

Flood Risk Management under Uncertainty in Transboundary Basins: A delicate balancing act

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Flooding is an inherently uncertain hydrometeorological phenomenon. When it occurs in transboundary basins, the complexity of its management is amplified by international treaties and needs for political accountability. Little has been written about FRM under the inevitable uncertainty in these transboundary contexts. This paper addresses this gap through an exploratory case study of a new FRM plan (Plan 2014) in the Great Lake Ontario and St. Lawrence River system in North America. We examine the evolving nature of contemporary FRM towards more flexible approaches in the face of increasing uncertainty. When this new management plan coincided with severe transboundary flooding, this highlighted deep tensions, notably between upstream and downstream communities, expert and lay opinion, and between the planners setting rules and the operators using those rules. This story also showcases the complex balancing act faced by flood risk managers operating across national boundaries who are asked to contend with hydrological variability as well as public needs for certainty. We contend that the negotiation and agreed dispute resolution processes surrounding these tensions is a fundamental component of FRM in international basins, and one that may become ever more important as climate change further increases the uncertainty regarding these hydrometeorological hazards.

Keywords: flooding; transboundary basins; uncertainty; strict/flexible risk management; lay/expert opinion; planners/operators; upstream/downstream; USA/Canada

Introduction

When water bodies are divided by international boundaries, their management becomes more complex. Many international systems have been created to govern these issues but they are almost always confronted with complexity regarding hydrological interdependence and the competing interests of different stakeholders. Flood risk is particularly difficult to mitigate in these contexts because management of the river basin requires cooperation across different national contexts, and between their upstream and downstream riparian communities. The inherent unpredictability of flooding also makes

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its management across borders particularly problematic. Indeed, decision-makers must design systems that are flexible enough to account for the variation and unpredictability of flooding as well as juggle political needs for stable, unambiguous procedures and public accountability.

On the border between Canada and the United States of America, transboundary water issues have been managed since the 1970s by the International Joint Commission (IJC), which is headed by six Commissioners, three from each country. In the past, the IJC has regulated transboundary water quantities through control structures such as dams and their strict water release rules. However, recent recognition of problems with this system has led to new flood risk management practices that are more flexible and designed to bring hydrological systems closer to their natural characteristics.

For the Great Lake Ontario and the St. Lawrence river basin, in Eastern North America, *Plan 2014* is one such strategy devised to better manage water issues in the river basin, including in the operation of the Moses-Saunders dam (see below). This Plan was created in part to address failures in previous systems by accounting for hydro-climatic uncertainty in the basin and promoting more natural flood regimes and ecological status. Years of negotiation backed with cutting-edge scientific discussions were required to develop this plan. Unfortunately for the IJC, two extreme flooding seasons occurred in the region in 2017 and 2019, following the implementation of *Plan 2014* in December 2016. This was a catalyst to debate the value of such a paradigm shift that illustrates the political risk of framing uncertainty in transboundary flood risk management (FRM), a topic that has yet to be properly discussed in academic literature. The new framework of *Plan 2014* brought to light key issues of reconciling national interests with modern flood risk management practices within complex environmental and political contexts where lay opinions and expert judgements can sometimes be in conflict.

This paper examines the issues surrounding flood risk management in international basins or river basins through this example, providing what we suggest to be one of the first analyses of uncertainty in transboundary flood risk management. The uncertainty we are analysing here surrounds decisions on how best to manage the Lake Ontario/St Lawrence system today, given the inherently unpredictable nature of flooding and the even greater hydrometeorological uncertainties we might expect in the future given climate change and urban development. Methodologically, the research design is one of an exploratory case study (Yin, 2009), but preceded and followed by an analysis of the issues in a wider international context. The information we have used in the case study comes from a variety of sources, including both academic and ‘grey’ literature such as policy reports and contemporary news articles that describe the nature of management decisions and the historical context in which they were made.

Uncertainty in transboundary flood risk management

Uncertainty is a measure of the unknown where information is lacking or debated (Hall, 2014). In the world of environmental discourse, there are many definitions of the term, stemming from two fundamental sources, notably as classified by Walker et al. (2003) and as used by the IJC in its logic underpinning of *Plan 2014* (Table 1). First, *ontological* (or variability) *uncertainty* exists due to the inherent complexity and variation of a particular environmental system. Next, *epistemic*

uncertainty is a product of imperfect information and knowledge gaps, and can therefore potentially be reduced through the gaining of new knowledge (van der Keur *et al.*, 2008).

Flood risk and uncertainty

Flood risk and its management involve both these types of uncertainty. The two categories often reinforce one another and can increase over time, unpredictability affecting the time-scales of scientific canon and policy development (Ranger *et al.*, 2010). However, policy-making often requires clear, binary, solutions that have no room for ‘shades of grey’, in particular in situations where loss of life or damage to property can occur. Several ideas have been developed to guide decisions about unknown or uncertain outcomes, such as the precautionary principle (van Asselt & Vos, 2006). Additionally, criteria have been developed to provide quantitative decision-making tools such as multi-attribute theory or multicriteria analysis (MAUT or MCA) that allow decisions to be weighed against each other to guide and justify the choice of one option over another (Green & Weatherhead, 2014). However, translating quantitative measures of uncertainty for policy making and for the public can be difficult. To this end, it is necessary to build trust, greater political acceptability and flexible opportunities for policy change (van der Bles *et al.*, 2019). Seminal work on the communication of uncertainty can provide some effective tools to this end. Notably, it has been argued that communication should be tailored to contexts, using local knowledge and involving communities through the decision-making process via close consultation and partnership (Basic, 2009; Chao, Hobbs & Venkatesh, 1999; Norman & Bakker, 2013).

Serious flooding is generally associated with extreme weather which is uncertain by definition, occurring at the tail of probability distributions. Indeed, hazard anticipation is complex, and perfectly accurate prediction quasi-impossible (Ranger *et al.*, 2010; Stainforth *et al.*, 2007). In fact, Hall (2014, v) even states that flood risk management itself is ‘a process of decision making under uncertainty’. As such, flood managers are often forced to make decisions with incomplete or debated information (Green & Weatherhead, 2014); detailed uncertainty analysis in FRM, is still in its infancy (Chauhan & Bowles, 2001; Hall & Solomatine, 2008); additionally, Hall (2014:p.4) notes that this analysis ‘does not remove the need for judgement, especially when decisions are value-laden and contested’.

The prospect of climate change greatly complicates hazard prediction and risk management by involving extremes that stretch the bounds of what are considered average seasonal patterns and extremes. (Intergovernmental Panel on Climate Change, 2012, 2014). To deal with this uncertainty, building flexibility into existing management plans can be an effective approach (Ranger *et al.*, 2010). Indeed, building flexibility is increasingly seen as a fundamental component of resilience and climate change adaptation (Intergovernmental Panel on Climate Change, 2001). This flexibility can be expressed through impact (instead of forecast) based policy or through water control structures with wider operational bounds that determine water height or flows. This said, flooding's inherently high levels of predictive uncertainty make it difficult to develop rigorous rules for decision-making and use them systematically in practice, despite these often being demanded by those at risk or paying for FRM investments.

Transboundary flood risk management

In this context, while international rights to water have long been established, flooding is still rarely found in the canon of international law (Norman & Bakker, 2013). Indeed, according to Cooley et al. (2009), floods were the primary focus of only nine percent of 20th century international treaties despite the significant representation of transboundary flooding globally. Indeed, Bakker (2007) calculates that almost one tenth of all river floods in the world come under the jurisdiction of more than one country; and that, of the 152 countries in the world that experience flooding, around 75% of them share these events with another country (Norman & Bakker, 2013:p.26). Further, between 1958 and 2005, flooding in international basins has accounted for 32% of all flood-related casualties in the world, around 60% of impacted individuals, and 14% of financial damages (Bakker, 2007).

It has been hypothesized that the lack of integration of uncertainty in international water management treaties and policies stems from the high political effort and cost this requires: these regulatory mechanisms must tread the fine line between being both ‘politically feasible and hydrologically effective’ (Fischhendler, 2004, 299). Indeed, any negotiation is predicated on clear and detailed issues on which both parties agree, and public accountability and trust is necessary for the acceptance of these treaties. This takes time. Various partners in the different countries must have a common understanding of risks and clear and well-publicised agreements must be reached on the methods and rules to manage this risk. Structural flood risk management, such as with the Moses-Saunders Dam, introduces an additional dynamic that lies between those who design rules and regulations (here we term these ‘the planners’), and those who execute them (‘the operators’). Managing uncertainty therefore becomes a shared responsibility between these two sets of actors.

As such, measures of unknowns and variability can be difficult to discuss and integrate within transboundary agreements. Cohen, Norman, and Bakker (Norman et al. , 2009, p. 256) therefore ask ‘Under what conditions the border is an obstacle to or facilitator of effective water governance [?]’ and ‘Will our existing institutions be able to cope with these dynamic changes, or will innovators need to seek new solutions that work around, rather than through, existing arrangements?’

Conditions for successful transboundary water governance

From the relatively few case studies available in the academic canon, several conditions are seen to be essential for answering these questions and promoting successful transboundary water governance, guiding transboundary flood risk management.

- The impact of flooding can be dramatically reduced when robust and legitimate institutions manage transnational floods through a process of agreed-upon rules and operating procedures (Bakker, 2007; Norman & Bakker, 2013).
- Best practices for transboundary FRM include data exchange, clear treaties, harmonized efforts, local knowledge, and trust (Norman & Bakker, 2013; Swanenvleugel, 2012).

- An integrated setting where stakeholders have a common perception of the issues, similar mindsets and responsibilities, can be particularly helpful in managing the complexity of issues such as uncertainty (Bernauer, 2002; Clamen, 2013).
- Trusted and adopted scientific evidence and transparent information is also necessary to ensure that epistemic uncertainty is minimised (National Research Council (U.S.), 2006)
- Comprehensive ecosystem management can be a successful tool for transboundary FRM as this prioritizes natural boundaries over international borders, focusing on basin-wide rather than national tools for flood risk management (Hildebrand, Pebbles & Fraser, 2002)

Despite this theorising and its occasional testing, the necessary cross-border cooperation in these matters does not always translate into practice, as is captured by Wiering et al.'s (2010:p.2670) term 'the invisible wall' between ideas and practice. The overarching debate that lingers in all issues of transboundary water governance is whether agreements should be strengthened (i.e. made stricter) or loosened (i.e. made less stringent).

Unbalanced interdependence

Flooding in these transboundary contexts is additionally an issue of unbalanced interdependence; two levels of tension in its management that pit national and local interests against each other, as well as highlight asymmetries in upstream and downstream riparian concerns (Wiering *et al.*, 2010).

Managing expectations between competing domestic and transnational policies is a major issue. Competing local interests may come into conflict with international treaties, laws, or policies. Indeed, governments tend to make decisions for their constituents that put national and regional concerns before international ones, despite evidence that this may be detrimental in the long run (Crow & Singh, 2009). Additionally, effective flood risk management can mute the effect of flooding downstream with whatever mitigating tool is used: for instance, a dam can protect the downstream from excess water but will not necessarily help the upstream community. As such, downstream riparian communities generally show strong support for cooperation in FRM because it can mitigate for them the impacts of the natural hazard. Upstream communities, on the other hand, can bear the brunt of responsibility and costs when it comes constructing FRM infrastructure, and may not reap the benefits (Bernauer, 2002; Wiering *et al.*, 2010).

Such intersecting discussions about uncertainty and transboundary flood risk management have yet to be comprehensively addressed in the existing literature. However, Cosens (2010) does identify uncertainty as present in all factors contributing to flood hazard and risk (such as climate change, demographics, infrastructure, public participation). She argues it as a complexity-inducing variable for transboundary water management that it is fundamental to address, notably through governance structures and public participation (Cosens, 2010). This requires balancing interests and contexts on both sides of an international border, and the case study here exactly matches that situation. Whether the cross-border agreements involved should be strengthened or

loosened is the dilemma that frames our analysis of these processes in transnational flood risk management and its uncertainties.

Flood risk management in Eastern North America

All the North American Great Lakes are connected, with water levels in one influencing levels in the next. On this hydrological chain, Lake Ontario is the furthest east (Figure 1), split in half by the Canadian-USA border separating the Province of Ontario and the State of New York. Its outlet is the St. Lawrence River that flows north-eastwards, eventually crossing into the Province of Quebec (Hudon, 2004; McNeese, 2005). Communities on the lake and river on both sides of the border experience seasonal springtime flooding with significant impacts. Under the jurisdiction of the IJC, the *International Lake Ontario-St. Lawrence River Board* (ILOS RB) monitors and regulates the water flow between Lake Ontario and the St-Lawrence, working with the *Great Lakes-St. Lawrence River Adaptive Management Board* (International Lake Ontario- St. Lawrence River Board, 2020b).

Structural flood risk management

In the latter half of the 20th century, water quantity became a concern for management of the Great Lakes, mostly led by demand for hydro-electric power and shipping routes (Cook, 2014; Venkatesh & Hobbs, 1999). This concern drove structural strategies to manage the water quantity needed for these economic activities. In 1952, the ILOS RB approved the construction of the Moses-Saunders dam, one of the first major hydro-electric structures on the Canadian-American border, a controversial project that led to the displacement of 6,500 people (Parham, 2009).

Today, the dam doubles as a flood management structure: its gates retain the flow of water from the lake to the river and thus are used to regulate water levels on both sides of the border (International Lake Ontario- St. Lawrence River Board, 2020a). As explained by the IJC (in this case our ‘planners’) : ‘since 1960, Lake Ontario would have set new record high water levels several times without regulation’ (International Lake Ontario- St. Lawrence River Board, 2020c:p.4). The water quantity structures are overseen by the ILOS RB whose staff (our ‘operators’) can increase or decrease outflow amounts through the dam through a set of rules that determine appropriate water levels on Lake Ontario and the lower St-Lawrence river. When executed in a timely manner, this type of regulation has been particularly useful for downstream flood alleviation (International Lake Ontario- St. Lawrence River Board, 2020c).

Two different approaches to managing uncertainty

Many different strategies can be taken to manage flood risk. The history of structural regulation in the Great Lakes and St. Lawrence River system, leading to Plan 2014, showcases the evolution of approaches to this end.

Plan 1958D and strict water level regulation

In 1963, on-going discussions about the regulation of water quantity through the Moses-Saunders dam created *Plan 1958-D* (hereinafter Plan 58D) that used formal

hydrological equations to regulate water heights of the lake and the river². Lake Ontario's outflow was thus determined by two sets of rule curves, seasonal adjustments, a number of limitations for reasons of hydropower, ice formation and navigation, as well as limitations in the flow changes in order to ensure that 'downstream flow/levels are no greater than would occur without regulation' (Fay, 2005:p.160). These equations set 'absolute constraints on outflow' and determined how much water could be released by the dam in any given time (Fay, 2005:p.161).

The predictability attempted by these rules was the result of complex transboundary negotiations at the IJC that allowed for clearer management and greater political acceptability, notably as desired by shipping companies and hydro-electricity producers who depended on predictable water levels (MacFarlane, 2014). However, adhering to these rules proved difficult, with the infrastructure struggling to manage hydro-climatic variability. Notably during extreme weather conditions, the natural fluctuations of the water levels were difficult to contain within the strict bounds allowed by the regulation. The operators and their Management Board found that they had too often to deviate from the 'inflexible, date specific' boundaries set in the Plan 'sometimes several times within a week in response to changing conditions' (Fay, 2005:p.172).

In recognition of this problem, the dam's Management Board was given discretionary power to deviate from the Plan whenever necessary in order to provide 'beneficial effects or relief from adverse effects to one interest without appreciable adverse effects to others' (Fay, 2005:p.161). Over the years, many adjustments to the rule curves were attempted, notably in an update in the 1980s through *Plan 1958-D with Simulated Deviations* which allowed the operators a wider range of acceptable high and low water levels, and more discretion to release water in case of flood emergencies (Fay, 2005). We found little evidence of public scrutiny or criticism of this old regulation plan and its variations, perhaps because of its more rigid (and therefore less-discretionary) rules or because the operators' problems were not understood or appreciated.

A new FRM strategy: Plan 2014.

Hand in hand with concerns about climate change and ecosystem restoration, recent environmental discourse has sought a return to less structured, more natural water management strategies including for the regulation of Lake Ontario and the St. Lawrence River. Starting in 1998, a new strategy was proposed to manage the levels of the Great Lakes in order to 'meet regulation objectives under a broad range of possible future water level conditions' (International Upper Canada Lakes Study, 2012:p.7). Strict regulation of water levels such as those in Plan 1958-D would no longer be acceptable.

² The history of this regulation in fact goes back to 1952 with the '1952 Order of Approval' for the Moses-Saunders dam. In July 1958, a working committee began discussing the 'operation details' of rule-based regulation called Plan 1958-A (1960) (International St. Lawrence River Board Of Control Working Committee, 1959:p.1) . This document was then refined in quick succession by Plan 1958-C (1962) and then by Plan 1958-D in 1963 (International Joint Commission, 2014:pp.9–10).

With this shift, after sixteen years of negotiation and 20 million USD spent in consultation, *Plan 1958 D* was replaced by the *Regulation Plan 2014 for the Lake Ontario and the St. Lawrence River* (hereinafter Plan 2014) (International Joint Commission, 2014). Clamen and Macfarlane (2018) outline in detail the evolution of this regulation. The overarching goal of Plan 2014 is to bring fluctuating water levels closer to natural cycles and restoring riparian ecosystems, balancing many competing interests (Clamen & Macfarlane, 2018). It promotes a focus on adaptive management to identify and manage uncertainty, as well as sets up a coordinated regional climate change model to test the specific regulation rules in the face of future uncertainties (Clamen & Macfarlane, 2018; International Joint Commission, 2014).

This type of regulation differs in form and in rationale from the previous strategies. Instead of stating the daily absolute water levels, the release rules for the dam laid out in Plan 2014 (called the B7 rules) use constantly recalculated algorithms reflecting changing daily conditions, and are adjustable on a much wider range of water heights. This allows for much lower and higher water levels to be reached in the lake and river, thus creating greater flexibility of the control system notably to account for extremes and uncertain circumstances. Under this more flexible plan, greater discretion is given to the Management Board and the dam operators to deviate from the old rules. In the calculations embedded in the plan to be followed by the operators, the B7 rules combine short-term hydrological forecasts with longer-term projections and calculations of water heights in normal, unregulated conditions to determine the timing and quantity of water releases. When a discharge is seen to exceed normal conditions (greater than 7,011 m³/s), more water is released based on complex rule curves (International Joint Commission, 2014:p.26): differences in weekly releases are addressed by averaging monthly short-term water quantity forecasts to smooth the variability of the regulation, effectively accelerating the rate of water release when the lake levels are rising.

The Plan also set an emergency trigger for high water levels in the lake that, if reached, provides the Management Board with discretion to ‘provide all possible relief to the riparian owners upstream and downstream’ (International Joint Commission, 2014:p.19). Plan 2014 also tackles climate change uncertainty by allowing the definition of extreme water levels to change as ‘normals’ change, stating that ‘the rule curve parameters should be updated periodically to account for climate change’ (International Joint Commission, 2014:p.28). Later, in their report on the floods in 2019, the ILOSRB warned: ‘we know extremes have occurred in the past and we expect they will occur again in the future, so we must be better prepared for the next event, even though it is difficult to know how soon that will be’ (International Lake Ontario- St. Lawrence River Board, 2020a:p.33).

Through the development of Plan 2014, the IJC has thereby identified two main areas of uncertainty about flood risk and water level regulation: 1) ontological uncertainty about extreme weather events, given their influence on the operation of the new release rules, and 2) epistemic uncertainty as to the accuracy of the models used with which to design those rules. As seen in Table 1, the wording of Plan 2014 firmly sets uncertainty as a fundamental problem that is to be addressed by this new regulation.

Key Flood Events in 2017 and 2019

The implementation of Plan 2014 was immediately followed by record flood seasons in the Springs of 2017 and 2019. It was unfortunate timing for a state-of-the-art strategy aimed to promote a shift to more effective flood risk management.

Flood outcomes

Flooding in Great-Lakes and St. Lawrence basin is seasonal: every year, in the spring as the snow and ice melts, the basins get saturated and the main water bodies and their tributaries overflow their banks. In 2017 and 2019, Spring flooding all along Lake Ontario and the St. Lawrence River was at record levels. One of the worst hit cities in both the years was Montreal, the first major city on the St. Lawrence River. In 2017, more than 400 people had to be evacuated from the city and the immediate emergency response over the course of a few days brought costs of over 8 million \$CAD to the city (Service de sécurité incendie de Montréal/ Direction de la sécurité civile et de la résilience, 2017). In 2019, floods are estimated to have cost the city over 17 million \$CAD (Corriveau, 2020). In New York State's Rochester, on Lake Ontario, the damage from the floods also cost the State hundreds of millions of dollars both in 2017 and 2019 (Orr, 2018).

The emergency measures outlined in Plan 2014 guided the flood response in both those years. In 2017, the operators and Management Board decided to decrease significantly the flow of water out of the lake on the 8th of May, one day after the peak impacts were felt in Montreal, and slowly returned it to normal as the highwater level receded (Perreux, 2018). In interviews given in the aftermath, the IJC explained that, if it had lowered water levels of Lake Ontario by only one centimetre by releasing more water through the dam, this would have raised the water levels near Montreal by a factor of ten (Semeniuk, 2017). Similarly, in the autumn of 2018, the water height at the Moses-Saunders dam again neared the maximum 'L-limit' of Plan 2014 (established as the highest possible outflow from the dam). In the early winter, the levels of Lake Ontario rose with increased precipitation until ice formation. On the 7th of May 2019, water levels reached the high level emergency triggers (Criterion H14) (International Lake Ontario- St. Lawrence River Board, 2020c:para.2). The Board gave the dam operators authority to deviate from the usual regulation 'in order to continue balancing ongoing high water conditions in the lower St. Lawrence River with increasing water levels upstream on Lake Ontario and the upper St. Lawrence River' (International Lake Ontario- St. Lawrence River Board, 2020a:p.24).

Political outcomes and public reaction

The severity of the 2017 and 2019 floods brought the role of the IJC into public consciousness, and the reaction to these events demonstrates the tension surrounding transboundary flood management in a context of uncertainty and new extremes. Concerns that had already arisen regarding the higher water levels allowed by the Plan were concretised (Clamen & Macfarlane, 2018) and as the main new element of the governance plan, the new flexibility of the release rules was the focus of public debate. The divide was encapsulated in this quote from a 2018 news article: 'The controversy over water management and the record floods of 2017 pitted the interests of Americans against Canadians, experts against politicians, and property owners against each other,

not to mention shipping companies and shoreline wildlife' (Perreux, 2018, para.1). Table 2 shows further examples of these reactions.

Upstream, the backlash against Plan 2014 among communities on Lake Ontario has been substantial (Clamen & Macfarlane, 2018). In 2019, the State of New York even launched a lawsuit against the IJC for 50 million USD in compensation for negligence in protecting the interests of New Yorker property owners, stating that the IJC 'failed to increase outflows from Lake Ontario to lower the water levels and abate flooding along the Lake Ontario shorefront' (Berkman, 2019:p.23). The lawsuit specifically highlights that 'nothing could be further from the truth' in the IJC's early claim that the benefits of Plan 2014 would outweigh the minor increased risk of flooding (Berkman, 2019: 2). The first section of the lawsuit describes New York State's perception that Plan 2014 and the decisions made within it in 2017 and 2019 were unfair; it ends on this paragraph which illustrates particularly well the tensions of managing the uncertainty and interdependence of flooding:

'The DEC³ recognizes that the water levels on Lake Ontario are in part a function of natural conditions, and that to expect the IJC to prevent all flooding—particularly in the face of climate change—is unrealistic. The DEC also recognizes that the IJC must balance multiple factors in managing outflows, including the interests of upstream and downstream riparian owners, environmental concerns, and navigation and power. But the key word is “balance”. The IJC cannot saddle the (New York) State with the brunt of the damage.' (Berkman, 2019: 3).

The New York State is arguing that American law provides an exception to sovereign immunity for any claim in which money damages are sought against a foreign state, permitting a valid lawsuit against international organisations (such as the IJC), allowing them to be sued. The lawsuit remains unresolved.

Downstream on the Canadian side of the border, arguably less attention has been paid to Plan 2014 and the role of the IJC, and emphasis has been placed instead on examining changes in extreme weather and urban planning (Table 2). For instance, the city of Montreal's official reports on the 2017 floods show no evidence of work with Plan 2014 or the IJC (Service de sécurité incendie de Montréal/ Direction de la sécurité civile et de la résilience, 2017). If anything, the plan's flexible regulation had protected the city from much higher water levels than occurred in the severe situation that occurred; perhaps the more recent floods in 2019 will be catalysts in creating greater awareness of the IJC's importance role in the protection of Montreal.

Discussion: Tackling uncertainty in transboundary flood risk management

We have discussed the evolving nature of managing transboundary flood risks towards a more flexible approach, and the situation in our case study when new rules encapsulating this greater flexibility coincided with major flooding affecting communities on both sides of a border. The 'symbiotic relationship' of upstream and downstream communities here and elsewhere makes equitable flood risk management complex (Orr & McDermott, 2017). As Peter Annin, author of the *Great Lakes Water*

³ The New York State Department of Environmental Conservation

Wars, stated in an interview in 2018: ‘Relief for one community harms another community [...] there are no simple solutions’ (Perreux, 2018:para.18).

But there can be positives here. The term ‘disaster cooperation’ has been used to refer to the notion by which nations can work together in times of crisis - this may be particularly true if strong institutions and relationships are already well-established (Glantz, 2003; Hannigan, 1976; LeMarquand, 1977). Notably, LeMarquand (1993:p.77) indicated that the IJC’s reputation for impartiality ‘has earned it respect’, and the institution has been named as a successful example of transboundary cooperation. However, the backlash after the 2017 and 2019 floods exposes two difficulties with regard to uncertainty in modern flood risk management to which transboundary situations add another layer of complexity; in times of shock, the importance of these difficulties can be brought to the forefront as increased pressure is put on local decision makers such as dam operators.

(1) Tight flood risk management rules are often preferred by local policy makers and their lay publics as they create more predictability that is easier to understand, accept, and used as vehicles for promoting accountabilities; but

(2) Flood risk management systems and rules need to be made flexible in order to account for inherent hydro-meteorological uncertainty and the even greater uncertainties regarding future risks with climate change.

Two issues are important here. First, animosity between these upstream and downstream communities can be particularly complex and strong in transboundary contexts where planners are asked to balance the two potentially different local self-interests of those who may have very different attitudes to risk and uncertainty; for instance, the broader political contexts in the US and Canada have differed widely in the last few years. Managers and politicians are caught in a delicate balancing act of promoting their constituents’ interests, attempting to juggle jurisdictional differences (or what Cook (2014) calls ‘fragmentation’) while upholding international principles and treaties meant to ensure equity.

Secondly, structural approaches to flood risk management can pit river basin communities against each other, notably because releasing water through dams requires an active decision by operators that, whatever it is, will impact communities on both sides of the structure and will most likely generate those feelings of unfairness discussed by Clamen and Macfarlane (2018) and highlighted here. Considerable uncertainty may well surround current and future situations but decisions are needed on the operation of interventions today using infrastructures that were designed decades ago and may well last another 50 or 100 years. The situation we have described shows a break in trust in the governance arrangements (notably in the IJC) by some of the affected communities, a distrust of the science behind the flexible plan (which was misunderstood), and a pervasive requirement from that public and its politicians for greater certainty than the science suggested is possible.

In these ways, uncertainty puts much socio-political pressure on regulators who are expected to interpret hydro-meteorological forecasts and observations and to make decisions on mitigation pathways that are fair for all. It is not a given that the public accepts even overwhelming scientific evidence or arguments. Additionally, the vocal public debate also exemplifies an underlying tension of transboundary governance that

we articulated earlier: whether we should make agreements and treaties stricter or loosen them. While in the past the role of the IJC has mostly been ignored by the public, recent developments propelled the institution into political consciousness; there seems to have been little previous understanding of the mechanisms of Plan 2014, its rationale of uncertainty, and even its transnational links. In this case, even though the IJC was created to balance out self-interest and has for years provided a platform for international cooperation, it has now been blamed for the 2017/19 crisis. We can see in this respect that the conditions for successful transboundary water governance raised earlier in this paper may be necessary but they are not sufficient.

Expert and lay opinion

The case also illustrates the problem of lay opinion versus expert opinion with regards to uncertainty (Table 2), and raises the question of which should dominate FRM decision-making.

If we were to accept that lay opinion should dominate, because communities are flooded and losses are incurred while their taxes are paying for FRM, then the evolution towards more flexible and adaptive management might have to be reconsidered, because these communities seek stability and predictable outcomes. However, as this case study shows, predictable flood outcomes are hard to come by given the in-built uncertainty in the phenomenon. There is also no such thing as a monolithic lay opinion on best FRM practices, not least owing to the dynamics between upstream and downstream communities. The uncertainty that stems from the plurality of opinions and interests is another issue faced by decision-makers.

If, on the other hand, we make decisions based on scientific results and expert opinion about how to manage uncertainty in flood risk management across national boundaries, then we should persevere with flexible new rules in anticipation that they are best placed with which to manage the uncertainty inherent in the situations we observe, and put efforts into building relationships with communities to ensure that they are kept abreast of any changes in flood risk management strategies.

As researchers, we may prefer the latter strategy, but recognise that inherently this must involve greater communication between the experts and the lay community than has occurred hitherto, to explain the complexity of the situation, if we are to counter any of the inevitable public backlash when floods occur that expert opinion might not or could not have anticipated.

Planners and operators

Decision-makers must be accountable and able to justify their actions based on the best available science.

Our example also illustrates that if we accept that increasing the flexibility of regulation is the best tool to deal with uncertainty, this means we are also shifting some responsibility for decision-making further away from the planners and closer to those implementing the rules: the operators. With more rigid regulations, the planners are accountable for the outcomes which they shape. The more flexible the regulations, the more this responsibility moves to those implementing and interpreting the rules. These operators therefore become more susceptible to criticism of their decisions, and more

likely to experience political and public backlash, local lobbying and political influence, leading to unforeseen consequences and reactions.

Within the transboundary institution whose role is already to balance the interests of all involved by the management of flood risk (in our case the IJC) it may be necessary to bolster clear and agreed inter-nation liability parameters and their associated dispute resolution mechanisms, recognising the positions of both the planners and the operators.

Communicating uncertainty for transboundary cooperation

The effectiveness of transboundary flood risk management relies on adequate communication by decision-makers (i.e. planners and operators, in our context) and the continued success of transboundary institutions. It is beyond the scope of this paper to fully examine the public communication surrounding Plan 2014, but two insights do emerge from the story.

First, effective cooperation requires sufficient information and its communication; all parties must have enough information about the situation and its uncertainties in order for them to trust and therefore support any decisions made. This is not easy. In our case, public backlash to Plan 2014 shows evidence that public understanding of flood risk's hydrometeorological uncertainty and of the role of the regulators is lacking. That uncertainty is a particularly complex concept for the public to grasp, as a large canon of literature records. This difficulty has been highlighted in the Great Lakes themselves in fact, for example in Chao et al (1999) which compares different tools to communicate climatic uncertainty in the basin.

Secondly, for transboundary cooperation to be effective, information held and interpreted on both sides of the border also must be symmetrical, to promote mutual confidence (Bernauer (2002); Durth (1996)). Again, this is not easy. There have clearly been different interpretations of Plan 2014 between the Canadian and American public and governments. This suggests asymmetries in the understanding and political framing of the regulation and of the responsibilities of the IJC's planners and the dam operators, leading inter alia to the lawsuit that we have described and our concern that future flooding incidents will face the same complexities and lead to further disputes.

Social and political uncertainty

This story additionally allows us to expand our definitions of uncertainty: there is great social and political uncertainty regarding flooding, in people's reactions and in institutions' responses, overlaid on epistemic and ontological uncertainty contained in the hazard itself (cf. Penning-Rowsell and Korndewal, 2018). Parallels can be made here between Clamen and Macfarlane's (2018) argument that the IJC's strategic error might have been to ignore the non-technical aspects of FRM and Hall's (2014) caution about the importance of using judgement in potentially contentious situations dominated by uncertainty. As such, not only is flexibility in structural flood risk management necessary to address uncertainty, but accountability and flexibility in the managing institution may also be particularly important. Under more flexible systems, decision-makers such as dam operators may be more often challenged, and there is a need for liability to be pre-delimited and disputes moderated, and in transboundary contexts it

would always be preferable that these accountability mechanisms lie outside of national legal systems.

Further case studies of cross-border flooding situations from other international contexts could enhance our understanding of these many dimensions and help formulate recommendations, as would longitudinal analyses of the story surrounding Plan 2014 as this will continue to develop and be discussed in the future.

Conclusions

The case of Plan 2014 and recent floods in the Lake Ontario/St. Lawrence River system exemplifies how uncertainty can exacerbate the complexity of transboundary flood risk management.

Here, and elsewhere, creating flexibility in the operation of structural and related other FRM measures is one way to address this hydro-meteorological uncertainty and prepare for a range of future flooding scenarios. However, with this strategy, transboundary water managers must negotiate different and difficult socio-political tensions, notably the need to balance the public demand for predictability as well as risk reduction, protecting both upstream and downstream communities as much as possible from the impacts of flooding. The roles of different actors will change, with sometimes unpredictable consequences. This reinforces the need for the delicate balance we are advocating, here between planner and operator, notably through increased transparency supported by proper and agreed and implementable dispute resolution processes.

The theoretical underpinnings of Plan 2014, both in its institutional structure and rationale, might have held the ingredients for a successful flood management tool. In practice, however, the public's reaction suggests tensions can exist no matter how grounded in expertise is the decision making, pressures which are heightened in periods of crisis. The case study reveals in stark detail the multiple tensions concerning adaptive management of episodic events such as flooding: there is no 'silver bullet' here.

What is necessary, however, in these and similar situations internationally, is for this approach towards greater flexibility to recognise the need for clear and appropriate rules for the operation of flood risk management interventions. Better communication of the need for flexibility and the possible increased risk to members of the public is also necessary. Additionally, clear scientific attribution of the causes of any damaging event must be communicated, so that false interpretations of the merits of flexibility are minimised. One way forward may be to ensure that the relevant institutions - like the IJC - are properly equipped to make expert decisions transparently and independently from political considerations, whilst remaining accountable to communities on both sides of any border and all parties are bound by agreed dispute resolution processes.

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Figure 1. The Great Lakes and the St. Lawrence River Basin (Map courtesy IJC, 2018, <https://ijc.org/en/great-lakes-st-lawrence-river>)

