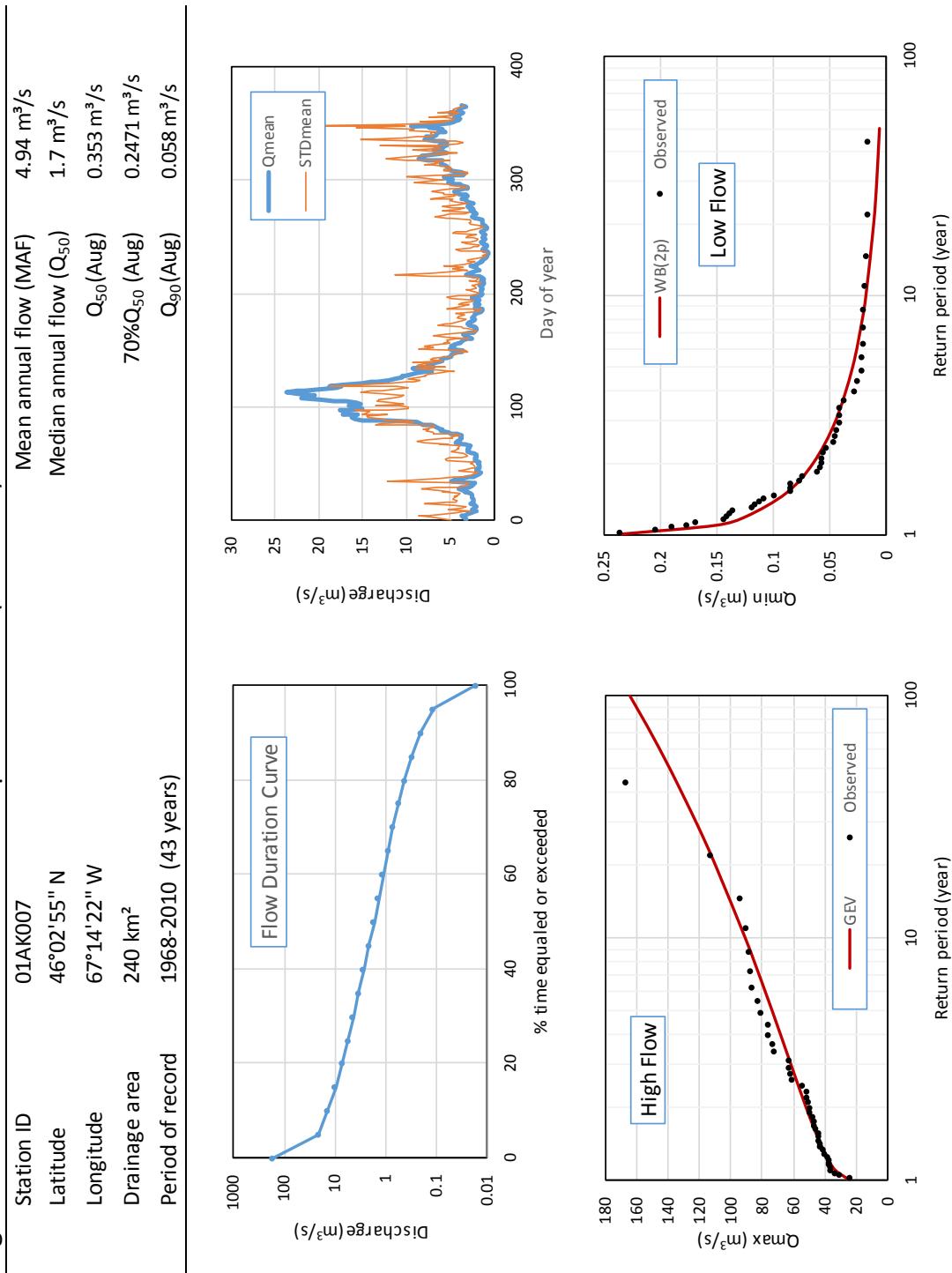
Figure B.13 : Nackawic River near Temperance Vale (01AK007)

Figure B.13 : Nackawic River near Temperance Vale (01AK007) (Continued)

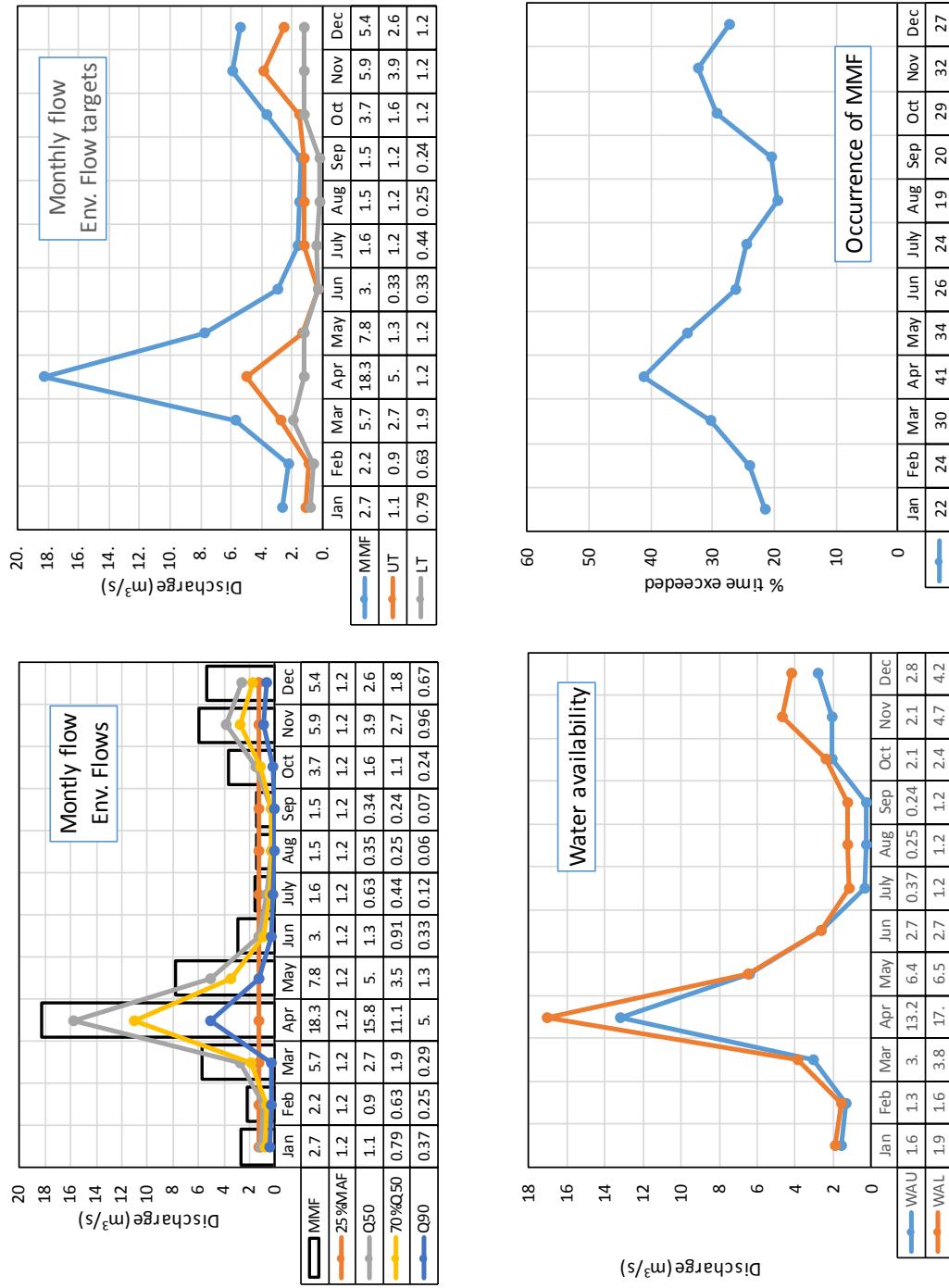


Figure B.14 : Eel River near Scott Siding (01AK008)

Station ID	01AK008	Mean annual flow (MAF)	10.5 m ³ /s
Latitude	45°56'12" N	Median annual flow (Q ₅₀)	5.4 m ³ /s
Longitude	67°32'49" W	Q ₅₀ (Aug)	2.145 m ³ /s
Drainage area	531 km ²	70%Q ₅₀ (Aug)	1.5015 m ³ /s
Period of record	1974-1993 (20 years)	Q ₉₀ (Aug)	0.6841 m ³ /s

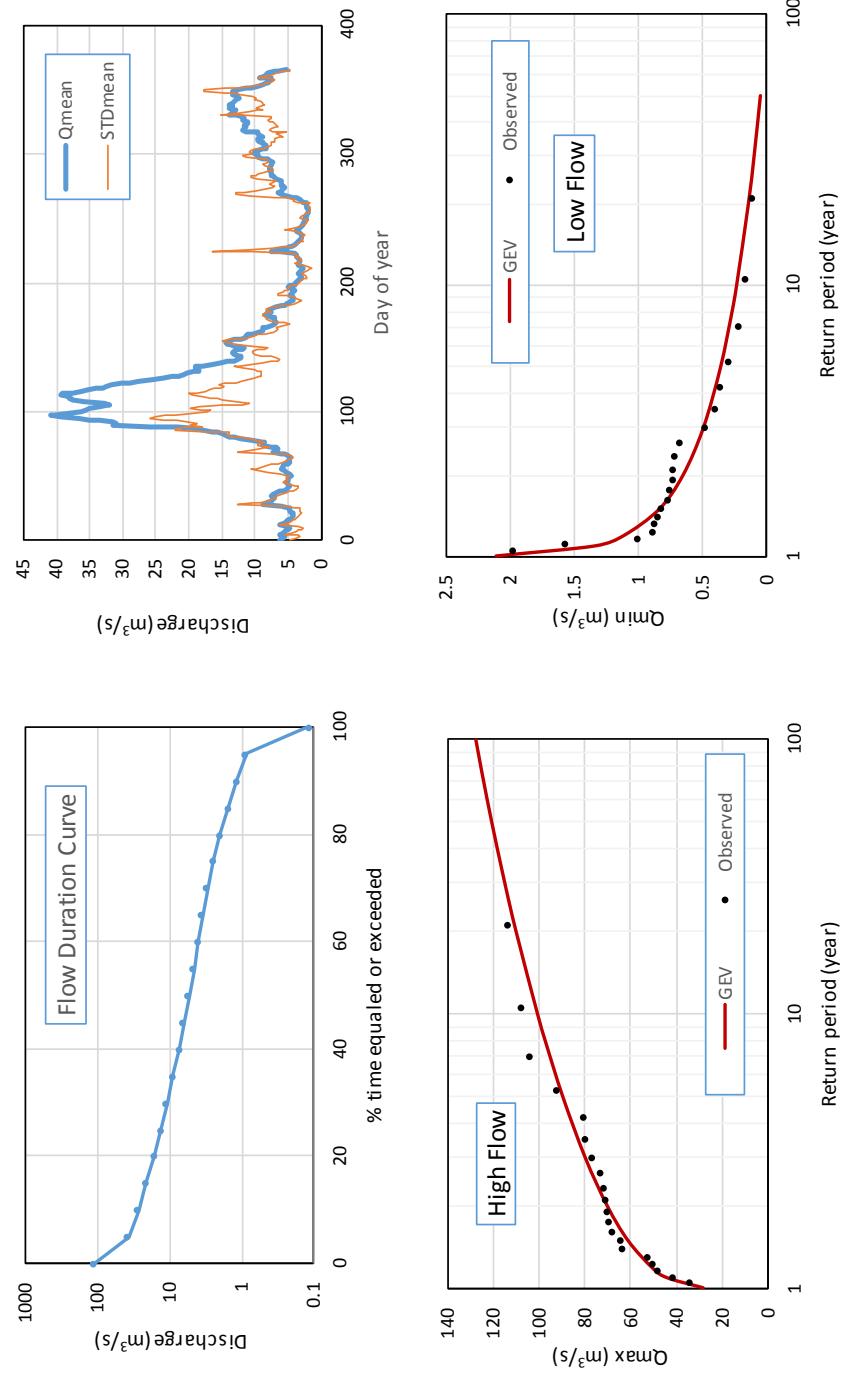


Figure B.14 : Eel River near Scott Siding (01AK008) (Continued)

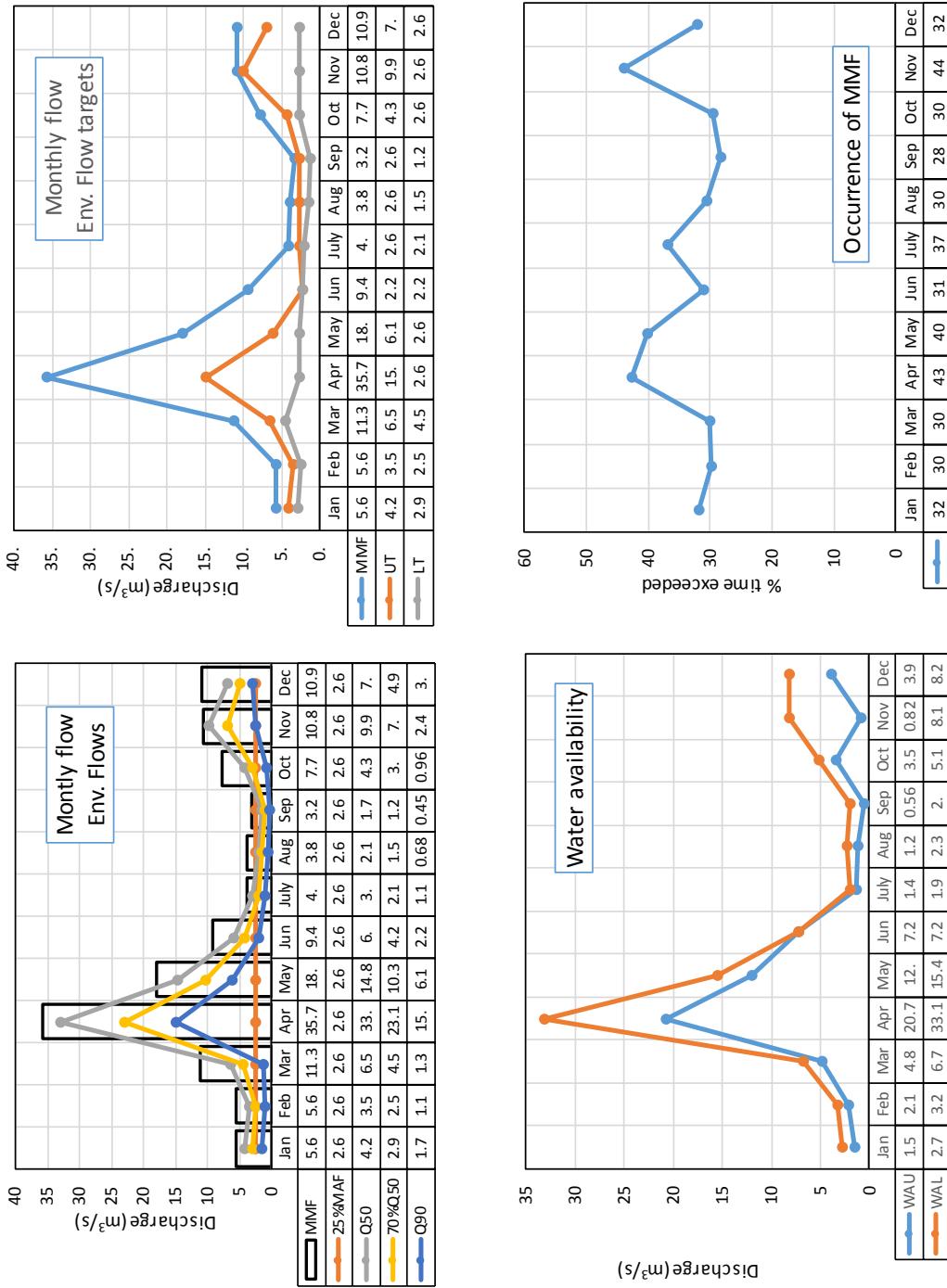


Figure B.15 : Nashwaak River at Durham Bridge (01AL002)

Station ID	01AL002	Mean annual flow (MAF)	35.8 m ³ /s
Latitude	46°07'33" N	Median annual flow (Q ₅₀)	18.7 m ³ /s
Longitude	66°36'40" W	Q ₅₀ (Aug)	8.45 m ³ /s
Drainage area	1450 km ²	70%Q ₅₀ (Aug)	5.915 m ³ /s
Period of record	1962-2010 (49 years)	Q ₉₀ (Aug)	4.11 m ³ /s

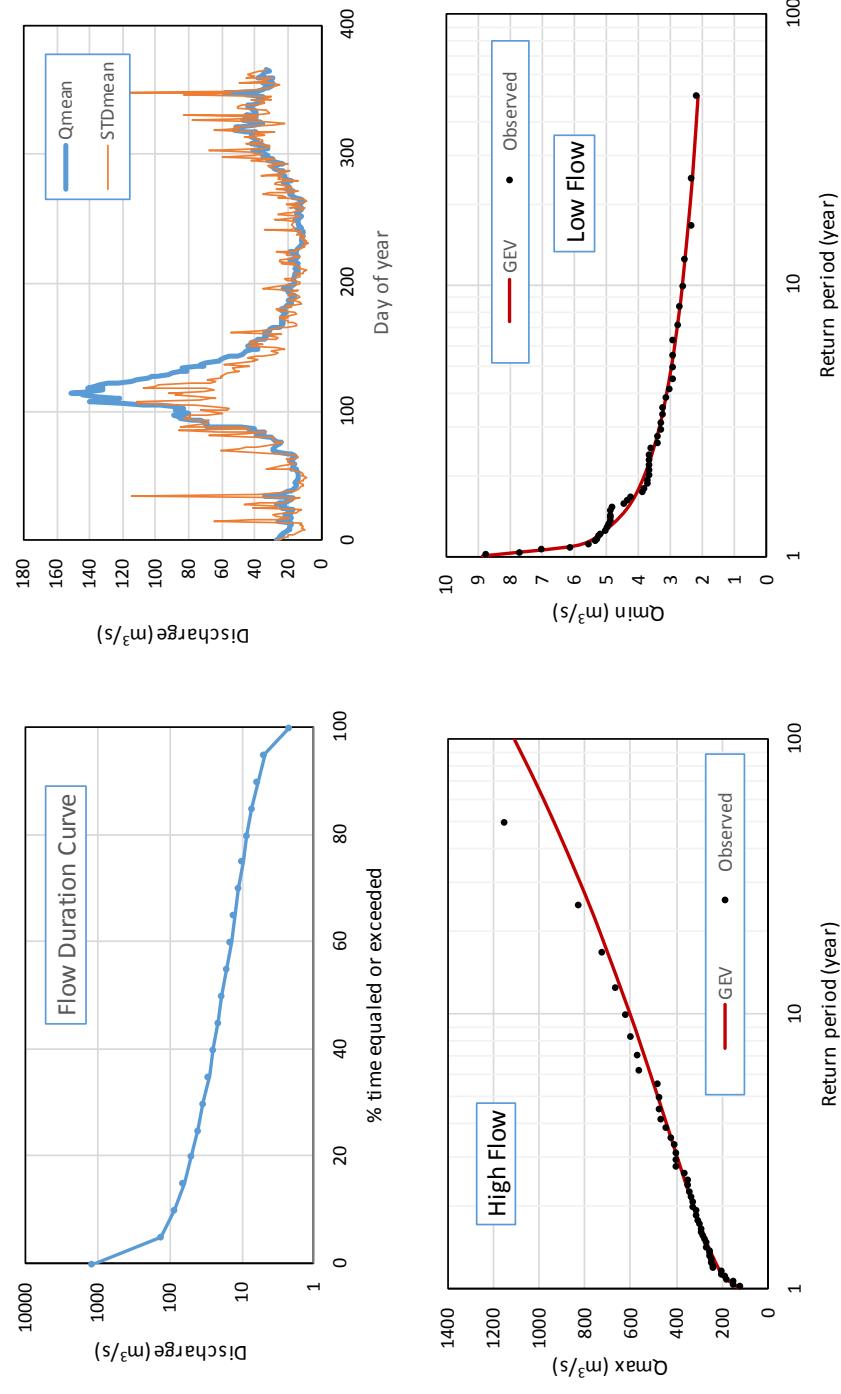


Figure B.15 : Nashwaak River at Durham Bridge (01AL002) (Continued)

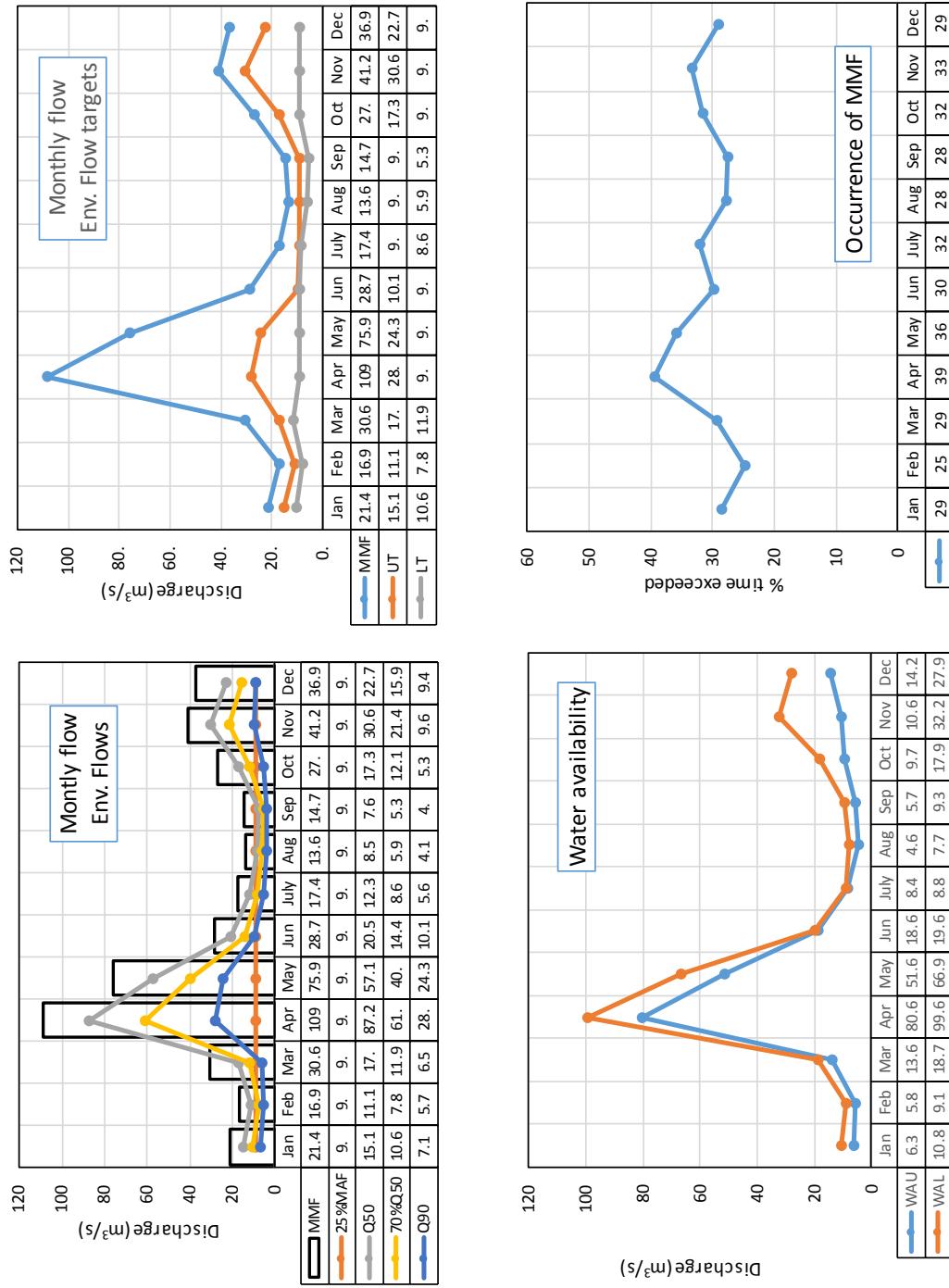


Figure B.16 : Hayden Brook near Narrows Mountain (01AL003)

Station ID	01AL003	Mean annual flow (MAF)	0.177 m ³ /s
Latitude	46°17'56" N	Median annual flow (Q ₅₀)	0.088 m ³ /s
Longitude	67°02'13" W	Q ₅₀ (Aug)	0.042 m ³ /s
Drainage area	6.48 km ²	70%Q ₅₀ (Aug)	0.0294 m ³ /s
Period of record	1971-1993 (23 years)	Q ₉₀ (Aug)	0.022 m ³ /s

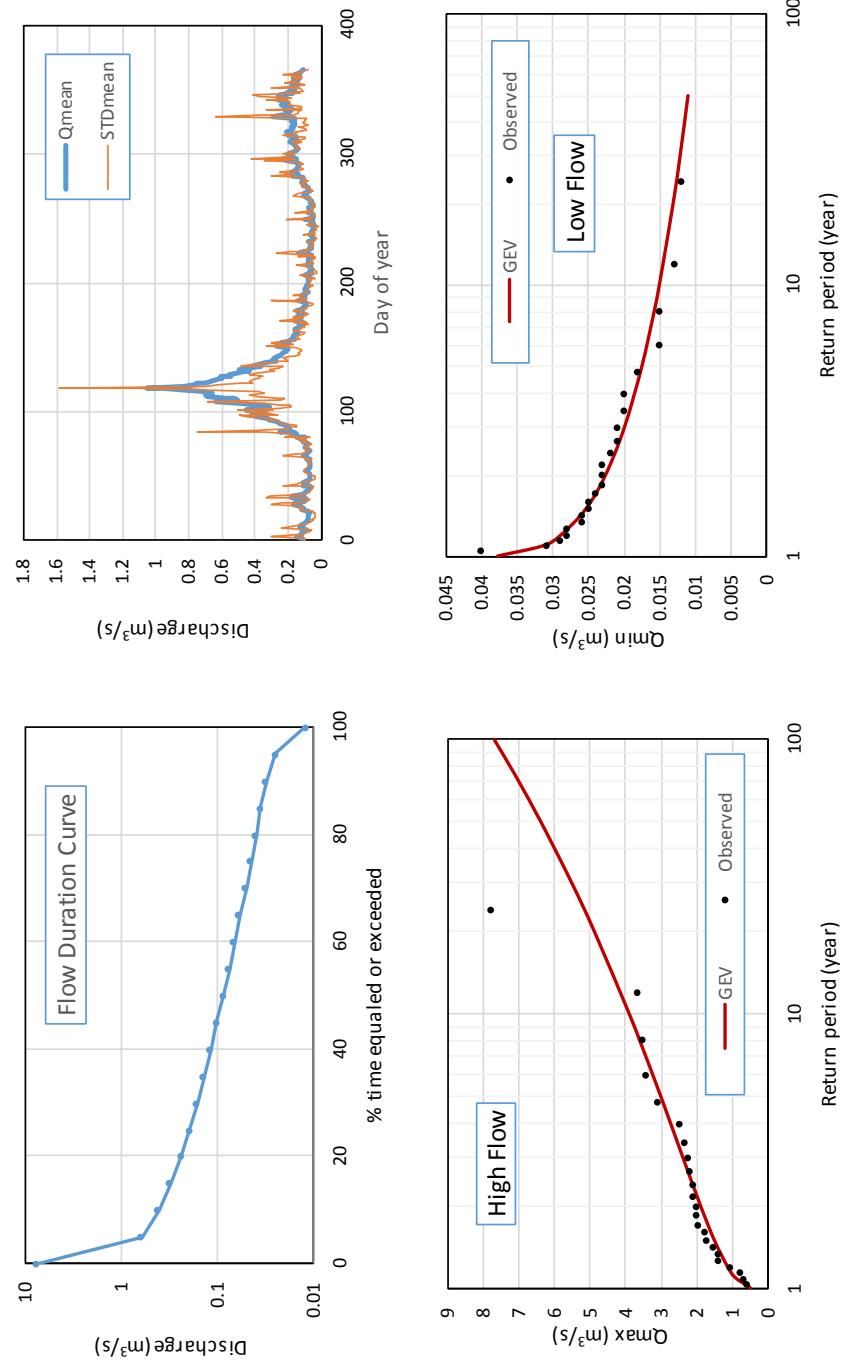


Figure B.16 : Hayden Brook near Narrows Mountain (01AL003) (Continued)

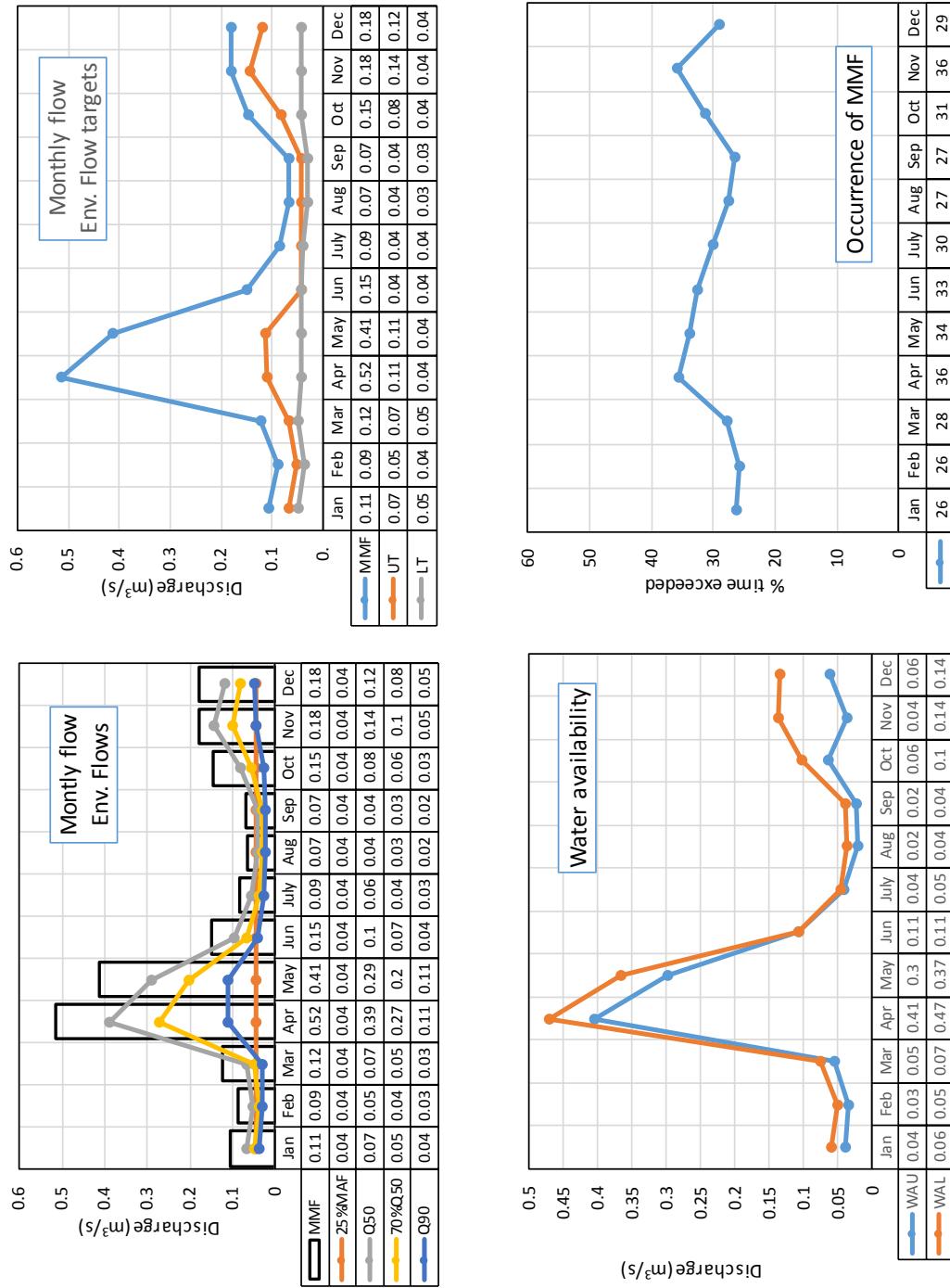


Figure B.17 : Narrows Mountain Brook near Narrows Mountain (01AL004)

Station ID	01AL004	Mean annual flow (MAF)	0.098 m ³ /s
Latitude	46°16'37" N	Median annual flow (Q ₅₀)	0.045 m ³ /s
Longitude	67°01'17" W	Q ₅₀ (Aug)	0.016 m ³ /s
Drainage area	3.89 km ²	70%Q ₅₀ (Aug)	0.0112 m ³ /s
Period of record	1972-2010 (39 years)	Q ₉₀ (Aug)	0.005 m ³ /s

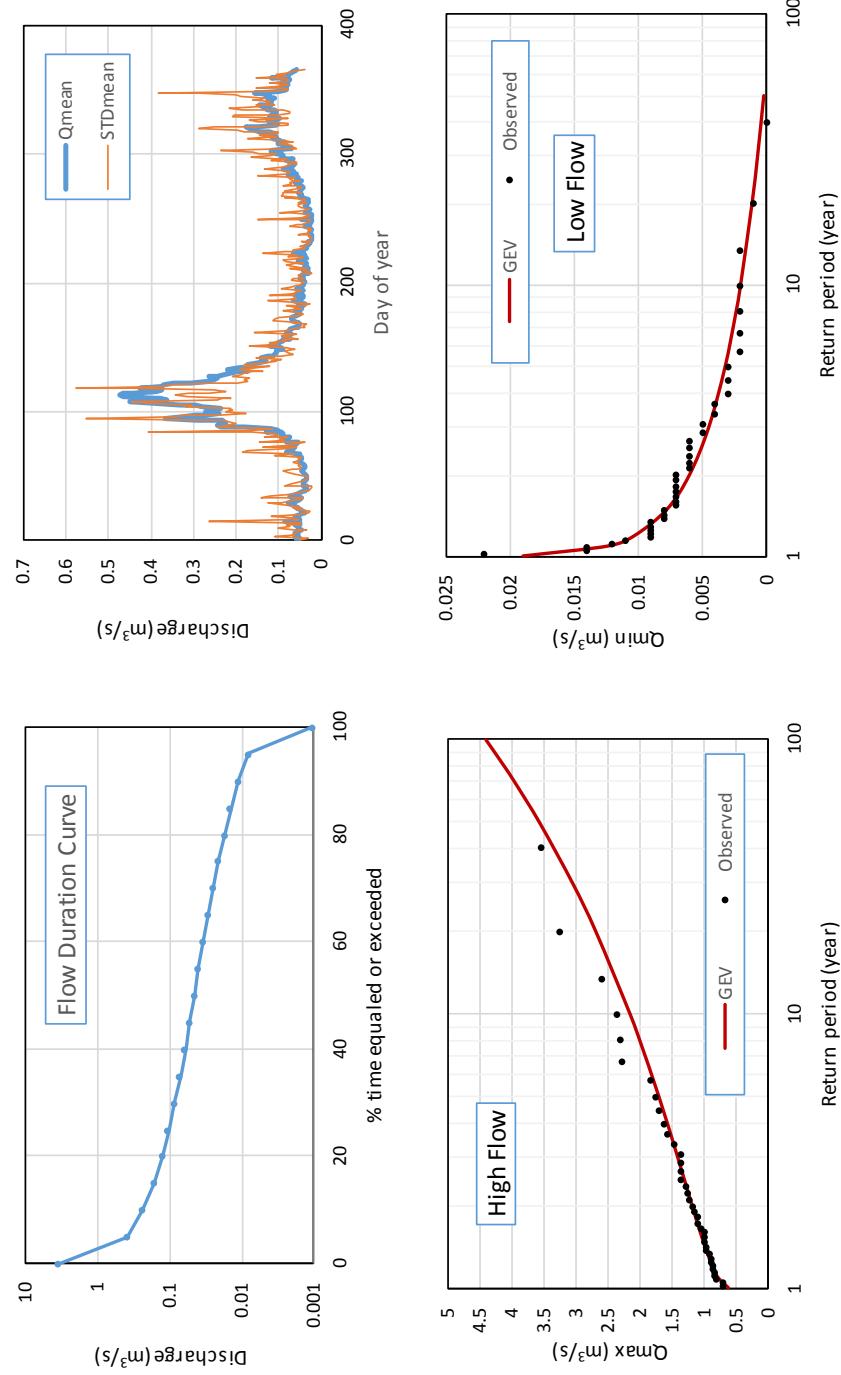


Figure B.17 : Narrows Mountain Brook near Narrows Mountain (01AL004) (Continued)

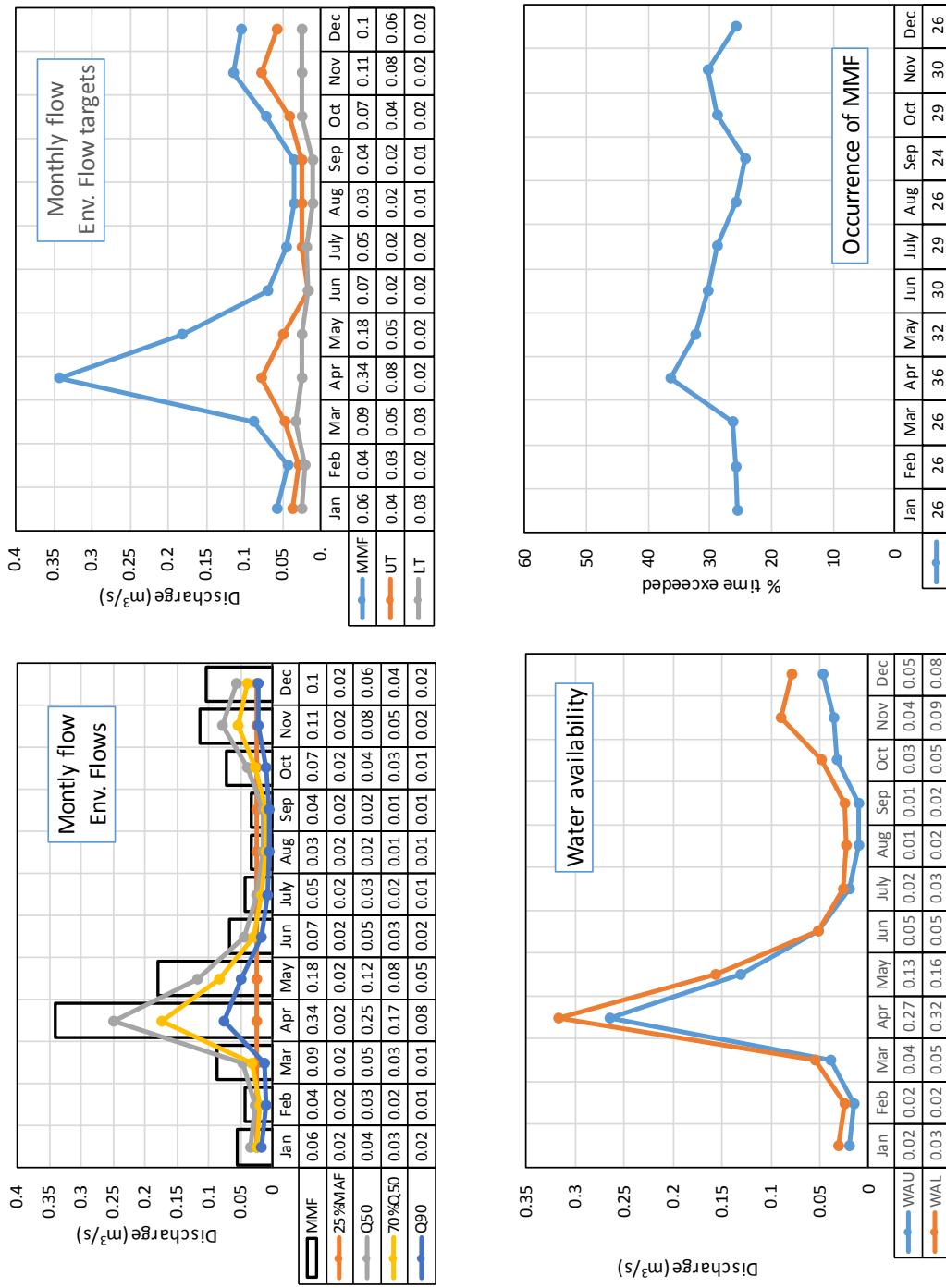


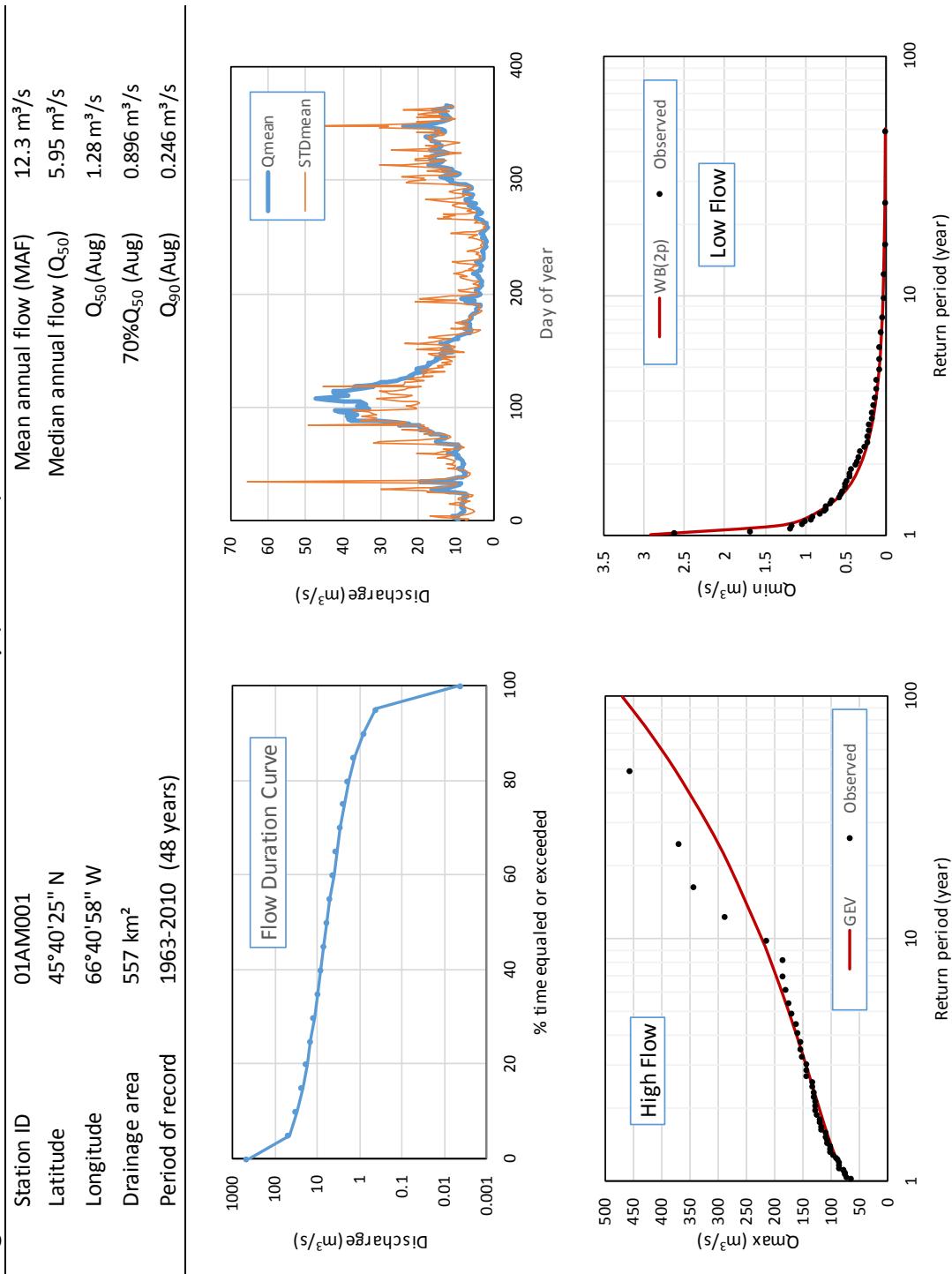
Figure B.18 : Northwest Oromocto River at Tracy (01AM001)

Figure B.18 : Northwest Oromocto River at Tracy (01AM001) (Continued)

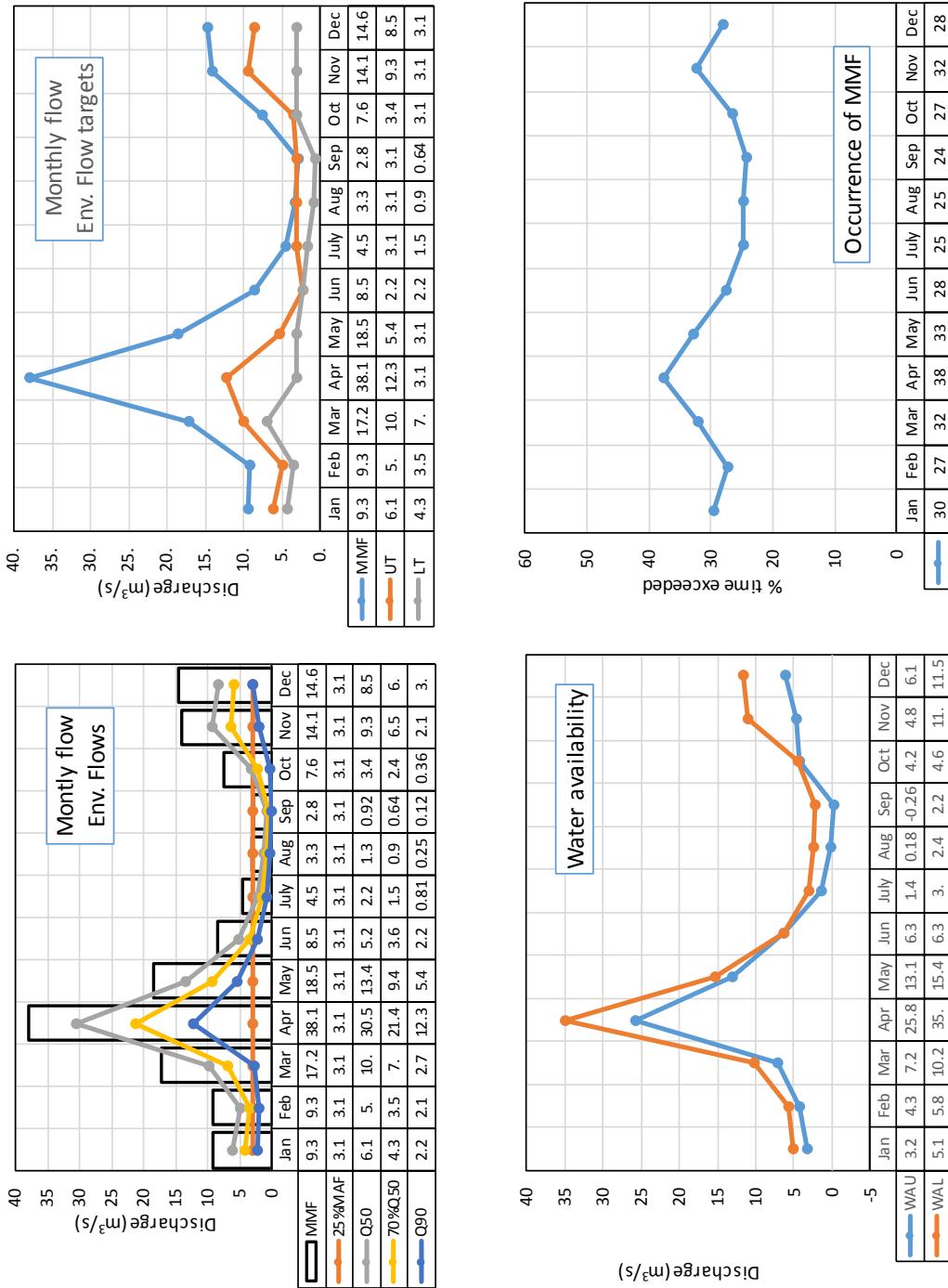


Figure B.19 : Castaway Brook near Castaway (01AN001)

Station ID	01AN001	Mean annual flow (MAF)	0.874 m ³ /s
Latitude	46°17'54" N	Median annual flow (Q ₅₀)	0.454 m ³ /s
Longitude	65°42'43" W	Q ₅₀ (Aug)	0.244 m ³ /s
Drainage area	34.4 km ²	70%Q ₅₀ (Aug)	0.1708 m ³ /s
Period of record	1972-81,1983-1993 (21 years)	Q ₉₀ (Aug)	0.081 m ³ /s

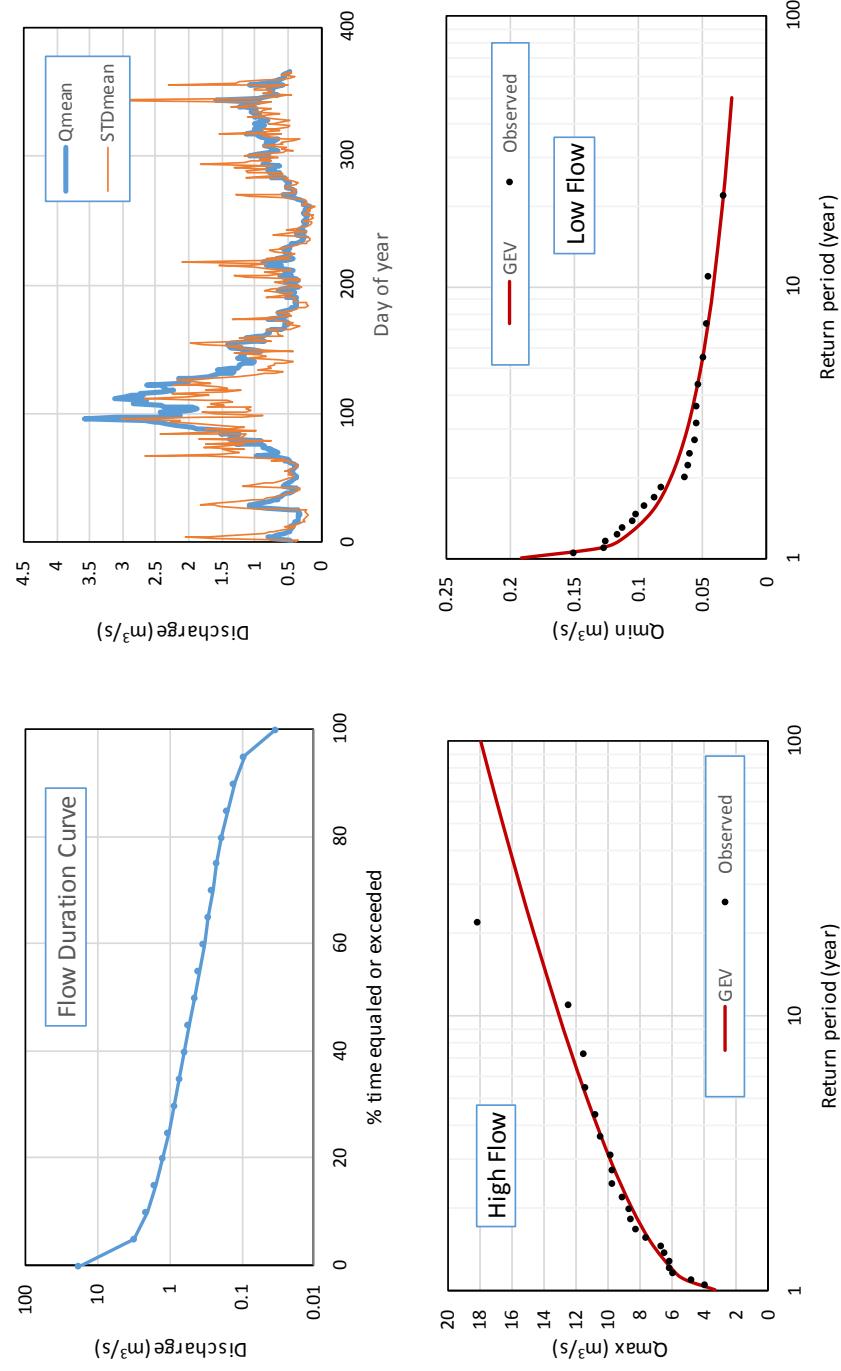


Figure B.19 : Castaway Brook near Castaway (01AN001) (Continued)

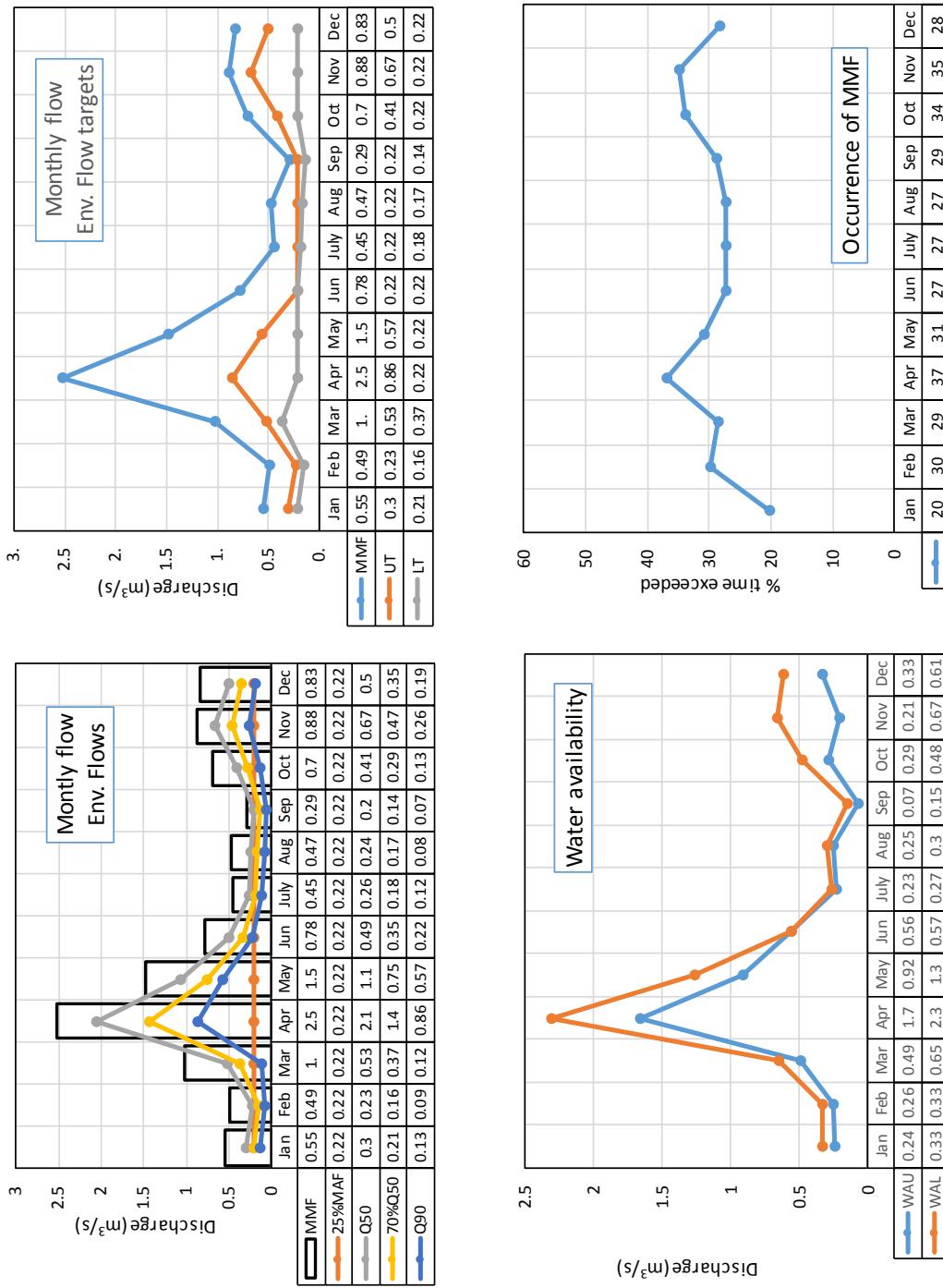


Figure B.20 : Salmon River at Castaway (01AN002)

Station ID	01AN002	Mean annual flow (MAF)	22 m ³ /s
Latitude	46°17'26" N	Median annual flow (Q ₅₀)	10.6 m ³ /s
Longitude	65°43'21" W	Q ₅₀ (Aug)	3.96 m ³ /s
Drainage area	1050 km ²	70%Q ₅₀ (Aug)	2.772 m ³ /s
Period of record	1974-2012 (39 years)	Q ₉₀ (Aug)	1.908 m ³ /s

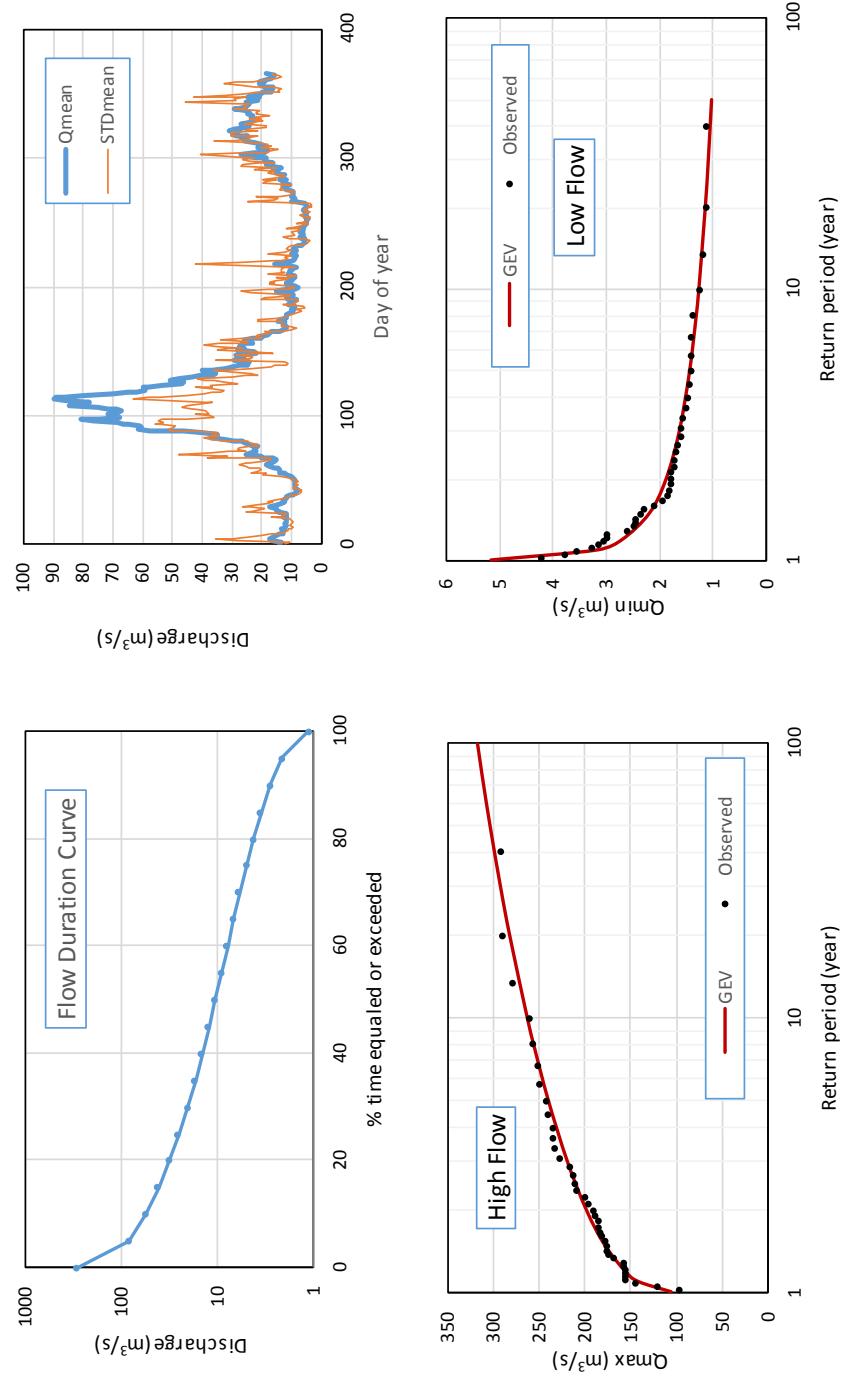


Figure B.20 : Salmon River at Castaway (01AN002) (Continued)

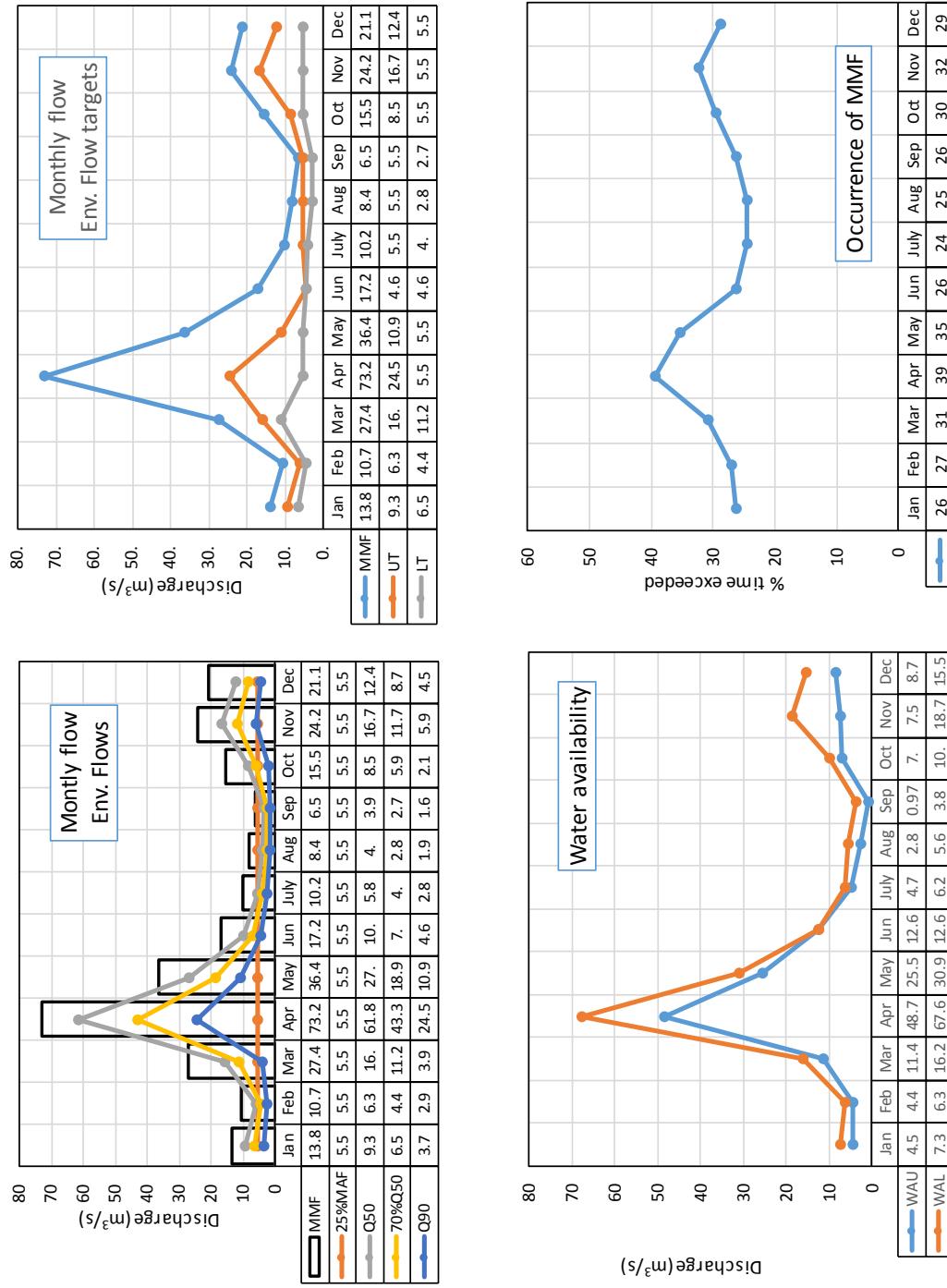


Figure B.21 : Canaan River at East Canaan (01AP002)

Station ID	01AP002	Mean annual flow (MAF)	13.5 m ³ /s
Latitude	46°04'20" N	Median annual flow (Q ₅₀)	5.76 m ³ /s
Longitude	65°21'59" W	Q ₅₀ (Aug)	1.155 m ³ /s
Drainage area	668 km ²	70%Q ₅₀ (Aug)	0.8085 m ³ /s
Period of record	1926-40,1963-2011 (64 years)	Q ₉₀ (Aug)	0.357 m ³ /s

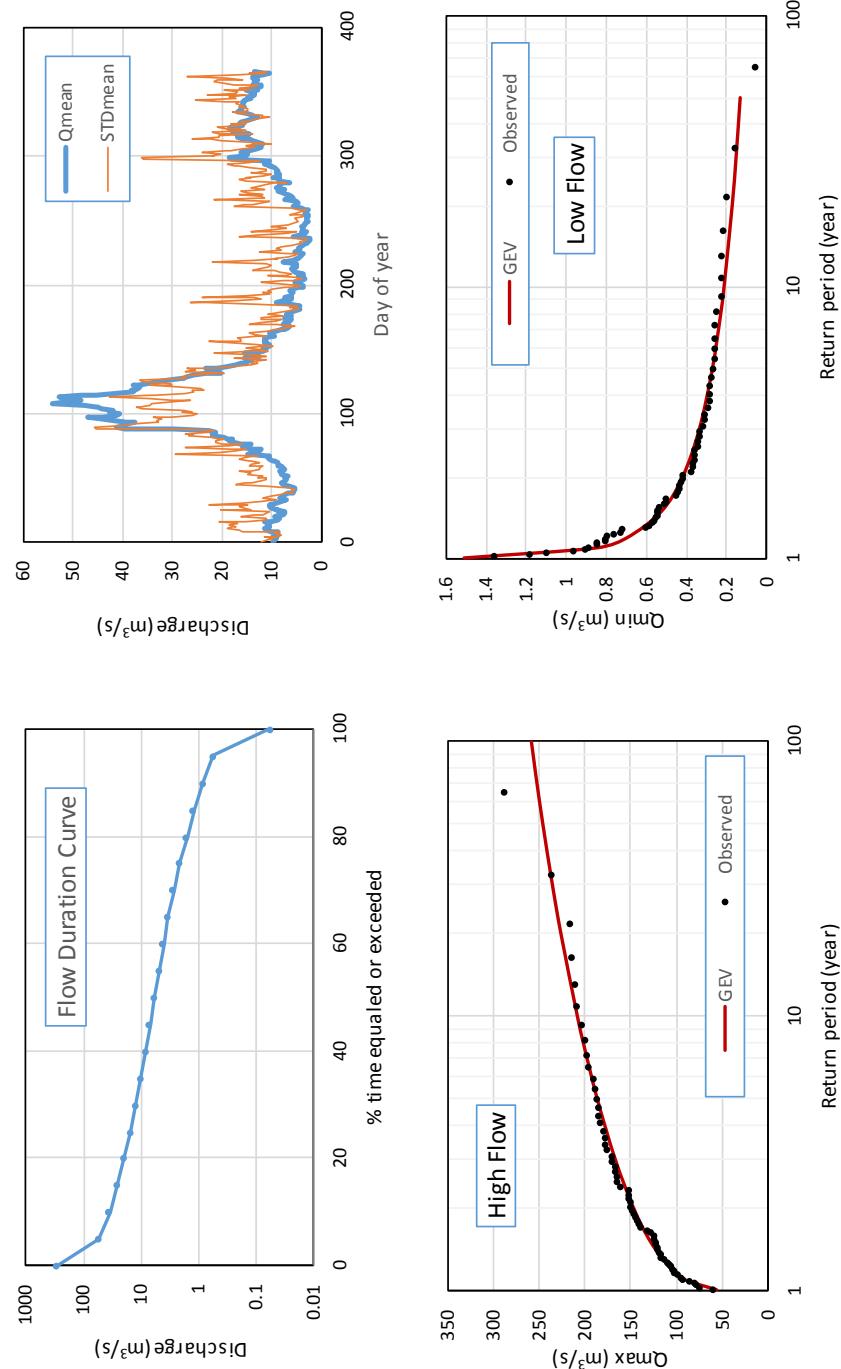


Figure B.21 : Canaan River at East Canaan (01AP002) (Continued)

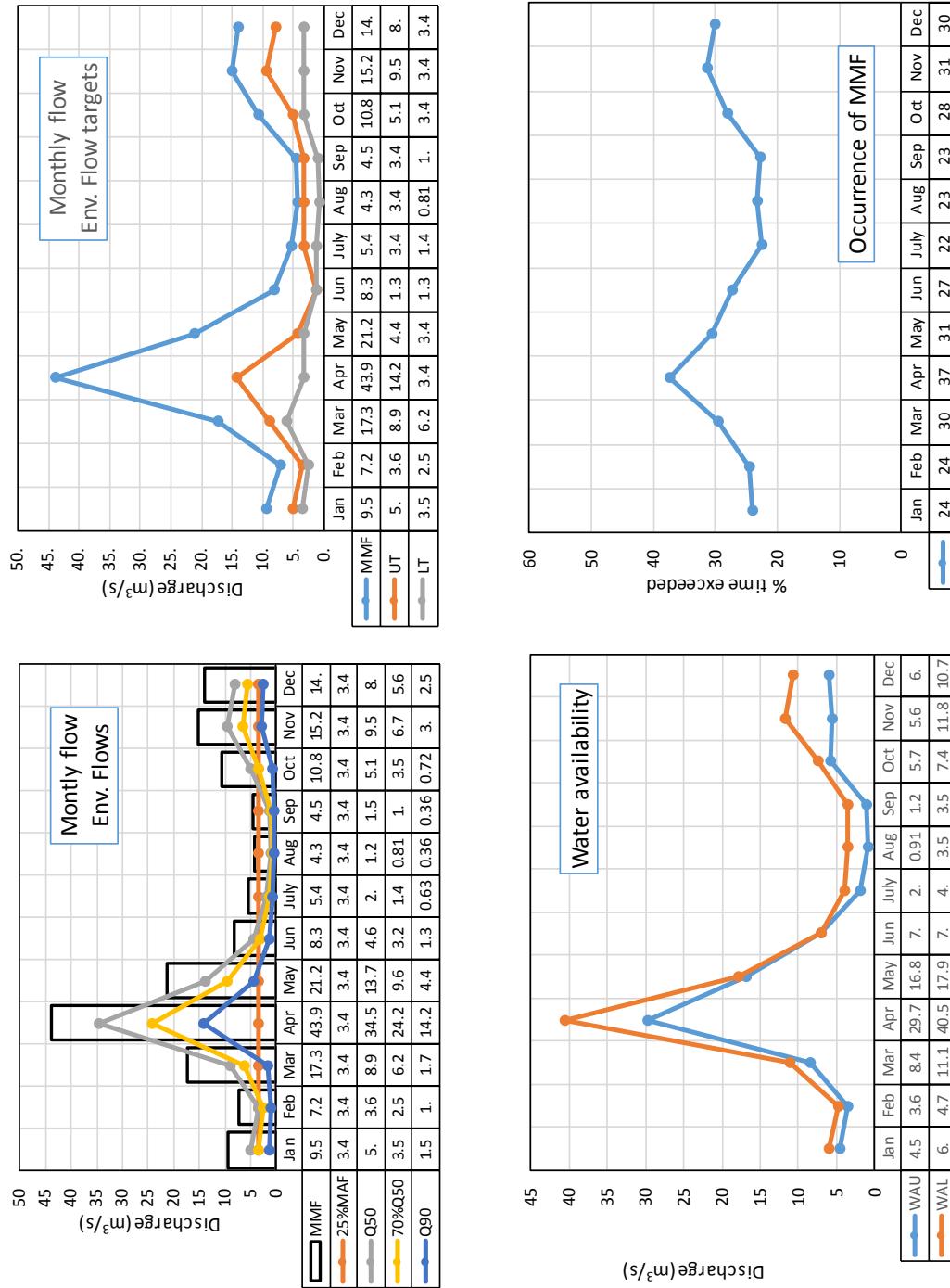


Figure B.22 : Kennebecasis River at Apohaqui (01AP004)

Station ID	01AP004	Mean annual flow (MAF)	25.5 m ³ /s
Latitude	45°42'05" N	Median annual flow (Q ₅₀)	14.1 m ³ /s
Longitude	65°36'06" W	Q ₅₀ (Aug)	4.6 m ³ /s
Drainage area	1100 km ²	70%Q ₅₀ (Aug)	3.22 m ³ /s
Period of record	1962-2011 (50 years)	Q ₉₀ (Aug)	2.55 m ³ /s

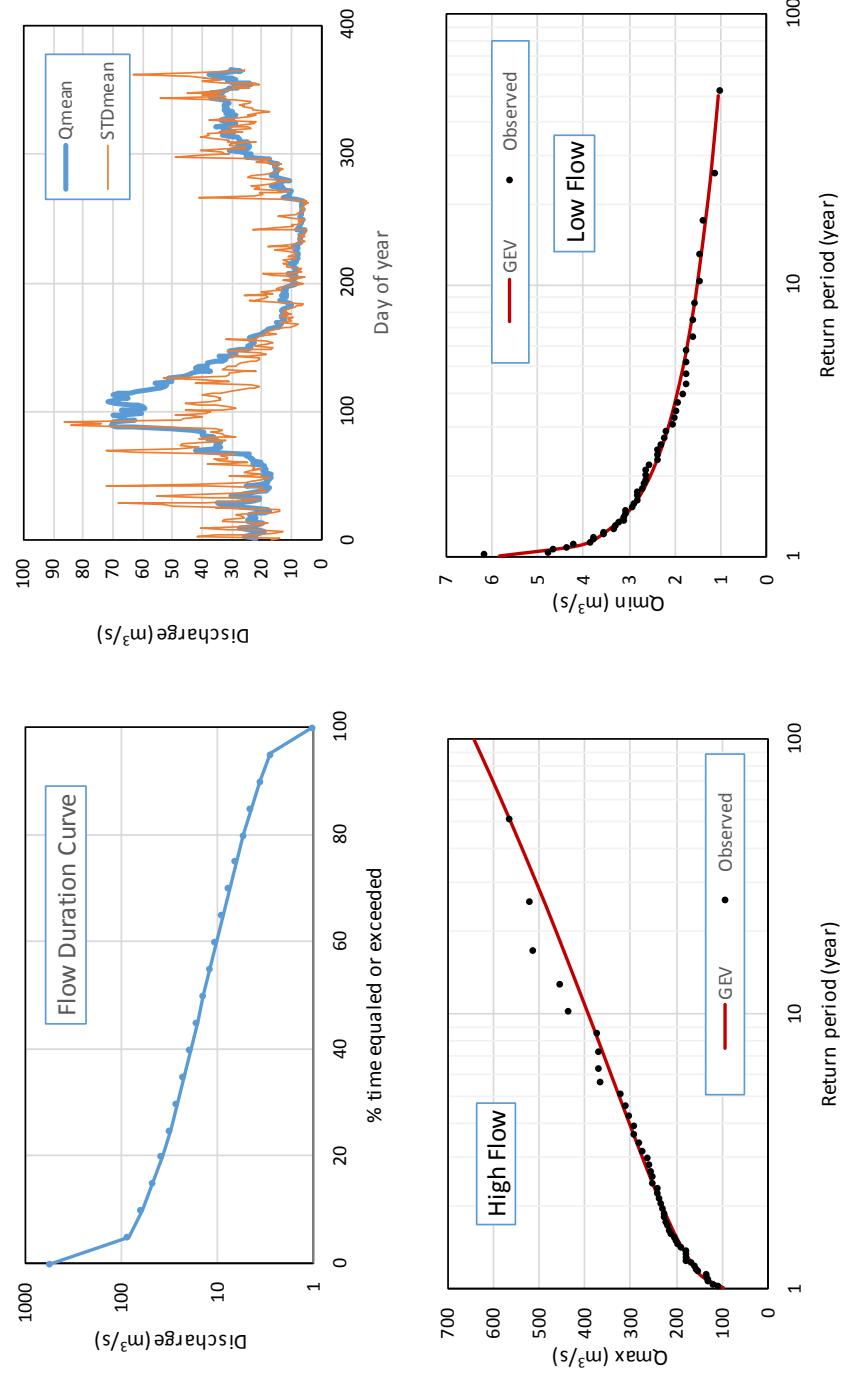


Figure B.22 : Kennebecasis River at Apohaqui (01AP004) (Continued)

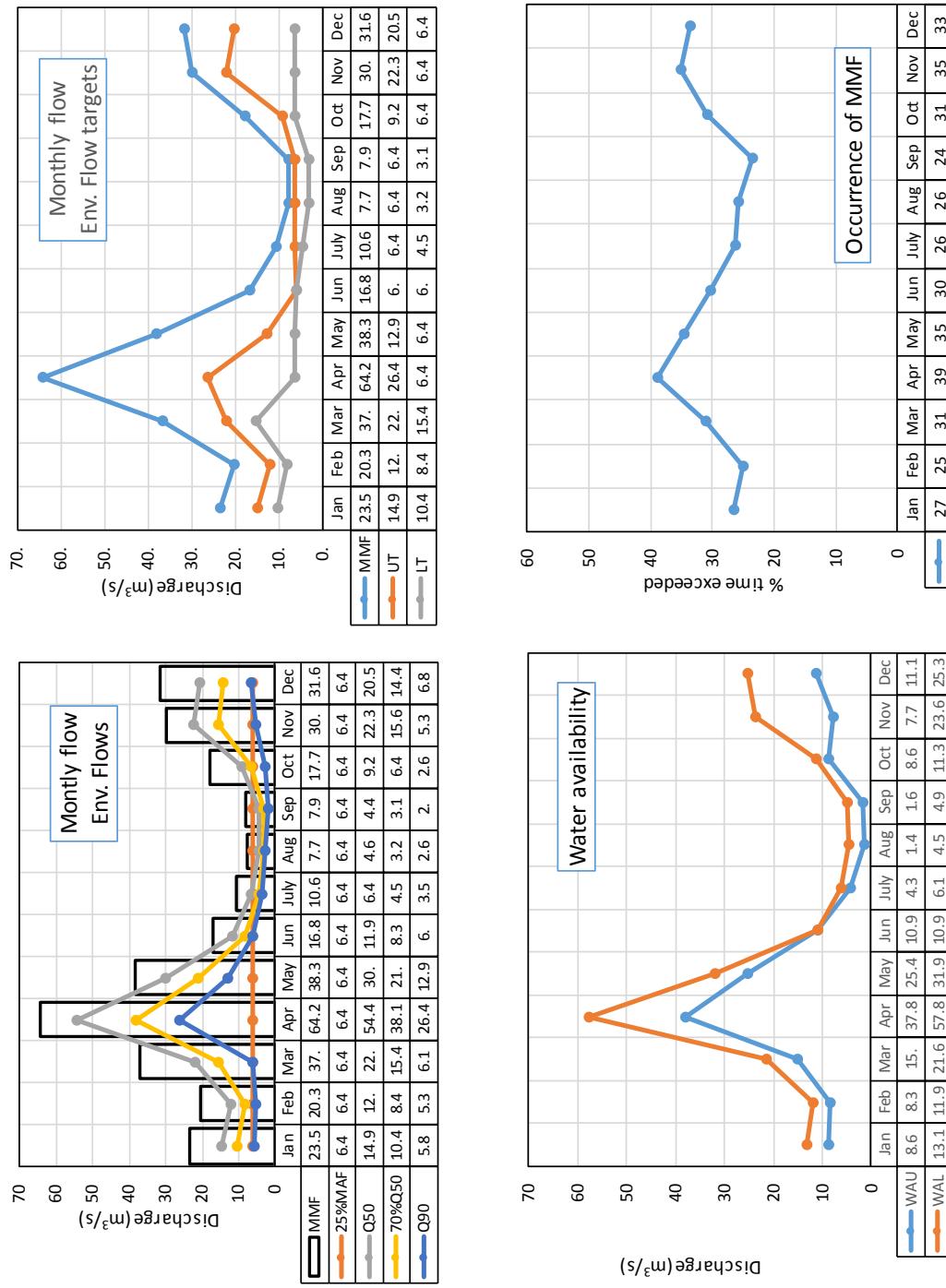


Figure B.23 : Nerepis River at Lepreau (01AP006)

Station ID	01AP006	Mean annual flow (MAF)	6.94 m ³ /s
Latitude	45°30'12" N	Median annual flow (Q ₅₀)	3.05 m ³ /s
Longitude	66°19'08" W	Q ₅₀ (Aug)	0.807 m ³ /s
Drainage area	293 km ²	70%Q ₅₀ (Aug)	0.5649 m ³ /s
Period of record	1976-1993,2009-2010 (20 years)	Q ₉₀ (Aug)	0.154 m ³ /s

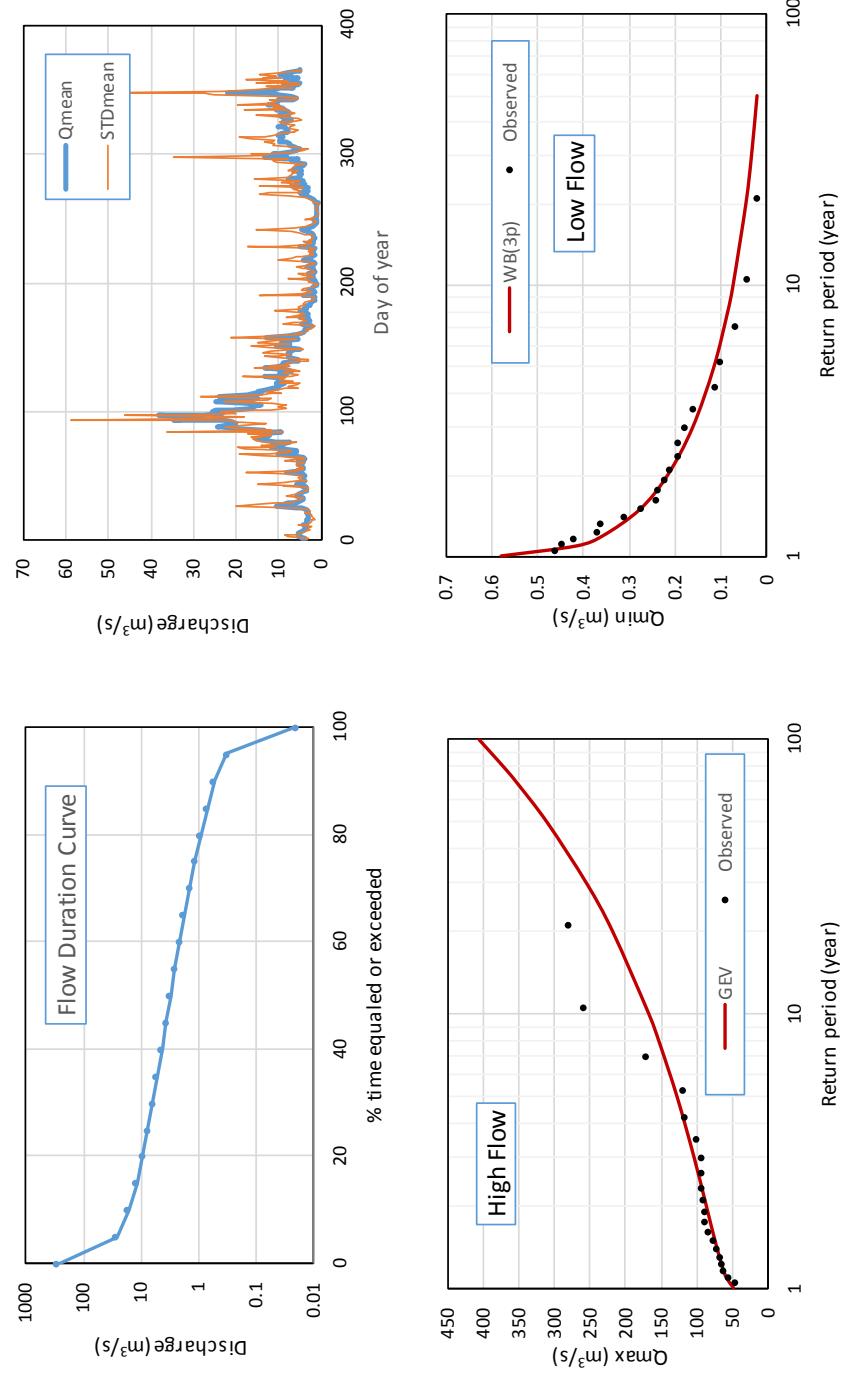


Figure B.23 : Nerepis River at Lepreau (01AP006) (Continued)

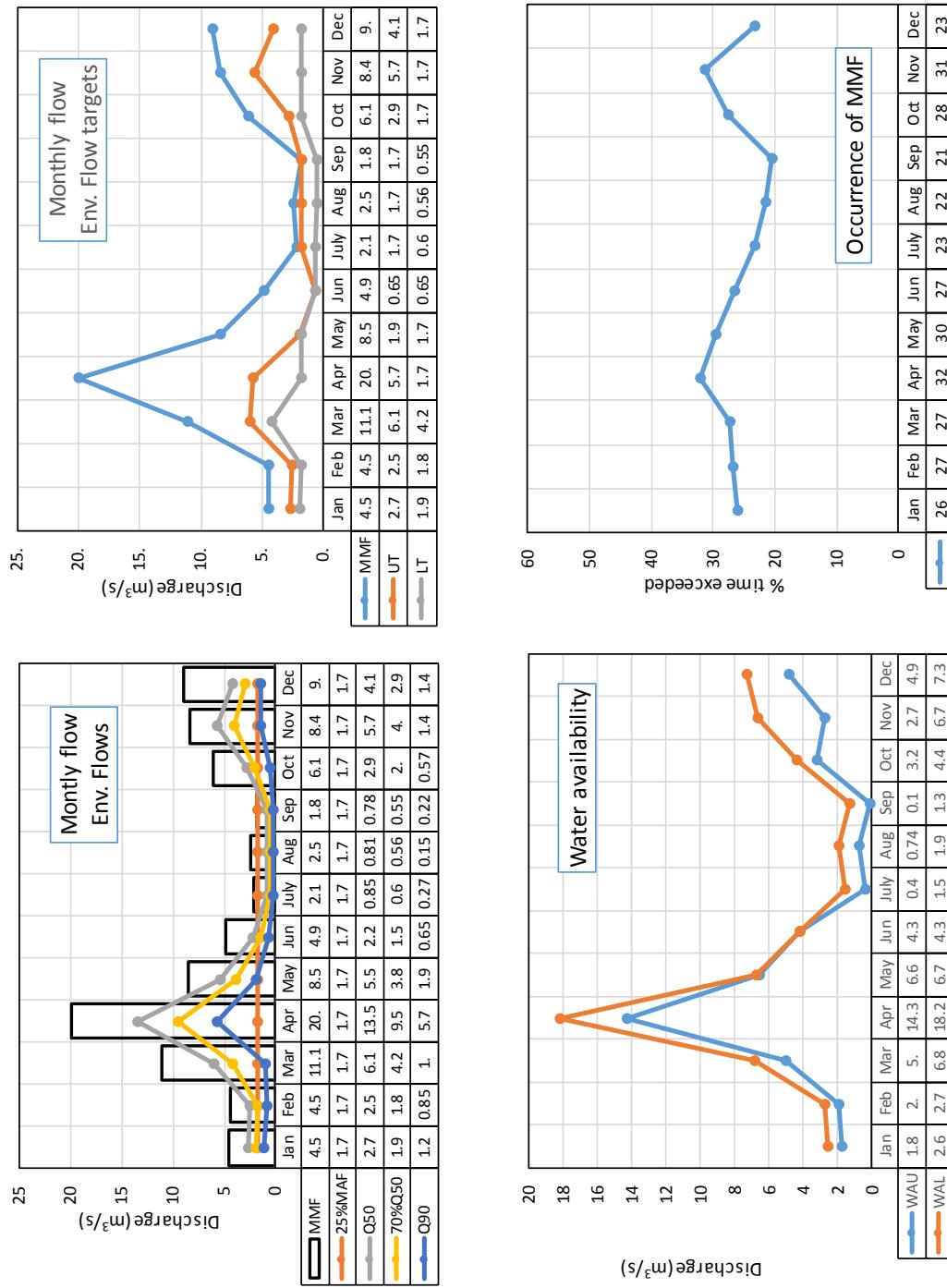


Figure B.24 : Lepreau River at Lepreau (01AQ001)

Station ID	01AQ001	Mean annual flow (MAF)	7.32 m ³ /s
Latitude	45°10'11" N	Median annual flow (Q ₅₀)	4.19 m ³ /s
Longitude	66°28'05" W	Q ₅₀ (Aug)	1.2 m ³ /s
Drainage area	239 km ²	70%Q ₅₀ (Aug)	0.84 m ³ /s
Period of record	1919-2011 (93 years)	Q ₉₀ (Aug)	0.275 m ³ /s

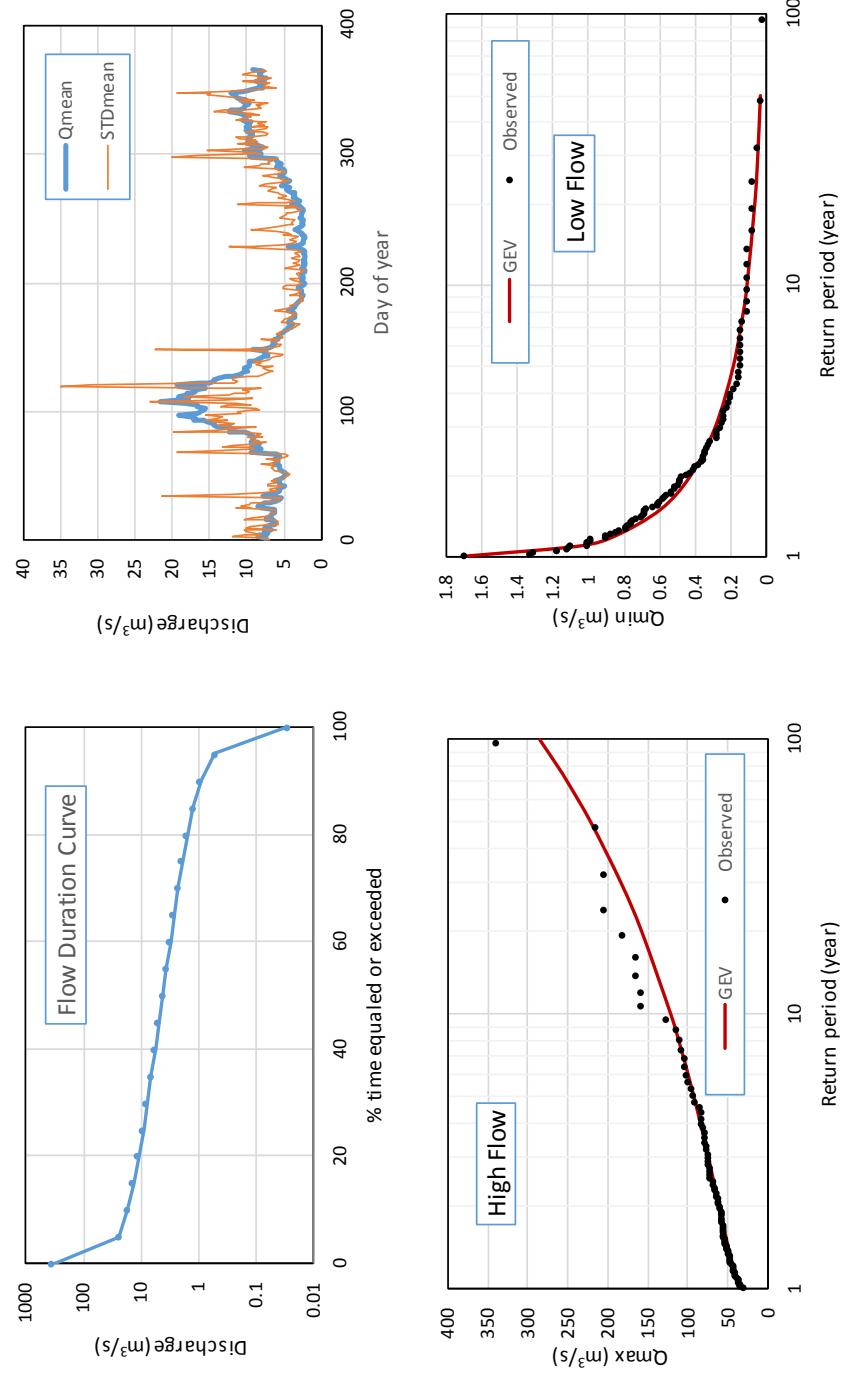


Figure B.24 : Lepreau River at Lepreau (01AQ001) (Continued)

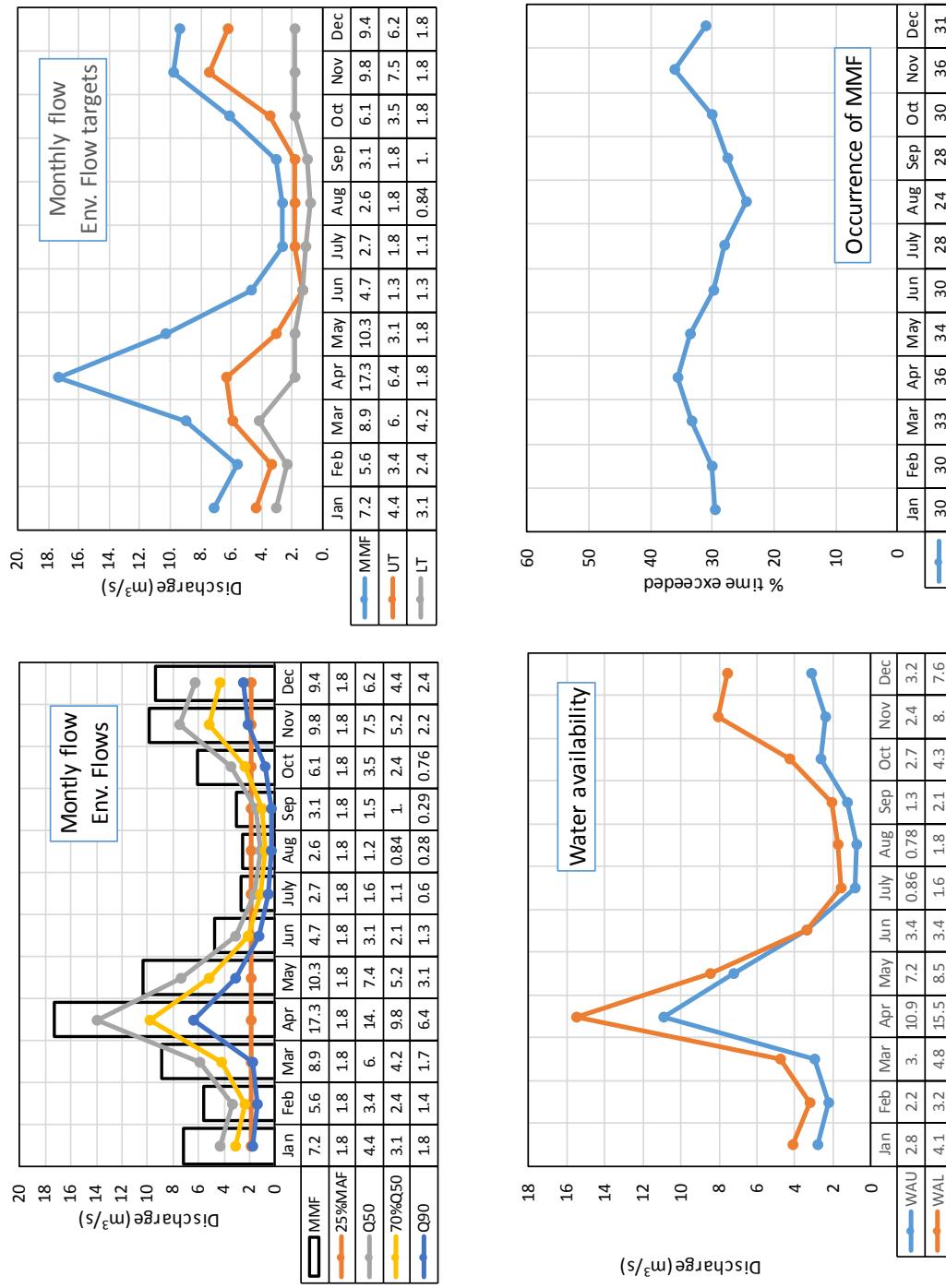


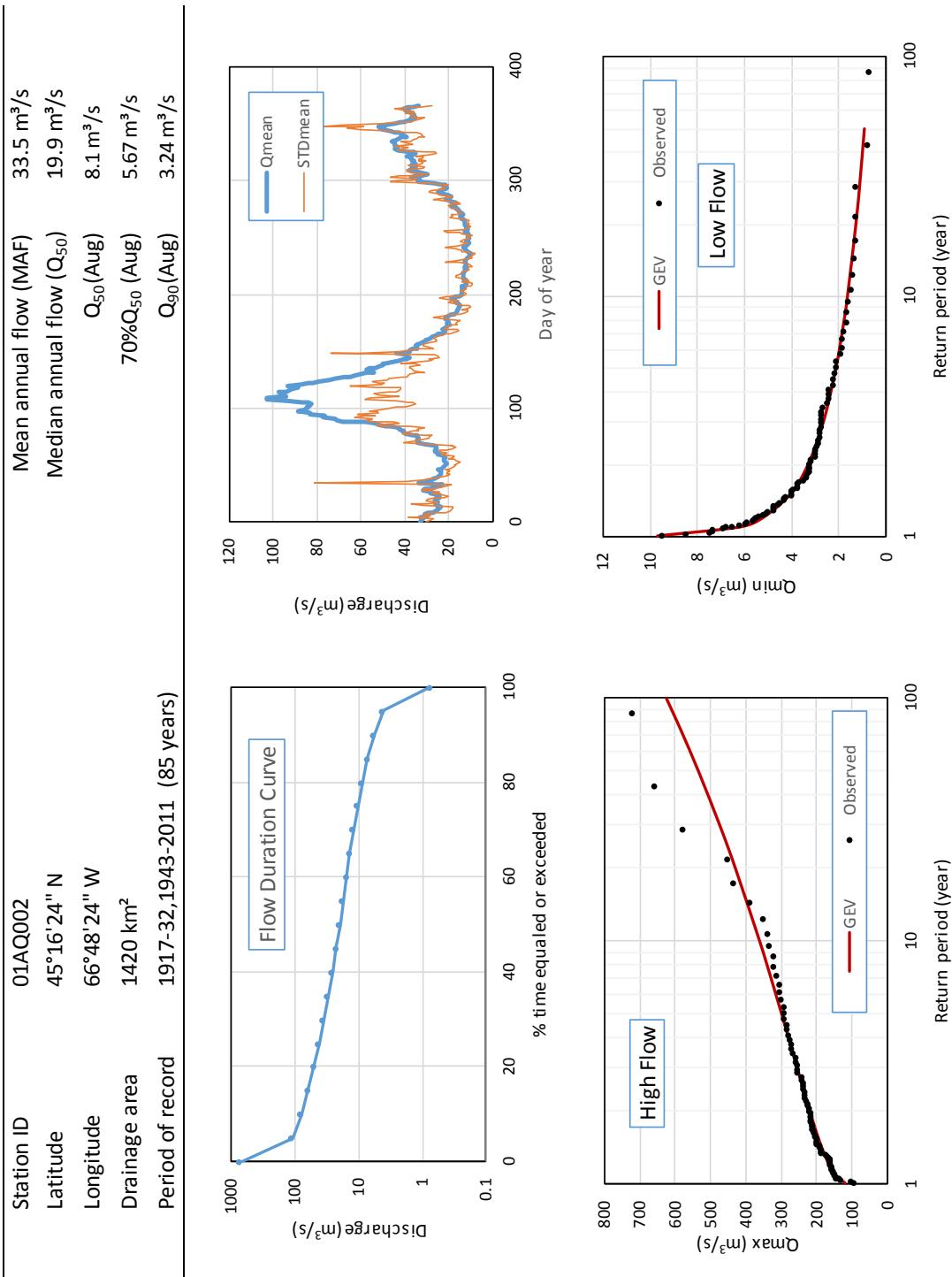
Figure B.25 : Magaguadavic River at Elmcroft (01AQ002)

Figure B.25 : Magaguadavic River at Elmcroft (01AQ002) (Continued)

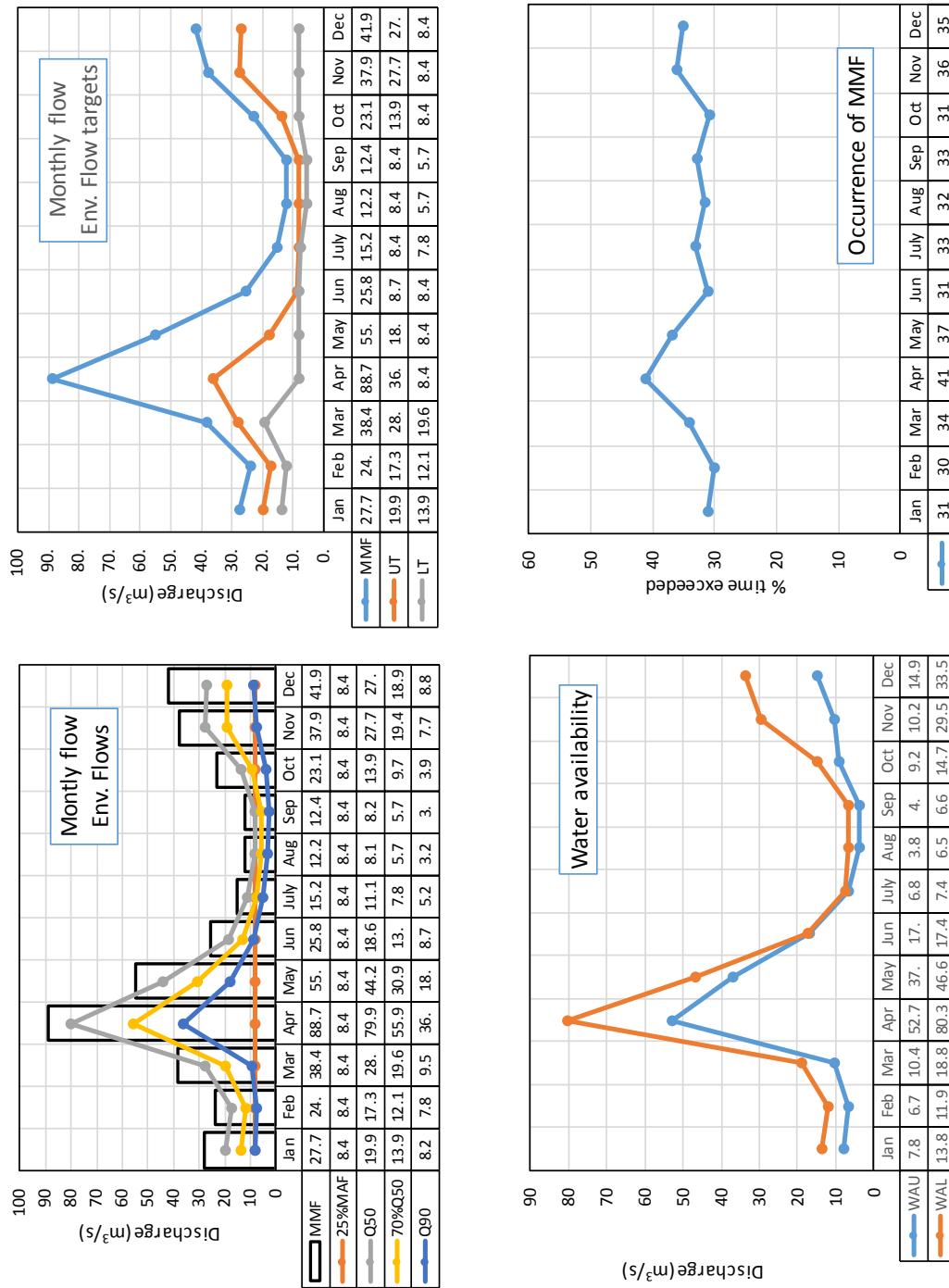


Figure B.26 : Dennis Stream near Saint Stephen (01AR006)

Station ID	01AR006	Mean annual flow (MAF)	2.78 m ³ /s
Latitude	45°12'35" N	Median annual flow (Q ₅₀)	1.36 m ³ /s
Longitude	67°15'45" W	Q ₅₀ (Aug)	0.253 m ³ /s
Drainage area	115 km ²	70%Q ₅₀ (Aug)	0.1771 m ³ /s
Period of record	1967-2012 (46 years)	Q ₉₀ (Aug)	0.04 m ³ /s

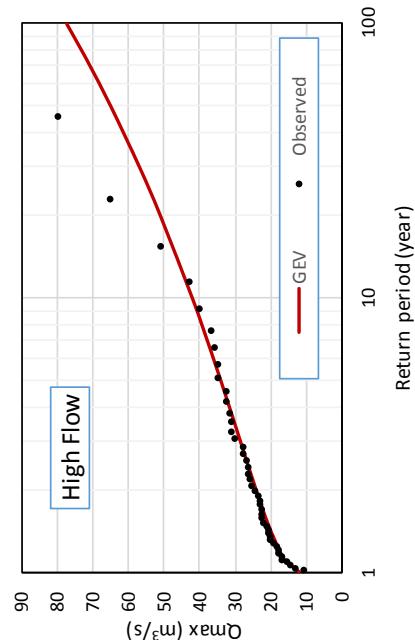
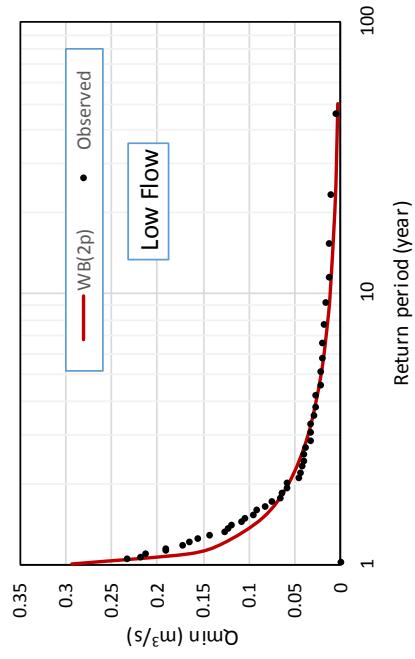
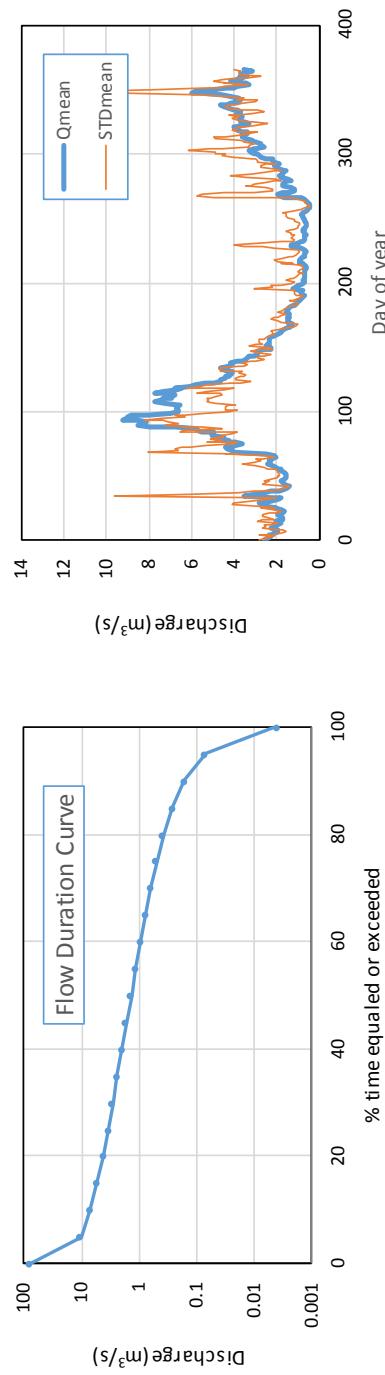


Figure B.26 : Dennis Stream near Saint Stephen (01AR006) (Continued)

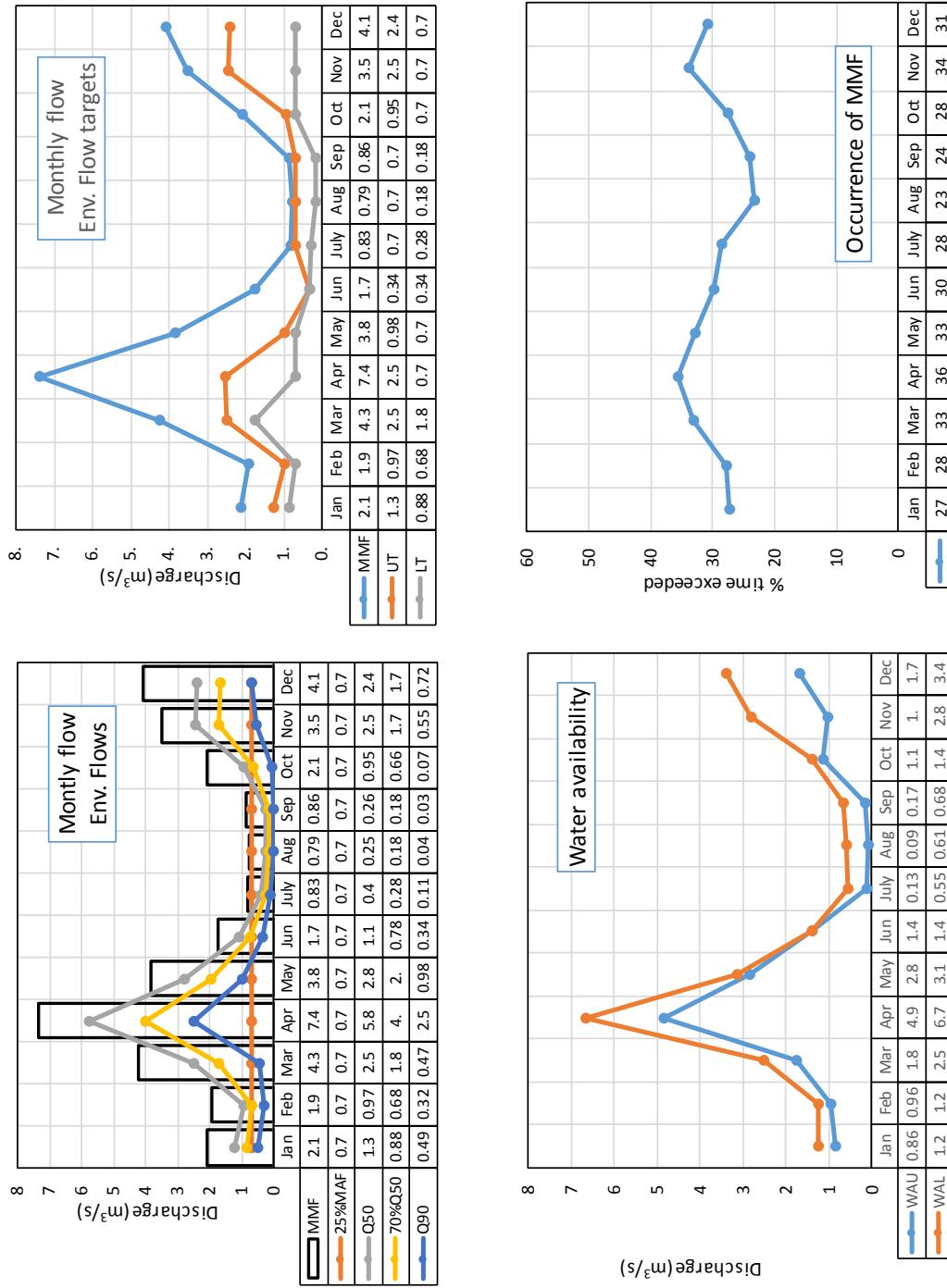


Figure B.27 : Bocabec River above Tide (01AR008)

Station ID	01AR008	Mean annual flow (MAF)	1.095 m ³ /s
Latitude	45°11'35" N	Median annual flow (Q ₅₀)	0.609 m ³ /s
Longitude	66°59'56" W	Q ₅₀ (Aug)	0.15 m ³ /s
Drainage area	43 km ²	70%Q ₅₀ (Aug)	0.105 m ³ /s
Period of record	1967-1979 (13 years)	Q ₉₀ (Aug)	0.0152 m ³ /s

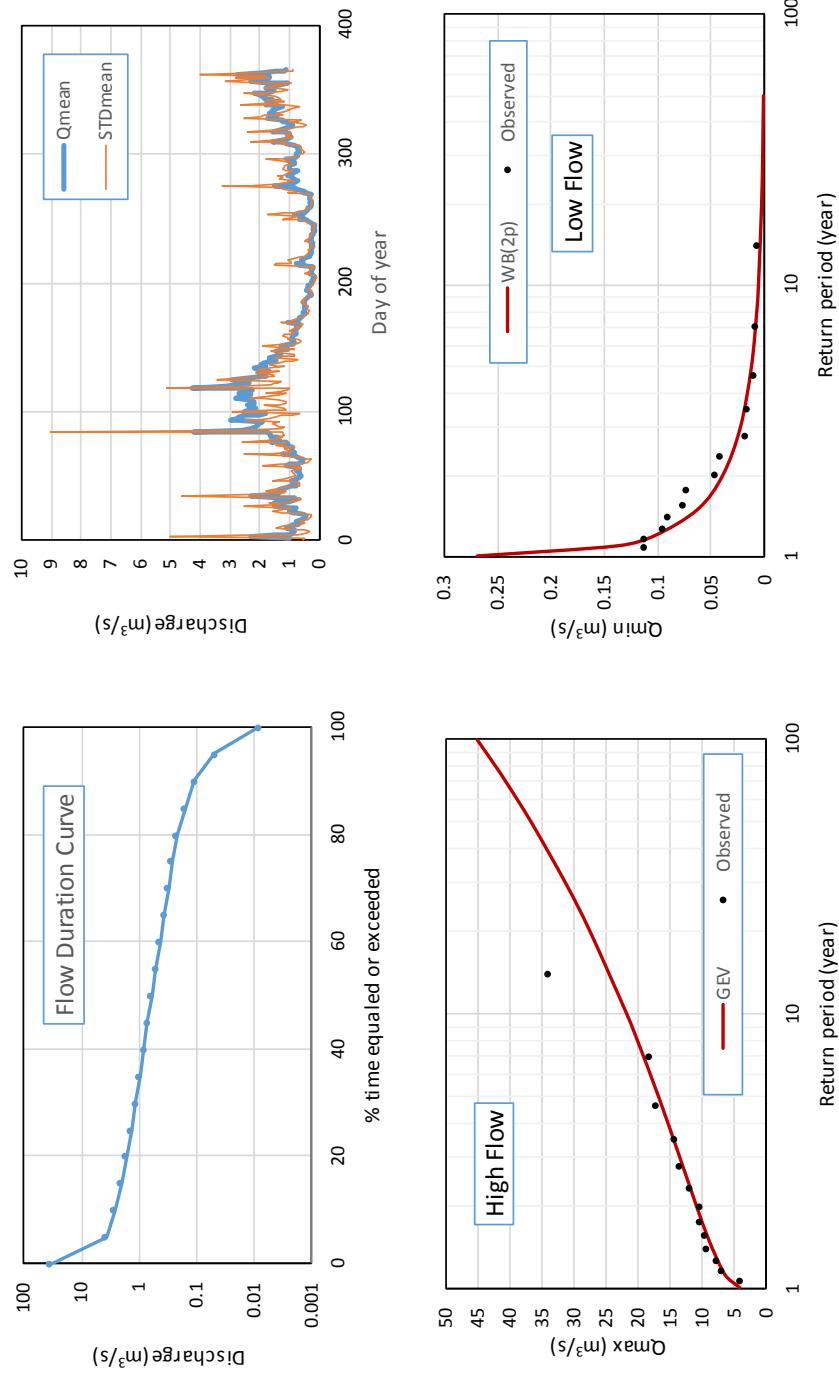


Figure B.27 : Bocabec River above Tide (01AR008) (Continued)

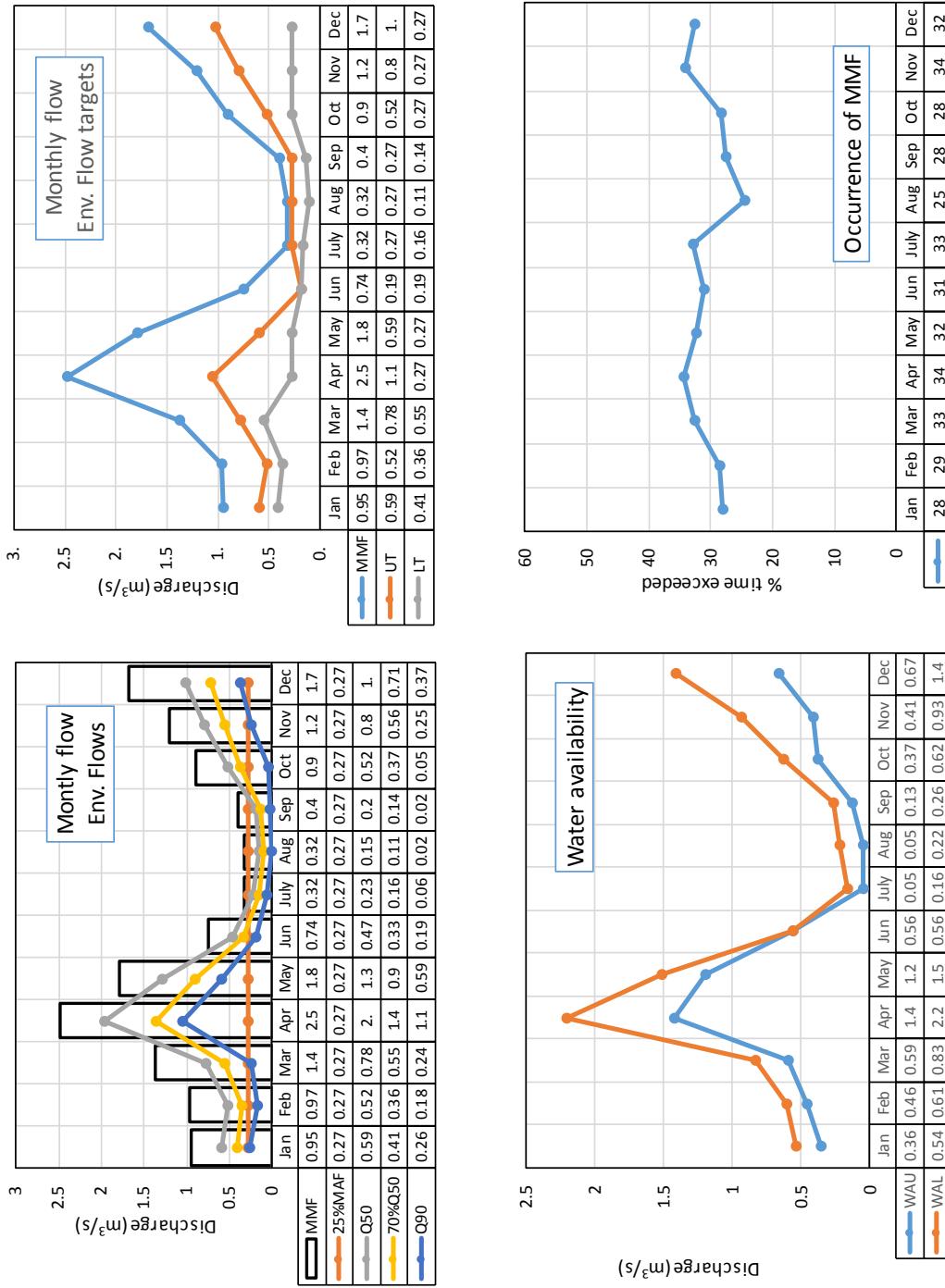


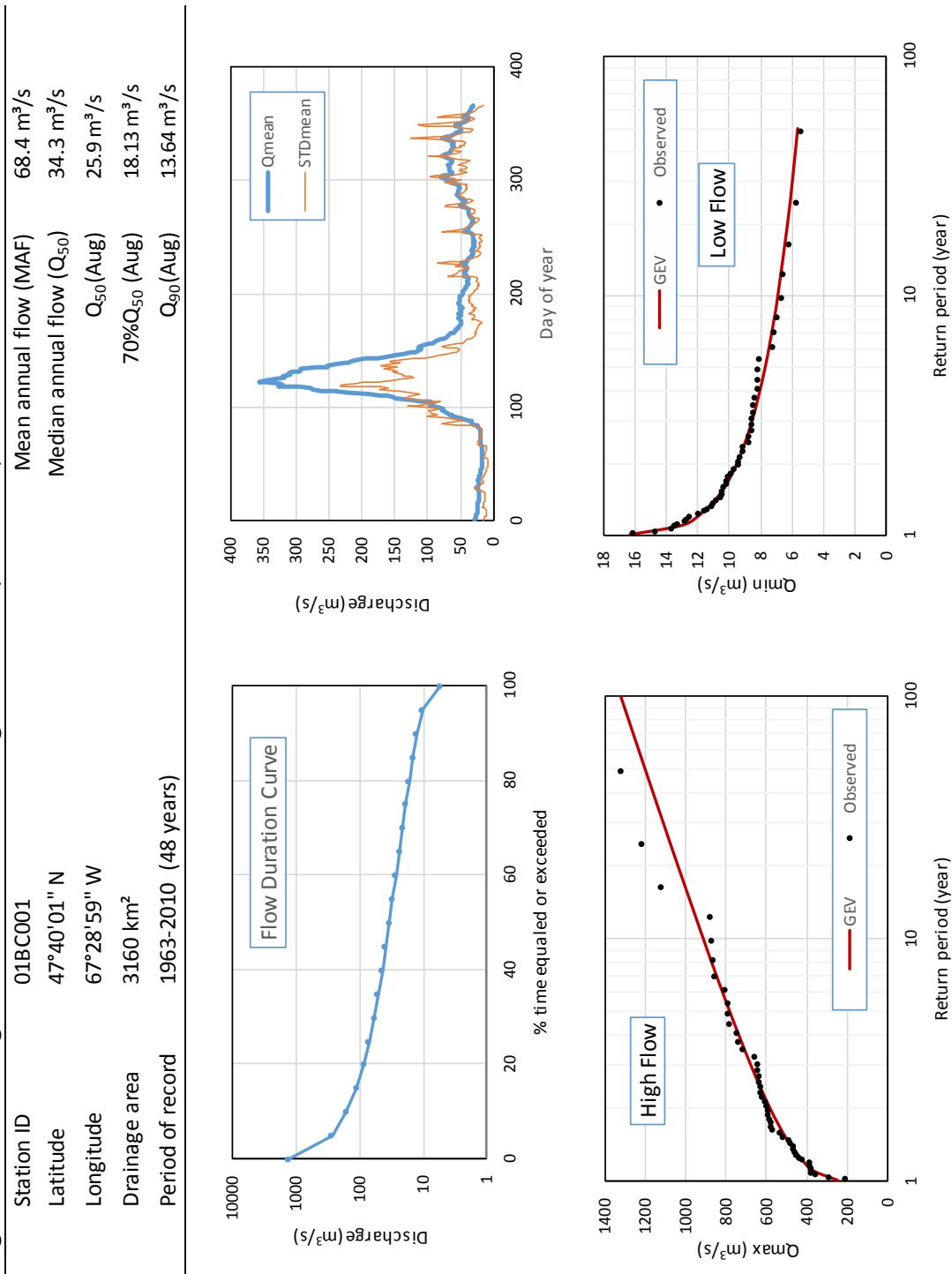
Figure B.28 : Restigouche River below Kedgwick River (01BC001)

Figure B.28 : Restigouche River below Kedgwick River (01BC001) (Continued)

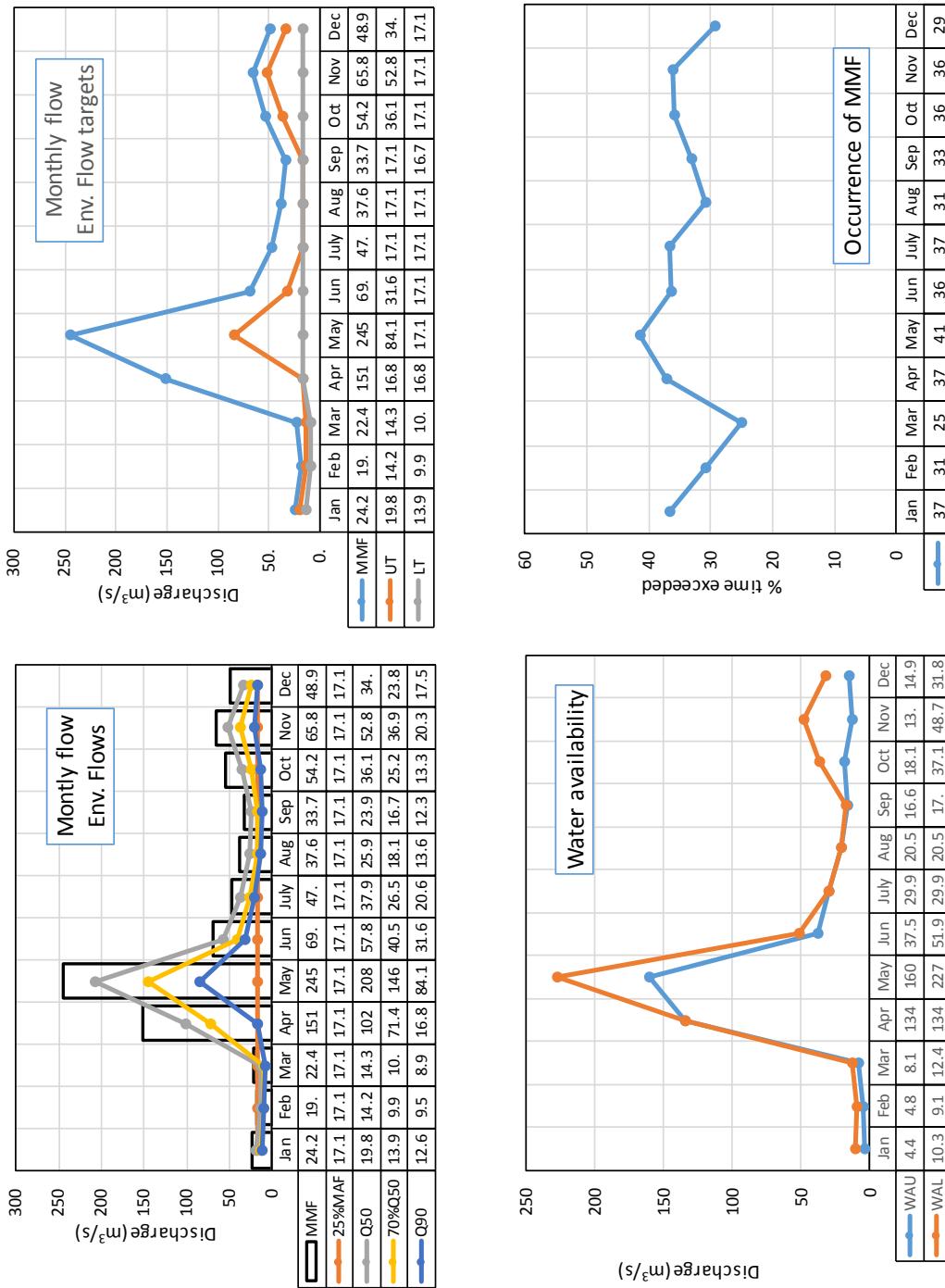


Figure B.29 : Upsilonquitch River at Upsilonquitch (01BE001)

Station ID	01BE001	Mean annual flow (MAF)	41.1 m ³ /s
Latitude	47°49'56" N	Median annual flow (Q ₅₀)	18.4 m ³ /s
Longitude	66°53'13" W	Q ₅₀ (Aug)	14 m ³ /s
Drainage area	2270 km ²	70%Q ₅₀ (Aug)	9.8 m ³ /s
Period of record	1919-32,1944-2010 (81 years)	Q ₉₀ (Aug)	7.67 m ³ /s

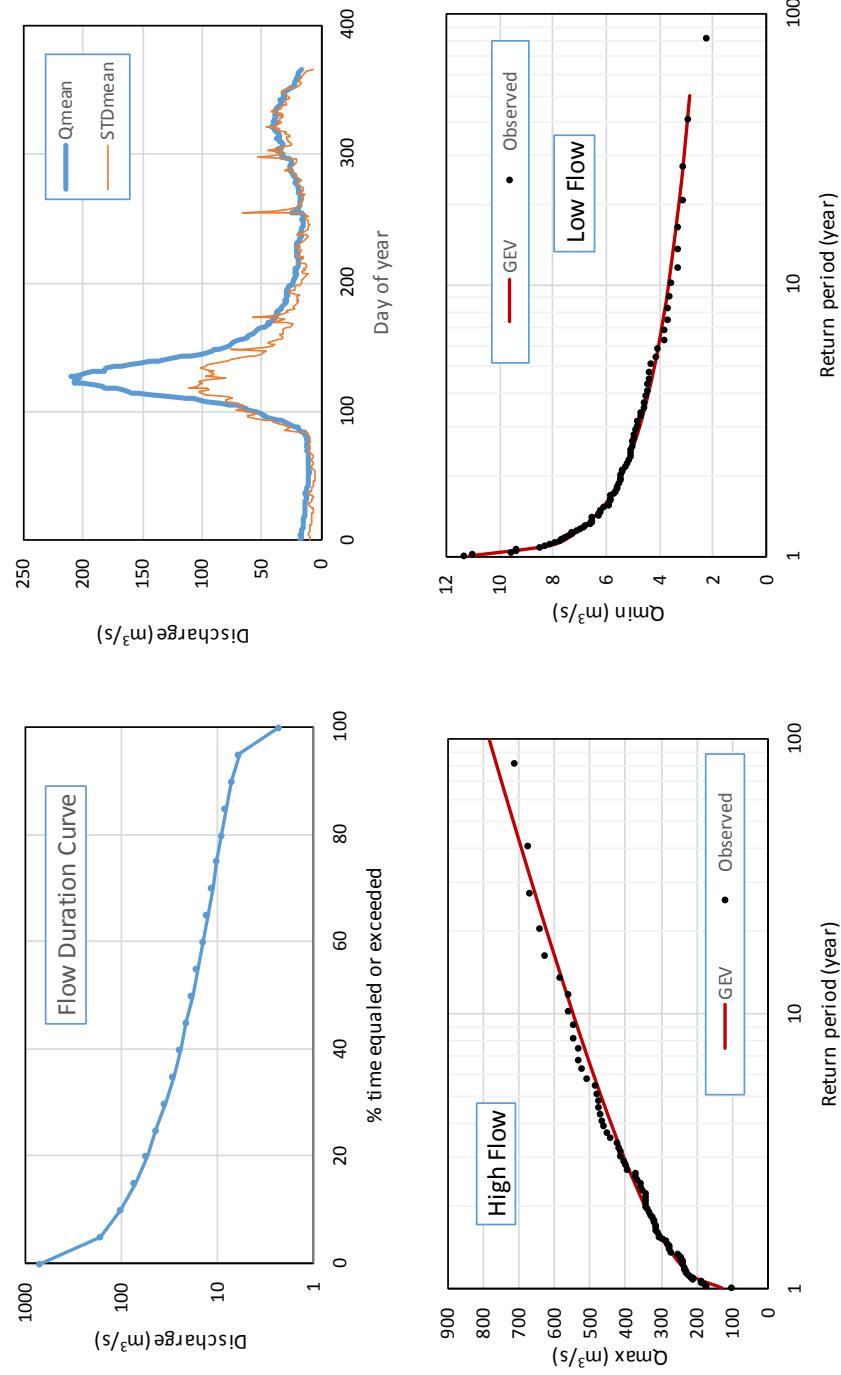


Figure B.29 : Upsilonquitch River at Upsilonquitch (01BE001) (Continued)

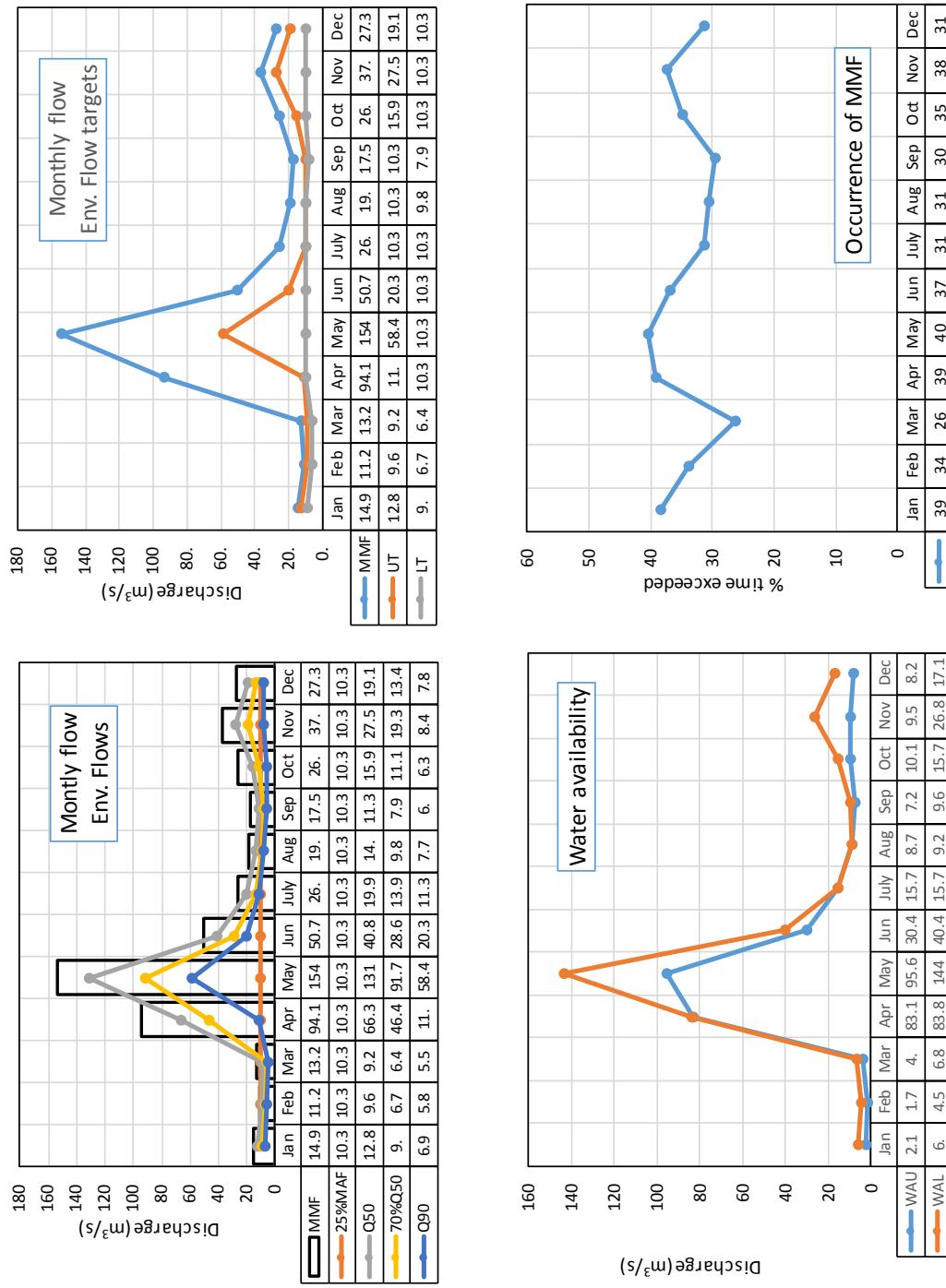


Figure B.30 : Tetagouche River near West Bathurst (01BJ001)

Station ID	01BJ001	Mean annual flow (MAF)	7.65 m ³ /s
Latitude	47°39'21" N	Median annual flow (Q ₅₀)	2.92 m ³ /s
Longitude	65°41'37" W	Q ₅₀ (Aug)	1.73 m ³ /s
Drainage area	363 km ²	70%Q ₅₀ (Aug)	1.211 m ³ /s
Period of record	1923-33,1952-1994 (54 years)	Q ₉₀ (Aug)	0.793 m ³ /s

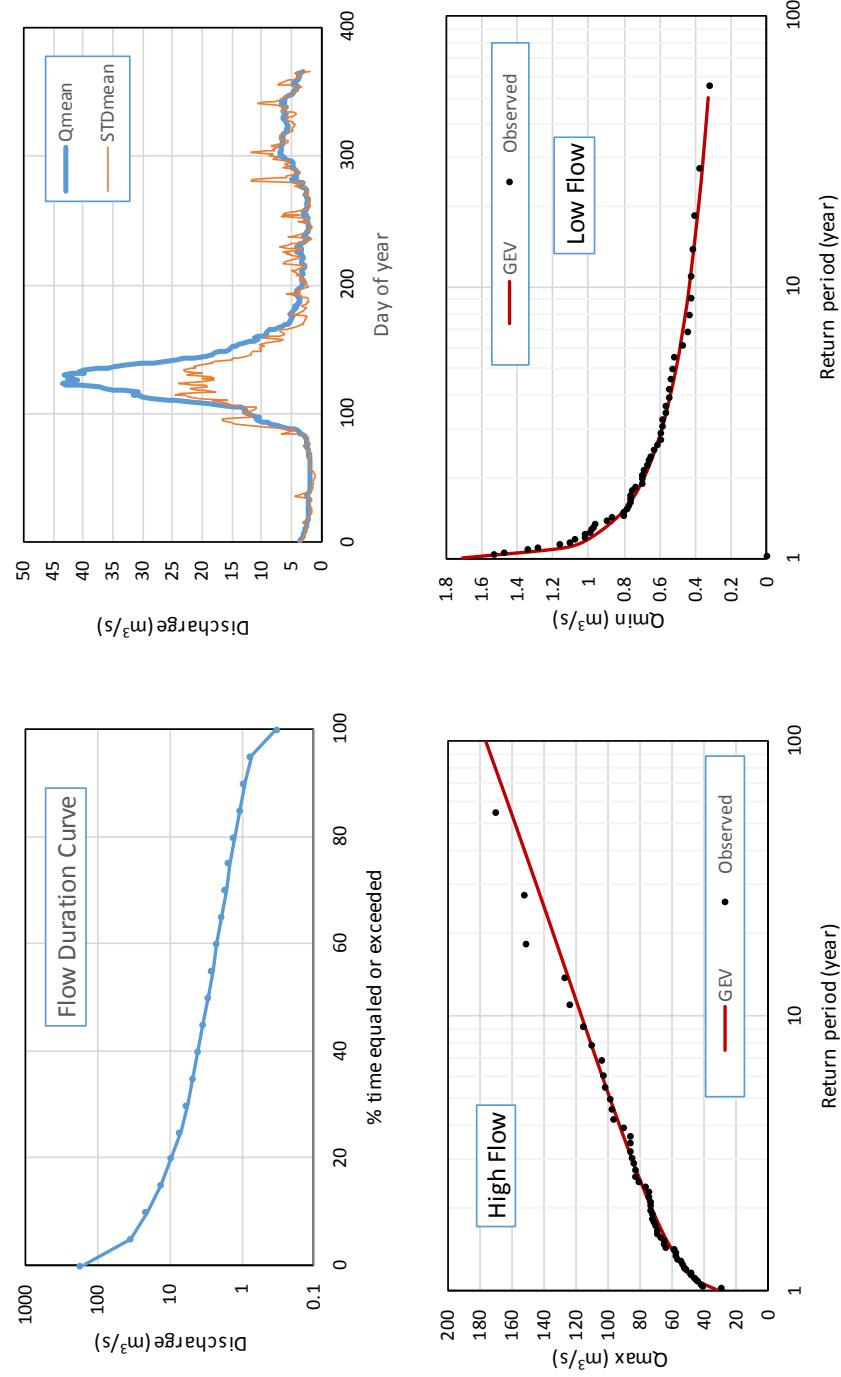


Figure B.30 : Tetagouche River near West Bathurst (01BJ001) (Continued)

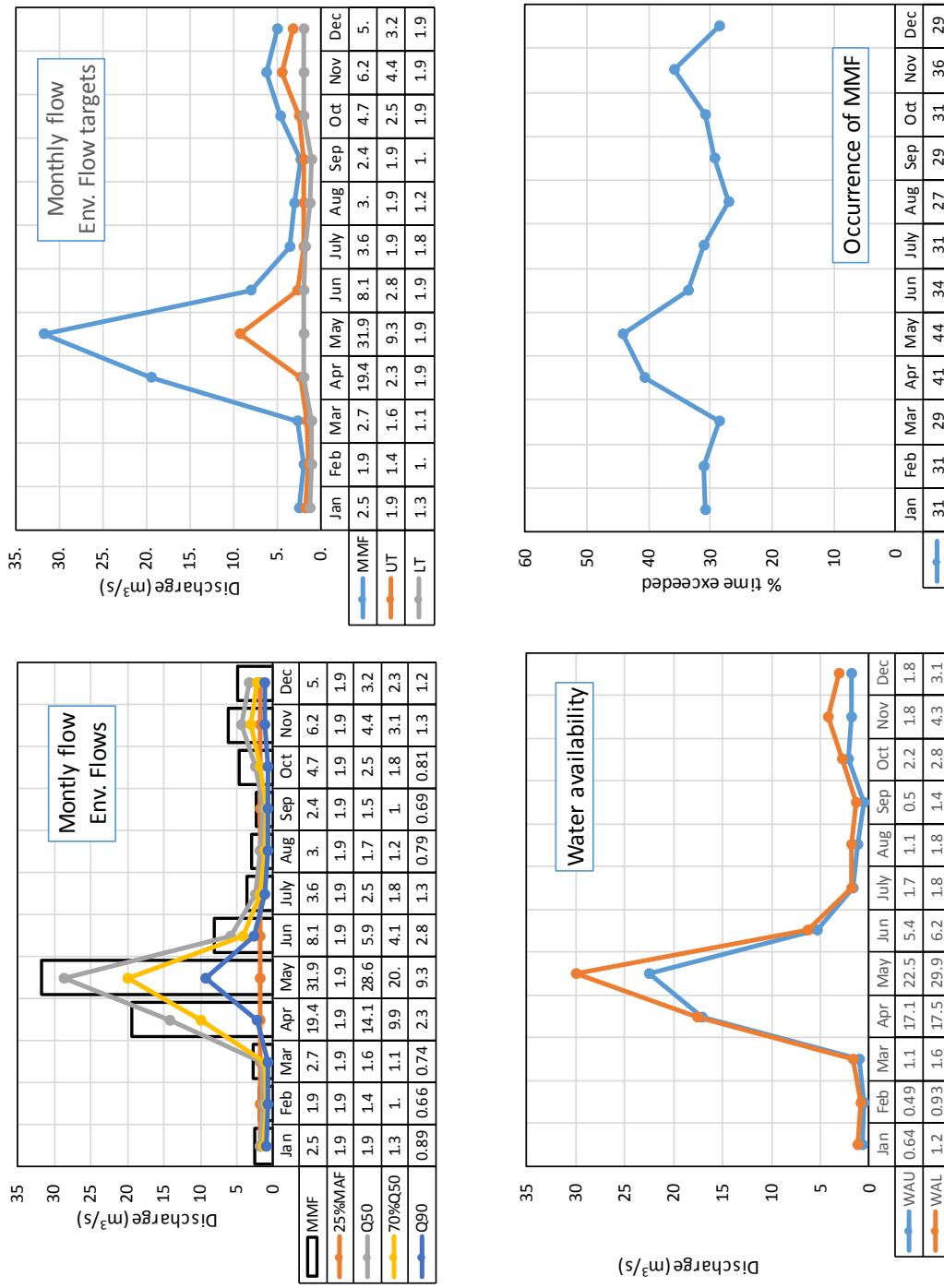


Figure B.31 : Jacquet River near Durham Centre (01BJ003)

Station ID	01BJ003	Mean annual flow (MAF)	10.7 m ³ /s
Latitude	47°53'37" N	Median annual flow (Q ₅₀)	4.03 m ³ /s
Longitude	66°01'30" W	Q ₅₀ (Aug)	2.63 m ³ /s
Drainage area	510 km ²	70%Q ₅₀ (Aug)	1.841 m ³ /s
Period of record	1965-2011 (47 years)	Q ₉₀ (Aug)	1.16 m ³ /s

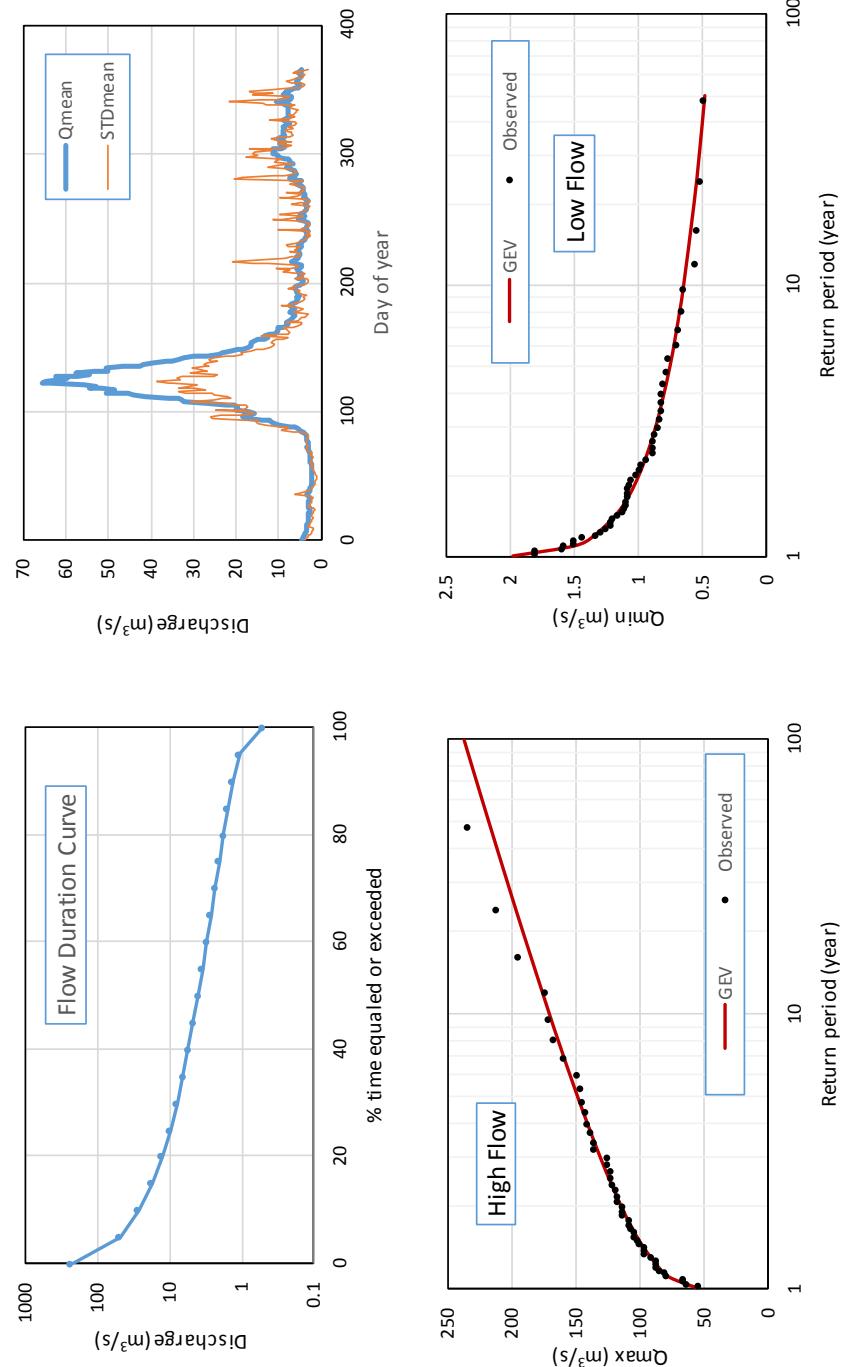


Figure B.31 : Jacquet River near Durham Centre (01BJ003) (Continued)

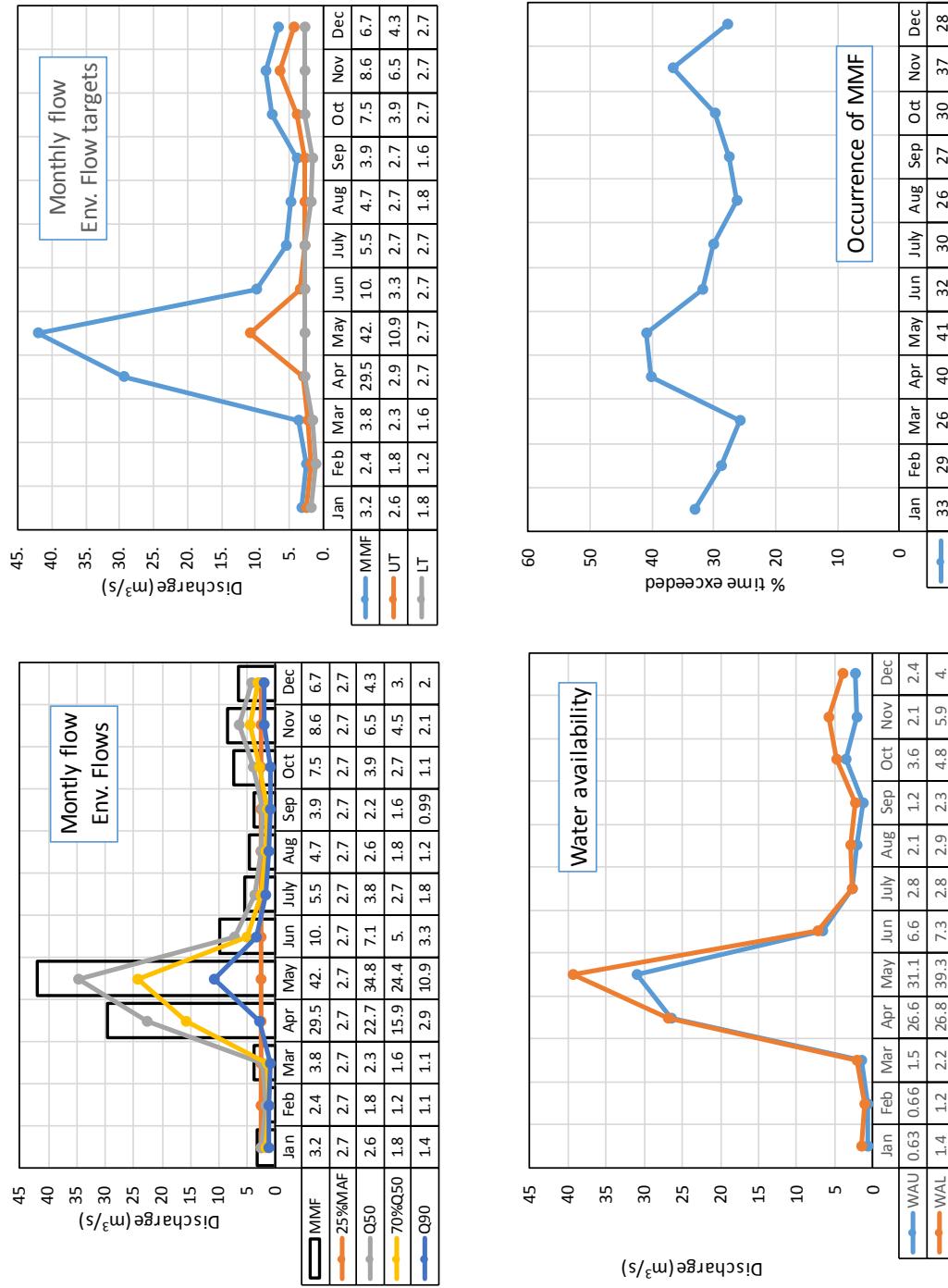


Figure B.32 : Eel River near Eel River Crossing (01BJ004)

Station ID	01BJ004	Mean annual flow (MAF)	2.11 m ³ /s
Latitude	48°00'52" N	Median annual flow (Q ₅₀)	0.776 m ³ /s
Longitude	66°26'18" W	Q ₅₀ (Aug)	0.4985 m ³ /s
Drainage area	88.6 km ²	70%Q ₅₀ (Aug)	0.34895 m ³ /s
Period of record	1968-1983 (16 years)	Q ₉₀ (Aug)	0.2085 m ³ /s

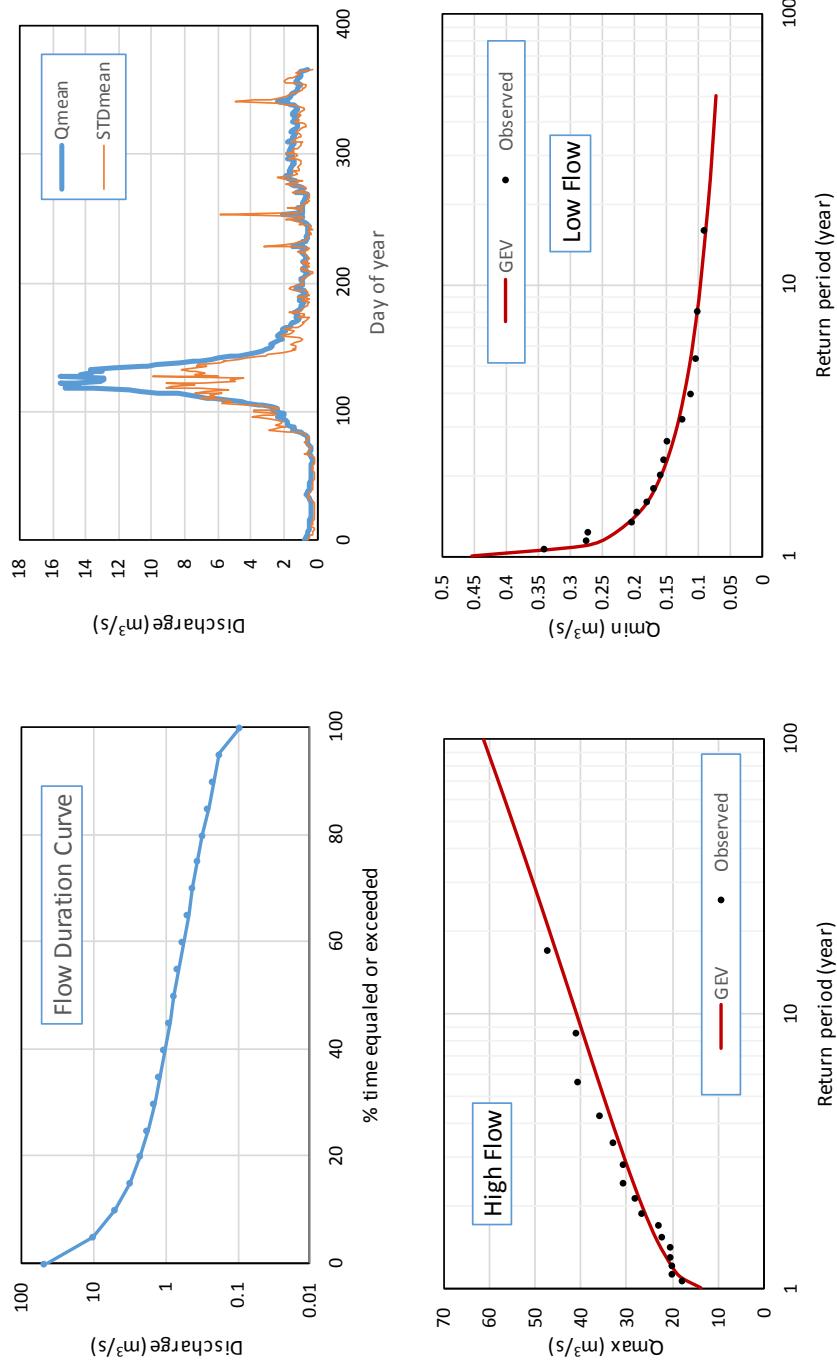


Figure B.32 : Eel River near Eel Crossing (01BJ004) (Continued)

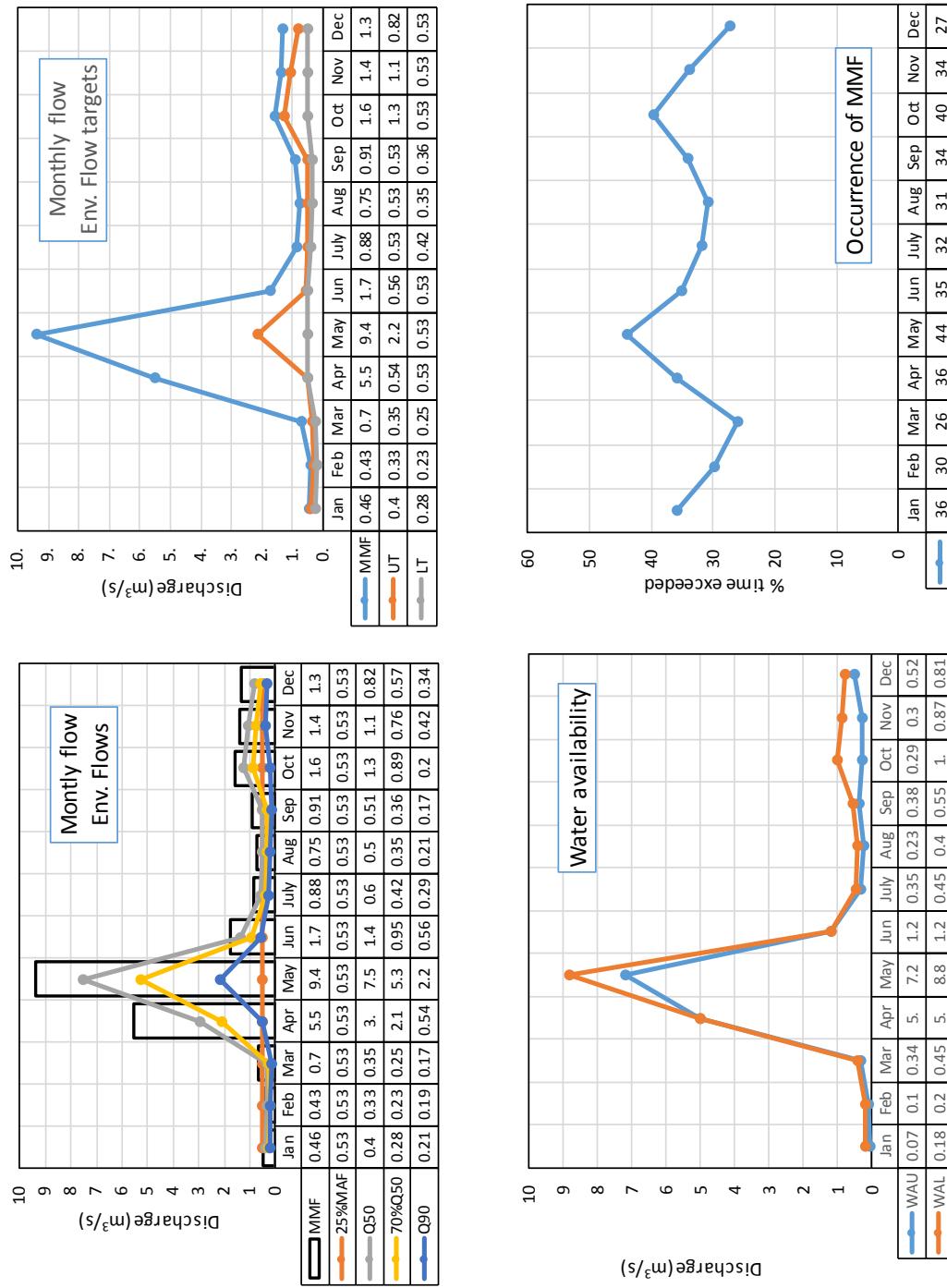


Figure B.33 : Restgouche River above Rafting Ground Brook (01BJ007)

Station ID	01BJ007	Mean annual flow (MAF)	163.4 m ³ /s
Latitude	47°54'31" N	Median annual flow (Q ₅₀)	80 m ³ /s
Longitude	66°56'53" W	Q ₅₀ (Aug)	62.05 m ³ /s
Drainage area	7740 km ²	70%Q ₅₀ (Aug)	43.435 m ³ /s
Period of record	1969-2010 (42 years)	Q ₉₀ (Aug)	34.8 m ³ /s

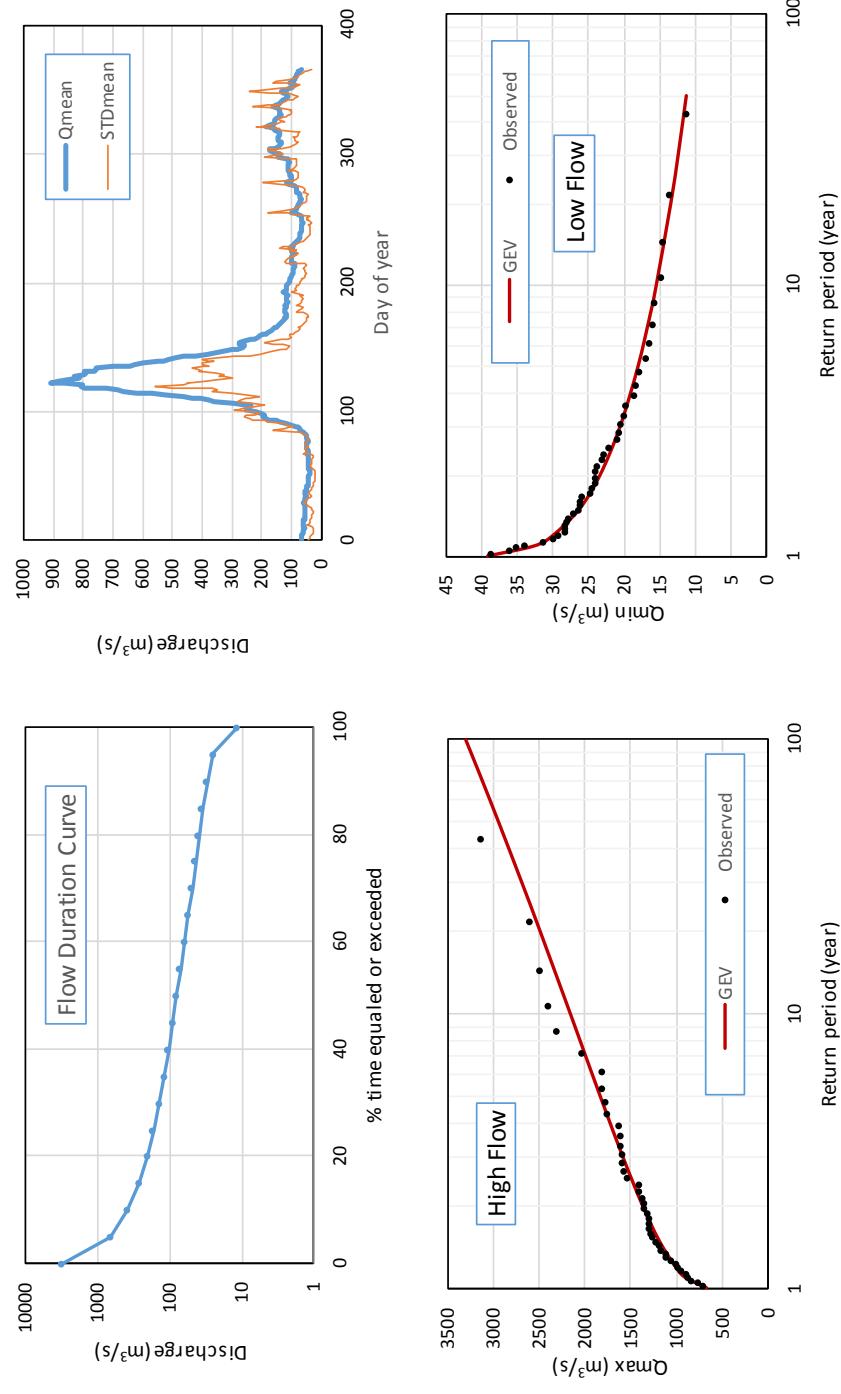


Figure B.33 : Restgouche River above Rafting Ground Brook (01BJ007) (Continued)

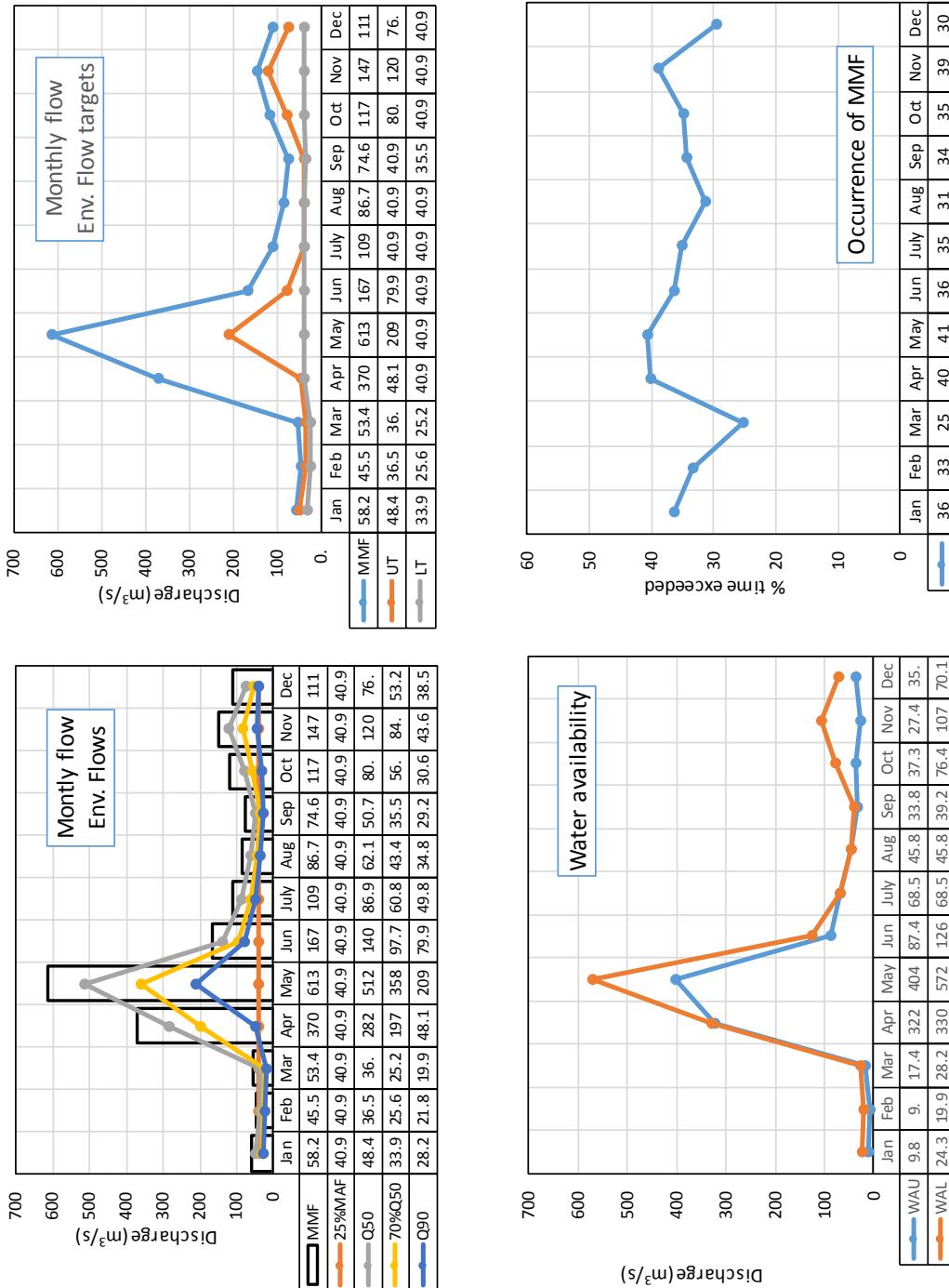


Figure B.34 : Nepisiquit River near Pabineau Falls (01BK004)

Station ID	01BK004	Mean annual flow (MAF)	45.2 m ³ /s
Latitude	47°29'40" N	Median annual flow (Q ₅₀)	23.8 m ³ /s
Longitude	65°40'50" W	Q ₅₀ (Aug)	17 m ³ /s
Drainage area	2090 km ²	70%Q ₅₀ (Aug)	11.9 m ³ /s
Period of record	1958-1974 (17 years)	Q ₉₀ (Aug)	10.8 m ³ /s

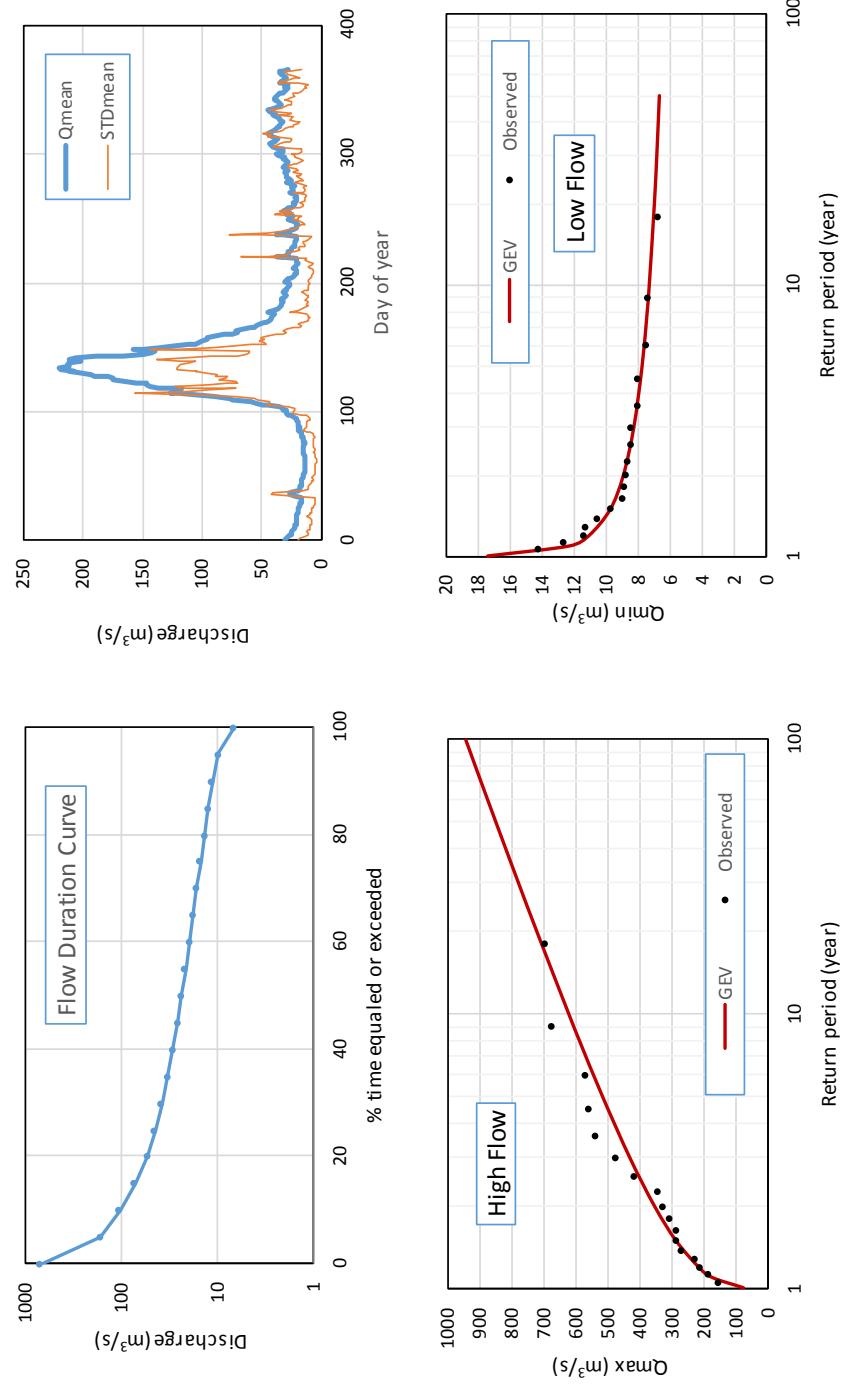


Figure B.34 : Nepisiquit River near Pabineau Falls (01BK004) (Continued)

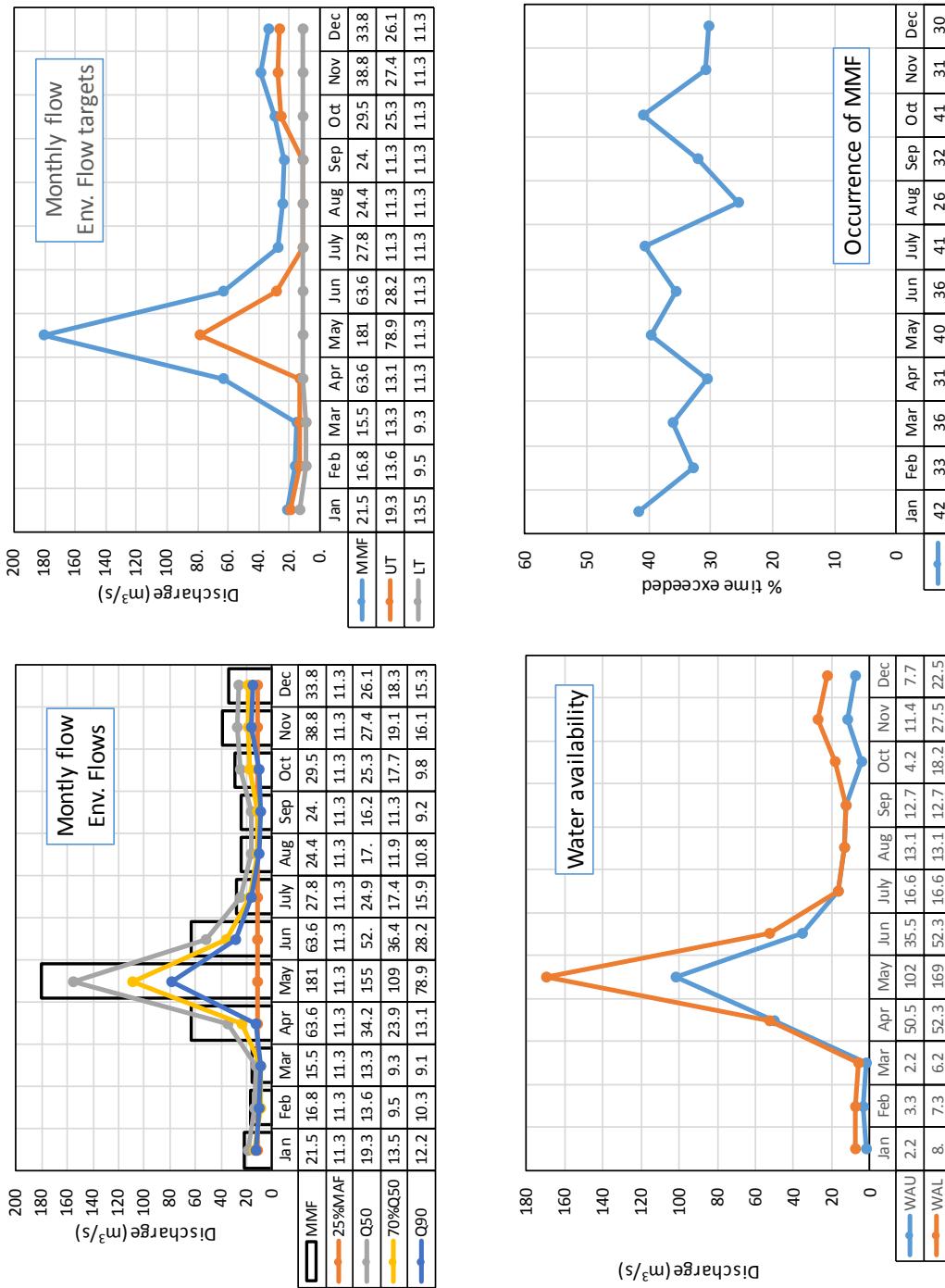


Figure B.35 : Bass River at Bass River (01BL001)

Station ID	01BL001	Mean annual flow (MAF)	3.16 m ³ /s
Latitude	47°39'00" N	Median annual flow (Q ₅₀)	0.845 m ³ /s
Longitude	65°34'40" W	Q ₅₀ (Aug)	0.323 m ³ /s
Drainage area	175 km ²	70%Q ₅₀ (Aug)	0.2261 m ³ /s
Period of record	1966-1990 (25 years)	Q ₉₀ (Aug)	0.081 m ³ /s

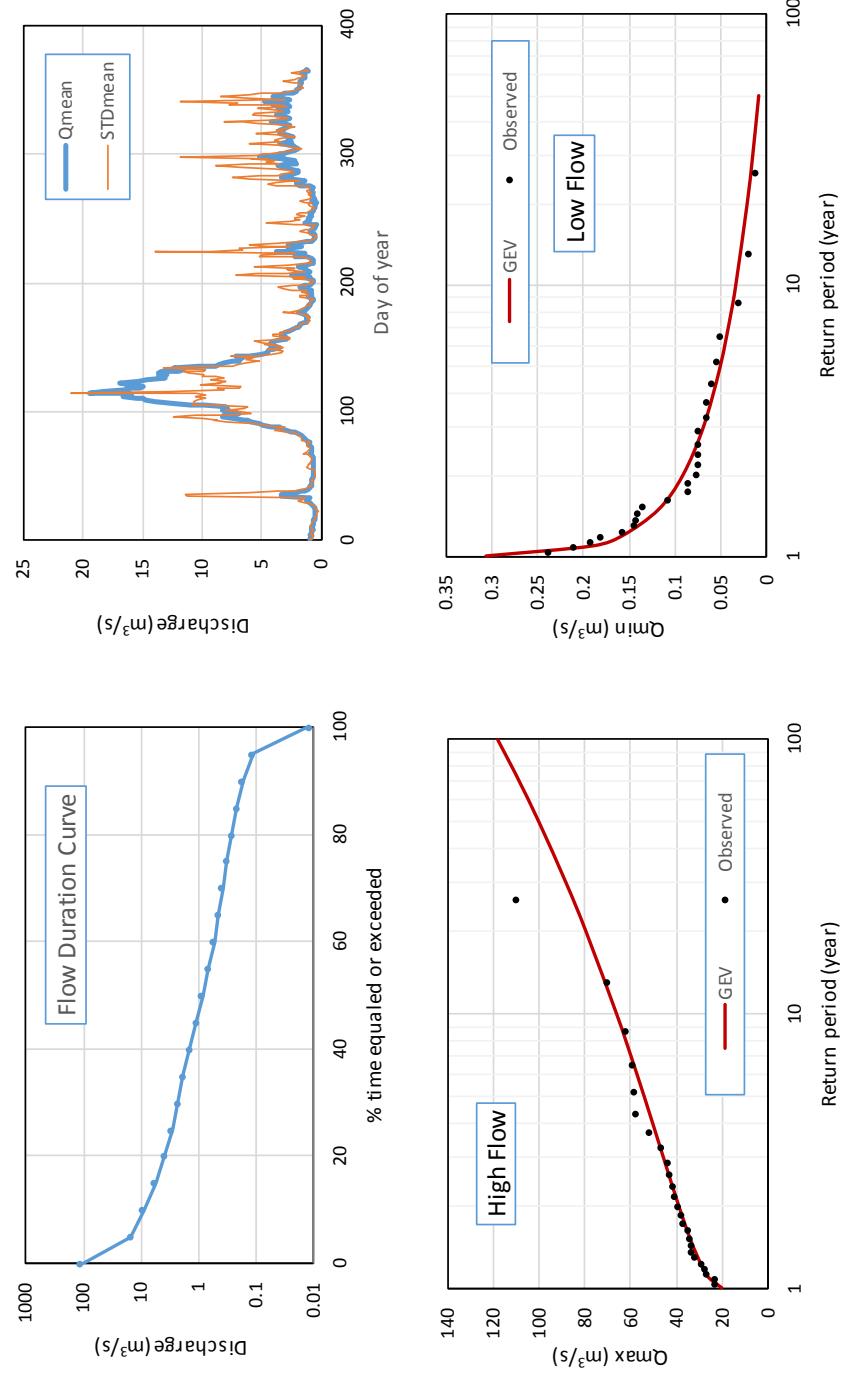


Figure B.35 : Bass River at Bass River (01BL001) (Continued)

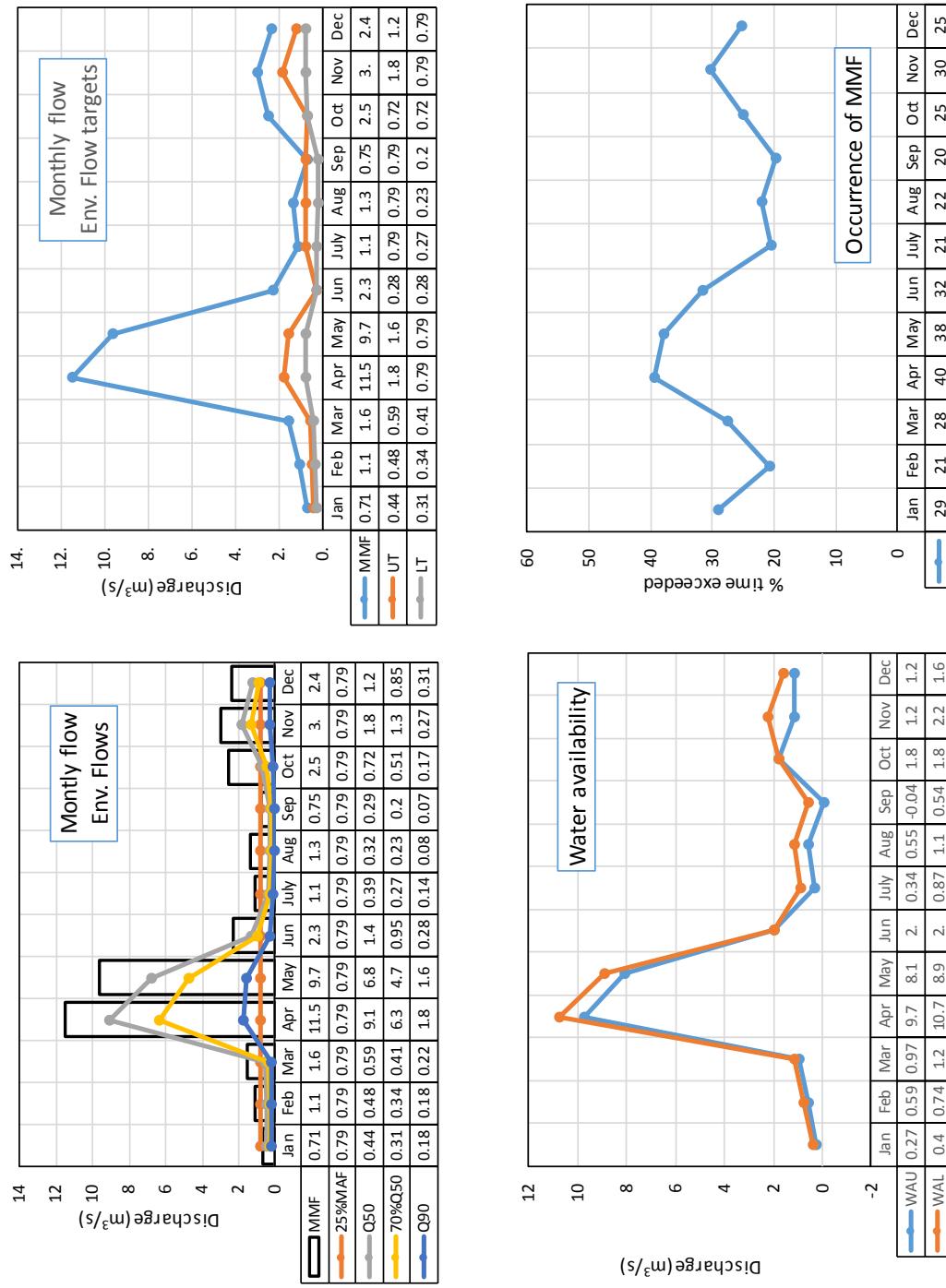


Figure B.36 : Southwest Caraquet River at Burnsville (01BL002)

Station ID	01BL002	Mean annual flow (MAF)	3.64 m ³ /s
Latitude	47°42'20" N	Median annual flow (Q ₅₀)	1.97 m ³ /s
Longitude	65°09'19" W	Q ₅₀ (Aug)	1.36 m ³ /s
Drainage area	173 km ²	70%Q ₅₀ (Aug)	0.952 m ³ /s
Period of record	1970-2010 (41 years)	Q ₉₀ (Aug)	0.878 m ³ /s

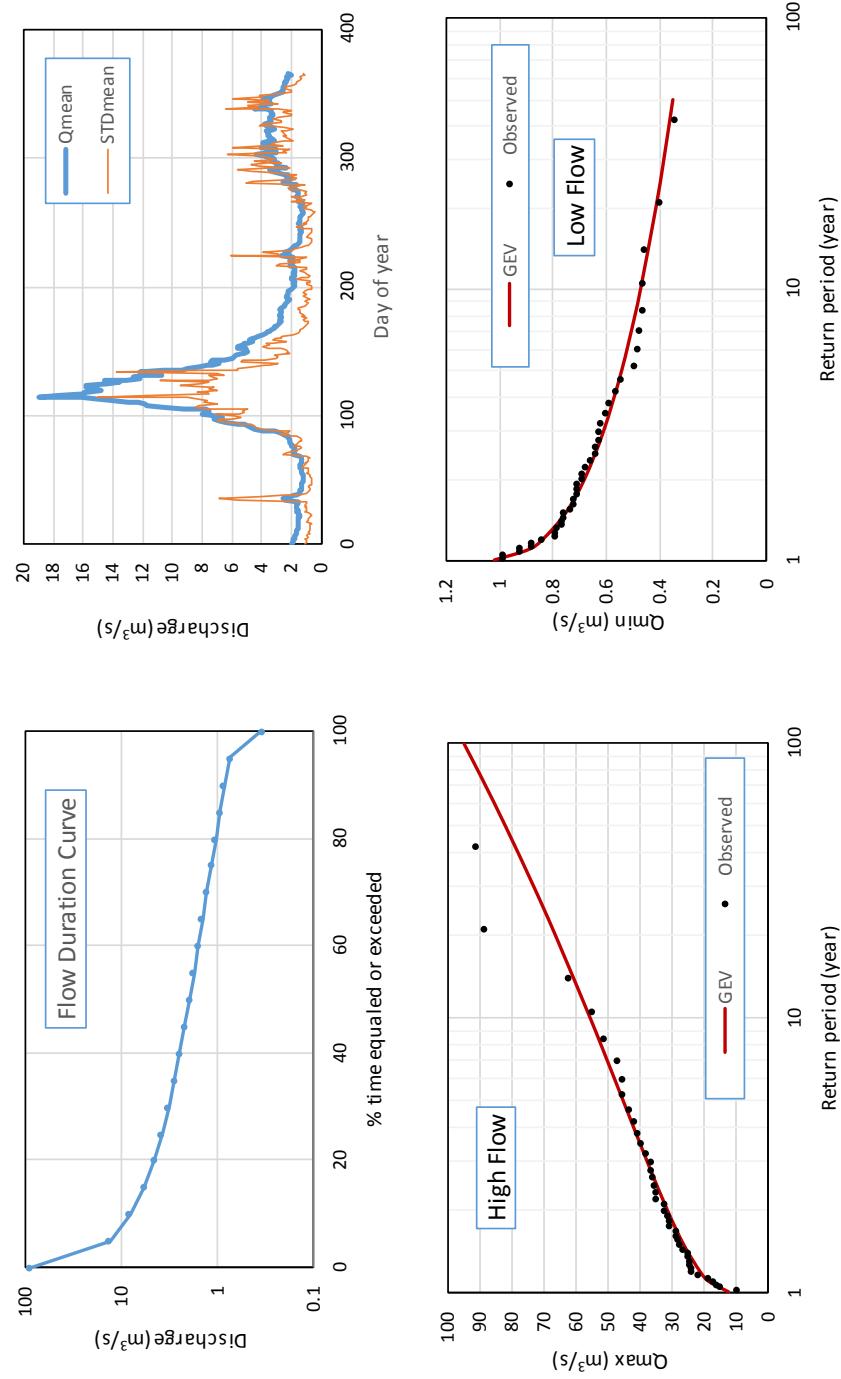


Figure B.36 : Southwest Caraquet River at Burnsville (01BL002) (Continued)

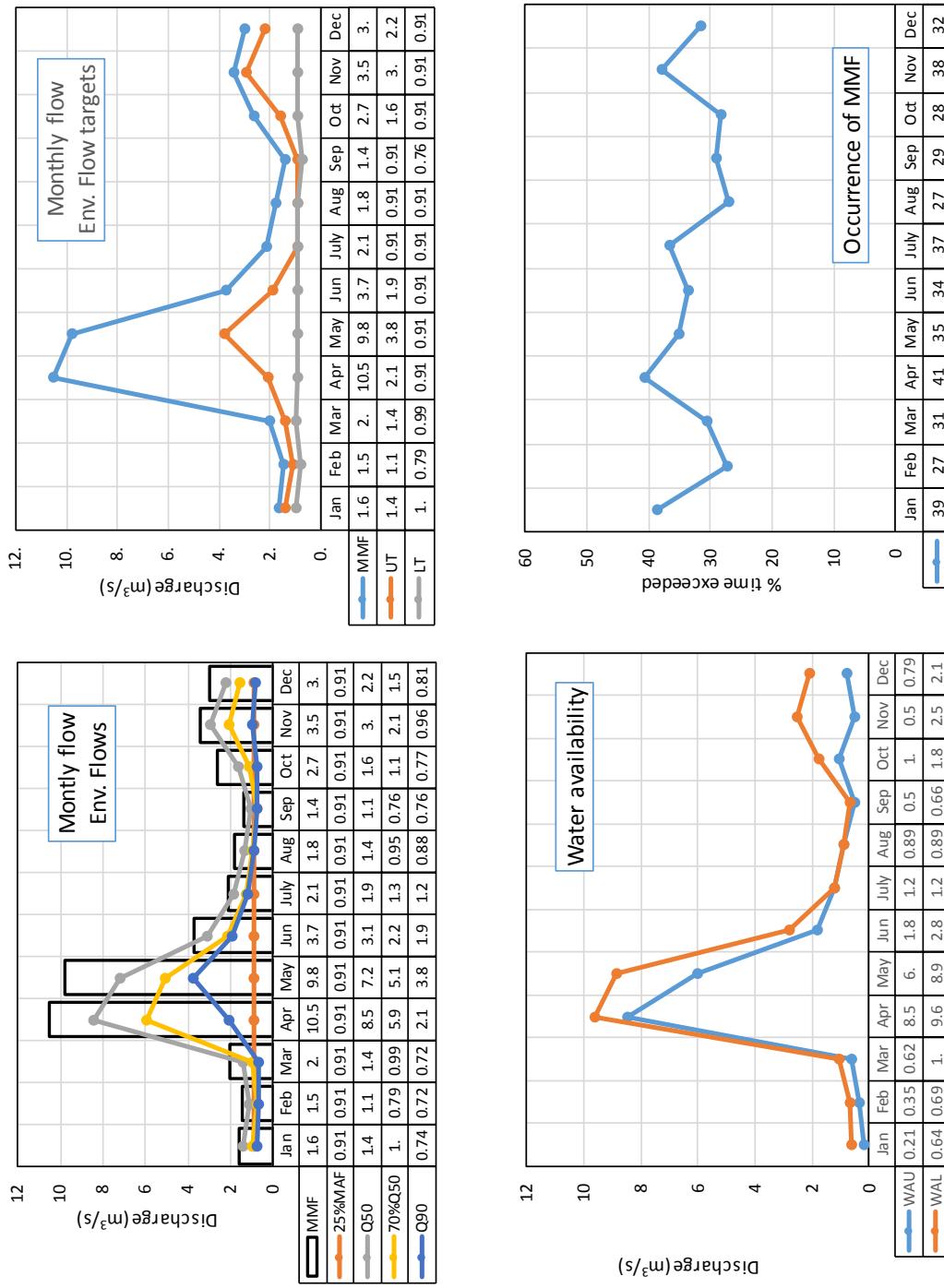


Figure B.37 : Tracadie River at Murphy Bridge Crossing (01BL003)

Station ID	01BL003	Mean annual flow (MAF)	8.36 m ³ /s
Latitude	47°26'08" N	Median annual flow (Q ₅₀)	4.53 m ³ /s
Longitude	65°06'21" W	Q ₅₀ (Aug)	2.95 m ³ /s
Drainage area	383 km ²	70%Q ₅₀ (Aug)	2.065 m ³ /s
Period of record	1971-2011 (41 years)	Q ₉₀ (Aug)	1.92 m ³ /s

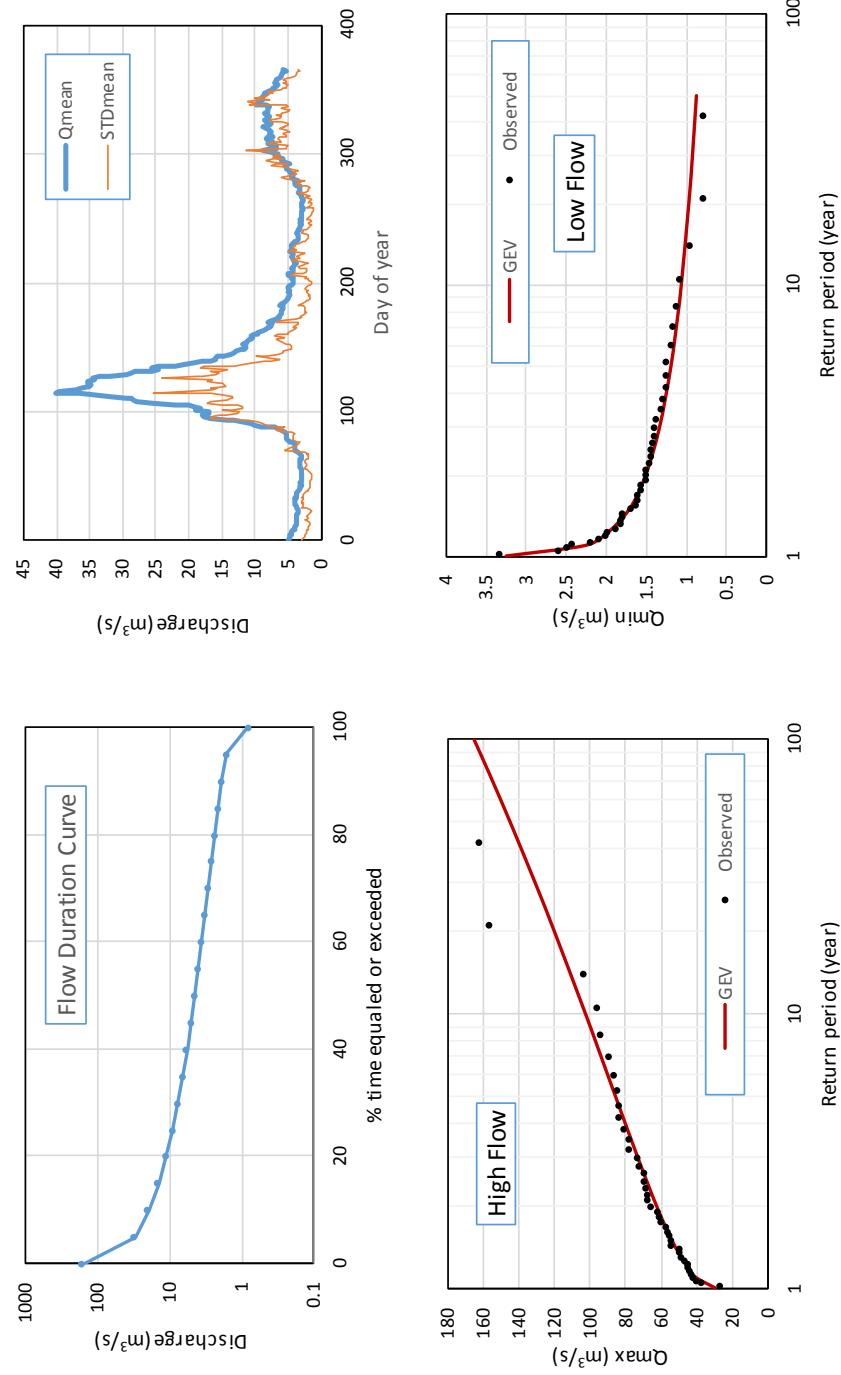


Figure B.37 : Tracadie River at Murphy Bridge Crossing (01BL003) (Continued)

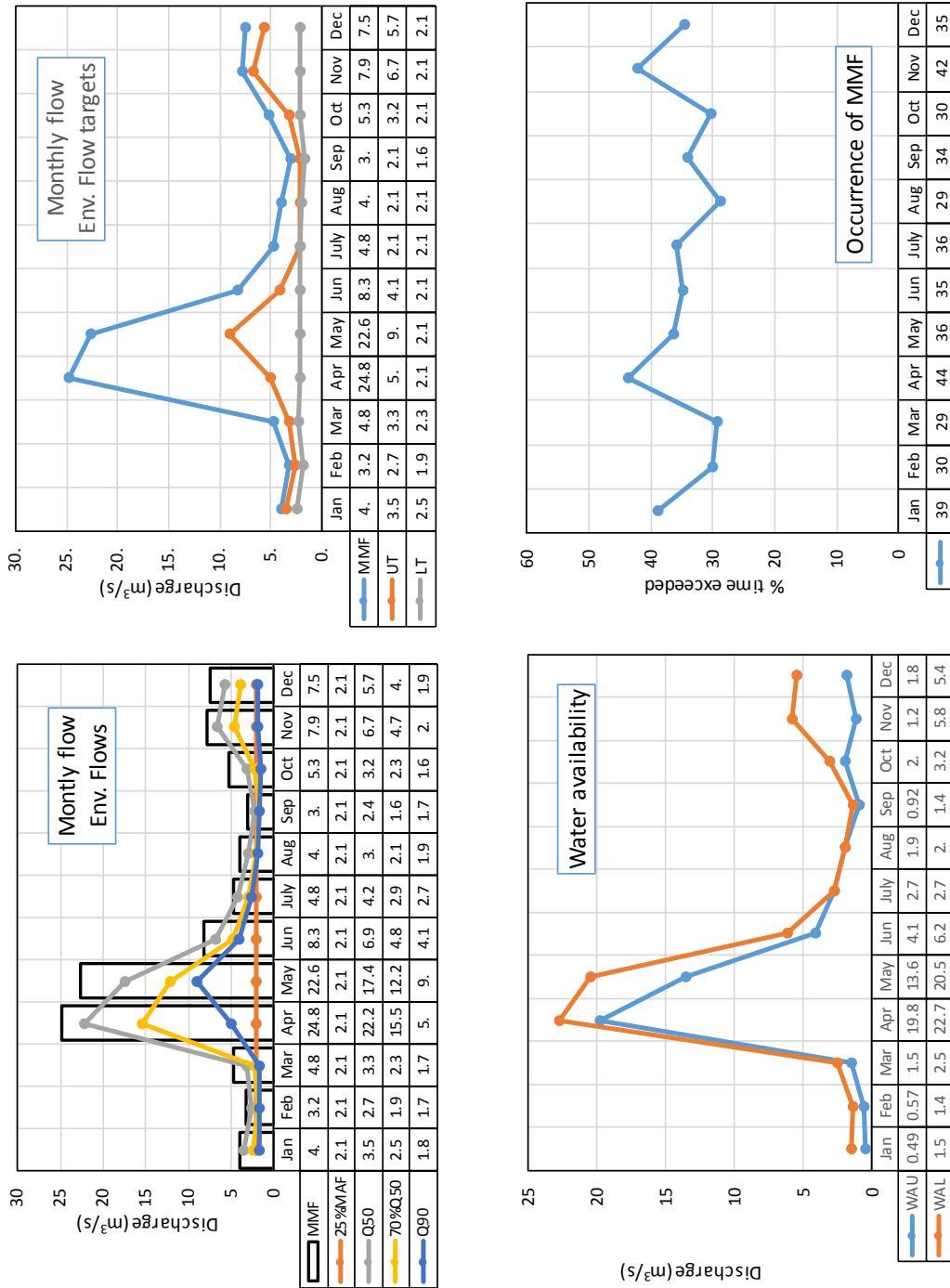


Figure B.38 : Southwest Miramichi River at Blackville (01BO001)

Station ID	01BO001	Mean annual flow (MAF)	118.1 m ³ /s
Latitude	46°44'09" N	Median annual flow (Q ₅₀)	63.25 m ³ /s
Longitude	65°49'32" W	Q ₅₀ (Aug)	37.9 m ³ /s
Drainage area	5050 km ²	70%Q ₅₀ (Aug)	26.53 m ³ /s
Period of record	1919-32,1962-2012 (65 years)	Q ₉₀ (Aug)	19.5 m ³ /s

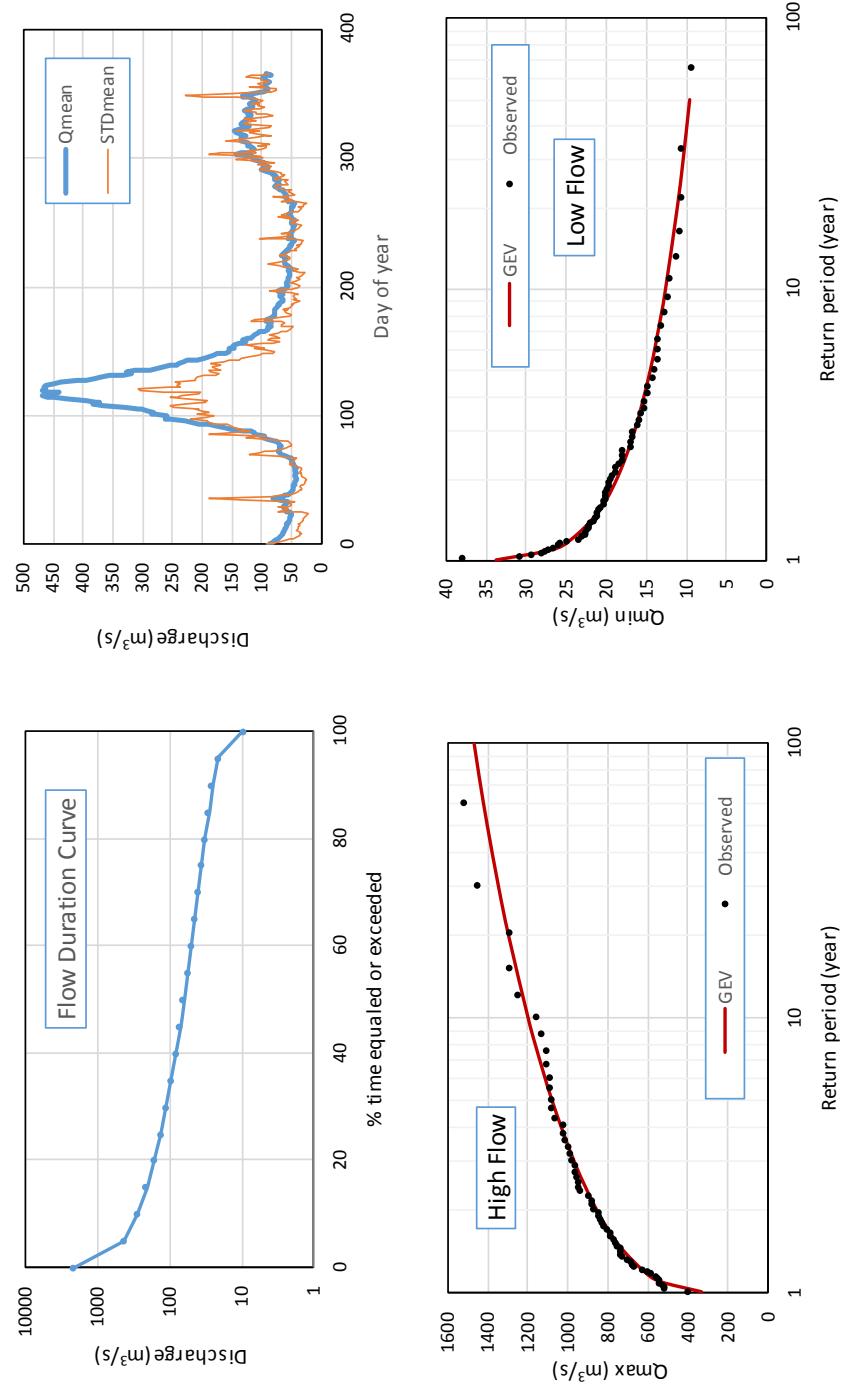


Figure B.38 : Southwest Miramichi River at Blackville (01BO001) (Continued)

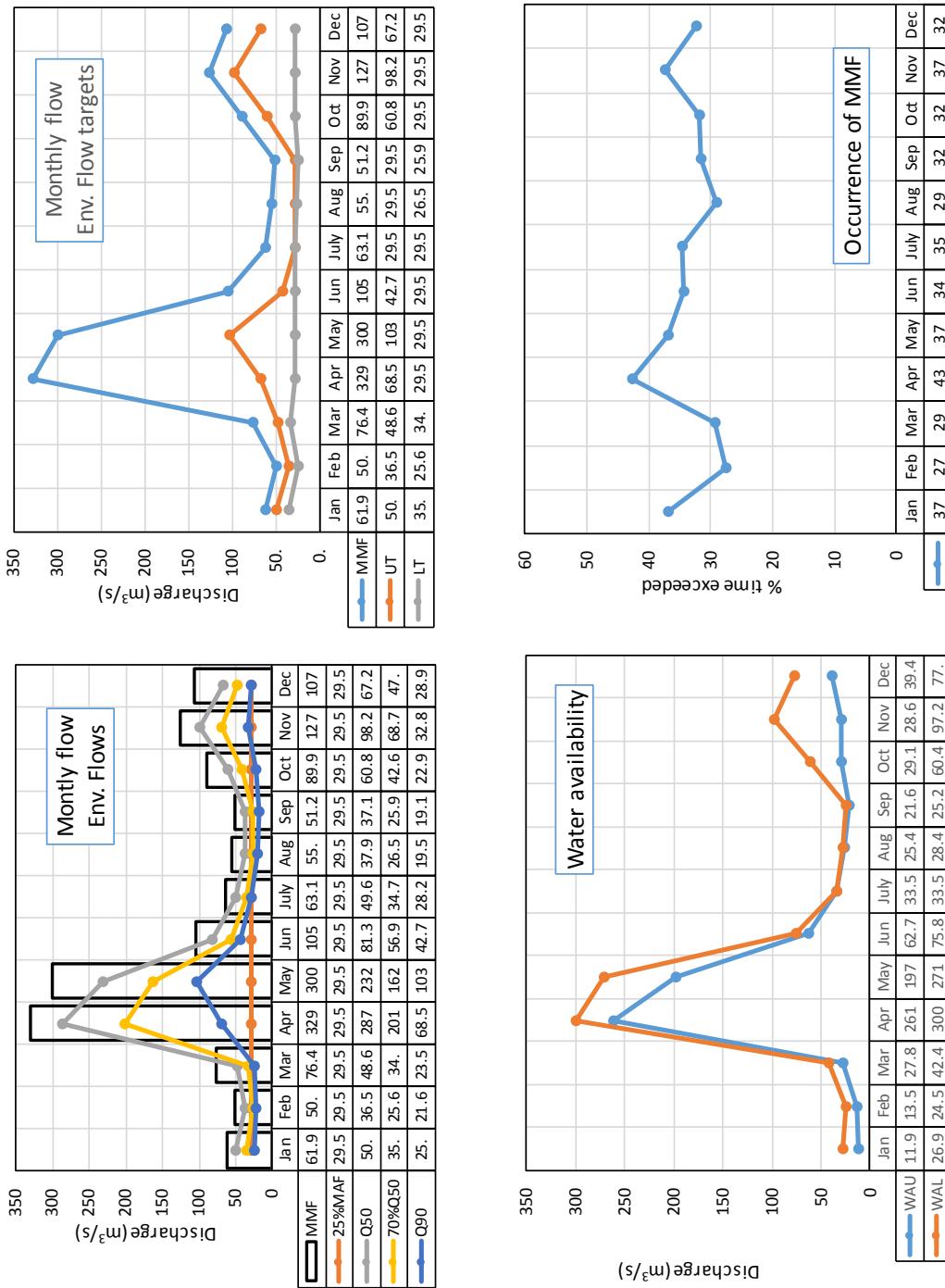


Figure B.39 : Renous River at McGraw Brook (01BO0002)

Station ID	01BO002	Mean annual flow (MAF)	14.7 m ³ /s
Latitude	46°49'17" N	Median annual flow (Q ₅₀)	6.945 m ³ /s
Longitude	66°06'53" W	Q ₅₀ (Aug)	3.26 m ³ /s
Drainage area	611 km ²	70%Q ₅₀ (Aug)	2.282 m ³ /s
Period of record	1966-1994 (29 years)	Q ₉₀ (Aug)	1.338 m ³ /s

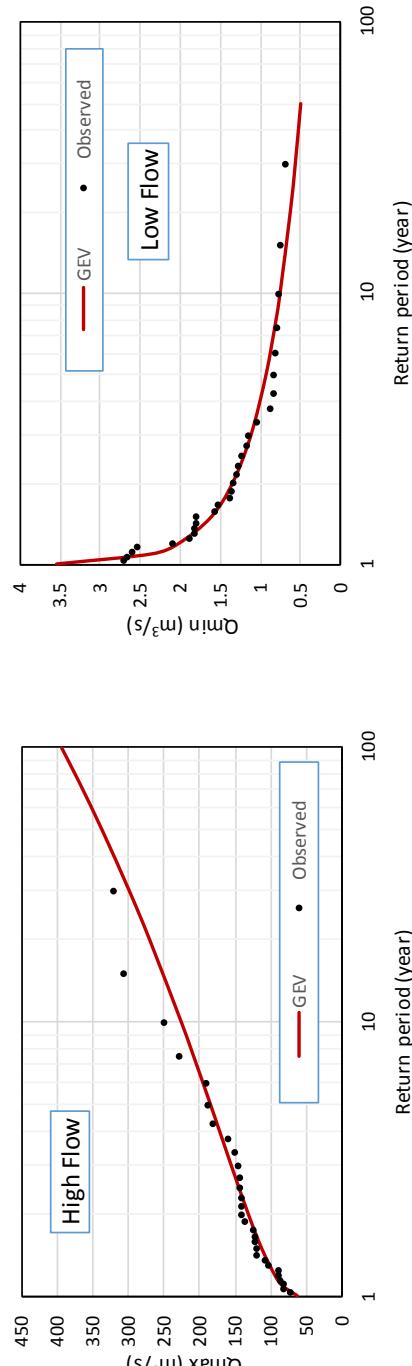
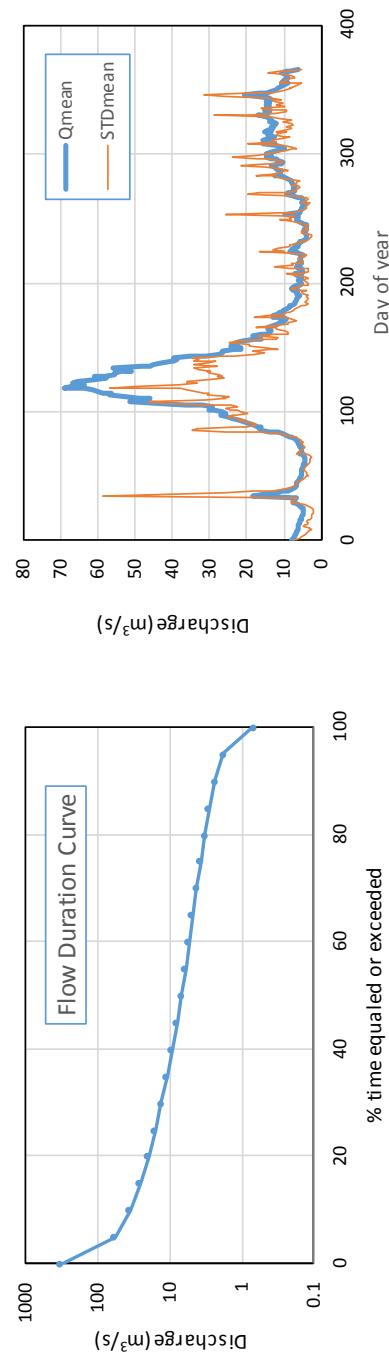


Figure B.39 : Renous River at McGraw Brook (01B0002) (Continued)

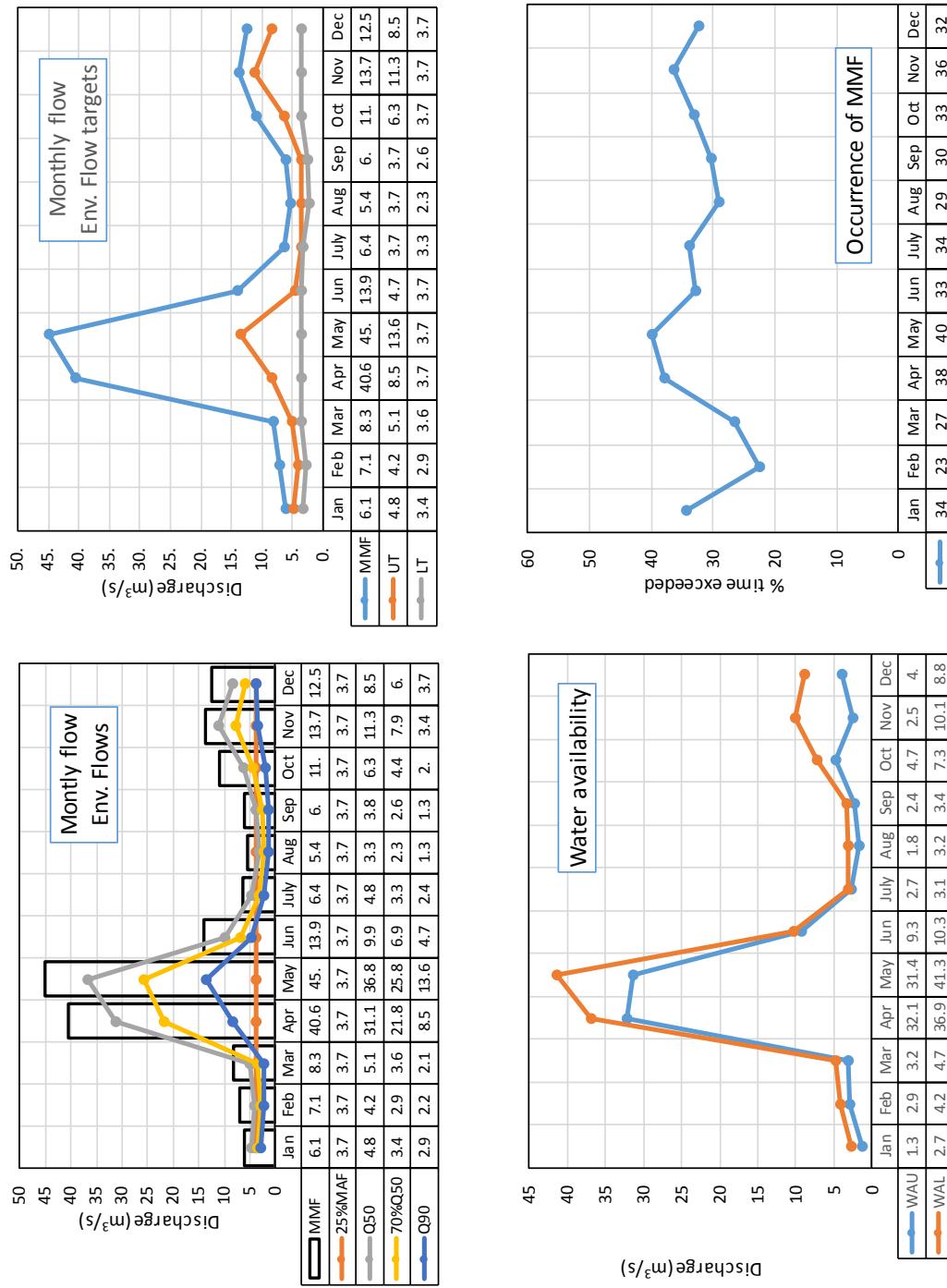


Figure B.40 : Barnaby River below Semiwagan River (01BO003)

Station ID	01BO003	Mean annual flow (MAF)	9.68 m ³ /s
Latitude	46°53'19" N	Median annual flow (Q ₅₀)	3.85 m ³ /s
Longitude	65°35'44" W	Q ₅₀ (Aug)	1.735 m ³ /s
Drainage area	484 km ²	70%Q ₅₀ (Aug)	1.2145 m ³ /s
Period of record	1973-1994 (22 years)	Q ₉₀ (Aug)	0.5783 m ³ /s

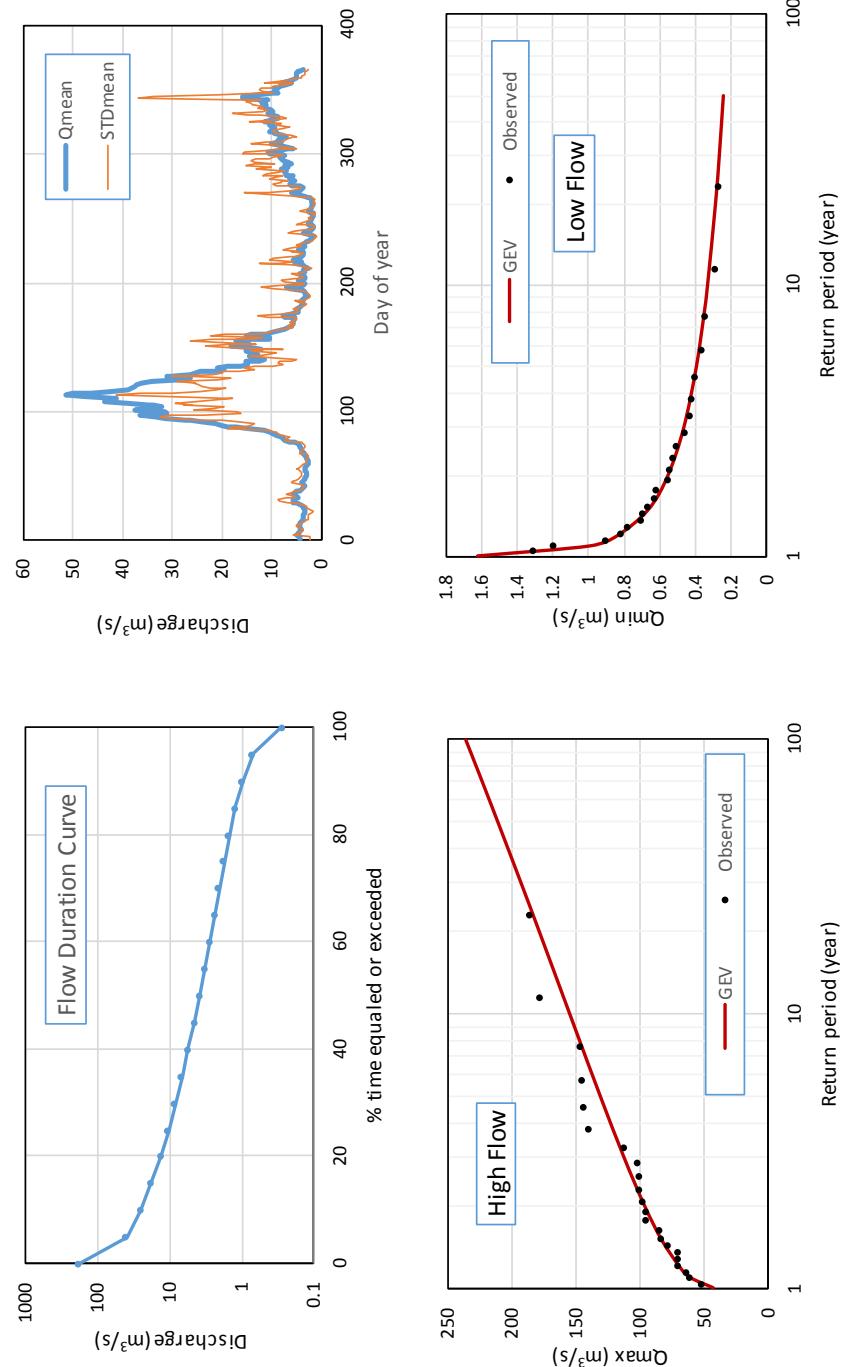


Figure B.40 : Barnaby River below Semiwagan River (01BO003) (Continued)

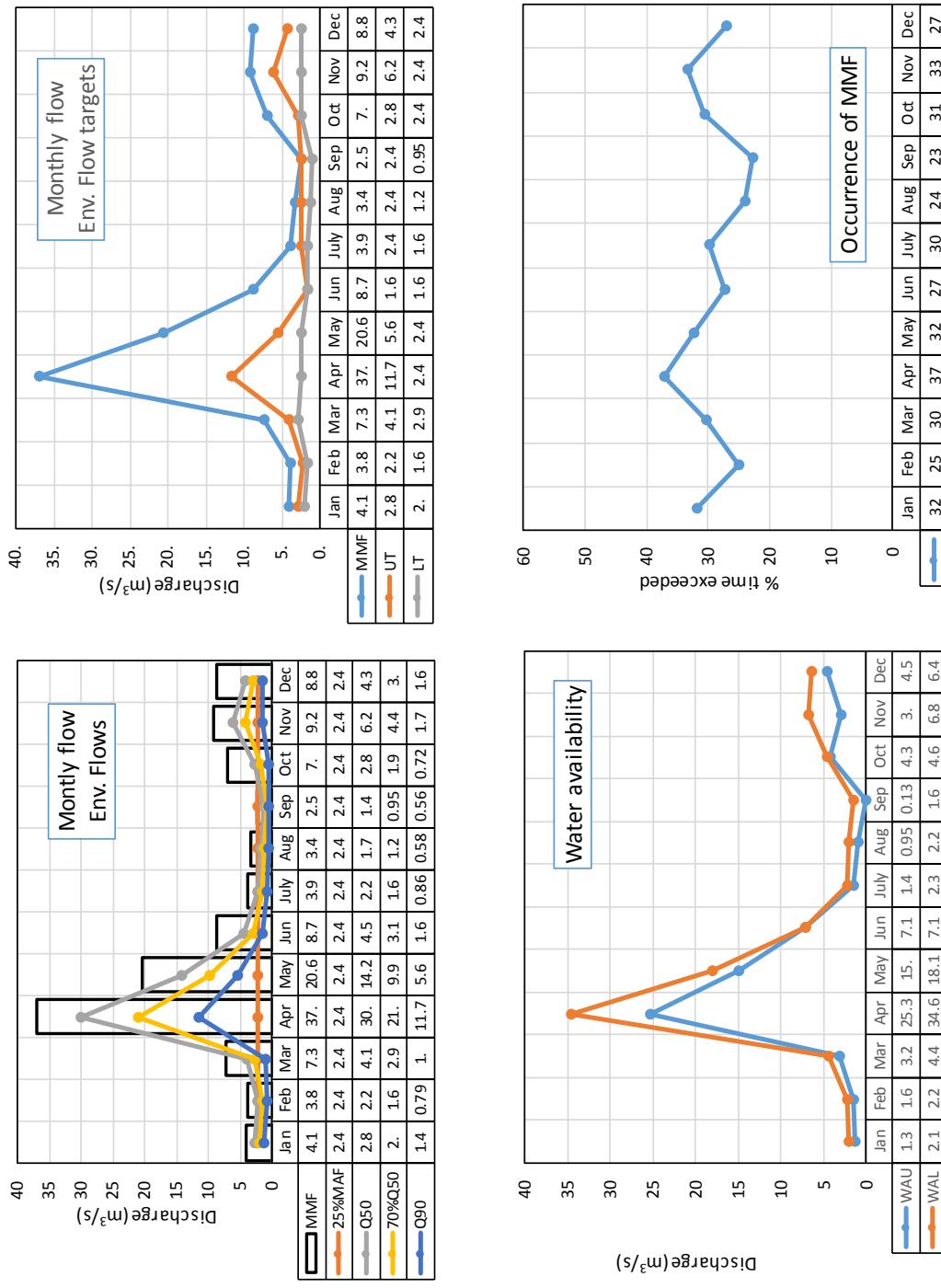


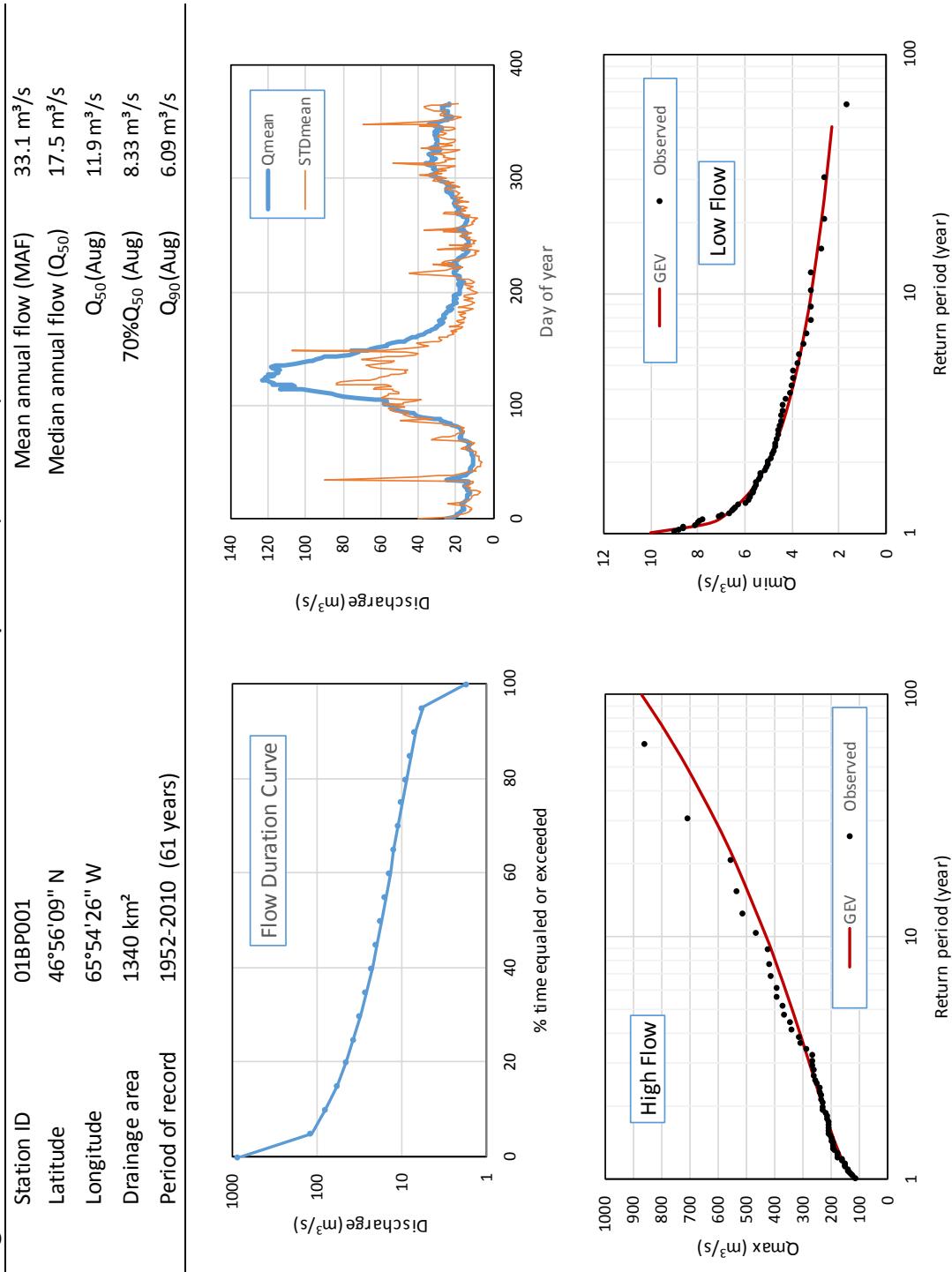
Figure B.41 : Little Southwest Miramichi River at Lyttleton (01BP001)

Figure B.41 : Little Southwest Miramichi River at Lyttleton (01BP001) (Continued)

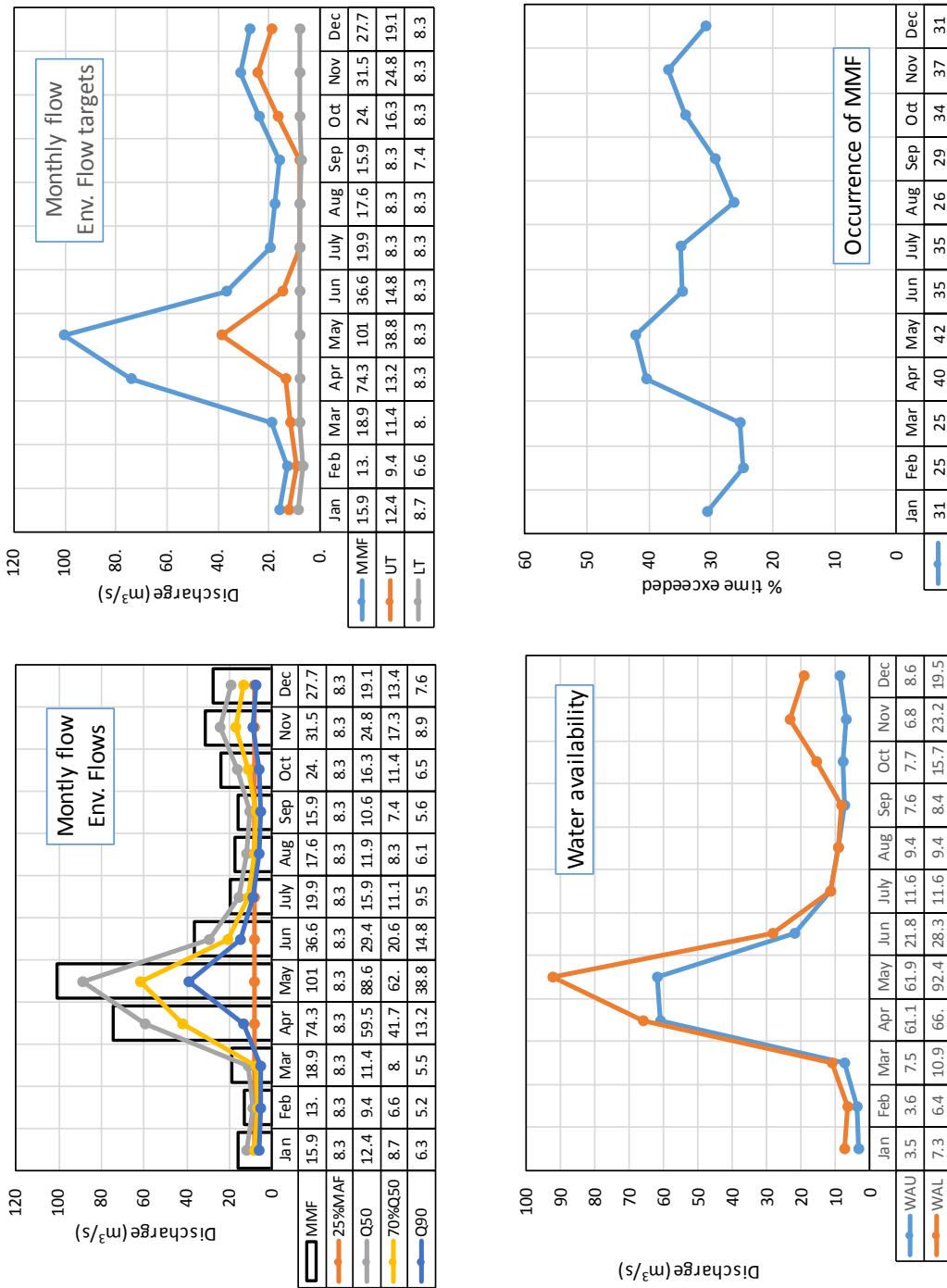


Figure B.42 : Catamaran Brook at Repap Road Bridge (01BP002)

Station ID	01BP002	Mean annual flow (MAF)	0.637 m ³ /s
Latitude	45°51'24" N	Median annual flow (Q ₅₀)	0.292 m ³ /s
Longitude	65°11'24" W	Q ₅₀ (Aug)	0.105 m ³ /s
Drainage area	28.7 km ²	70%Q ₅₀ (Aug)	0.0735 m ³ /s
Period of record	1990-2010 (21 years)	Q ₉₀ (Aug)	0.039 m ³ /s

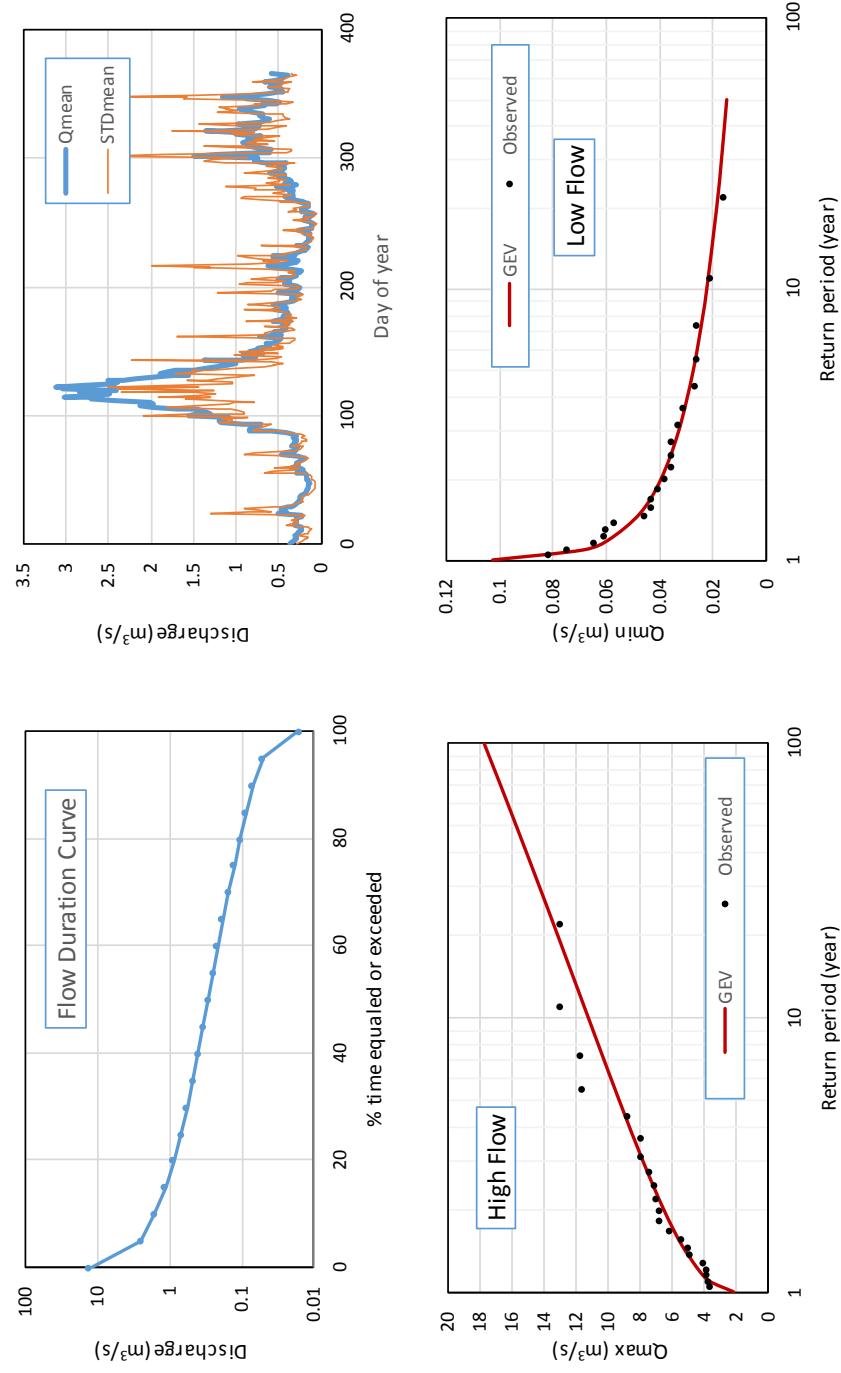


Figure B.42 : Catamaran Brook at Repap Road Bridge (01BP002) (Continued)

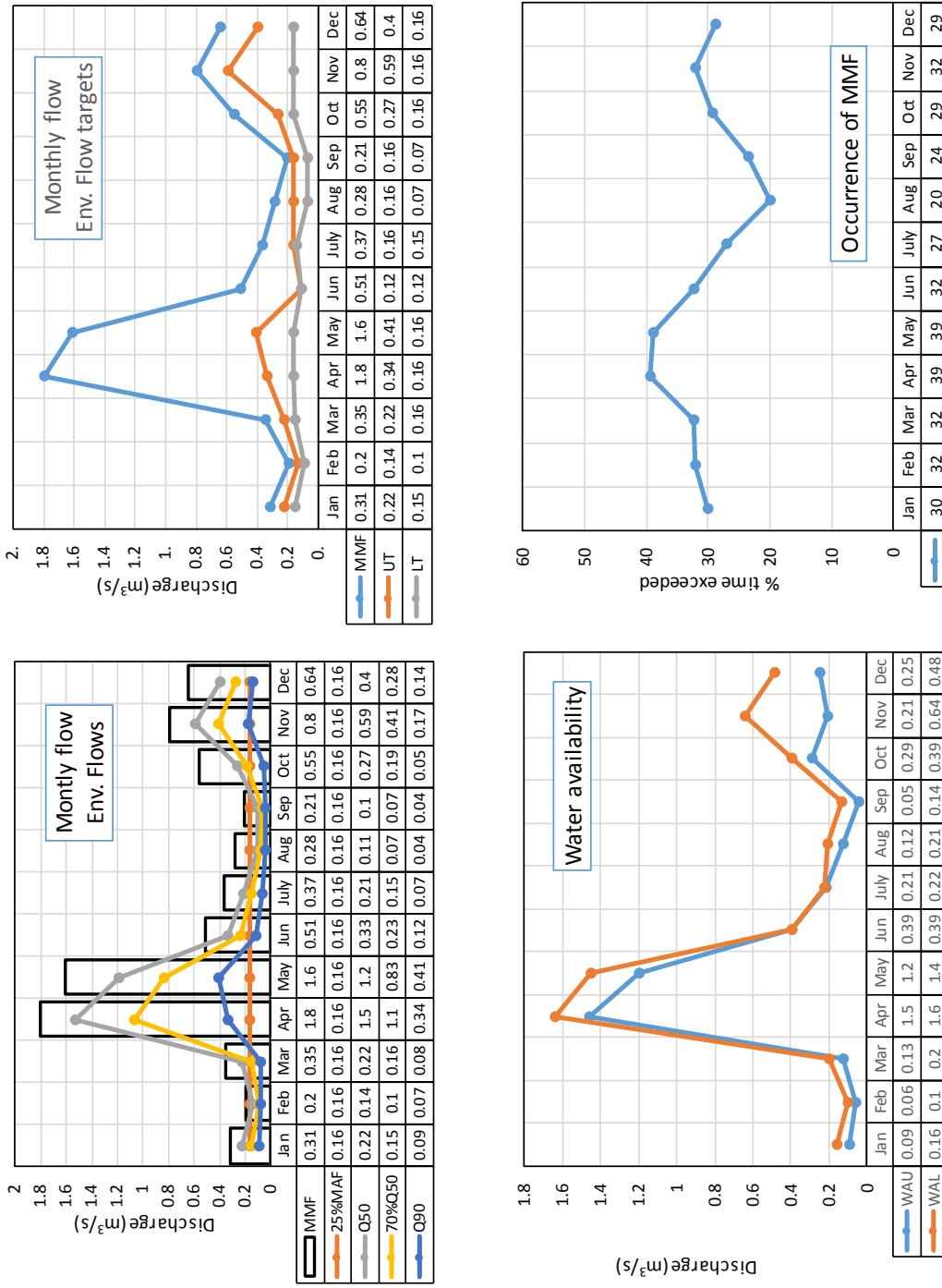


Figure B.43 : Northwest Miramichi River at Trout Brook (01BQ001)

Station ID	01BQ001	Mean annual flow (MAF)	21.6 m ³ /s
Latitude	47°05'41" N	Median annual flow (Q ₅₀)	10.1 m ³ /s
Longitude	65°50'11" W	Q ₅₀ (Aug)	6.11 m ³ /s
Drainage area	948 km ²	70%Q ₅₀ (Aug)	4.277 m ³ /s
Period of record	1962-2010 (49 years)	Q ₉₀ (Aug)	2.86 m ³ /s

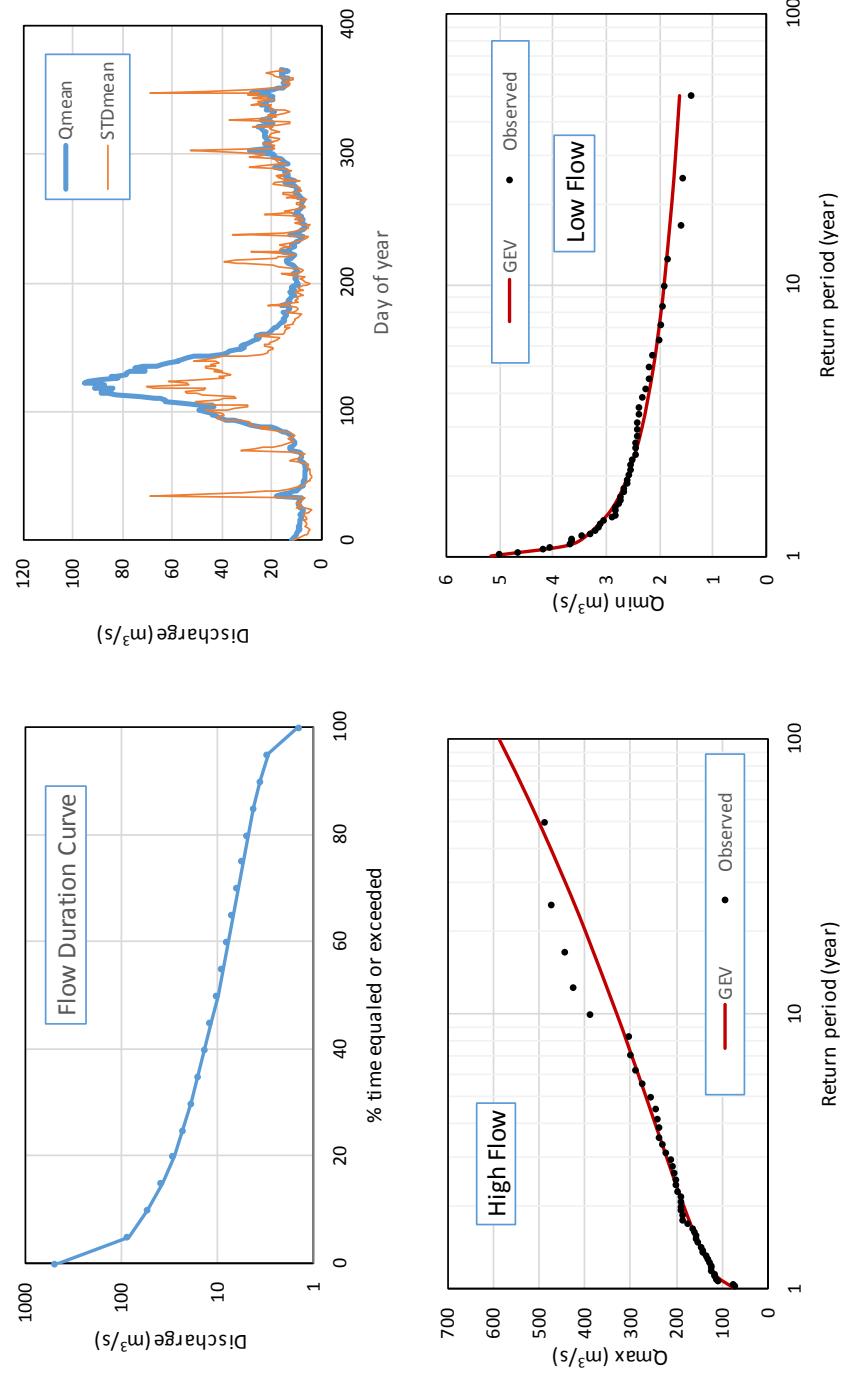


Figure B.43 : Northwest Miramichi River at Trout Brook (01BQ001) (Continued)

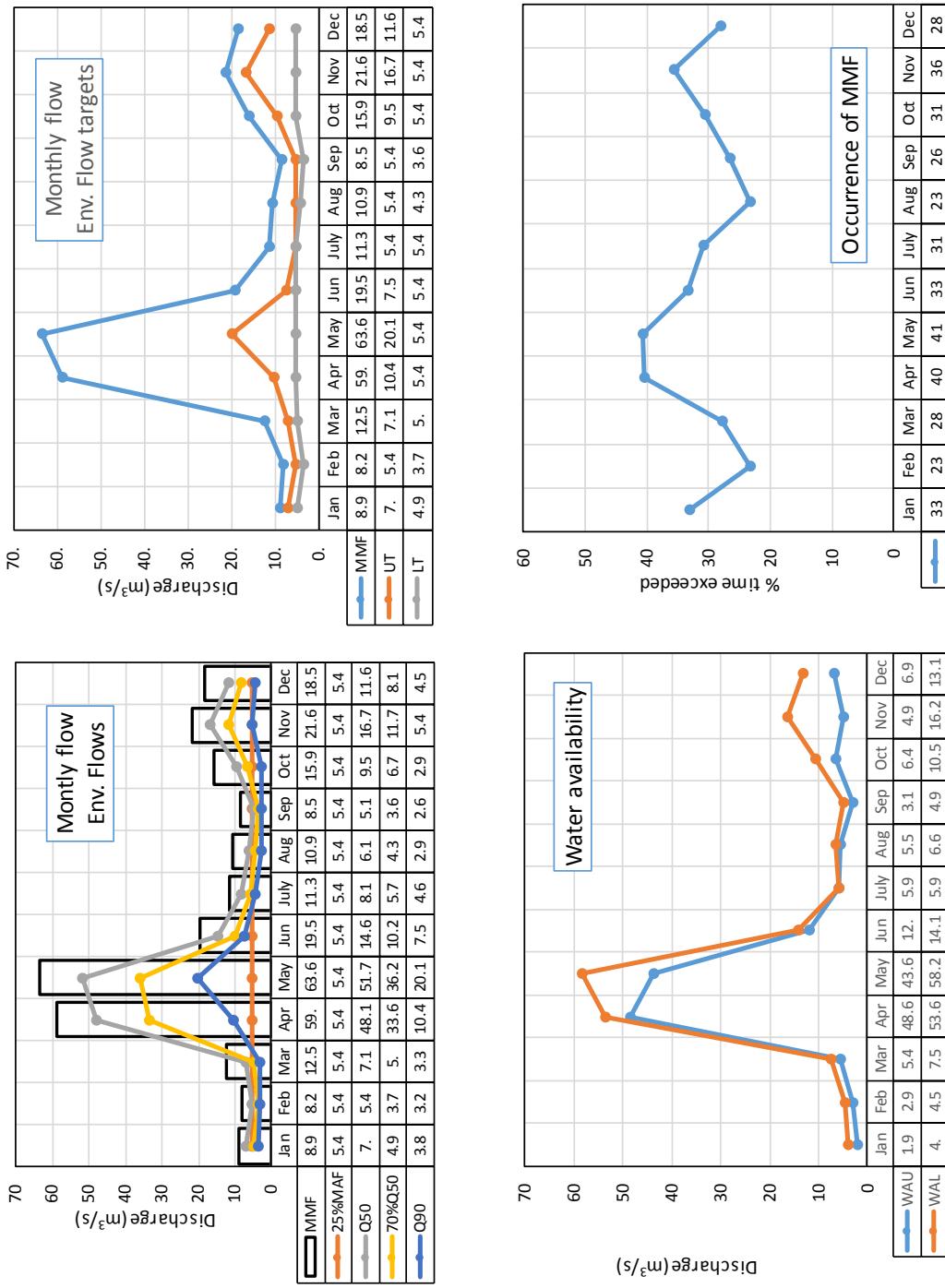


Figure B.44 : Kouchibouguac River near Vautour (01BR001)

Station ID	01BR001	Mean annual flow (MAF)	3.74 m ³ /s
Latitude	46°44'36" N	Median annual flow (Q ₅₀)	1.81 m ³ /s
Longitude	65°12'17" W	Q ₅₀ (Aug)	0.977 m ³ /s
Drainage area	177 km ²	70%Q ₅₀ (Aug)	0.6839 m ³ /s
Period of record	1931-32,1970-1994 (27 years)	Q ₉₀ (Aug)	0.4312 m ³ /s

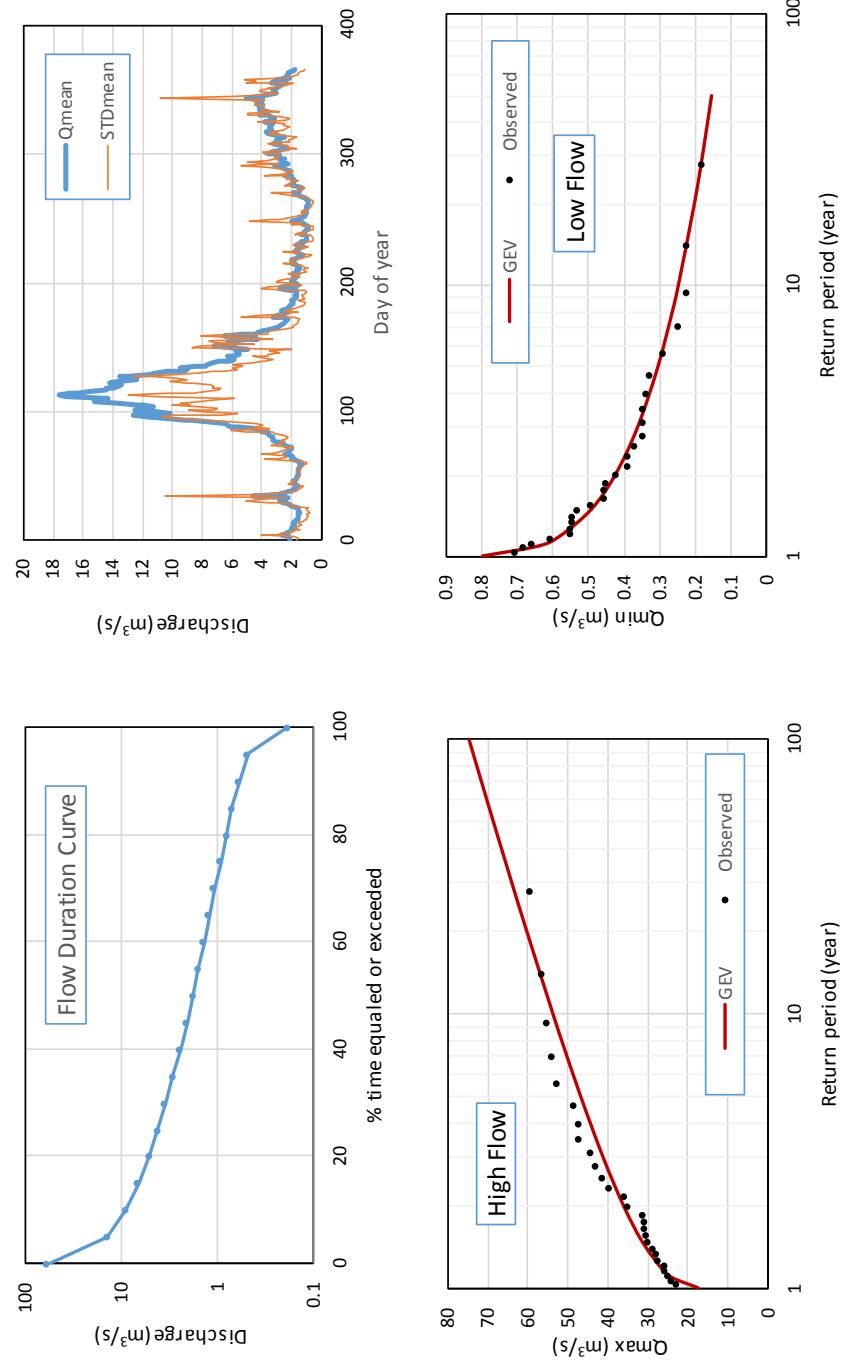


Figure B.44 : Kouchibouguac River near Vautour (01BR001) (Continued)

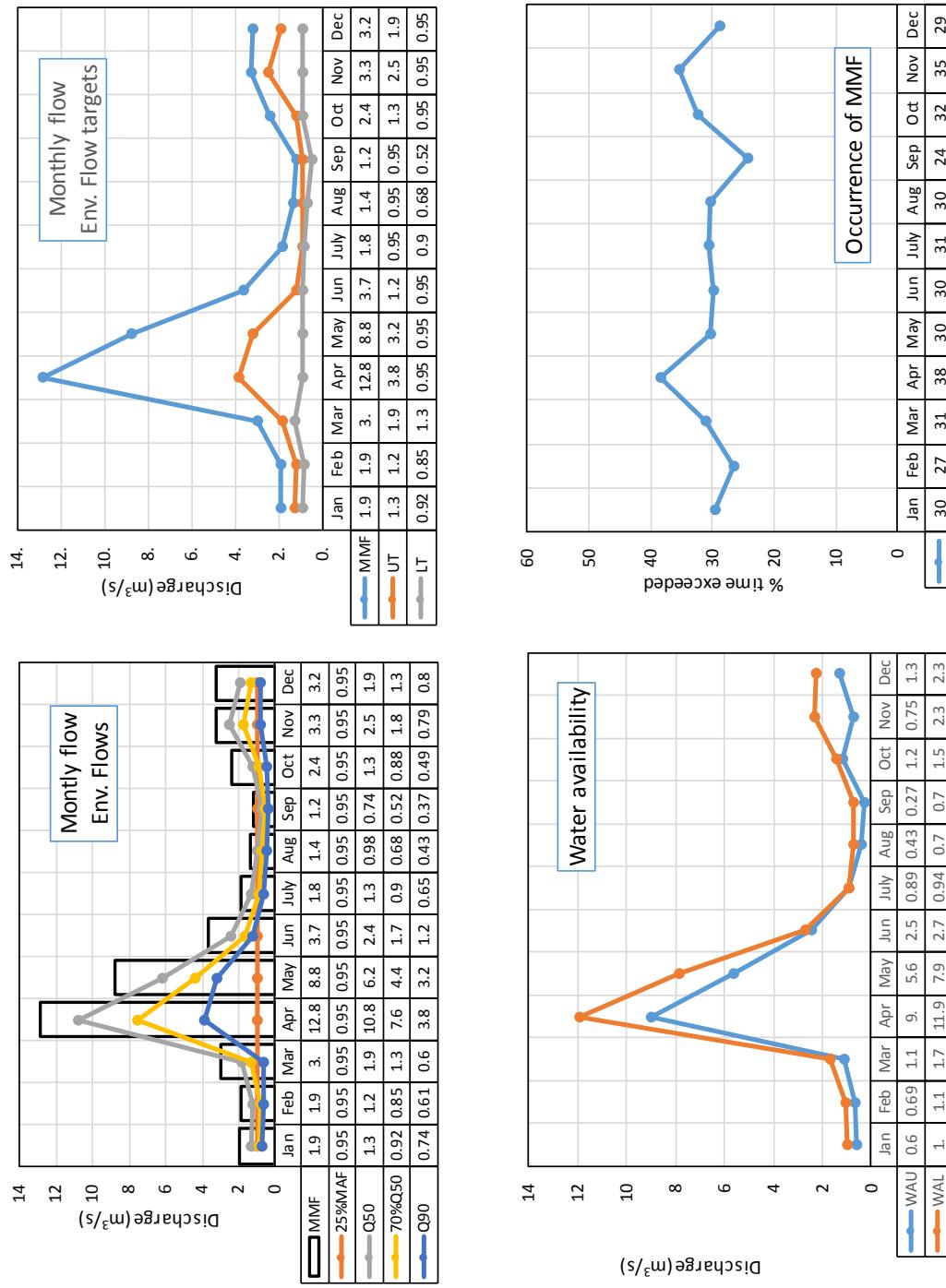


Figure B.45 : Coal Branch River at Beersville (01BS001)

Station ID	01BS001	Mean annual flow (MAF)	3.69 m ³ /s
Latitude	46°26'38" N	Median annual flow (Q ₅₀)	1.56 m ³ /s
Longitude	65°03'53" W	Q ₅₀ (Aug)	0.439 m ³ /s
Drainage area	166 km ²	70%Q ₅₀ (Aug)	0.3073 m ³ /s
Period of record	1964-2011 (47 years)	Q ₉₀ (Aug)	0.198 m ³ /s

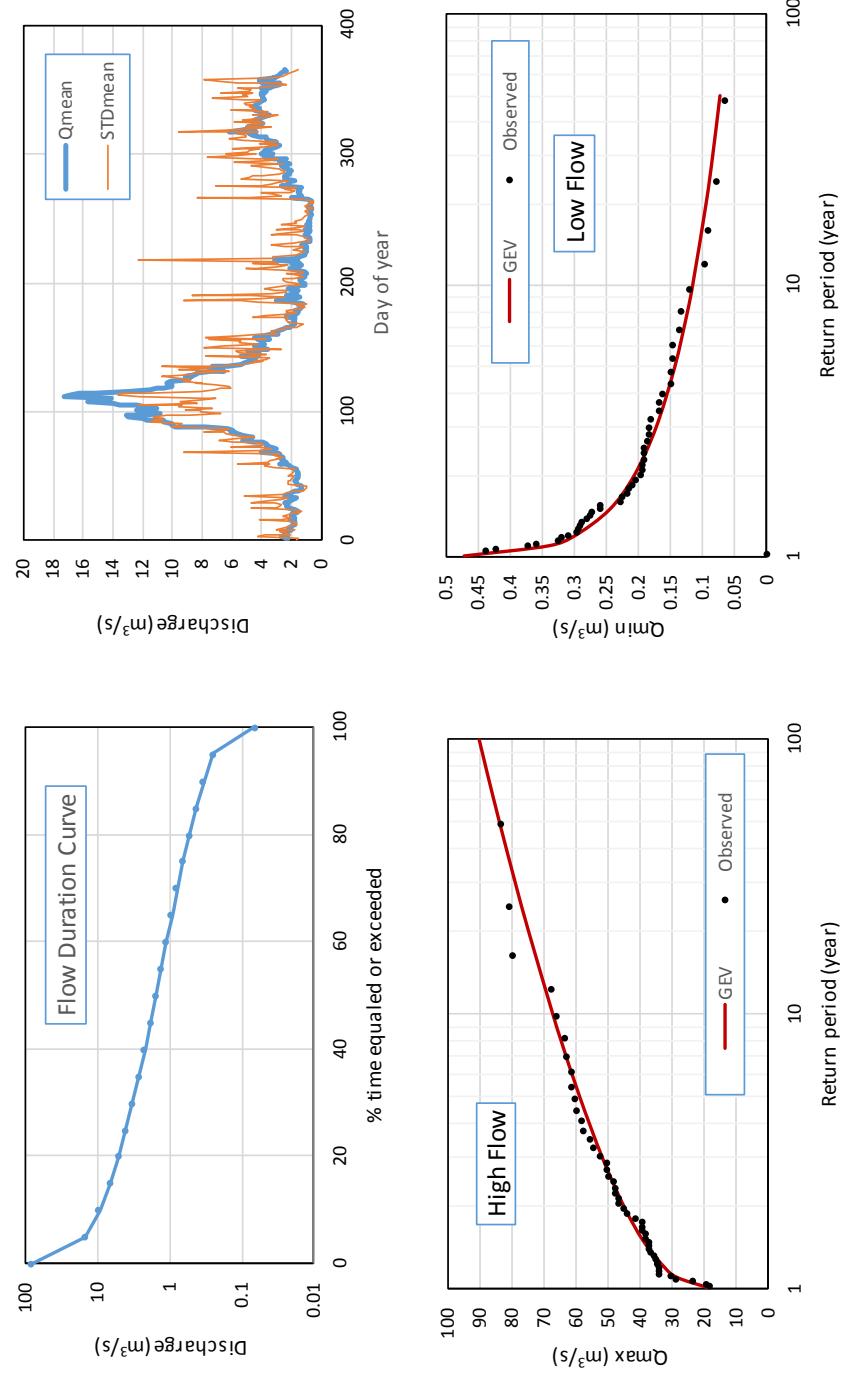


Figure B.45 : Coal Branch River at Beersville (01BS001) (Continued)

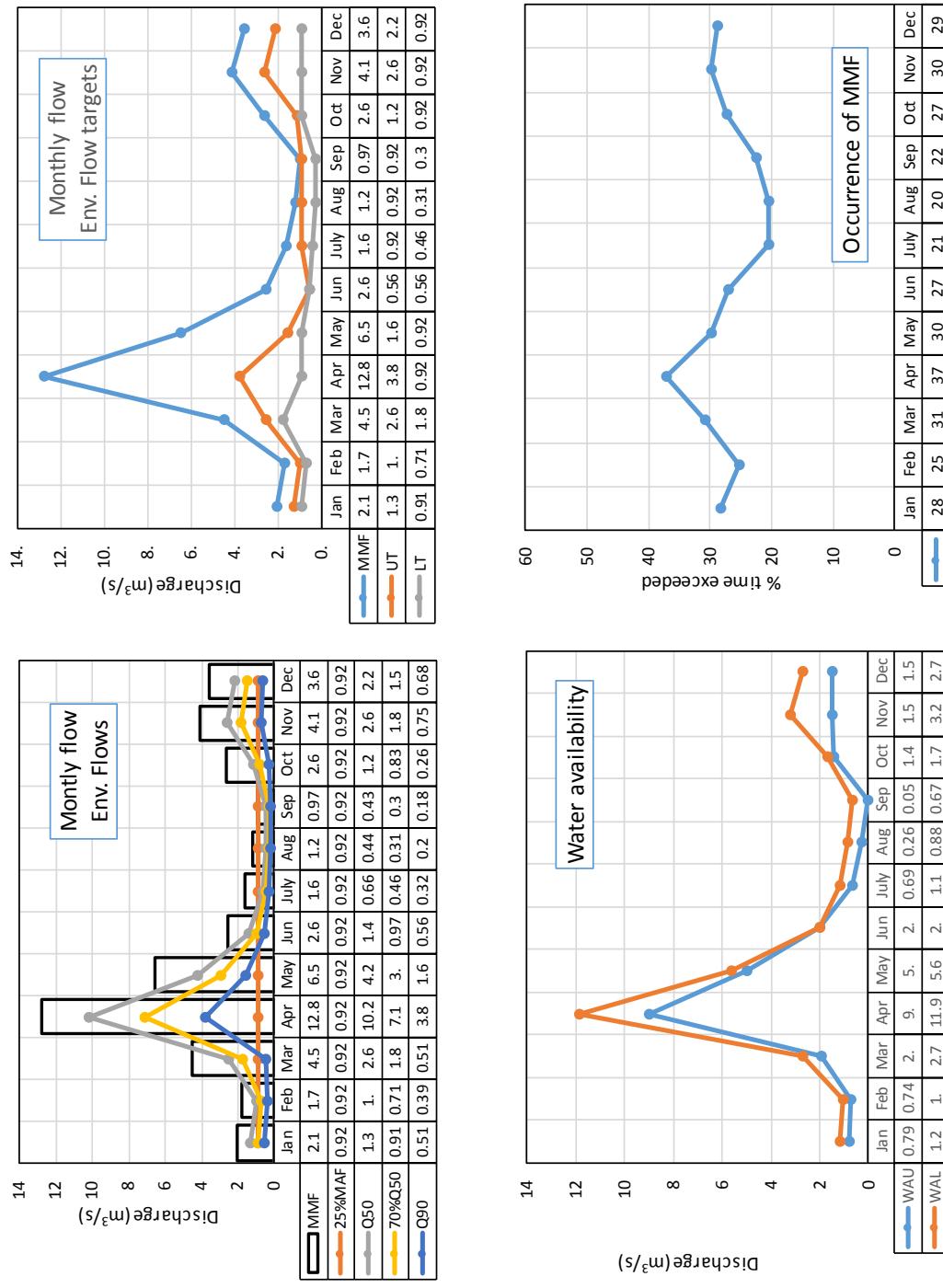


Figure B.46 : Petitcodiac River near Petitcodiac (01BU002)

Station ID	01BU002	Mean annual flow (MAF)	8.07 m ³ /s
Latitude	45°56'47" N	Median annual flow (Q ₅₀)	3.52 m ³ /s
Longitude	65°10'05" W	Q ₅₀ (Aug)	0.9015 m ³ /s
Drainage area	391 km ²	70%Q ₅₀ (Aug)	0.63105 m ³ /s
Period of record	1962-2011 (50 years)	Q ₉₀ (Aug)	0.362 m ³ /s

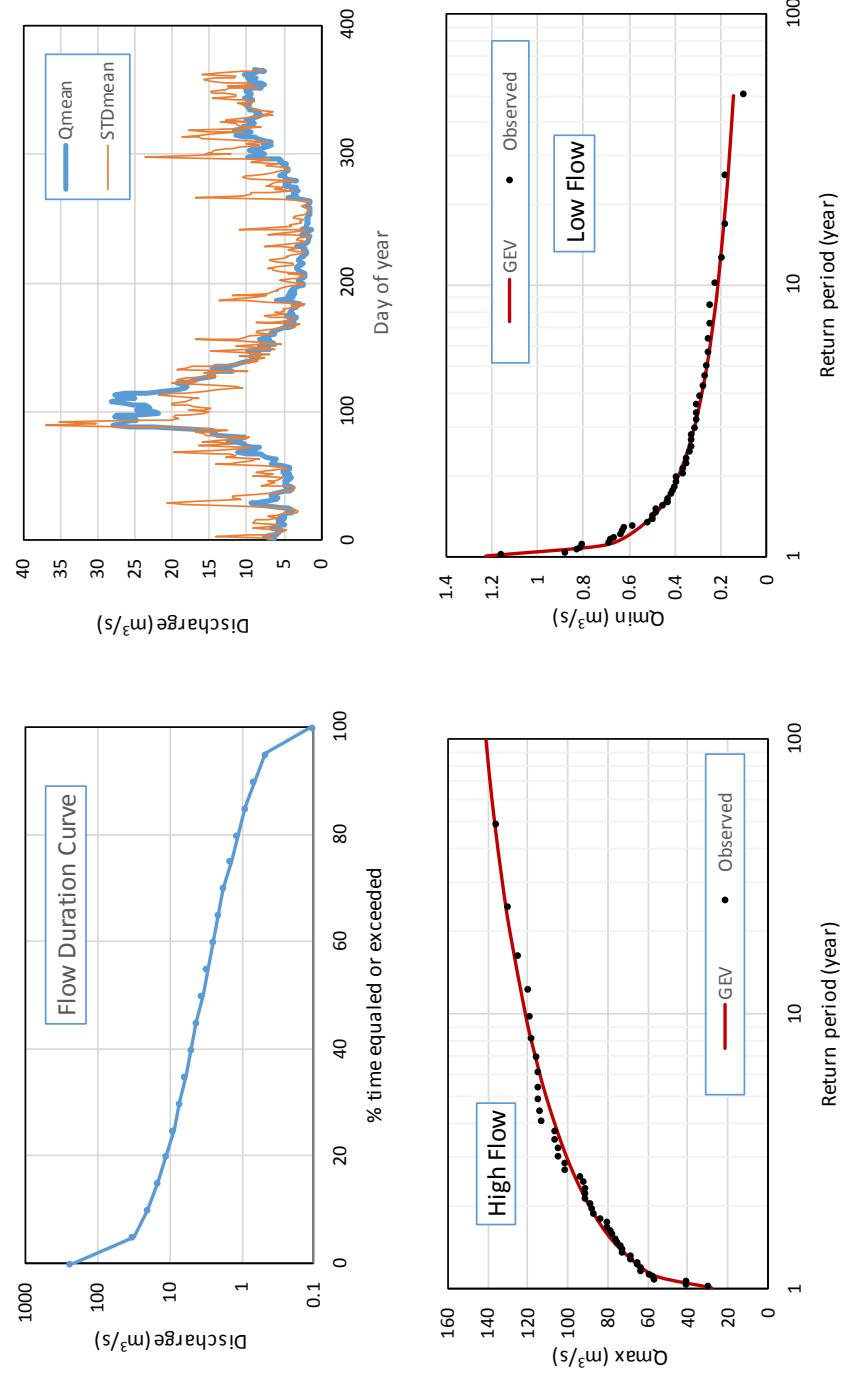


Figure B.46 : Petitcodiac River near Petitcodiac (01BU002) (Continued)

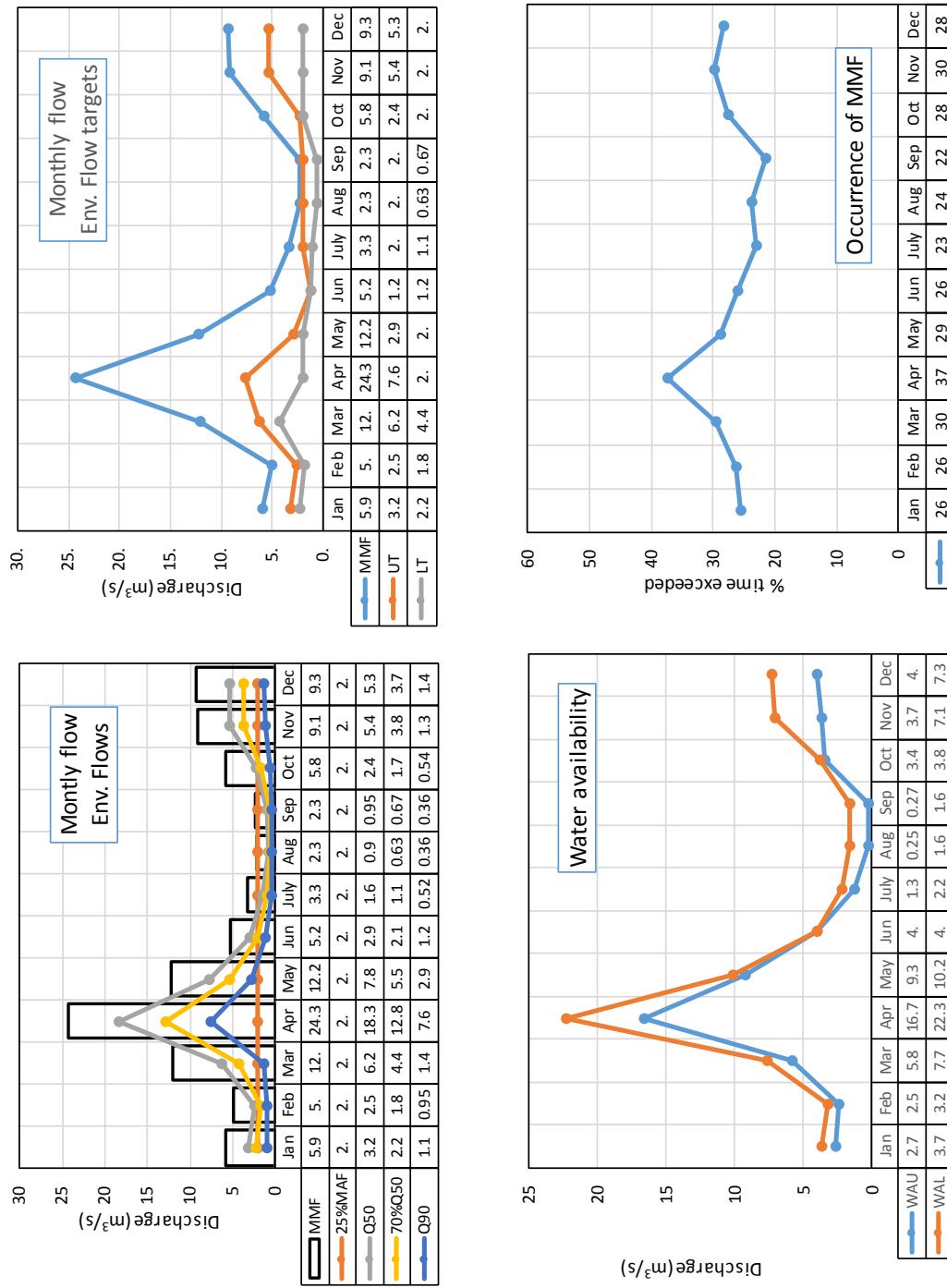


Figure B.47 : Turtle Creek at Turtle Creek (01BU003)

Station ID	01BU003	Mean annual flow (MAF)	3.61 m ³ /s
Latitude	45°57'34" N	Median annual flow (Q ₅₀)	1.73 m ³ /s
Longitude	64°52'40" W	Q ₅₀ (Aug)	0.51 m ³ /s
Drainage area	129 km ²	70%Q ₅₀ (Aug)	0.357 m ³ /s
Period of record	1963-2010 (48 years)	Q ₉₀ (Aug)	0.3207 m ³ /s

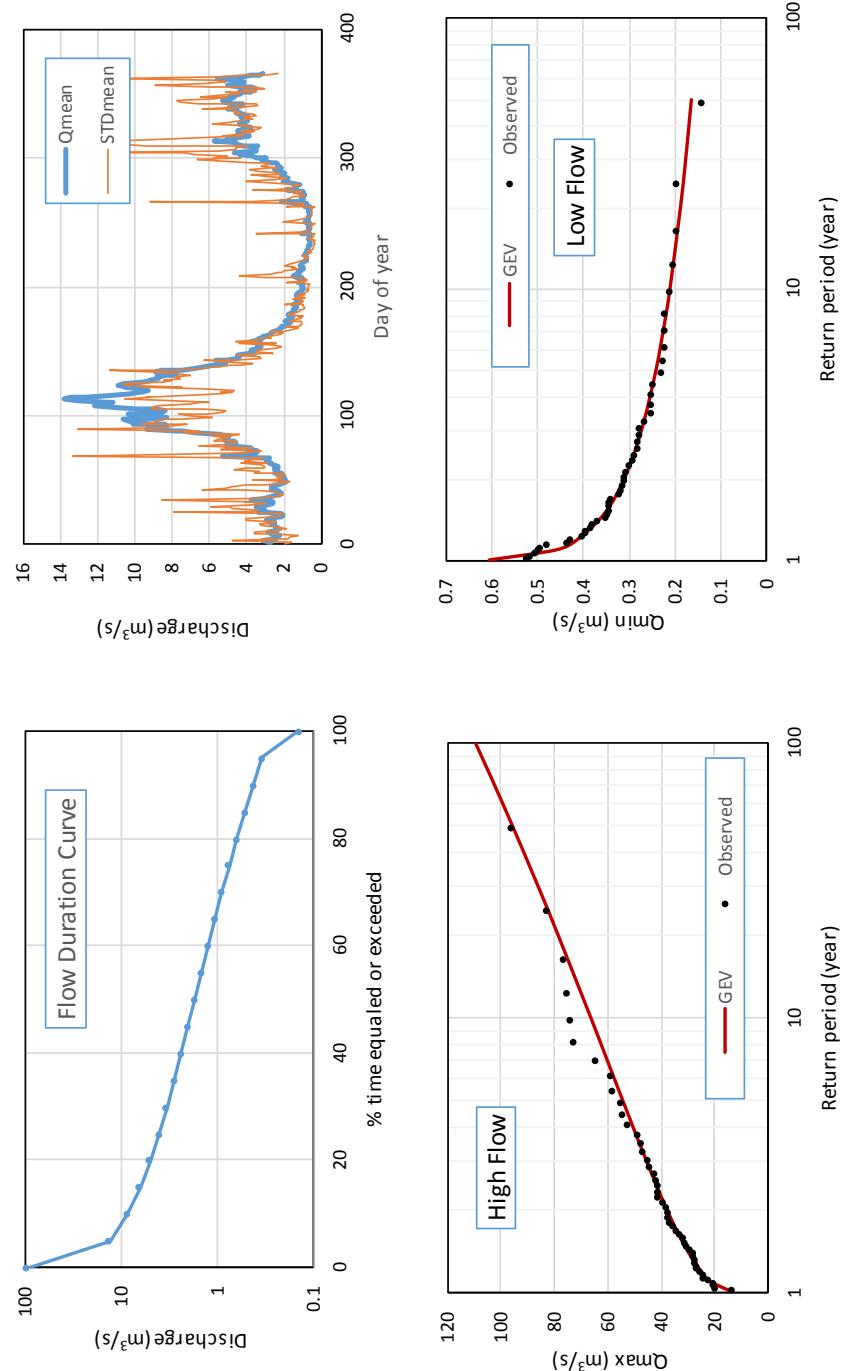


Figure B.47 : Turtle Creek at Turtle Creek (01BU003) (Continued)

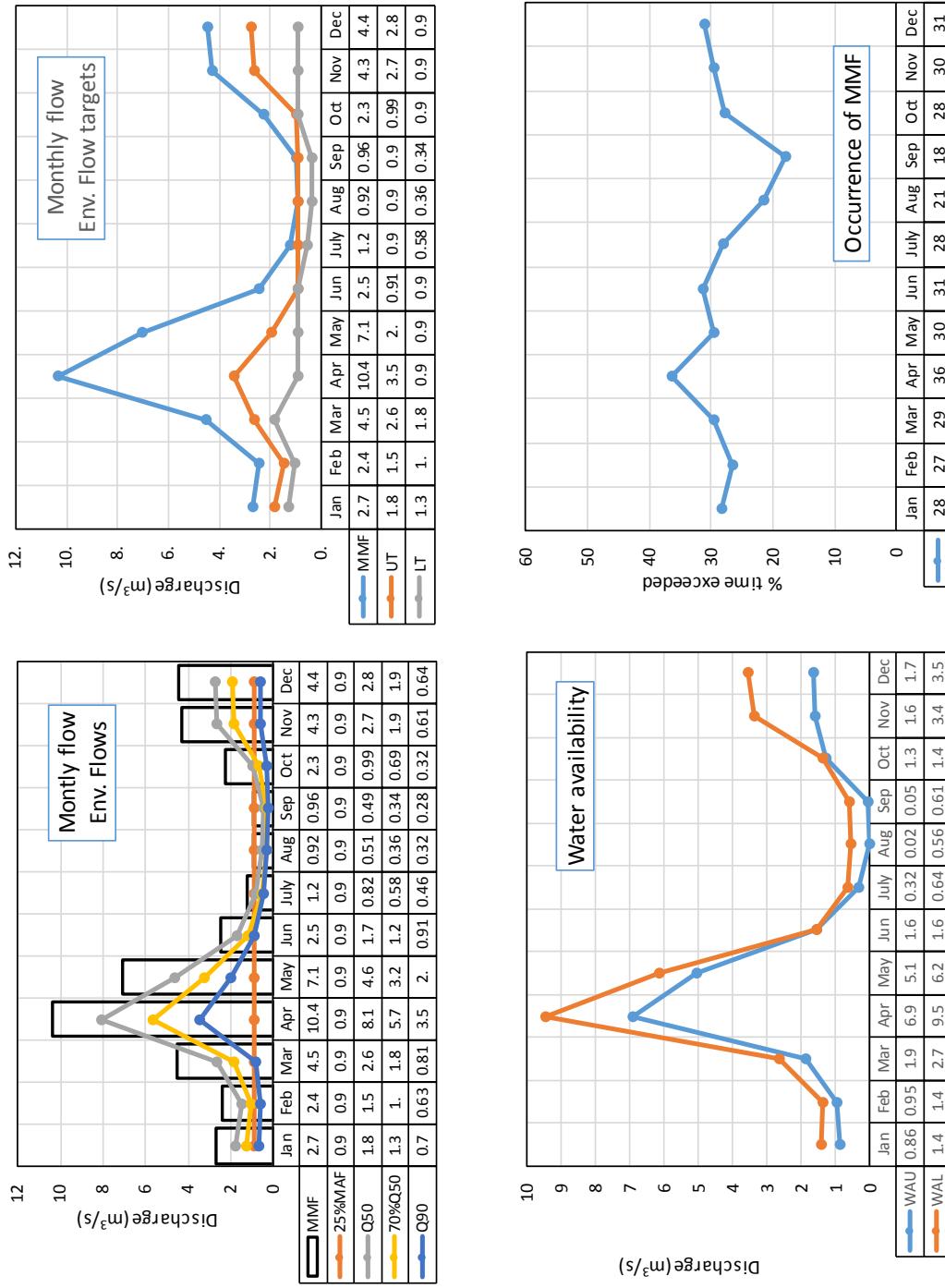


Figure B.48 : Palmer's Creek near Dorchester (01BU004)

Station ID	01BU004	Mean annual flow (MAF)	0.934 m ³ /s
Latitude	45°53'14" N	Median annual flow (Q ₅₀)	0.464 m ³ /s
Longitude	64°30'59" W	Q ₅₀ (Aug)	0.165 m ³ /s
Drainage area	34.2 km ²	70%Q ₅₀ (Aug)	0.1155 m ³ /s
Period of record	1967-1985 (19 years)	Q ₉₀ (Aug)	0.045 m ³ /s

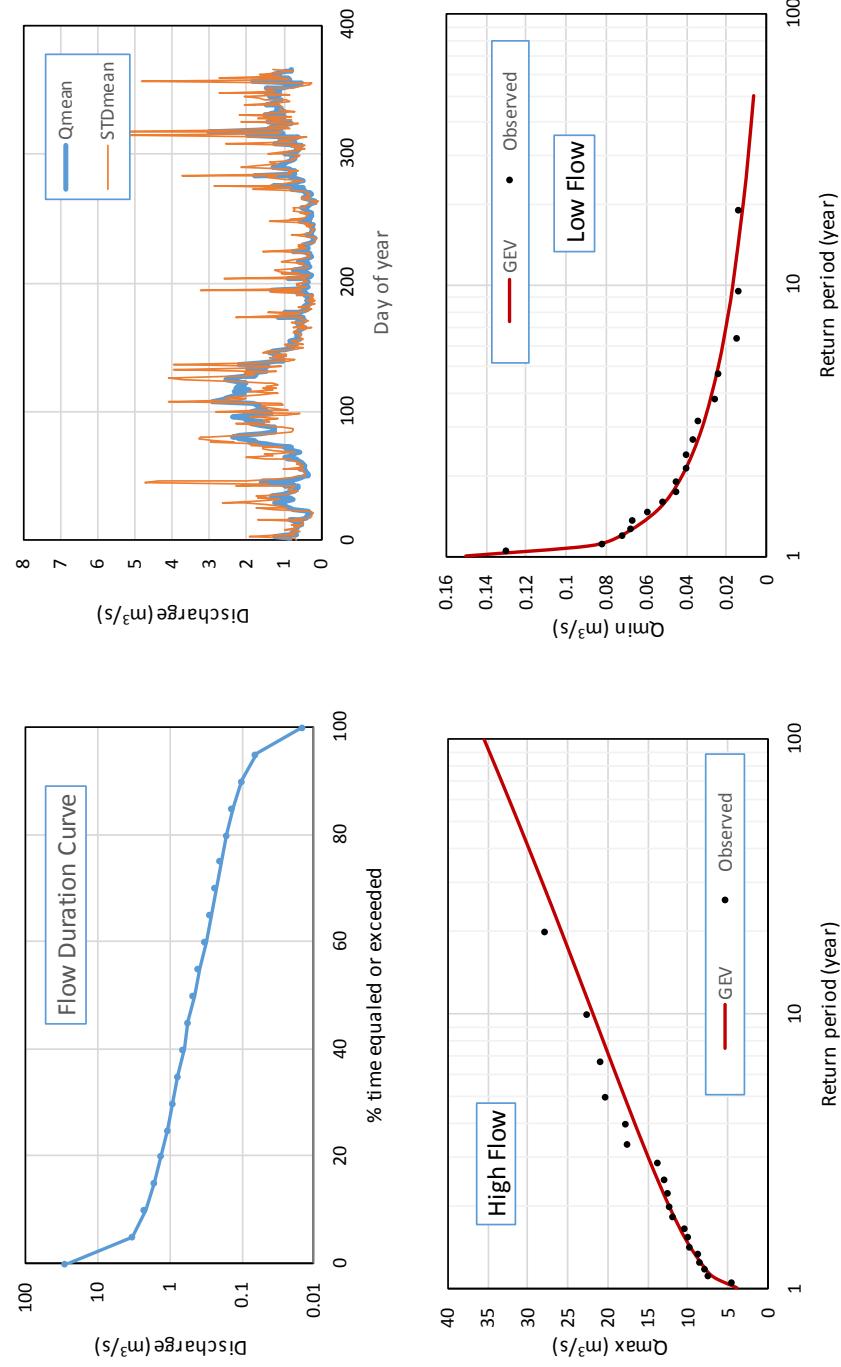


Figure B.48 : Palmer's Creek near Dorchester (01BU004) (Continued)

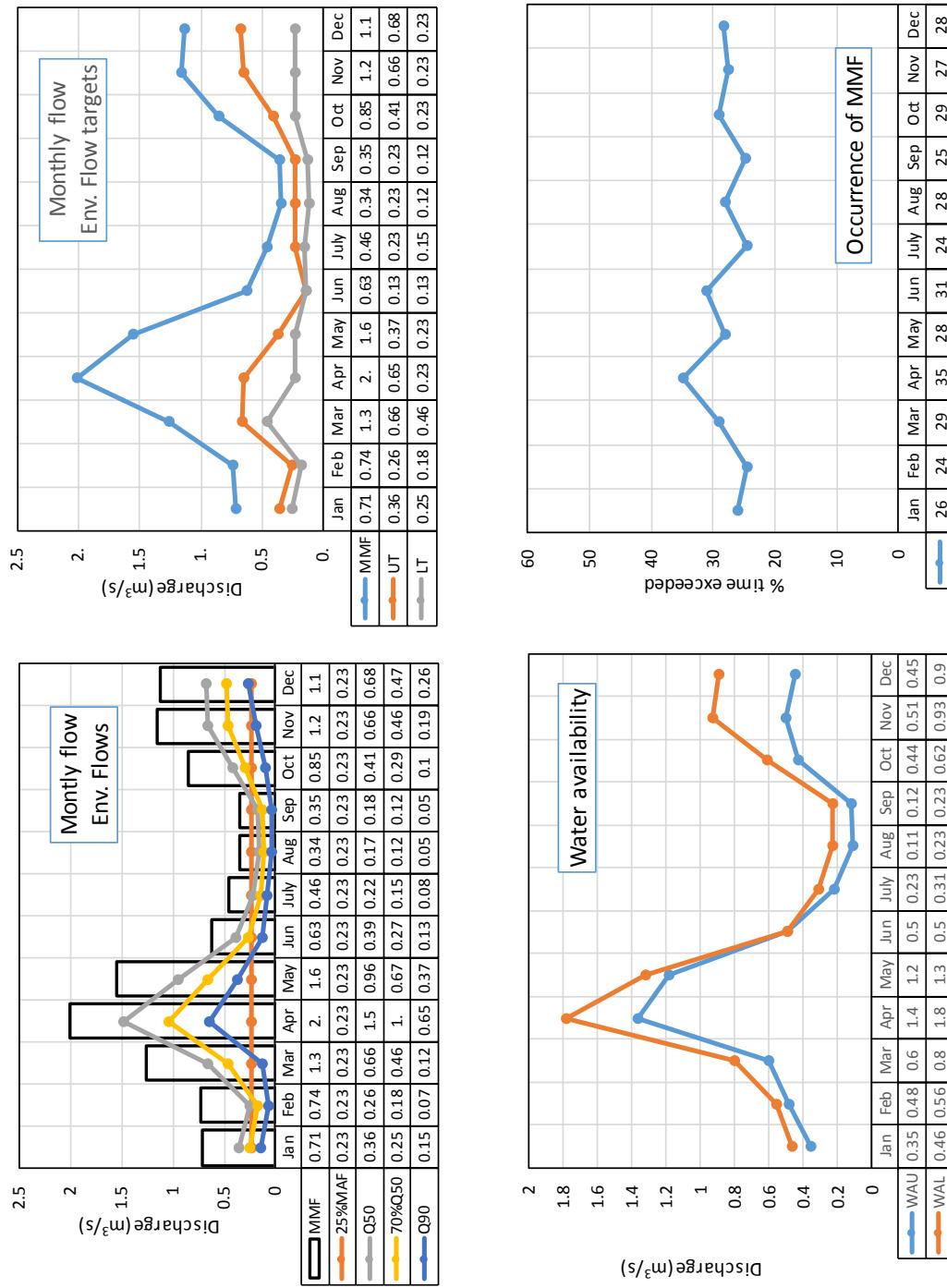


Figure B.49 : Ratcliffe Brook below Otter Lake (01BV005)

Station ID	01BV005	Mean annual flow (MAF)	0.995 m ³ /s
Latitude	45°22'04" N	Median annual flow (Q ₅₀)	0.549 m ³ /s
Longitude	65°48'42" W	Q ₅₀ (Aug)	0.306 m ³ /s
Drainage area	29.3 km ²	70%Q ₅₀ (Aug)	0.2142 m ³ /s
Period of record	1961-1971 (11 years)	Q ₉₀ (Aug)	0.093 m ³ /s

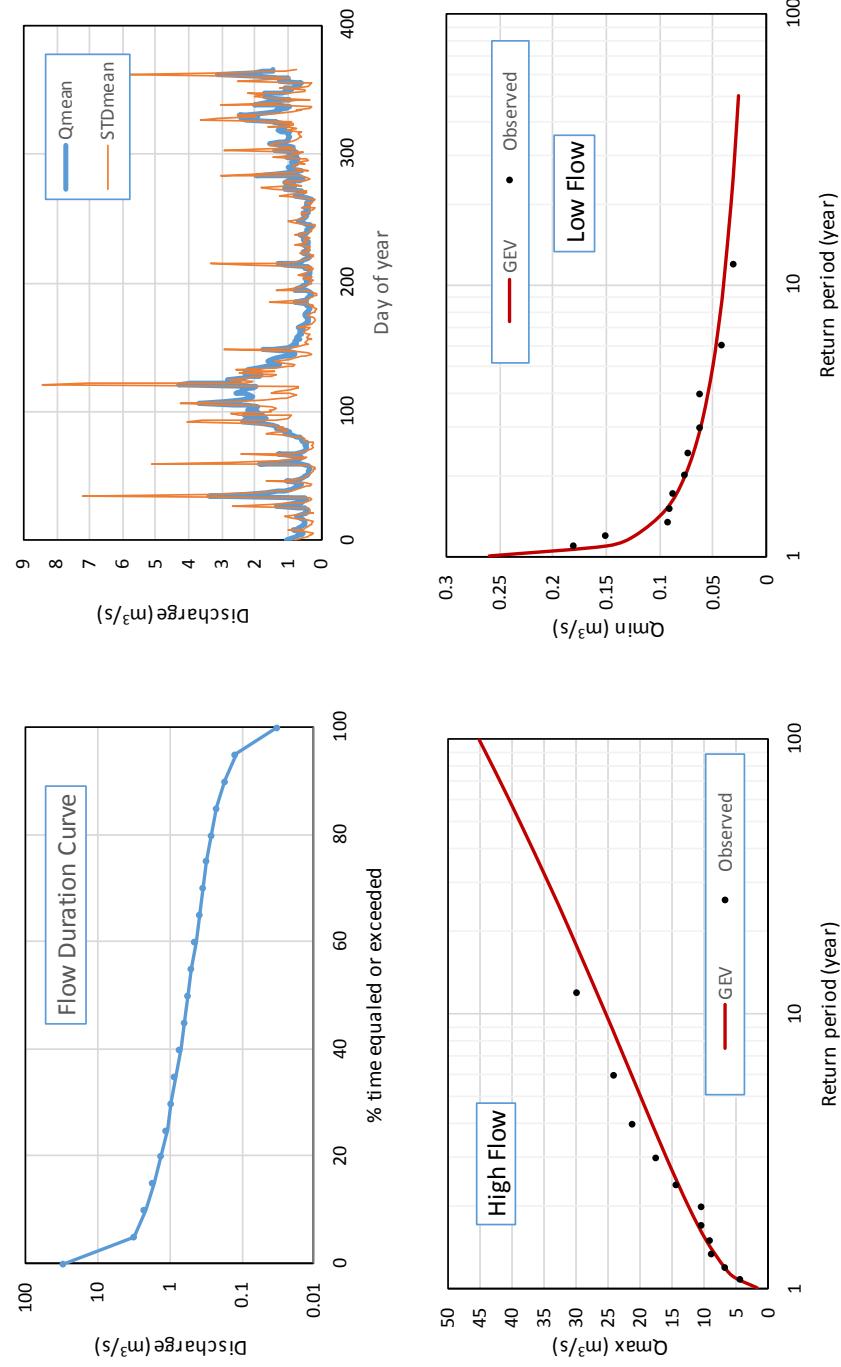


Figure B.49 : Ratcliffe Brook below Otter Lake (01BV005) (Continued)

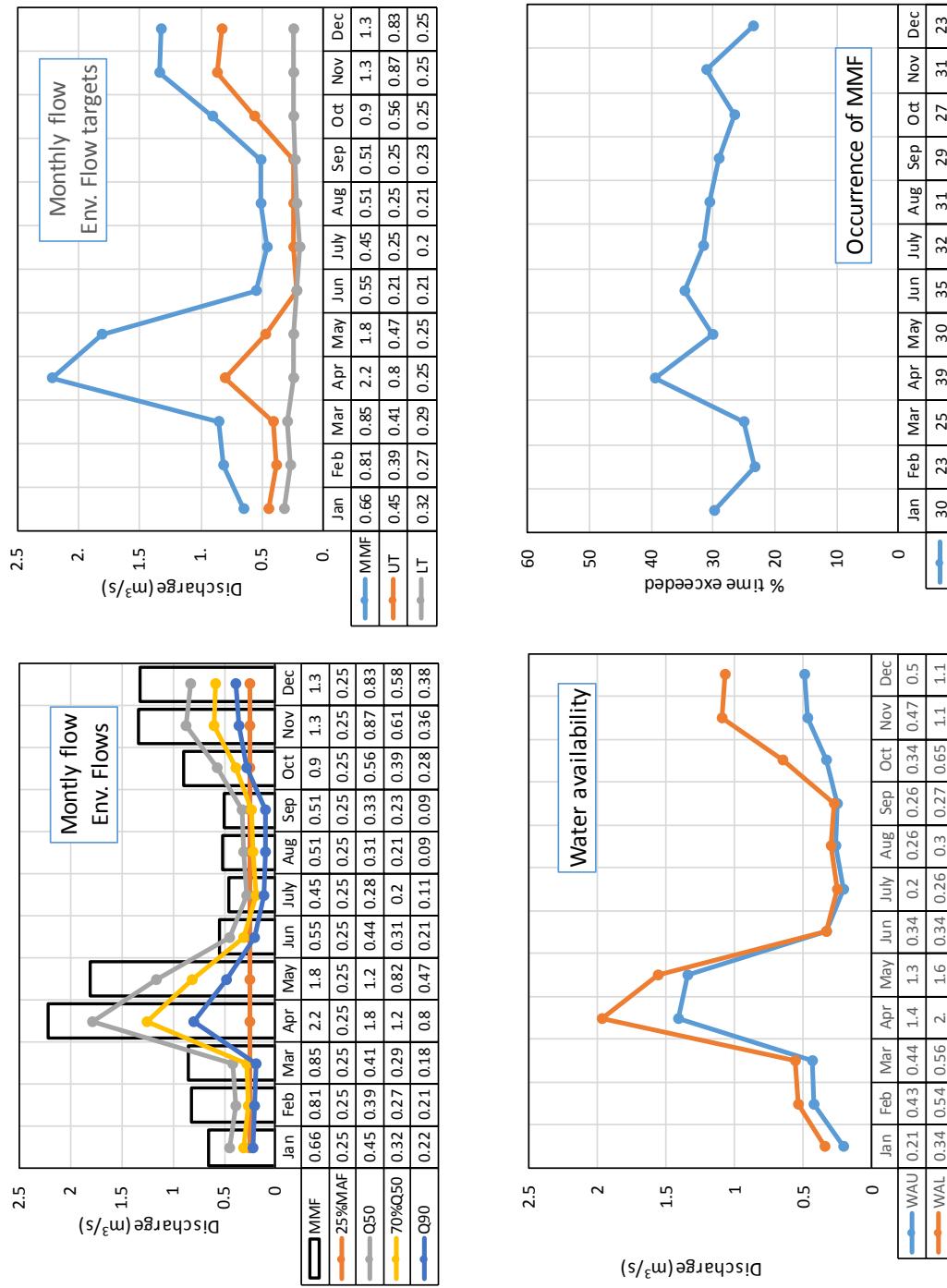


Figure B.50 : Point Wolfe River at Fundy National Park (01BV006)

Station ID	01BV006	Mean annual flow (MAF)	5.11 m ³ /s
Latitude	45°33'30" N	Median annual flow (Q ₅₀)	2.88 m ³ /s
Longitude	65°00'57" W	Q ₅₀ (Aug)	1.09 m ³ /s
Drainage area	130 km ²	70%Q ₅₀ (Aug)	0.763 m ³ /s
Period of record	1964-2011 (48 years)	Q ₉₀ (Aug)	0.3106 m ³ /s

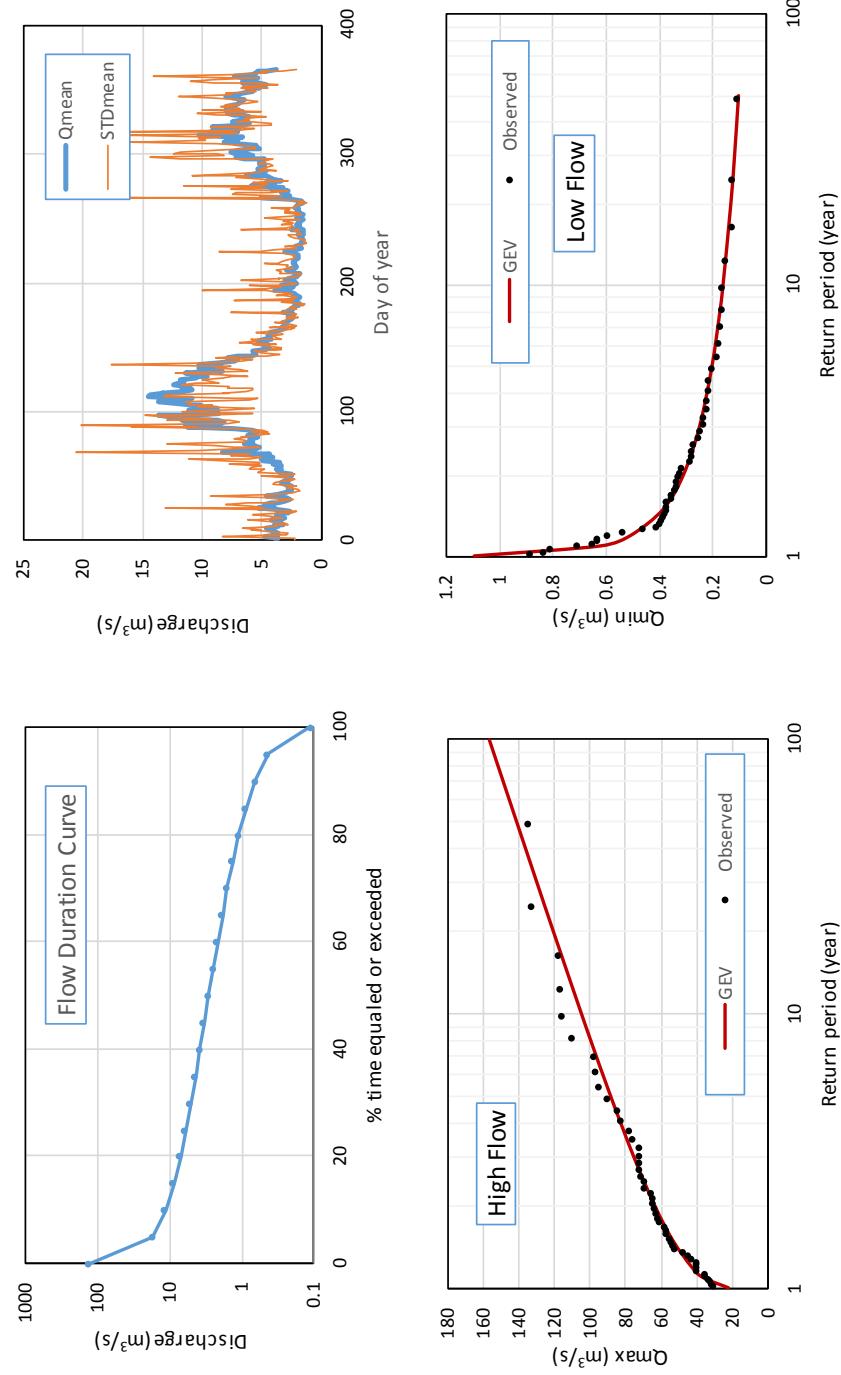


Figure B.50 : Point Wolfe River at Fundy National Park (01BV006) (Continued)

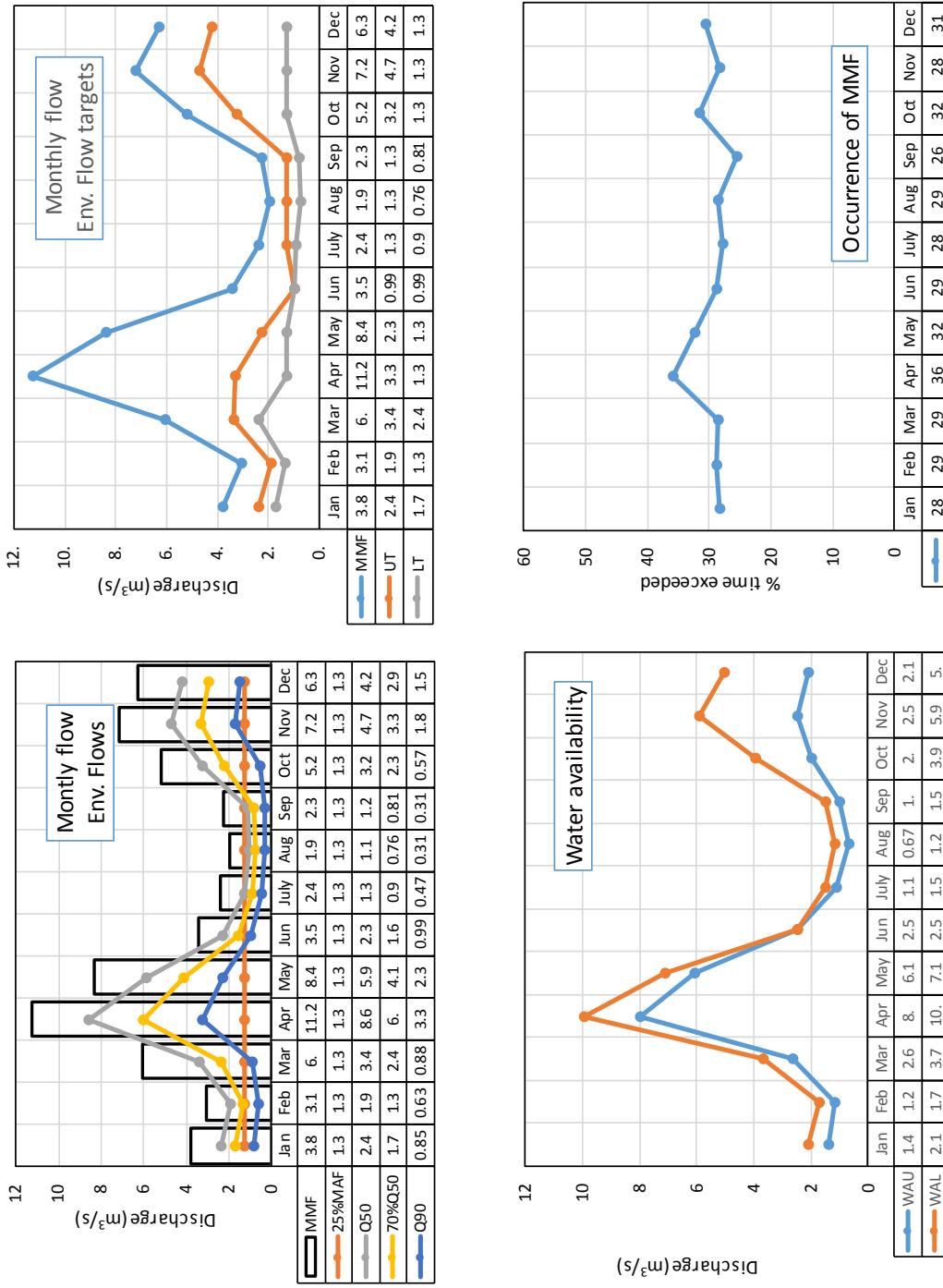


Figure B.51 : Upper Salmon River at Alma (01BV007)

Station ID	01BV007	Mean annual flow (MAF)	7.05 m ³ /s
Latitude	45°36'40" N	Median annual flow (Q ₅₀)	3.85 m ³ /s
Longitude	64°57'22" W	Q ₅₀ (Aug)	1.72 m ³ /s
Drainage area	181 km ²	70%Q ₅₀ (Aug)	1.204 m ³ /s
Period of record	1968-1978 (11 years)	Q ₉₀ (Aug)	0.501 m ³ /s

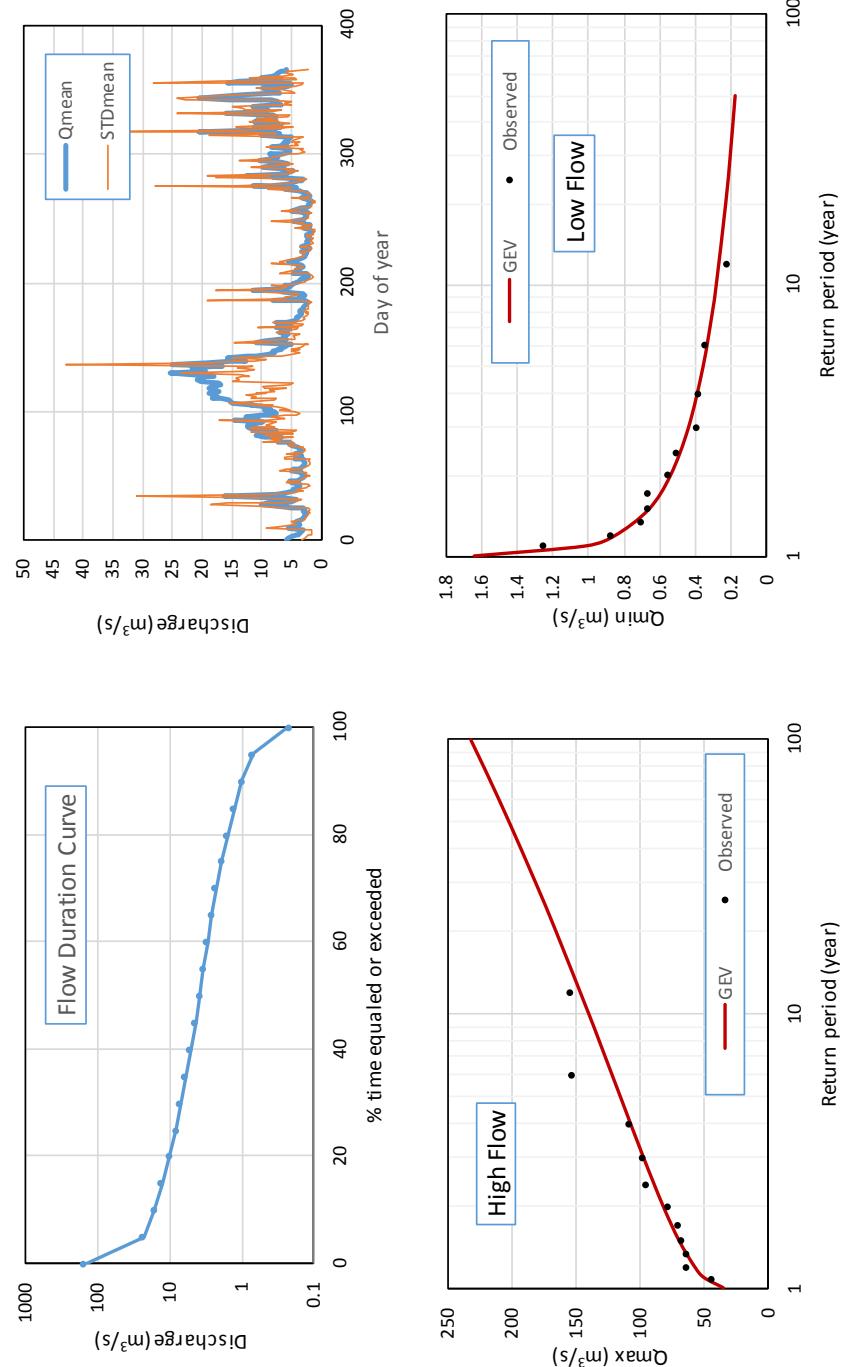


Figure B.51 : Upper Salmon River at Alma (01BV007) (Continued)

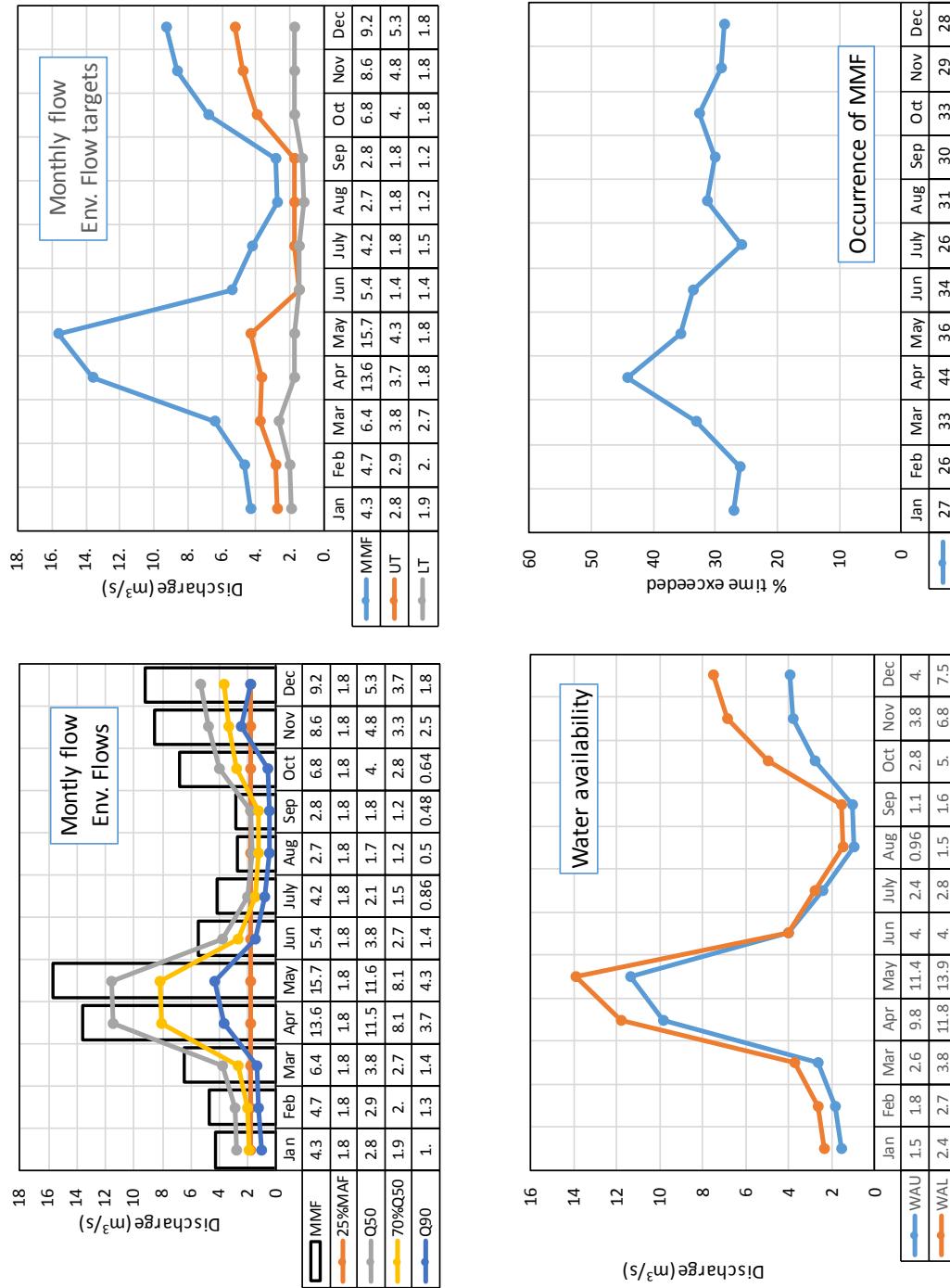


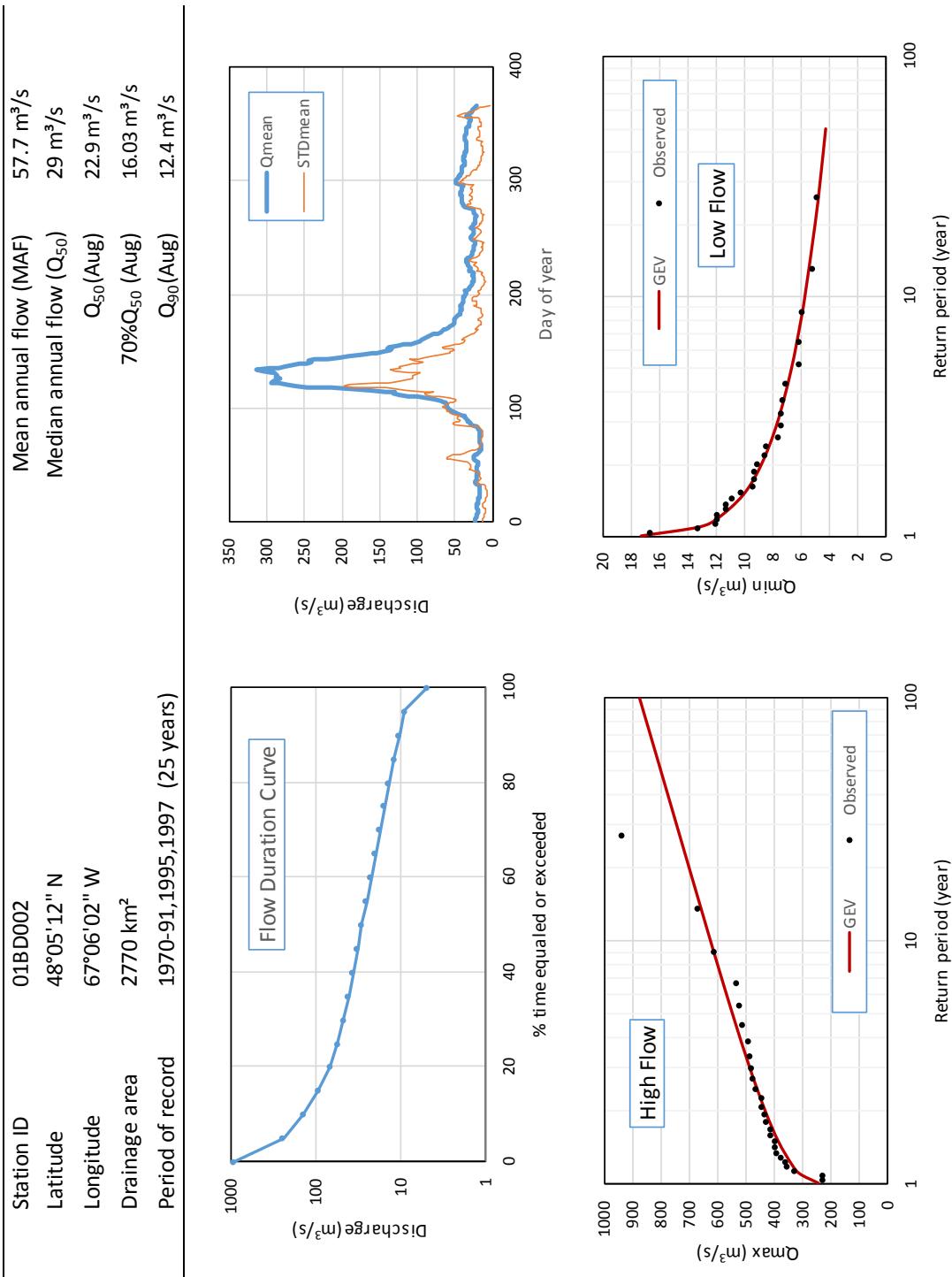
Figure B.52 : Matapedia en Amont de la Rivière assémetquagan, QC (01BD002)

Figure B.52 : Matapedia en Amont de la Rivière assémetquagan, QC (01BD002) (Continued)

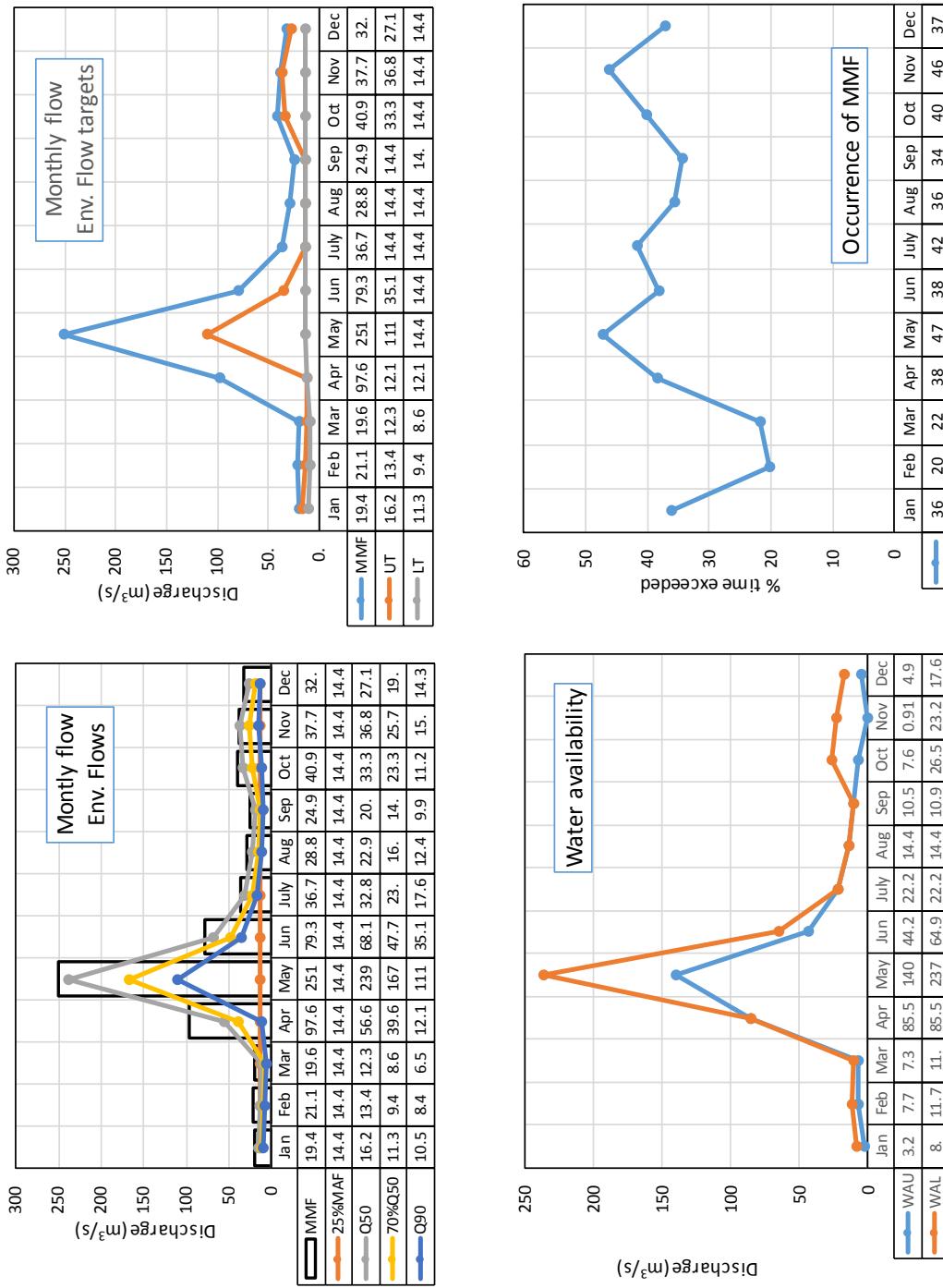


Figure B.53 : Kelley River at Eight Mile Ford, NS (01DL001)

Station ID	01DL001	Mean annual flow (MAF)	1.85 m ³ /s
Latitude	45°35'12" N	Median annual flow (Q ₅₀)	1.03 m ³ /s
Longitude	64°27'02" W	Q ₅₀ (Aug)	0.2375 m ³ /s
Drainage area	63.2 km ²	70%Q ₅₀ (Aug)	0.16625 m ³ /s
Period of record	1970-96,1999-2011 (40 years)	Q ₉₀ (Aug)	0.062 m ³ /s

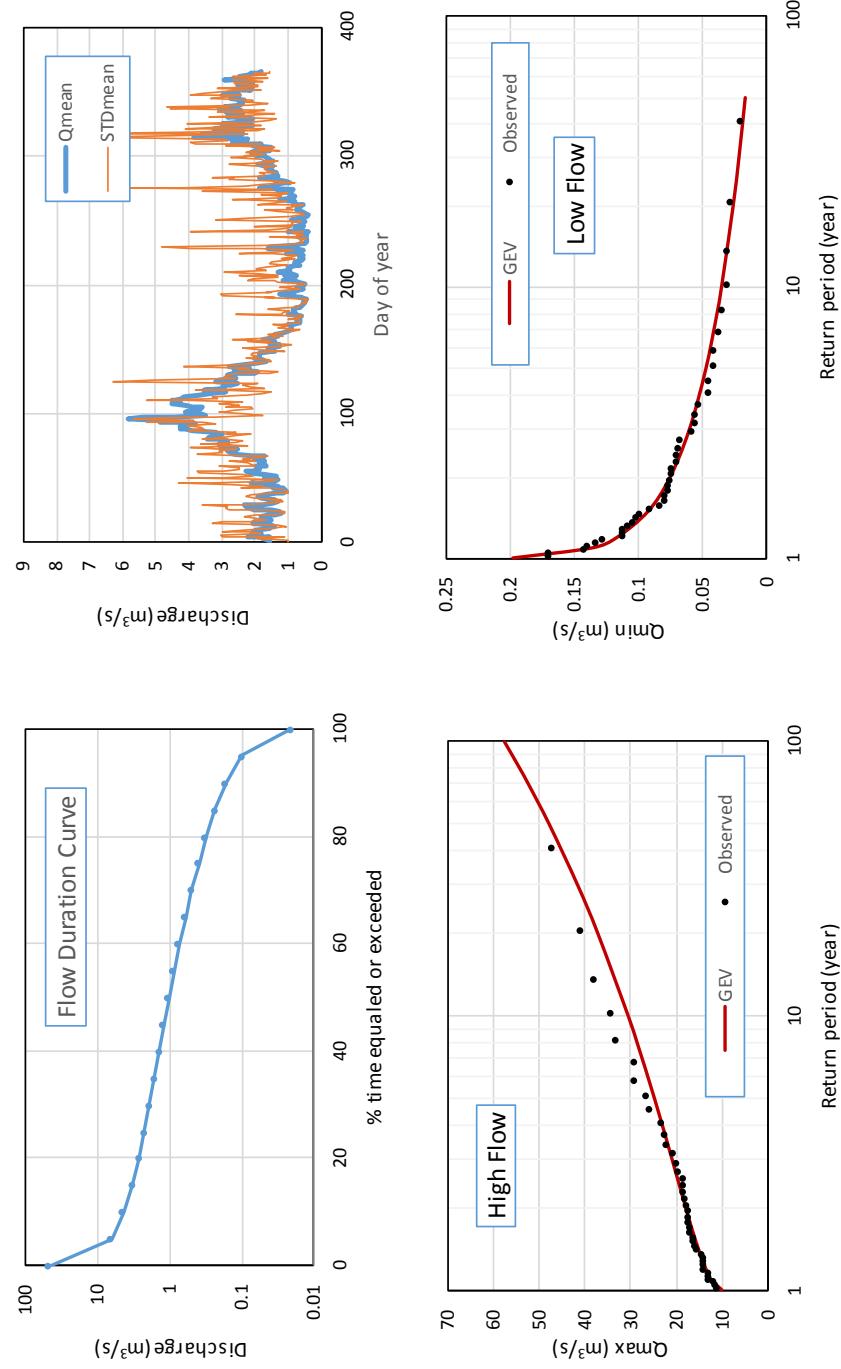


Figure B.53 : Kelley River at Eight Mile Ford, NS (01DL001) (Continued)

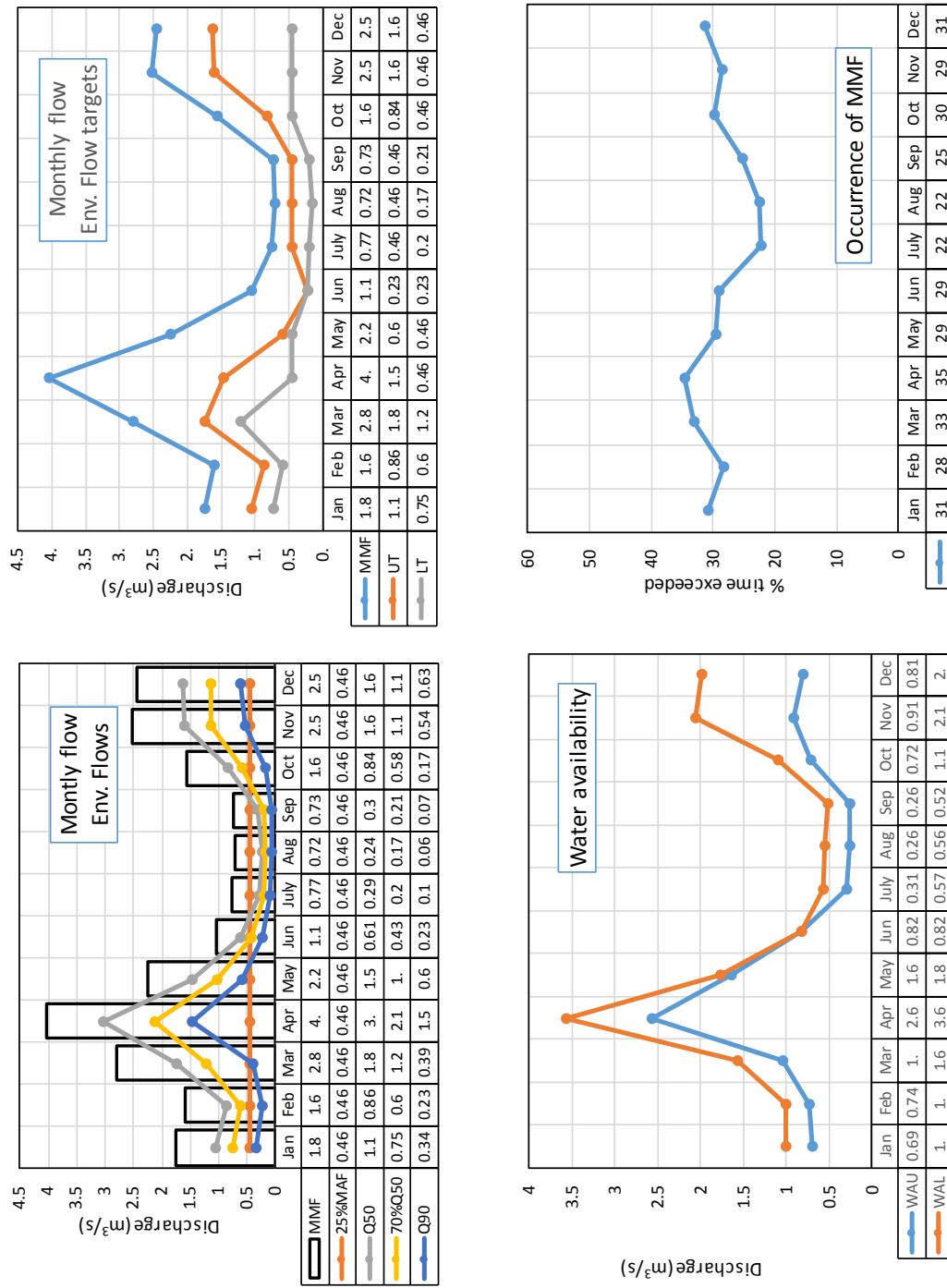


Figure B.54 : Nouvelle au Pont, QC (01BF001)

Station ID	01BF001	Mean annual flow (MAF)	25.9 m ³ /s
Latitude	48°09'26" N	Median annual flow (Q ₅₀)	11.8 m ³ /s
Longitude	66°20'58" W	Q ₅₀ (Aug)	9.3255 m ³ /s
Drainage area	1140 km ²	70%Q ₅₀ (Aug)	6.52785 m ³ /s
Period of record	1965-2000 (36 years)	Q ₉₀ (Aug)	5.444 m ³ /s

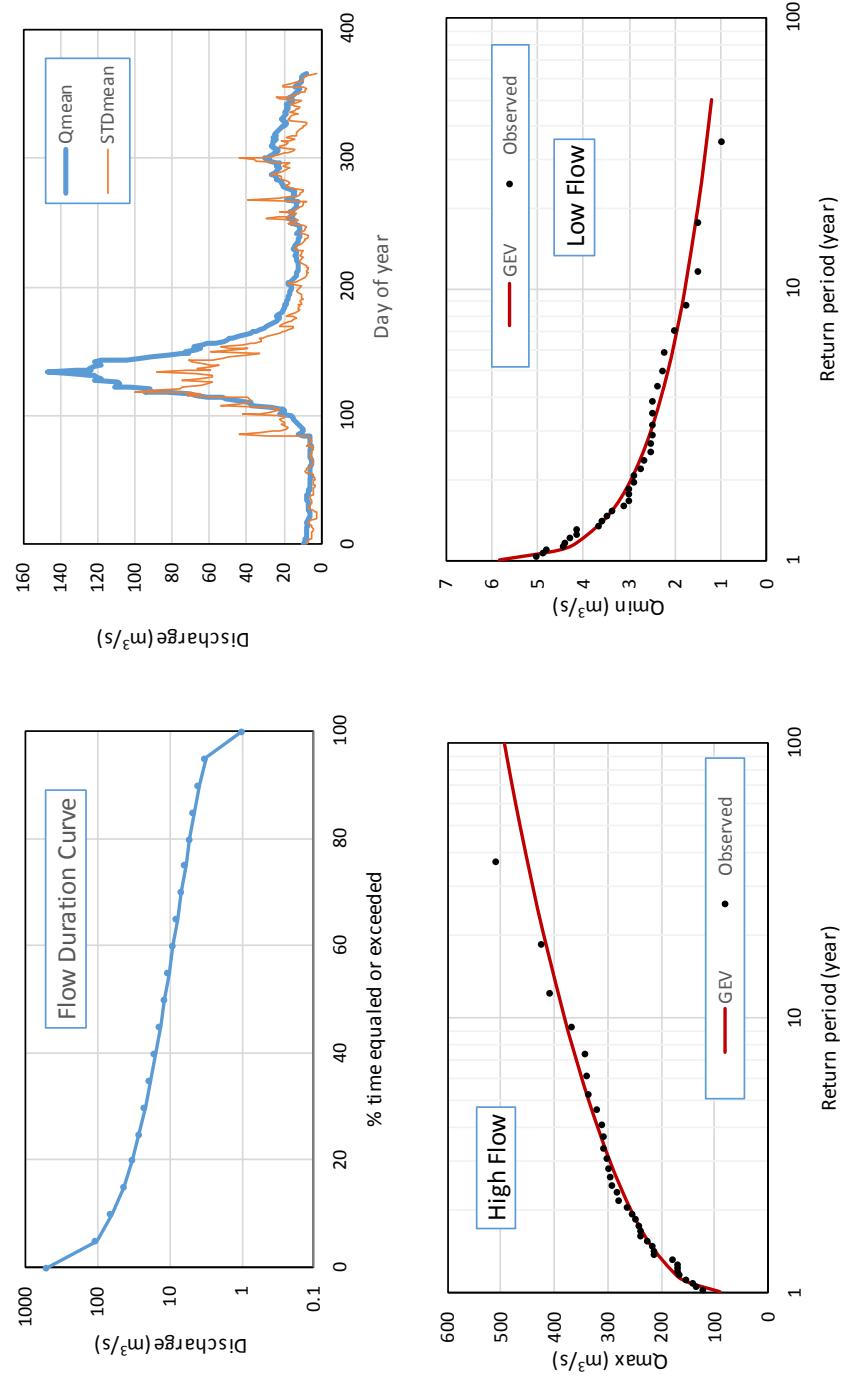
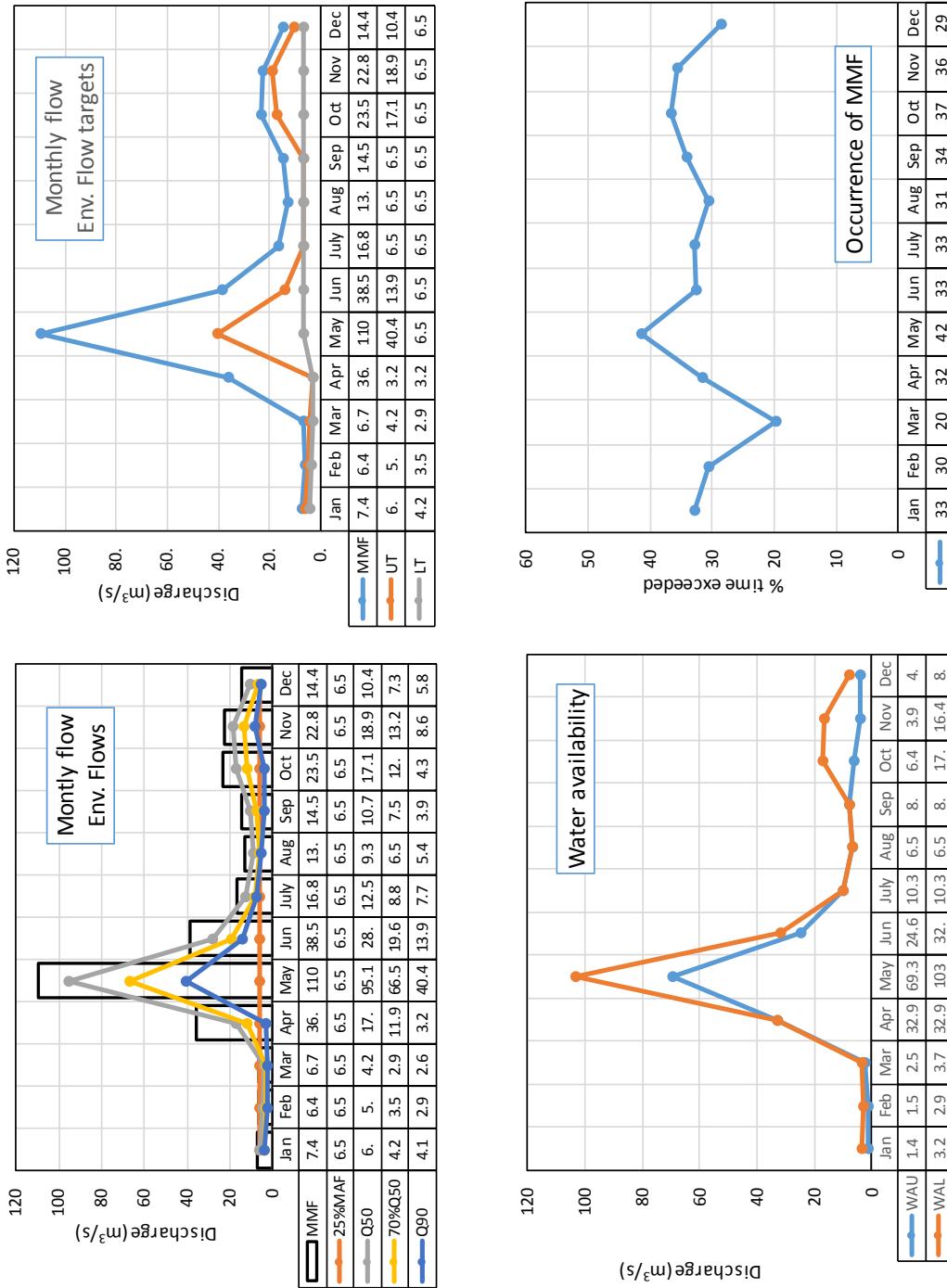


Figure B.54 : Nouvelle au Pont, QC (01BF001) (Continued)





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CHARACTERISATION OF NATURAL FLOW REGIMES AND ENVIRONMENTAL FLOWS EVALUATION IN NEW BRUNSWICK

MARCH 2015