River discharge and channel width relationships for New Brunswick rivers

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ABSTRACT

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River hydrology and fluvial morphology are key components for river engineering, river restoration, water resources planning and river ecosystems studies. For instance, the hydrologic regime within a given region will influence river hydraulic conditions which influence the shape of the stream. These physical attributes are important for fisheries because they influence fish habitat and stream productivity.

This study provides an analysis of river discharge and channel width for New Brunswick rivers. The analysis was conducted at two scales, at the basin level for the analysis of streamflow and on a provincial basis for the analysis of more general hydrological / morphological characteristics. The analysis, at the basin level, was conducted within the Miramichi River basin mainly to show the relationships between flow components typical of New Brunswick rivers (small vs. large rivers), and their corresponding flow frequencies (e.g., flow duration analysis). This basin was selected because it is centrally located within the province and has gauged basins of varying size. Results showed that water availability (e.g., mean annual flow per drainage area) was consistent within the region, and that the median flow (Q_{50}) corresponded to approximately half of the mean annual flow. Furthermore, the mean annual flow represents a discharge that is exceeded approximately 28% of the time whereas the bankfull discharge was exceeded for only 1% of the time.

A province-wide analysis was conducted to establish regression equations between flow variables and river characteristics. Regression equations were developed between wetted river width and the mean annual flow as well as between bankfull river width and bankfull discharge. A regression equation was calculated for basin drainage area and both mean annual flow and bankfull discharge. A regression equation was also established between drainage area and river width (at bankfull discharge). The equations were then compared to results found in the literature.

RÉSUMÉ

Caissie, D. 2005. River discharge and channel width relationships for New Brunswick rivers. Can. Tech. Rep. Fish. Aquat. Sci. 2637: 26p.

Hydrologie et la géomorphologie des cours d'eau jouent un rôle important pour l'ingénierie des cours d'eau, la restauration des rivières, la gestion des ressources hydriques ainsi que pour les études d'écosystèmes aquatiques. Par exemple, le régime hydrologique d'une région influence l'hydraulique des rivières qui déterminera ultimement les caractéristiques géomorphologiques fluviales. Ces caractéristiques physiques des cours d'eau sont aussi importantes dans le domaine halieutique car ils influencent l'habitat du poisson et la productivité des cours d'eau.

Cette étude présente une analyse du débit et de la largeur des cours d'eau au Nouveau-Brunswick. L'analyse a été effectuée à deux échelles différentes, soit à une échelle d'un basin versant afin d'analyser les différentes composantes de l'écoulement et à une échelle provinciale pour étudier les caractéristiques hydrologiques et géomorphologiques à cette échelle. L'analyse au niveau d'un basin versant a été effectuée à l'aide du bassin de la rivière Miramichi afin de d'étudier les relations de débits entre petits et grands cours d'eau ainsi que la fréquence de ces débits (courbe de débit classée). Ce bassin versant fut choisi car il est situé dans la partie centrale de la province et il possède également plusieurs bassins jaugés de différentes superficies. Les résultats ont démontré que la disponibilité en eau (débit moyen par unité de surface) était similaire dans la région en étude, et que le débit médian représente environ la moitié du débit moyen. De plus, le débit moyen représente un débit d'une fréquence de dépassement d'environ 28% tandis que le débit à plein bord possède une fréquence de dépassement de 1% seulement.

Une analyse au niveau de la province du Nouveau-Brunswick a été effectuée afin d'établir des équations de régression entre les paramètres fluviaux et le débit. Des équations de régression ont été développées entre la largeur du cours d'eau et le débit moyen ainsi qu'entre la largeur du cours d'eau (au débit à plein bord) et le débit à plein bord. Des équations de régression ont été établies en fonction de la superficie drainée du bassin versant et le débit moyen ainsi que le débit à plein bord. Des équations de régression ont également été établies entre la largeur du cours d'eau (au débit à plein bord) et la superficie du bassin. Les équations calculées ont par la suite été comparées avec ceux de la littérature.

1.0 INTRODUCTION

The study of river hydrology and fluvial morphology is important in the overall understanding of river systems. They are key components for river engineering and restoration, for water resources planning and for river ecosystems studies. Fluvial morphology provides a framework for a systematic order of river characteristics resulting from physical forcing processes and river hydrology. As such, fluvial morphology is the science that deals with the shape and forms of rivers including river width, sinuosity and meandering patterns. Understanding the hydrology and geomorphology of river systems is crucially important if we want to conserve their natural beauty, habitats and resources. River hydrology influences the temporal and spatial distribution of discharge including the water availability within a given region. Notably, streamflow characteristics can inform flood and drought conditions which ultimately impact on fisheries resources. River hydrology also provides valuable information on the capacity of rivers to dilute pollutants during low flow events and is as well an essential component of environmental impact assessment and instream flow studies (Caissie and El-Jabi 2003). It is well recognized that high river discharge (also called the bankfull discharge) determines many physical characteristics of the river or fluvial morphology.

From an engineering perspective, river hydrology and fluvial morphology are generally used in the design of water resources projects and / or in the solution of river engineering related problems. Fluvial morphology can also provide valuable information to biologists seeking a better understanding of aquatic habitat use, habitat structure and population dynamics in general. As a consequence, river morphology can provide information related to the distribution of fish habitat as well as habitat changes in relation to river discharge. For example, the spacing of riffles (distance apart) is related to the bankfull river width with riffles spacing approximately 5 to 7 river widths (Leopold *et al.* 1964). Other physical characteristics of the rivers, such as the total meander wave length and radius of curvature are also related to the bankfull river width, as shown in Figure 1. These physical attributes play an important role in fish habitat and stream productivity because they maintain a flow complexity, an essential component for good fish habitat diversity. Therefore, they should be considered in stream design and river restoration (Newbury and Gaboury 1993).

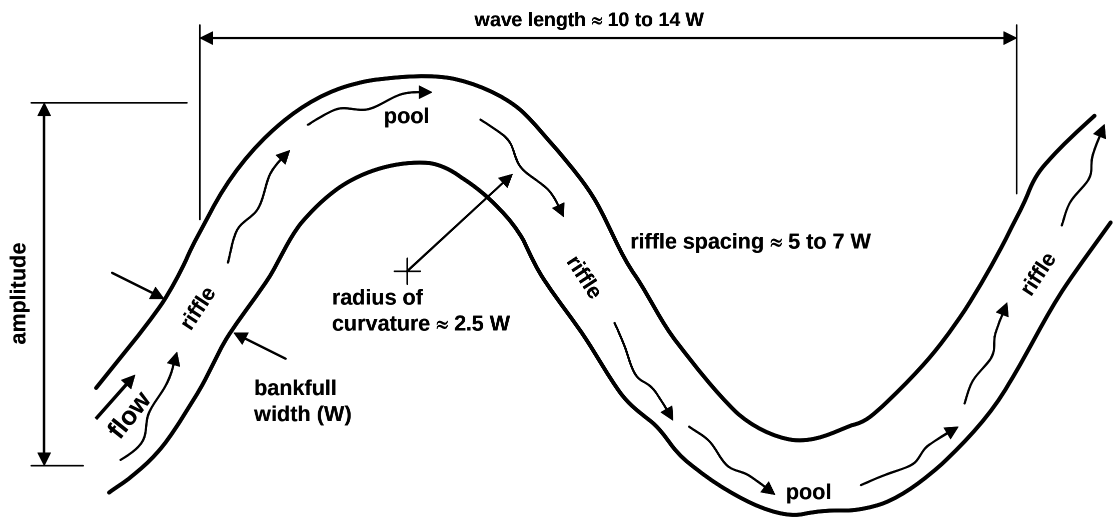

Figure 1. Physical characteristics of rivers in relation to the bankfull river width.

Although river hydrology and fluvial morphology constitute an important component of fisheries and river management, few studies have investigated regional patterns for New Brunswick rivers. Recent studies have investigated channel characteristics within the Miramichi River system (Burge 2004; Burge and Lapointe 2005) and have found that many of these rivers can be characterized as wandering rivers, i.e., a state between braided and meandering rivers. The present study will focus initially on discharge characteristics, namely on the analysis of streamflow components to quantify water availability as well as the spatial / temporal variability, and will follow with a study of channel width characteristics. The calculation of the mean annual flow as well as other important flow components (i.e., flow duration analysis and low return floods or bankfull discharge) will be calculated at two regional levels. A comparison of different streamflow components will be carried out for rivers within Miramichi River systems whereas a general analysis of river discharge and channel width will be conducted for the province. The specific objectives of the study are: 1) to compare streamflow characteristics (mean flow, flow duration and bankfull discharge) at the local scale, using hydrometric stations within the Miramichi River basin, 2) to calculate useful averages and index of flows at the local scale, 3) to relate river widths to different flow magnitudes and drainage basin sizes in New Brunswick and 4) to calculate regional equations for mean annual flow and bankfull discharge on a provincial basis.

2.0 MATERIALS AND METHODS

It is important to understand the variability of flow throughout a region. In the present study, this analysis is conducted for rivers within the Miramichi basin, because it is centrally located within the province and a wide range of hydrometric gauges are available within the basin. Four hydrometric stations within the Miramichi River basin were used for the study: Catamaran Brook (01BP002; 28.7 km^2), the Renous River (01BO002; 611 km^2), the Little Southwest Miramichi River (01BP001; 1340 km^2), and the Southwest Miramichi River (01BO001; 5050 km^2) and where the drainage basin area represents the area upstream from the gauging station (Figure 2). Note that stations on Figure 2 are labelled using a short ID, e.g. 01BP002=1BP2. Hydrological conditions within the provinces of New Brunswick are such that the mean annual air temperature varies between 3.2°C in north and 5.8°C in the south. The northern part of the province receives approximately 1100 mm (36% as snowfall) of precipitation annually while the southern portion experiences slightly more precipitation at approximately 1400 mm (20% as snowfall), especially along the Bay of Fundy.

Mean annual flow, low return floods (floods with recurrence interval of 1.5-year and 2-year) and flows of different duration were compared. The mean annual flow (Q_{MAF}) represents the average annual daily discharge, expressed in m^3/s. This parameter provides information on water availability for a given river and drainage basin. The mean annual flow for the different hydrometric stations was obtained from the HYDAT database (Environment Canada 2001). Another relevant flow index and related to the mean annual flow was the water contribution per unit area, i.e., the mean annual flow per drainage basin area. When the mean annual flow is divided by the drainage basin area, the resulting units are $m^3/s/km^2$ or m^3/s per km^2. Sometimes such values are very small, therefore we can multiple the results by 1000, which is the equivalent of expressing these flows as L/s per km^2 or $L/s/km^2$. This parameter can thereafter be used to more easily compare water availability among basins of different sizes.

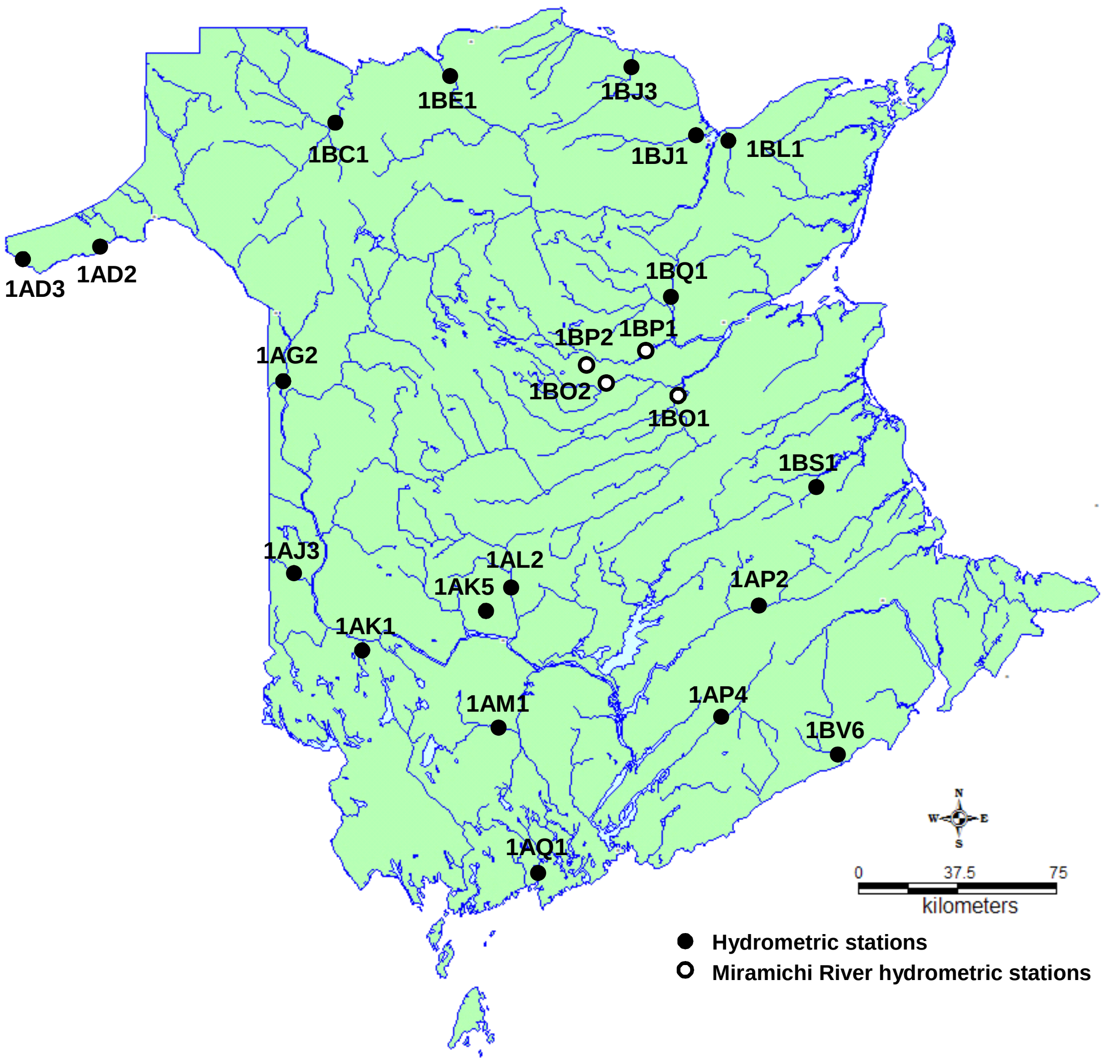

Figure 2. Location of analysed hydrometric stations within the Miramichi River basin and for the province of New Brunswick (see Table 2 for river name).

Following the mean annual flow calculations, a flow duration analysis was conducted. This analysis provided information on the duration or time that specific flows were exceeded within a given time period. A flow duration analysis is a nonparametric cumulative distribution function of daily discharge. 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 flows of different frequencies or percentiles can be determined (e.g., 50% or median flow, 90%, etc.). In this study, the flow duration analysis was carried out using the FLODUR software (Caissie 1991), which makes the necessary calculations using Environment Canada flow data. Important flow characteristics, taken from the flow duration curve, were the Q_{50} or median flow (i.e., the flow that is exceeded 50% of the time), the Q_{90} and Q_{95}. The Q_{90} and Q_{95} are flows that are exceeded 90% and 95% of the time on the flow duration curve and represent low flow characteristics. The above flows were calculated and comparisons were made for different rivers within the Miramichi system. The estimation of such frequencies was calculated for both the mean annual flow and the bankfull discharge.

The return period of annual floods was determined using the 2-parameter lognormal distribution (Kite 2004) to estimate 1.5-year and 2-year flood. Bankfull discharge is the discharge that fills the channel and above which any further increase in flow will result in water flowing onto the floodplain (Figure 3). The bankfull discharge is important in fluvial morphology because it is often identified as the channel forming discharge. The bankfull discharge can be measured by field observations; however, very good relations have been observed between the bankfull discharge and frequently occurring floods. As such, the bankfull discharge is often estimated as having recurrence intervals between 1.5 and 2 years (Leopold 1994). Both the 1.5-year and 2-year flood discharges are relatively close to each other and the 2-year flood is sometime used over other flows, because it is a commonly calculated flow in many hydrological studies in water resources engineering (e.g., Bray 1973). For instance, the 2-year flood was used in this geomorphologic study to relate a number of river parameters (e.g., depth, width and cross sectional area). In the present study, the 1.5-year and the 2-year floods were compared and ratios (or index of flows) were calculated such as the ratio between the 1.5-year and the 2-year flood as well as the ratio between the 2-year flood and the mean annual flow for rivers within the Miramichi system.

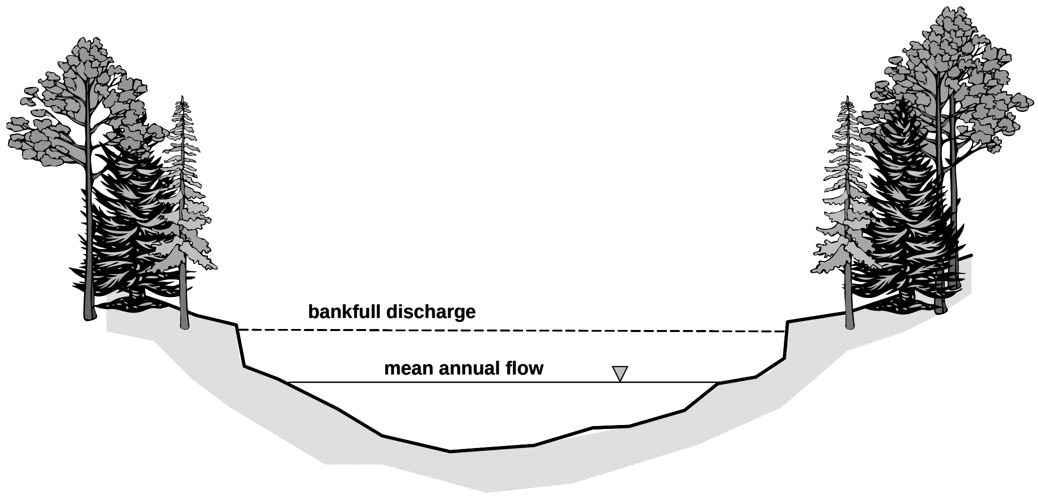

Figure 3. Cross section of a river showing the water level at both the mean annual flow and at the bankfull discharge.

Following the analysis of river discharge within the Miramichi system, a province-wide analysis of discharge and the geomorphic characteristic of channel width was carried out. Specifically, regional equations were calculated between wetted river width (width at the mean annual flow) and discharge as well as equations between bankfull river width and bankfull discharge. Regression equations were developed between river characteristics (river width, mean annual flow and bankfull discharge) and drainage basin area. The mean annual flow for hydrometric stations across the province (including those from the Miramichi system) was obtained from HYDAT (Environment Canada 2001). Bankfull discharges for New Brunswick rivers were estimated using the 2-year floods and obtained from single station analysis taken from a flood frequency study (Environment Canada 1987). Data on wetted river width at the mean annual flow were obtained from Environment Canada using cross sectional data from hydrometric stations. Wetted channel width (at the mean annual flow) reflects the fish habitat conditions for average flow conditions, which is important in the evaluation of the total habitat availability. Bankfull river widths were also obtained from hydrometric station cross sectional data and the width corresponding to the 2-year flood discharge.

3.0 RESULTS AND DISCUSSION

3.1 Streamflow characteristics within the Miramchi River basin

To understand the relationship between flow and drainage area or channel width characteristics, an analysis was initially carried out using four hydrometric stations within the Miramichi basin (Table 1). The mean annual flow (MAF) varied between 0.608 m^3/s and 116 m^3/s. To compare flows for rivers of different sizes, the discharge was normalized by the drainage basin area and expressed as a discharge per unit area, (i.e., Litres/second per km^2 or $L/s/km^2$). The ratio of the mean annual flow to the drainage area was consistent for rivers within the Miramichi system with discharge ranging between 21.2 $L/s/km^2$ (Catamaran Brook) and 24.1 $L/s/km^2$ (Little Southwest Miramichi River) with an average value of 23.0 $L/s/km^2$. With consistent discharge values per unit area, it is possible to estimate water availability for a wide range of basin sizes within a similar hydrological area.

A flow duration analysis was then conducted for gauged rivers with the Miramichi system. This analysis provides information on the percentage of the time flows are exceeded such as 50%, 90% and 95% (i.e., Q_{50}, Q_{90} and Q_{95}). The median flow (Q_{50}) varied between 0.288 m^3/s (Catamaran Brook) and 61.6 m^3/s (Southwest Miramichi River). The Q_{50} generally corresponds to approximately half of the mean annual flow (Leopold 1994). This was consistent with observation made in this study where the Q_{50} for the four rivers ranged between 47% and 53% of the mean annual flow with an overall average of 50%. In other words, a discharge 50% of the MAF occurs approximately 50% of the time for rivers within the Miramichi basin.

Table 1. Flow characteristics of gauging stations within the Miramichi River basin showing the discharge relations between small and large rivers.

Parameters[1]	Catamaran Brook	Renous River	Little Southwest Miramichi River	Southwest Miramichi River
Station ID	01BP002	01BO002	01BP001	01BO001
Area, A (km^2)	28.7	611	1340	5050
Years	14	29	52	42
MAF (m^3/s)	0.608	14.6	32.3	116
MAF/A (L/s/km^2)	21.2	23.9	24.1	23.0
Q_{50} (m^3/s)	0.288	6.96	16.8	61.6
Q_{90} (m^3/s)	0.071	2.33	6.81	25.4
Q_{95} (m^3/s)	0.051	1.78	5.60	21.3
MAF on FDC (%)	27%	28%	27%	28%
$Q_{1.5}$ (m^3/s)	5.17	116	199	714
Q_2 (m^3/s)	6.05	137	241	841
$Q_{1.5}$ / Q_2	0.85	0.85	0.83	0.85
Q_2 / MAF	10.0	9.4	7.5	7.3

1. A = drainage area, km^2; MAF = Mean Annual Flow, m^3/s; Q_{50} = median flow or flow exceeded 50% of the time on the Flow Duration Curve (FDC), m^3/s; Q_{90} = flow exceeded 90% of the time on the FDC, m^3/s; Q_{95} = flow exceeded 95% of the time on the FDC, m^3/s; MAF on FDC (%) = % of time that the MAF is exceeded on the FDC; $Q_{1.5}$ = the 1.5-year flood, m^3/s. Q_2 = the 2-year flood, m^3/s

The Q_{90} and Q_{95} represent low flow conditions on the flow duration curve, The ratio of the Q_{90} to Q_{50} is sometime used as an index of base flow (Gordon *et al*. 1996). In addition, flow duration data can also be expressed as a discharge per unit area. Figure 4 shows discharge per unit area for hydrometric stations within the Miramichi basin. Flow duration curves were very consistent among rivers at higher flows (e.g., higher than the Q_{50}). Conversely, significant departures were observed at low flows. For example, the smaller river systems, the Renous River and Catamaran Brook, showed more severe low flows (e.g., Q_{90}; Figure 4). Lower baseflow contributions were also displayed with ratios (Q_{90}/Q_{50}) of 0.25 for Catamaran Brook and 0.33 for Renous River compared to values of 0.4 for the larger systems. All studied rivers within the

Miramichi drainage basin displayed consistent MAF/area at approximately 23.0 L/s/km^2. The MAF corresponded to a flow that was exceeded 27-28% of the time on the flow duration curve (Table 1; MAF on FDC). This means that for 72% of the time (on average 263 days per year) the flow within these river systems is less than the MAF. These observations are consistent with those made for other river systems. For instance, Leopold (1994) reported that the MAF was generally exceeded 25-30% of the time on the flow duration curve.

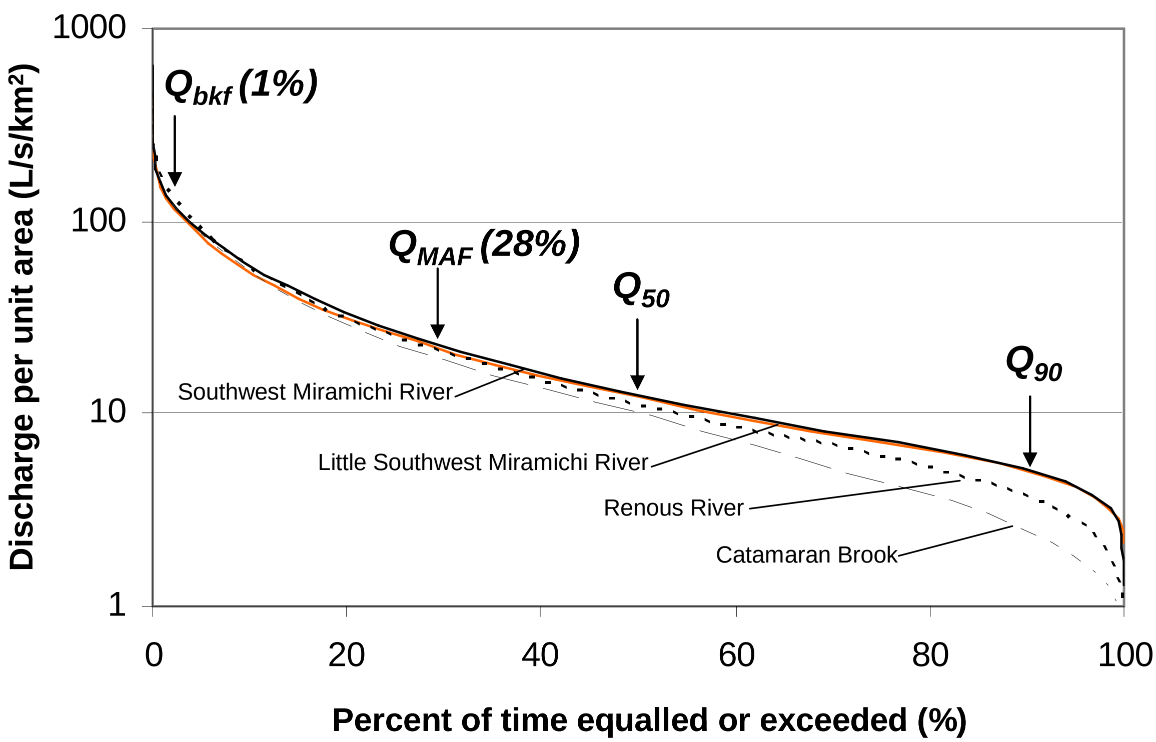

Figure 4. Flow duration curve analysis for rivers in the Miramichi River basin.

The bankfull discharge, or the channel forming discharge, is often estimated using a flow with a 1.5 to 2 year recurrence interval. The 1.5 year discharge ($Q_{1.5}$) varied between 5.17 m^3/s (Catamaran Brook) and 714 m^3/s (Southwest Miramichi River), while the 2-year flood was slightly higher (Table 1). In addition, it was noted that the ratio of the 1.5-year to the 2-year flood discharge was consistent within this hydrological region. In the Miramichi system, this ratio was calculated at 0.85 for all rivers except for the Little Southwest Miramichi River where it was 0.83. Because the 2-year floods are more commonly available in flood frequency studies, this discharge will be used in this study to represent the bankfull discharge. Notably, this discharge is a flow that is exceeded approximately 1% of the time (fewer than 4 days per year) on the flow duration curve (Figure 4). Another important discharge parameter is the ratio of the bankfull discharge to the MAF. This ratio ranged between 7.3 and 10.0 with the higher values being associated with the smaller rivers. This is consistent with the fact that small rivers generally experience higher flood discharge per drainage area (smaller basins are more responsive to rainfall and snowmelt events), even when the average flow (MAF) is comparable among rivers.

3.2 River discharge and channel width relationships for New Brunswick rivers

Data on flow and fluvial geomorphologic characteristics (i.e., river widths, mean annual flow and bankfull discharge) were analyzed for 23 hydrometric stations across the province of New Brunswick. Data on flow and channel width characteristics are presented in Table 2.

The analysed rivers varied in drainage area between 27 km^2 (station 01AK005) and 14730 km^2 (station 01AD002) and the mean annual flow ranged between 0.53 m^3/s and 275 m^3/s at these stations respectively. A regression analysis was carried out between the mean annual flow and the wetted channel width at the mean annual flow and the following equation was calculated:

$$[1] \qquad W_{MAF} = 9.7\sqrt{Q_{MAF}}$$

where W_{MAF} represents the wetted river width (m) corresponding to the mean annual flow, and Q_{MAF} the mean annual flow (m^3/s). The coefficient of determination, R^2, for this equation was calculated at 0.93 and the results are shown in Figure 5. A greater scatter of data points can be observed at flows between 3 m^3/s and 30 m^3/s; however, the regression line represents the river widths well at the corresponding mean annual flows.

Table 2. Analysed hydrometric stations in New Brunswick showing the different flow and river width characteristics.

River	Station number	Drainage area, A (km^2)	Mean annual flow, Q_{MAF} (m^3/s)	Wetted river width at Q_{MAF} (m)	Bankfull discharge Q_{bkf} (m^3/s)	River width at bankfull (m)
Saint John	01AD002	14730	275	186	2550	211
St Francis	01AD003	1350	25	36.1	243	52
Limestone	01AG002	199	3.6	17.8	34	19.5
Meduxnekeag	01AJ003	1210	25	48	243	60
Shogomoc	01AK001	234	5	18	38	26.5
N. Nashwaaksis	01AK005	27	0.53	6.3	6.2	9
Nashwaak	01AL002	1450	35	52.8	315	66
NW Oromocto	01AM001	556	12	50	130	64
Canaan	01AP002	668	13	35	151	76.5
Kennebecasis	01AP004	1100	25	35	234	49
Lepreau	01AQ001	238	7.4	32.5	63	35
Restigouche	01BC001	3160	66	81	591	90
Upsalquitch	01BE001	2270	41	58	394	61
Tetagouche	01BJ001	362	7.8	21	78	31
Jacquet	01BJ003	510	10.5	28	119	44
Bass	01BL001	175	3.2	23	43	27.5
SW Miramichi	01BO001	5050	116	89	841	121
Renous	01BO002	611	15	52	137	58.5
Little SW Mira.	01BP001	1340	32	76	241	99
Catamaran	01BP002	29	0.6	7.9	6.1	10.6
NW Miramichi	01BQ001	947	21	53	221	67
Coal Branch	01BS001	166	3.7	18	45	21
Point Wolfe	01BV006	130	5.1	20.5	59	40

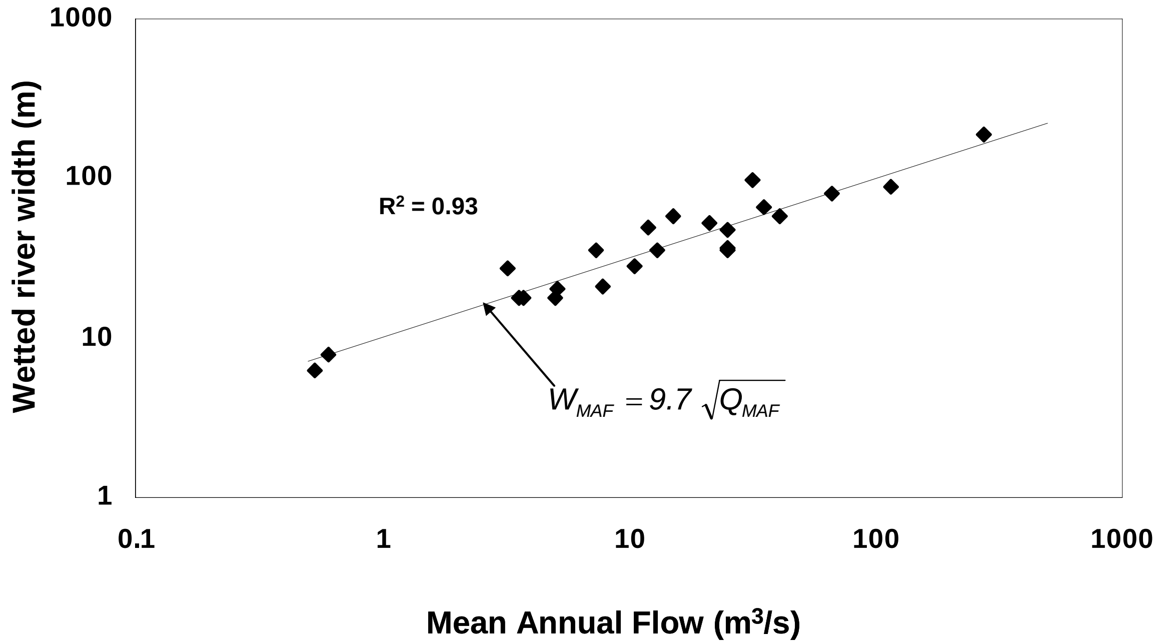

Figure 5. Relationship between the mean annual flow and the wetted river width for New Brunswick rivers.

A regression analysis was conducted between the bankfull discharge, represented by the 2-year flood, and the bankfull river width (Figure 6). Results of this regression analysis gave the following equation:

$$W_{bkf} = 4.0\sqrt{Q_{bkf}} \quad [2]$$

where W_{bkf} represents the bankfull river width (m) and Q_{bkf} represents the bankfull discharge. In the case of the relationship between the bankfull discharge and the bankfull river width, the coefficient of determination was calculated at 0.92, and similar to the mean annual flow vs. wetted channel width relationship. Notably, the exponent of both regression equations (Q_{MAF} and Q_{bkf}) was 0.5 (square root) of discharge.

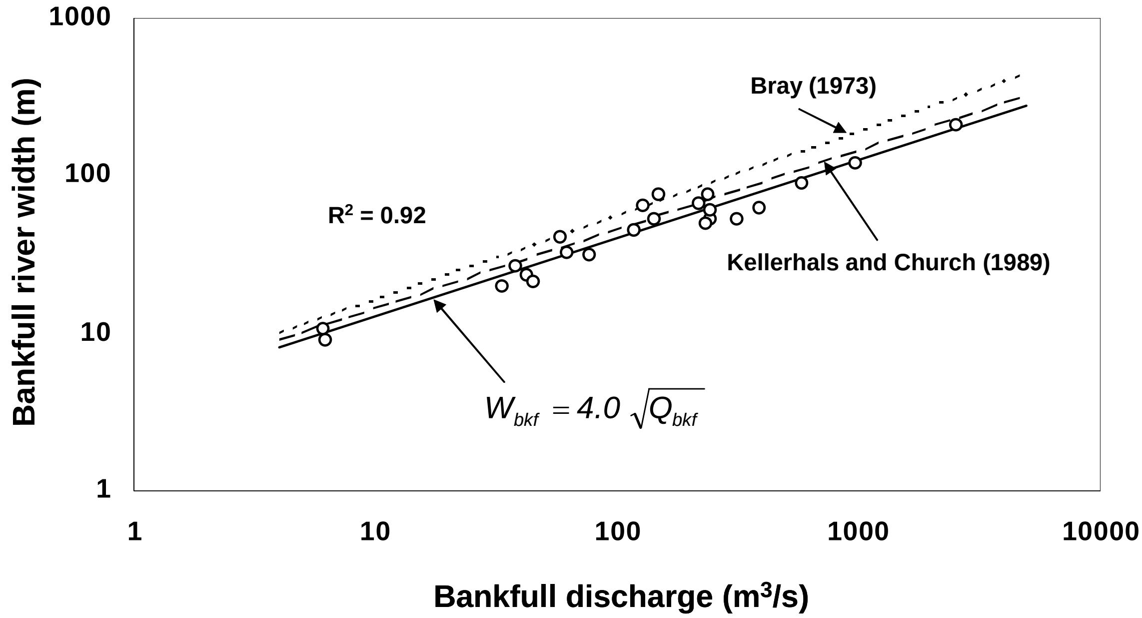

Figure 6. Relationship between the bankfull discharge and the bankfull river width for New Brunswick rivers as well as results from other studies reported in the literature.

The bankfull discharge vs. bankfull river width relationship calculated for New Brunswick rivers was very similar to that found by Kellerhals and Church (1989) for similar sized rivers, i.e., a power function with an exponent close to 0.5. In the case of Kellerhals and Chruch (1989), data came from different sources, and represented a wider range of river conditions, which led to the following equation (also presented in Figure 6):

[3] $$W_{bkf} = 4.47 \sqrt{Q_{bkf}}$$

Kellerhals and Church (1989) noted that the power function exponent was closer to 0.4 for very small rivers and experimental flumes, whereas very large rivers showed an exponent closer to 0.55. Medium sized rivers showed a power function exponent close to 0.5. Bankfull river width and bankfull discharge was also analysed by Bray (1973; 1975) where he showed the following best fit equation, with an R^2 of 0.96:

[4] $$W_{bkf} = 4.75\, Q_{bkf}^{\ 0.53}$$

This equation, derived from Alberta rivers, predicted slightly higher bankfull river widths than shown in this current study (Figure 6). Bray (1973) also reported results from previous studies that showed most power function exponents (i.e., relations between bankfull river width and bankfull discharge) were generally very close to 0.5 (0.5-0.53) with coefficients varying between 2.99 and 4.75. It should be noted that in general higher coefficients result from larger river widths.

Another important relationship is the relation between drainage area and the mean annual flow. This type of equation can be useful in the calculation of water availability (for usage purposes) of different basins including ungauged basins. These types of equations have also been very useful for instream flow studies (Caissie and El-Jabi 1995). The following equation relating the mean annual flow to drainage area of New Brunswick Rivers was calculated:

[5] $$Q_{MAF} = 0.0255\, A^{0.98}$$

where A represents the drainage area (km^2) and Q_{MAF} the mean annual flow (m^3/s). The coefficient of determination for this equation was calculated at 0.99 (Figure 7). This shows that the mean annual flow in New Brunswick rivers is highly related to drainage area as shown in previous studies (e.g., Caissie and El-Jabi 1995). The exponent was very close to unity, showing that the relationship is almost linear. Similar results were observed by Leopold (1994) for basins in central and northern California and where he showed exponents of most relationships being close to unity as well (0.98-0.99), even for very different hydrological regions. In fact, although the relationships were very similar (parallel lines), the discharge per unit area varied significantly from approximately 2.3 L/s/km^2 (Alameda region) to 34 L/s/km^2 (Lower Eel & S. Humboldt region) which could be attributed to varied precipitation amount (Leopold 1994). In New Brunswick rivers, the discharge per unit area, calculated from equation [5], is approximately 23

L/s/km^2 for a typical river of 300 km^2. These results are also similar to those observed in the Miramichi River basin.

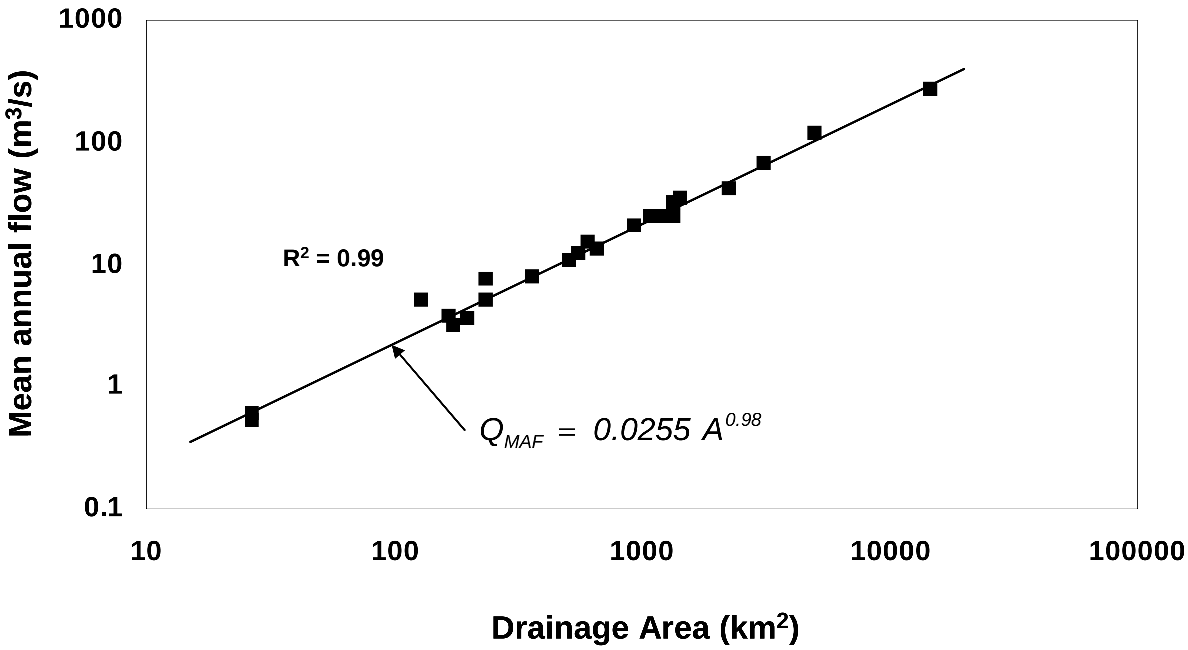

Figure 7. Relation between the mean annual flow and drainage area for New Brunswick rivers.

The bankfull discharge can also be expressed as a function of drainage area, similar to the mean annual flow. The following regression equation was calculated for New Brunswick rivers:

[6] $$Q_{bkf} = 0.343\ A^{0.93}$$

This equation showed a good relationship between bankfull discharge and drainage area (R^2 = 0.98; Figure 8). In the literature, bankfull discharge vs. drainage area relations tends to show different results of power functions depending on location (Leopold 1994). Leopold (1994) observed two groups of relations, one having lower bankfull discharge per drainage area with corresponding power function exponents close to 0.65-69. The other group of rivers showed higher bankfull discharge per drainage area and with corresponding exponents closer to 0.92 on average. The latter group was similar to the New Brunswick rivers (i.e., exponent of 0.93).

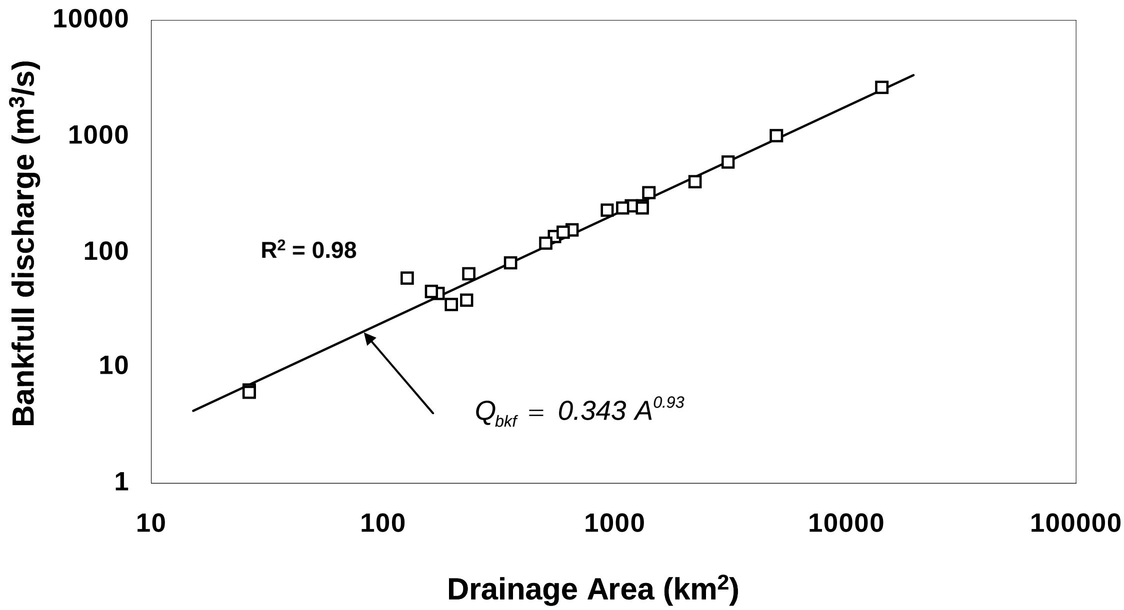

Figure 8. Relation between the bankfull discharge and drainage area for New Brunswick rivers.

Because bankfull discharge is related to contributing drainage basin area and the bankfull river width is related to bankfull discharge, then the drainage area can be used to estimate the bankfull river width. The following equation was calculated from this analysis:

[7] $$W_{bkf} = 2.4\ A^{0.46}$$

where, A represents the drainage area (km^2) and W_{bkf} the bankfull river width (m). The coefficient of determination for this equation was calculated at 0.88. The relationship between river width (at bankfull discharge) and drainage area is shown in Figure 9. This figure also shows results for Washington and Idaho rivers as reported in Newbury and Gaboury (1993). In addition, Newbury and Gaboury (1993) showed that Manitoba rivers had similar bankfull river widths to those of Idaho rivers, which was somewhat lower than results for New Brunswick and Washington rivers. Although differences can be observed between river widths, the slopes of the equations were similar with an exponent of 0.46 for New Brunswick rivers, 0.42 for Idaho rivers and 0.39 for Washington rivers (Figure 9).

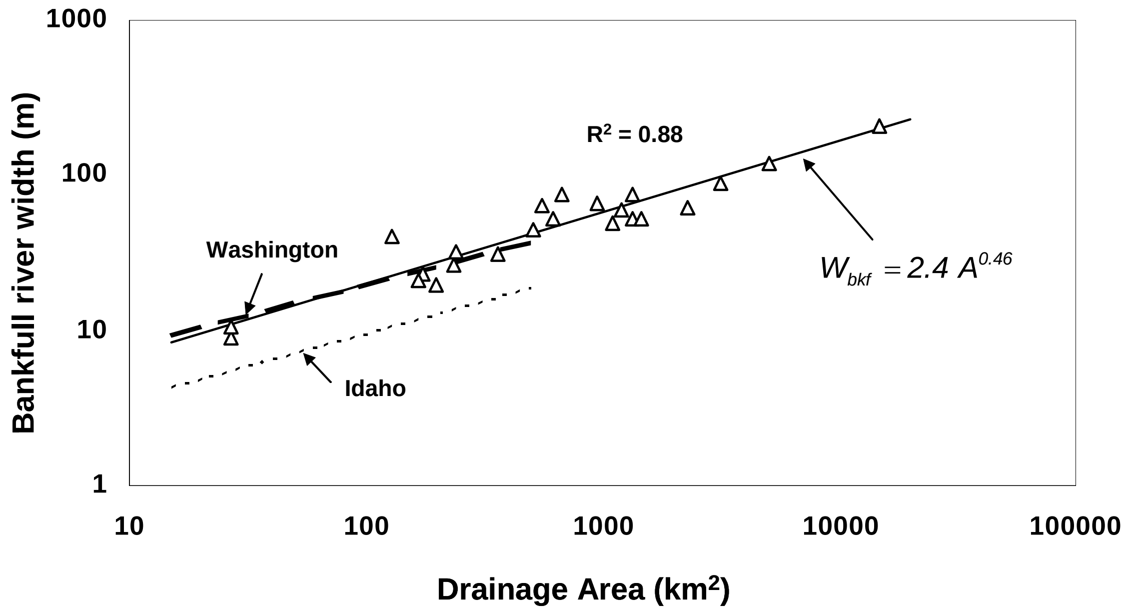

Figure 9. Relation between the bankfull river width and drainage area for New Brunswick rivers and other studies reported in the literature.

4.0 SUMMARY AND CONCLUSIONS

This study investigated the relationships between river discharge and basin area at two different scales. These discharges and flow indices are important for river restoration and river engineering projects. Specifically, these data are relevant to the study of channel forming processes and in the evaluation of water and habitat availability within a region. River hydrology and fluvial morphology play a key role in the productive capacity of fish habitat and therefore, must be considered in the overall management of stream ecosystems.

Water availability within the Miramichi River basin was very consistent among the different sub-basins. The mean annual flow for the four study basins was 23 L/s per km^2. The median river flow (Q_{50}) corresponded to approximately half (50%) of the mean annual flow in magnitude. Moreover, the mean annual flow was exceeded approximately 28% of the time on the flow duration curve whereas the bankfull discharge was exceeded 1% of the time (less than 4 days per year). The 1.5-year flood corresponded to approximately 85% of the 2-year flood, and the 2-year flood was used to represent the bankfull discharge in this study.

Province wide equations were developed between bankfull discharge and bankfull river width as well as between wetted river width (at the mean annual flow) and the mean annual flow. Results were comparable with those reported in the literature where river width varied with the square root of both the mean annual flow and the bankfull discharge. Following this analysis, equations were calculated between the mean annual flow and drainage area as well as between the bankfull discharge and drainage area. Results showed almost linear relationships with the exponent of the power function at 0.98 for the mean annual flow and at 0.93 for the bankfull discharge. Finally, bankfull river width was expressed as a function of drainage area where the power function exponent showed a value of 0.46, which was similar to values reported in the literature.

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