# WATER AVAILABILITY AND SECURITY IN NEW BRUNSWICK


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by

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| | |
|---|---|
| AMNO | North America Domain |
| CGCM | Coupled Global Climate Model |
| CORDEX | Coordinated Regional Climate Downscaling Experiment |
| CRCM | Canadian Regional Climate Model |
| DRI | Drought Risk Index |
| HYDAT | Hydrometric database |
| IPCC | Intergovernmental Panel on Climate Change |
| MAF | Mean annual flow |
| MMF | Mean monthly flow |
| NGO | Non-Governmental Organization |
| OECD | Organization for Economic Co-operation and Development |
| RCP | Representative concentration pathways |
| SRES | Special report on emission scenarios |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| WA | Water availability |
| WAL | Water availability lower target |
| WAU | Water availability upper target |

| | |
|---|---|
| a, b | Regression parameters |
| A, DA | Drainage area |
| $I_{DR}$ | Drought Risk Index |
| $Q_{MMF}$ | Mean Monthly Flow |
| $Q_{50}$ | Median flow |
| $Q_{90}$ | 90% flow |
| $R^2$ | Coefficient of determination |
| $R_{el}$ | Reliability Index |
| $R_{es}$ | Resiliency |
| T | Return period |
| $V_{ul}$ | Vulnerability Index |
| $w_1$, $w_2$, $w_3$ | weights |

## ABSTRACT

New Brunswick is experiencing economic growth, giving rise to increased water demand for industrial, municipal and irrigation uses, and for the production of energy. New Brunswick has among the highest per capita consumption of water in Canada with reported values 821 l/day per capita in 2009, compared to the Canadian average consumption of 510 l/day per capita. Sustainability, health and the quality of life require that water quality, quantity and important aquatic habitats be protected. New Brunswick is a province with a high and intra-annual water availability ranging from droughts in winter and late summer to floods in the spring. Rainfall, snowmelt, and groundwater all contribute to the volume of flow, producing variations from season to season and year to year.

Many facets of our daily lives depend on water. As such, water security is becoming increasing important not only for water availability but also for the protection of water quality, quantity and the sustainability of water supplies within the Province. This requires a comprehensive technical evaluation that includes determining the status of current water availability and withdrawals, as well as assessing the anticipated future water demands, water quality, cumulative impacts, and ecosystem health.

The present study will focus on water availability and security by addressing a variety of issues such as: (1) Defining the concept of water security; (2) Quantifying water availability in the Province and (3) Presenting methods for water system managers to assess current status and potential risks to water availability and security.

## RÉSUMÉ

Nouveau-Brunswick connaît une croissance économique, donnant lieu à une demande accrue d'eau pour ses usages industriels, municipaux et d'irrigation, et ainsi que pour la production d'énergie. En 2009, la consommation d'eau était de 821 l/jour par habitant, par rapport à la consommation moyenne canadienne de 510 l / jour par habitant. Le développement durable, la santé et la qualité de vie exigent la protection de la qualité et la quantité de son eau ainsi que ses habitats aquatiques importants. Nouveau-Brunswick est une province avec une disponibilité d'eau allant de la sécheresse en hiver et fin de l'été à des inondations au printemps.

De nombreux aspects de nos vies quotidiennes dépendent de l'eau. En tant que tel, la sécurité de l'eau devient de plus en plus important non seulement pour sa disponibilité, mais aussi pour sa protection et son approvisionnement. Cela nécessite une évaluation complète qui comprend la disponibilité, les retraits courantes, les demandes futures et les effets cumulatifs sur la santé de l'écosystème.

La présente étude se concentrera sur la disponibilité et la sécurité de l'eau en abordant une variété de questions telles que : (1) Définir la notion de sécurité de l'eau ; (2) Quantifier la disponibilité de l'eau dans la province et (3) Présenter des méthodes aux gestionnaires pour l'évaluation de l'état actuel et les risques potentiels pour la sécurité et la disponibilité de l'eau.

## 1. INTRODUCTION

Water security is a fairly new concept and the definition of the term is evolving depending on the region and specific study. Water security has been promoted by international organizations such as the Global Water Partnership, the World Economic Forum and the United Nations through UNESCO's Institute for Water Education. These organizations share the growing recognition that water security is critical to address threats from pollution, improve human well-being and the productive capacity of water resources, as well as ensuring environmental sustainability.

Water security is also about meeting short-term and long-term needs for access to sufficient water quantity and quality, at a fair price, for human health, safety, welfare and productive capacity at the local, provincial and national levels. The preferred definition of water security used by those working with the Canadian Water Network, is "sustainable access, on a watershed basis, to adequate quantities of water, of acceptable quality, to ensure human and ecosystem health" (Norman et al., 2010). Definitions of water security depend on the perspective from which one views them, and the scale of the issues.

Existing indicators for water security are usually univariate (e.g. relating to either water quality or quantity), rarely integrating aquatic ecosystems and human health considerations, or land-use and water management. Overall, the issue of scale is an ongoing problem in most assessments and governance; indicators are often site-specific, or framed at a specific scale that is not transferable to other scales. While wider scale assessment models have made progress in addressing complex water security issues these indicators are rarely appropriate at a scale that is meaningful, such as at a community level.

The present study will focus on water availability and security in New Brunswick by addressing a variety of issues such as sustainable water supply, water resources protection, and flood and drought management. To address these water security issues, important data need to be collected on river flows, as well as on the demand for water (both consumptive and non-consumptive use). With future projected increases in resources demands, particularly in the natural resources sector, the sustainability of water resources needs to be assessed. Accordingly, the availability of water resources needs to be quantified both spatially and temporally within the province for future needs and climate change needs to be incorporated in such analyses. Therefore, this study is of significant interest and has the following objectives: (1) defining the concept of water security; (2) quantifying water availability and uses in the province of New Brunswick and (3) presenting methods for water managers to assess current status and potential risks to water security.

Climate change studies have been carried out in New Brunswick and these studies will be used to infer potential water resources impacts in the future and potential implications on water availability and security.

## 2. BACKGROUND

Water is essential in almost all human activities, and is essential for life itself. However, it has been reported that 80% of the world's population is exposed to high levels of water security risk, with consumptive water use being one of the strongest stressors (Vörösmarty et al., 2010). In an age defined by extreme weather events and climate change, ensuring the long-term health of water and aquatic ecosystems is becoming ever more important. Managing a resource with such importance requires a long-term vision and a well-planned series of actions. In Canada, water management is a provincial responsibility; however, the federal government shares some of the responsibilities of quantifying water in terms of quantity and quality.

New Brunswick is experiencing economic growth, giving rise to increased water demand for industrial, municipal and irrigation uses, as well as for the production of energy. Among the different provinces in Canada, New Brunswick had one of the highest per capita consumption of water. In 2009 the consumption was estimated at 810 l/capita/day, while the Canadian average consumption was 510 l/capita/day Sustainability, health and the quality of life require that water quality and quantity, as well as important aquatic habitats, be protected.

New Brunswick is a province with a high variability in inter-annual and intra-annual water availability ranging from droughts to floods. Rainfall, snowmelt, and groundwater all contribute to the volume of flow, producing variations from season to season and year to year. Most high flows and floods are caused by spring snowmelt. Heavy rainfall can also cause high flows and floods, especially in small streams. Lowest flows in rivers generally occur in late summer, when precipitation is low and evaporation is high, and in winter, when precipitation is stored until spring in the form of ice and snow (Environment Canada, 2013). Drought duration, magnitude, severity and recurrence remain difficult to forecast with the same precision as flood events (Loáiciga, 1996). In the future, climate change could result in higher variability that could result in more extreme conditions (both high and low flows). According to Swansberg et al. (2004), annual minimum air temperature may increase by approximately 4 to 5°C (by 2099), while maximum air temperature may increase by approximately 4°C. Slightly larger increases in air temperature are anticipated in central parts of New Brunswick compared to northern or southern regions. These changes in air temperature will most likely modify the proportion of the precipitation that falls as rain or snow and influence summer evapotranspiration rates, which can potentially impact water availability (Johnston, 2009).

The combination of environmental pressure and increasing demand for water poses a significant challenge to water managers in the province of New Brunswick. By taking a broad and long-term vision that emphasizes the current status of water as well as the risk of water security impacts in the future, the government is more likely to meet its water-related economic, environmental and social objectives. In this context, water security acquires increased importance for the New Brunswick Department of Environment and Local Government. This requires a comprehensive technical evaluation that includes determining the status of current water availability and withdrawals, as well as assessing the anticipated future water demands, water quality, cumulative impacts, and ecosystem health. Therefore, within the context of New Brunswick, this document is of significant interest and has as purposes (1) defining the concept of water security and (2) presenting methods to assess current status and potential risks to water security.

***Defining water security***

As water security is a fairly new concept, definitions of the term appear to be evolving. Water security has been promoted by international organizations such as: the Global Water Partnership, the World Economic Forum, and the United Nations through UNESCO's Institute for Water Education (Cook and Bakker, 2012). These organizations share the growing recognition that water security is critical to address threats from pollution, improve human well-being and productive capacity, support poverty alleviation, and ensure environmental sustainability (Global Water Partnership, 2000). Most recently, Cook and Bakker (2012) identified several framings of water security term. Based on this work, one can identify four general areas:

(1) Human development;
(2) Ecological sustainability;
(3) Geopolitics and international relations; and
(4) Vulnerability and risk.

Each conceptual area informs on both how water security is used and the methods by which it is assessed. Swaminathan (2001) stated that water security "involves the availability of water in adequate quantity and quality in perpetuity to meet domestic, agricultural, industrial and ecosystem needs." Determinants of water security include adequate precipitation and pollution abatement (Kaplowitz and Witter, 2002), water availability for ecosystems, as well as "an acceptable level of water-related risks to people, environments and economies" (Grey and Sadoff, 2007). Water security is also about meeting short-term and long-term needs for access to sufficient water quality, at a fair price, for human health, safety, welfare and productive capacity of position (local, provincial and national levels) (Witter and Whiteford, 1999). Water security has been found to be closely related to political, social, and economic power of people in society (Kaplowitz and Witter 2002). One definition often cited in the literature is from Witter and Whiteford (1999), who define water security as "a condition where there is sufficient quantity of water at a quality necessary, at an affordable price, to meet both the short-term and long-term needs to protect the health, safety, welfare, and productive capacity of population". This definition includes an economic component to the water security. Common to these approaches to water security is the emphasis on access to water to meet human needs. However, such a framing is narrow in scope and fails to recognize the critical linkages to aquatic ecosystems. The preferred definition of water security used by those working with the Canadian Water Network, is ″sustainable access, on a watershed basis, to adequate quantities of water, of acceptable quality, to ensure human and ecosystem health" (Norman et al., 2010). Arguably, this definition comes from a predominantly ″social science″ perspective. Despite increased concern about water-related issues, a universally accepted definition does not exist (Grey and Sadoff 2007). Definitions of water security depend on the perspective from which one views them, and the scale of the issues. Some consider competing livelihoods (e.g., Grey and Sadoff, 2007), other mention water privatization (Bakker, 2003), some consider large scale agriculture and water for energy (e.g., Turral et al., 2011), whilst others focus on water for environment (Vörösmarty et al., 2010), and finally on basic needs (Sullivan, 2002). As a concept, there are also broader criticisms of water security. Lautze and Manthrithilake (2012) developed an index for water security after claiming that ˝understandings of the term are murky and quantification is rare˝.

***Assessing water security***

While there may be advantages to define qualitatively the concept of water security, there are also several benefits to translate water security into numerical terms. Indeed, this can help promote a more tangible understanding of the concept for practical purposes.

Many tools for monitoring and reporting the state of water security, such as indices, indicators, report cards, hazard (or risk/vulnerability) frameworks, and checklists have been developed in Canada, at the federal, provincial, and local levels (Dunn and Bakker 2009). However, for water security assessment, indicators are one of the most commonly used methods, as they enable users "to take complex scientific and social data to provide a simplified, quantified and communicated expression that anyone can understand" (US EPA, 2008). Table 1 shows some indicators that are related to water and human development (Jepson, 2014).

Previous studies have used single-variable measures, such as census data on household (Wescoat et al., 2008) or basic water requirement (Gleick, 1996).

Experience-based biocultural measurements of emotional distress related to water security employ a scaling method and address the question of individual water security (e.g., Wutich and Ragsdale, 2008). Water Poverty Index (WPI) is an integrated indicator for water management that tries to capture ‘‘a more comprehensive picture of the water-management challenge’’ (Sullivan et al., 2006) by combining weighted averages of five variables (resources, access, capacity, use, and ecological integrity).

**Table 1. Water security indicators (Adapted from Jepson, 2014)**

| Conceptual domain | Water security indicator | Scale | References |
|---|---|---|---|
| Human development | Basic Water Requirement | Individual | Gleick (1996) |
| Sustainability | Water Poverty Index | Political or ecological territory | Sullivan et al. (2003) |
| Vulnerability and risk adaptation | Water Availability | Provincial | Scott et al. (2012) |

The WPI is designed to assess structural water problems faced by different countries or regions and has been useful in cross-regional and cross-national assessments.

Each indicator is limited in its capacity to address ‘‘water security’’. Existing indicators are usually univariate (e.g. relating to either water quality or quantity), rarely integrating aquatic ecosystems and human health considerations, and/or land-use and water management (Wheater and Evans, 2009). Notably, narrowly-focused indices may be operationally useful for water managers (e.g., Falkenmark and Rockström, 2004). Overall they impede integration, which is arguably a core issue for communities grappling with competing uses, where balancing specific trade-offs is a key management challenge (Sullivan and Meigh, 2007). Furthermore, the issue of scale is an ongoing problem in assessment and governance. Indicators are often site-specific, or framed at a specific scale that is not transferable to other scales (van der Zaag and Gupta 2008) as small-scale interventions are likely to have reduced environmental impacts (van der Zaag and Gupta 2008). Whilst wider scale assessment models have made progress in addressing complex water security issues (Vörösmarty et al. 2010), these indicators are rarely commensurate at a scale that is meaningful at a community level.

Although the concept of “water security” has emerged within the policy and development literature as a way to address water-related issues, most of these discussions are framed globally, with little attention to the local context. One such exception is the Water Security Status Indicators (WSSI) assessment framework developed by Norman et al. (2013) which suggests that water security needs to be understood at a regional scale and in collaboration with local stakeholders.

***Assessing risk to water security***

To develop a more comprehensive assessment of water security, the risk to water quality and/or quantity should also be assessed. Applying an analysis of the current status of water security in combination with a risk assessment (e.g. Simpson, 2012) could provide communities with a set of powerful tools to help guide community planners and decision-makers. An important element of water security is the likelihood that the water source may become deteriorated in some way and have some impact on human or ecosystem health (Dunn et al., 2012).

Risk is most often defined as the probability and the amount of harm resulting from a hazard (United Nations International Strategy for Disaster Reduction; UNISDR, 2004). According to the Organization for Economic Co-operation and Development (OECD, 2014), the risk is at the intersection of hazard, exposure and vulnerability. Therefore, the reduction of any one of the three factors consequently would reduce the risk. Water security is primarily about risk management. The OECD (2014) identifies four water related risks:

i) Risk of shortage: lack of sufficient water to meet demand (in both short-and long-run) for beneficial uses by all water users;
ii) Risk of excess: overflow of the normal confines of a water system or the destructive accumulation of water over areas that are not normally submerged;
iii) Risk of inadequate quality: lack of water suitable quality for a particular purpose or use;
iv) Risk of undermining the resilience of freshwater systems: exceeding the coping capacity of the surface and groundwater bodies, possibly crossing tipping points, and causing irreversible damage or system collapse.

These risks have to be addressed in a coordinated manner, as they are interrelated. Interventions to reduce one risk can increase others. For instance, increasing diversions to reduce the risk of water shortage can increase the risk of undermining the resilience of freshwater systems (OECD, 2014).

Several methodologies have been developed in order to assess water-related risks. Dong and Liu (2014) presented approaches for risk assessment of water security in Haihe River Basin (China) during drought periods. Risk assessment of water security during drought periods tends to use the three indices of reliability, resiliency, and vulnerability, as well as a drought risk index (DRI). For its compact formulation, the authors used the DRI which is a linear weight function based on the three above indices (Mondal and Wasimi, 2007). The DRI is a probability index that reflects the degree of loss due to failure events of water supply systems; the larger the DRI value, the more severe the water shortage will be. Generally, the reliability index (Rel) can be described as the overall system performance over time in evaluating the degree of water demand being satisfied by the water supply system (Hashimoto et al. 1982a, 1982b). The resiliency (Res) is a statistical characteristic calculated from all failures that can occur. The vulnerability index (Vul) is introduced as a measure of risk effect and severity degree in regard to social and economic systems. Therefore, the value of the DRI can be obtained as follows:

$$I_{DR} = w_1(1 - R_{el}) + w_2(1 - R_{es}) + w_3 V_{ul} \tag{1}$$

where $w_1$, $w_2$, $w_3$ are weights which the sum equal to 1. $(1 - R_{el})$ is the failure risk of a water supply system; $(1 - R_{es})$ is the non-recovery risk of the water supply system; and $V_{ul}$ describes the degree of water shortage of the water supply system (Jinno et al., 1995).

Smakhtin et al. (2004) attempted to estimate the volumes of water required to maintain freshwater ecosystems and the services they provide across the world's river basins, making an important distinction between low-flow requirement (the minimum for fish and other species through the year) and high-flow requirement (important as a stimulus for migration and spawning, for wetland flooding and recruitment of riparian vegetation). The essential aim of the study was to adjust a standard ratio of withdrawals to availability (in their case, mean annual runoff) with an estimate of the 'Environmental Water Requirement'. This study computed the Environmental Water Requirement for river basins rather than individual countries, since ecosystems are not organized along administrative boundaries.

In the case of New Brunswick, water security consists of evaluating the water availability to assure future water demand and consumption, associated with their occurrences. The water availability in the present study was estimated by initially quantifying river flows, then subtracting environmental flows necessary to protect rivers and their ecosystems, which provides an estimate of the water availability for external (off-stream) use.

## 3. MATERIALS AND METHODS

This section is divided into two primary sections. The first section is an overview of the general context of New Brunswick in terms of precipitation, runoff and general water use. The second section outlines the proposed methods and approaches that could be used to assess the current water availability and security status as well as the risks to water in New Brunswick's watersheds.

***Context of New Brunswick***

Context of New Brunswick: New Brunswick watershed includes lands in Quebec and the United States draining into New Brunswick rivers. New Brunswick rivers drain into the Gulf of St. Lawrence to the east or to the Bay of Fundy in the south. For example, in 2013, precipitation was very close to normal throughout the province (90-110%); however, runoff showed slightly high values (ranging from 100-140%; Figure 1).

In fact, during that year the western portion of the province experienced above normal runoff (140%) whereas the precipitation was close to normal. Groundwater levels across most of the province and along the border in Maine were in the normal range for most of the year (Government of New Brunswick, 2013).

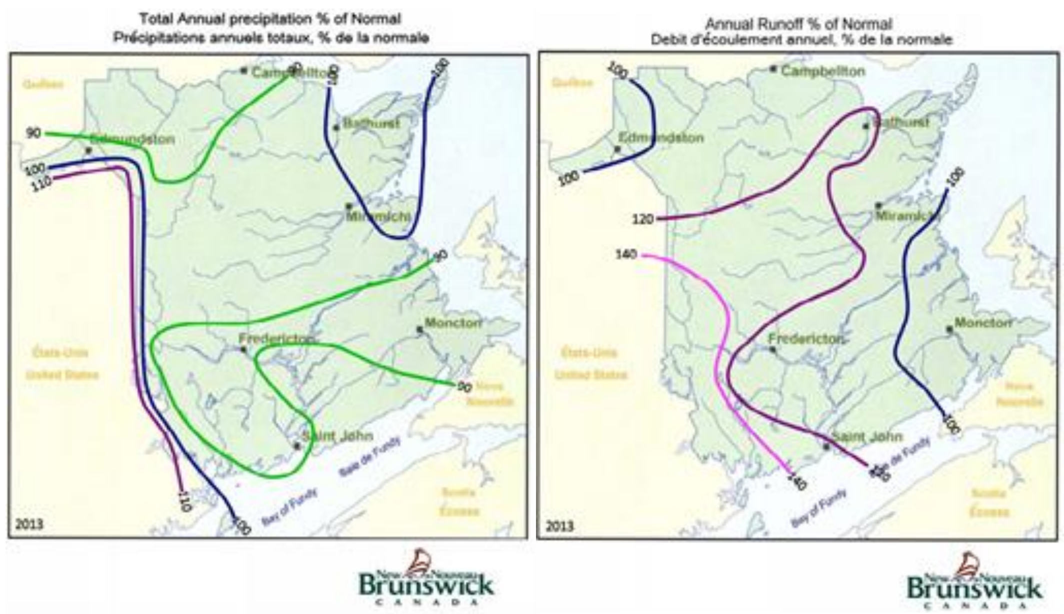



**Figure 1. Percentage of normal of the annual runoff and total annual precipitation for the year 2013 in the province of New Brunswick**

In New Brunswick, about 59% of the population obtain their water supply from surface water. The remaining population rely on private groundwater wells or on municipal wellfields (Table 2, Statistics Canada, 2013).

**Table 2. Potable water use in the province of New Brunswick**

| | Surface water | Groundwater | Groundwater under the direct influence of surface water | Total |
|---|---|---|---|---|
| Potable water volumes processed by drinking water plants (millions of $m^3$) | 60.6 | 26.0 | 3.0 | **89.6** |
| Total capital expenditures of drinking water plants (millions of $) | 5.5 | 11.7 | 0.2 | **17.4** |
| Population served by drinking water plants (persons) | 224 393 | 140 923 | 15 604 | **380 920** |

New Brunswick's fresh water is used by the residential, commercial and industrial sectors. The residential sector accounts for 31% of water use, while the industrial sector only accounts for 11%. The province of New Brunswick is heavily dependent on forestry, mining, and fishing. The province contains the largest petroleum refinery in Canada and has a developing natural gas industry including the first liquid natural gas degasification plant in Canada.

New Brunswick has very clean surface water, based on levels of ammonia, arsenic, chloride, copper, iron, nitrogen, oxygen, pH, phosphorus, turbidity, and zinc (Wood, 2013). However, some of the provincial water management issues includes salt water intrusion into coastal water wells, a proliferation of small dams, and pulp mill effluent discharges.

Changing climatic conditions and human water demands are putting substantial pressure on Canada’s freshwater resources and hydrological systems (Schindler and Donahue 2006). Turkkan et al. (2011) completed a study on the impact of climate change on the discharge regimes in New Brunswick rivers. The hydrological responses of seven catchments to two emission scenarios were simulated using an artificial neural network (ANN). Future high flows were estimated by the introduction of a Regional Climate Index (RCI), and it was found that the frequency of events would most likely increase by 11–21% toward the end of the century, depending on the emission scenario. Swansberg et al. (2004) also provided an indication of the direction of changes in climate and river discharge in New Brunswick. They used statistical downscaling to project changes in temperature, precipitation, and river flow at several locations in the province, assuming a worst-case scenario (a tripling in carbon dioxide ($CO_2$)). By downscaling river flow, they found that the average annual discharge would likely increase significantly. They noted that changes in peak flows would be more severe than changes to the mean annual flow. Disaster mitigation and climate change adaptation are inherently linked. Water infrastructure in Canada is aging and often outdated, making it vulnerable to hazards, especially given the expected increase in extreme weather events (Simonovic, 2008).

## 4. METHODOLOGY

To develop a more comprehensive assessment of water availability and security in New Brunswick, the risk to water quantity should also be assessed. Applying an analysis of the current status of water security through ***evaluation of water availability*** in combination with a risk assessment, could provide the Province with a set of powerful tools to help guide water planners and decision-makers.

Although the concept of "water availability and security" has emerged in policy and development literature as a way to address water-related issues, most of these discussions are framed globally, with little attention to local context. To develop a comprehensive assessment of water availability and security for New Brunswick, five steps will be performed:

1. Adoption of rational approaches to optimize water data monitoring networks is necessary to ensure the future availability of reliable databases and continuity of effective control and water security development programs. Various theoretical aspects regarding the estimation of river flow, and the extension of short data series will be analyzed and generalized for application to the efficiency of hydrometric networks. The approach will be based on minimizing the loss of information during the process of rationalization (Mishra and Coulibaly, 2009);

2. Characterisation of flows in New Brunswick with the objectives to focus on flow metrics that best describe the natural flow regime and the hydrological characteristics of rivers within the Province (El-Jabi et al, 2015). This consists of analyzing parameters describing flow availability which includes, among others: the mean annual flow, median flow, and 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 events 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.

3. Determination of thresholds under which water extraction should not be permitted. These thresholds will be analyzed to determine potential extractable water (water generally available for off-stream use) within each region of the Province and for different times of year. This part of the study should identify which parts of the province have more (or less) extractable water during

different times of year, and which parts of the province are more vulnerable to future potential development (e.g. potential impacts) (El-Jabi et al, 2015).

4. Description of the spatial and temporal water availability within the province by developing water availability status: differences in hydrological regimes may provide some information on which part of the province could better support some industries (e.g., irrigation, water supplies, etc.) and which part of the province is more deficient in water resources depending on the time of year;

5. Impact of climate change on water availability and security: climate change studies have been carried out in New Brunswick (Turkkan et al. 2011; Swansberg et al. 2004). These climate change studies will be used to infer potential impacts on resources in the future and potential implications on water availability and security.

### 4.1 Optimization of water data monitoring networks

Hydrometric network availability remains of great importance for quantity monitoring and for water resource management (as well as flood and drought prevention). The spatial and temporal density of data collected and analyzed, especially the length of the registration periods, can improve the precision associated with estimates of design flows. Several examples presented in the literature have shown that depending on the objectives, an excess of stations in a network (redundancy), or a deficiency of stations in a network may affect the accuracy throughout hydrological phenomena simulations. Hence a rationalization of the New Brunswick hydrometric network was proposed, with the purpose of providing a comprehensive methodology for the existing network evaluation, using methods of information quantity and similarity measures between different sets of multivariate data. The Hierarchical Classification, Principal Component Analysis, and Entropy methods were retained for this purpose, and allowed the initial division of the study area into two homogeneous hydroclimatic regions. After this step, groups of homogeneous stations were formed, based on the similarity of information available at each station, after which a ranked prioritization of stations was made based on the amount of information provided by each station, indicating their relative “worth”.

This study permitted the assessment of the robustness of multivariate analysis methods used in the analysis of an existing hydrometric network in order to optimize it. Finally, results of this research can be seen as a decision support tool for users and managers of hydrometric data collection station networks in a context of unprecedented budget cuts, and also when looking to optimize data regarding criteria like record length, quality, and representative spatial location.

### 4.2 Characterisation of flows

The hydrological analysis was carried out using historical data from 54 hydrometric stations, of which 51 are located in New Brunswick (Figure 2; Table 3). 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.

The water availability was characterized using the specific mean annual flow (MAF), the specific seasonal flow, the specific mean monthly flow (MMF) and a flow duration analysis.  The specific mean annual flow provides valuable data on the water availability (total discharge of water per square kilometer) for the given watershed whereas the specific mean seasonal or monthly flow provides information on the distribution of the total water on a seasonal basis (winter, spring, summer and autumn) and on monthly basis.

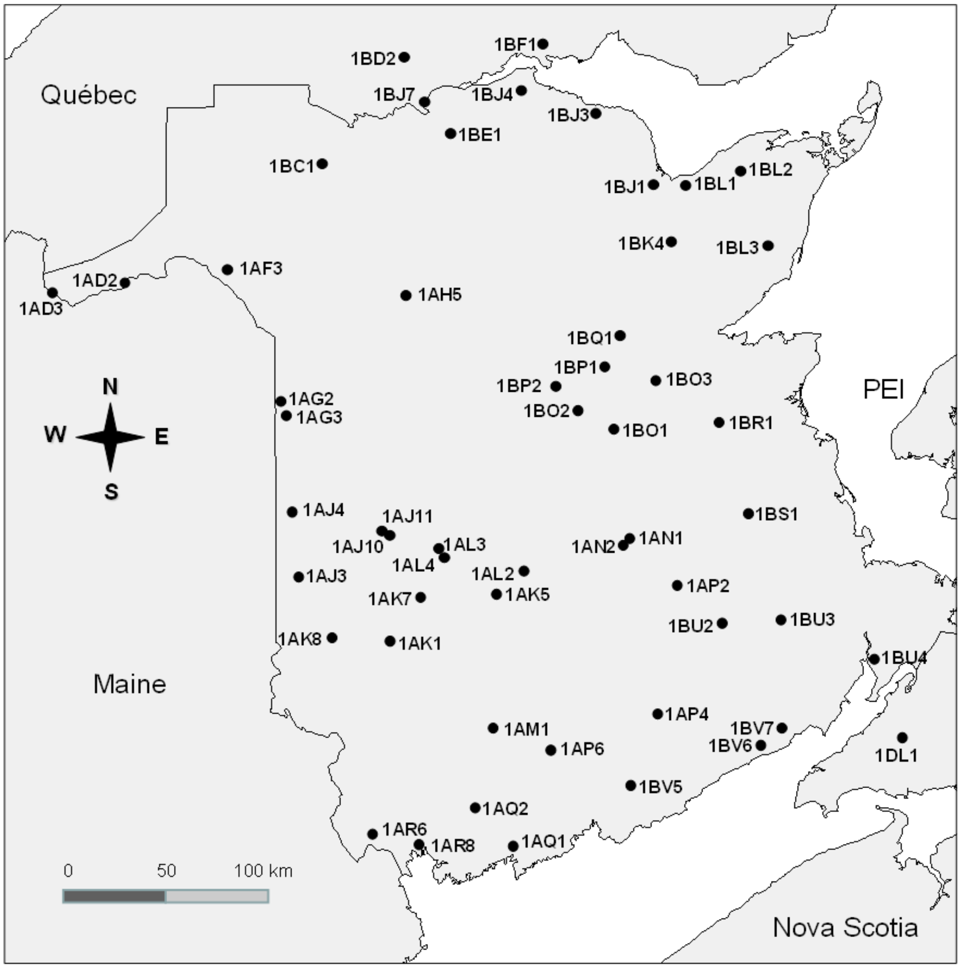



**Figure 2. Location of selected hydrometric stations in New Brunswick (54 stations).**

**Table 3. Analyzed hydrometric stations in New Brunswick**

| Station ID | Station Name | DA ($km^2$) | Period of Record | N | MAF ($m^3/s$) |
|---|---|---|---|---|---|
| 01AD002 | Saint Johhn 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 | Mamozekel 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 Rriver 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 | Restgouche 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

A flow duration analysis was also conducted for each hydrometric station. This analysis provided 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. 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 (R Development Core Team, 2008), which makes the necessary calculation using Environment Canada (HYDAT) flow data. (El-Jabi et al, 2014).

To generalize the water availability metrics for New Brunswick, a regionalization approach was performed, taking into consideration the drainage basin area and the % time of exceedance. 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 and physiographic parameters describing the basin. With the water availability as the dependent variable and the physiographic factors as the independent variables (in this case, drainage area in $km^2$), a regression was performed in order to evaluate the parameters of the following equations:

Regional Mean Monthly Flow:

$$Q_{MMF} = aA^b \tag{2}$$

Regional flow $Q_{50}$:

$$Q_{50} = aA^b \tag{3}$$

Regional flow $Q_{90}$:

$$Q_{90} = aA^b \tag{4}$$

Regional flow duration:

$$Q = \frac{A}{aP + bA} \tag{5}$$

where $Q$ is the flow in $m^3/s$, $A$ is the drainage area in $km^2$ and $P$ is % time exceedance (25% < $P$ < 95%). Parameters $a$ and $b$ were calculated using nonlinear regression. Table 4 to 7 represent these parameters and the correlation coefficients for each month. Table 4 provide the coefficients for the mean monthly flow where the $R^2$ varies between 0.87 (March) to 0.99 (April). Table 5 presents the coefficients for the median flow ($Q_{50}$) where $R^2$ are similar to monthly flows (Table 4). Results of the regional regression analysis were also good for $Q_{90,}$ where $R^2$ varied between 0.87 and 0.95 (Table 6). Table 7 provides the regional regression equations for the flow duration curve for each month, where both the drainage area and the percentile are used as input variables.

This regional analysis will permit the development of spatial and time analyses of flows. For example, Figure 3 shows the specific annual flow for New Brunswick and its spatial distribution. This figure clearly shows a higher mean annual flow in the southern part of the province (e.g., 39 L/s/km$^2$) along the Bay of Fundy, whereas more homogenous flows are observed elsewhere (some stations, e.g., 01AH005 showing close to 18 L/s/km$^2$; Figure 3). Annex B describes the same metric by seasons and on monthly basis. These figures shows the water availability in time and space for New Brunswick, considering mean values instead of extremes. For these, El-Jabi et al (2015), introduce the extreme water availability by studying floods and droughts for the Province and their occurrences in time.

**Table 4. Parameters of regional Mean Monthly flow, $Q_{MMF}$**

| Month | a | b | R2 |
|---|---|---|---|
| Jan | 0.0216 | 0.8968 | 0.93 |
| Feb | 0.0218 | 0.9226 | 0.92 |
| Mar | 0.0463 | 0.8746 | 0.87 |
| Apr | 0.0925 | 0.985 | 0.99 |
| May | 0.0382 | 1.0486 | 0.96 |
| Jun | 0.0163 | 1.0245 | 0.98 |
| Jul | 0.01 | 1.0119 | 0.98 |
| Aug | 0.0092 | 0.998 | 0.98 |
| Sep | 0.0091 | 0.9866 | 0.97 |
| Oct | 0.0252 | 0.934 | 0.98 |
| Nov | 0.0374 | 0.9204 | 0.97 |
| Dec | 0.0429 | 0.8809 | 0.95 |

**Table 5. Parameters of regional median flow, $Q_{50}$**

| Month | a | b | R2 |
|---|---|---|---|
| Jan | 0.0111 | 0.946 | 0.94 |
| Feb | 0.0092 | 0.9386 | 0.94 |
| Mar | 0.0217 | 0.8651 | 0.88 |
| Apr | 0.0756 | 0.922 | 0.96 |
| May | 0.0233 | 1.0842 | 0.95 |
| Jun | 0.0088 | 1.0638 | 0.97 |
| Jul | 0.0042 | 1.0791 | 0.95 |
| Aug | 0.0033 | 1.0631 | 0.94 |
| Sep | 0.0036 | 1.043 | 0.93 |
| Oct | 0.0116 | 0.9678 | 0.96 |
| Nov | 0.0237 | 0.9453 | 0.98 |
| Dec | 0.0228 | 0.9118 | 0.96 |

**Table 6. Parameters of regional 90% flow, $Q_{90}$**

| Month | a | b | R2 |
|---|---|---|---|
| Jan | 0.0043 | 0.9784 | 0.95 |
| Feb | 0.003 | 0.9936 | 0.94 |
| Mar | 0.0041 | 0.9615 | 0.94 |
| Apr | 0.038 | 0.832 | 0.87 |
| May | 0.0086 | 1.0957 | 0.94 |
| Jun | 0.0028 | 1.114 | 0.93 |
| Jul | 0.0012 | 1.1468 | 0.91 |
| Aug | 0.0007 | 1.1544 | 0.88 |
| Sep | 0.0009 | 1.1112 | 0.87 |
| Oct | 0.002 | 1.0393 | 0.92 |
| Nov | 0.0065 | 0.9664 | 0.95 |
| Dec | 0.007 | 0.9486 | 0.95 |

**Table 7. Parameters of regional flow duration**

| Month | a | b | R2 |
|---|---|---|---|
| Jan | 2.473 | 0.00423 | 0.96 |
| Feb | 3.032 | 0.006765 | 0.95 |
| Mar | 2.342 | 0.00672 | 0.83 |
| Apr | 0.5787 | -0.0001078 | 0.91 |
| May | 0.4 | 9.54E-05 | 0.94 |
| Jun | 1.222 | 0.000522 | 0.95 |
| Jul | 2.1379 | 0.0004999 | 0.97 |
| Aug | 3.1224 | 0.000505 | 0.96 |
| Sep | 3.499 | -2.16E-05 | 0.97 |
| Oct | 2.1399 | -5.47E-05 | 0.97 |
| Nov | 1.354 | 0.000602 | 0.97 |
| Dec | 1.7261 | 0.002039 | 0.97 |

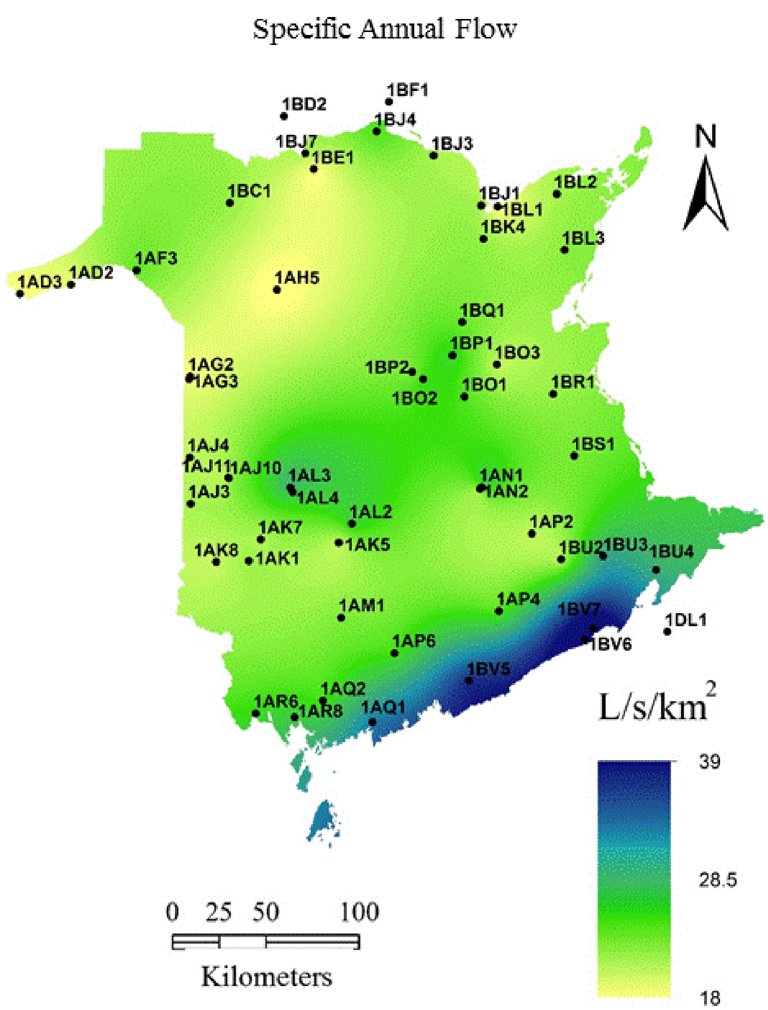



**Figure 3. Specific annual flow in New Brunswick**

Figure 4 shows the water availability for the month of April as a function of the exceedance probability (flow duration). For example, a drainage basin of 5 $km^2$ has a flow of 1 $m^3/s$ 0% of the time whereas the same size basin has a flow of 0.1 $m^3/s$ approximately 78% of the time (Figure 4). Similarly, if a flow of 1 $m^3/s$ is required in April for 100% of the time, then the drainage basin needs to be larger than 250 $km^2$.

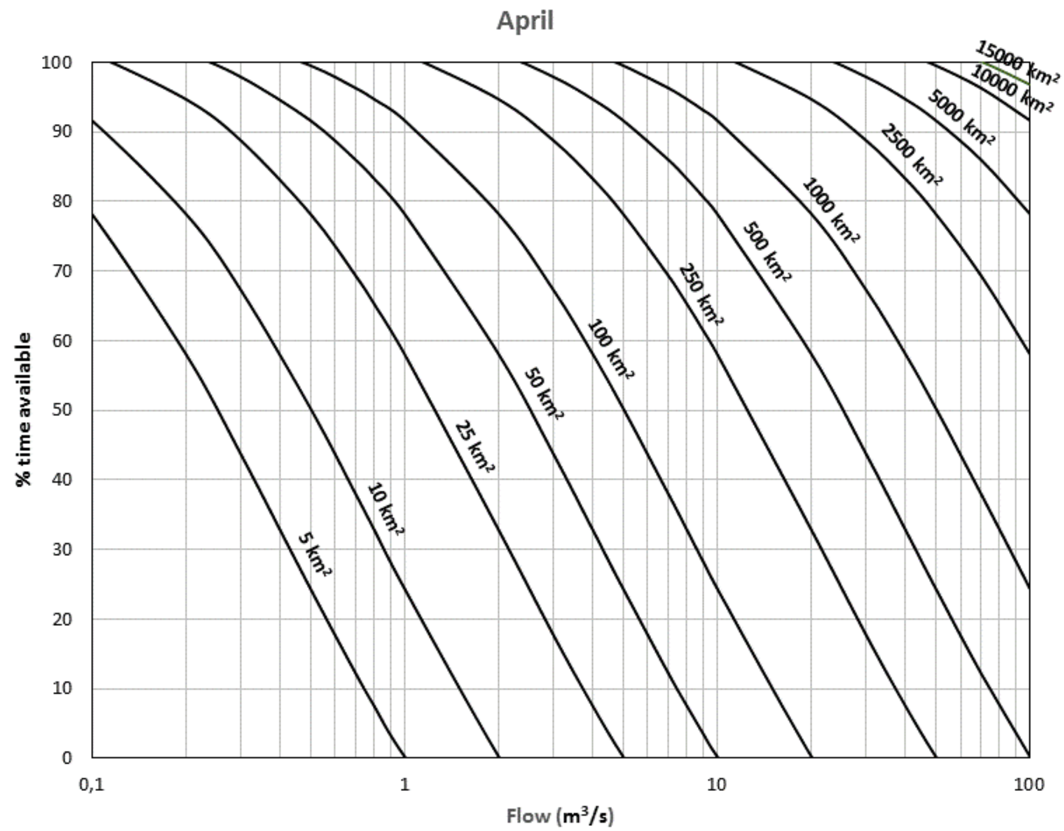



**Figure 4. Water availability in New Brunswick for the month of April**

### 4.3 Determination of thresholds

Following the description of the natural flow regime, the study will quantify environmental flows for each river system using commonly used approaches. This environmental flow will be considered as the in stream flow or the threshold to maintain in each river and will not be available for withdrawal or consumption. For this part of the study, four commonly used environmental flow methods were considered:

1) Fixed 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. In Atlantic Canada, the presence of large rivers and relatively low 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 many demands, even at the sub-drainage area level. Nevertheless, the timing of low flows is particularly problematic where water becomes a 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.

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, two different targets were used as a range of potential environmental flows. For instance, the lower target provides more extractable water, thus less protective for fish habitat whereas the upper target is more conservative from a fish habitat perspective. The selection of targets or specific environmental flows should be carried out by fisheries managers based on the importance of the fisheries resources requiring protection. However, for the purpose of the present study, these two potential targets were selected to provide an estimate of potential water availability for off-stream use. For instance, 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 (Table 8).

**Table 8. Potential environmental flow targets by season**

| Month | Season | Lower target | Upper target |
|---|---|---|---|
| Jan<br>Feb<br>Mar | Winter | 70% $Q_{50}$ | $Q_{50}$ |
| Apr<br>May<br>Jun | Spring | 25% MAF | $Q_{90}$ |
| Jul<br>Aug<br>Sep | Summer | 70% $Q_{50}$ | 25% MAF |
| Oct<br>Nov<br>Dec | Autumn | 25% MAF | $Q_{50}$ |

Also, Figure 5 shows important flow metrics in relation to high and low flow frequencies from a regional perspective (i.e., using regional equations), for small and large rivers, associated with upper and lower target for environmental flows.

The flow metrics provided in Figure 5 are the MAF, 25% MAF, $Q_{90}$ (May) and 70% $Q_{50}$ (September). This figure also shows that the MAF, $Q_{90}$ flow for May, and 25%MAF are within the range of high and low flows; however, the 70% $Q_{50}$ (September) can be within the range of the 2-year flow low, especially for small basins.

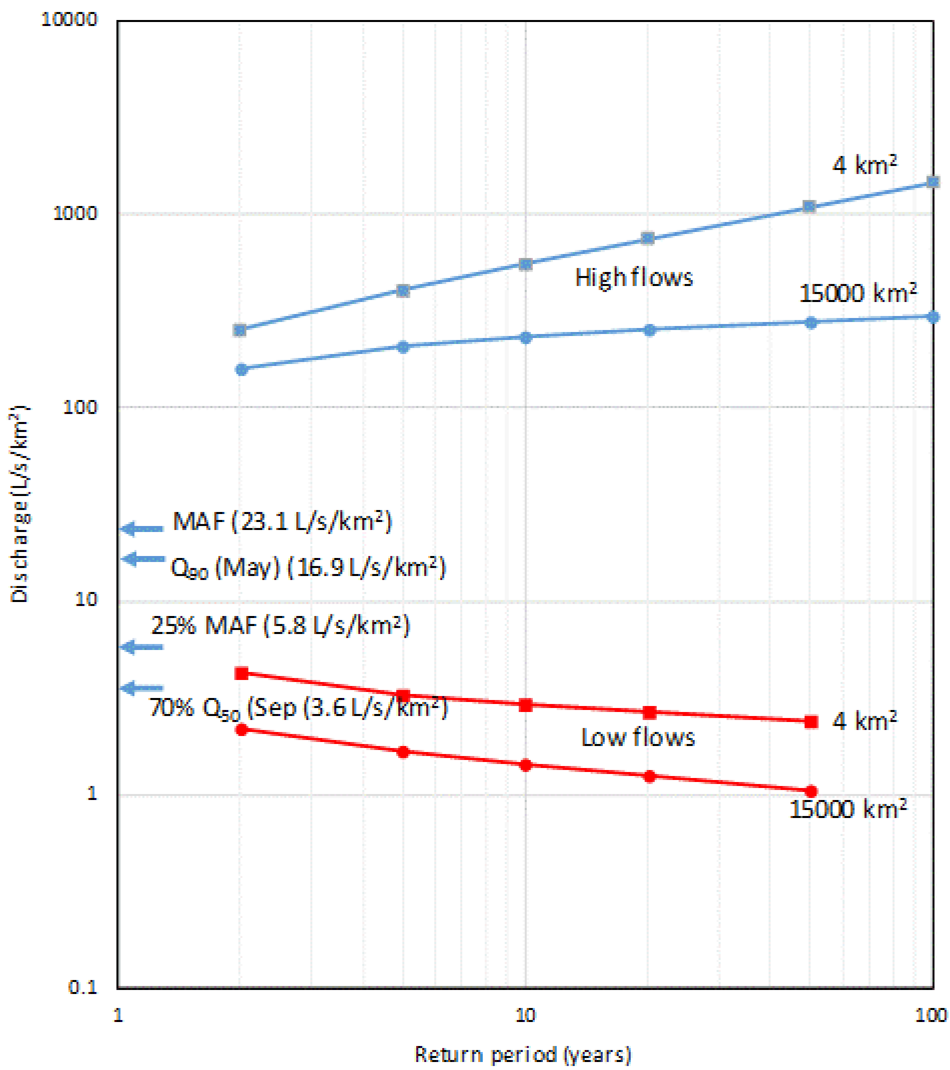



**Figure 5. Summary of discharge regimes and corresponding environmental flows in New Brunswick**

## 4.4 Description of the spatial and temporal water availability

The determination of water availability in New Brunswick consists of subtracting the environmental flows from the river flows, which could potentially indicate the amount of extractable water. In fact, the difference between these flows represent the water availability for the watercourse under study. Such flows can provide information on spatial and temporal variability of water availability in New Brunswick. Water availability, presented in Figure 6, shows the variability of the environmental flows corresponding to the upper target, i.e. the most conservative environmental flows in terms of annual average specific discharge in L/s per km$^2$.

This figure shows that the southern part of the province has more potential extractable waters then the northern part on an annual basis. The Bay of Fundy area has approximately 21 L/s per km$^2$ of potential extractable waters whereas the area near station 01AK008 has only 9 L/s per km$^2$. Such important spatial variability needs to be considered when analyzing water withdrawal projects.

This analysis was performed by month (Annex C), to provide decision makers not only with the spatial data, but also a temporal analysis of water availability throughout the year. Such data can help in decisions and assessment of existing and future water resources projects.

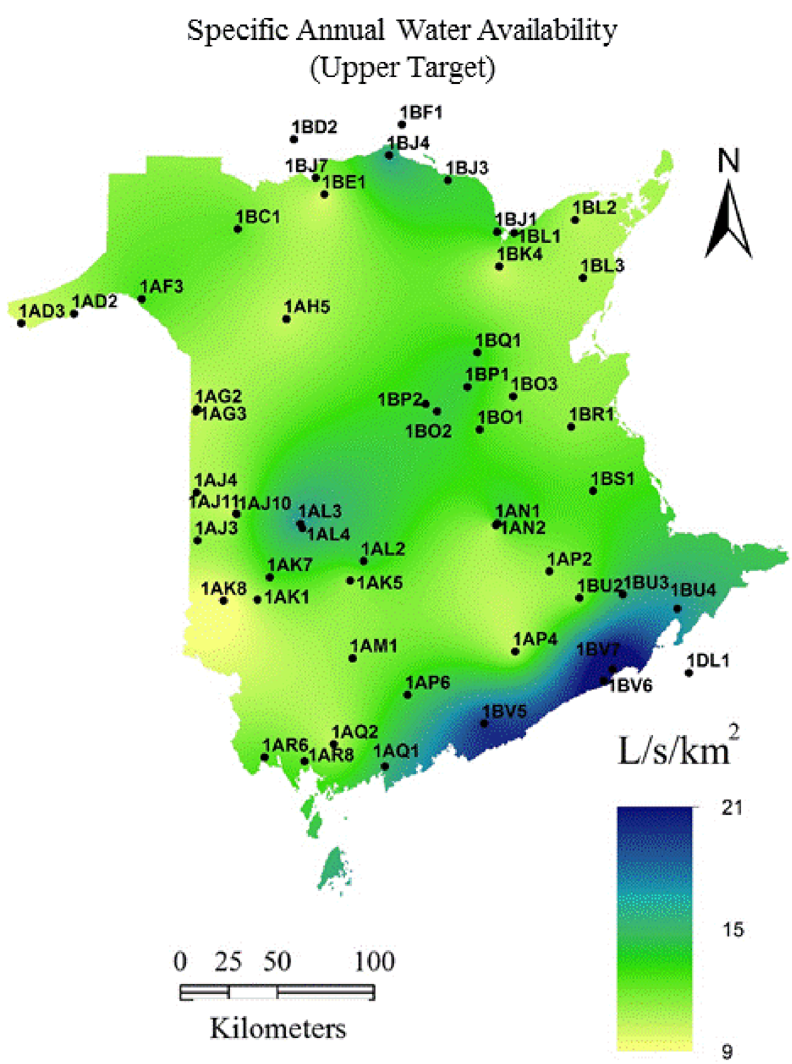



**Figure 6. Specific annual water availability (upper target) in New Brunswick**

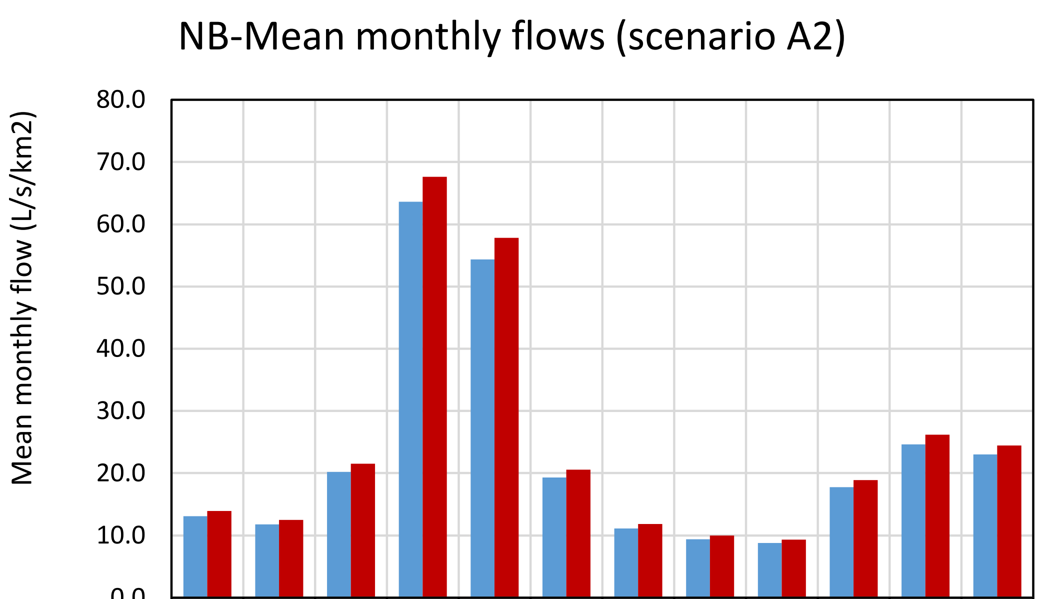
## 4.5 Impact of climate change on water availability

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. Mean monthly flows for New Brunswick rivers are projected to slightly increase in the future (Figure 7, El-Jabi et al., 2010).

The new Canadian regional climate model CanRCM4 uses CORDEX (Coordinated Regional Climate Downscaling Experiment) experiments for the North American region with two representative concentration pathways (RCP) scenarios:

- RCP4.5: Stabilization without overshoot pathway to 4.5 W/m$^2$ at stabilization after 2100
- RCP8.5: Rising radiative forcing pathway leading to 8.5 W/m$^2$ in 2100.

Representative Concentration Pathways (RCPs) are greenhouse gas concentration (not emissions) trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report (AR5) in 2014. The CanRCM4 scenario RCP8.5 follows closely the SRES A2 scenario. Therefore, no changes are predicted to the results given in Figure 7.




| | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1970-2000 | 13.1 | 11.7 | 20.2 | 63.6 | 54.4 | 19.3 | 11.1 | 9.4 | 8.8 | 17.8 | 24.6 | 23.0 |
| 2070-2100 | 13.9 | 12.5 | 21.5 | 67.6 | 57.8 | 20.5 | 11.8 | 10.0 | 9.3 | 18.9 | 26.2 | 24.5 |

**Figure 7. New Brunswick mean monthly flows using climate change scenario A2**

## 5. HYDROLOGICAL RELIABILITY ASSESSMENT

The hydrological reliability *(R)* represents the availability of a quantity of water for users, described by its return period or probability of occurrence, coupled with an acceptable timeframe period *n*:

$$R = \left(1 - \frac{1}{T}\right)^n \tag{6}$$

where *R* is hydrological reliability to observe this flow in percentage, *T* is the return period in years, and *n* is the time considered to assure flow occurrence in years. Figure 8 and Table 9 represents the hydrological reliability of flows. For example, a 100-year recurrence interval has a hydrological reliability of *R* = 0.95 over the next 5 years. This essentially means that there is about a 5% chance that a 100-year event will occur over the next 5 years.

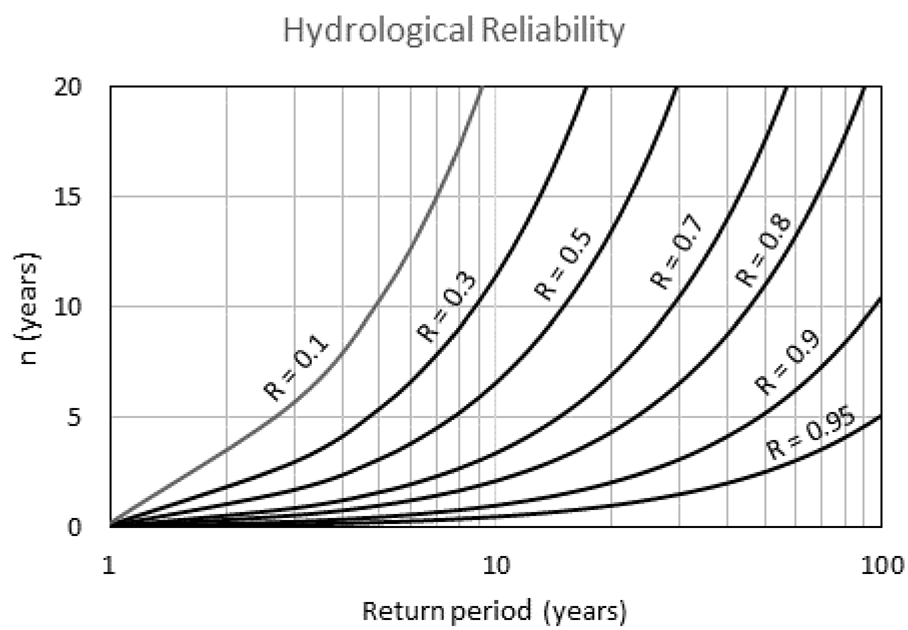



**Figure 8. Summary of hydrological reliabilities**

**Table 9. Hydrological reliabilities**

| | Return period, T (years) | | | | | |
|---|---|---|---|---|---|---|
| n (years) | 2 | 5 | 10 | 20 | 50 | 100 |
| 0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 5 | 0.03 | 0.33 | 0.59 | 0.77 | 0.90 | 0.95 |
| 10 | 0.00 | 0.11 | 0.35 | 0.60 | 0.82 | 0.90 |
| 15 | 0.00 | 0.04 | 0.21 | 0.46 | 0.74 | 0.86 |
| 20 | 0.00 | 0.01 | 0.12 | 0.36 | 0.67 | 0.82 |

## 6. CASE STUDIES

The case studies presented in this section provide practical examples of how water availability corresponding to water demand may be estimated using charts and figures provided in this report. An Excel software accompanying this report can also be used in different ways to provide estimates to water demand. Three case studies are considered:

***Case study 1: Municipal demand***

The town of XYZ in the Acadian peninsula decides to build a water distribution system using surface water.

Data: Estimated population in 2050: 5000 people

Daily consumption: 300 L/day per person or 1500 $m^3$/d or 0.017 $m^3$/s

Water period availability: Year around

Probability of water availability: 90%

Solution:

Catchment area needed: $\geq$ 10 $km^2$ (Fig. CS1a, below)

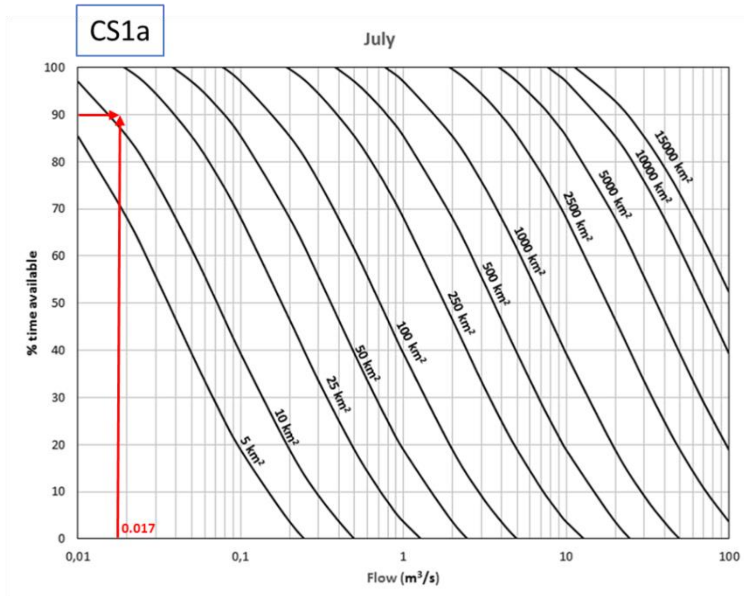
Verification:

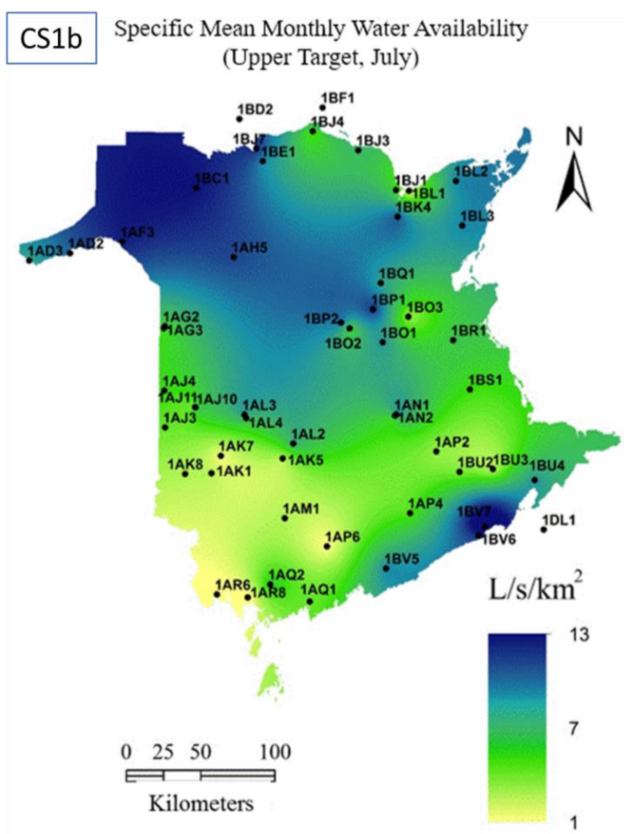
Water demand: 0.017 $m^3$/s

Water availability, upper target, critical period is July low flows (Fig. CS1b): 9 L/s/$km^2$ * 10 $km^2$ = 0.09 $m^3$/s

Water demand 0.017 $m^3$/s < water availability 0.09 $m^3$/s, OK!

This means that the above water demand would be met 90% of the time when using a drainage basin larger than 10 $km^2$.


CS1a
July
% time available
Flow (m³/s)
0.017
5 km²
10 km²
25 km²
50 km²
100 km²
250 km²
500 km²
1000 km²
2500 km²
5000 km²
10000 km²
15000 km²


CS1b
Specific Mean Monthly Water Availability
(Upper Target, July)
L/s/km²
13
7
1
0 25 50 100
Kilometers
N

***Case study 2: Industrial demand***

A seafood manufacturing ABC decides to build a new facility in the region of Fundy. This new facility will work 8 hr/d and will use surface water.

Data: Daily consumption: 100 000 L/d or 0.0035 $m^3/s$

Water period availability: Summer (Jun, Jul & Sept)

Probability of water availability: 99%

Solution:

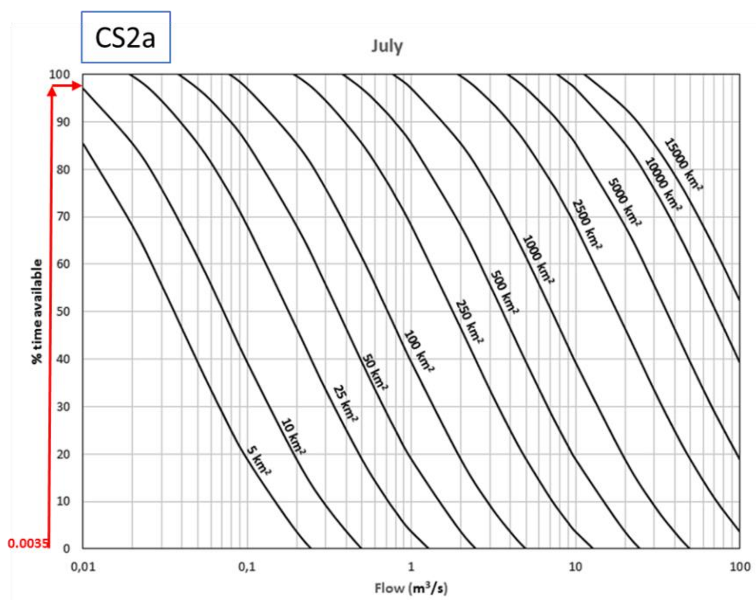
Catchment area needed: ~ 10 $km^2$ (Fig. CS2a)

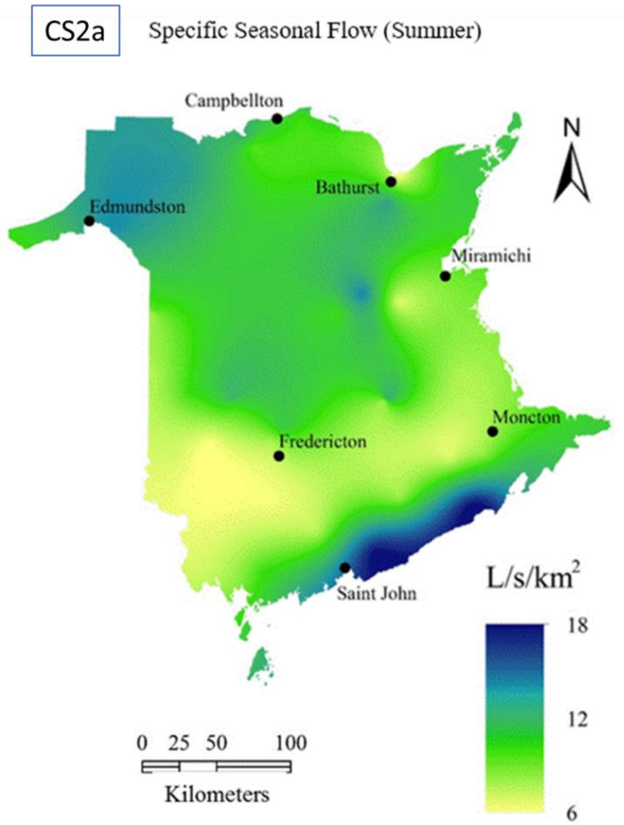
Verification:

Water demand: 0.0035 $m^3/s$

Water availability, upper target, critical period is summer low flows (Fig. CS2b): 8 $L/s/km^2$ * 10 $km^2$ = 0.08 $m^3/s$

Water demand 0.0035 $m^3/s$ < water availability 0.08 $m^3/s$, OK!






***Case study 3: Mining demand***

A mining company DEF decides to exploit a mine in the region of Chaleur Peninsula and will use surface water.

Data: Daily consumption: 200 $m^3/d$ or 0.0023 $m^3/s$

Water period availability: year around

Probability of water availability: 75%

Solution:

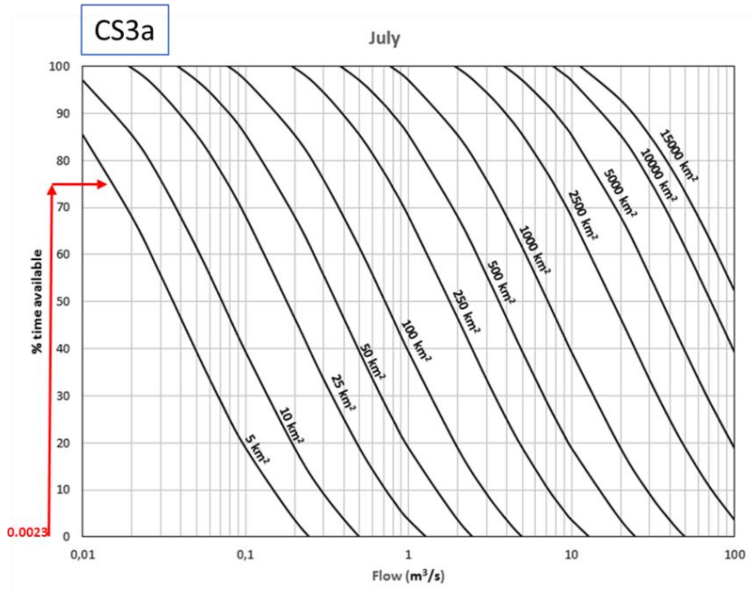
Catchment area needed: ~ 5 $km^2$ (Fig. CS3a)

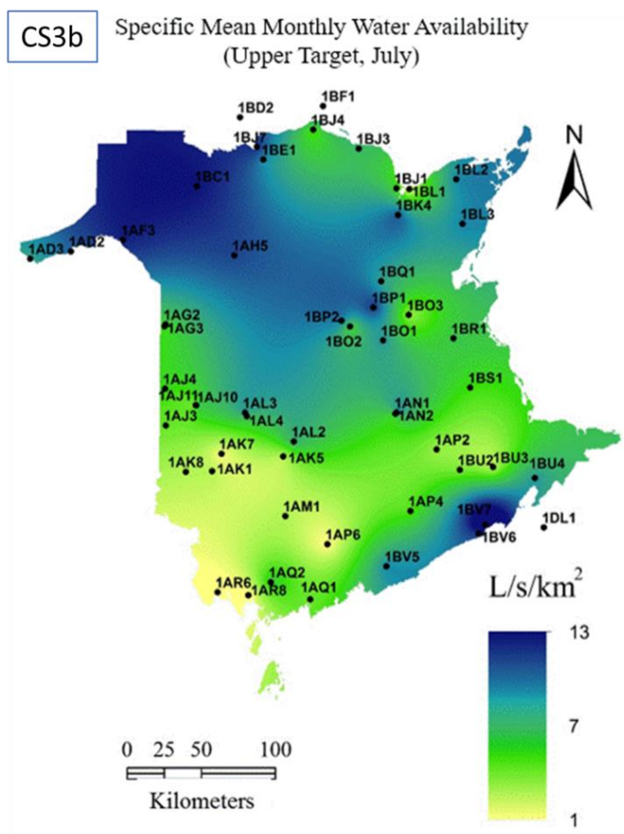
Verification:

Water demand: 0.0023 $m^3/s$

Water availability, upper target, critical period is July low flows (Fig. CS3b): 9 $L/s/km^2$ * 5 $km^2$ = 0.045 $m^3/s$

Water demand 0.0023 $m^3/s$ < water availability 0.045 $m^3/s$, OK!


CS3a
July
% time available
Flow (m³/s)
0.0023
15000 km²
10000 km²
5000 km²
2500 km²
1000 km²
500 km²
250 km²
100 km²
50 km²
25 km²
10 km²
5 km²


CS3b
Specific Mean Monthly Water Availability
(Upper Target, July)
L/s/km²
13
7
1
0 25 50 100
Kilometers
N

***Case study 4: Greater Moncton***

The City of Moncton and Greater Moncton would like to verify its water supply from Turtle Creek:

Data: Estimated population in 2050: 200 000 people

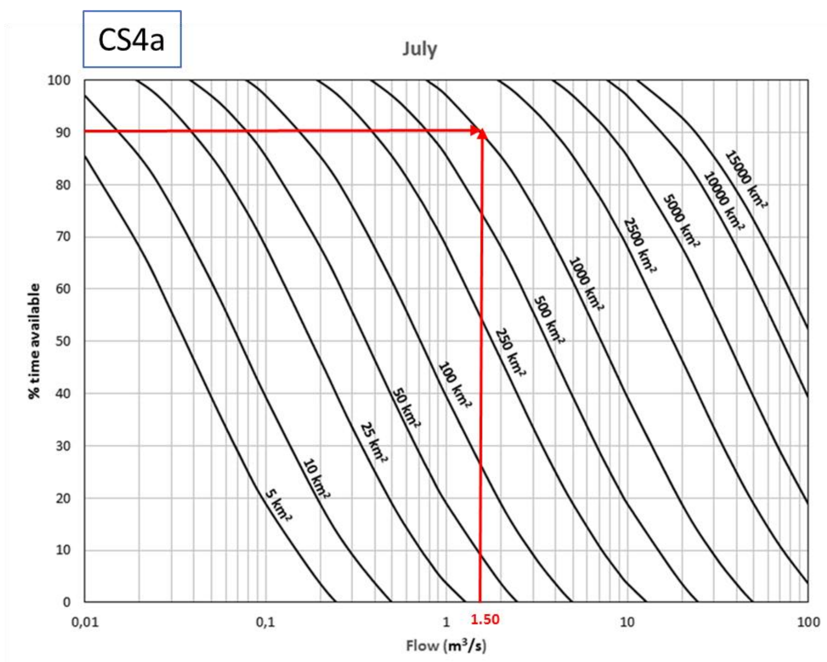
Daily consumption: 650 L/d/p or 130 000 $m^3$/d or 1.50 $m^3$/s

Water period availability: Year around

Probability of water availability: 90%

Solution:

Catchment area needed: ~ 1000 $km^2$ (Fig. CS4a)

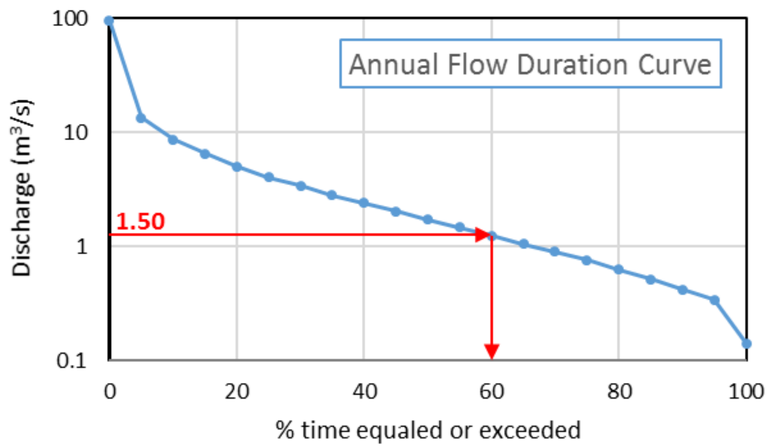



Verification:

Turtle Creek

| | |
|---|---|
| Station ID | 01BU003 |
| Latitude | 45°57'34" N |
| Longitude | 64°52'40" W |

| | |
|---|---|
| Drainage area | 129 km$^2$ |
| Period of record | 1963-2010 (48 years) |

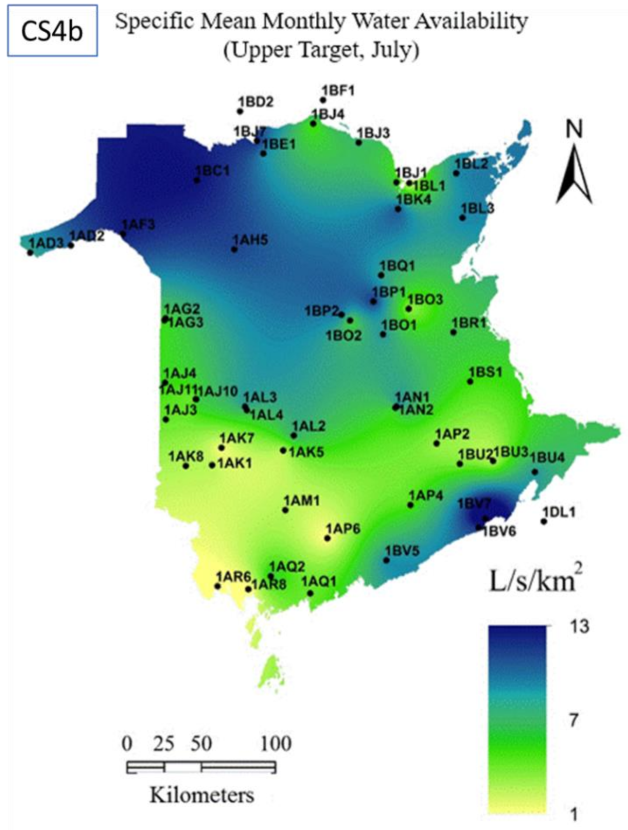



Water availability: 1.50 m$^3$/s, only 60% on yearly basis

Need a storage for the 40% on yearly basis.

Water availability, upper target, critical period is July low flows (Fig. CS4b):

7 L/s/km$^2$ * 129 km$^2$ = 0.9 m$^3$/s ~ 60% * 1.50 = 0.9 m$^3$/s, OK.




### *Case study 5: Irrigation demand*

In the northwest of the province, a need of irrigation water supply was identified, using surface water from Restigouche River below Kedgwick River.

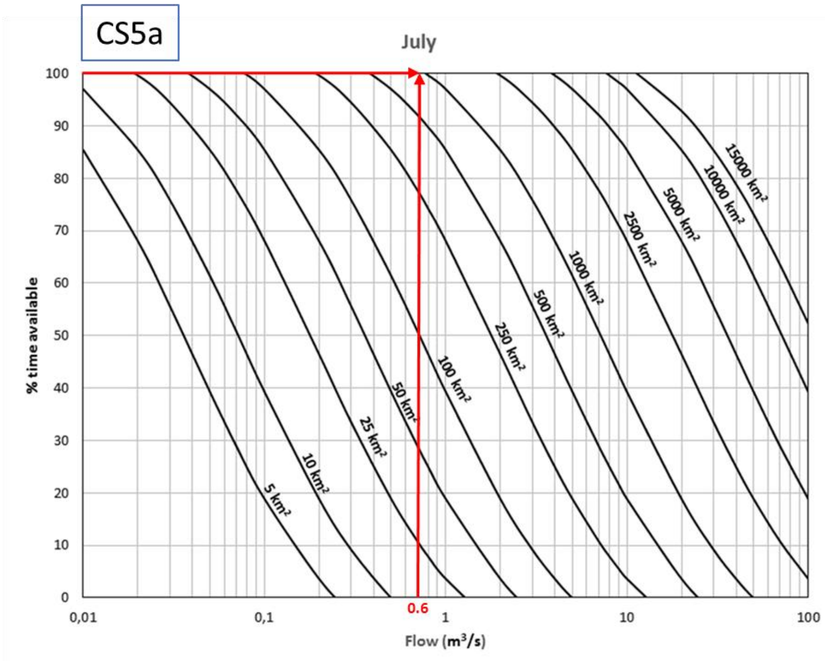
Data: Daily consumption: 50 000 $m^3$/d or 0.6 $m^3$/s

Water period availability: June and July

Probability of water availability: 100%

Solution:

Catchment area needed: 1000 $km^2$ (Fig. CS5a)




Verification:

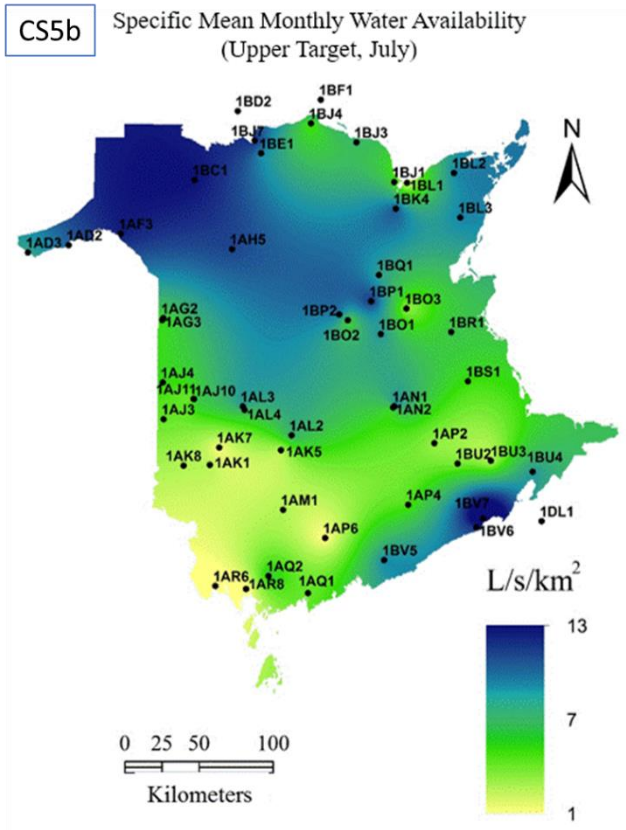
Restigouche River

| | |
|---|---|
| Station ID | 01BC001 |
| Latitude | 47°40'01" N |
| Longitude | 67°28'59" W |
| Drainage area | 3160 km² |
| Period of record | 1963-2010 (48 years) |

Water availability, upper target, critical period is July low flows (Fig. CS5b): 8 L/s/km$^2$ * 3160 km$^2$ = 25.3 m$^3$/s

Water demand 0.6 m$^3$/s < water availability 25.3 m$^3$/s, OK!

Restigouche River will be able to supply irrigation demand 100% during June and July.




## 7. DISCUSSIONS AND CONCLUSIONS

The present study presents a conceptual framework for assessing water security in the province of New Brunswick. The approach consisted of calculating discharge from a wide range of rivers within the province, then estimating a potential range of environment flows to protect aquatic habitats for each river. The difference between average river flow and environmental flows provided information on the water availability (i.e., for off-stream use / water withdrawal) which was used as an indicator of water security. Based on the literature review, it is concluded that:

- No single definition is generally agreed upon for water security. The concept of water security is approached from a range of scales (e.g., community, regional, national), and with contributions from a variety of subject areas;

- No widely-accepted standard index of water security exists in Canada. Current water-related indices tend to focus on drinking water and do not allow decision-makers to effectively assess and mediate between conflicting demands for water use (e.g. other uses such as aquatic habitat, etc.);
- Few water security assessment methods are user-friendly at the local scale (e.g., watershed);
- When examining a watershed, greater emphasis should be placed on the sum of all the parts: flow, water use, quality, and ecosystem. Policy-makers, water resource managers, NGOs, industry, and agriculture, all need this information, despite their competing needs. If the complete picture is not available, then how can good decisions be made which can maintain a functioning ecosystem in the long-term? This creates significant risks to watershed integrity and thereby to public health, which can in turn create significant costs.
- To assess water security status, a new approach was proposed in New Brunswick, namely based on river discharge and environmental flows.
- Water-related risk assessment requires knowledge of hazard potential related to flow occurrence and its frequency distribution.
- The choice of one methodology of water security risk assessment over another largely depends on the objectives of the analysis, the availability of datasets, the level of detail to be achieved, and the dimensions of risk to be addressed. Water security is an extremely challenging issue for which to construct indicators. Even the physical resource itself presents numerous conceptual and technical difficulties, characterized by spatial and temporal variability.

## AKNOWLEDGEMENTS

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## APPENDIX A: MONTHLY % TIME WATER AVAILABILITY CHARTS

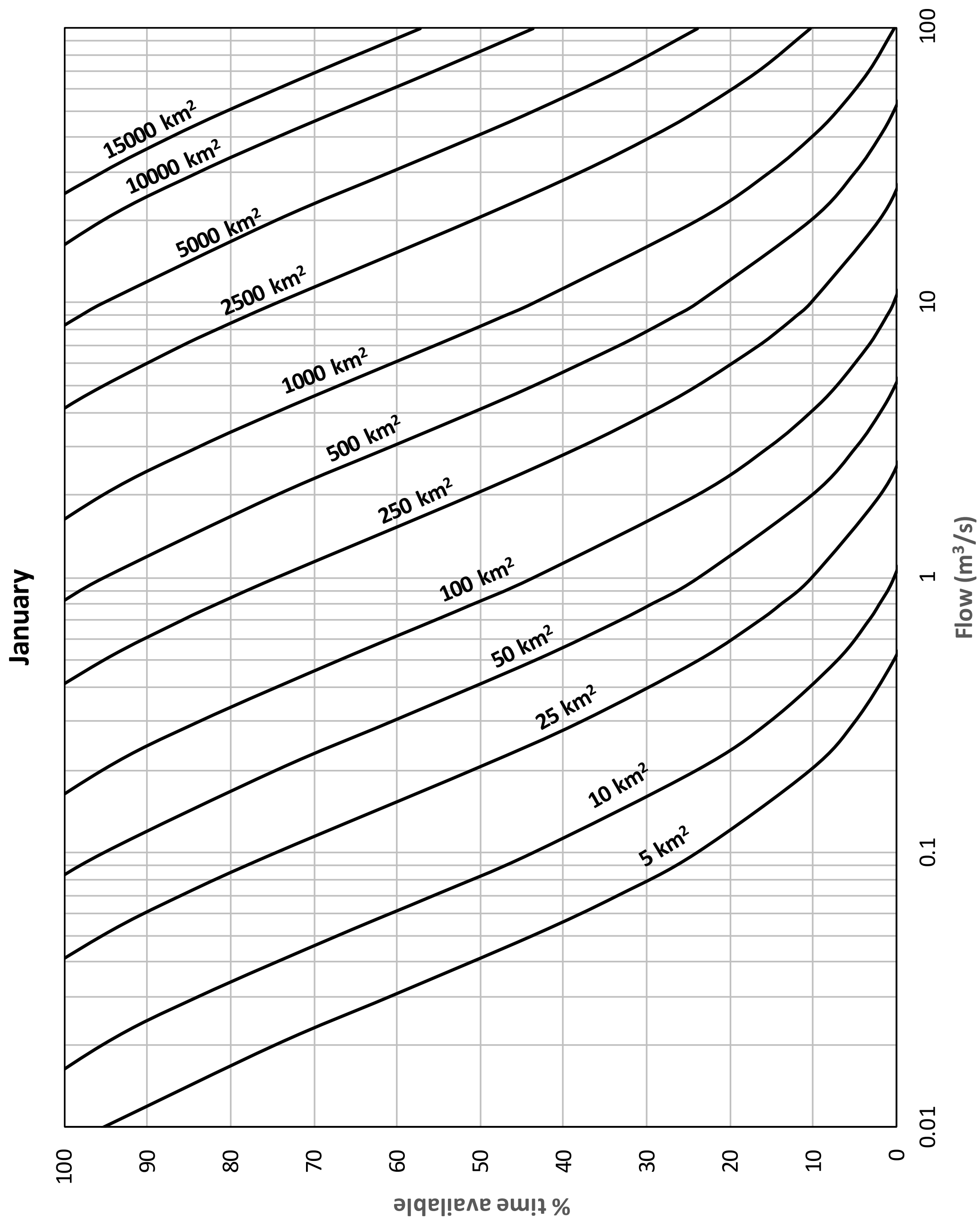


**Figure A1. Water availability in New Brunswick for the month of January**

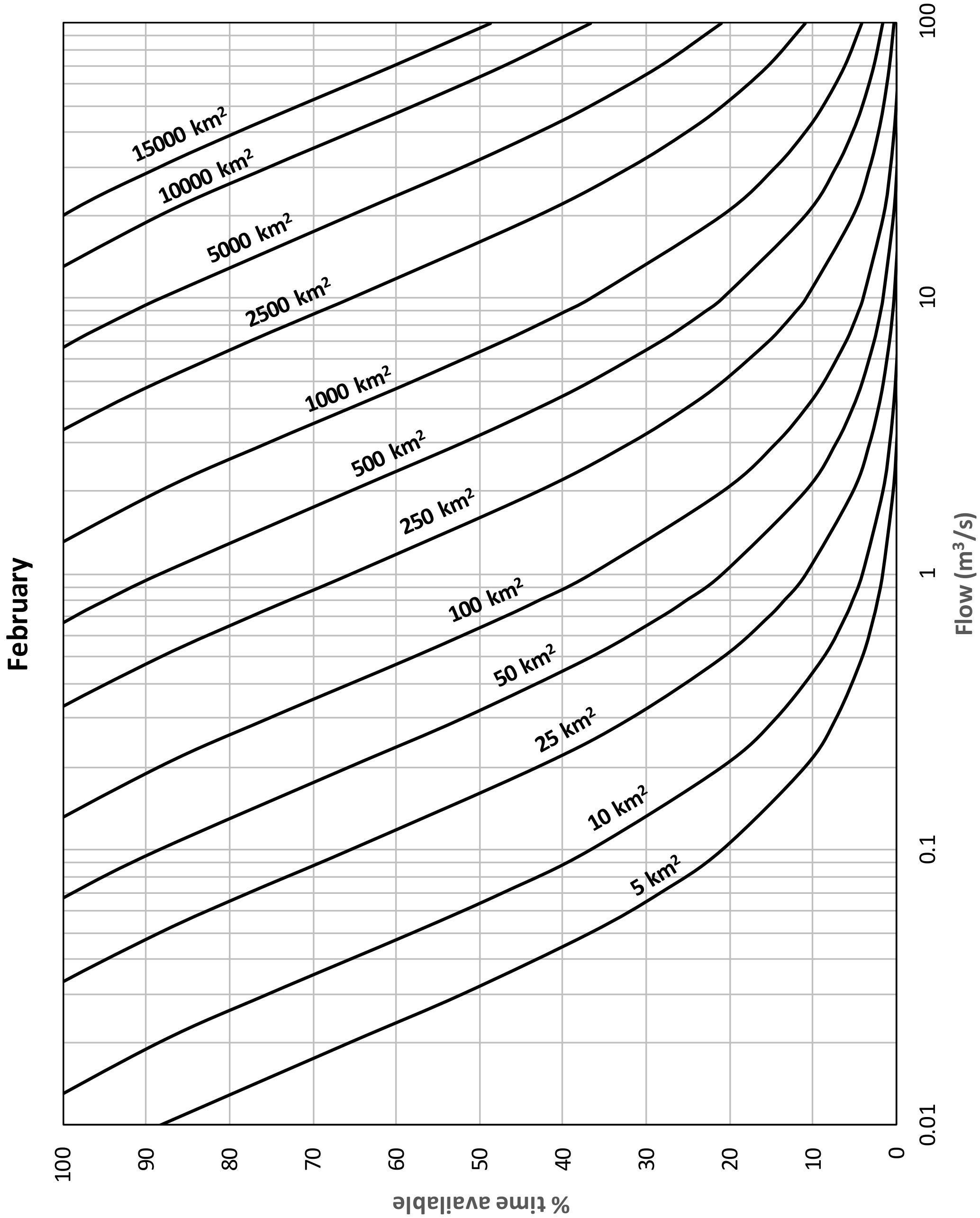


**Figure A2. Water availability in New Brunswick for the month of February**

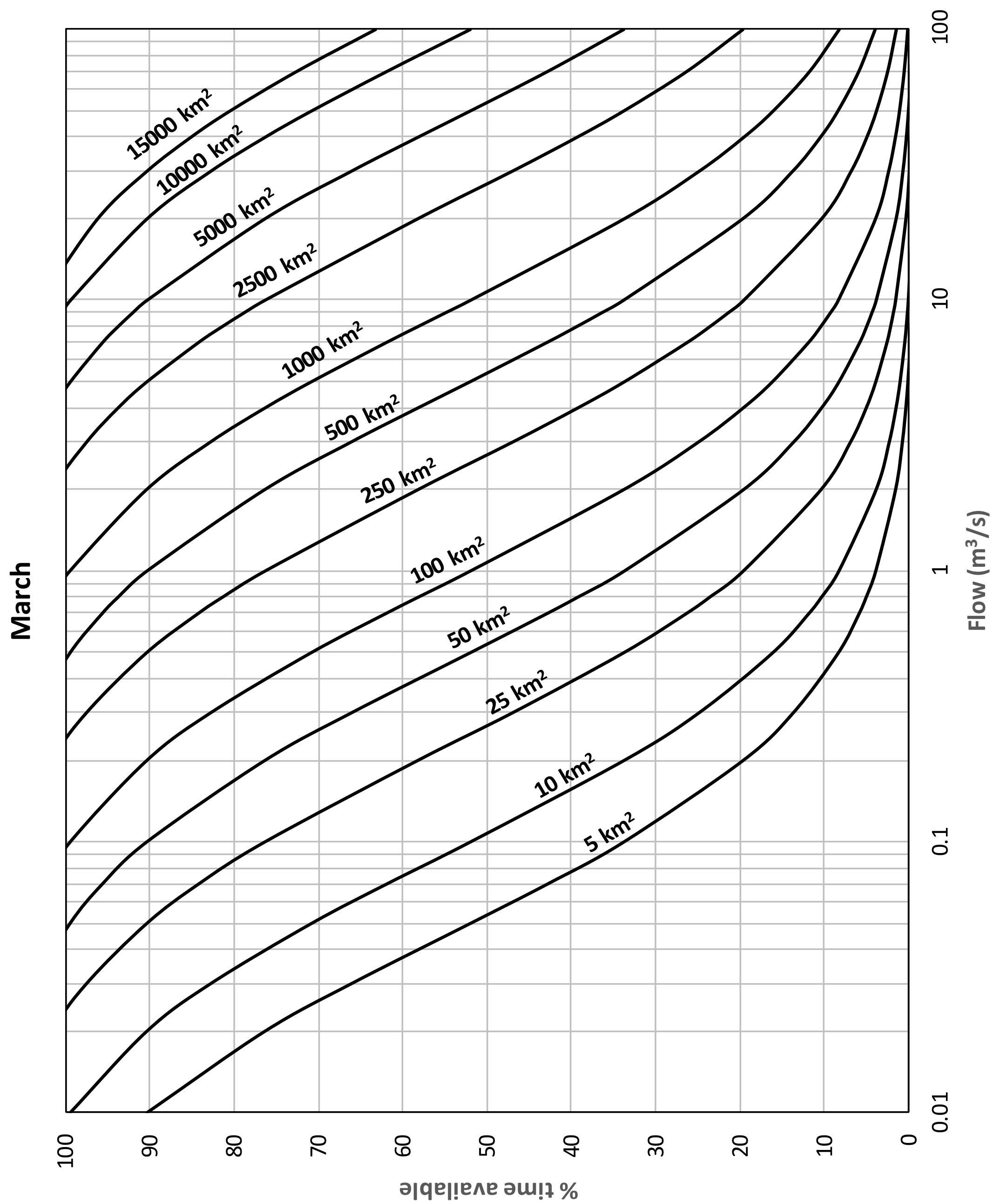


**Figure A3. Water availability in New Brunswick for the month of Mars**

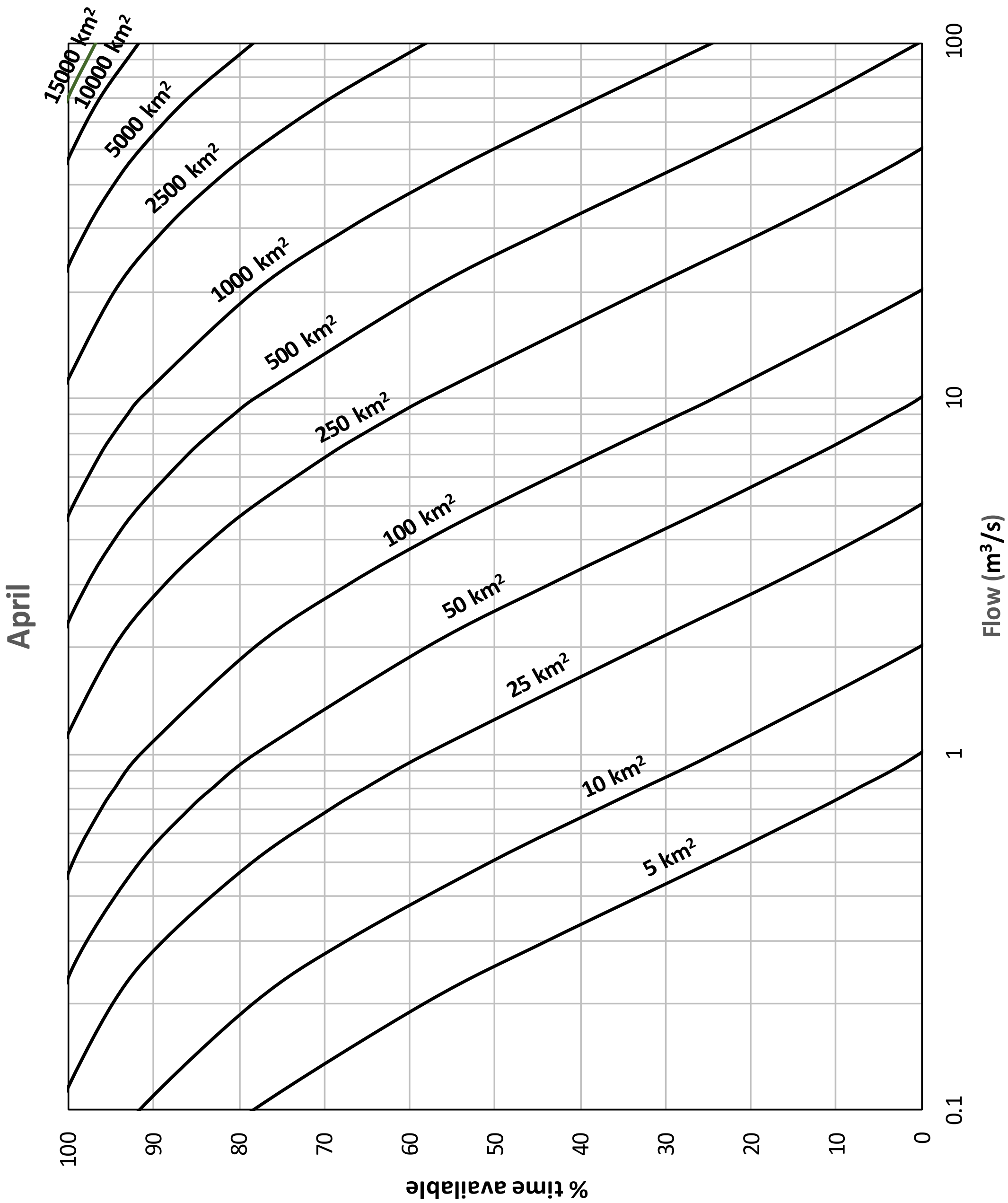


**Figure A4. Water availability in New Brunswick for the month of April**

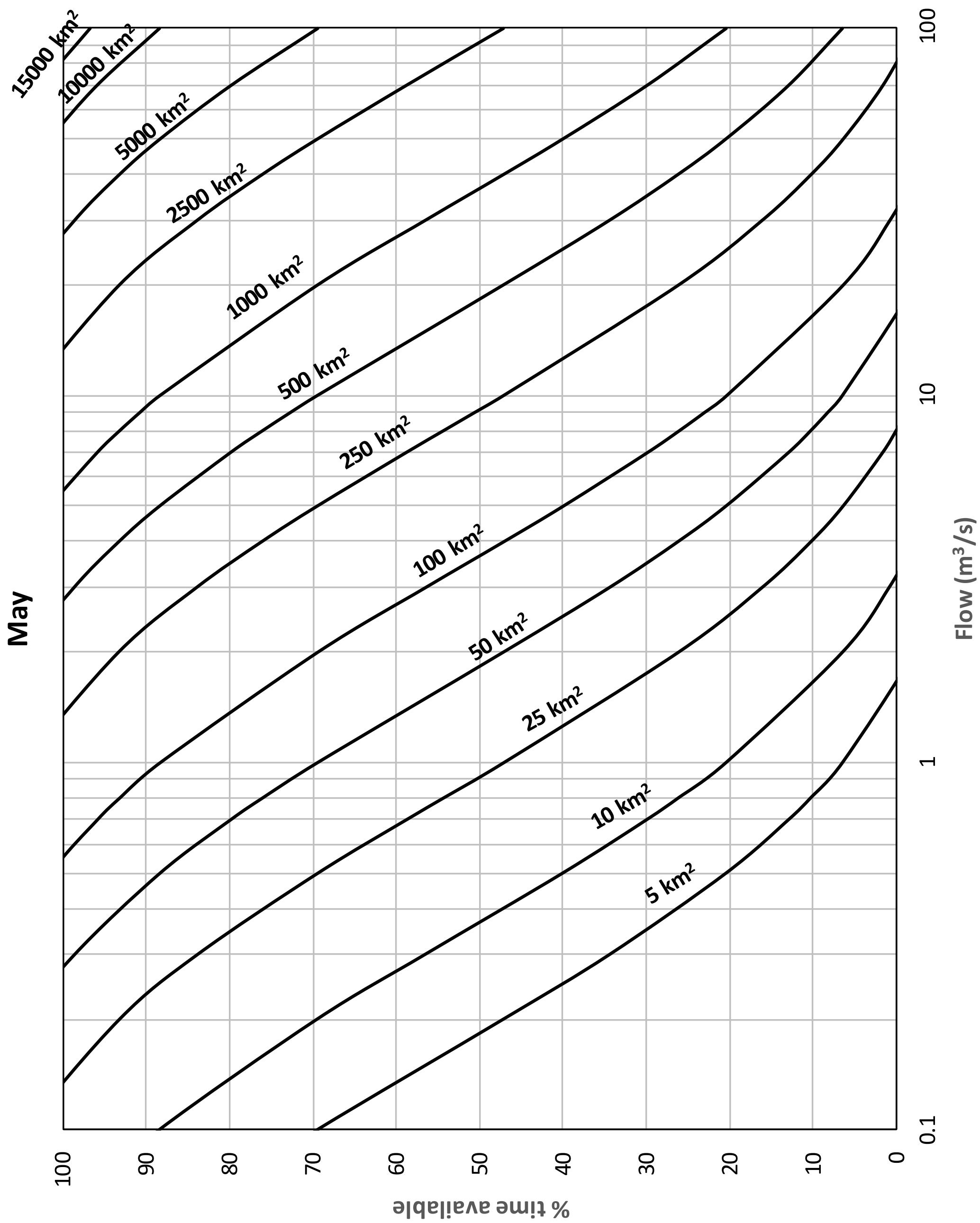


**Figure A5. Water availability in New Brunswick for the month of May**

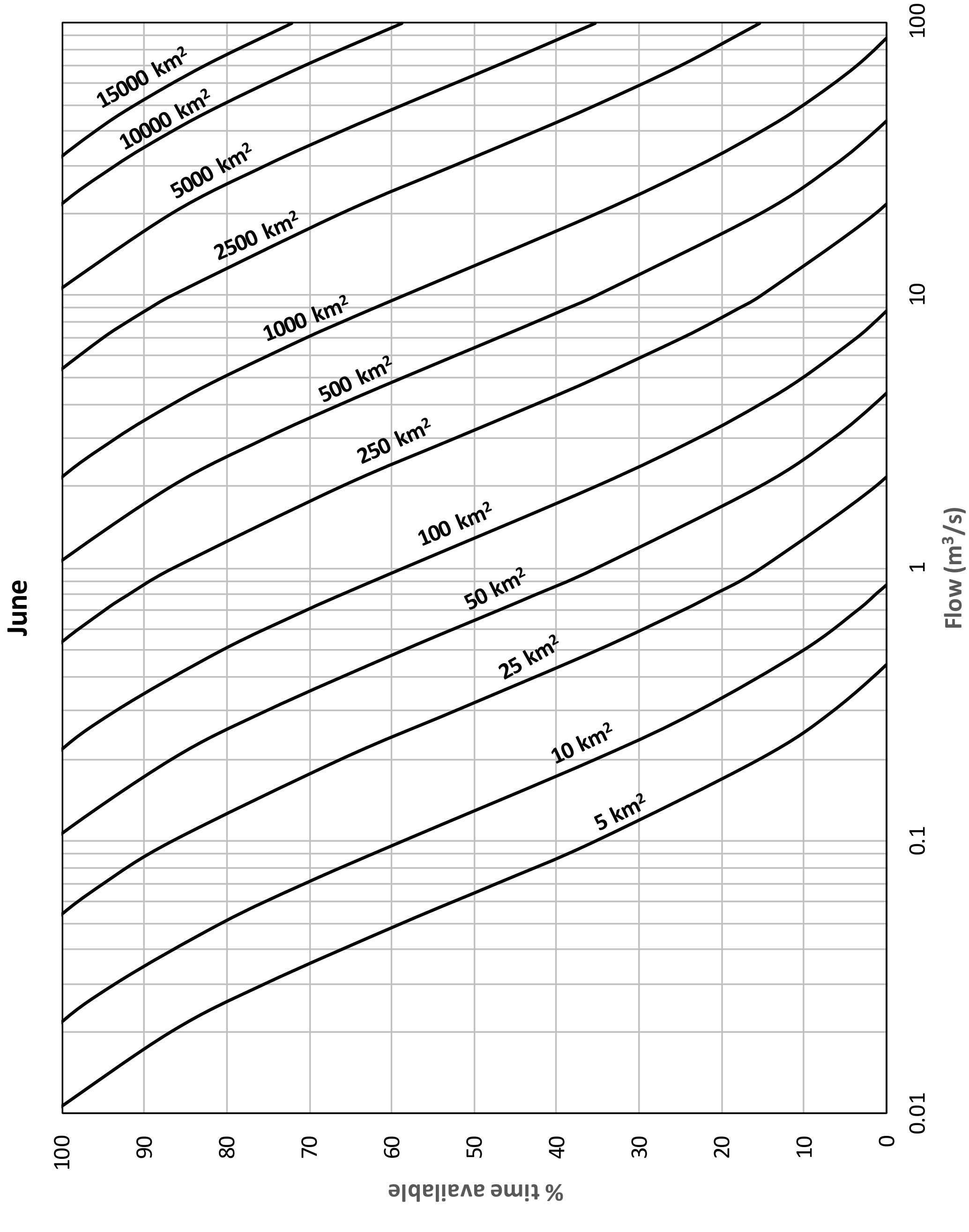


**Figure A6. Water availability in New Brunswick for the month of June**

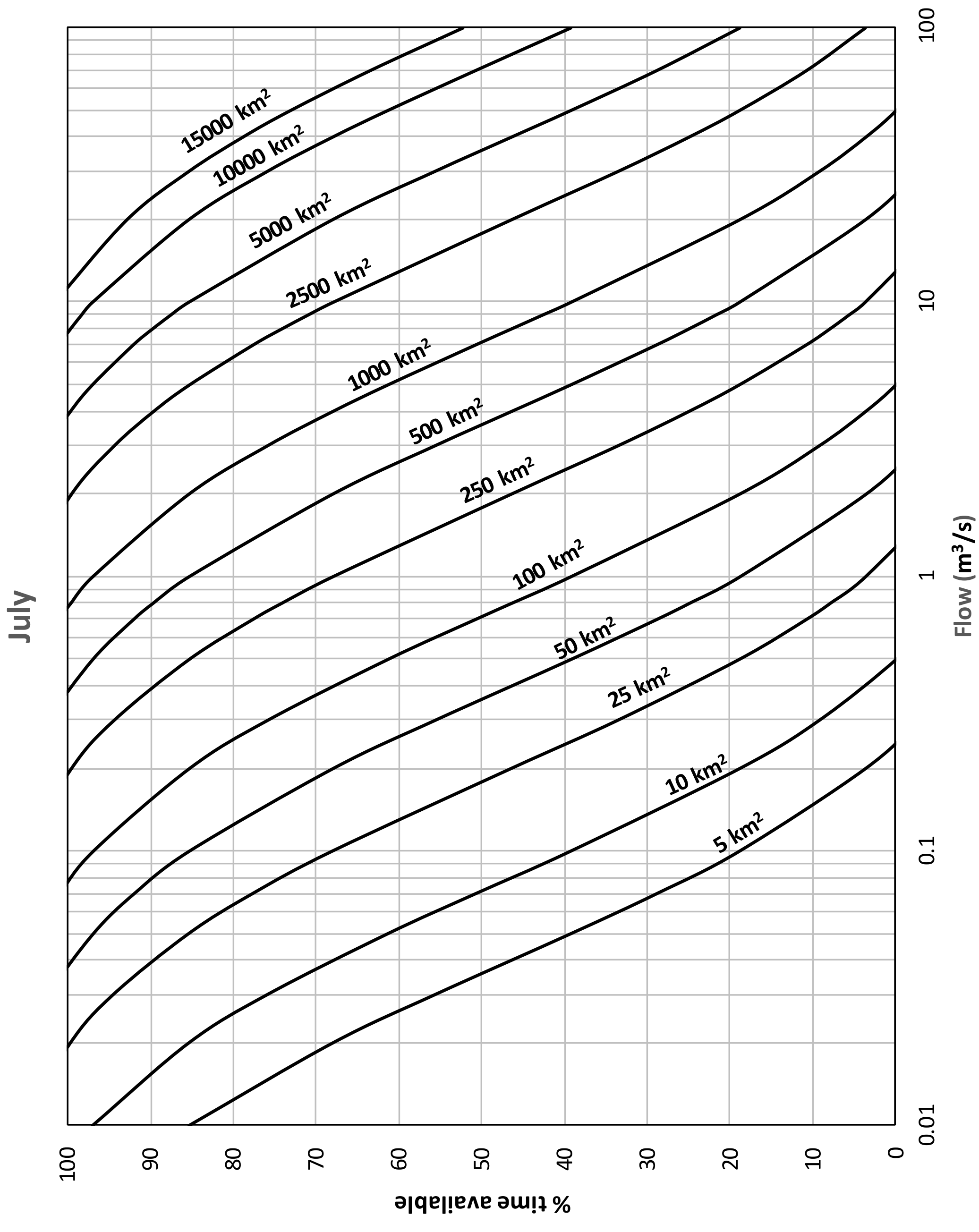


**Figure A7. Water availability in New Brunswick for the month of July**

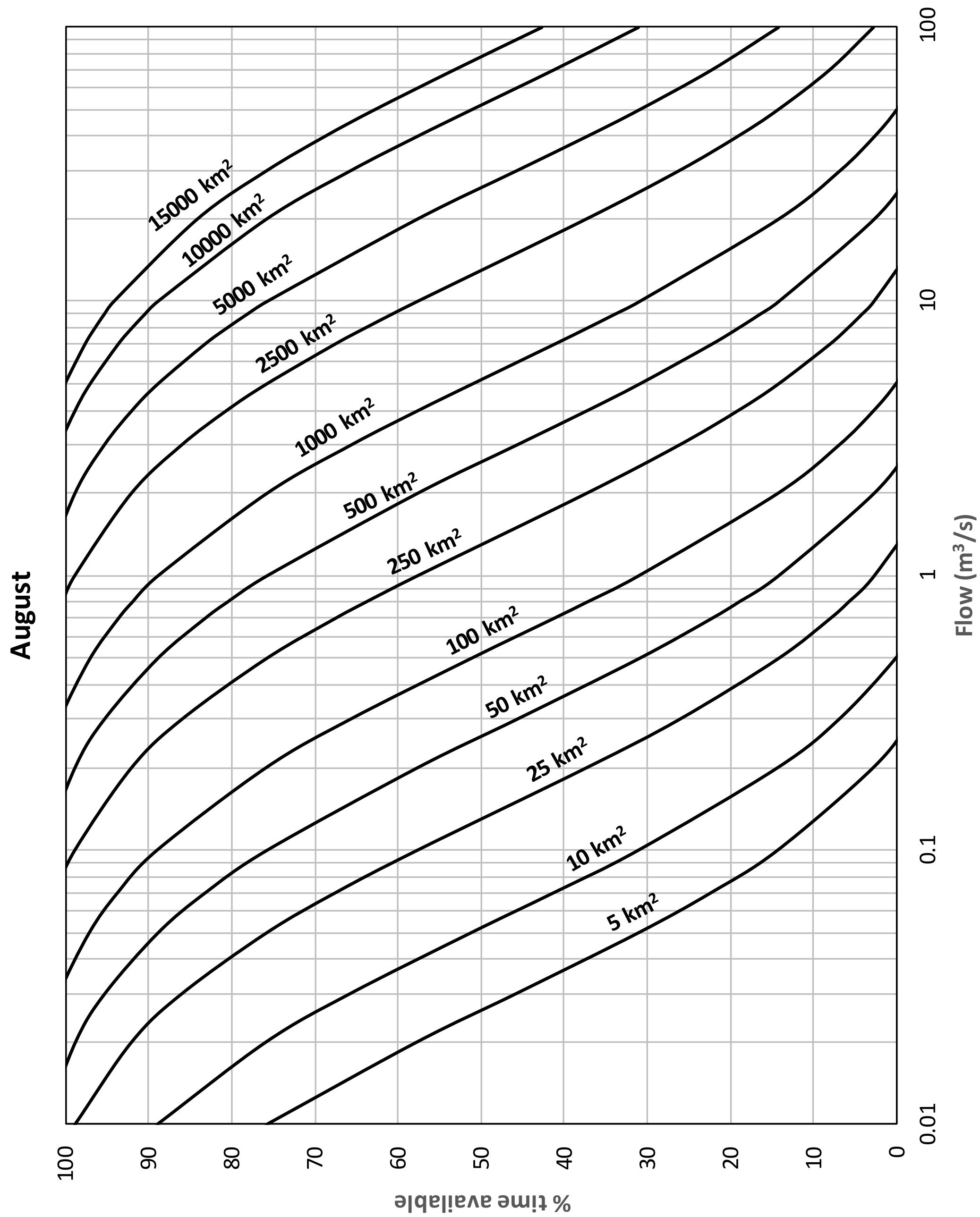


**Figure A8. Water availability in New Brunswick for the month of August**

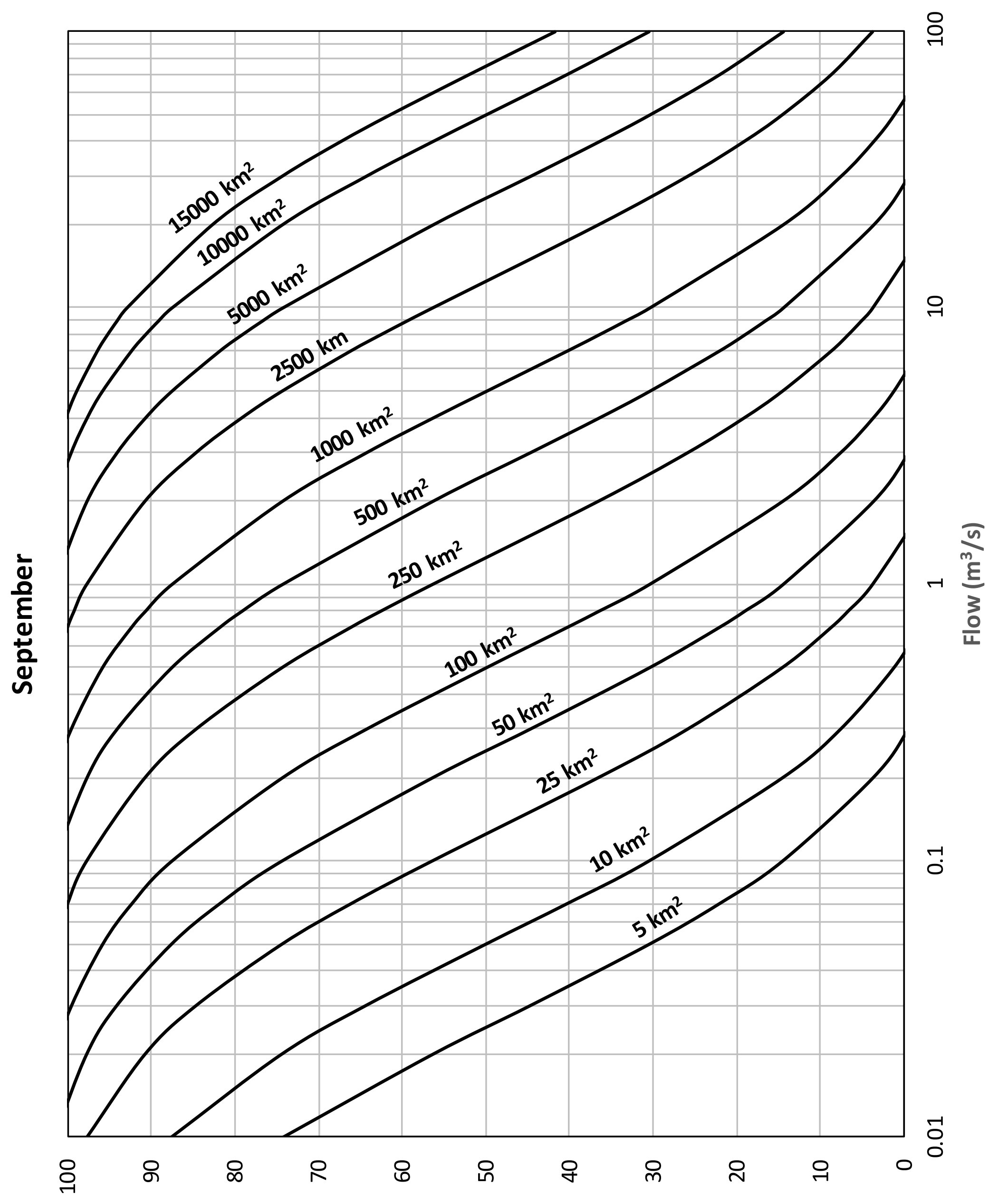


**Figure A9. Water availability in New Brunswick for the month of September**

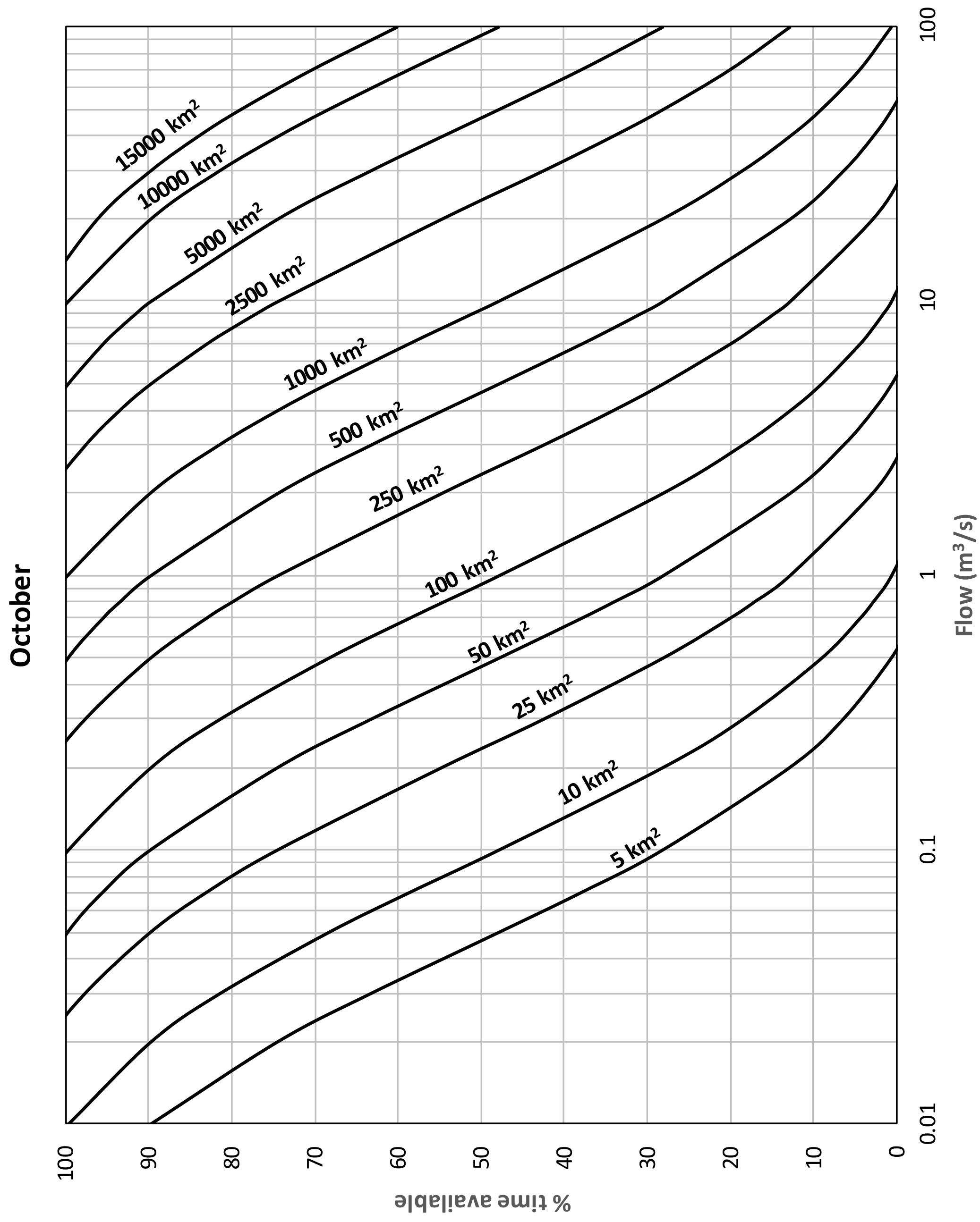


**Figure A10. Water availability in New Brunswick for the month of October**

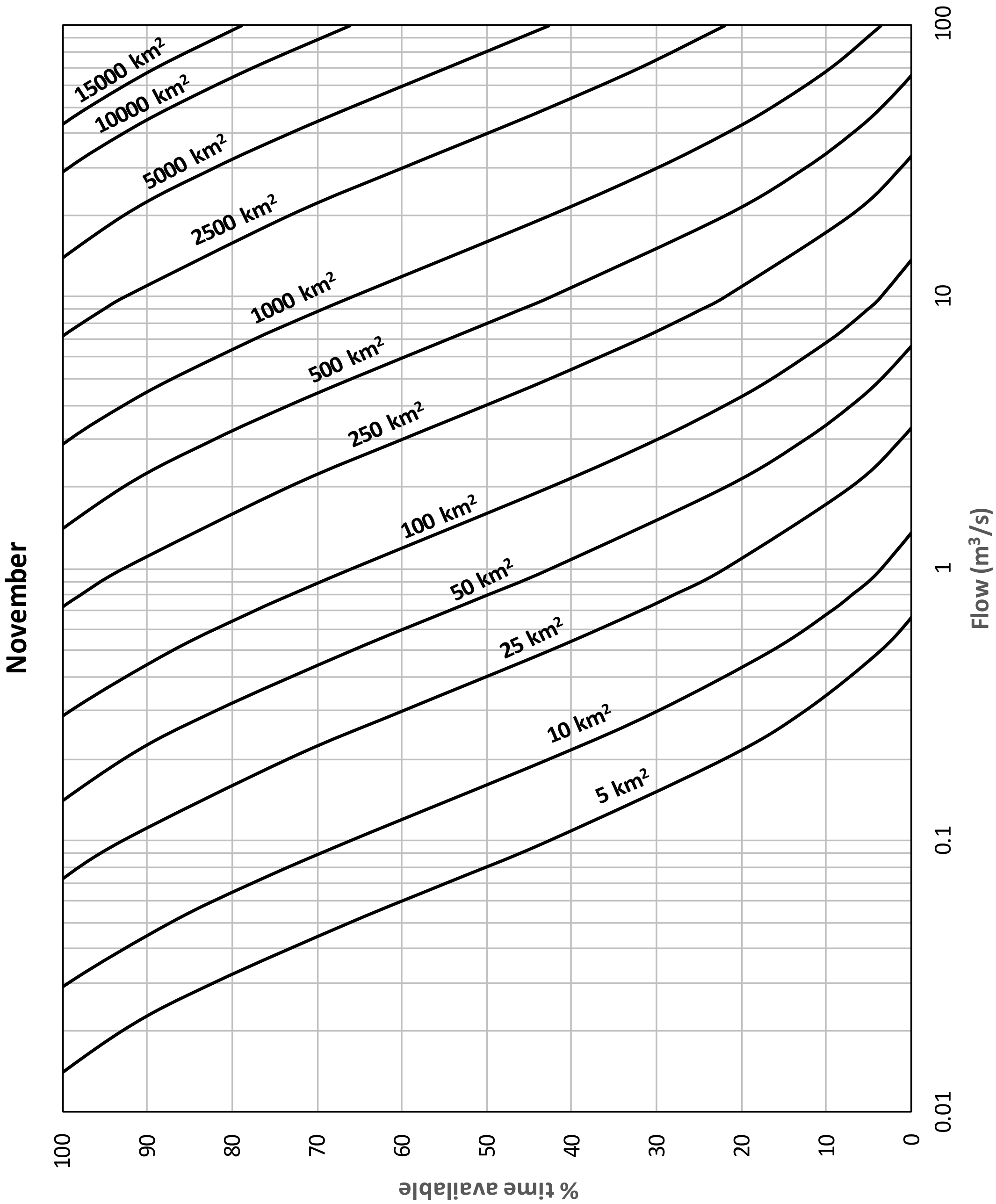


**Figure A11. Water availability in New Brunswick for the month of November**

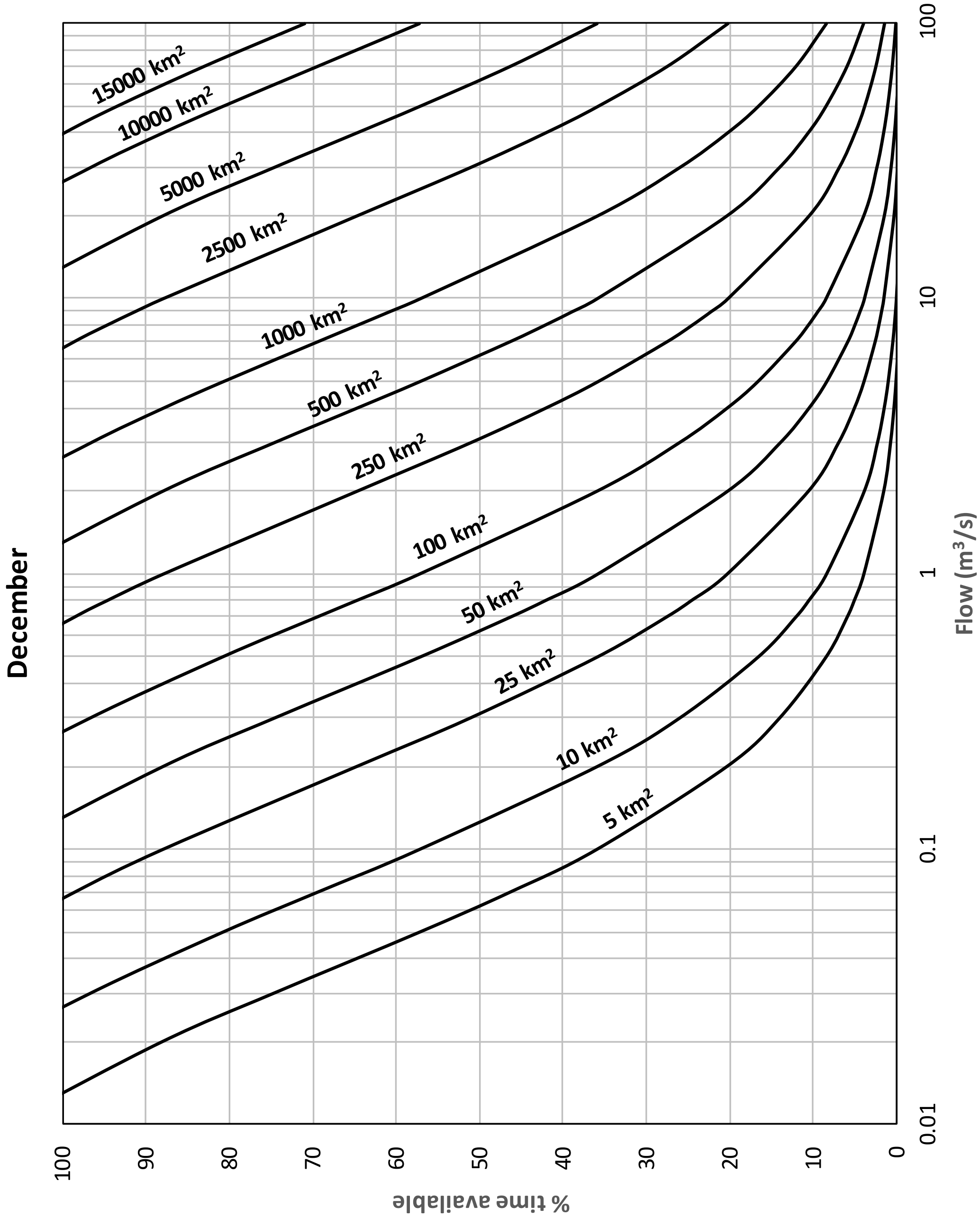


**Figure A12. Water availability in New Brunswick for the month of December**

## APPENDIX B : SPECIFIC FLOWS

- Specific Mean Monthly Flows
- Specific Seasonal Flows

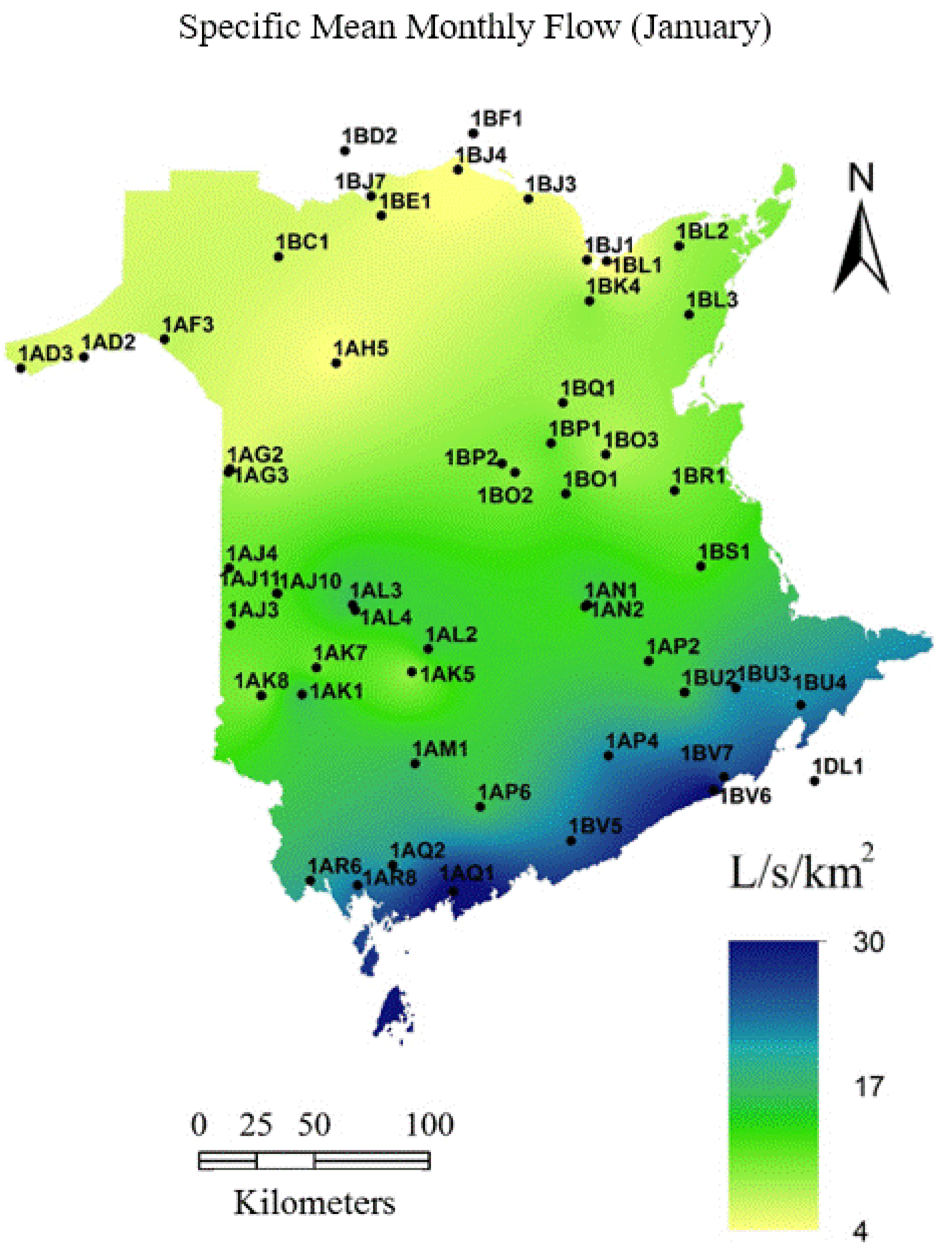


**Figure B1. Specific mean monthly flow for January in New Brunswick**

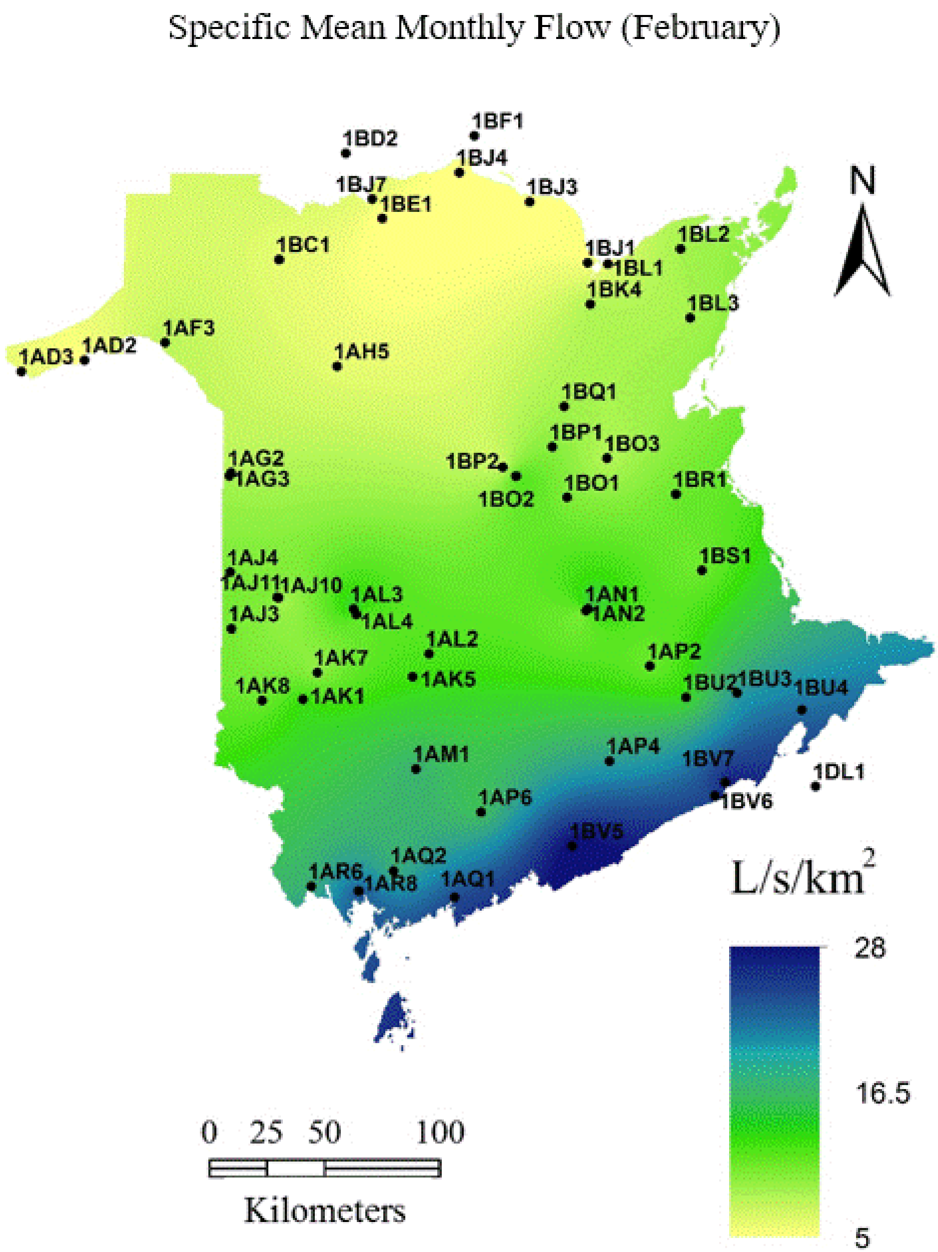


**Figure B2. Specific mean monthly flow for February in New Brunswick**

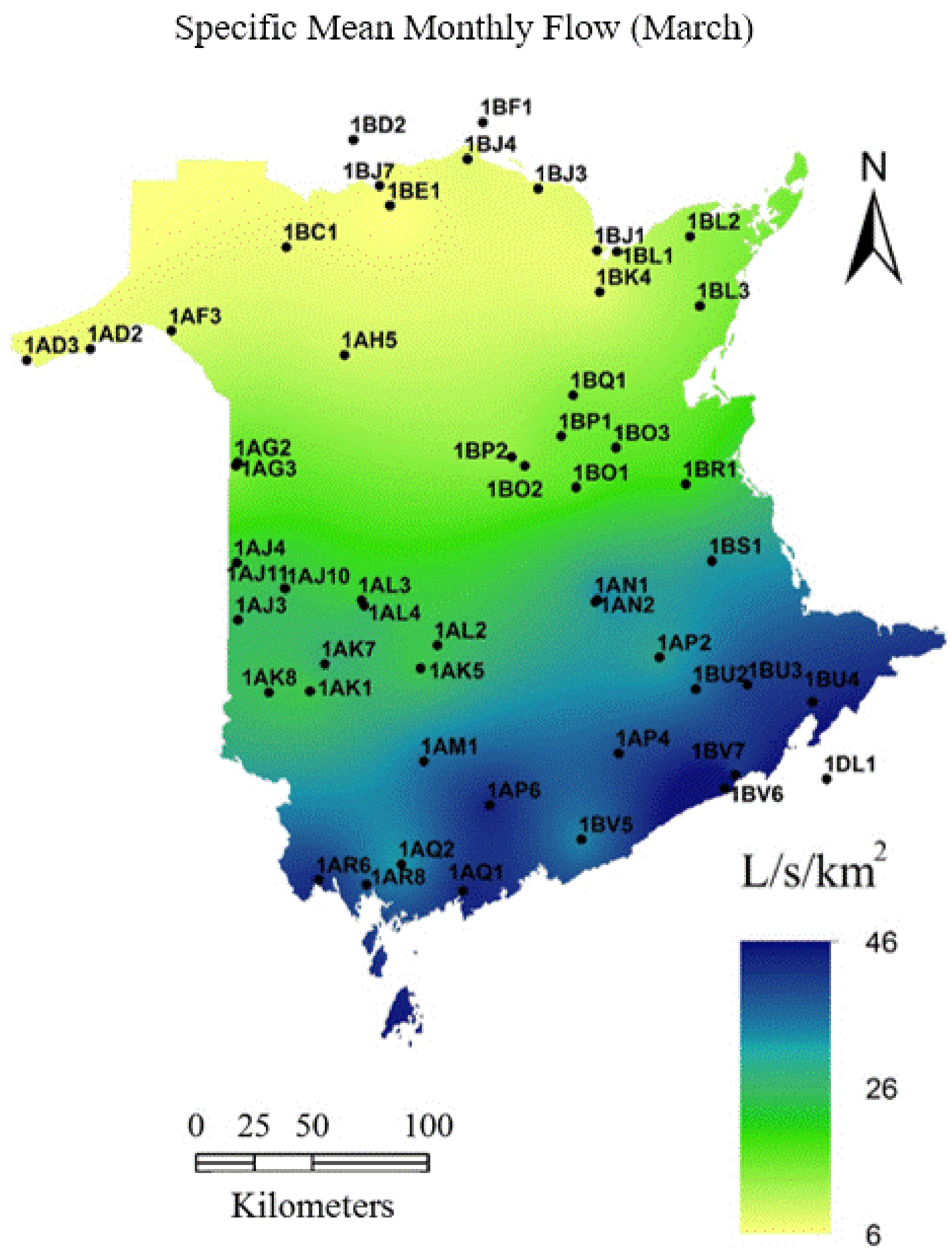


**Figure B3. Specific mean monthly flow for March in New Brunswick**

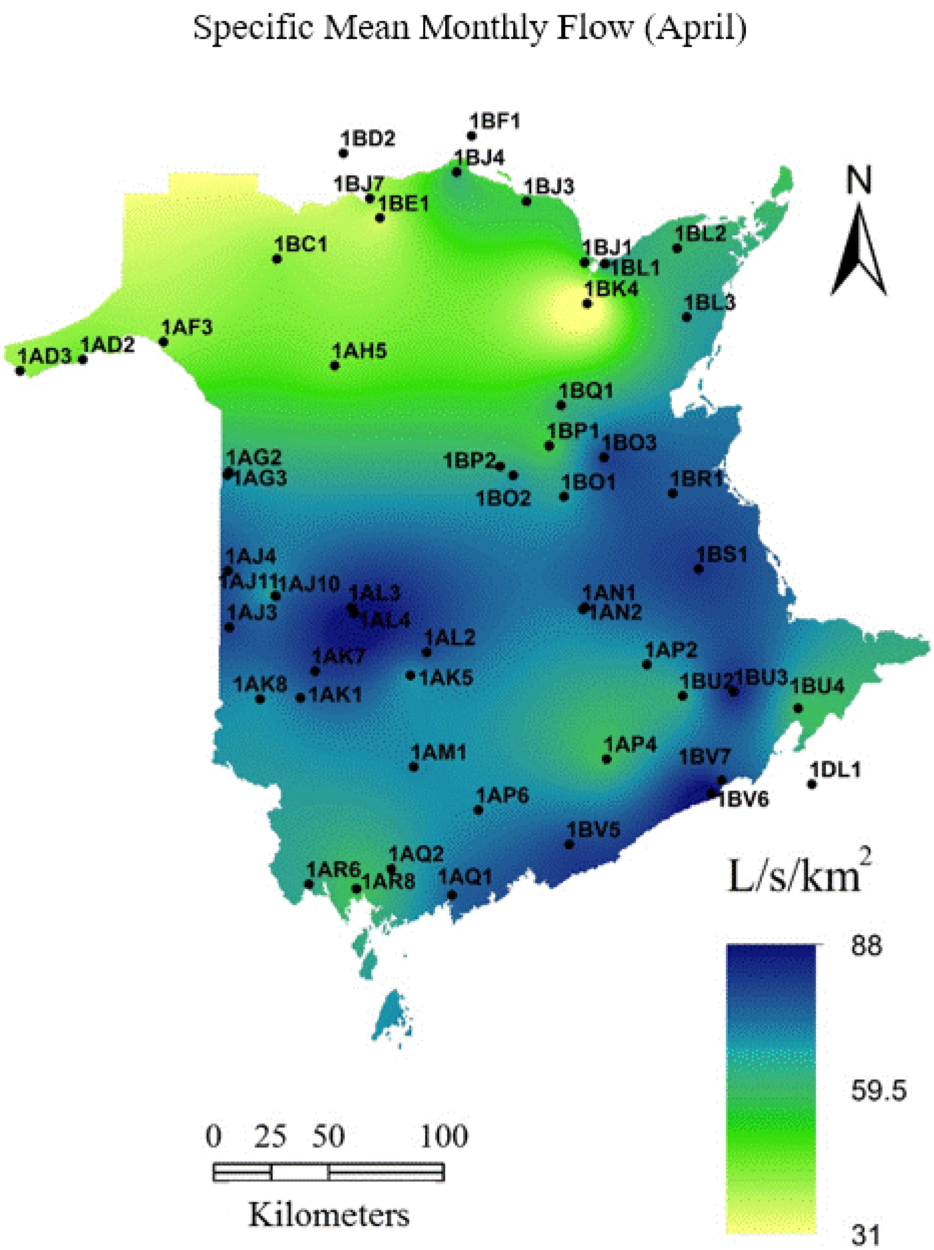


**Figure B4. Specific mean monthly flow for April in New Brunswick**

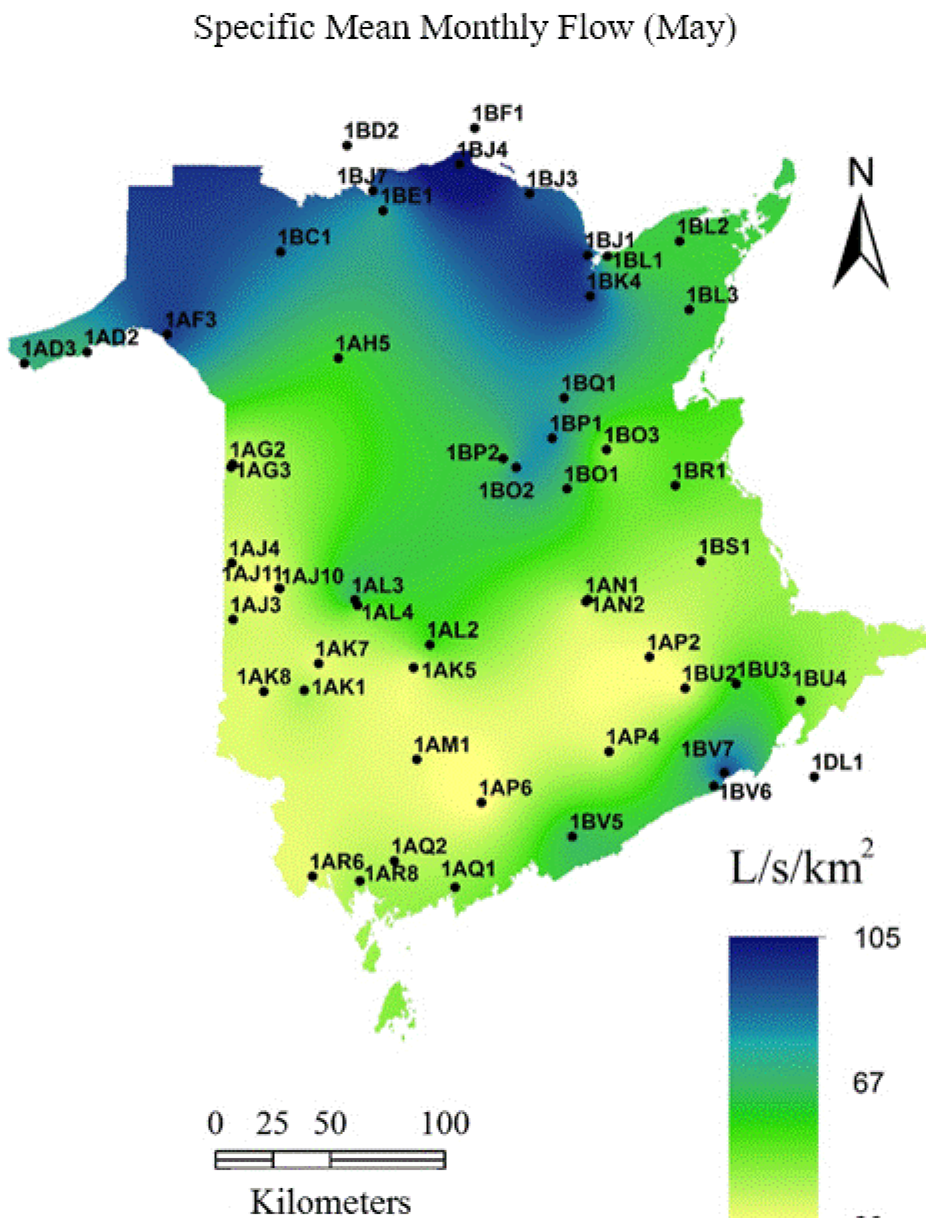


**Figure B5. Specific mean monthly flow for May in New Brunswick**

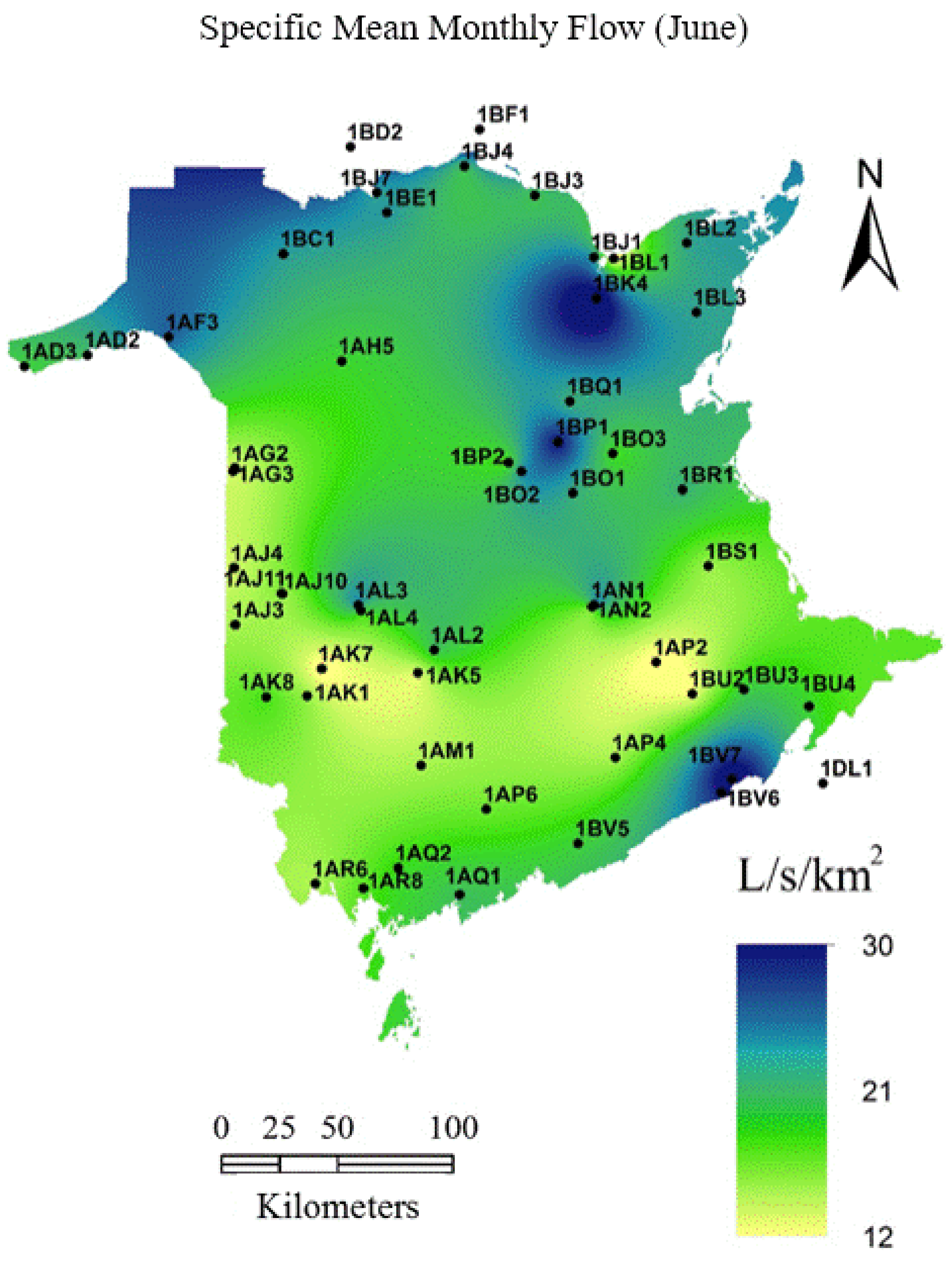


**Figure B6. Specific mean monthly flow for June in New Brunswick**

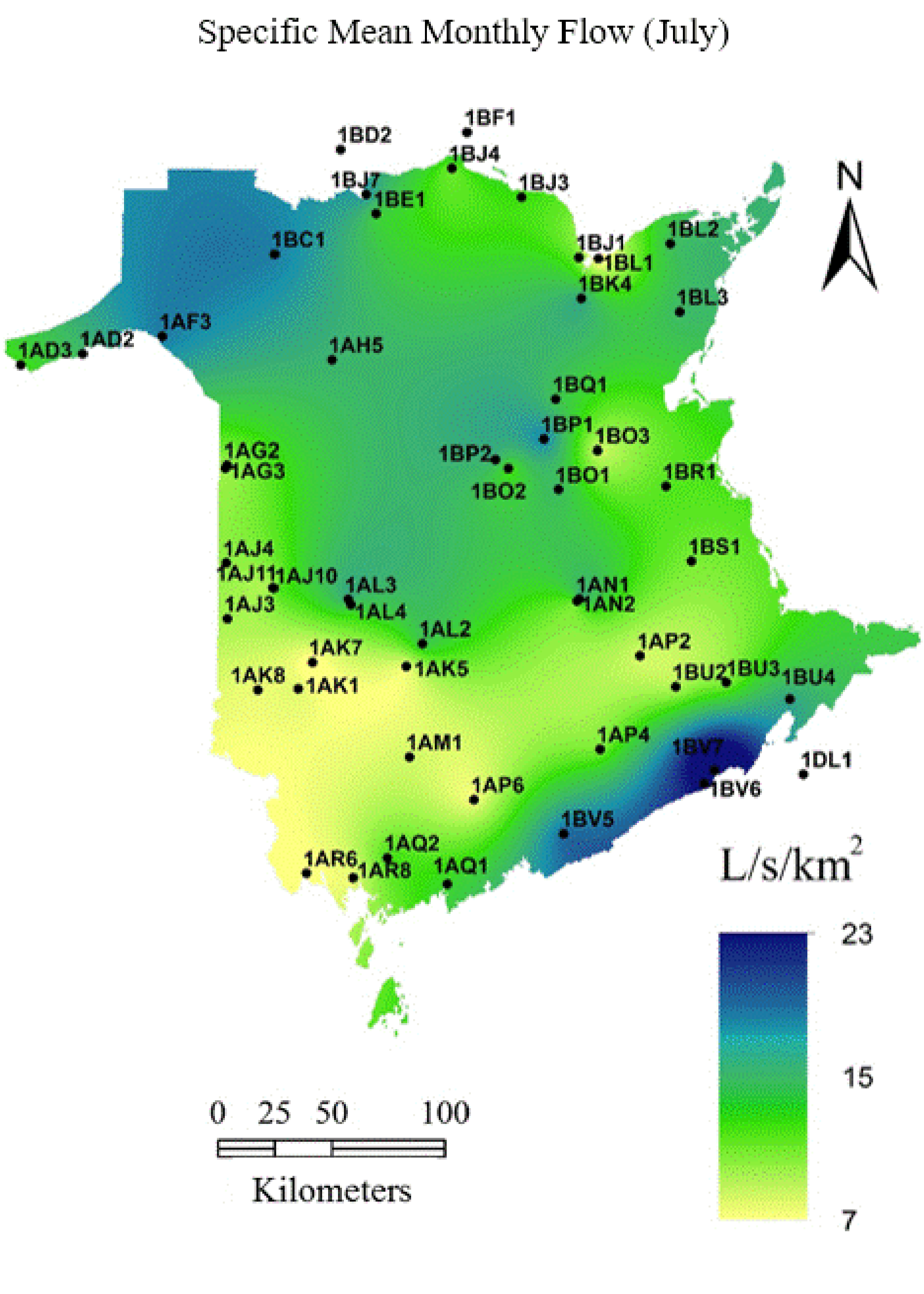


**Figure B7. Specific mean monthly flow for July in New Brunswick**

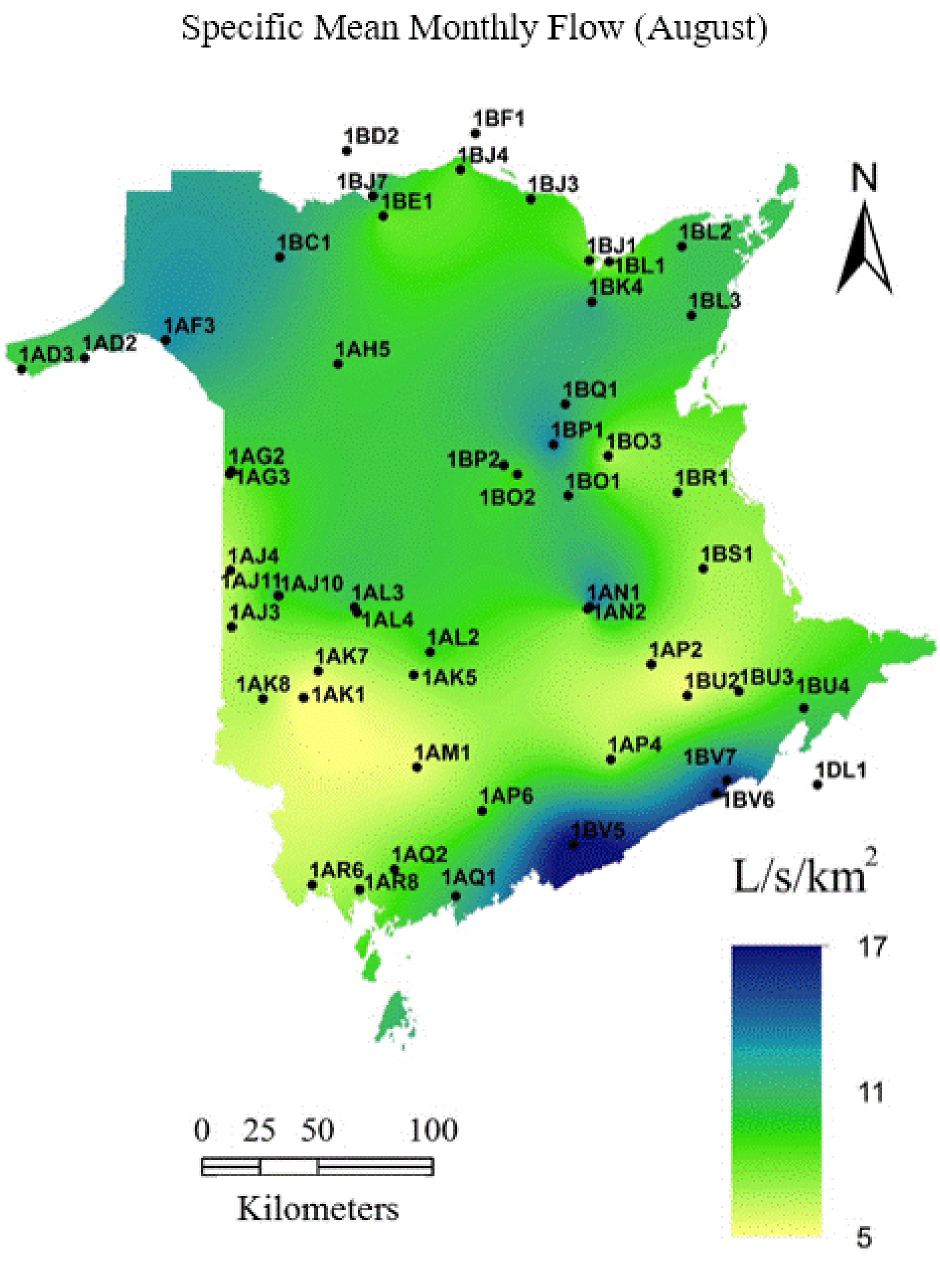


**Figure B8. Specific mean monthly flow for August in New Brunswick**

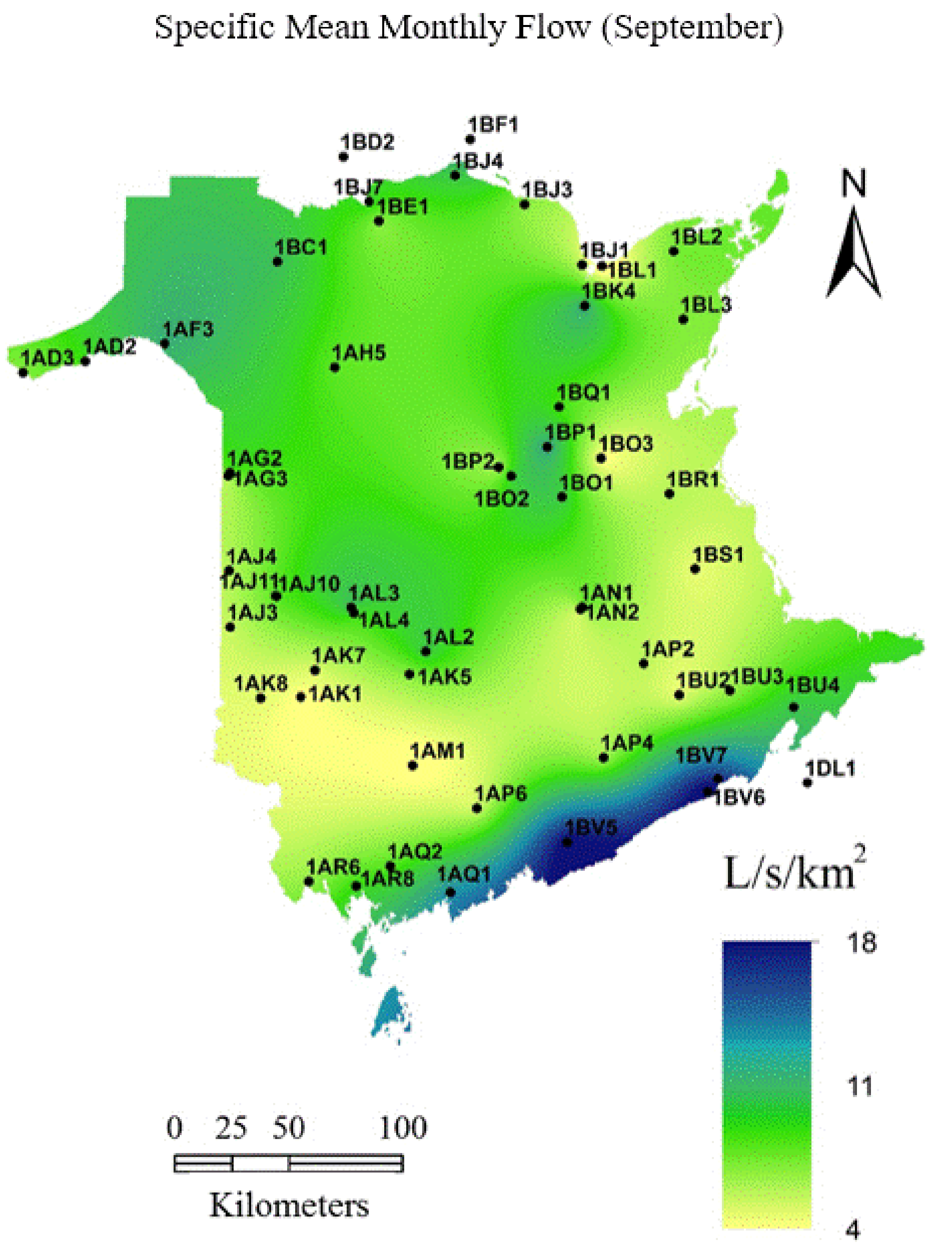


**Figure B9. Specific mean monthly flow for September in New Brunswick**

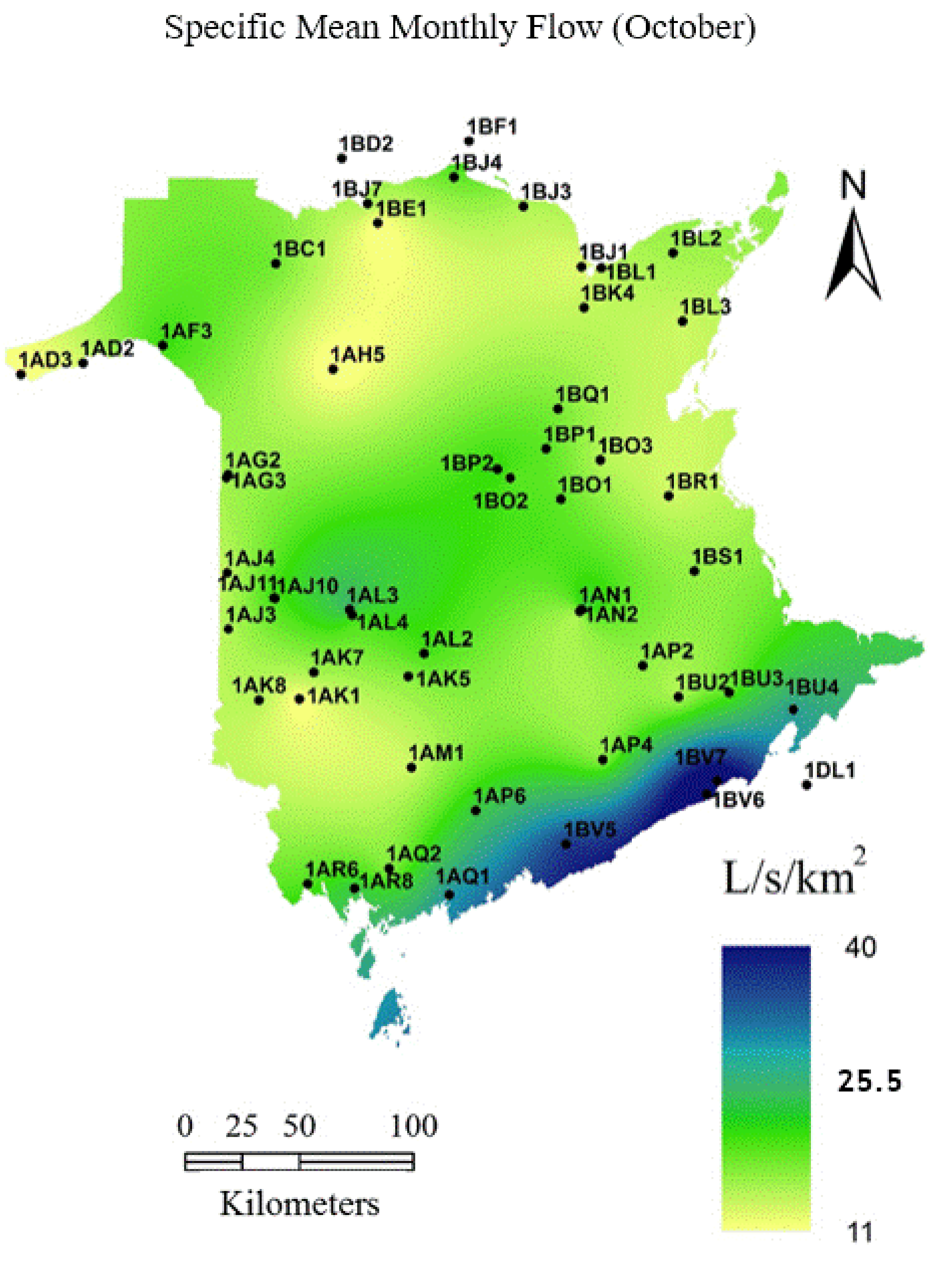


**Figure B10. Specific mean monthly flow for October in New Brunswick**

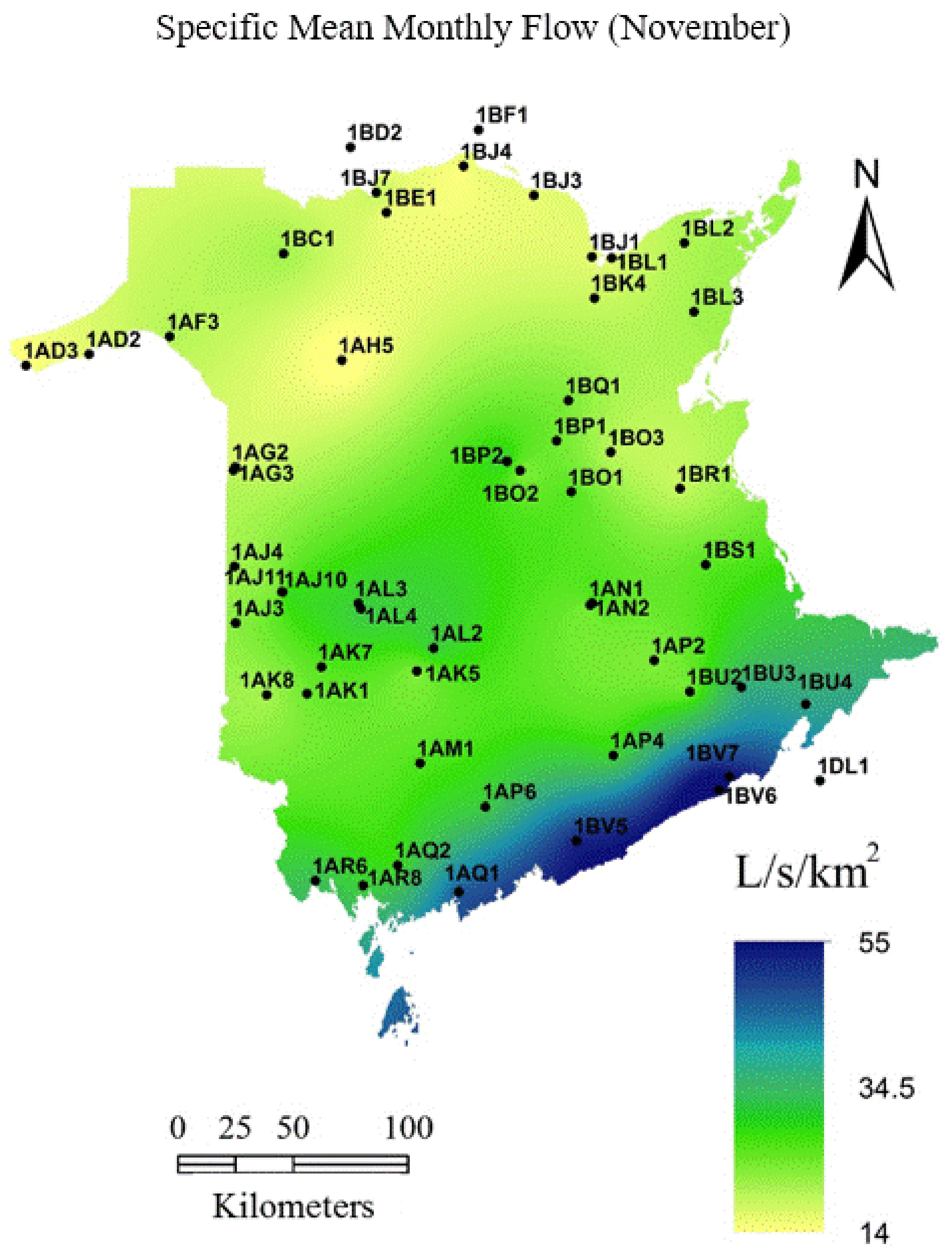


**Figure B11. Specific mean monthly flow for November in New Brunswick**

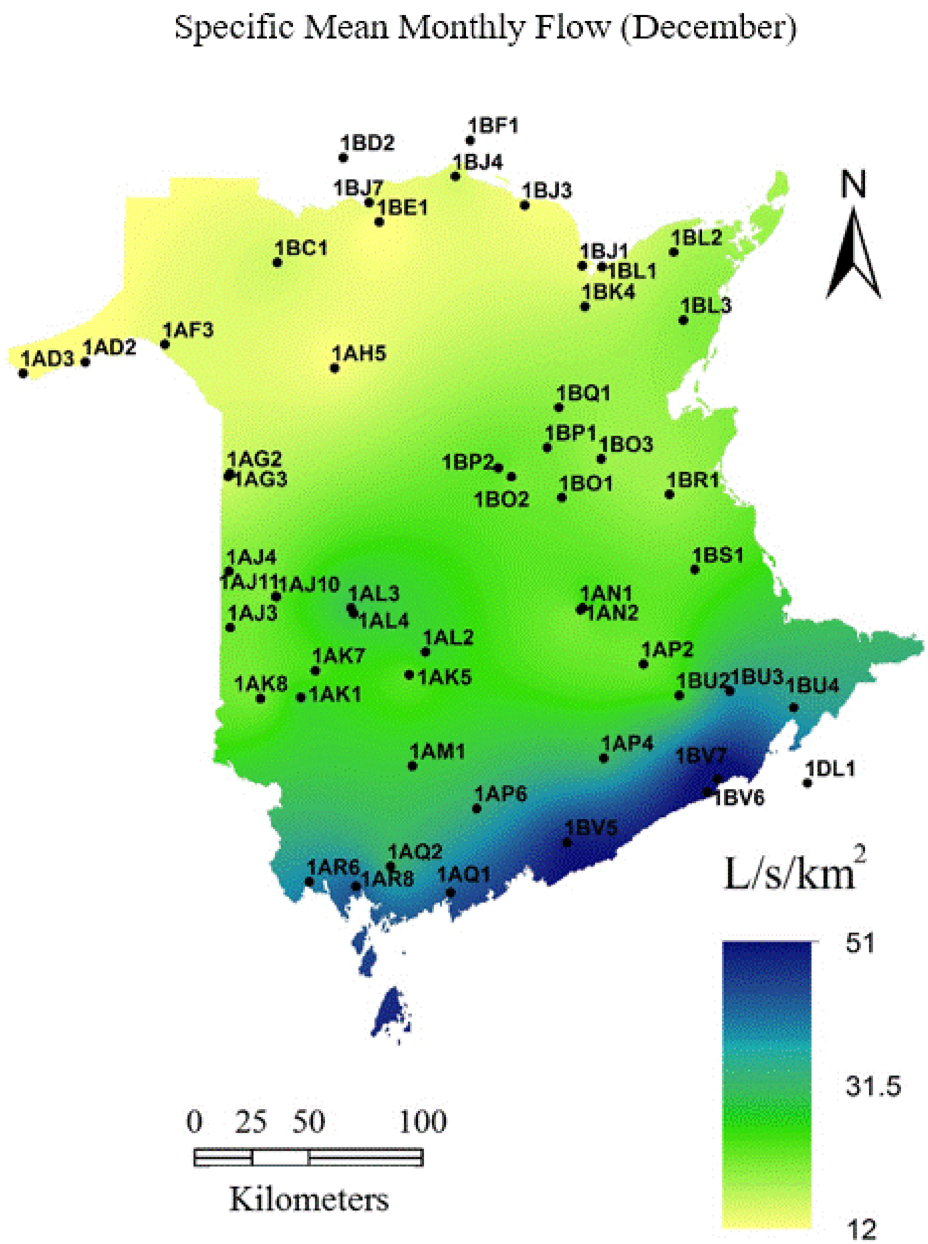


**Figure B12. Specific mean monthly flow for December in New Brunswick**

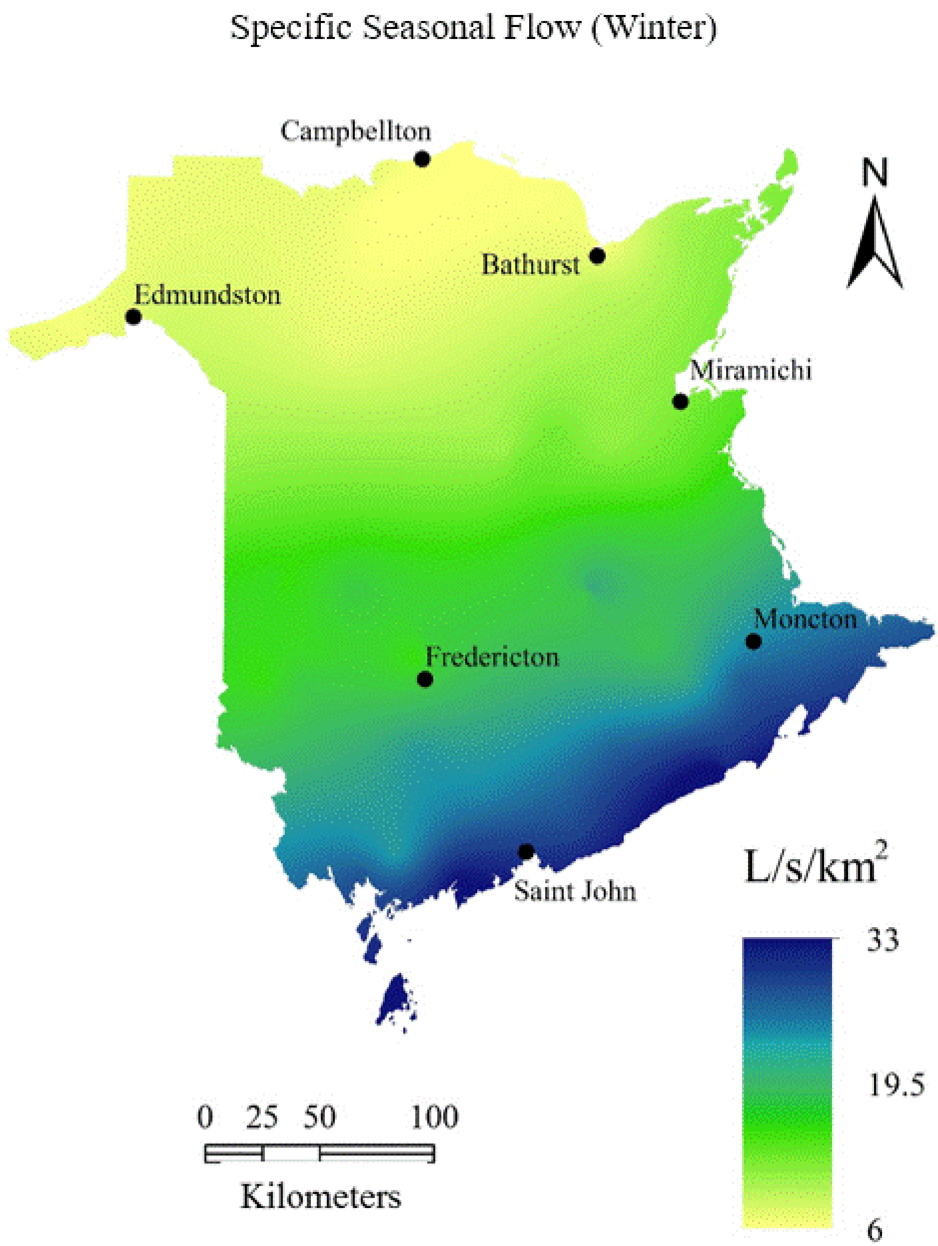


**Figure B13. Specific mean winter flow (January to March) in New Brunswick**

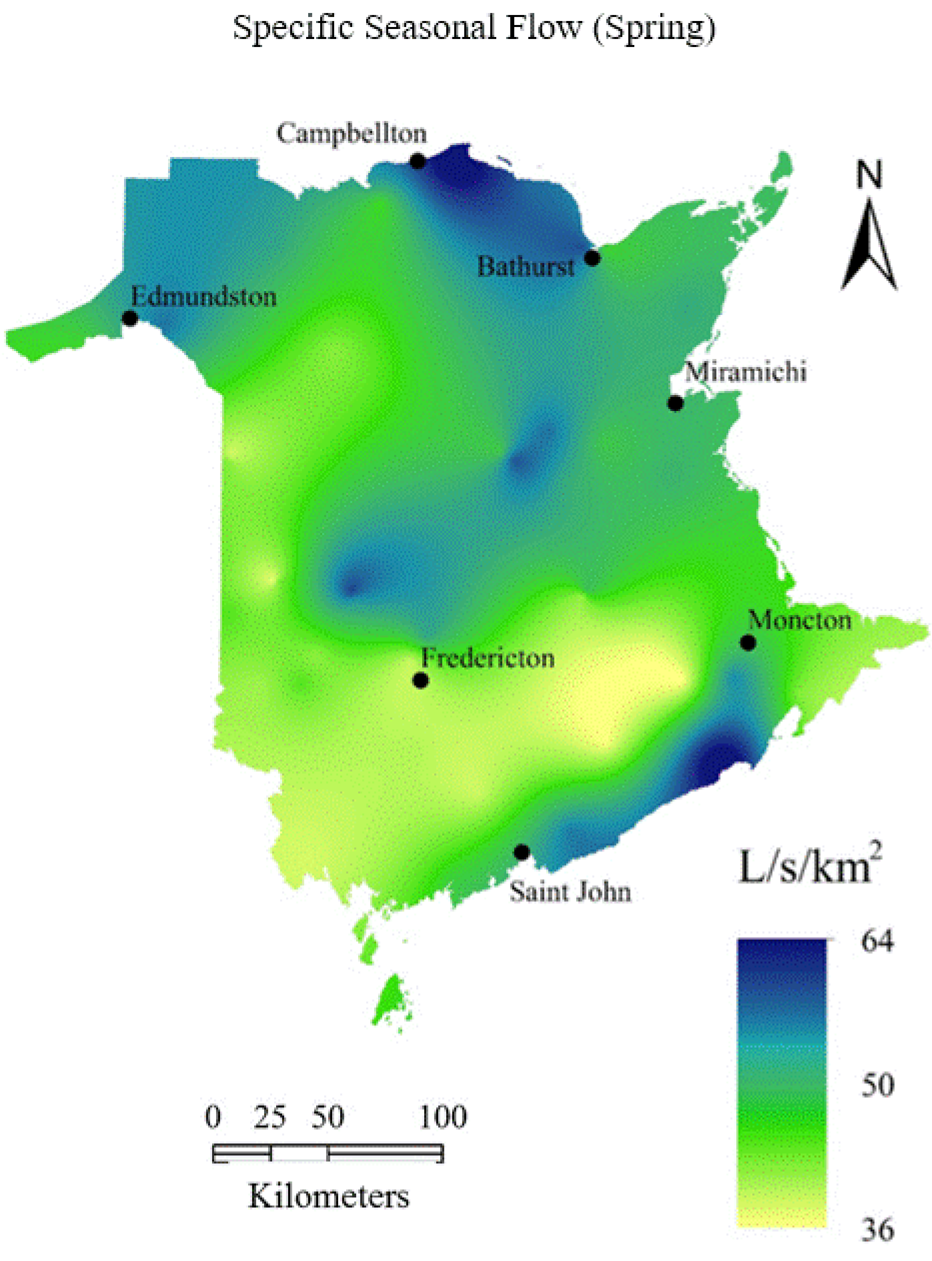


**Figure B14. Specific mean spring flow (April to June) in New Brunswick**

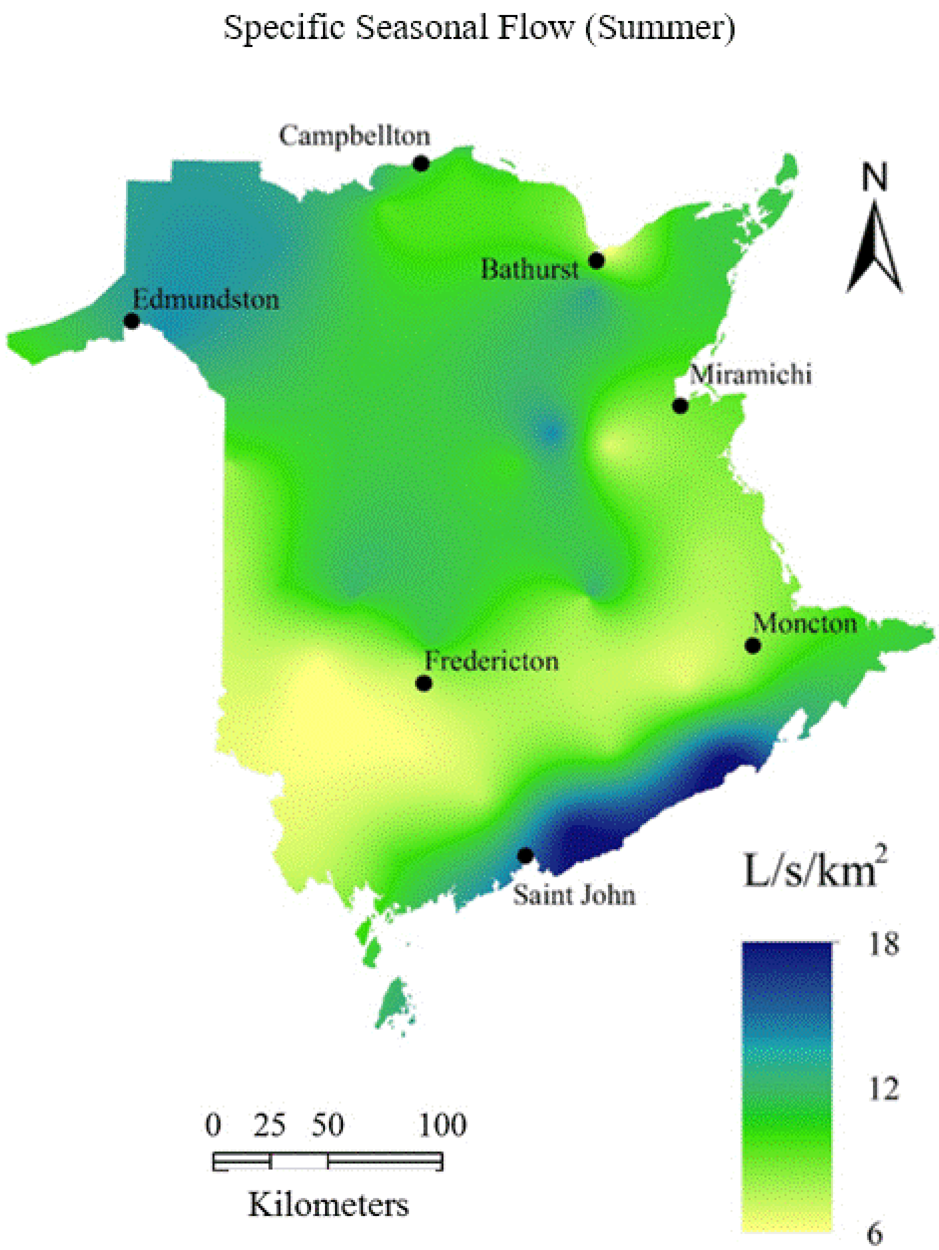


**Figure B15. Specific mean summer flow (July to September) in New Brunswick**

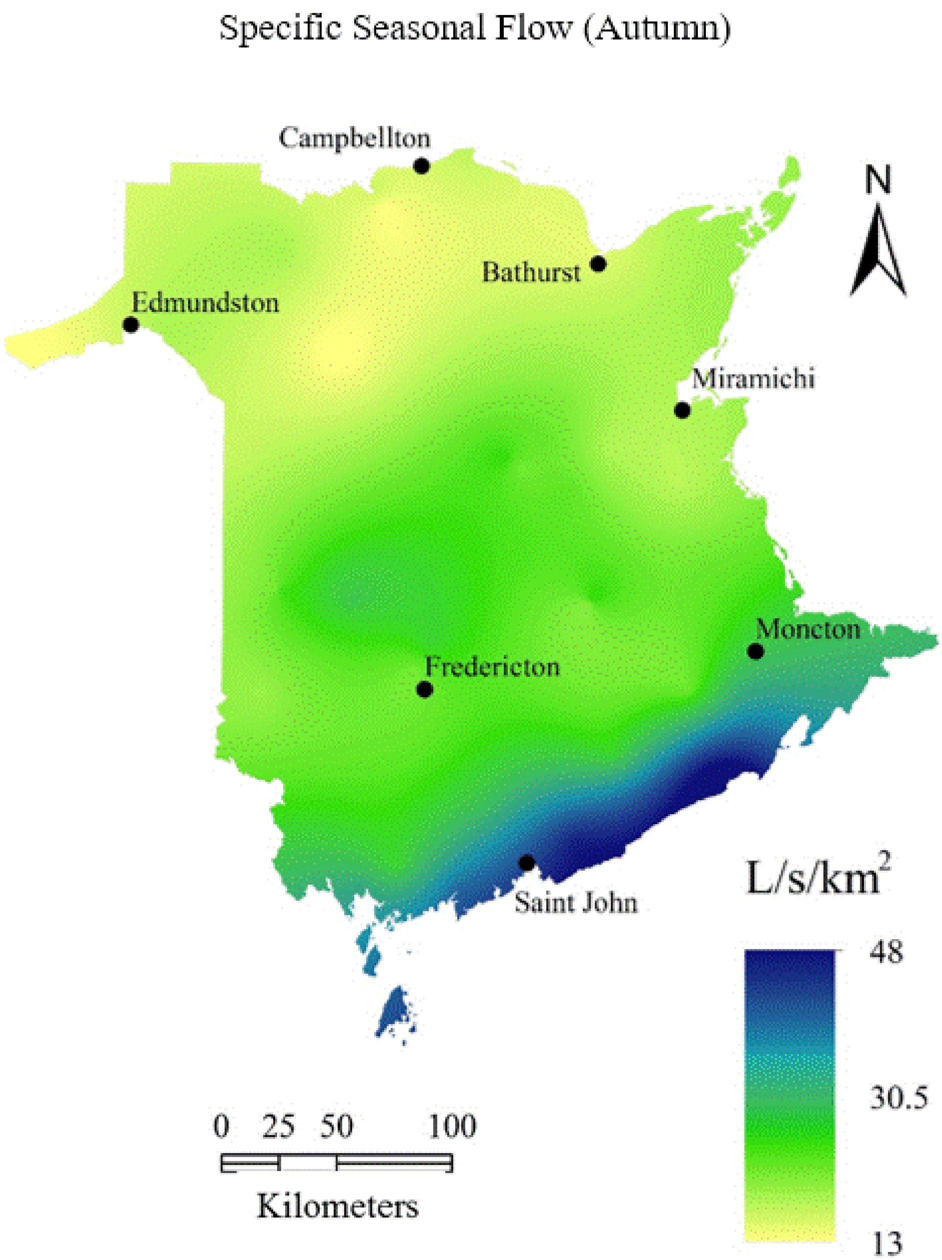


**Figure B16. Specific mean autumn flow (October to December) in New Brunswick**

## APPENDIX C: SPECIFIC WATER AVAILABILITY

- Specific Mean Monthly Water availability (Upper Target)
- Specific Seasonal Water availability (Upper Target)

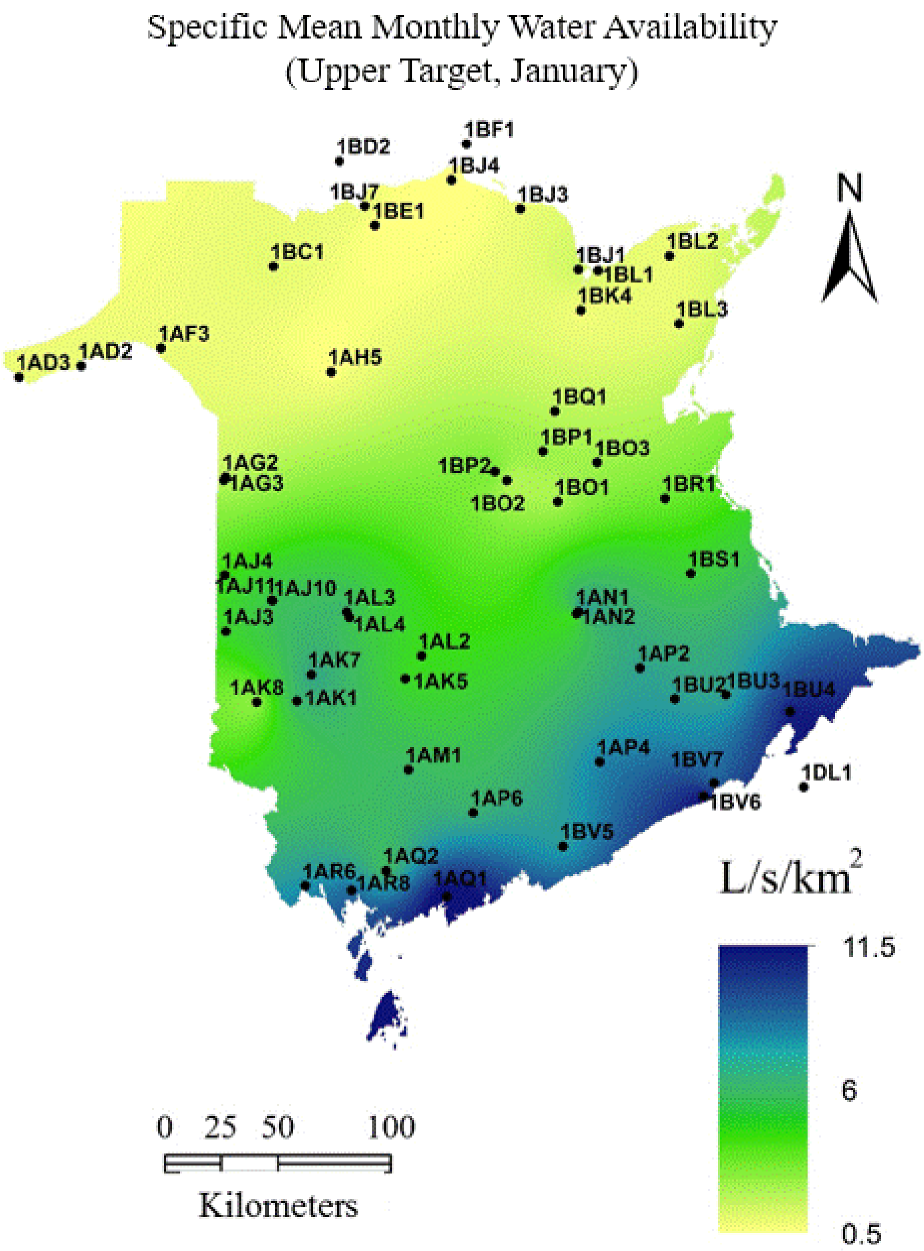


**Figure C1. Specific mean monthly water availability for January (upper target) in New Brunswick**

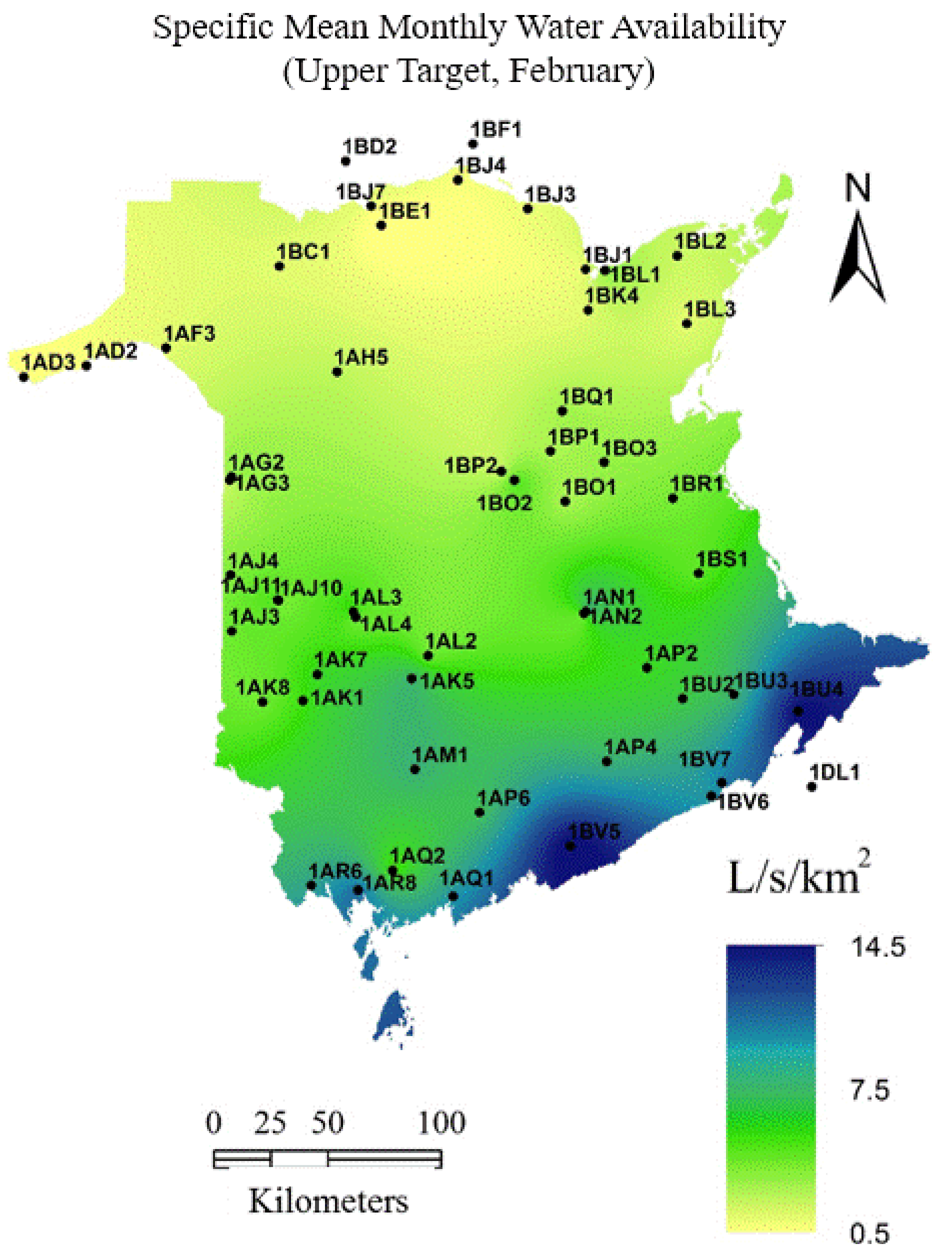


**Figure C2. Specific mean monthly water availability for February (upper target) in New Brunswick**

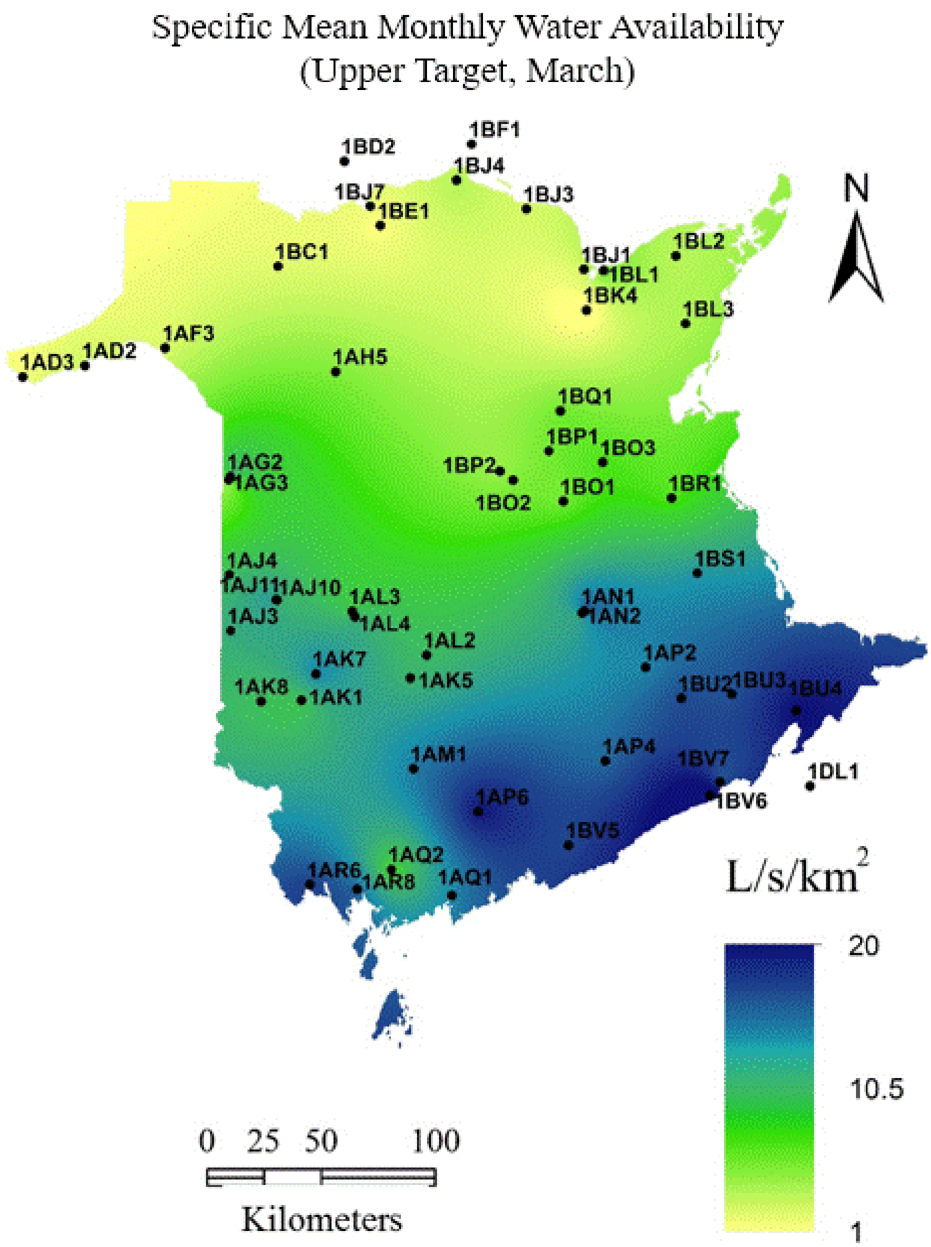


**Figure C3. Specific mean monthly water availability for March (upper target) in New Brunswick**

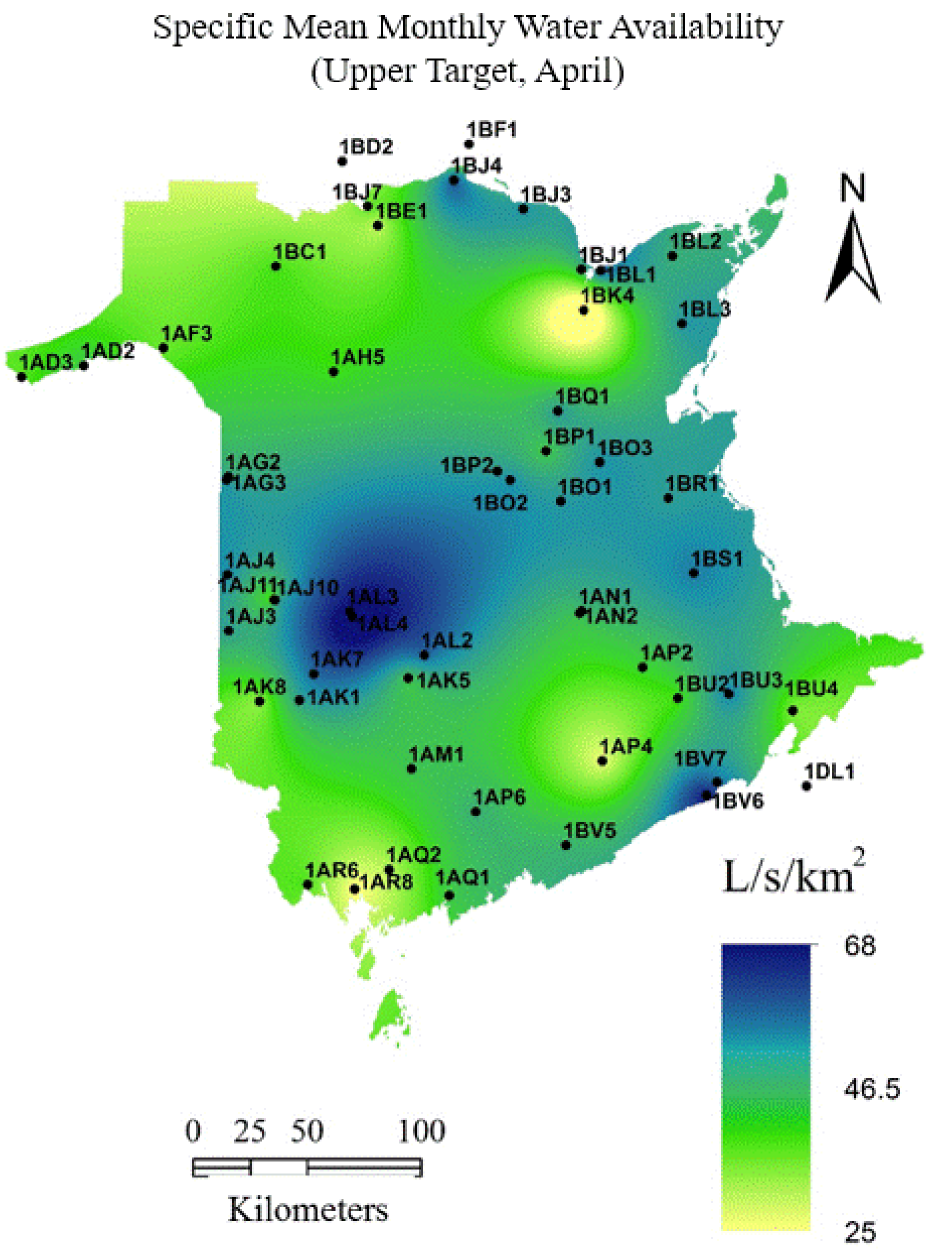


**Figure C4. Specific mean monthly water availability for April (upper target) in New Brunswick**

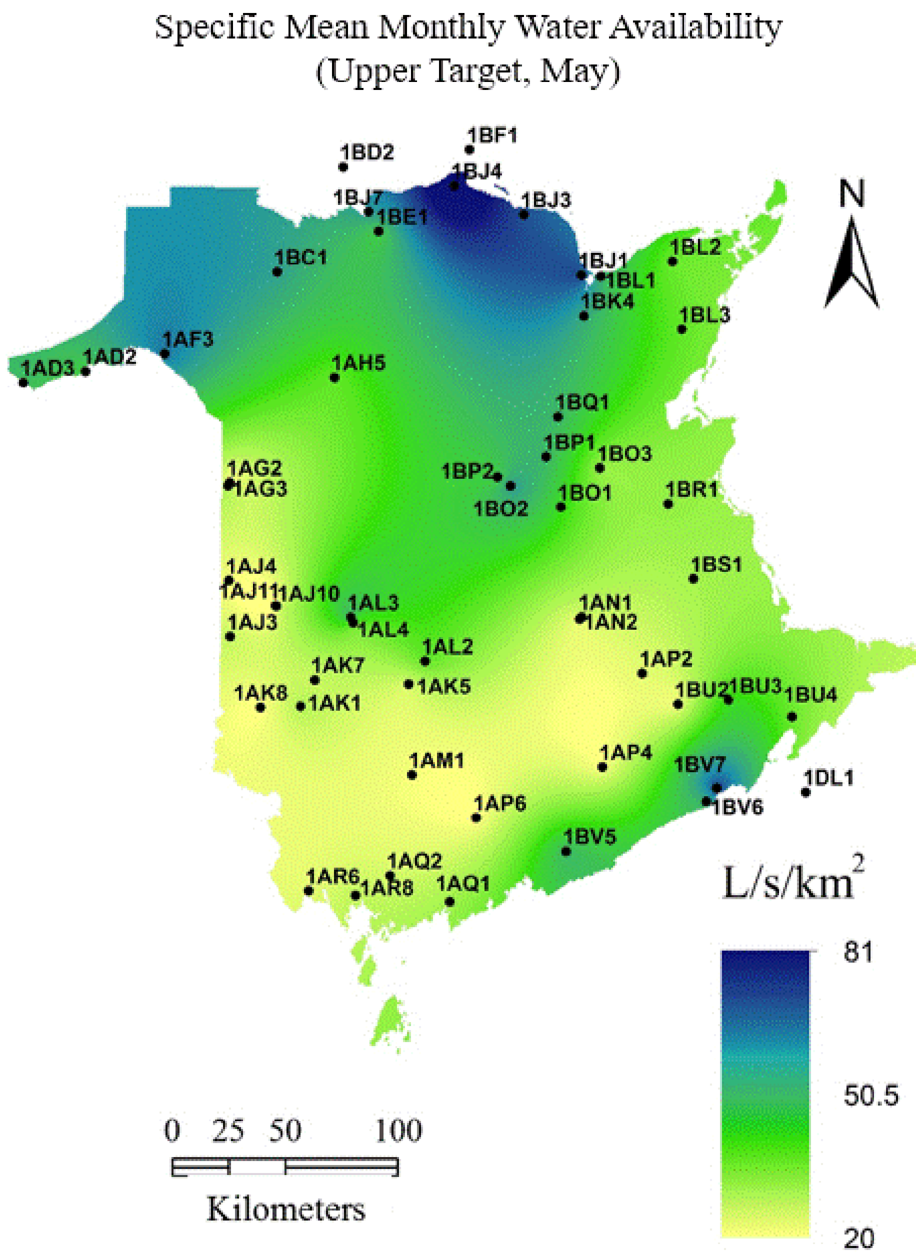


**Figure C5. Specific mean monthly water availability for May (upper target) in New Brunswick**

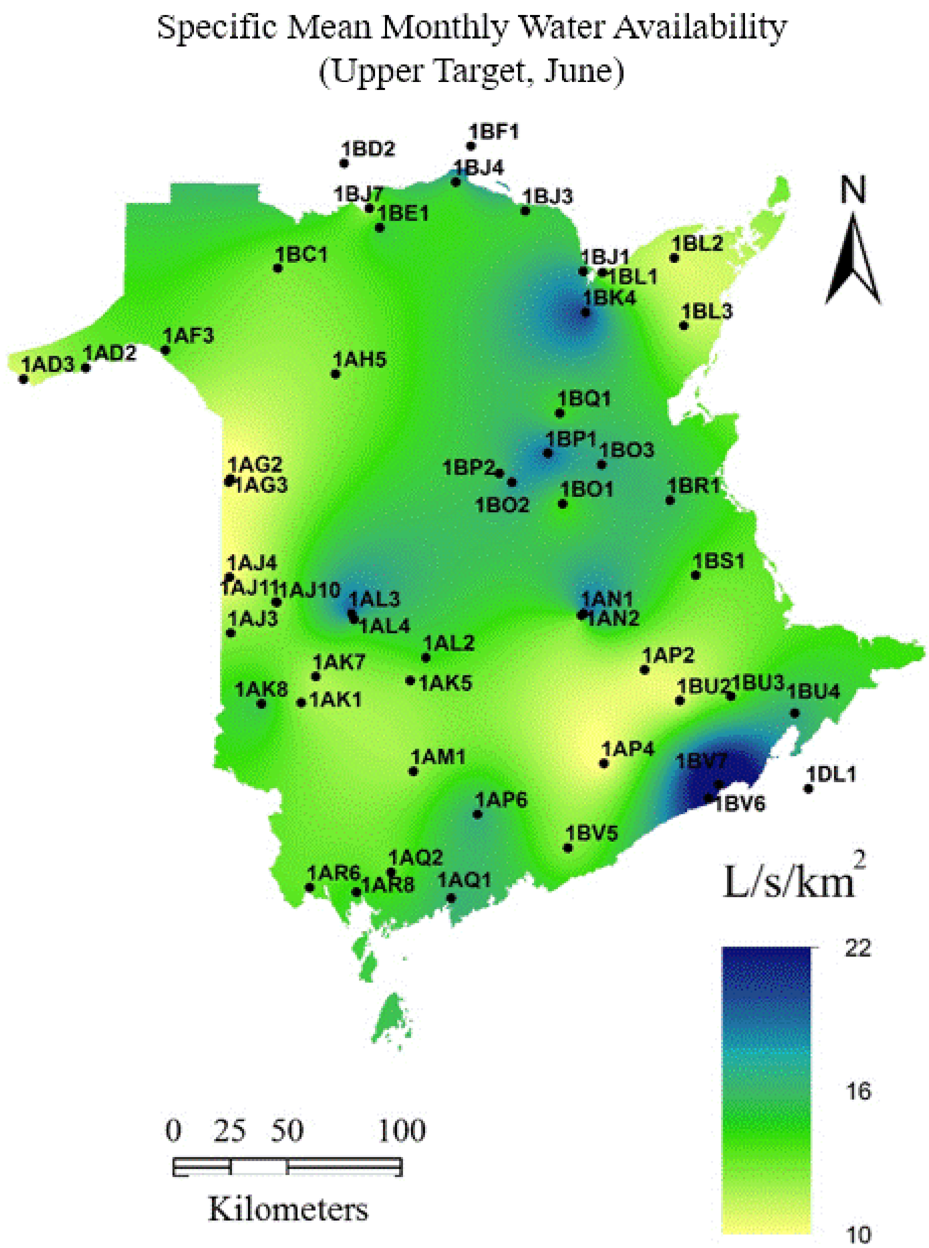


**Figure C6. Specific mean monthly water availability for June (upper target) in New Brunswick**

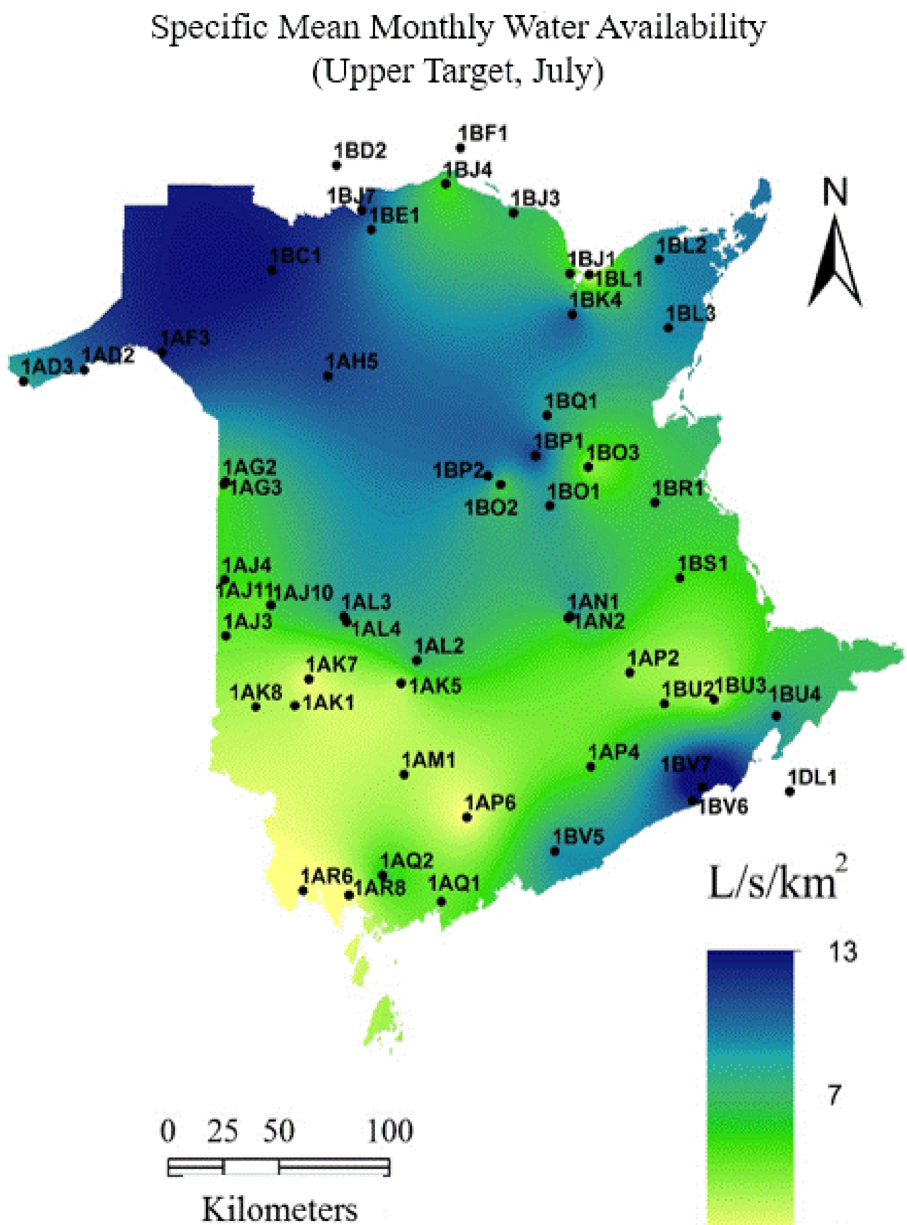


**Figure C7. Specific mean monthly water availability for July (upper target) in New Brunswick**

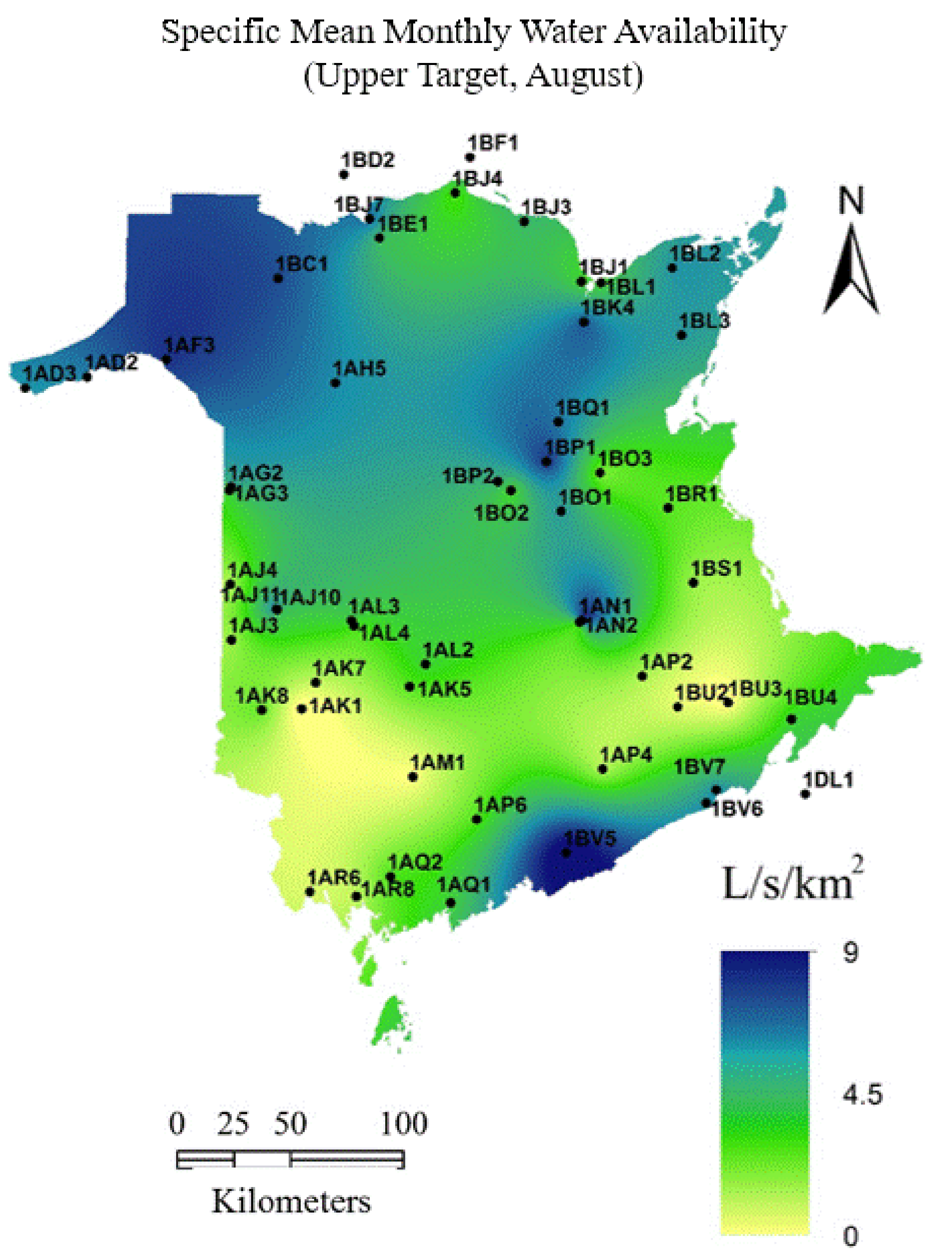


**Figure C8. Specific mean monthly water availability for August (upper target) in New Brunswick**

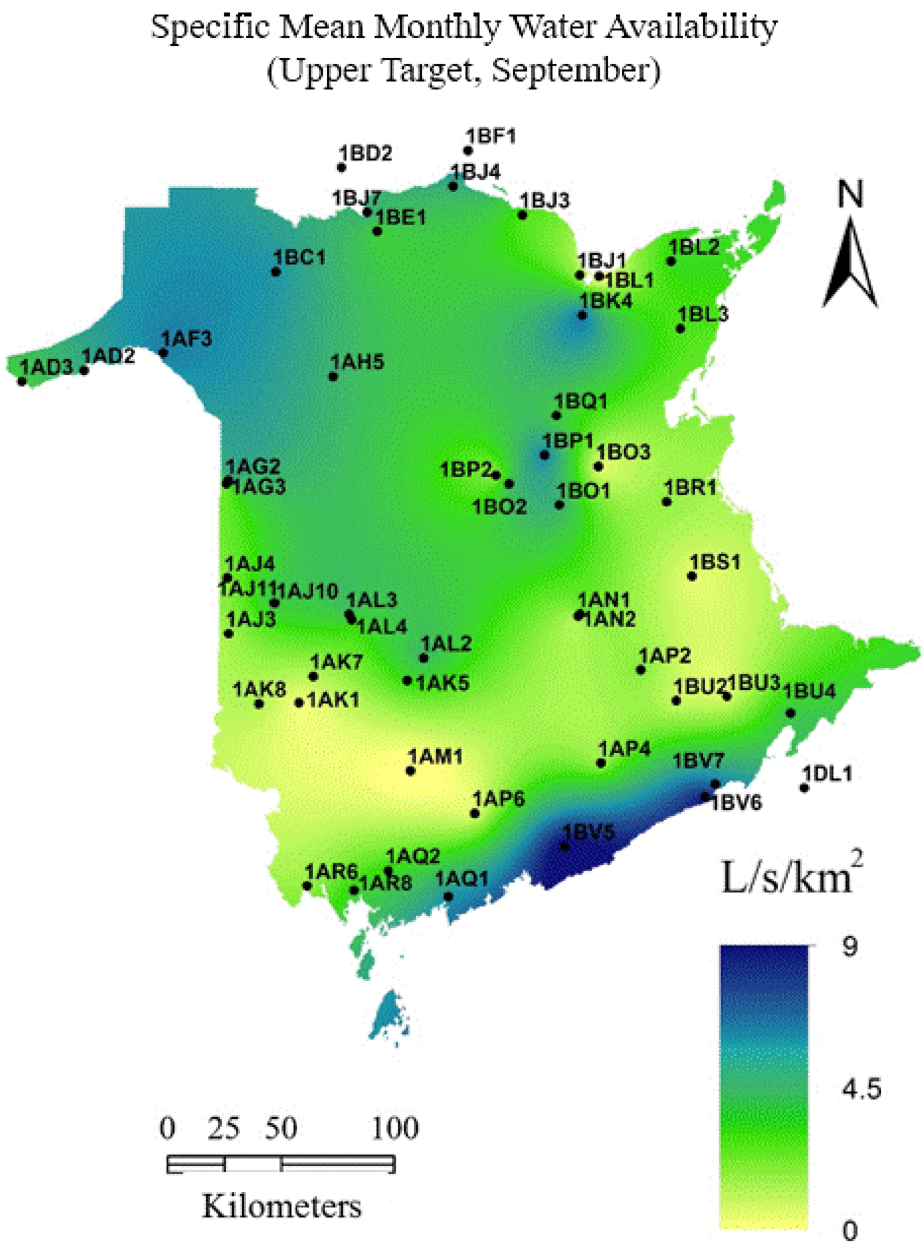


**Figure C9. Specific mean monthly water availability for September (upper target) in New Brunswick**

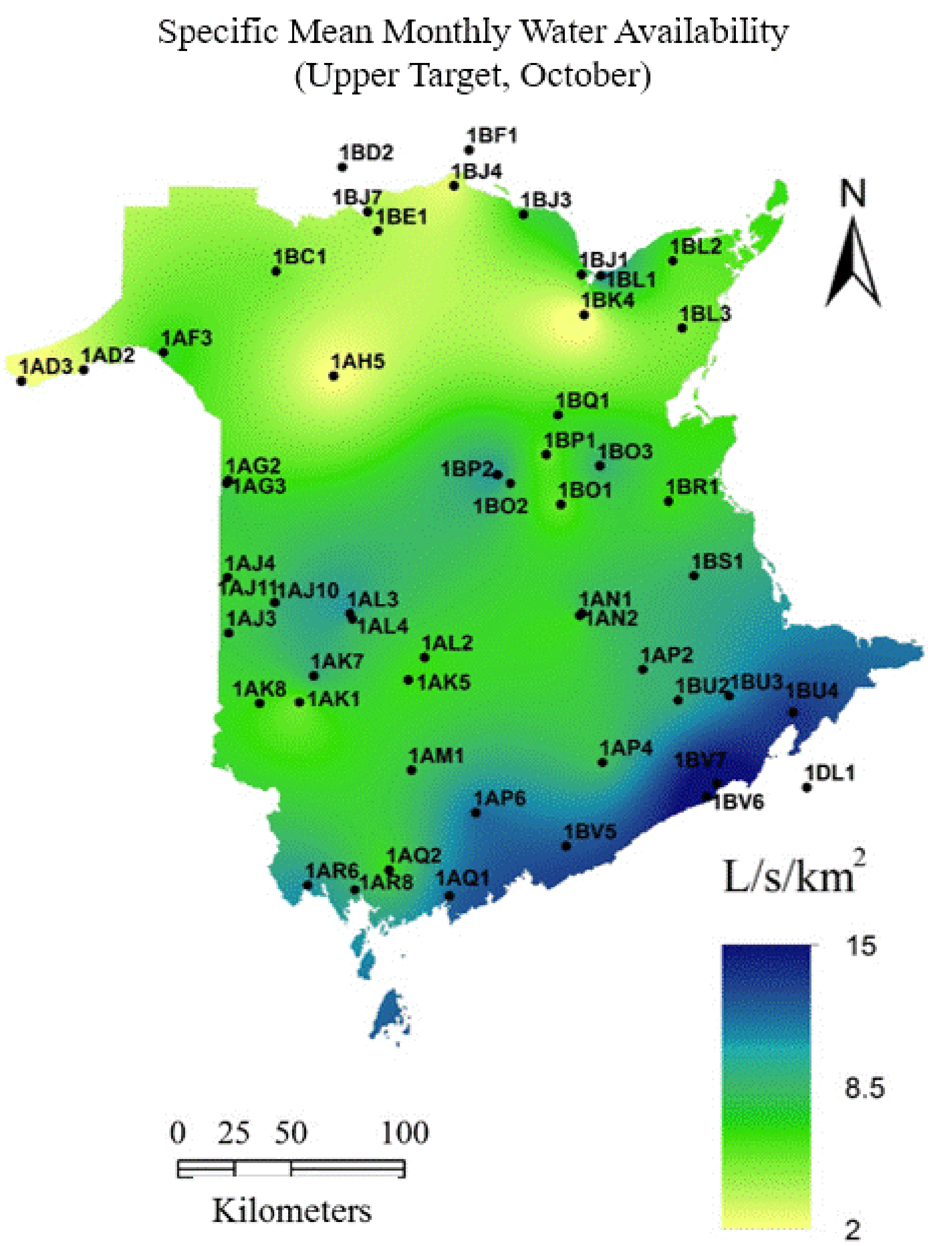


**Figure C10. Specific mean monthly water availability for October (upper target) in New Brunswick**

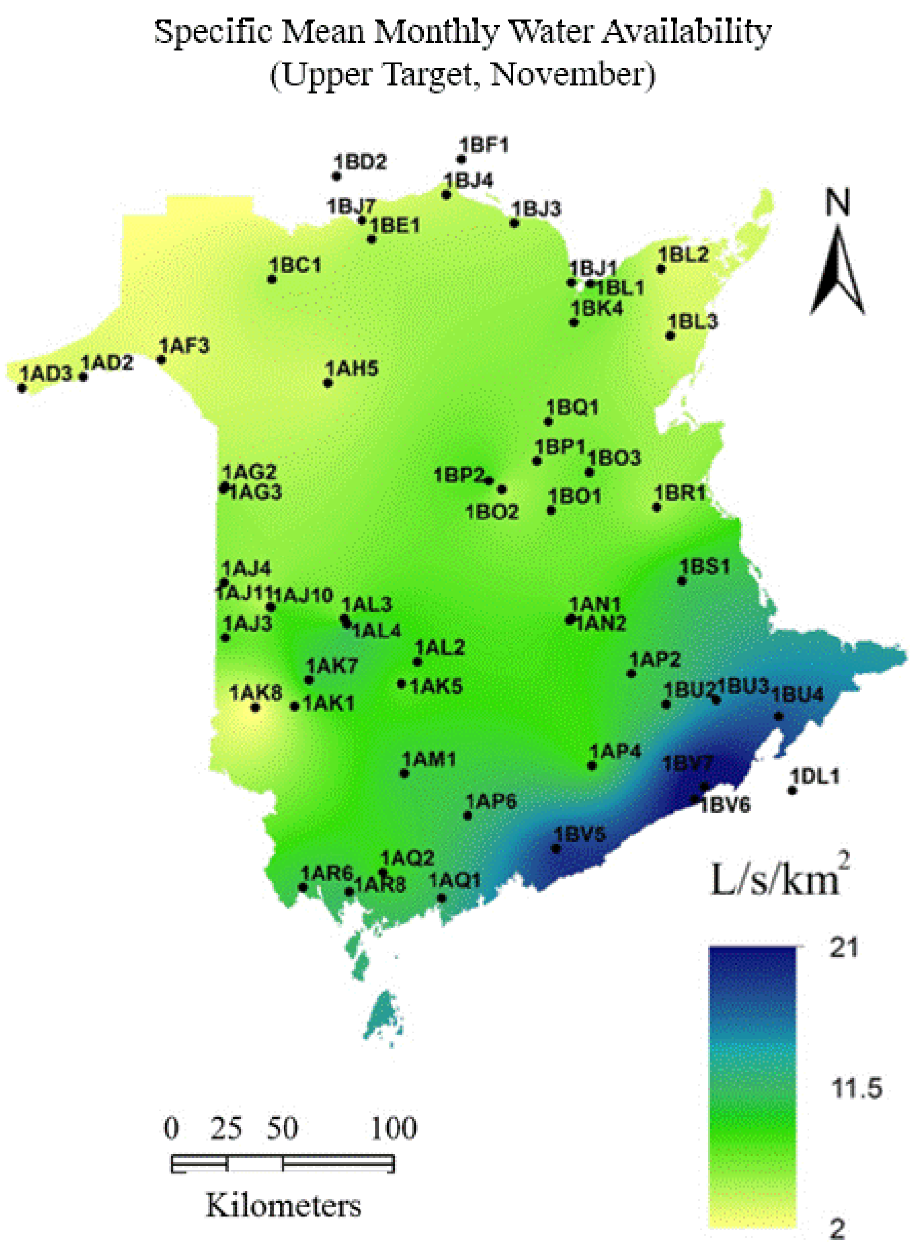


**Figure C11. Specific mean monthly water availability for November (upper target) in New Brunswick**

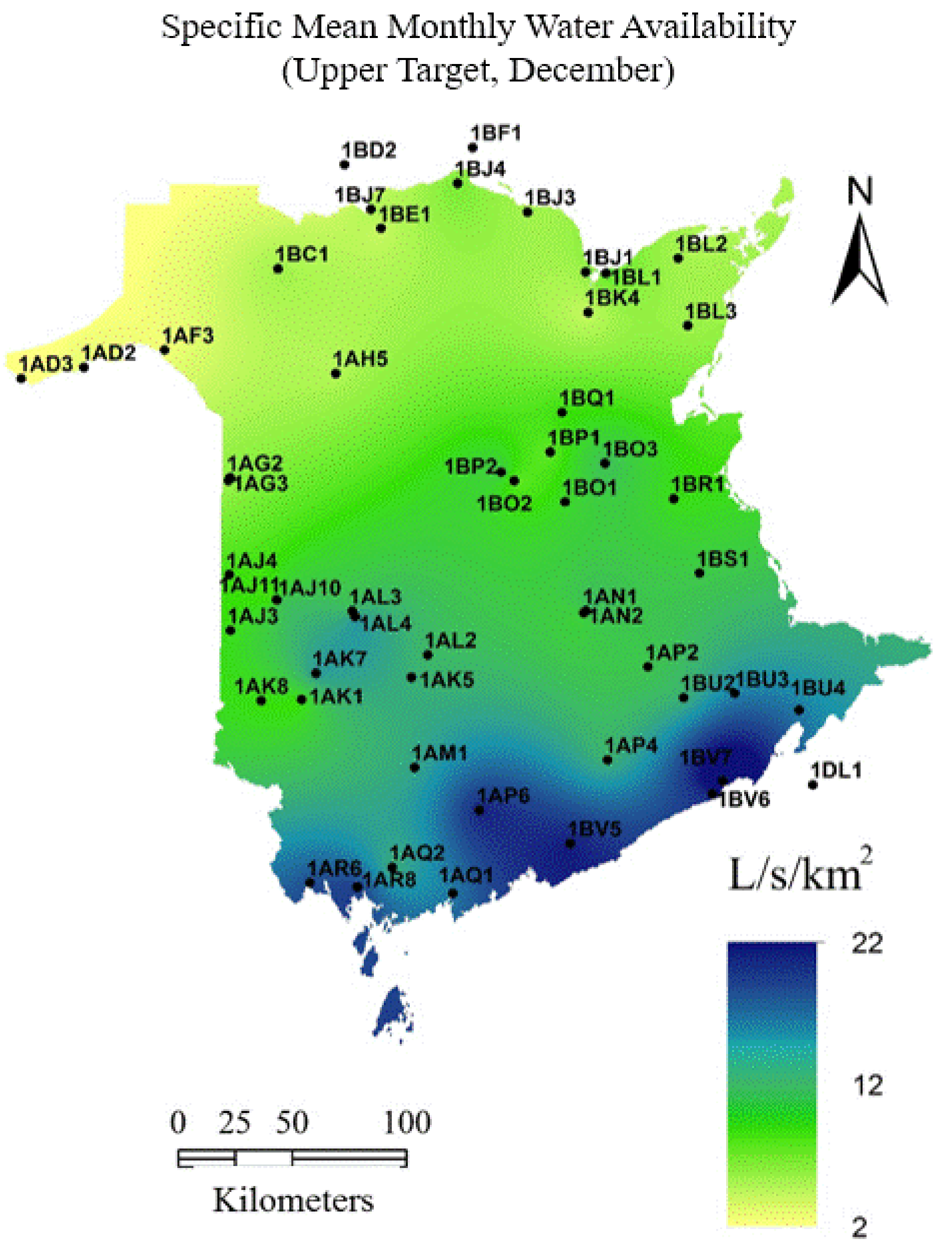


**Figure C12. Specific mean monthly water availability for December (upper target) in New Brunswick**

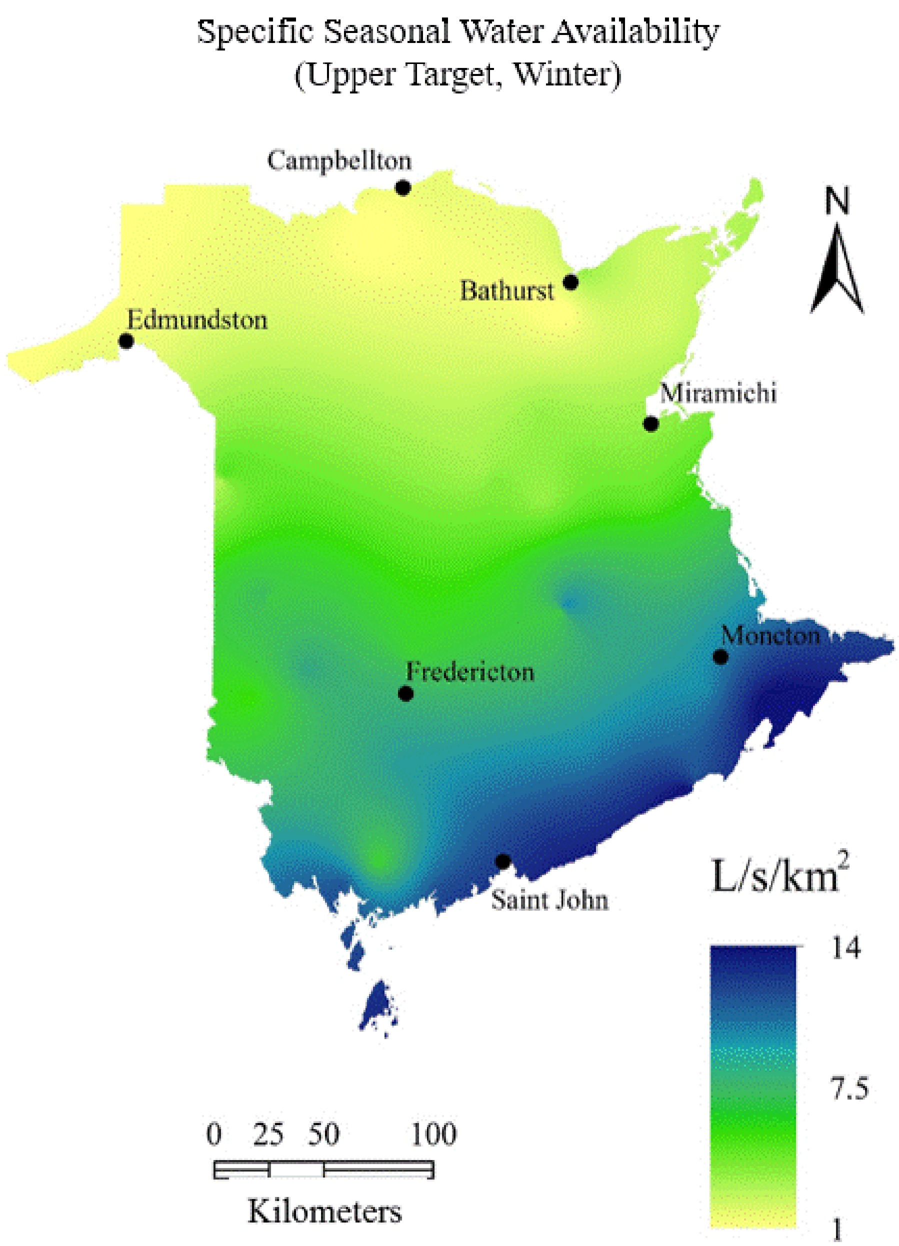


**Figure C13. Specific mean winter water availability (January to March), (upper target) in New Brunswick**

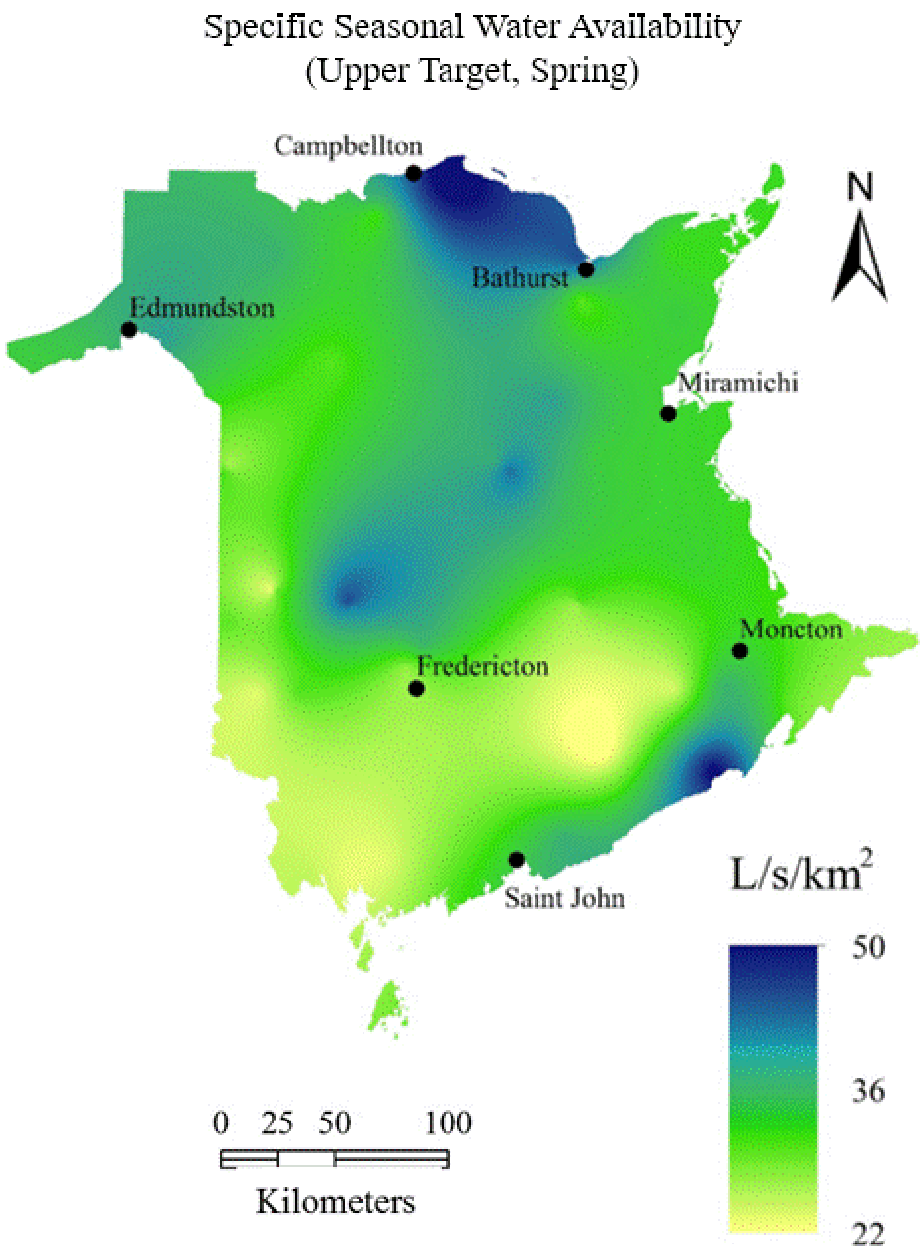


**Figure C14. Specific mean spring water availability (April to June), (upper target) in New Brunswick**

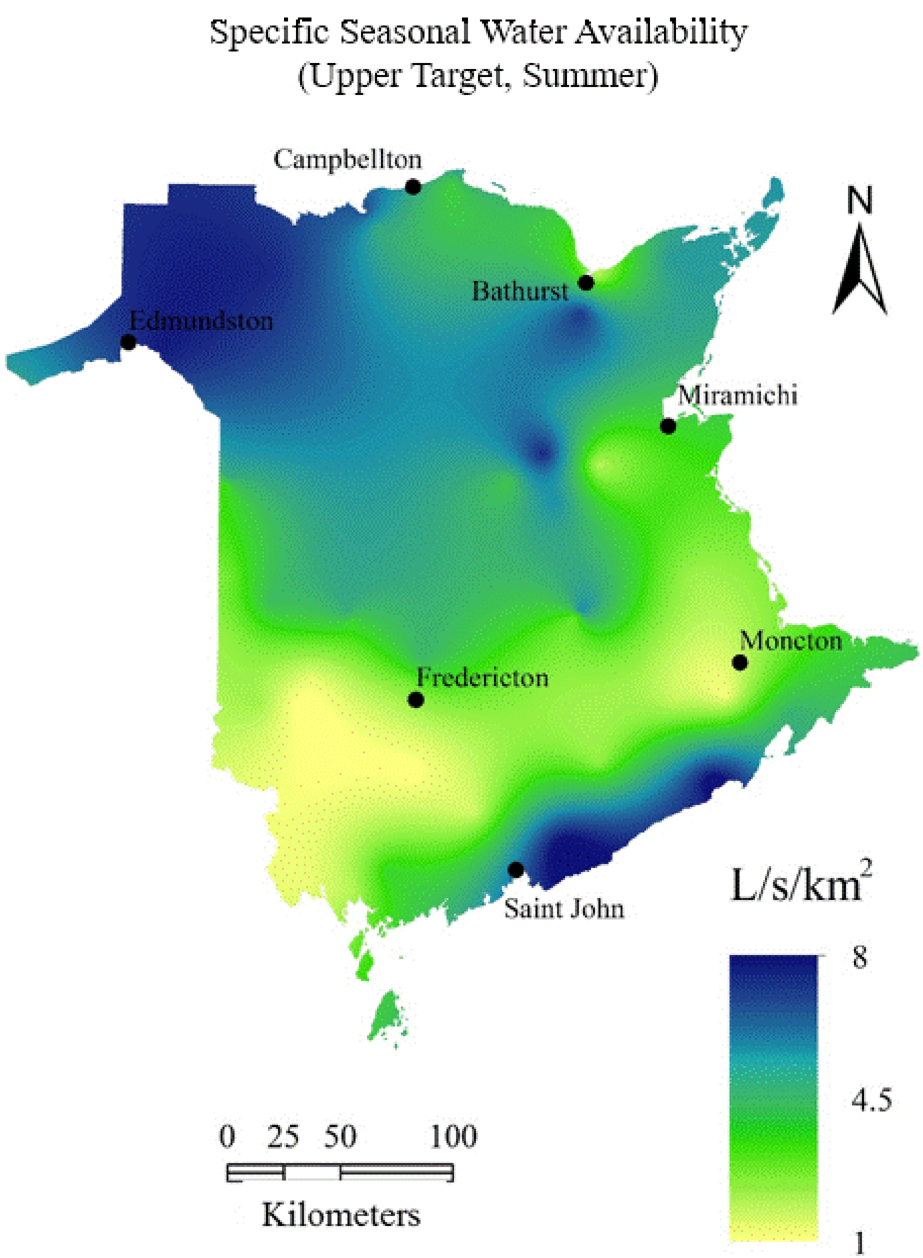


**Figure C15. Specific mean summer water availability (July to September), (upper target) in New Brunswick**

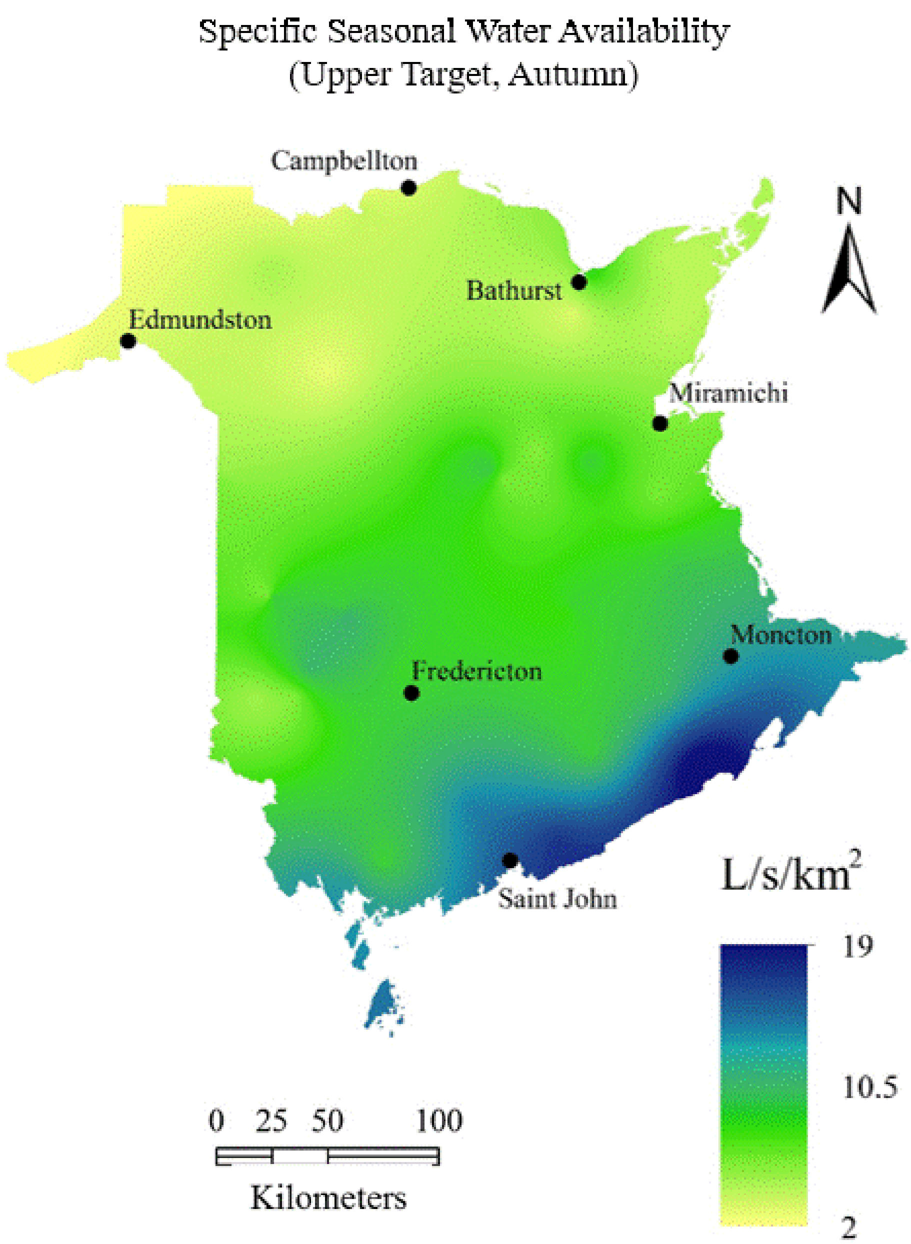


**Figure C16. Specific mean autumn water availability (October to December), (upper target) in New Brunswick**

New Nouveau Brunswick
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# WATER AVAILABILITY AND SECURITY IN NEW BRUNSWICK

## MARCH 2016