CHRONOLOGICAL RECONSTITUTION OF FLOODS OF THE SAINT-FRANÇOIS DRAINAGE BASIN, QUÉBEC, CANADA

Diane Saint-Laurent, UQTR Géographie, Trois-Rivières, Québec
Jean-Philippe Saucet, Groupe-Conseil Lasalle Inc., Montréal, Québec

Résumé

Cette étude vise à reconstituer la chronologie des inondations du bassin de la rivière Saint-François de ce siècle. Plusieurs rivières du bassin de la Saint-François sont soumises à des inondations fréquentes qui affectent plusieurs municipalités. Les municipalités les plus souvent affectées sont Sherbrooke, Lennoxville, Bromptonville, Coaticook, Cookshire, Richmond, Saint-Nicéphore et Notre-Dame-de-Pierreville. Pour la période de 1900-2000, on constate que les années les plus catastrophiques pour les municipalités touchées sont celles de 1913, 1924, 1942, 1943, 1977, 1982, 1996 et 1998. Les inondations sont dues soit à des fortes pluies, aux crues printanières ou à la formation d'embâcles qui entraînent un rehaussement rapide du niveau des eaux des cours d'eau. Outre les facteurs climatiques, les facteurs d'origine anthropique (occupation des plaines inondables, rives aménagées, etc.) participent à l'aggravation des phénomènes d'inondation. On peut souhaiter que les politiques gouvernementales pour la protection des rives et des plaines inondables soient davantage renforcies afin de réduire les impacts négatifs des inondations dans cette région.

Abstract

This study aims at recreating the chronology of flooding in the Saint-François drainage basin in the last century (period 1900-2000). Many rivers of the Saint-François drainage basin have been subjected to frequent flooding affecting several municipalities. The municipalities most frequently affected are Sherbrooke, Lennoxville, Bromptonville, Coaticook, Cookshire, Richmond, Saint-Nicéphore and Notre-Dame-de-Pierreville. The worst flooding in the 20th century occurred in 1913, 1924, 1942, 1943, 1977, 1982, 1996 and 1998. The floods were mainly caused by heavy rains, heavy spring floods or ice jams on the river, which cause water levels to rise rapidly. In addition to climatic factors, anthropogenic factors (use of floodplains, development of river banks, etc.) contributed to increased flooding. Ideally, government regulations aimed at protecting riversides and floodplains should be enforced more stringently in order to reduce urban development and the adverse effects of flooding in this area.

1. INTRODUCTION

Flooding represents a major risk to riverside populations and floodplains, in addition to causing substantial environmental impacts (e.g. bank erosion, effects on aquatic fauna and flora). Though it is a natural phenomenon, flooding is often exacerbated by the presence of riverside infrastructures (such as bridges, piers, and landing wharves) and by poor development practices (riverside "development," excessive clearing, encroachment upon waterways, dredging, etc.), which may change the hydrological balance of the waterways involved (Brookes 1985, Nolan and Marron 1995).

A number of researchers have studied the physical and sedimentological impact of flooding on the receiving environment (Irvine and Drake 1987, Lewin 1989, Kochel 1988, Brooks and Lawrence 2000). Meanwhile, other researchers have investigated anthropogenic factors and the impact of urban development on changes to the river system and increased flooding (Hollis 1975, Roberts 1989, Simon 1992, Costa *et al*. 1995). Over the last 40 years, several Québec waterways have experienced various transformations of an anthropogenic nature (such as the creation of dams), which have led to changes in the hydrological balance or variations in erosion or sedimentation. Some of these transformations may have also had an impact on the rate and extent of flooding (Lewin 1989, Roberts 1989, Costa *et al*. 1995, Jones 1996, Nelson *et al*. 1999, Awadallah, *et al.* 1999, Bouillon *et al*. 1999, Saint-Laurent *et al*. 2001).

This study aims at reviewing the flood events in the Saint-François River drainage basin (Québec) that have taken place during the last century in order to assess the rate of flooding and the areas most affected. The Saint-François River basin was chosen given that we were able to observe a high number of floods in the area that had not yet been listed in detail. Several riverside municipalities, including large towns such as Sherbrooke and Lennoxville, are in fact regularly subjected to flooding. Moreover, few studies have been done on the physical and physiographic characteristics of the Saint-François River drainage basin in relation to flooding, especially in terms of the periodicity or severity of the events. It is useful, in a context of integrated basin management, to know the main components of the basin's physical environment and to thus gain a better understanding of the hydrological system and related flooding. Lastly, the later stages of this study will involve studying climatic and hydrological data in greater detail and tracing the geomorphological evolution of stream terraces, especially by sedimentological and stratigraphic analysis.

2. STUDY AREA

The Saint-François drainage basin is located south of the Saint-Laurent River between the basin of the Yamaska River to the west and that of the Chaudière River to the east. This vast basin is part of the Eastern Townships Region extending from the south shore of the Saint-Laurent to northern Vermont, in the United States (Figure 1). This drainage basin is the third largest basin on the south shore of the Saint-Laurent after the Chaudière River basin and Yamaska River basins. The Saint-François River is the main waterway of the Saint-François basin; it originates in Lake Aylmer north of the basin and flows into the Saint-Laurent River at Lake Saint-Pierre. There are 9 dikes and dams along the Saint-François River, including the Aylmer and Jules-Allard Dams, which control the water levels of these large lakes and regulate the flow of water upstream from the Saint-François River.

There are major variations in the relief of the Saint-François River drainage basin from the head of the basin to its outlet. Upstream from the basin, the relief is characterized by mountains, hills and valleys dominated by vast wooded areas, while in the downstream part of the basin there are large plain surfaces mainly dominated by farmland (crops and animal breeding) and urban areas. The Saint-François drainage basin has a medium-altitude ranging from 304 m to 762 m, with the higher altitudes located on the American side (Adirondack Mountains). This area is formed by the Saint-Laurent Lowlands and the Appalachian Plateau, which are the two major physiographic divisions that characterize the Saint-François drainage basin.

Figure 1. Location of study area. The map shows the Saint-François drainage basin with main streams and lakes.

3. PRINCIPAL CHARACTERISTICS OF THE SAINT-FRANÇOIS DRAINAGE BASIN

The Saint-François drainage basin has a total surface area of 10 221 km^2, most of which lies in the Appalachian foothills. In addition to the Saint-François River, there are several other major tributaries, including the Eaton, Coaticook, Massawippi and Saumon Rivers (Figure 1). The upstream portions of the upper basin of the Saint-François are somewhat rectangular in shape and more elongated further downstream. The Upper basin is characterized by a denser drainage pattern than the lower basin. The drainage system of the Saint-François basin was studied based on various hydromorphological characteristics (Saint-Laurent *et al*. 2001, Saint-Laurent & McNeil 2002). The basin’s drainage system has been subdivided into eight sub-basins, most of which are found in the Appalachian Region. The Massawippi and Magog Rivers sub-basins have by far the highest drainage density. A high drainage density can increase the risk of flooding because of the significant volume of water moving from the tributaries to the main course. However, bigger ponds and lakes such as Lake Memphremagog produce a buffer effect that lowers the intensity of flow (Jones, 1996, Saint-Laurent *et al*. 2001).

A study conducted on the physical and hydrographic characteristics reveals that the middle of the basin serves as a point of convergence for several major tributaries, including the Magog, Massawippi and Eaton Rivers, which feed into the Saint-François (Saint-Laurent *et al*. 2001). In all likelihood, these rivers considerably modify the hydrological balance of the Saint-François River during freshets or extremely high water levels. For example, the Magog River, which junctures with the Saint-François River at Sherbrooke, adds a considerable volume of water to the Saint-François during flood periods, thereby increasing the risk of flooding in this region. Other areas located at the confluence of major tributaries, such as the municipalities of Cookshire, Lennoxville and Ascot, are also prone to flooding (Saint-Laurent *et al*. 2001).

4. METHODS

To reconstruct the flood events which occurred from 1964 to 2000, the data were compiled using various government sources, such as data from the Ministère de l’Environnement and data made available by the Ministère de la Sécurité publique (Mauricie-Centre-du-Québec and Montérégie-Estrie regional directorates). The main information consulted consisted of data from flood follow-up sheets and situation reports from municipalities. It took several months of work to compile the data. Government data from 1900 to 1964 were either incomplete or non-existent. Therefore, various sources had to be consulted, including government of Québec hydrological reports, regional and local newspapers, regional monographs, as well as various historical databases (Société historique de Sherbrooke and Centre d’études québécoises – UQTR). The data were then compiled into tables and figures. The next stage will consist in studying flood rates in greater detail with respect to the study area’s climatic (e.g. rainfall, temperature) and hydrological data (river levels, flow rates, critical levels, etc.).

5. THE MAJOR FLOODS OF THE SAINT-FRANÇOIS DRAINAGE BASIN (PERIOD 1900-2000)

When studying all the data recorded for the Saint-François drainage basin, we were able to identify the major floods which affected the area over a 100-year period. There were at least three or four annual flood sequences which characterized major floods along the Saint-François River. The early 1900s were characterized by two major periods of heavy flooding, i.e. 1913, 1915 and 1924, and later, 1942 and 1943 (Figure 2). The second half of the century was again characterized by two major flood sequences, 1977–1982 and 1994–1998, including three major floods, i.e. in 1982, 1996 and 1998 (Figure 2). The 1982 flood is in fact compared to that of 1942, as both floods affected several municipalities and resulted in major property damage.

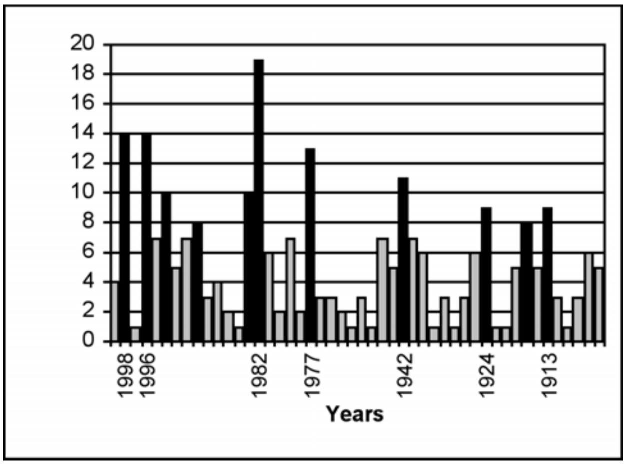

Figure 2. Number of municipalities affected by flooding in the Saint-François drainage basin (between 1900-2000).

Table 1 displays the principal municipalities are affected by flooding during the last century (1900-2000). The municipalities of Cookshire, Lennoxville and Sherbrooke are particulary affected by floods because they are located at the confluence of major tributaries (Magog, Eaton Massawippi Rivers) characterized by significant volume of water.

Table 1. The principal municipalities are affected by frequent floods (period 1900-2000).

Municipalities	Number of floods	
	10-15	> 15
Coaticook	X	
Cookshire		X
Bromptonville		X
Lennoxville		X
Notre-Dame-de-Pierreville	X	
Richmond		X
Saint-Nicéphore		X
Sherbrooke		X

In the cases of municipalities of Saint-Nicéphore and Notre-Dame-de-Pierreville, the fact that they are located in low-relief area increase the risk of flooding.

Table 2 shows the major floods events during the 20th century (1900-2000). Several floods occurred at different times of the year, although flooding most often occurs during the spring (Saint-Laurent *et al.* 2000). In many cases, spring flooding occurs in March and April when the snow melts and there are ice jams and abundant rainfall. For instance, the floods in 1982 and 1998, two of the heaviest in the last two decades, occurred in the spring, on April 17 and March 29, respectively.

Table 2. Major floods from 1900 to 2000 in the Saint-François drainage basin.

Years	Dates	Principal causes
1998	March 29 to April 4	Rain and snowmelt
1996	January 17 to 25	Rain, snowmelt and ice jams
1996	February 26	Ice jams
1996	August 9	Rain
1982	April 17	Rain and snowmelt
1977	March 9 to 17	Rain and snowmelt
1943	June 16 to 17	Rain
1942	June 14	Rain
1924	September 8 to 10	Rain
1915	February 24 to 26	Snowmelt and ice jams
1913	March 23 to 27	Rain, snowmelt and ice jams

Figure 3 shows the distribution of the main climatic factors causing the floods in the Saint-François drainage basin. The numbers indicate the respective percentages of the various climatic conditions (e.g., rainfall, snowmelt, ice jams) which cause flooding in the Saint-François basin. About 49,1% of floods are caused by rainfall during the winter, summer or fall, and 43,4 % of floods are due to winter rainfall, snowmelt and ice jams. The rest of floods are caused by snowmelt and ice jams excluding rainfall. Generally, the spring snowmelt, along with rainfall and ice jams, are the events most often listed as the cause of largest floods in the literature.

However, there were several major floods which occurred during the summer and were caused by heavy rainfall (lasting 24 to 72 hours). Generally summer floods result form excessive or intensive rainfalls. For instance, the largest floods record during the last century are occurred in 1942-1943 during the summer (June 14, and on June 16 and 17, respectively). The largest floods that occurred during the summer season are relatively frequent in our climate.

For instance, It is important to remember the heavy summer rainfall that caused catastrophic floods from July 18 to 21, 1996 in the Saguenay area (Brooks and Lawrence 2000). Though a severe rainstorm was the principal cause for these catastrophic floods, we know now that the mismanagement and insufficient spilling capacity of dams localised upstream of Saguenay river have aggravated the problem (CSTGB, 1997). The catastrophic floods in southeastern Manitoba also occurred during the summer saison (June, 2002) caused substantial damages.

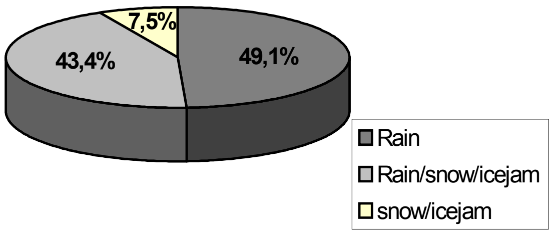

Figure 3. Diagram shows the principal climatic conditions causing floods in the Saint-François basin.

6. THE PRINCIPALS CAUSES AFFECTING FLOODING

6.1 Climatic and geomorphologic factors

Most of the floods recorded in Québec and Canada generally occur in the spring when river water levels are at their highest, especially following the spring snowmelt and when ice jams hinder the normal flow of the water (Environment Canada, 1993). However, heavy or torrential rains can occur at various times during the year and lead to major floods. For instance, several major floods have been recorded in the Saint-François drainage basin during the summer and fall (Table 2). These exceptional, short-duration events are sufficient to increase river water levels and cause unexpected major flooding.

Table 3. Summary of flood frequency for each month (period 1900-2000)

D	J	F	**M**	**A**	M	J	J	A	S	O	N
2	8	6	19	13	4	8	1	5	2	2	0

There are natural factors other than climatic conditions, especially those related to the river configuration, the density of the drainage system, the landform, the vegetation cover, and the downcutting of the river are all factors which must be studied to better understand flooding. The configuration of the river and shoreline, for instance, are important physical parameters to consider to properly understand river behavior. The presence of large floodplains is undoubtedly one of the leading geomorphological parameters for evaluating river behavior during extreme events (Kochel 1988, Costa and O'Connor 1995, Brooks and Lawrence, 2000) as their creation is in fact the result of recent or sub-recent floods. For instance, the presence of large alluvial plains around Saint-Nicéphore points to successive floods which led to the creation of these stream terraces.

6.2 Anthropogenic factors

Floods are natural phenomena which may, however, be aggravated by various installations or infrastructures (e.g. bridges, embankment) or by riverside developments which affect the normal flow of the watercourse to some extent (Costa and O'Connor, 1995; Hollis 1975). The hydroelectric dams that were built along the Saint-François river in the 1920s and 1930s have been usually favourable, but sometimes these have been blamed as factors that exacerbated flooding. Upstream of the Hemmings dam in Drummondville, for instance, the ice jams created by the presence of the dam may have created more frequent river overflows. Attempts were made over time to reduce these adverse effects by modifying dam management practices, such as leaving water levels sufficiently high to allow ice to flow more freely during the spring snowmelt. But also, the configuration of the river (meander channel) in this area contributes to aggravate the floods. The presence of bridges was also identified as one of the factors that contributed to flooding during the melting of the ice cover. Bridge pillars hinder the downstream flow of ice in the spring, forming jams which then lead to the river overflowing its banks.

The progressive occupation of floodplains must also be considered as a factor contributing to flooding. As the number of riverside dwellers increased in these vulnerable areas, the number of individuals and amount of property at risk of flooding also rose. Moreover, the occupation of floodplains by riverside dwellers often dramatically impacted these areas, such as by decreasing the size of wooded areas and modifying the natural appearance of the shoreline. Though government policies from the 1980s (MEF, 1987) on the protection of shorelines and floodplains have considerably helped slow down residential development as well as other types of development in floodplain areas, pressure for urban and residential development presents a major challenge to administrators and elected municipal representatives who must apply the government regulations. At times, the simple lack of municipal resources or means to ensure compliance with the standards stated in government policies led to the appearance of loopholes which resulted in the regulations not being followed (e.g. development of artificial banks, decrease in the barrier strip, non-conforming expansions of existing buildings).

7. CONCLUSION

Floods in the Saint-François drainage basin are frequent events which affect several municipalities in the area. Those most affected are Sherbrooke, Coaticook, Cookshire, Lennoxville, Bromptonville, Richmond, Saint-Nicéphore, and Notre-Dame-de-Pierreville. Flooding is most frequent during the spring, when the snow melts and ice jams are formed. However, major floods can also occur in the summer or fall during extreme climatic events (torrential rains or extended rainfall). The data recorded in the 20th century do not allow us to conclude that there has been an increase in flooding in the Saint-François drainage basin even though there has been a rise in the number of flood events elsewhere in Canada (Tucker, 2000). It is even difficult to attribute such events to climatic variations associated with such factors as global warming or changes in human activity such as intensive deforestation along shorelines or the progressive occupation of floodplains through residential and urban development. Later stages of this study will involve studying climatic and hydrological data in greater detail and tracing the geomorphological evolution of stream terraces, especially by sedimentological and stratigraphic analysis.

ACKNOWLEDGEMENTS

The authors would like to thank NSERC provided to support this research and Université du Québec à Trois-Rivières (UQTR) for the funding (FIR) and the ministère de la Sécurité publique (MSP), Direction régionale Mauricie-Centre du Québec and Direction régionale Montérégie-Estrie.

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