RECREATIONAL BOATING ON LAKE SAINT-LOUIS: SENSITIVITY AND VULNERABILITY TO WATER-LEVEL FLUCTUATIONS

Report ST-229E

Recreational Boating on Lake Saint-Louis: Sensitivity and Vulnerability to Water-Level Fluctuations

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READERS' COMMENTS

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Management Perspective

One of the objectives of the St. Lawrence Vision 2000 Action Plan is to protect and conserve the St. Lawrence River in order to reclaim the river for use by the public. Since 1999, the issue of water-level fluctuations has been considered particularly important for the St. Lawrence ecosystem and its uses.

In addition, the review of the water-level regulation plan for the Lake Ontario–St. Lawrence River corridor has offered the opportunity to better document certain aspects, such as the biophysical components of the St. Lawrence River and some especially sensitive uses, like recreational boating, on which little empirical data exists.

Finally, climate change is critical to the analysis of water-level fluctuations and their impact on the St. Lawrence ecosystem and its uses. As yet little documented at the regional level, climate change, which is a source of great concern for the Government of Canada, has been integrated into the analysis to highlight the vulnerability of recreational boating to water-level fluctuations and the adaptive measures taken.

This report focuses on a key section of the St. Lawrence River, Lake Saint-Louis, a "hot spot" for recreational boating and an area where the water level is partially controlled and subject to the impacts of climate change on the Great Lakes–St. Lawrence River basin.

Perspective de gestion

Un des objectifs du plan d'action Saint-Laurent Vision 2000 est de protéger et de conserver le fleuve Saint-Laurent afin d'en redonner l'usage à la population. Ainsi, depuis 1999, l'enjeu des variations des niveaux d'eau a été reconnu comme particulièrement important pour cet écosystème et ses usages.

En outre, la révision du plan de régularisation des eaux du lac Ontario et du Saint-Laurent a été l'occasion de mieux documenter certains aspects, dont les composantes biophysiques du fleuve et certains usages particulièrement sensibles comme la plaisance, sur laquelle il existait peu de données empiriques.

Enfin, les changements climatiques constituent un facteur critique pour l'analyse des variations des niveaux d'eau et de leurs effets sur l'écosystème du Saint-Laurent et sur ses usages. Encore peu documentés à l'échelle régionale, ces changements, qui préoccupent grandement le gouvernement canadien, ont été intégrés à l'analyse afin de mieux faire ressortir la vulnérabilité de la plaisance aux variations des niveaux d'eau et les mesures déployées pour s'y adapter.

Le présent rapport porte sur un territoire clé du Saint-Laurent, le lac Saint-Louis, à la fois haut lieu de la plaisance et section du fleuve partiellement régularisée et soumise aux changements climatiques du bassin Grands Lacs–Saint-Laurent.

Foreword

This study was conducted as part of a pilot project intended to evaluate the impacts of climate change on certain key uses of a hydrographic sector of the St. Lawrence River and to review possible and desirable adaptations to these changes. This project is original in that it links "integration of knowledge," "modelling" and "consultation with stakeholders." As part of the Climate Change Action Fund (CCAF, Natural Resources Canada), this project applies primarily to a clearly delimited area, touches on many socio-economic and environmental aspects, is adequately documented and benefits from the development of new tools while responding to concerns expressed locally (ZIP committees) and nationally (Public Interest Advisory Group [PIAG] and International Joint Commission [IJC]).

The present report is interested specifically in the case of recreational boating from a sectoral perspective and in connection with the problem of its vulnerability to water-level fluctuations. This dimension is prioritized as part of a wide-ranging study sponsored by the IJC and adds to other aspects of climate change tackled by other members of the CCAF team. There is a direct link between the two studies, which complement each other, as well as between the general concerns of the two institutions.

Acknowledgments

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Abstract

Recreational boating is one of the St. Lawrence River's least known activities, particularly regarding the constraints posed by water-level fluctuations. This report is a synthesis of the available data on the subject and proposes an analytical method that considers the problem of climate change. Thus, the "impact and adaptation" perspective has been chosen to guide the reflection on the sensitivity and vulnerability of pleasure boating to normal and extreme water-level conditions.

Low water levels affect infrastructures on Lake Saint-Louis differently, depending on the location. The Île Perrot shoreline, for example, is particularly vulnerable to low water levels. Thus, most boats on the lake, because of their design, cannot navigate or encounter difficulty when water depth at the dock is less than four feet. High water levels do not hinder navigation, but may damage facilities and change the waterscape of the lake.

The study of the impacts of water-level fluctuations is based in part on the development of several scenarios. Scenarios 5 and 6 represent nearly ideal water depths, while scenarios 1, 2 and 3 (end of summer 1999 and 2001) are usually problematic for most boats. However, high-water-level scenario 8, similar to the flooding of 1974 and 1976, does not represent a major problem for navigation.

People affected by water-level fluctuations, such as marina owners and/or operators and recreational boaters, react by taking various adaptive measures. This behaviour enables them to decrease their sensitivity to water-level fluctuations to a point called the "vulnerability threshold."

Adaptation to a situation is usually based on past behaviour and manifests itself as a gradual individual (affected person) and sectoral (recreational boating) adjustment. The measures taken show how big the adaptation problem can be in the wider context of integrated water management and sustainable development, including environmental conservation and protection considerations as well as uses.

Résumé

La plaisance constitue l'une des activités les moins bien connues du Saint-Laurent, surtout pour les contraintes que lui imposent les variations des niveaux d'eau. À ce sujet, le présent rapport renferme une synthèse des données existantes et propose une démarche d'analyse qui fait intervenir la problématique des changements climatiques. La perspective « impacts et adaptations » a ainsi été retenue afin de guider la réflexion sur la sensibilité et la vulnérabilité de ce secteur d'activités aux conditions normales et extrêmes des niveaux d'eau.

Au lac Saint-Louis, les bas niveaux d'eau affectent différemment les infrastructures selon leur localisation. Par exemple, les rives de l'île Perrot sont particulièrement touchées par les bas niveaux d'eau. Ainsi, le profil des embarcations qui circulent sur le lac témoigne du fait qu'une proportion importante de la flotte ne peut naviguer (ou difficilement) lorsque la hauteur de l'eau à quai est de moins de quatre pieds. Par ailleurs, les hauts niveaux d'eau n'entravent pas la navigation, mais peuvent frapper les installations et modifier le paysage lacustre.

L'étude des impacts des variations des niveaux d'eau s'appuie entre autres sur l'élaboration de plusieurs scénarios. Les scénarios 5 et 6 représentent des conditions de hauteur d'eau à peu près optimales, alors que les scénarios 1 à 3 (fin de l'été 1999 et 2001) sont problématiques pour la majorité des embarcations. Le scénario 8 de haut niveau d'eau, équivalent aux inondations de 1974 et 1976, ne pose toutefois pas un problème majeur pour la navigation.

Les personnes touchées par les variations des niveaux d'eau, tant les exploitants de marinas que les plaisanciers, y réagissent par l'adoption de mesures d'adaptation. Ce comportement permet de réduire la sensibilité aux variations des niveaux d'eau jusqu'à un degré, appelé « seuil de vulnérabilité ».

L'adaptation à une situation s'appuie le plus souvent sur des comportements hérités du passé et prend la forme d'un ajustement graduel à la fois individuel (celui de la personne touchée) et sectoriel (celui des opérations de plaisance). Les mesures prises laissent entrevoir l'ampleur du problème d'adaptation dans un contexte plus général de gestion intégrée de l'eau et de développement durable du territoire, ce qui comprend également les questions de conservation et de protection de l'environnement en plus de celles des usages.

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1 Introduction

Climate change is one of the major issues likely to confront the St. Lawrence River and other watercourses. These changes will modify the basic parameters on which many uses are based. Water level is a particularly critical parameter. The emphasis on water-level management by the International Joint Commission (IJC) is further evidence of the importance of this variable within a wider context of multiple uses of the Great Lakes–St. Lawrence River basin.

Among the various uses likely to be particularly sensitive, the IJC considers environmental components and recreational boating to be insufficiently documented. This report attempts to provide an initial perspective on the case of recreational boating, the other uses being tackled by other research scientists at the St. Lawrence Centre and at the Canadian Meteorological Service, Quebec Region.

Proceeding from the observation that there is a link between climate and water-level fluctuations, this analysis deals with the effects of these fluctuations on recreational boating, and focuses in particular on the adaptive capacity of owners and operators of marinas and yacht clubs, as well as on the perception of users (pleasure boaters), two distinct categories of stakeholders.

An evaluation of the St. Lawrence River must respect its biophysical limits. Lake Saint-Louis is both a distinct biogeographical unit and a particularly important place for recreational boating activities. It is an especially good area in which to explore the effects of water-level fluctuations on this industry, a concern to owners and operators of recreational boating facilities alike, not to mention boaters.

To define the parameters of the assessment and analysis, we begin by reviewing the notions of sensitivity and adaptation, on the basis of which we can better clarify the relative importance of water-level constraints for recreational boaters (Chapter 2). From there, we define an approach that addresses in turn the question of sensitivity and vulnerability to water levels (Chapter 3). The focus then turns to the results stemming from the evaluation of sensitivity (Chapter 4) and relative to adaptation patterns (Chapter 5). The association drawn between sensitivity and adaptations allows us to bring out the context of vulnerability. Finally, we conclude with the main observations and the implications for integration with other components (Chapter 6).

2 Behavioural Change, Sensitivity, Adaptation and Vulnerability

Over the past decade, numerous efforts have been made to define certain concepts regarding the effects of climate change, as a prelude to tackling the question of water-level fluctuations. Inspired by environmental impact studies and engineering sciences, these concepts have helped to fashion a new vocabulary that henceforth called on the social and human sciences. As such, the general problem of change and adaptation is directly linked to the behavioural sciences, particularly to the behaviourist approach developed in the United States in the 1940s and 1950s. This is the approach advocated by the International Panel on Climate Change (IPCC 2001a), among others, when it addresses the issue of adaptation to climatic stimuli.

This connection between behaviour and environmental stimuli is well defined by the concept of sensitivity, which takes into account the relative weight of environmental constraints for various stakeholders. Furthermore, the "response" to stimuli is interpreted from the perspective of adaptation — behavioural adaptation that also involves a cognitive dimension, in that individuals analyse a situation, choose an option and assess the consequences. The adaptation options chosen thus reveal the preferred behavioural patterns relative to constraints such as climate change and water-level fluctuations, and provide an indication of the vulnerability of stakeholders to such changes. The concept of vulnerability makes possible this link between reaction and decision, thereby enabling an evolution from a mechanical vision to a more socio-economic vision of adaptation.

2.1 BEHAVIOURAL CHANGE

In the context of water-level fluctuations, behavioural changes are generally based on the idea that these variations act as stimuli, or a set of stimuli, of a particular behavioural reaction, or a set of specific behaviours modulated by various factors. The way that human beings react to environmental variations, particularly to water-level variations, is nevertheless neither one-to-one, linear nor easily predictable. Moreover, it has long been recognized that individual and situational variables and the dynamic of social interactions affect the connection between the stimulus (which we refer to as environmental pressure) and the reaction (O'Riordan 1977).

A range of behaviours can also emerge from the particular experience of individuals, their motivations and their attitudes (Fishbein and Azjen 1980; Fisher 1994) — shaped, in general, by beliefs and values (Weber 1997) and linked, for example, to the aesthetic value of the lake — and from their understanding and rational knowledge of the environmental dynamic of the lake (Jaffe and Al-Jayyousi 2002).

In a more operational context, attitudes and behaviours are often guided by self-interest in the advantages and disadvantages of known choices and by the risk of the consequences that result.[1] The issue is thus to determine beforehand the relative sensitivity of stakeholders regarding water-level constraints that actually pose a risk to navigation and commercial operations.

2.2 SENSITIVITY TO CHANGE

The hydrological regime, climate change, upstream water-level management as well as basin usage all define the particular sensitivity of a lake (NRC 2002), which generally manifests itself as a shortage or an excess of water (Bruce et al. 2000) and a risk that is relative to use. For recreational boaters and owners/operators of marinas and yacht clubs, the result is potentially difficult boat operations and manoeuvring.

But what determines this sensitivity? Three main variables are cited in the analysis of environmental effects (André et al. 1999): the *intensity* of the impacts of water-level fluctuations (e.g. extreme levels), the *frequency* of the impacts (recurrence, degree of regularity) and the characteristics of the *place* (e.g. configuration of the bed, banks and infrastructure, and the nature of the preferred use). Sensitivity, a concept that considers a potential impact before an actual loss can be observed and adaptation occurs (Olmos 2001), assumes a particularly strong geographical and temporal sense in the context of water-level fluctuations. An owner/operator will be more or less sensitive to water-level fluctuations depending on the services offered, the type of craft chosen, the nature of the infrastructure (mobile or fixed) and the location on the bank (deep or shallow zone) as well as the length of the season. Sensitivity is thus relative to the context and

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1 Some individuals are strongly averse to risk (Bruce et al. 1996), while others tend to take more risks, and still others to adopt a rather neutral attitude to risk (Duckstein and Goicoechea 1994). In addition, certain institutional (i.e. indemnity) and private (i.e. insurance) mechanisms can influence the way that risk is managed (Godard et al. 2002).

can be expressed to different degrees. As a result, the way in which and the extent to which recreational boating is sensitive to water-level fluctuations must be specified.

2.3 ADAPTATION

A particular adaptive behaviour will or will not be observed depending on the relative degree of sensitivity to water-level fluctuations. In the context of recreational boating on Lake Saint-Louis, adaptation is a recurrent reaction on the part of marina owners/operators and users in response to water-level constraints in order to limit negative consequences. The recurrence of the reactions in question corresponds to a continuous behavioural adjustment to the variability of environmental conditions (IPCC 2001a). This process is generally slow, particularly if this variability is considered slight over time or if the effects of this variability are not very noticeable (Cairns 1997). Usually, the changes expected are gradual or, when they are sudden, not significant (Howlett 2001).

There are numerous ways to adapt, and no typology can fully account for this variability. Hirschman (1992) identified three basic behavioural options in situations of change and economic and political uncertainty: adaptation, exit or voice. According to the IPCC (2001a) adaptation comprises the following six risk management options:

- quit or avoid the impacts;
- bear the loss;
- protect from the effects or the loss;
- prevent the effects or the loss;
- share the effects or the loss;
- remediate the loss.

The latter typology makes a good starting point for specifying the adaptation dynamic in a decision-making context. That said, the level of decision making at which adaptation takes place is crucial. In fact, preventing the effects could involve attacking climate-changing greenhouse gases prior to tackling the problem of water levels (Bergeron et al. 1997). There are a whole series of such mitigation options in the literature (see IPCC 2001b; 2001c). In the present case, we are mainly interested in “local” adaptations that are not a matter of public policy on prevention or protection of infrastructure and equipment (Jansen et al. 1991).

By applying the preceding terms to the local level, we can explore in more detail the range of adaptations. Thus, it is understood that *bear the loss* involves minor adaptations that allow activities to be maintained while assuming the additional cost that these adaptations involve, such as changing the location of docks within the marina. *Protect from the effects* assumes that more substantial adaptations can be carried out, such as digging an access channel to the marina that may provide a critical passageway in the event of low water levels (Zins Beauchesne and Associates 2002a; 2002b; McCullough and Associates and Diane Mackie and Associates 2002a; 2002b). *Prevent the effects* would imply prior action, for example redesigning the marina with extensive dredging or, conversely, favouring craft with shallower drafts (technical innovations regarding hulls, motors, etc.). *Share the loss* could mean the active collaboration of another stakeholder, who assumes part of the costs and responsibilities. For example, in cases where the Canadian Coast Guard ensures navigational safety on the lake, the cost of adaptation (and of managing the risk of incident or accident) is then shared with this public agency. *Remediate the loss* would involve rebuilding, if necessary, the same facility in the same place (or close by) in order to provide and maintain the same use. An additional "adaptation," if it can be called that, is to *give up or abandon* the activity.

Adaptive capacity refers, for its part, to the mobilized resources supporting adaptation choices. This capacity depends on available resources, such as the total individual and collective knowledge acquired (e.g. assessment of the degree of water-level fluctuations and acknowledgment of impacts), expertise (e.g. operating and manoeuvring skills) and existing technology (e.g. spatial positioning with GPS, identification of shoals with an echo sounder), the financial resources and materials available (e.g. the financial situation of the owners/operators of access sites) and the resilience of the *hydrosystem* (e.g. other hydrological inputs that compensate for a drop in upstream levels).

Adaptive capacity can also be understood from the perspective of autonomy and the capacity to act on expressed needs (INSPQ 2002); it is demonstrated either as individual versus collective responses, or autonomous and private versus institutional responses (IPCC 2001a). Responses can also be more centralized, more market-driven or more able to attract community support (Marjolein and Rotmans 2002). The recurrence of some responses over time and space leads to the definition of an *adaptation mode* specific to recreational boating. Examining the type of measures adopted, and the regularity of these measures over time and in space, allows for a better empirical definition of this mode. Note also that this more local adaptation mode is part of a wider context of multiple uses of the Great Lakes–St. Lawrence system, within which several sectoral adaptation modes can coexist. Several examples of these adaptation modes are presented and described in connection with particular interests in *Methods of Alleviating the Adverse Consequences of Fluctuating Water Levels in the Great Lakes–St. Lawrence River Basin* (IJC 1993).

2.4 VULNERABILITY

An effective adaptation mode can attenuate the impacts of a constraint such as fluctuating water levels. Yet, there is an objective limitation to adaptation, which remains a partial reaction to a situation, temporally delayed or spatially removed. As a result, there is always a portion of irreducible residual effects or loss. The relative significance of these effects or this loss with regard to effective adaptive capacity constitutes the *vulnerability* of the socio-environmental system. Thus, vulnerability cannot simply be evaluated from the perspective of possible and probable adaptations on the part of individuals and institutions. Vulnerability resides in the management of undesired effects or possible loss (IPCC 2001b; 2001c), particularly in the capacity to attenuate loss in an extreme situation.

Considering the lack of progress in the area of adaptation (Olmos 2001; NRC 2002), particularly for uses like recreational boating, the relationship between the hydrological regime and the sensitivity of uses must first be defined. Next, the range of adaptations to water levels on the part of those involved in recreational boating must be determined. Few studies have covered this field; the one that comes closest to it avoids the question of whether the adaptations are long-term (see Planning and Zoning Center Inc., Michigan State University Department of Parks, Recreation and Tourism Resources and EPIC-MRA 2001). A pattern of adaptations has yet to be drawn.

Identifying the adaptation pattern is the first step toward acknowledging the vulnerability (Burton et al. 2002; NRC 2002). Vulnerability is difficult to establish, inasmuch as access site owners and/or operators display a certain de facto adaptation to lakes. In fact, the evolution of adaptations must be understood in the light of real-life situations of extreme levels, both through adaptations that were carried out and those that were merely considered. In describing an adaptation pattern, we must look further than simply whether or not a particular measure was adopted. Adopted behaviours depend on various constraints, such as level of expertise and missing or biased information, limited human and financial resources, communication mechanisms that are more or less effective, and external controls and rules with different degrees of stringency (Friedberg 1993).

In a more pragmatic sense, the question for recreational boating in the short and medium term is rather to what degree the present fleet can resist extreme situations in the specific context of Lake Saint-Louis, considering its infrastructural characteristics, the particular location of boats and adaptations being undertaken by users and owners/operators, as well as their respective expectations. This is the question guiding the present study, which is, after all, sectoral and limited. In fact, in the longer term, indirect effects linked to the quantity of water and to other climatic effects that modulate the activity (IPCC 1998), as well as secondary impacts on the ecosystem and other users of the lake resulting from previous adaptations should be considered from an integrated-management perspective.

The vulnerability of recreational boating must be addressed according to a certain linearity of relationships that highlight the sensitivity of the use and the adaptations made by the stakeholders concerned. The exploratory hypothesis selected is that a study focused on physical sensitivity to variations of a waterbody such as Lake Saint-Louis must be coupled with an examination of adaptations in order to better understand the vulnerability of a sector, such as recreational boating, at the local level.

3 Approach for Assessing the Sensitivity and Vulnerability of Recreational Boating to Water-Level Fluctuations

This chapter presents an analysis of the sensitivity and vulnerability of recreational boating to water-level fluctuations from a perspective that integrates physical and socio-economic factors. Water-level fluctuations resulting from climate change are thus observed through their effects on infrastructure accessibility and on the use of the lake for recreational boating. This approach allows us to better describe sensitivity, taking into account the different levels of impact characteristic of Lake Saint-Louis. In fact, impact is felt both at the level of access sites (micro) and of the lake as a whole (meso or macro). The first type of impact mainly affects owners and operators of marinas and yacht clubs, while the second concerns the boating community. The selection of reference cases as well as sensitivity thresholds also allows us to better define the parameters of the evaluation. In addition, developing adaptation patterns enables us to describe the vulnerability of the recreational boating sector, which results from the behaviour of stakeholders.

3.1 PHYSICAL SENSITIVITY AND FIELD DATA

To meet the conditions of the previously proposed hypothesis, we must begin by finding out how the sensitivity of the pleasure-boating sector can be determined in relation to water-level fluctuations.

The relationship between water levels and the infrastructure of Lake Saint-Louis must be established, based on reference thresholds, as a first step toward developing a clearer understanding of the relationship between water level and use. Physical field data (water depth at different measurement points) can be cited as a function of a common reference water depth (from hydrometric stations), standardized according to the *International Great Lakes Datum* (IGLD) of 1985, a recognized, up-to-date standard. The availability of field data from a period of particularly low levels (summer 1999) also allows for the identification of potentially problematic access sites, considering the shallow depths observed, the presence of abundant aquatic plants or infrastructure that is not readily moveable.

Also taken into account are the distinctive characteristics of boat-launching ramps, which are among the features that draw boaters to particular lakes. Ramps are essentially used by small craft with shallow drafts. Nevertheless, they can be of limited use when the water level is lower than the ramp and when the slope of the lake limits launching manoeuvres. During boat launching and haul-out, the constraint is felt when high levels submerge the ramp (which is less probable than the problem of low levels in the case of the St. Lawrence, downstream of Cornwall).

3.2 SELECTING REPRESENTATIVE ACCESS SITES

In the case of the lake as a whole, the entire shoreline of Lake Saint-Louis can be considered simultaneously. In principle, there are no particular technical problems, except that of the relative density of measurement points (precision level) at various places in the lake. Access sites are a different matter. Because each site has characteristics related to its location, it is difficult to generalize results at this scale. In this case, relative representativeness by geographical sub-sector or by type of access site seems more relevant. Hence the need for criteria for selecting and classifying access sites.

The first criterion selected depended on site visits that enabled the identification of sites that were more fragile to available water depth, and others that were less so. Three degrees of sensitivity to water-level variations (very sensitive, moderately sensitive and slightly sensitive) were selected to represent the geographical variability within Lake Saint-Louis. Sites that were already considered potentially sensitive, based on a field inventory of cases of low levels conducted during the summers (July and August) of 1999 and 2000, can be identified (Figure 1). During field studies, access constraints were evaluated so that access sites could be selected for subsequent analyses and simulations according to their degree of sensitivity.

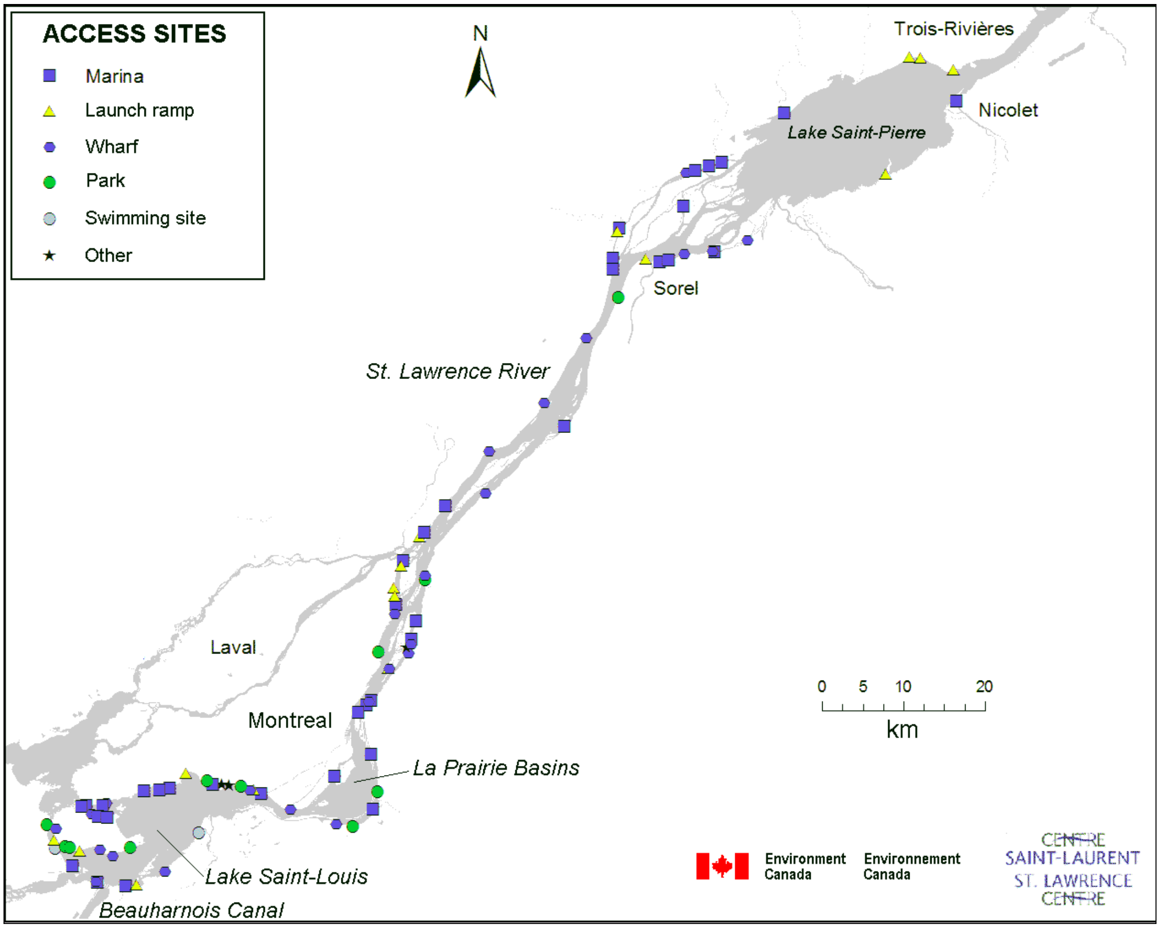

Figure 1 Access sites inventoried in 1999 and 2000

The classification of access sites by degree of sensitivity covers marinas and yacht clubs, as well as other services inventoried, such as canoe clubs and outfitters around the lake (Table 1). One site in this territory was not inventoried: a new marina that opened in summer 2002 in the Lachine Canal sector (toward the Old Port). This site was, in fact, completely developed with the reopening of the Lachine Canal.

Table 1
Identification of sites according to degree of sensitivity and relative usefulness for simulations

Access site	Location	Number of measurement points
HIGH SENSITIVITY		
Royal St. Lawrence Yacht Club (Dorval)	North shore	**High**
Baie d’Urfe Yacht Club	North shore	**High**
Pointe-des-Cascades Marina	West bank	Moderate
Melocheville Marina Inc.	West bank	Moderate
Île Perrot Marina	Island	**High**
Centre Nautique de Châteauguay	South shore	Low
Pourvoirie Chez Aumais (Île Perrot)	*Island*	*Low*
MODERATE SENSITIVITY		
Pointe Claire Yacht Club	North shore	**Very high**
Beaconsfield Yacht Club	North shore	**Very high**
Lord Reading Yacht Club	North shore	**High**
Île Perrot Yacht Club	Island	Moderate
LOW SENSITIVITY		
Lachine Racing Canoe Club	North shore	Low
Canadian Power & Sail Squadrons	North shore	Low
Pointe Claire Canoe Club	North shore	**High**
Sainte-Anne Marine	North shore	Moderate
Port de Plaisance de Lachine	North shore	**Very high**
Beauharnois Marina	South shore	**High**
Allard Marina (Île Perrot)	Island	Low
Baie d’Urfe Boating Club	North shore	**High**
Centre Notre-Dame-de-Fatima (Île Perrot)	Island	Moderate

Note: For each waterbody, sites where the number of measurement points justifies a modelling exercise are shown in bold. Italics indicate access to outfitters.

Next, the spatial distribution of these sites (on banks or islands) within the lake must be determined (second criteria). Finally, sites with a minimum number of measurement points facilitating modelling and subsequent simulations must be identified (third criteria). To this end, four categories were developed to better classify the access sites in terms of the number of measurement points:

- Fewer than 5 (low);
- 6 to 10 (moderate);
- 11 to 20 (high);
- more than 20 (very high).

Table 1 presents some sites that are representative of the three degrees of sensitivity selected based on field studies. The sites in bold characters were used for the modelling exercises.

3.3 SELECTING REFERENCE WATER LEVELS

To better reflect the diversity of water-level conditions, the sensitivity analysis involves varying the reference conditions of lake water levels in order to see how this sensitivity responds to various hydrodynamic conditions. This analysis depends particularly on the hydrodynamic modelling developed by the Meteorological Service of Canada. Following are some basic elements of this modelling.

First, defining reference scenarios determines the capacity of the model for the range of discharge (or flow) rates in the river. The work of Morin and Bouchard (2001) is an initial synthesis that is useful to the present approach (Table 2). These scenarios are based on probability, because for a given discharge, there is a variance linked to other conditions (inputs, wind, waves, friction, etc.). This permits real and potential water-level situations to be contrasted. The most probable and common scenarios nevertheless remain in the range between the third scenario from the top of Table 2 (occurrence 1/2) and the sixth (occurrence 1/3). The other scenarios correspond to situations that are rarer and to more extreme water levels. For the purposes of simulations, we can thus compare more common situations to those that are more extreme.

In addition to basic data, we must have an idea of the relationship between flow rate and level. The data from the reference hydrometric gauging stations are located at several points along the river and apply to the sectors considered by the analysis; a streamflow station in LaSalle complements the hydrometric stations at Pointe-Claire and Sainte-Anne-de-Bellevue, among others. In addition, there is data on some of these flow/level relationships, particularly for two seasons, which are also the busiest for recreational boating. Spring and summer data correspond to the high season for this activity, even though it continues into the fall.

Table 2
Basic hydrodynamic data for simulations

Scenario No.	Scenario (recurrence /year)	Discharge scenarios (m^3/s)	Pointe-Claire station (chart datum, m)*	Seasonal relationship (probability of occurrence based on observations)		
		LaSalle Station		Spring	Summer	Fall
8	1/7 000**	14 531	ND	73%	ND	ND
7	1/16	13 174	ND	75%	ND	ND
6	1/2	11 396	21.96	78%	ND	ND
5		10 102	21.71	82%	86%	85%
4	1/1	8 304	21.20	83%	89%	88%
3	1/3	6 997	20.71	80%	89%	88%
2	1/70	5 740	ND	ND	89%	88%
1	1/10 000*	4 572	ND	ND	92%	ND

Source: Adapted from Morin and Bouchard, 2001.

* Chart datum corresponding to this key station in Lake Saint-Louis are preliminary, pending more complete results.
** For these extreme cases, the ratio of minimum and maximum values is used, based on mean daily discharge.
ND: No data.

Note: Discrepancies between scenarios vary depending on whether levels are high (2500 to 3000 m^3/s) or low (1500 m^3/s).

Clearly, other factors can cause water levels to fluctuate, such as an abundance of aquatic plants, wind speed and direction, and type of substratum. In many respects, the model allows precisions for these parameters to be added. A friction index is particularly useful for simulating the presence of abundant aquatic plants in the environment and the effect on the downstream water level (for example, along the north shore of Lake Saint-Louis). The outcome of this variation, attributable to different factors, can cause the water level to vary by up to 20 cm over some 10 km downstream (J. Morin 2002, personal communication).

Moreover, the situation in Lake Saint-Louis is particular since this lake also receives water from the Ottawa River. In general, the flow rate in the Vaudreuil or Sainte-Anne canals is not significant (885 to 900 m^3/s on average between 1962 and 1989 and between 1981 and 1989), representing an average of just over 10% of the flow coming from the St. Lawrence River over the same period (Fortin et al. 1994). However, the flow rate of the Ottawa River can vary from as little as 306 m^3/s to as much as 8190 m^3/s, which changes the impact on Lake Saint-Louis.

Nevertheless, the scenarios selected offer a good approximation of the conditions that are most likely applicable to Lake Saint-Louis.

3.4 THE SIMULATION APPROACH

Linear extrapolation was used for the evaluation of particular access sites, following the work begun by Renou et al. (2001), without reference to the hydrodynamic model as such.

Conversely, two-dimensional modelling (surface area and depth) provided a general appreciation of the configuration of the lake as a whole. In this case, the hydrodynamic model[2] can predict local water depth, mean vertical flow velocity and the wetted area for target events (flows) for which field measurements are not available. In fact, this model is based on a structured set of relationships established according to physical principles that govern the interactive processes affecting the way the freshwater portion of the surface water of the St. Lawrence River is distributed laterally and horizontally (two-dimensional model) (see INRS 1999). This is a “drying/wetting” model because it can determine the position of the shoreline as a function of flow rate. This characteristic of the model is useful when (almost always) the environment has mobile boundaries (tidal estuaries, rivers) where the area wetted by the flow will be influenced by the hydrological regime or the water level.

Using this model, the simulation began by integrating the limiting conditions of the flow rates and water levels of the fluvial section under study. Once there is convergence of the digital calculations, the results are analysed. If there is divergence between the digital results and the values measured, certain digital parameters, such as turbulence and water viscosity, are modified in order to yield results that more accurately represent reality (Rioux 2000).

Data were reviewed in light of the present analysis and selected available data. In the case of the modelling, the use of complementary data gathered by the Canadian Hydrographic Service is also required, and in certain cases, the grid of the lake must be modified to ensure spatial coherence.

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[2] The model consists of a grid of finite elements on which hydrodynamic equations are solved. The relationships used in the HYDROSIM software are equations from Saint-Venant. They represent flow mathematically, taking into account conservation of mass and quantity of movement. The topography of the study area is assembled point by point on the grid of finite elements with the help of MODELEUR software and is then interpolated between each grid point to enable its use in the digital calculation. The model also takes into account the substratum by converting it into Manning’s coefficient, an index of flow resistance exerted by the riverbed on the waterbody (Rioux 2000).

Next, the locations of the measurement points were plotted, taking into account the initial sensitivity of the access sites. The particular sites used for the first simulations were selected from among the sites located in Figure 2. Marinas and yacht clubs, where problems are most evident and economic repercussions likely to be the highest, are the focus of the impact modelling. Figure 2 also indicates the location of the access sites, which were chosen based on their sensitivity and the number of measurement points allowing simulations, as detailed in Section 3.2. Each section of the area under study is presented in the screen format (zoom) in which it appears in MODELEUR, and then in an enlarged map that more clearly locates the sites selected for modelling.

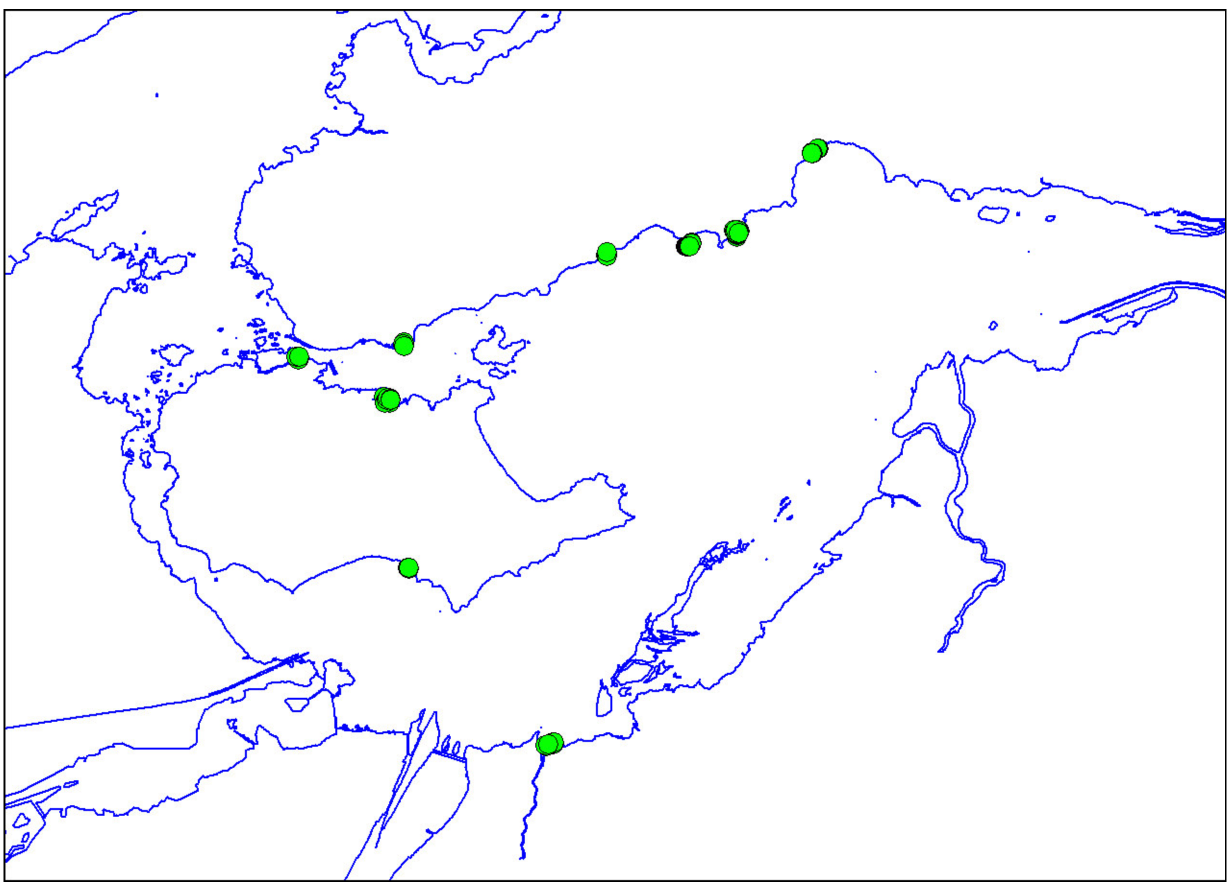

Figure 2 Location map of the sites selected for simulations in Lake Saint-Louis

This relatively static representation nevertheless hides the elaborate grid of the area, as used in the application of the HYDROSIM model, or, in the case of Lake Saint-Louis, the many points considered within the geographic areas of the marinas and the other access sites selected. In the case of linear (1D) and two-dimensional simulations (2D), the same reference scenarios are used in all cases in order to facilitate the comparison by distinguishing the situation in spring (April to June), prior to the growth of aquatic plants, from the situation in summer (July to September), when conditions are more difficult due to the growth of aquatic plants. Among the eight reference scenarios, only four (low levels) apply to summer conditions. Considering the absence of relevant data, the exercise cannot be done for scenarios 1 and 2. Conversely, it is possible to consider scenarios 3, 4 and 5 as reflections of low level situations and scenario 6 as that of a relatively “normal” year.

3.5 DETERMINING SENSITIVITY THRESHOLDS

To complement the data on water-level constraints, usable sensitivity thresholds must be established for access sites and the lake as a whole. The draft of different boat types is thus selected as an indicator of water level demand. In general, the different types of boats that use marinas and yacht clubs have different drafts, non-motorized boats generally having a deeper draft. Lake Saint-Louis is dominated by non-motorized craft with an absolute minimum water level requirement of 1.2 m (4 ft). If a safety margin of 30 cm is added, a threshold of 1.5 m (5 ft) of water must be ensured by each access site in this particular sector.

Based on a survey of marina operators (Zins Beauchesne and Associates 2002a; 200b) to which the first author of the present report contributed, a connection can be drawn between boat draft (without safety margin) and the proportion of boats that can navigate, depending on the water-level constraint. Based on this survey, an estimated 2780 boats can use the access sites on Lake Saint-Louis. Table 3 details the relationship between the drafts of the recreational boats on Lake Saint-Louis and the percentage of craft having or not having navigational difficulties, with no reference to a safety margin.

The following evaluation of the minimum water depth for safe recreational boating in a navigation channel, conducted in the United States by Tobiasson and Kollmeyer (2002, p. 302), further support these data:

- 1.2 m (4') for boats shorter than 30 ft (motorized and non-motorized);
- 2.1 to 2.55 m (7 to 8.5') for motorboats measuring 30 to 60';
- 2.7 to 4.35 m (9 to 14.5') for sailboats measuring 30 to 60';
- 2.7 m (9') for the longest motorboats (65');
- 4.65 m (15.5') for the longest sailboats (65').

This evaluation assumes a safety margin of at least 90 cm (3') beneath the draft, which represents a conservative situation. Thus, there is some convergence between the two approaches in terms of the determination of water depth "needs," at least in low-level situations.

Table 3
Draft requirements of recreational boats on Lake Saint-Louis as a whole
(based on boats using access sites)

Draft (feet)	Motorboats whose draft needs are met (%)	Non-motorized boats whose draft needs are met (%)	All boats on Lake Saint-Louis (%)
2.5	50	0	28
3.0	77	0	43
3.5	89	0	48
4.0	94	68	83
4.5	100	68	86
5.0	100	68	86
5.5	100	87	96
6.0	100	95	99
6.5	100	98	99
7.0	100	100	100

Note: Pale grey shading shows that a rule of absolute majority is met (> 66.6%) for draft needs. Dark grey shading shows draft needs are met for the entire recreational fleet. Percentages are cumulative: the deeper the water, the higher, in principle, the number of boats that can navigate.

In addition, a preliminary survey conducted in 2000 and based on the summer of 1999 (13 respondents for Lake Saint-Louis) revealed that despite the difficulty of accurately estimating water depth, respondents nevertheless indicated the water depth that they considered ideal, by means of a range of values. For most, this depth is between 1.8 and 2.4 m (6 and 8') (Boudier and

Bibeault 2001). The range of "ideal" water levels can also be perceived as the range of full-use potential (100% of docks usable) with no constraint. It would be reasonable to believe that this range of water depths is in fact close enough to the draft needs of the fleet and that it better specifies water level preferences. As a result, a certain number of sensitivity classes, based on needs that are common to the fleet and to owners and/or operators of access sites, can be established for the purpose of analysing water-level sensitivity.

	Water depth at dock
Low water levels	0 to 90 cm (0–3') = critical (red alert)
	90 cm to 1.2 m (3–4') = minimum (orange alert)
	1.2 to 1.8 m (4–6') = fair (yellow warning)
Optimum water levels	1.8 to 2.4 m (6–8') = ideal (smooth sailing – green sign)
High water levels	2.4 to 3.5 m (8–11'8") = fair (yellow warning)
	3.5 to 3.8 m (11'8"–12'8") = minimum (orange alert)
	More than 3.8 m (12'8") = critical (red alert)

These classes also illustrate a degree of asymmetry between a low level and a high level situation for recreational boating on Lake Saint-Louis. The impact is, in fact, more marked for low levels than for high levels, contrary to Lake Ontario (see McCullough and Associates and Diane Mackie and Associates 2002a; 2002b). In the case of low levels, if a depth of 1.8 to 2.4 m (6 to 8') is the optimum range, the portion from 0.9 to 1.8 m (3 to 6') comprises two distinct categories, 1.2 m (4') being the minimum acceptable threshold. Furthermore, high levels have an impact on infrastructure, but a weak or negligible impact on boats (hence the absence of decline in the number of boats affected by high levels).

To simplify the exercise, three contrasting colours (green, yellow and red) were created. The relative proportion of points in each category provides an overview of the condition of access sites.

In the case of boat-launching ramps, however, it is more difficult to determine sensitivity thresholds. Generally, when the water level is between the top and the bottom of the slope of the ramp, it can be assumed that the access site remains functional and that launching manoeuvres do not present any particular problems. Problems occur when the water level is beyond these limits. Sensitivity then depends on the site's natural slope, which complements that of the ramp. In certain cases, the natural slope prolongs the slope of the ramp, impeding very minimally the launching manoeuvre. In other cases, there is a sharp drop-off, and launching is impossible. Ideally, this evaluation should be performed on a case-by-case basis.

Nevertheless, several ramps were completely dry in July and August of 1999, with the waterline sometimes a few metres beneath the lowest point of the ramp. In fact, a distance of one metre between the bottom of the slope and the waterline is often problematic. In addition, safety criteria, which are more conservative in the design of channels and various access sites in the United States, require a water depth of 30 to 60 cm above the bottom of the slope.

It is even more difficult to reach a conclusion regarding high levels, although in the United States, ramps are designed to maintain a threshold of 60 cm (2') above the highest levels ever observed. Nevertheless, the top of the slope is often at the same elevation as the parking lot or the dock from which the ramp extends. This would lead one to believe that if the water level is higher than the top of the slope, launching is at risk, yet this risk varies according to the adjacent development.

Nearly two-thirds of those who use the lake prefer to use a ramp instead of a marina or a yacht club (estimate based on Gardner Pinfold Consulting 2003, for Lake Saint-Louis to Lake Saint-Pierre). These boaters generally own a small boat with a shallow draft. They use ramps because they are more practical and they provide access to the lake near their home, in addition to being free of charge (there is no user fee for public ramps). If there happens to be a problem with this ramp, the boater can always pay a fee to use a marina with a ramp that is better adapted to low levels. In this regard, constraints that arise at access sites could constitute a good approximation of the situation of boaters on the lake as a whole.

3.6 REPRESENTATION AT TWO SCALES (MICRO- AND MACRO-ANALYSIS)

In the present case, the sensitivity analysis involves a two-scale representation in order to consider the various levels of constraint posed by different water levels (scenarios). A representation at the scale of marinas and of the lake as a whole proves to be complementary insofar as the spatial representation remains different from the point of view of the owner/operator of the service (very strong constraint) and that of the more mobile user within the lake (less strong constraint).

To ensure the coherence of the results and to accurately attribute the relative weight of the constraints, we used a colour rating (three colours), based on the boats and their drafts. Boat drafts remain relevant both within the access sites and outside them (the lake in general). This rating system is used for each simulation and permits the changing effects of water-level constraints to be better assessed from one scenario to another. To be exact, we used a GIS representation on the ARCView system (see the example of Renou et al. 2001) and the interface associated with the MODELEUR simulation system (see Rioux 2000).

3.7 VULNERABILITY AND ADAPTATION PATTERNS

Vulnerability cannot be assessed directly. In fact, because it ensues from relative capacity to adapt, an approach for assessing adaptation must first be defined. To do so, we prefer an approach based on adaptation pattern. This pattern can provide an indication of the type of adaptation identified (typology), the recurrence of adaptations and the extent of their use for a given group of stakeholders, in the case of owners and operators on one hand, and users on the other.

Three aspects of adaptation are of particular interest: common or usual practices, those that are less common and more innovative and already being used, and those that stakeholders are considering for the future. This pattern aims to show the preferred direction of adaptations, which would provide a better indication of vulnerability to extreme situations. In a context of uncertainty, Marjolein and Rijkens-Klomp (2002) indicate that there is often a pathway in the series of adaptations that directs the future development of activities. Thus, at the methodological level, adaptive capacity and mode can be deduced from past behaviour, from the behaviour of other owners/operators grappling with similar circumstances and, to a lesser extent, the intentions of stakeholders regarding future adaptations.

What should inductively emerge regarding vulnerability is that it can be revealed to what extent there is an intensification of more common past behaviours (decisions that are limited in scope, Friedberg 1993) or to the contrary, of more innovative behaviours that are able to integrate more constraints (Schon and Argyris 1978; Argyris 1990). It is in this context that we can bring up the normative problem often referred to as the “right” adaptation (NRC 2002).

4 Evaluating the Physical Sensitivity of Recreational Boating to Water Levels

Physical sensitivity depends on the selective impact of various water-level scenarios, and it must be evaluated by considering spatial repercussions at selected access sites and the lake in its entirety. The findings of this chapter indicate the possible impact of extreme climate conditions as reflected in the water-level fluctuations of the St. Lawrence River in general, and Lake Saint-Louis in particular.

4.1 SENSITIVITY OF ACCESS SITES

Water depth measurements taken at various sites and expressed as navigational constraints (draft) indicate the relative accessibility of the docks. The figures presented in tables 4 and 5, which correspond to the measurements at various points in the area occupied by marinas and yacht clubs, provide an indication of the proportion of surface area unsuitable for navigation.

Based on this estimate, the first observation that can be made based on hydrological conditions is the lack of major problems in cases of high levels (scenarios 6, 7 and 8, summer and spring) for the five chosen sites along the north shore of the lake (Table 4). The Beauharnois Marina, on the south shore, is the exception. Most access sites have, in a sense, already partially adapted to regular water-level fluctuations by building mobile docks.

The second observation, particularly for the sites on the north shore (Table 4), is the emergence of low level problems as of scenario 3P, which reflects the fact that a significant proportion of the fleet using these sites (sailboats) have deep drafts. Thus the Pointe Claire Canoe Club seems particularly sensitive to the water depth available for boats at the docks. In this particular case, clearer knowledge of the site would allow the situation to be qualified, insofar as the site and its mobile docks are used primarily by boats with shallow drafts (contrary to the types of boats on the lake as a whole).

The two other more sensitive sites, the Beaconsfield Yacht Club and the Pointe Claire Yacht Club (Figure 3), have a similar sensitivity pattern. They experience certain problems as of scenarios 3P and 3E, which are even more pronounced under scenarios 2P and 1P (one would imagine that if they were available, summer scenarios 1E and 2E would indicate a very high sensitivity for these two sites).

Table 4
Distribution of measurement points according to degree of sensitivity of sites and various flow and level reference scenarios (Lake Saint-Louis–north and south shores)

Site	Sensitivity rating	Spring scenarios								Summer scenarios			
		1P	2P	3P	4P	5P	6P	7P	8P	3E	4E	5E	6E
Baie d'Urfé Yacht Club	Red	ND	0	0	0	0	0	0	0	0	0	0	0
	Orange	ND	4	0	0	0	0	0	1	0	0	0	0
	Yellow	ND	0	4	0	0	4	4	3	4	0	0	4
	Green	ND	0	0	4	4	0	0	0	0	4	4	0
Beaconsfield Yacht Club	Red	ND	5	0	0	0	0	0	0	0	0	0	0
	Orange	ND	5	4	0	0	0	0	1	5	0	0	0
	Yellow	ND	1	7	8	0	8	11	10	6	8	0	6
	Green	ND	0	0	3	11	3	0	0	0	3	11	5
Pointe Claire Yacht Club	Red	ND	11	3	0	0	1	3	5	3	0	0	1
	Orange	ND	3	6	2	0	2	2	1	6	1	0	1
	Yellow	ND	3	6	10	3	9	15	14	6	11	3	9
	Green	ND	3	5	8	17	8	0	0	5	8	17	9
Lord Reading Yacht Club	Red	ND	0	0	0	0	0	0	0	0	0	0	0
	Orange	ND	4	0	0	0	0	0	1	0	0	0	0
	Yellow	ND	1	5	0	0	5	5	4	5	0	0	5
	Green	ND	0	0	5	5	0	0	0	0	5	5	0
Pointe Claire Canoe Club	Red	ND	5	3	0	0	0	0	0	3	0	0	1
	Orange	ND	0	2	1	0	0	0	0	2	1	0	0
	Yellow	ND	0	0	4	2	0	4	5	0	4	2	0
	Green	ND	0	0	0	3	5	1	0	0	0	3	4
Beauharnois Marina	Red	ND	3	3	2	0	4	3	4	3	2	0	3
	Orange	ND	1	0	1	1	1	1	2	0	1	1	1
	Yellow	ND	3	2	0	2	4	–	1	2	0	2	5
	Green	ND	2	4	6	6	0	3	2	4	6	6	0

Source: Results of one-dimensional simulations performed by D. Rioux.
ND: No data.

The Baie-d'Urfé Yacht Club and the Lord Reading Yacht Club reveal a pattern slightly less sensitive to low levels, but the same pattern in situations of high levels (Figure 3). Finally, the only site on the south shore (Beauharnois Marina) shows a relatively higher degree of sensitivity. For this site, which is potentially sensitive to low and high levels, scenarios 5P, 5E and 6P could qualify as preferable. Thus, depending on whether we are on the north or the south shore, the effect of water-level variations differs.

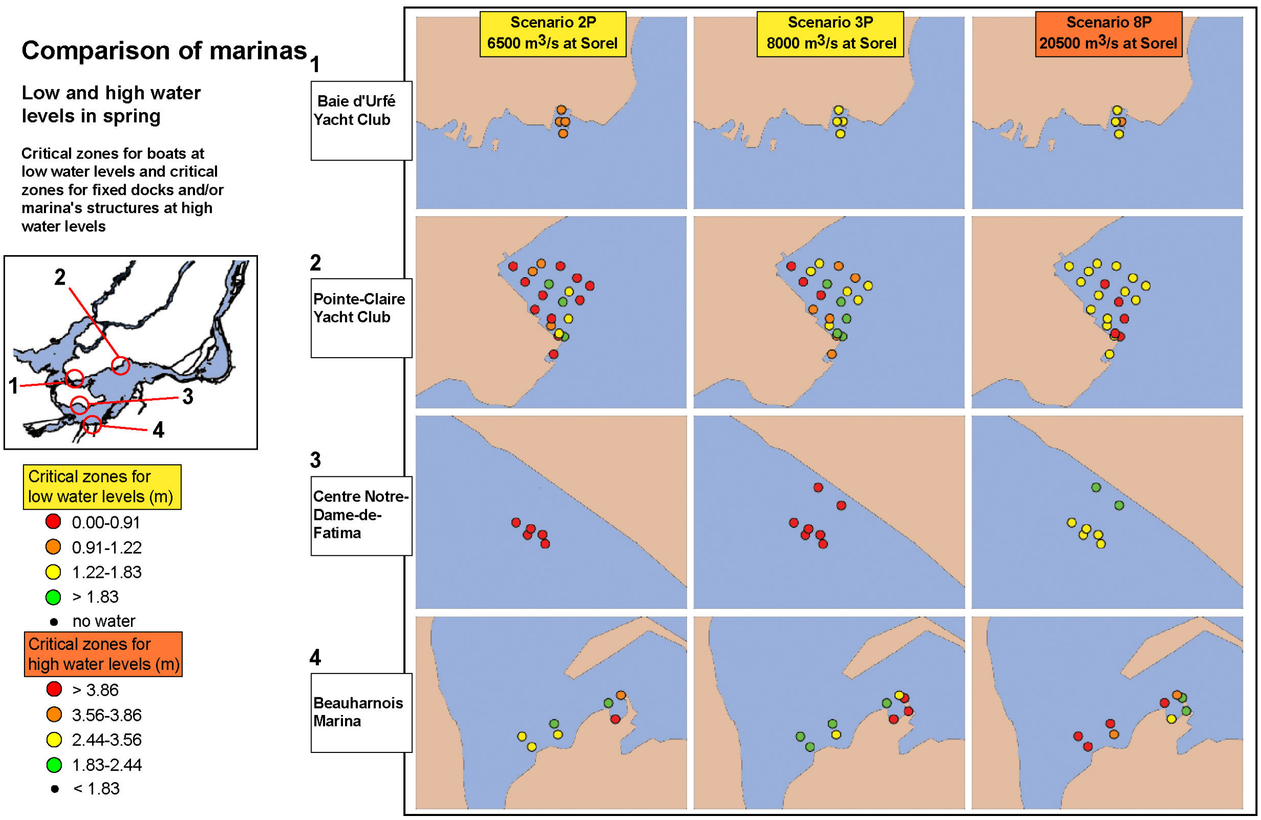

Figure 3 Constraints on recreational boating of various scenarios of low and high water levels in spring (April–June) at selected sites

The other place with a uniqueness all its own is around Île Perrot (Table 5). In this case, given the very limited number of points available for the sensitivity analysis, sensitivity related to different scenarios is consequently excessively high. Particular caution is warranted here.

In Table 5, the two sites with the highest number of points reveal quite a similar pattern of sensitivity. The Île Perrot Marina is slightly less sensitive to low-level scenarios and not very sensitive to cases of high levels. The Centre Notre-Dame-de-Fatima appears to be very sensitive to low levels and quite sensitive to high levels, at least in summer (6E). In the case of low levels, the field survey revealed that the site was located in an area where the level was particularly low during summer 1999 and that the natural slope giving access to the site was very shallow.

Table 5
Distribution of measurement points according to degree of sensitivity of sites and various flow and level reference scenarios (Lake Saint-Louis–Île Perrot)

Site	Sensitivity rating	Spring scenarios								Summer scenarios			
		1P	2P	3P	4P	5P	6P	7P	8P	3E	4E	5E	6E
Allard Marina	Red	ND	2	2	2	1	3	2	3	2	2	2	2
	Orange	ND	0	0	0	1	0	1	0	0	0	0	1
	Yellow	ND	1	0	0	0	1	0	0	0	0	0	1
	Green	ND	1	2	2	2	0	1	1	2	2	2	0
Île Perrot Marina	Red	ND	7	2	0	0	0	0	2	4	0	0	1
	Orange	ND	1	4	1	0	0	2	0	3	1	0	0
	Yellow	ND	2	3	6	2	5	7	8	2	6	2	3
	Green	ND	0	1	3	8	5	1	0	1	3	8	6
Centre Notre-Dame-de-Fatima	Red	ND	7	7	2	0	2	0	0	7	2	0	3
	Orange	ND	0	0	5	0	0	0	0	0	5	0	0
	Yellow	ND	0	0	0	7	0	3	5	0	0	7	0
	Green	ND	0	0	0	0	5	4	2	0	0	0	4

Source: Results of one-dimensional simulations performed by D. Rioux.
ND: No data.

The third case, Allard Marina, is more problematic as there are very few measurement points available. We note that the difference between the scenarios prevents the location of an optimal or satisfactory scenario for this access site. While such a scenario could likely be located between 5P and 6P and between 5E and 6E, it is impossible to determine the optimal flow. Considering the small size of the marinas on Île Perrot and the limited number of measurement points, we preferred to observe the impact of low levels through field visits in 1999 and a visual examination, rather than not to do the exercise at all.

For Lake Saint-Louis, excluding the more difficult cases, it is generally possible to determine that maintaining level and flow conditions near scenario 5 (spring and summer) would limit the impact of water-level fluctuations. Maintaining a slightly wider range that would include scenario 4 would not cause major problems on the north shore, but would possibly have a more negative effect on the south shore and at certain sites along Île Perrot.

On the other hand, in response to the hypothesis that extreme scenarios would be more frequent, a marked change was observed in the aquatic landscape, probably more significant in the spring for high levels and at the end of the summer in the case of low levels. Figure 4 provides a general idea of the constraints imposed on boat navigation (scenario 1P) in the case of extreme low levels, even in the absence of aquatic plants. Note the red shading, which represents water depths that are especially critical for boats, particularly in the Valois Bay sector (north shore of the eastern tip of Île Perrot, the channel near the municipality of Les Cèdres and in the Îles de la Paix sector on the south shore).

The overall picture that emerges is that of a lake dotted by small islands that would demand an even greater knowledge of shoals and better navigational skills on the part of recreational boaters. Furthermore, we note that getting from Lake Saint-Louis to the Sainte-Anne-de-Bellevue locks and Lake of Two Mountains, or on the south shore, to marinas on the Châteauguay River, would be more difficult and would force boaters to stay within the ship channel. The problem of low water levels goes beyond marinas and thus would demand a concerted effort beyond the limits of these individual areas. It should be noted that this situation is, for the moment, limited to a short period of the year, and no data yet allow us to accurately predict how long these scenarios could last.

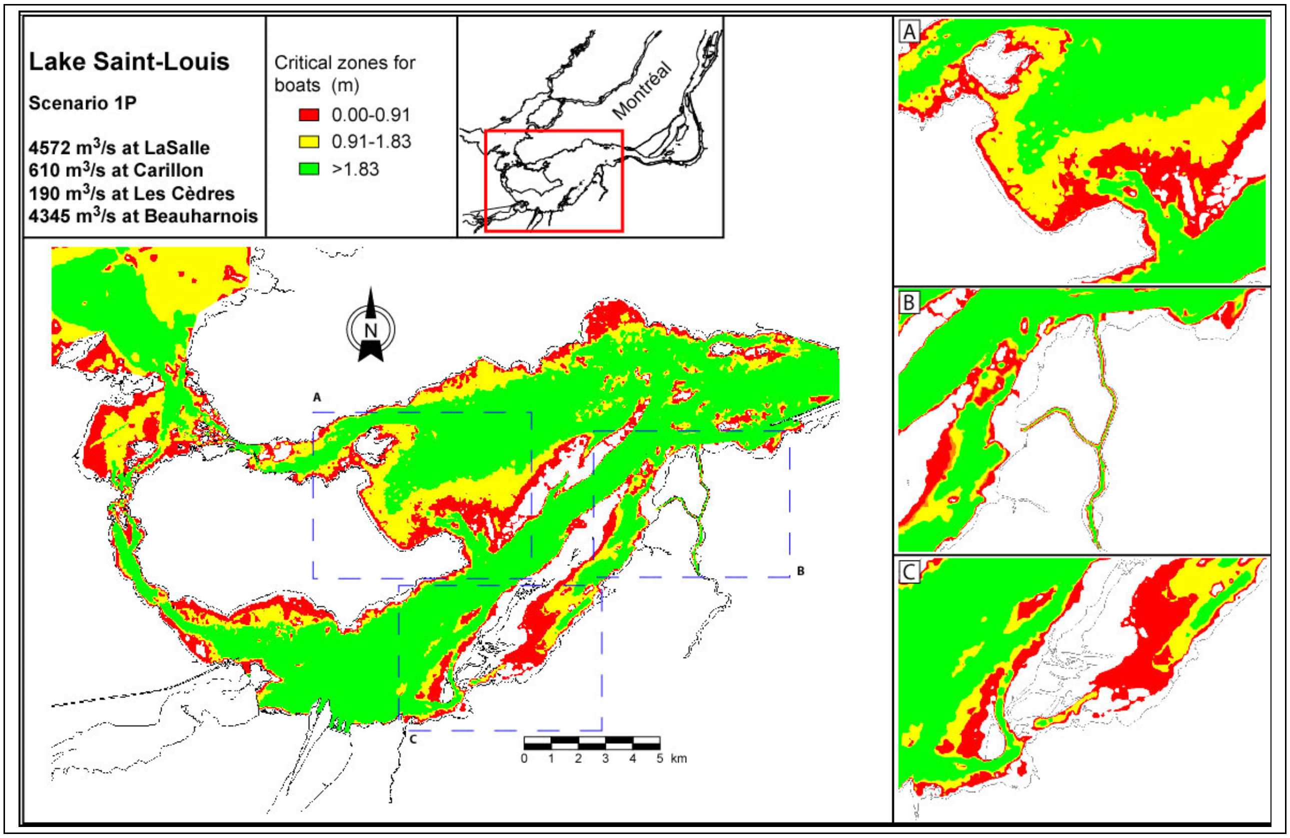

Figure 4 Constraints on recreational boating due to extreme low-water-level scenarios in spring (April–June)

Figure 5 shows an extreme high-water-level situation with problems of potential flooding of fixed infrastructure (scenario 8P), a situation that did in fact occur in the spring of 1974 and 1976. The fixed infrastructure at the mouth of the Châteauguay River, on several sectors of Île Perrot, and on the north shore of Dorval and Lachine are all at risk. On the other hand, high-level scenarios (7P and 8P) would facilitate the navigation of boats in all sectors, some of which could even navigate above the sector currently occupied by the Îles de la Paix. Links with the Lake of Two Mountains and the Châteauguay River would also be facilitated, the water level problem thus being in the area of flood zones, particularly on the north shore toward Dorval and Lachine, at various parts of Île Perrot (Pointe de Brucy, Notre-Dame-de-l'Île-Perrot on the east shore and Pointe au Sable on the west shore), at Vaudreuil, and in the sectors of Île Saint-Bernard and Maple Grove on the south shore.

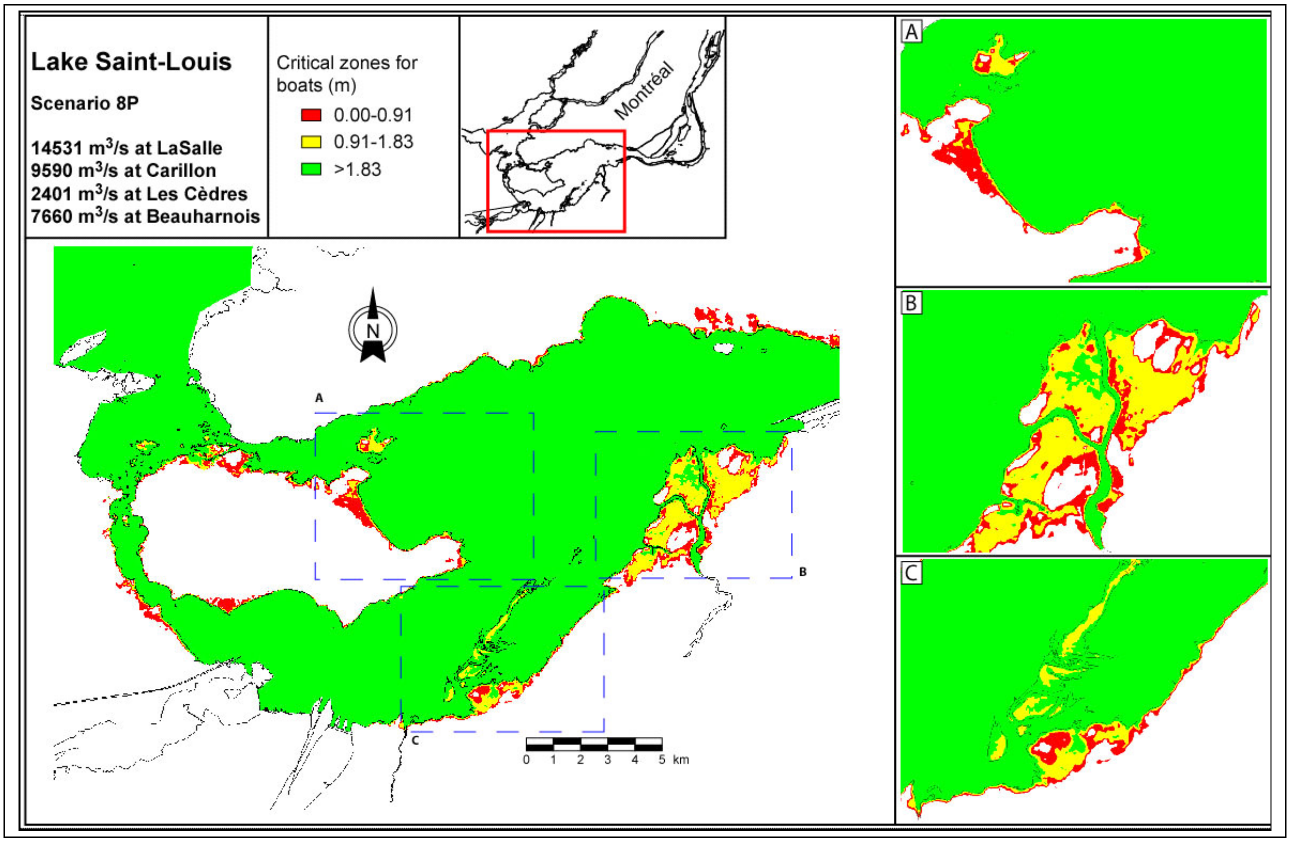

Figure 5 Constraints on recreational boating due to extreme high-water-level scenarios in spring (April–June)

In a context of climate change, when the level of the river tends (on average) to drop, scenario 8, which was rare enough in the past (twice over the last three decades), would be even less probable. Furthermore, because most of the infrastructure is mobile and recreational boaters can choose from a range of access sites, they are relatively less sensitive to high levels than they are to low levels. These simulations reveal that there is in fact a strong asymmetry between the possible effects of extreme high and low levels for the recreational boating sector.

In light of more recent climatic simulations, the very low levels of scenario 1 remain highly unlikely in the short and medium term, scenarios 2 and 3 being more probable. While the low level hypothesis initially assumed a possible decrease of 40% of the flow at the mouth of the Great Lakes (Mortsch et al. 2000; Slivitzky 1997), recent data from the CGCM1 and the HadCM2 models, applied to the Great Lakes, indicate a wider range of estimates. These projections could nevertheless mean levels on Lake Saint-Louis as low as one metre below chart datum (19.44 m according to the CGCM1) or just under 10 cm below chart datum (20.33 m according to HadCM2) in 2030 (Table 10 presented by Lofgren et al. 2002).

Yet even in the most optimistic case (Hadley scenario), the survey data indicate that less than 50% of the boats in the fleet would be able to navigate on Lake Saint-Louis and to access docks in their current state. In the worst case, hardly any boats would be able to use existing access sites. More recent simulations initiated under the aegis of the International Joint Commission (data not yet published) could indicate potentially less extreme situations.

Without discussing the respective merits of each scenario in this highly uncertain context, we note that low-level situations would have a major impact on recreational boating on Lake Saint-Louis (considering also that the IJC's Plan 1958-D for the regulation of Lake Ontario and the St. Lawrence River entails obligations to other uses). The adaptation measures adopted can, in part, limit vulnerability to extremes beyond a certain threshold that corresponds approximately to low-level situations experienced in late summer of 1999 and 2001 and to scenario 3, used during simulations. In the case of high levels, however, there is more flexibility, and the maximum threshold proves to be more difficult to indicate based on the preferences expressed. The 1-in-100-year flood line, which particularly applies to buildings, would probably provide a better indication of tolerance to high levels.

4.2 SENSITIVITY AND THE RECENT CONTEXT OF LOW WATER LEVELS

To complement the evaluation of physical sensitivity, a portrait can be drawn of reference year 2001, which was a year of very low levels that approached scenario 3E. For Lake Saint-Louis, the vast majority (16 of 20) of marina owners and operators participated in a survey that specifically aimed to identify the operational constraints they faced. Despite the small number of respondents, the data can nevertheless be considered very representative of the Lake Saint-Louis sector.

Following are some basic observations drawn from the main survey (Zins Beauchesne and Associates 2002a; 2002b):

Capacity

- 20 access sites (marina, yacht club or other) around Lake Saint-Louis;
- an average of 139 places per site (16 of 18 total respondents for Lake Saint-Louis);
- 2780 places available on Lake Saint-Louis (2224 for 16 of 18 respondents);
- a relatively stable capacity over the five fiscal years from 1996 to 2001, although some (4 of 16 respondents) anticipated increasing their capacity (for 2002–2004);
- service provided mainly by mobile docks (99.4%);
- all sites have a launching ramp on-site or nearby;
- season lasts 22.1 weeks on average (varies from less than 21 weeks to more than 24 weeks), generally stable over time (in relation to the four years preceding the 2000–2001 fiscal year).

Attractions

- The majority offer winter storage facilities (about 22 of 34 respondents) and fuel (17 of 34 respondents);
- a variety of related services are offered: restaurant, repair, marine supplies, travel, launch, haul-out in fall, boat and equipment rental, boat sales and, in some cases, accommodation.

Use

- Highest occupancy rate is in July and lowest in September (although respondents were very uncertain about their estimates);
- on Lake Saint-Louis, in particular, an estimated 24.7% of available spaces were unusable for the entire 2001 season (the percentage can vary significantly by month, week and day); Lake Saint-Louis is more “sensitive” in this aspect than the other sectors;
- after correcting for other factors, the proportion of unusable places attributable to low levels is nevertheless estimated at 11%;
- in 2001, the average occupancy rate for sites on Lake Saint-Louis was 72%.

Perception of water levels

- 81.2% of respondents estimated that the effect of fluctuating water levels in recent years (1996–2001) was “major” or “severe” (levels 4 and 5 on a scale of 1 to 5);
- almost half the respondents (7 of 15 respondents for Lake Saint-Louis) identified loss of revenue as the main impact; also identified were declining business (5 of 15 respondents), loss of clientele (4 of 15 respondents), and the problem of boat access (2 of 15 respondents);

- the most critical areas where low levels are felt are, by order of importance, the access channel (4 of 16 respondents), slips, shores, or the whole site (2 of 16 respondents); respondents were allowed to mention more than one;
- in fall 2001, three-quarters of the respondents from Lake Saint-Louis (12 of 16 respondents) indicated that the level was too low (the others considered it adequate or did not know);
- on average, 15 spaces were unusable in 2001.

Water level preferences expressed (in feet and inches) by respondents)

- critical minimum: 24.6" (2') = 43.5% of docks unusable;
- minimum acceptable or tolerated: 36.6" (3');
- maximum acceptable or tolerated: 140" (11' 8");
- critical maximum: 152" (12' 8") = 19.2% of docks unusable.

During the preliminary survey, some respondents commented that an access problem for a user in one season often meant an irreversible loss of clientele in subsequent years.

It is more difficult to decide on the effect of a particular year on users. There is relatively little information on pleasure boating for Lake Saint-Louis (much like other riverine sections of the St. Lawrence). Most of the information consists of sporadic data on recreational use. In the case of Lake Saint-Louis, an integrated report conducted in 1994 by Jourdain et al. (1995) cited data from the early 1980s. The estimate conducted as part of the *Archipel* project indicated more than 29 000 people participated, with a frequency of some 254 000 pleasure boating days (11.4 days on average per boater). The number of boats navigating on Lake Saint-Louis was estimated at 7383 in 1981 — 51% motorboats, 31% sailboats and the rest classified as “other” (e.g. kayaks). Capacity was estimated at 2360 places (with, however, certain problems of availability).

Recently, according to the first large-scale survey of users conducted for the St. Lawrence to date (see Dewailly et al. 1999), 17% of riverside residents went boating on the St. Lawrence at least once a year. Regional data for the shores of Lake Saint-Louis indicate that the proportion of riverside boaters ranged from 13.3% (Montreal) to 23% (Montérégie). In 2001, a new survey that used a somewhat different stratification nevertheless revealed a boating proportion on the order of 15.4% for the Montreal region (Grondin et al. 2003). However, the location where they practise the activity is not specified at the scale that interests us.

Nevertheless, based on historical data, certain relationships can be drawn that would allow us to anticipate the potential effects on the use value of different water levels. We can estimate that the number of boats on the lake is more than three times the number of moorings or slips available. We estimated the number of days of use at 42 days per boating season, based on the DBSF (2002) data (about six months). Gardner Pinfold Consulting (2003) indicates, in the context of a survey based on the problem of water levels in the St. Lawrence and Lake Ontario, that frequency of use depends on boat type. Owners of boats shorter than 25 feet (7.6 m) use the sector from Lake Saint-Louis to Lake Saint-Pierre over a period of 39.2 days, while owners of boats longer than 25 feet use the same body of water an average of 54.3 days per year (the weighted average would be 40.7 days). Data from the survey conducted in 1994 by Fisheries and Oceans Canada revealed a Canadian average of 25.7 days (Industry Canada 1999). Taking into consideration this range of data, an average of 40 days per season would be a rather realistic estimate.

Regarding the economic contribution of recreational boaters for the year 1995, we estimate an average daily expenditure of $49 for a boating excursion of several hours with two to three passengers and $145 per day for an excursion of more than one day (Zins Beauchesne and Associates and SECOR 1997). A more recent survey with a large number of respondents indicates expenditures of up to $275 per day (DBSF 2002). In fact, if we apply a weighted average that takes into account the various types of outings, the result is closer to $146 per day. Goss Gilroy Inc. (2003) estimates spending in Canada at $150 per day, while according to Gardner Pinfold Consulting (2003), this figure is $224 for the St. Lawrence, from Lake Saint-Louis to Lake Saint-Pierre (for a sub-group representative of recreational boaters using marinas), a value higher than that observed for the upper St. Lawrence and Lake Ontario ($174, $175 and $176 per day). For users of public boat launches, expenditures could, however, be closer to $140, according to a similar survey conducted on the American side of Lake Ontario and the St. Lawrence River (unpublished data, Connely 2003). Furthermore, an evaluation of adventure tourism indicated an average expenditure of $130 per day for kayaking ecotourists (rental included) and $150 per day for rafting (Chaire de tourisme de l'UQAM 1999). The value of $150 per day consequently seems quite representative of the order of magnitude so that it can be used as a basis for evaluation, from which the number of days of use lost per access site and for the lake as a whole can be extrapolated.

These few data provide a glimpse of the increasing impacts of a percentage of the boats navigating and docking on Lake Saint-Louis, not counting the several million dollars worth of equipment, repairs and maintenance, insurance and other annual fees that could be added (Gardner Pinfold Consulting 2003).

Finally, we must also consider the fact that daily expenditures generate an impact on marinas and neighbouring communities, as well as on the economy of related consumable goods and services like boats and equipment (primary and secondary effects or direct, indirect and induced effects). It is consequently possible to calculate the multiplier effect of expenditure in the local, regional and provincial economy. Goss Gilroy Inc. (2003) indicates, despite some missing data, aggregate data of $2.169 million per year, the maintenance of 20 693 full-time-equivalent jobs and $633 million in revenue for Quebec. Even if just a fraction of these values is linked to this activity on the St. Lawrence River and Lake Saint-Louis, it nonetheless remains that the indirect impacts are far from negligible.

Table 6 presents an estimate of the direct impact that could be associated with the draft of boats on Lake Saint-Louis. The probable number of boats (two-thirds using a public boat-launching ramp), estimated number of boating days, average daily expenditures, as well as the possible number of people affected are provided for a range of boat drafts. If these values are varied, the relative intensity of impacts may also vary. For example, if the period of use is reduced by nearly two-thirds (only two weeks of use) of what is presented in the table, the value of the expenditures at stake will decrease accordingly, for a maximum amount of about $17.5 million. On the other hand, in this case, the impact on the number of users will not necessarily change. Furthermore, it must be remembered that these data are likely to change according to the context of economic growth specific to recreational boating, depending on increased or decreased demand, expressed in terms of use of the lake, and the type of boats used (deeper or shallower draft). Economic vulnerability is thus not mechanically and deterministically established.

Note that even though recreational boaters are first and foremost considered in this capacity, they can also be fishers, swimmers, scuba divers and nature lovers. Satisfying the needs of recreational boaters is thus likely to increase the overall satisfaction of many other users of the lake. As a result, maintaining this use will also contribute to the wider context of recreation in an aquatic environment (Benjamin and Perrault 2002)

Table 6
Relationship between water level and impact indicators

Draft, in feet (water level)	Boats able to navigate (%) on Lake Saint-Louis (all types considered)	Estimated number of boats (marina berths × 3 for total number)	Estimated number of boating days (× 40 days per season)	Estimated expenses per stay per boat ($150/day)	Estimated number of boaters (× 3 persons per boat)
2.5 (19.94)	28	2 335	93 400	14 010 000	7 005
3.0	43	3 586	143 440	21 516 000	10 758
3.5	48	4 003	160 120	24 018 000	12 009
4.0 (20.40)	83	6 922	276 880	41 532 000	20 766
4.5	86	7 172	286 880	43 032 000	21 516
5.0	86	7 172	286 880	43 032 000	21 516
5.5	96	8 006	320 240	48 036 000	24 018
6.0	99	8 257	330 280	49 542 000	24 771
6.5	99	8 257	330 280	49 542 000	24 771
7.0 (21.320)	100	8 340	333 600	50 040 000	25 020
12.5 (23.00)	95	7 923	316 920	47 538 000	23 769
13.0	81	6 755	270 200	40 530 000	20 266

Note: Estimates are based in particular on the number of vessels in 2001 (Zins Beauchesne et Associés, 2002a), on boating days during stays and on related expenses (DBSF, 2002). Measurement of a water level of 4 ft. at the Pointe-Claire station reflects a chart datum of 20.4 m.

This chapter is an examination of the possible effect of extreme situations as they relate to specific water-level constraints. The next chapter echoes this portrayal by presenting the corresponding adaptation patterns.

5 Adaptation Patterns and Vulnerability

Assessing the sensitivity of recreational boating by examining access sites and the constraints imposed on this activity must be supplemented by an examination of adaptation patterns, as stakeholders (owners, operators and users) react to hydrological and climatic events in different ways. However, adaptation is more difficult to define, and as documentation is rare, a number of different sources are used in the attempt.

Based on a variety of survey data, we can identify the adaptation measures or means that testify to a relative willingness and ability on the part of stakeholders to reduce their vulnerability to fluctuations in climate, and in particular, in water levels.

5.1 PAST ADAPTATIONS BY OWNERS AND OPERATORS OF MARINAS AND YACHT CLUBS

Water-level problems are not new to owners and operators of marinas and yacht clubs. On Lake Saint-Louis, most access sites have been in operation for several decades: 9 of 16 respondents indicated prior to 1970; two indicated between 1970 and 1985; and three indicated between 1986 and 1996 (Zins Beauchesne and Associates 2002a). In a few cases, the sites have existed since the 19th century (e.g. 1888 for the Royal St. Lawrence Yacht Club) (Royal St. Lawrence Yacht Club 1988). At the other extreme, just one respondent indicated that they had recently set up shop (between 1997 and 2000), and one was unable to answer.

Owners and/or operators adapt to a set of constraints linked directly or indirectly to low level situations. More than 10 respondents (10 to 12, depending on the subject, out of 16 respondents) indicated that they had already taken corrective actions related to water depth near docks, to the presence of rocks, to the entrance channel and its surroundings, or to aquatic plants. In fact, the oldest marinas have probably made many modifications since they began operations (see The Royal St. Lawrence Yacht Club 1988 and De Lagrave 1992).

The type of intervention most frequently mentioned dealt with safety measures (e.g. flags) (4 of 10 respondents), followed by dredging, digging or maintaining the lake bottom and moving docks (2 of 10 respondents in both of these cases). It should be noted that two respondents also indicated having requested a permit for future dredging.

Looking to the future, operators planned few new actions for the period 2002–2004. Favoured local or regional solutions for future water management are, in order of importance, improved surveillance of water levels (4 of 16 respondents), decreasing upstream water levels (3 of 16 respondents), the construction of a new dam downstream (2 of 16 respondents), and improved communication with marinas (2 of 16 respondents). On a broader level, preferred solutions are: a review of political decisions (3 of 16 respondents), followed by a review of water control measures (2 of 16 respondents).

Despite the fact that they are based on only 23 respondents, 12 of whom refer to Lake Saint-Louis (excluding Lake Saint-Pierre), data from the preliminary survey (Boudier and Bibeault 2001) further clarify these responses. In fact, a question regarding possible adaptations, based on their respective effectiveness according to three iterative questions (first, second and third choice), brought out certain "key" solutions for owners and/or operators and some innovative, albeit unconventional, solutions (Table 7).

Table 7
Preferred adaptation options of 23 respondents according to three successive iterative questions

Options considered	First preferred strategy	Second preferred strategy	Third preferred strategy
Dredging	8	7	2
Safety measures	6	3	2
Refurbish/build	2	1	0
Relocate docks	1	5	2
Miscellaneous	6	3	5
Favour boats with smaller drafts	0	0	1
Review pricing	0	0	1
No other option considered	0	4	10

Source: Data from the preliminary survey of Boudier and Bibeault, 2001.

This iterative questioning raises the fact that dredging, the most costly and most difficult measure to carry out — considering the need for a certificate of authorization — is considered the most immediate solution. At least two interpretations are possible: either this measure is already frequently taken, despite the fact that the great majority of respondents say that they have not had to resort to it as of yet, or else the message is that public authorities should accord greater attention to this option.

In general, dredging, improving safety measures and relocating docks are the most obvious and most efficient options from the point of view of owners and operators. Nevertheless, the more the iterative questioning progressed, the more difficult it was for respondents to anticipate new options. They do, however, anticipate options at another level ("other" category), even though they have no direct influence in this matter. Finally, demand management arises at the very end of the questioning, with the review of fees (meaning, adjust the financial incentive) or restricting certain types of boats. Although they are in the minority, these comments indicate the possibility of further exploring other courses of action to which little consideration has been given. The preference for structural solutions, technically more flexible, is thus evident. The analysis of vulnerability should be able to consider these options.

The other aspect is that according to the preliminary survey on the low level season of 1999 (Boudier and Bibeault 2001), owners/operators are adapting to a variation of about 25 cm or more (in some cases, it can rise above 50 cm in the routine management of their operations). Thus, they can live with uncertainty regarding water level data, an ability that becomes critical when the depth of the water at the dock or in the access channel is generally less than 1.2 m (4 ft), as indicated in Chapter 4. Structural solutions thus only emerge in conditions of extreme low levels.

5.2 VULNERABILITY FROM THE PERSPECTIVE OF LOSSES AND ADAPTATION COSTS

Another way to approach vulnerability involves taking a socio-economic perspective to identify the losses and costs associated with various adaptive measures. In the case of lost revenues or enjoyment, the information reveals a certain incapacity to maintain use in extreme conditions. On the other hand, adaptation costs reveal a capacity on the part of service providers, users or public authorities to internalize these costs.

In the case of losses, some estimates can be made using available data. For the costs of adaptations, we can proceed in the same way, but a specific problem arises: it is difficult to separate an investment that specifically concerns the issue of water level. Furthermore, the evaluation made by owners/operators depends on their ability to accurately distinguish an extraordinary expenditure from a routine one. Finally, there are intervention measures that require overtime or a reallocation of effort, rather than additional investment. In this regard, there is an opportunity cost to the time allocated to managing the impacts of water-level fluctuations.

Indirectly, there is also a cost ensuing from private insurance premiums, which can in turn increase and partly internalize the risk that water-level fluctuations pose to movable (e.g. boats) and immovable (e.g. docks) property. In the latter case, no precise estimates have been published to date.

5.2.1 Loss of revenue for owners and operators of marinas and yacht clubs

Regarding revenue loss, the owners and/or operators indicated this effect quite clearly for the summers of 2002 and 1999. In 2001, an estimated 24.7% of the average number of slips/berths and moorings (123) in each site on Lake Saint-Louis were unusable (higher than elsewhere along the St. Lawrence or in Lake Saint-Pierre), for an average of 30 places lost in each of the 16 access sites considered (18 in total). Just under half of this number could be attributed to the “low water level” factor. A loss of 15 places per site is probably more realistic.

The impact could certainly have been more severe at the end of the season (in August and September the levels were particularly low); thus we must be careful about referring to this as a loss applicable to the entire season. However, it is reasonable to believe that the impact was high during at least four weeks of the season (each week having seven days of continuous operation). The difference from one site to another can be very great.

It must be remembered that the estimated revenue per slip is on average about $160 per day for the St. Lawrence (Lake Saint-Louis to Lake Saint-Pierre) (Gardner Pinfold Consulting 2003). In addition, usage is very high in July and August (occupancy rate of slips of more than 85%), hence the particular seasonal context during which adaptive measures must be deployed. Next in order of importance are June and September (80 to 85%), followed by May and October (45 to 55%), months that are also critical because of boat launchings and haul-outs, and finally, albeit rather marginally, April, March and November (10% and less) (Gardner Pinfold Consulting 2003, Table F-6).

It is worth noting that in general, without further reference to the monthly impact, most stakeholders (owners and/or operators) agree that three consecutive years of low levels are critical to the survival of businesses (Boudier and Bibeault 2001). This finding testifies to a certain resilience in the face of a year of low levels, yet indicates the limits that would be imposed by several consecutive years of low levels.

Finally, even if the impact is not necessarily disastrous locally, private revenue losses have also had an indirect effect on the economic activity of the communities in which these sites are located and on the economic sectors structurally dependent on recreational boating (e.g. manufacture of boats and shipborne equipment) and associated tourism. In the latter case, tourism's dependence on water levels depends on the area of the lake. Sainte-Anne-de-Bellevue, a sector located at the confluence of Lake of Two Mountains and the St. Lawrence River, and fed by the Ottawa River, is an example of a sector heavily dependent on recreational boating.

5.2.2 Additional costs of adaptive measures undertaken by owners

It is difficult to assess precisely the information on adaptive measures as the exact cost of each option is not available. The cost of dredging, for example, can be very high if preliminary environmental assessments are considered and if the volume in question is high. Conversely, if the work is restricted to selective dredging of the marina's access channel, the cost can be much lower. Thus, the relative cost of the material removal method, the degree to which these materials are contaminated and the cost of disposing of them, including possible treatment to decontaminate the dredged materials, must also be considered.

Finally, an adaptive measure can also be proactive to the extent that the intended objective is to increase business, rather than just to maintain it at the current level. In the latter case, a "reactive" adaptation such as dredging could in fact be an opportunity for commercial expansion. In this regard, a more precise idea is needed of the particular constraints and opportunities considered by owners and operators of access sites. The reopening of the Lachine Canal for recreational boating in 2002, coupled with the still-possible reopening of the Canal de Soulanges, as well as the projects of the Corporation de Promotion et de Développement du Croissant de l'Est (2002) could, in fact, justify the expansion of current access sites and services.

5.2.3 Additional costs for public boat-launching ramps and docks

Marinas, yacht clubs and related services are not the only sites providing access to the lake. Public boat-launching ramps and public docks are other basic facilities. Although it is difficult to assess the impact of low levels on the infrastructure, we can still point out some data.

Based on the preliminary survey conducted in 2000 (based on the 1999 season), it is clear that the municipalities generally considered access sites a marginal part of the capital infrastructure they manage. Maintenance costs vary from $3000 to $20,000, depending on the municipality, for problems of all types (safety issues dominate). The planning of work also depends little on water levels. In the worst cases, municipalities may review spending so as to include the eventual extension or rebuilding of launching ramps. Even in these cases, costs vary depending on whether the repairs are minor ($30,000) or major ($600,000).

Nevertheless, in 1999, six of the 16 responding riverside municipalities between Lake Saint-Louis and Contrecoeur indicated that access to public docks was compromised, and 12 of the 16 indicated that the use of launching ramps was limited or prevented by low levels. Eight of 16 respondents indicated that they anticipated various measures to manage this problem, such as selective dredging, enlargement or extension of current ramps or construction of new ones.

According to these data, taking into account financing costs, (e.g. an annual interest rate of 10%) and the possibility of amortizing the investment over five years, the total cost of intervening for eight municipalities ($30,000 to $100,000 depending on the case) would involve an estimated sum of $240,000 to $800,000 based on $68,000 per year (minimum) to $225,000 per year (maximum). For Lake Saint-Louis, this value would apply particularly to the north shore and Île Perrot, where expenditures could exceed these estimates.

It should be noted that water levels do not yet pose a major problem for municipalities, subject to increased usage. In fact, it appears that to date and with few exceptions (Pointe-Claire had a development plan for recreational boating), recreational boating is not yet well integrated into the fabric of urban development. Initiatives of the *Montréal Bleu* type could, however, fill this gap, on the condition that adaptation to low levels is also recognized as a development issue.

5.2.4 Additional costs of public safety

Owners and/or operators of access sites generally consider the lake at least as safe as anywhere else (15 of 21 respondents, two did not reply). Others consider the St. Lawrence "moderately dangerous" (2 of 21 respondents) or "very dangerous"[3] (4 of 21 respondents) (Boudier and Bibeault 2001). On a wider scale, 43% of residents living along the banks of the St. Lawrence consider recreational boating on the river to be safe, while conversely, 36% consider the river "very dangerous" (Dewailly et al. 1999). The latter information, however, applies to the river and the Gulf of St. Lawrence.

The most notable effect has without a doubt been an increase in the number of recreational boating incidents. In the case of Lake Saint-Louis, the Canadian Coast Guard noted an increase of about 55% in requests for assistance in 1999 over 1998 (Fisheries and Oceans Canada 2001). Each request for assistance involves a trip for a boat and crew. The cost varies according to the service required and the distance travelled.

The service of the Canadian Coast Guard Auxiliary is of minimum economic value compared to other costs. Nevertheless, the costs of intervention cannot easily be distinguished from regular surveillance costs. Moreover, these costs are determined by many variables, hence the difficulty of separating the "water level" factor from other factors (e.g. travel costs for the fleet, limited budgets, etc.) (R. D'Arcy 2003, personal communication). Finally, there are other costs related to safety on the lake, notably those related to the maintenance and moving of navigational aids when levels are particularly low. In fact, the use of such aids on Lake Saint-Louis has been reviewed, and a new nautical chart has been available since 2002. The estimated cost for the surveys of 2001 and 2002 approaches $185,000, to which must be added the cost of integrating the new data and the production of the nautical chart ($50,000) (R. Dorais 2003, personal communication). Although the link to the water level problem may not be direct, low levels increased the need for an update, stimulating the adoption of a measure that could be considered adaptive by means of acquiring more suitable information.

5.3 ADAPTATIONS ON THE PART OF USERS

To complement the picture painted by target stakeholders, data that have recently been integrated into a pattern of uses of the St. Lawrence could be used to complete the profile drawn to this point. Conducted as part of St. Lawrence Vision 2000, this survey deals with several

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[3] This is a subjective assessment with no specific definition. The model uses a graduated scale from not or somewhat dangerous, to moderately, to very dangerous. The value of these judgements is thus relative and useful mainly in a comparative manner (in relation to another place or another time).

aspects of use of the St. Lawrence, including emerging issues like low water levels. The results drawn from this survey allow for an analysis of three areas, including the Montreal region, which will serve as a reference in the present report.[4]

To place the area of concern (the metropolitan area) in relation to the problem of low water levels (Table 8), 14% of riverside residents compared to 23.4% of residents of the fluvial section say that they recognize a problem ("many" and "a few"). In both cases, the proportion of concerned riverside residents is high.

Table 8
Perceived problems related to decreased water levels, by region

	Perceived problems									
	Many		A Few		None		DK/NA		Total	
Region	%	EP	%	EP	%	EP	%	EP	%	EP
Metro-politan area	4.8	71 524	9.2	136 704	84.3	1 251 910	1.6	24 327	100.0	1 484 465
River corridor	6.7	52 359	16.7	130 642	76.0	595 888	0.6	4 966	100.0	783 855

Source: Duchesne et al., 2004.
Note: Value of $p < 0.001$, excluding the DK/NA (don't know/no answer).
EP: Estimated population.

With further analysis of this problem, we discover that, in general, users are at least twice as likely as other citizens to identify water level problems. This finding remains true in all geographic areas considered (metropolitan area, river corridor). In the specific case of those who use the river for recreational boating, they are almost three times more sensitive (29.5% versus 11.2%) than others to the effects of low water levels (column 2, grey row, Table 9), which is consistent with the fact that users have a direct experience with situations of water-level fluctuations.

Motorboaters, closely followed by sailors, are particularly likely to perceive a problem of low levels. This observation applies quite well to Lake Saint-Louis insofar as this lake is a

4 These data are provided with the permission of the main author, J. Grondin.

centre for recreational boating within the Montreal archipelago and offers many sites for sailboats. It thus also reflects the experience of users of this lake.

It is worth noting that paddlers, whose boats generally have a shallower draft, are also very concerned about low levels.

Table 9
Problems related to decreased water levels perceived by recreational boaters and residents of the metropolitan area

	Yes (problem exists)		No (no problem)	
Use	%	EP	%	EP
Watercraft on the river				
Yes	29.5	67 617	70.5	161 297
No	11.2	140 611	87.0	1 090 058
DK/NA	0.0	0	22.4	555
Type of craft				
Motorboat	39.6	41 223	60.4	62 841
Sailboat	37.4	8 127	62.6	13 589
Rowboat	26.8	7 636	73.3	20 907
Other	15.5	10 632	84.5	57 955
DK/NA	0.0	0	100.0	6 004

Source: Duchesne et al. 2004. Value of $p < 0.001$.
EP: Estimated population.
Note: p values are calculated excluding the DK/NA (don't know/no answer). The DK/NA for "Problem exists" are absent, and that is why total percentages do not always amount to 100%.

In general (Table 10), water level problems are manifested in various ways, and many of the ways mentioned may be directly or indirectly linked to pleasure boating.

The first way is the degradation of water quality (31.5%). Particularly in summer, low levels occur at the same time as aquatic plants bloom. During the summers of 1999 and 2001, there was a massive bloom of aquatic plants near shores and certain access sites, negatively affecting the lake's relative aesthetic appeal for all uses.

The anticipated direct impact on recreational boating is also quite marked (14.8%). In this case, explicit reference is made to navigational problems.

Table 10
Impact of decreased water levels according to residents of the metropolitan area

Impact	%	EP
Negative impact on water quality	31.5	65 599
Anticipated negative impact on boating *	14.8	30 712
General impact on access and use	14.7	30 593
Broad perception of negative impact	14.4	29 944
Impact on aquatic fauna or nature	12.9	26 781
DK/NA	7.5	15 702
Negative impact on water supply	4.3	8 898
TOTAL	100.0	208 229

Source: Duchesne et al. 2004. Preliminary data. Value of $p = 0.134$, excluding the DK/NA (don't know/no answer).
EP: Estimated population.
* Pleasure boating only.

The anticipated impact on nature or wildlife is also quite important to riverside residents of the metropolitan area (12.9%). Recreational boaters who are interested in fishing can also be affected, in as much as the main reason for using a boat is fishing or nature watching.

Other impacts indicated are more general in nature rather than specific to recreational boating, but it is not impossible that recreational boaters also appear in these categories and recognize that the state of the lake has degraded.

These perceptions are among the driving forces of users' reactions to low levels. Thus, the perception of problems by concerned residents prompts a good many of them to do something about it (98.6 to 100% for "somewhat" or "very" affected) (Table 11). In fact, even though nearly two-thirds of respondents said they were somewhat affected, they do not hesitate to react to low-level situations.

Table 11
Measures taken by residents of the metropolitan area in response to decreased water levels

	Measures adopted for decreased water levels							
	Very affected		Somewhat affected		DK/NA		Total	
	%	EP	%	EP	%	EP	%	EP
Metropolitan area	31.7	60 943	67.4	129 794	0.9	1 790	100.0	192 526

Source: Duchesne et al. 2004.
Note: Value of $p = 0.992$, excluding the DK/NA (don't know/no answer).
EP: Estimated population.

Boaters on the river have a strong tendency to adopt a particular measure regarding water levels (almost one boater in two), and this is particularly obvious for motorboaters (Table 12). Sailors and paddlers come in second and are more or less equally active in this area.

Table 12
Measures taken in response to decreased water levels, by type of craft

	Yes (measures taken)		No		
	%	EP	%	EP	
WATERCRAFT ON THE RIVER					
Yes	49.3	32 131	50.7	32 999	
No	22.6	28 812	76.0	96 794	
p value					< 0.001
TYPE OF CRAFT					
Motorboat	58.7	24 180	41.3	17 043	
Sailboat	45.1	3 663	54.9	4 464	
Rowboat	46.0	3 128	54.1	3 679	
Other	12.9	1 160	87.1	7 814	
p value					0.037

Source: Duchesne et al. 2004.
Note: Values of *p* were calculated excluding the DK/NA (don't know/no answer). DK/NA for measures taken in response to decreased water levels are absent, and that is why total percentages do not always amount to 100%.

The measures undertaken testify to the relative importance accorded to the various problems attributable to low water levels (Table 13). Recreational boaters in the metropolitan area tend mainly to move their activity to another part of the river, while to a lesser extent, they stay loyal to the same lake. This reaction is truer of paddlers than of sailors and those with motorboats. Boat draft thus does not appear to be the only factor responsible.

Table 13
Measures taken by metropolitan-area residents in response to decreased water levels, by type of craft

	Craft					
	Motorboat		Sailboat		Rowboat	
	%	EP	%	EP	%	EP
Metropolitan area						
Going elsewhere	32.5	7 851	42.7	1 564	50.0	1 564
Relocating, changing boating times, making boat or access modifications	19.6	4 737	23.7	870	50.0	1 564
Switching to other activities	0.0	0	0.0	0	0.0	0
Finding out about and discussing the problems	0.0	0	0.0	0	0.0	0
Getting involved locally	0.0	0	0.0	0	0.0	0
Other/not relevant to pleasure boating	43.1	10 433	33.6	1 230	0.0	0
DK/NA	4.8	1 160	0.0	0	0.0	0

Source: Duchesne et al. 2004.

The situation nonetheless remains quite problematic for sailors and motorboaters, who consider avoidance an option, to the possible detriment of access sites, which could lose some of their clientele. Avoidance is, in fact, more than one-and-a-half-times more popular than adaptation to local conditions among these users.

Note that in the case of Lake Saint-Louis in particular, avoidance options (substitution) are rather easily available and offer good value for recreational boating: Lake Saint-François (closely regulated) or Lake of Two Mountains. For those who remain loyal to Lake Saint-Louis, the choice is quite varied: north shore, south shore and Île Perrot. There are other options, but boaters do not necessarily choose them (see the white rows in Table 13).

In general, local involvement (participation in protest activities) and acquiring information on water levels are not yet options that recreational boaters seriously consider. Note that the picture of user perspectives remains partial to date and that more intensive questioning would be required to better portray the other climatic variables and the variables related to the context of use.

5.4 ADAPTATIONS AND VULNERABILITY

The previous data reveal a pattern that shows, first, that adaptive measures are quite varied. For operators, relocating docks, dredging and signage are among the measures most readily considered. In the case of public authorities, they are most likely to intervene in matters concerning the lake from the perspective of safety (surveillance, nautical charts), and through various police forces and emergency response teams. On shore, the role of municipalities is played out through their plans and programs for infrastructure refurbishment.

In light of the measures already or likely to be undertaken in the short term, structural solutions predominate for owners of marinas and yacht clubs, as well as for municipalities, while behavioural solutions (avoidance, modification of use parameters) are adopted by users. That users would consider trading-in their boat for one with a shallower draft is not clearly mentioned as an option.

Thus, though certain types of adaptation are dominant for certain stakeholders, there is an overall trend toward adaptation based on use. Nevertheless, solutions intended to better regulate demand for owners/operators of marinas and yacht clubs (attractive pricing, etc.), as well as shared risk management with private insurers, do not stand out as obvious options. Relocating commercial activities does not appear either, nor does the rationalization of access sites according to water-level constraints.

In the latter case, municipal authorities face the same problem. The fact that there is no charge to use public boat-launching ramps is certainly attractive to the user, but their technical design remains deficient in many cases, and there are as yet no plans to organize and adapt access sites for the lake as a whole (which would require municipalities to work together).

Furthermore, the first reaction is rarely to worry about either sharing the lake with other stakeholders or forming a coalition of interest groups. Yet a variety of models exist: the Regroupement des Usagers du Saint-Laurent (RUSL), recreational boating associations (e.g. Canadian Power and Sail Squadrons), including the Ontario Marine Operators Association (OMOA), probably the best model at the provincial level, or the SLV 2000 Navigation Committee, an initiative of the St. Lawrence Vision 2000 Action Plan that involves federal and provincial departments, non-governmental organizations, and members of recreational boating associations and the marine industry.

Finally, environmental components are not very well integrated into the decision-making process as of yet, as evidenced by a reaction that favours infrastructural solutions, such as dredging, instead of fleet management. In this context, vulnerability results from a way of resolving problems related to low water levels and of adaptation that thus far remains sectoral and limited — an observation that has been made elsewhere in other contexts of resource management and environmental problems (Mermet 1993).

6 Conclusion

Evaluating recreational boating's sensitivity and vulnerability to water-level fluctuations, and ultimately to climate change, poses a certain challenge in that a series of logical and relevant connections must be made between the water needs of users and owners and/or operators of access sites, the locational constraints of each access site, various water level and flow situations, and the adaptive behaviour of stakeholders. To do so, this report follows a four-step approach to overview pleasure boating's vulnerability: defining the water level constraint faced by the fleet; simulating various hydrological conditions and observations of effects at the level of both the lake as a whole and access sites; evaluating potential socio-economic impacts; and presenting adaptation patterns.

In the case of low levels, it is clearly a question of constraints to navigability and berthing. For high levels, the problem relates to the constraint posed by certain components of the infrastructure. This constraint, however, can be considered less severe and critical than that of low levels, in the light of survey data that indicate owners' and operators' ability to adapt to and deal with high levels. Nevertheless, recent surveys coincided with a period of low levels. A survey conducted during a period of high levels could well confirm the results of the modeling for high-level situations.

Apart from the examination of physical sensitivity to water levels, the economic data tend to reinforce the idea that stakeholders, particularly owners/operators of marinas and yacht clubs, have historically acted rationally based on their own situation, although some do act on another level of adaptation (e.g. political pressure). The adaptations chosen are also a function of an implicit evaluation of the costs and benefits of commercial operations (e.g. marking with buoys, relocating docks, dredging), within which the environmental component is still considered little more than a constraint to navigation.

Anticipated adaptive measures reveal, for their part, the influence of habit and the known on behaviour. The adaptive mode that can be inferred is again sectoral and non-integrated, which also testifies to a gradual process of adjustment and a learning process on the part of stakeholders that depends on their individual context. Acting on another level does involve significant transactional costs, in that individuals have to get together, exchange ideas and continually intervene with public and political authorities.

For public authorities, adaptation is limited and contingent on other intervention priorities. The rationalization of services and the rising costs of refurbishing the infrastructure limit their interest in focusing on recreational boating.

For users, data at the level of the metropolitan area reveal that the problem, which they perceive more clearly, drives them primarily to avoidance behaviour (to practise their activities elsewhere), and to a lesser extent, to preventive behaviours that consider timing, type of craft and location of the access site.

From a wider perspective, particularly in the case of environmental problems involving cumulative effects, such as climate change, it is useful to remember that dialogue between scientists and communities remains key to a sustainable resolution process (Parker et al. 2002). There currently exist a variety of associations within which it would be possible to consider such a dialogue, thereby enabling adaptations to extend beyond sectoral limits. Moreover, the review of the regulation plan for Lake Ontario and the St. Lawrence River offers an opportunity to compare various modes of sectoral adaptation with one another and to come to a better solution, or at least a compromise that is more resilient to extreme water-level situations.

Furthermore, it is hoped that climate change research evolves toward an analysis that is horizontal, interdisciplinary, more integrated and likely to consider the “human” factor as central to making decisions in matters of adaptation.

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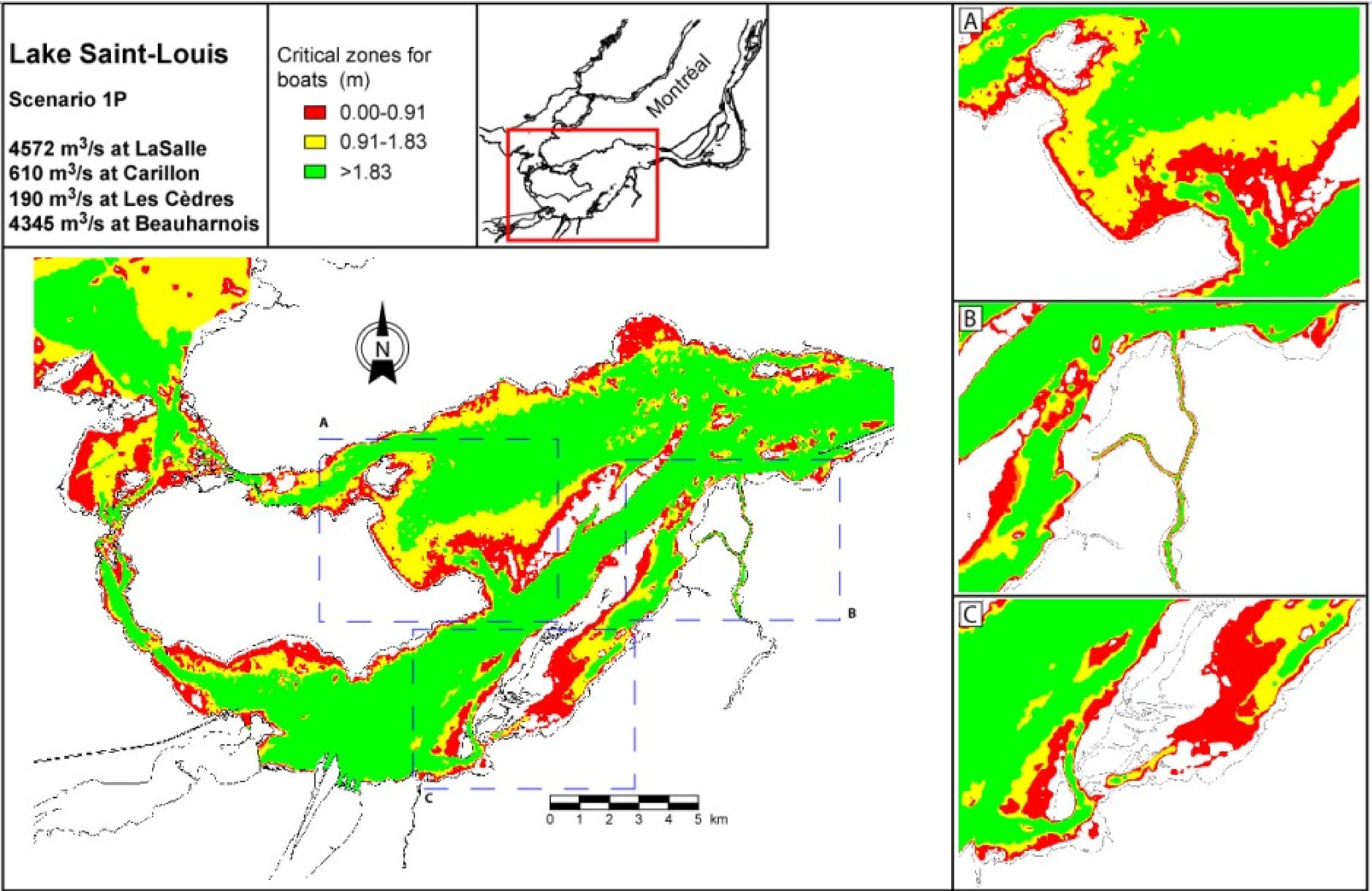
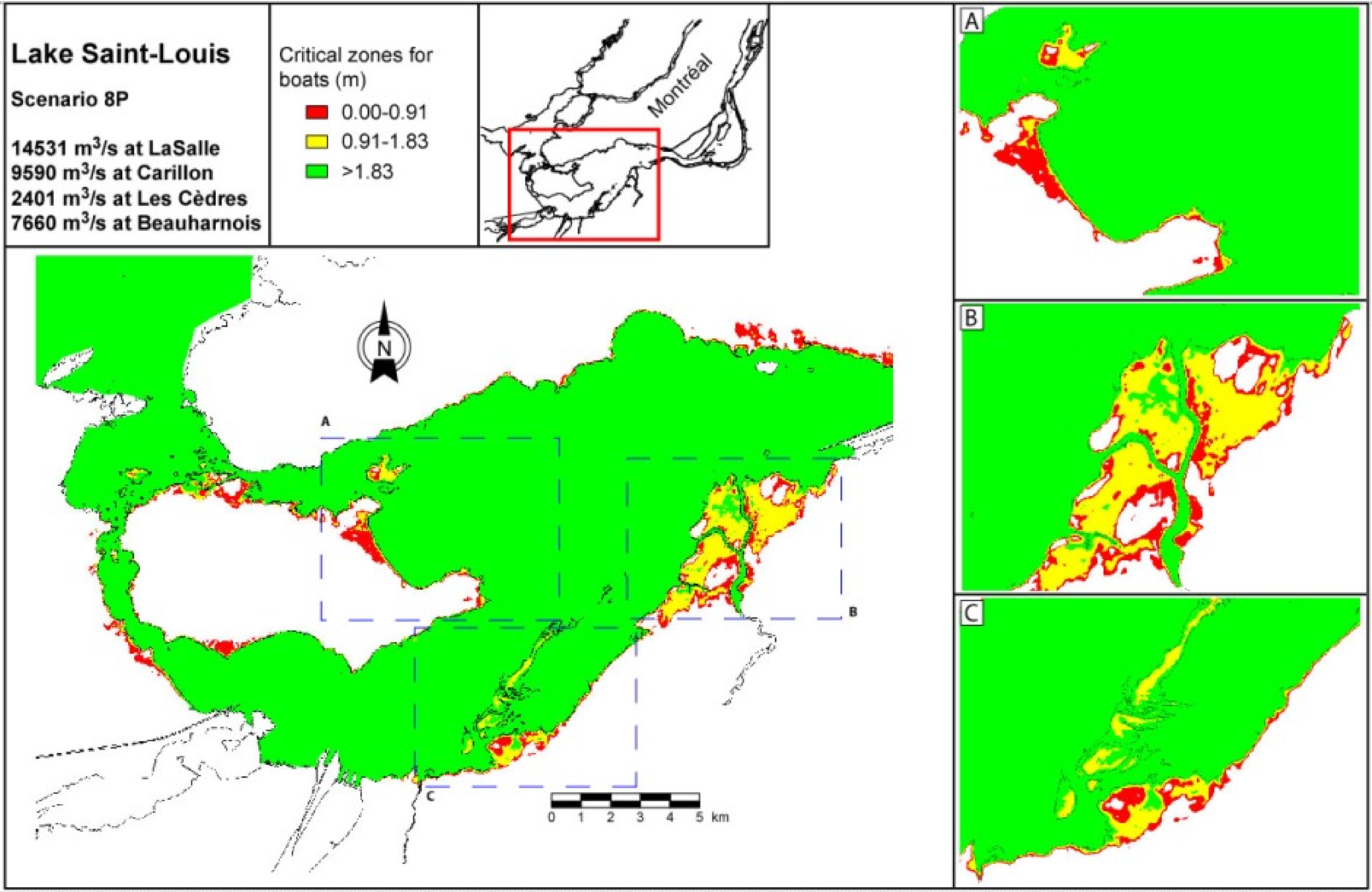
Cartographic Appendix


Lake Saint-Louis
Scenario 1P
4572 m3/s at LaSalle
610 m3/s at Carillon
190 m3/s at Les Cèdres
4345 m3/s at Beauharnois
Critical zones for boats (m)
0.00-0.91
0.91-1.83
>1.83
Montréal
N
A
B
C
0 1 2 3 4 5 km


Lake Saint-Louis
Scenario 8P
14531 m3/s at LaSalle
9590 m3/s at Carillon
2401 m3/s at Les Cèdres
7660 m3/s at Beauharnois
Critical zones for boats (m)
0.00-0.91
0.91-1.83
>1.83
Montréal
N
A
B
C
0 1 2 3 4 5 km