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Detection of Trends in Ice Season Characteristics of New Brunswick Rivers

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Analyses were performed on hydrometric data for 13 selected hydrometric sites in New Brunswick to detect trends in ice season characteristics (earliest and latest dates of ice effects on hydrometric records, the number of days with ice effect, freeze-up and breakup flows and the estimated number of break-up events each year). The coefficient of determination, r^2, and the p-value for the slope of a linear regression line were used to assess the significance of any possible trends in the data. The coefficient of determination, r^2, is a measure of the degree of relationship between two variables. The slope of the regression line depicts the average rate of change in a variable over time, and its probability indicates if the slope value is statistically significantly different from zero. In the absence of more specific information, the notation of a backwater effect in the hydrometric records was used to evaluate the beginning and end of periods of ice, the number of ice-covered periods and the duration of the ice season. The existence of a backwater effect is indicated in Environment Canada's HYDAT database by the symbol "B". It was found that trends in hydrologic data are beginning to appear in the hydrometric records. As the climate continues to change, trends in hydrologic data are expected to be more evident and statistically significant.

1.0 Introduction

A study was undertaken to ascertain if significant trends in selected hydrologic parameters attributable to climatic change could be detected using the hydrometric records of 13 hydrometric stations in New Brunswick, Canada (Figure 1, Table 1). The parameters related to ice season characteristics that were analyzed to determine the presence of trends included mean winter and spring seasonal daily flows, the Julian dates of spring flooding, earliest and latest dates of ice effects on hydrometric records, the number of days with ice effect, and the estimated number of break-up events each year.

Typically, ice covers form on New Brunswick rivers by mid December and obtain a maximum thickness near mid March. Midwinter breakup can occur, especially on southern rivers.

The presence of river ice can have significant effects on economic systems, including hydropower generation, infrastructure maintenance and repair, and winter outdoor recreation. One of the most significant effects is the increased potential for damaging flood events due to ice jamming, as evinced by the long history of damaging ice-related flood events in the Province. Changes in river-ice regimes are also indicators of changing hydro-climatic conditions.

2.0 Trend Analyses Methodology

Stations were selected based on the following criteria: natural flow > 25 years of record, active at the end of the available period of record, and drainage basin area > 150 km^2.

River ice increases boundary roughness thereby decreasing flow conveyance and increasing water levels at affected hydrometric stations. This backwater effect on hydrometric records is indicated in the HYDAT database by the symbol "B". The determination of the first and last dates of the backwater effect at hydrometric stations depends upon the method selected to determine the presence of backwater and on the judgment of the hydrometric technician. Backwater effects can be created by ice at the gauging station or further downstream in the stretch of river on which the hydrometric station is located. Nevertheless, in the absence of more specific information, the notation of a backwater effect in the hydrometric records is often used to evaluate the beginning and end of periods of ice, the number of ice-covered periods and the duration of the ice season.

Time series data was extracted form Environment Canada's Archived Hydrometric Data HYDAT and entered into an EXCEL spreadsheet. To determine if there is a statistically significant increasing or decreasing trend rather than random observations, r^2 and the p-value for the slope of the line were used

The coefficient of determination, r^2, is a measure of the degree of relationship between two variables. Lower values indicate increasing amounts of scatter in the data. In the case of a time series, the value of r^2 indicates how much (or how little) a change in the parameter of interest is correlated with time. The statistical significance of the trend line, however, is not dependent on the r^2 value.

The probability value (p-value) reflects the likelihood that results are due to chance. The slope of the regression line is the average rate of change in a variable over the period examined, thereby representing the rate at which change occurs over time. If the value of the slope is zero, no trend exists. To determine if the slope value is significantly different from zero, its probability is determined. The p-value, therefore, is a measure of how likely it is that there actually is a trend (a non-zero slope) in the data. Technically, p is the likelihood at some significance level α of obtaining the derived results if the parameter being observed was truly constant with the independent variable. Therefore, if $p < \alpha$, then it can be stated with a confidence level of $1-\alpha$ that a trend exists (since there is only a probability of p of explaining the results if there is not a real trend). For example, if α is 0.05 (or 5.0%), then p = 0.047 (or 4.7%) would show a confidence of 95% (i.e. $1-\alpha$) that a trend exists since there is only a 4.7% chance that the data could have come from a system where there was, in fact, no trend. One caution concerning the p-value is that it assumes the data is normally distributed.

For most of the annual parameters at most of the stations, no significant trend was found to exist at a normal confidence level (90% or 95%). Therefore, to ascertain if trends exist, the acceptable confidence level was lowered to 70%, as more trends would be significant.

3.0 Presentation and Discussion of Results

Winter and Spring Seasonal Flow Trends. Seasonal values were determined based on dates defined by the solstice (e.g., summer from June 21 to Sept. 21). Table 2 and 3 (and Figures 2 and 3) present the results for the annual mean daily winter and spring season flows, respectively.

At 11 of the 13 stations there is an upward trend, as indicated by a positive slope, meaning that mean winter flows generally appear to be increasing (Table 2, Figure 2). At five of the stations, the trends can be considered significant at the 70% confidence level. Intuitively, the flows in winter would increase as winter temperatures increase resulting in more winter precipitation falling as rain and increased snowmelt. In areas where hydrology is snowmelt-dominated, the sensitivity of runoff to temperature and potential evapotranspiration is complicated by changes in the seasonal runoff pattern resulting from changing climatic conditions.

Mean spring flows are decreasing as indicated by negative slopes of the linear regression line, but the trends are only significant at the 70% confidence level for four stations (Table 3, Figure 3). Three of the four stations (i.e., stations 01AL002, 01AP002, and 01AP004) that show a tendency towards increased mean annual spring daily flows are within the lower Saint John River Basin.

Initial Ice Effect. Table 4 provides the evaluation of trends in the Julian date of initial ice effect at 13 selected hydrometric stations, and Figure 4 depicts the trend direction at these stations. This is an indication of the date of ice cover formation or freeze-up. The amount of scatter in freeze-up dates is evident from the wide range of freeze-up dates and the low values of the coefficient of determination presented in Table 4. Six of the 13 stations have p-values less than 0.30, indicating that they are significant at the 70% confidence level. Of these, three stations in the northern half of the Province have statistically significant downward trends; with two trends significant at the 90% confidence level. Therefore, it appears that generally the date of initial ice effect at these hydrometric stations, and perhaps in the northern half of the Province, is becoming earlier in the year. In the southern half of the Province, a clear trend is less evident. Downward trends (indicating earlier freeze-up) are detectable in the hydrometric records for three hydrometric stations (with two trends significant at the 70% confidence limit) and upward trends (indicating later freeze-up) in the hydrometric records for the remaining three stations (with one trend significant at the 70% confidence limit).

It seems counter-intuitive that whereas most stations in the northern half of the province generally exhibit a trend towards earlier freeze-up while three stations in the south are exhibiting a trend towards later ice formation (assuming a direct relationship between ice effect at the gauging station and freeze-up in the river). The differences can be partially explained by the difference in the climatic regions, wherein the northern part of New Brunswick is affected more by continental systems and the southern part of New Brunswick is more likely to be influenced by marine systems.

Latest Ice Effect. Table 5 summarizes the evaluation of trends in the Julian date of latest ice effect at 13 selected hydrometric stations, and Figure 5 depicts the trend direction at the stations. This is an indication of the end of the ice cover, or more indirectly the breakup date. As with the dates of initial ice effect, the large amount of scatter in the data is evident from the wide range of the dates of last ice effect and the low values of the coefficient of determination. The slope of the linear regression line is negative at 12 of the 13 hydrometric stations indicating a trend towards an earlier end to ice effects. Of the 12 stations with a downward trend, 10 have p-values less than 0.30, indicating the trends are significant at the 70% confidence level. The exception is station 01BE001 Upsalquitch River at Upsalquitch, a northern flowing river in the northern half of the Province, which shows a significant upward trend (at the 70% confidence level). Despite this, the end of the ice effect at hydrometric stations in New Brunswick seems to be occurring earlier in the year, an indirect indicator of earlier ice breakup.

A cautionary note is provided about the interpretation of the trends in the end of supposed ice effect at a gauging station and the ice breakup and jamming conditions in the river. First, the ice effect indicates the presence of ice only in the immediate reach of a river within which a hydrometric station is located, severe enough to result in a backwater effect at the gauging station. Ice conditions elsewhere along the river may be very different from the conditions near the hydrometric station. Second, one cannot determine solely from the record of supposed ice effect in the hydrometric records whether or not the breakup was mechanical or thermal, whether or not the ice went quickly as a result of increased temperatures and flows or whether it went more gradually as a result of thermal deterioration. Third, the indication of an earlier end of ice effects at the gauging station does not imply, in itself, that ice jamming is becoming more severe. Throughout a long period of record, one would expect that earlier breakup dates could be associated with mechanical breakup more conducive to ice jamming, but it should also be remembered that the trend in ice conditions is a reflection of other changes in hydro-climatic conditions, which may have resulted in reduced ice cover integrity and earlier ice breakup. Trend analyses of the last dates of ice effect at hydrometric stations does indicate that change is occurring and can be interpreted generally as an indicator of earlier ice breakup. Detailed river-ice studies would have to be carried out to ascertain the effect of these changes on the potential for, and the magnitude of, ice jamming along a river system.

Length of the Ice Season. Table 6 summarizes the evaluation of trends in the length of the ice season, as determined by the number of days with a noticeable ice effect at the gauging station and Figure 6 depicts the trend direction at the stations. Generally, the trend is downward, that is, the number of days with ice effect is decreasing. This is an indirect indication of the shortening of the ice season. Trends towards a shortening of the ice season were significant at the 70% confidence level for four stations in the southeast quadrant of the Province. The only trend towards an increase of the number of days with ice effect significant at the 70% confidence limit was determined for station 01BE001 Upsalquitch River at Upsalquitch, which is in close proximity and is a tributary basin of the only station in the north of the Province with a shortening of the ice season significant at the 70% confidence level. A possible explanation rests with their differing lengths of record and orientation of the main rivers. When trends in the earliest and latest ice effect and in the number of days with ice effect are considered during the period 1969-2006 (the period in which both stations have flow data available), the apparent differences in trend disappear**.**

A shortening of the ice season has been reported by other investigators. For example, Zhang et al. (2001) found that that breakup of river ice and the ensuing spring freshet occur significantly earlier, and suggested that some evidence existed of earlier river freeze-up, particularly in eastern Canada. At coastal river streamflow-gauging stations in Maine, Dudley and Hodgkins (2002) found in general that the initial onset of ice was occurring later and the last ice-off dates in the spring were occurring earlier. They stated that a later ice-on in the winter and earlier ice-off in the spring contribute to a statistically significant decrease over time in the total number of days with ice-effect at most gauges on coastal rivers in Maine.

Number of Distinct Ice Periods. Table 7 summarizes the evaluation of trends in the number of distinct ice periods during the entire ice season, that is, the number of discernable periods of ice cover formation and breakup, and Figure 7 depicts trend direction. Periods of ice effect at the hydrometric stations less than five days in duration were ignored, thereby increasing the likelihood that the ice effect was associated with significant formation of the ice cover. At eight of the 11 stations, an upward trend is detected indicating an increase in the annual number of distinct ice periods. Six of these eight stations had significant trends at the 70% confidence level. A trend towards fewer ice breakups was significant at the 70% confidence level for one station, 01AK001 Shogomoc Stream near Trans Canada Highway.

Beltaos et al. (2003) stated that changing climates will likely result in more frequent midwinter ice jams along many Canadian rivers, thereby increasing the likelihood of flood damage and environmental changes. Where flow decreases suddenly upon a return to more seasonal winter temperatures, ice jams in the river reconsolidate and remain in place until a later breakup event, thereby possibly interfering with the clearance of broken ice during a subsequent breakup and thus aggravating spring ice jamming (Beltaos et al., 2003). Therefore, the possibility of more frequent ice jams has to be considered during the planning of flood damage reduction measures, the design of waterway structures, and the enactment of measures to protect the environment (Beltaos et al, 2003). The indication from the trend analysis is that the ice regimes of New Brunswick rivers may become more unstable, leading to more uncertainty about ice jamming conditions. This may have implications upon river ice monitoring in areas prone to ice jam formation.

4.0 Summary and Concluding Remarks

Table 8 present a summary of study results. These trends have developed mainly because of changes in hydro-climatic parameters during the past few decades. Climate change and variability seems to be the most plausible explanation of the observed trends. The identification of observed trends that may persist into the future provides yet further evidence that it can no longer be assumed that river ice regimes would remain the same in the future.

The authors recognize the study was limited in scope and do not wish to overstate the results. The length of record, inclusion of outliers (values much higher or lower than more typical parameter values), method and type of trend analysis, and data accuracy all have an influence on the results. Furthermore, as climate and land use continue to change, there is no guarantee that the trends identified herein can be extrapolated considerably into the future. The hydrologic trends detected apply only to selected hydrometric basins, and may not be indicative of regional trends, as statistical testing of the significance of trends within a region was beyond the scope of this study. Linear trends are indicators of the direction of change rather than an accurate basis for climate change projections. The study involved the analyses of recorded data to determine trends in data that may be indicative of future hydrologic conditions, but the authors do not contend that straight linear extrapolation of these trends will provide accurate estimates of future hydrologic conditions.

Sufficient information now exists from trend analyses and climate change projections for the Province that climate change is a real phenomenon. Although some uncertainty remains as to the magnitude of change, the direction of change is becoming clearer. Now is the time for infrastructure vulnerable to the effects of changing hydro-climatic conditions to be identified so that measures can be properly planned to reduce the vulnerability to climatic change.

5.0 References

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Figure 1. Map of New Brunswick Showing Locations of Hydrometric Stations Used in Study.

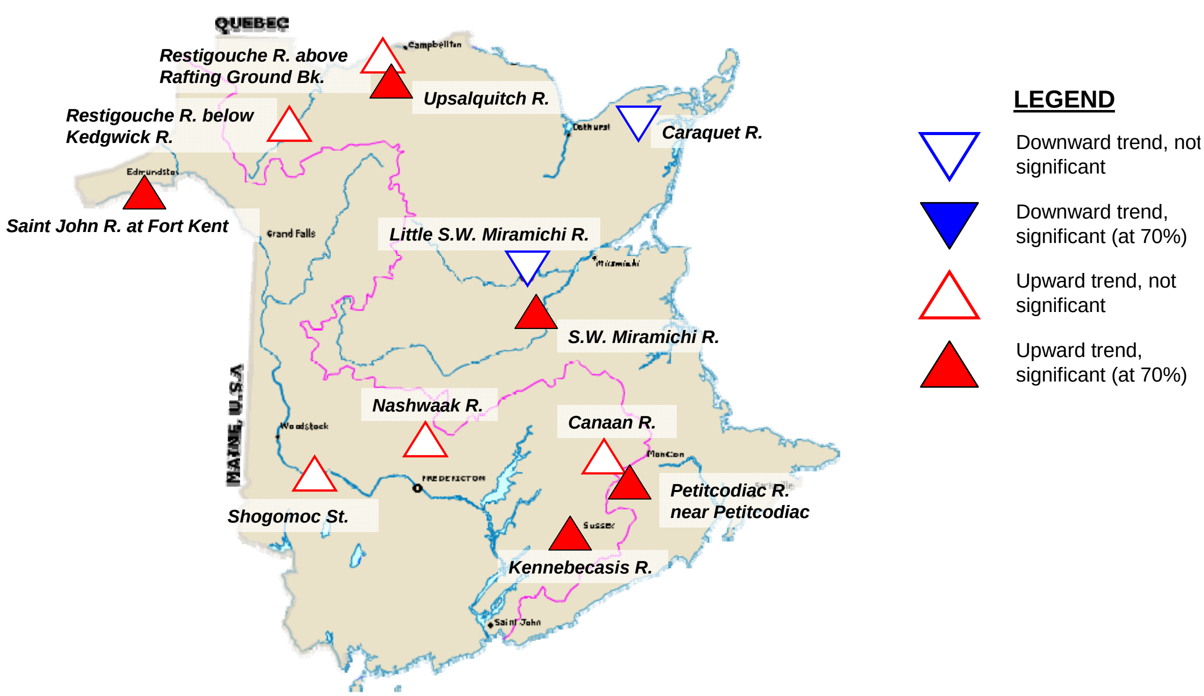
Table 1. Stations Used in the Present Study

Station ID	Station name	Latitude (N)	Longitude (W)	Drain-age Area, km^2	Period of Record
01AD002	Saint John River at Fort Kent	47°15'25"	68°35'35"	14700	1926 – 2006
01AK001	Shogomoc Stream near Trans Canada Highway	45°56'36"	67°19'13"	234	1918 - 1941 1943 – 2006
01AL002	Nashwaak River at Durham Bridge	46°07'33"	66°36'40"	1450	1962 – 2006
01AP002	Canaan River at East Canaan	46°04'20"	65°21'59"	668	1925 – 1941 1962 - 2006
01AP004	Kennebecasis River at Apohaqui	45°42'07"	65°36'05"	1100	1961 – 2006
01AQ001	Lepreau River at Lepreau	45°10'11"	66°28'05"	239	1916 – 2006
01BC001	Restigouche River below Kedgwick River	47°40'01"	67°28'59"	3160	1962 – 2006
01BE001	Upsalquitch River at Upsalquitch	47°49'56"	66°53'13"	2270	1918 - 1933 1943 – 2006
01BJ007	Restigouche River above Rafting Ground Brook	47°54'31"	66°56'53"	7740	1968 – 2006
01BL002	Rivière Caraquet at Burnsville	47°42'20"	65°9'19"	173	1969 – 2006
01BO001	Southwest Miramichi River at Blackville	46°44'09"	65°49'32"	5050	1918 - 1933 1938 - 1939 1961 – 2006
01BP001	Little Southwest Miramichi River at Lyttleton	46°56'09"	65°54'26"	1340	1951 – 2006
01BU002	Petitcodiac River near Petitcodiac	45°56'47"	65°10'05"	391	1961 - 2006

Reference: Environment Canada, 2008

Table 2: Trend Evaluation in Annual Mean Daily Winter Flows

Station Number and Name	Annual Mean Daily Winter Flows, m^3/s			Regression Results		
	Avg.	Max.	Avg.	Slope	p-Value	r^2 Value
01AD002 Saint John River at Fort Kent	90.6	254	21.1	0.792	0.001	0.144
01AK001 Shogomoc Stream near Trans Canada Highway	3.6	13.3	0.596	0.005	0.586	0.004
01AL002 Nashwaak River at Durham Bridge	21	56.1	7.83	0.121	0.329	0.022
01AP002 Canaan River at East Canaan	9.5	26.3	1.74	0.017	0.550	0.006
01AP004 Kennebecasis River at Apohaqui	24.7	51.1	5.19	0.145	0.279	0.027
01AQ001 Lepreau River at Lepreau	6.9	15.3	1.7	0.001	0.932	8. E-5
01BC001 Restigouche River below Kedgwick River	22.2	54.1	10.4	0.078	0.499	0.011
01BE001 Upsalquitch River at Upsalquitch	13.2	31.8	2.96	0.034	0.201	0.022
01BE001 Restigouche River above Rafting Ground Brook	52.6	119	25.3	0.042	0.899	0.000
01BL002 Rivière Caraquet at Burnsville	1.63	3.43	0.74	-0.004	0.693	0.005
01BO001 Southwest Miramichi River at Blackville	59.8	188	24.9	0.257	0.064	0.059
01BP001 Little Southwest Miramichi at Lyttleton	15.7	56.9	4.19	-0.030	0.721	0.002
01BU002Petitcodiac River Near Petitcodiac	6.46	21	1.07	0.054	0.215	0.036



(Fig. 2. Direction of Trends in Annual Mean Daily Winter Flows

Table 3: Trend Evaluation in Annual Mean Daily Spring Flows

Station Number and Name	Annual Mean Daily Spring Flows, m^3/s			Regression Results		
	Avg.	Max.	Min.	Slope	p-Value	r^2 Value
01AD002 Saint John River at Fort Kent	641	960	330	-0.301	0.681	0.002
01AK001 Shogomoc Stream near Trans Canada Highway	10.4	17.0	5.43	-0.017	0.105	0.031
01AL002 Nashwaak River at Durham Bridge	72.9	114	40.4	0.014	0.947	0.000
01AP002 Canaan River at East Canaan	26.7	41.5	13.9	0.001	0.978	0.000
01AP004 Kennebecasis River at Apohaqui	43.7	64	26.1	0.038	0.724	0.003
01AQ001 Lepreau River at Lepreau	11.8	21.2	6.4	-0.029	0.030	0.052
01BC001 Restigouche River below Kedgwick River	152	232	74.2	0.128	0.777	0.002
01BE001 Upsalquitch River at Upsalquitch	97.4	148	46.8	-0.020	0.841	0.001
01BE001 Restigouche River above Rafting Ground Brook	379	532	228	-2.965	0.015	0.153
01BL002 Rivière Caraquet at Burnsville	8.03	12.6	4.65	-0.048	0.128	0.065
01BO001 Southwest Miramichi River at Blackville	247	378	136	-0.104	0.670	0.003
01BP001 Little Southwest Miramichi at Lyttleton	70.1	116	39	-0.025	0.870	0.001
01BU002 Petitcodiac River Near Petitcodiac	15.6	24.2	8.67	-0.004	0.930	0.000

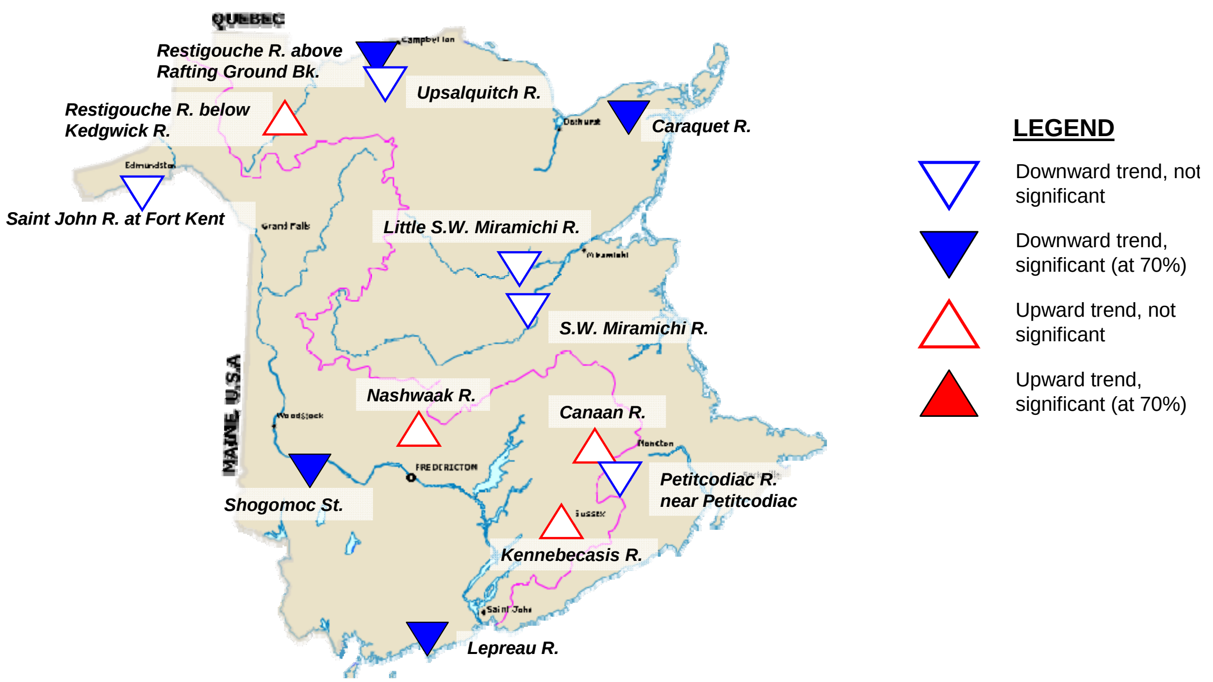


Fig. 3. Direction of Trends in Annual Mean Daily Spring Flows

Table 4. Trend Evaluation in the Date of Initial Ice Effect

Station Number and Name	Julian Date of Initial Ice Effect			Regression Results		
	Avg.	Latest	Earliest	Slope	p-Value	r^2 Value
01AD002 Saint John River at Fort Kent	340	3	314	-0.150	0.135	0.042
01AK001 Shogomoc Stream near Trans Canada Highway	342	19	320	0.072	0.156	0.024
01AL002 Nashwaak River at Durham Bridge	336	360	308	-0.012	0.943	0.000
01AP002 Canaan River at East Canaan	337	361	311	-0.029	0.634	0.004
01AP004 Kennebecasis River at Apohaqui	344	5	315	0.088	0.554	0.008
01AQ001 Lepreau River at Lepreau	346	36	312	-0.106	0.132	0.026
01BC001 Restigouche River below Kedgwick River	329	358	300	-0.026	0.860	0.001
01BE001 Upsalquitch River at Upsalquitch	338	4	307	-0.210	0.001	0.134
01BE001 Restigouche River above Rafting Ground Brook	332	360	306	0.057	0.772	0.002
01BL002 Rivière Caraquet at Burnsville	334	0	305	0.017	0.934	0.000
01BO001 Southwest Miramichi River at Blackville	334	363	308	-0.052	0.348	0.015
01BP001 Little Southwest Miramichi at Lyttleton	331	355	306	-0.165	0.094	0.052
01BU002 Petitcodiac River Near Petitcodiac	335	358	310	0.166	0.220	0.035

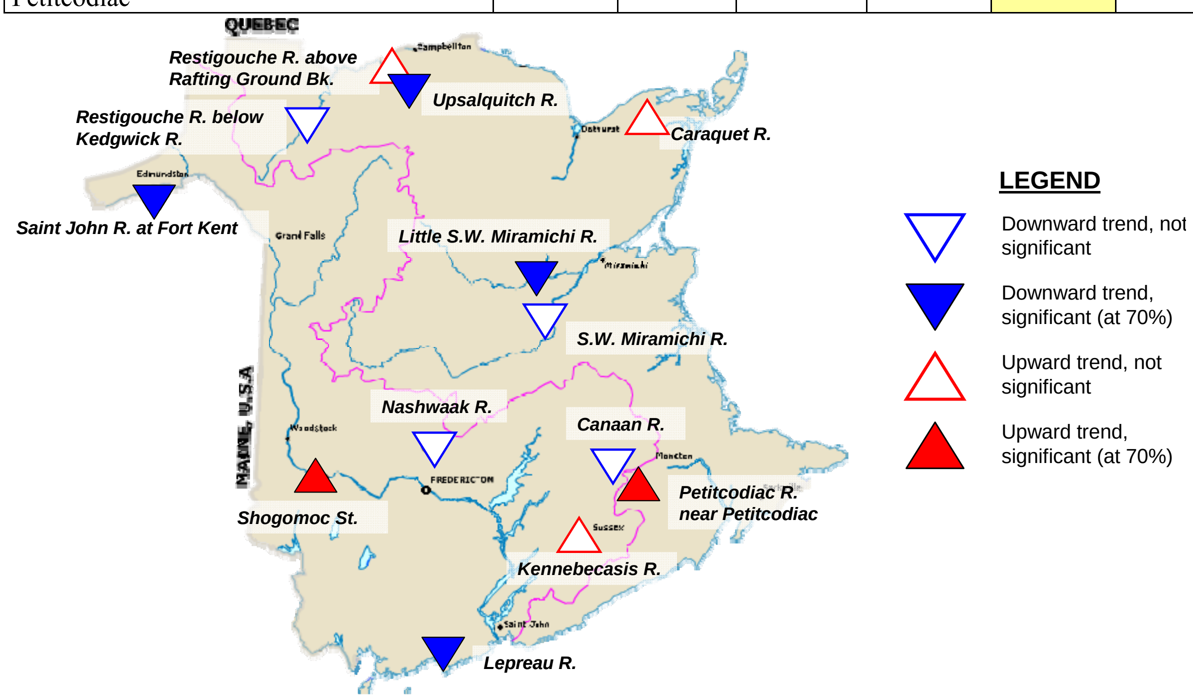


Fig. 4. Direction of Trends in Date of Initial Ice Effect (Ice Formation)

Table 5. Trend Evaluation in the Date of Last Ice Effect

Station Number and Name	Julian Date of Initial Ice Effect			Regression Results		
	Avg.	Latest	Earliest	Slope	p-Value	r^2 Value
01AD002 Saint John River at Fort Kent	106	121	86	-0.171	0.019	0.102
01AK001 Shogomoc Stream near Trans Canada Highway	79	109	36	-0.066	0.322	0.012
01AL002 Nashwaak River at Durham Bridge	95	118	62	-0.258	0.057	0.084
01AP002 Canaan River at East Canaan	97	119	79	-0.091	0.058	0.061
01AP004 Kennebecasis River at Apohaqui	81	109	43	-0.211	0.141	0.050
01AQ001 Lepreau River at Lepreau	91	118	24	-0.070	0.254	0.015
01BC001 Restigouche River below Kedgwick River	179	365	85	-0.180	0.867	0.001
01BE001 Upsalquitch River at Upsalquitch	102	122	15	0.119	0.068	0.044
01BE001 Restigouche River above Rafting Ground Brook	108	122	85	-0.147	0.224	0.041
01BL002 Rivière Caraquet at Burnsville	144	351	56	-0.155	0.922	0.000
01BO001 Southwest Miramichi River at Blackville	102	120	71	-0.054	0.261	0.022
01BP001 Little Southwest Miramichi at Lyttleton	111	130	86	-0.129	0.079	0.057
01BU002 Petitcodiac River Near Petitcodiac	91	119	61	-0.301	0.024	0.114

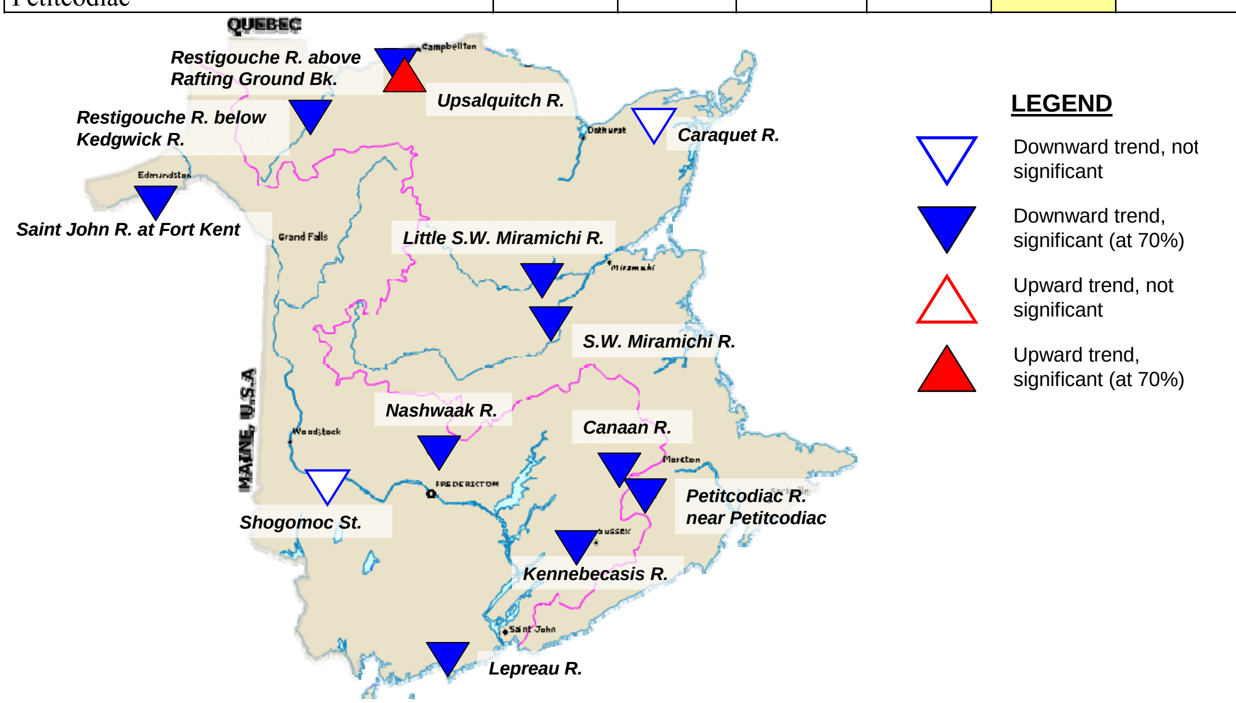


Figure 5. Trends in the Dates of Latest Ice Effect

Table 6. Trend Evaluation in Number of Days with Ice Effect

Station Number and Name	Julian Date of Initial Ice Effect			Regression Results		
	Avg.	Latest	Earliest	Slope	p-Value	r^2 Value
01AD002 Saint John River at Fort Kent	13	158	108	-0.031	0.774	0.002
01AK001 Shogomoc Stream near Trans Canada Highway	98	144	42	-0.082	0.371	0.010
01AL002 Nashwaak River at Durham Bridge	123	159	90	-0.289	0.105	0.061
01AP002 Canaan River at East Canaan	124	171	90	-0.118	0.134	0.038
01AP004 Kennebecasis River at Apohaqui	99	135	54	-0.420	0.043	0.092
01AQ001 Lepreau River at Lepreau	109	161	13	0.032	0.755	0.001
01BC001 Restigouche River below Kedgwick River	141	167	28	-0.238	0.116	0.058
01BE001 Upsalquitch River at Upsalquitch	128	161	28	0.290	0.001	0.130
01BE001 Restigouche River above Rafting Ground Brook	140	164	99	-0.425	0.061	0.094
01BL002 Rivière Caraquet at Burnsville	128	164	85	-0.291	0.288	0.032
01BO001 Southwest Miramichi River at Blackville	132	171	101	-0.033	0.612	0.004
01BP001 Little Southwest Miramichi at Lyttleton	144	179	109	0.008	0.946	0.000
01BU002 Petitcodiac River Near Petitcodiac	119	171	70	-0.542	0.008	0.154

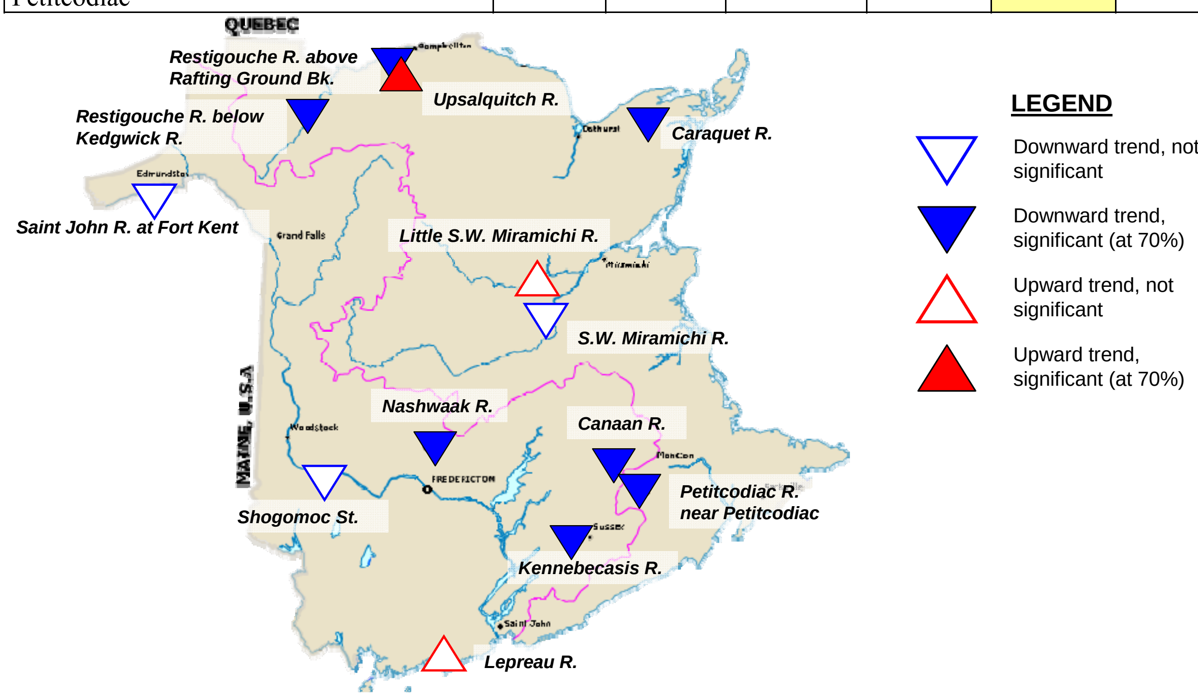


Figure 6 . Total Annual Days with Ice Effect

Table 7. Trend Evaluation in Annual Number of Breakup Events

Station Number and Name	Number of Distinct Periods of Ice			Regression Results		
	Avg.	Max.	Min.	Slope	p-Value	r^2 Value
01AD002 Saint John River at Fort Kent	1.2	4	1	0.002	0.629	0.005
01AK001 Shogomoc Stream near Trans Canada Highway	1.7	4	1	-0.004	0.280	0.014
01AL002 Nashwaak River at Durham Bridge	1.4	3	1	-0.008	0.308	0.025
01AP002 Canaan River at East Canaan	1.3	4	1	0.006	0.063	0.059
01AP004 Kennebecasis River at Apohaqui	1.8	3	1	0.012	0.162	0.045
01AQ001 Lepreau River at Lepreau	1.6	4	1	0.008	0.026	0.056
01BC001 Restigouche River below Kedgwick River	1.4	3	1	0.002	0.784	0.002
01BE001 Upsalquitch River at Upsalquitch	1.3	4	1	0.003	0.199	0.022
01BE001 Restigouche River above Rafting Ground Brook	1.3	2	1	0.007	0.287	0.031
01BL002 Rivière Caraquet at Burnsville	1.3	3	1	-0.007	0.404	0.020
01BO001 Southwest Miramichi River at Blackville	1.2	3	1	0.003	0.091	0.049
01BP001 Little Southwest Miramichi at Lyttleton	1.2	2	1	0.002	0.611	0.005
01BU002 Petitcodiac River Near Petitcodiac	1.6	4	1	0.007	0.483	0.012

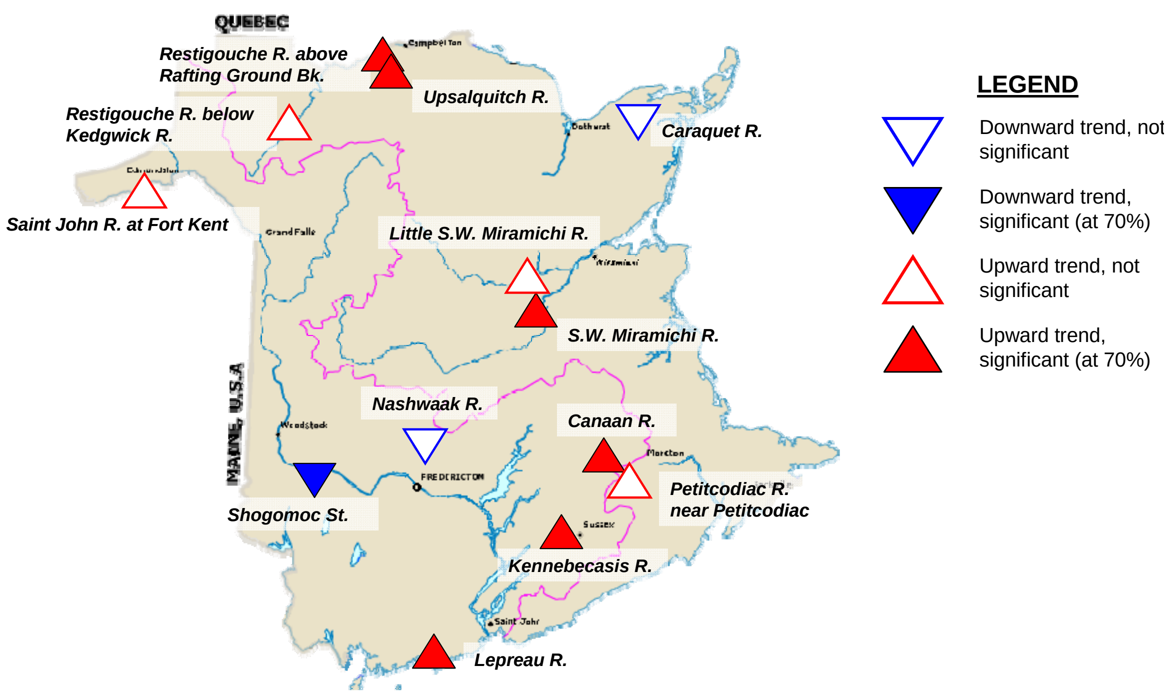


Figure 7. Annual Number of Breakup Events

Table 8 . Summary of Results

Parameter	Upward Trends		Downward trends		No. of Trends Significant at 70% Confidence Level	
	No.	Meaning	No.	Meaning	Up-ward	Down-ward
Annual mean winter flows	11	Increased mean winter flows	2	Decreased mean winter flows	5	0
Annual mean spring flows	4	Increased mean spring flows	9	Decreased mean spring flows	0	4
Timing (date) of Spring Floods	0	Later spring flood occurrence	13	Earlier spring flood occurrence	0	13
Date of Annual Initial Ice Effect on Hydrometric Records	5	Later occurrence of earliest ice effect (linked to ice formation)	8	Earlier occurrence of ice effect (linked to ice formation)	2	4
Date of Annual Latest Ice Effect on Hydrometric Records	1	Later occurrence of last ice effect (linked to ice breakup)	12	Ice-free period occurs earlier in year	1	9
Annual No. of Days with Ice Effect	3	More days with ice effect (linked to ice season length)	10	Less days with ice effect (linked to ice season length)	1	7
No. of Distinct Periods of Ice	10	More ice breakups (less stable ice covers)	3	Less ice breakups (less stable ice covers)	6	1