Water Policy 13 (2011) 877–894

Climate change and water governance: an International Joint Commission case study

Claire S. Bleser[a] and Kristen C. Nelson[b]

[a]*Corresponding author. Nine Mile Creek Watershed District, 7710 Computer Ave. Suite 135, Edina, MN 55117, USA. E-mail: cbleser@ninemilecreek.org*

[b]*Department of Forestry Resources and Department of Fisheries and Wildlife, University of Minnesota, 115 Green Hall, 1530 Cleveland Ave. N., St. Paul, MN 55108-6112, USA*

Abstract

Governance has been identified by many scholars as a challenge to managing natural resources in a sustainable way. In addition, climate change is impacting natural resources, and complicating management. In light of these concerns, it is important that key characteristics of sustainable management are not ignored. Scientific legitimacy, an integrative ecosystem approach, long-term monitoring and pro-active governance are all important characteristics of successful sustainable management plans. However, these characteristics have not all been included in the day-to-day functioning of the International Joint Commission. This paper looks specifically at the key characteristics required for sustainable management of transboundary water resources and determines if the International Joint Commission, and particularly the International Rainy Lake Board of Control, are applying them to policies for regulation and management of border waters shared by Ontario (Canada) and Minnesota (USA).

Keywords: Climate change; International Joint Commission; Minnesota; Ontario; Water governance

Introduction

Water resources, specifically freshwater resources, are essential to humans and ecosystems but these resources are also vulnerable to climate change which affects both the chemical and physical attributes of water resources (Bates *et al.*, 2008), through changes in temperature norms, precipitation patterns, snowmelt, runoff, evaporation and soil moisture, as well as the frequency of disturbances, such as drought and severe storms, among other factors (Schimel *et al.*, 2008). All of these changes have direct and indirect effects on water resources, humans (Falkenmark *et al.*, 2004), and the ecosystems that are dependent on the resource (Lettenmaier *et al.*, 2008). This vulnerability to climate change can be a barrier to effective long-range planning and management of water resources (Draper & Kundell, 2007).

doi: 10.2166/wp.2011.073

In developed countries, most water management systems run under the assumption of 'stationarity', the idea that natural systems fluctuate within a certain range of variability (Milly *et al*., 2008). This assumption results in a 'wait and see' approach to water governance and management of water resources. A 'wait and see' approach is not an effective strategy to deal with the uncertainty of climate change (Milly *et al*., 2008).

Furthermore, several studies have identified current governance institutions as one of the primary reasons why natural resources are managed in unsustainable ways (Dietz *et al*., 2003; Ostrom *et al*., 2003; Veeman & Politylo, 2003; Fischer *et al*., 2007). Water resource governance, as the Global Water Partnership (2009) defines it, is 'the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society'. Scholars and practitioners alike call for water resource governance, especially under climate change conditions, to be both pro-active and sustainable.

In the past, various arguments have existed about how water-sharing states should govern their resources. The Harmon Doctrine of 1896 claimed that water resources within sovereign territories should be used without any restrictions; this is also known as the 'territorial sovereignty theory' (Shiva, 2002). In contrast, 'the doctrine of absolute territorial integrity' gave rights to downstream riparian states and therefore restricted the use of water 'to not cause harm to other countries sharing the water' (Kliot, 2000). This concept of 'no harm' also emerged in the International Law Association's Helsinki Rules in 1966 (International Law Association, 1966) and the United Nations 'Convention on the Law of Non-Navigational Uses of International Watercourse' in 1997 (United Nations, 1997). Both of these agreements targeted international audiences, and primarily focused on measures to avoid international conflicts over water. Even though sustainability was introduced in both documents, it was a minor component compared to the focus on human needs. For example, Article 7 of the 'Law of Non-Navigational Uses of International Watercourse' focuses on the obligation not to cause harm. Article 7.1 states that 'Watercourse States shall, in utilizing an international watercourse in their territories, take all appropriate measures to prevent the causing of significant harm to other watercourse States' (United Nations, 1997). There is no mention of harm to the water resources. Both doctrines represent anthropocentric views.

In recent years, new rules and statements emerged, beginning with the Dublin Statement on Water and the Environment of 1992. Significant goals were established with regards to water governance (Rogers & Hall, 2003). For example, Principle 2 of the Dublin Statement states that 'Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels'. This was also reflected when the International Law Association revised the Helsinki Rules and established the Berlin Rules in 2004 (International Law Association, 2004). The Berlin Rules specifically looked at all water resources and developed principles that provided: (1) the right of public participation; (2) the obligation to use best efforts to achieve both conjunctive and integrated management of waters; and (3) duties to achieve sustainability and the minimization of environmental harm. These rules are also reflected within the Water Framework Directive from the European Union (2000). That framework specifically aims at maintaining and improving the aquatic environment in their community (European Council, 2000).

Scholars have also developed guidelines promoting sustainable governance for common pool resources (Dietz *et al*., 2003), earth systems (Biermann, 2007) and water resources (Falkenmark *et al*., 2004; Hall, 2005; Mandarano *et al*., 2008; GWP, 2009; Zawahri, 2009). These guidelines focus on attributes of authority and administration that will strengthen water resource governance.

The 'Authority' is the designation of the person(s)/institution that is legally responsible for the resource and is capable of making binding decisions. The 'Administration' is delegated responsibilities to implement the policies and decisions, coordinate activities, and mediate conflicts over the resource, specifying what is done to achieve the policy goals. The Administration administers the regulatory systems, programs, infrastructure, and conflict management processes. Both an authority and an administration are necessary in order to achieve sustainable governance of resources.

In addition, sustainable water management requires pro-active governance with inclusive, transparent and flexible characteristics. Early inclusion of all stakeholders allows concerns to be raised early and therefore actively develop decisions that will not create undesired tensions (Rogers & Hall, 2003). Transparency allows the public to hold an organization accountable and for any downfalls to be quickly identified (GWP, 2009). Any such problems can be quickly acted upon and conflicts prevented. With local and national authorities changing continually, governance also needs to be flexible towards changes in society and, therefore, needs to be flexible in its decisions (Mandarano *et al*., 2008). When new scientific findings come to light, decisions may need to be modified to increase the effectiveness of the programs and, ultimately, the end goals.

While governance needs to be proactive, it also needs to incorporate sustainable practices. Sustainable management needs to be supported by scientific legitimacy and long-term planning within an integrated ecosystem approach. Scientific legitimacy is important when making decisions, as it will allow decision makers to have better knowledge of the system and therefore develop policies or decisions that will minimize impacts (Falkenmark *et al*., 2004). These decisions also have to consider generations to come. Reactionary decisions that are made on the basis of short-term solutions could result in long-term damage. For example, in Arizona, where water resources are scarce, more and more communities are drilling wells to access water stored underground. Even though they can access the water now and use it, well drillers have not considered the long-term effects of their unregulated pumping, such as aquifer collapse (McKinnon, 2009). Therefore, it is important to incorporate long-term thinking when making sustainable decisions (Dietz *et al*., 2003).

Finally, sustainable decisions need to consider the problem via an ecosystem approach. Changes made on land can have wide-ranging effects on lake ecosystems (Ramstack *et al*., 2004). Many studies have documented anthropogenic impacts on water quality in lakes and streams (e.g. Hall & Smol, 1996; Hall *et al*., 1999; Quinlan *et al*., 2002; Ramstack *et al*., 2004; Pienitz *et al*., 2006; Smol, 2008). Changes in water quality vary from chemical changes to biological community shifts. Thus, it is important to have a full understanding of how decisions can impact the whole ecosystem. These characteristics, along with pro-active governance, are necessities for sustainable water resource management.

In this paper, the key concepts required for sustainable management of water resources in light of climate change have been developed. First, a framework for discussing international water governance (Figure 2) is presented. Then, the governance of the International Joint Commission (IJC), the regulatory authority for Canada–USA transboundary resources, is evaluated with regard to (1) how they have managed water resources; and (2) how responsive the IJC was to the effects of climate change, while at the same time promoting sustainable water use. A case study of the Rainy Lake–Namakan Reservoir region (in Ontario, Canada and Minnesota, USA) is used to explore these ideas. This paper fills a gap in the literature by identifying the main sustainable management criteria and evaluating whether the IJC follow these criteria. This is an important contribution because researchers have discovered that climate change is impacting our resources and because poor governance has been identified as the primary reason why water resources are not managed in a sustainable manner.

International water governance through authority and administration

As illustrated in the Transboundary Water Resources Framework, there are several critical characteristics of sustainable water governance and management based on a clear articulation of authority and administration (Figure 1). Authority includes the legal right to govern, as expressed in a law, treaty, and/or joint agreement, as well as designation of the party with decision-making power based on the legal document. This authority is often delegated to an administrative body for water resource programs to implement governance, conflict management procedures, and sustainable resource management.

A strong foundation of authority and administration are keys to a successful water management program (Figure 1). The authority is recognized as the political body having the right to govern over a water resource (Roseneau, 2003) and issue directives concerning that resource. Governance is especially problematic in the US, as documented by Mandarano *et al*. (2008), given the lack of clear authority in managing interstate water resources. Watershed basins are usually not self-contained within a political boundary; instead, watersheds may flow through several political boundaries.

An authority can be formalized via the establishment of an institution, such as a commission or board through a constitution and bylaws, and that institution is then legitimized through the signing of treaties and agreements by the relevant parties (Conca, 2006; Conca *et al*., 2006; Zawahri, 2009). For example, Rhine River riparian governments established the International Commission for the Protection of the Rhine (ICPR) by signing the Bern Convention in 1963. In developing an authority, governments allow the authority to 'monitor members' activities, make commitments more credible, sanction defectors, lower transaction costs and gather information' (Zawahri, 2009) as well as meet changing conditions (Mandarano *et al*., 2008). The Permanent Indus Commission (PIC) was able to monitor both India and Pakistan's activities throughout several wars, and was able to overcome individual states' fears of cheating by communicating directly with those states for over 40 years (Zawahri, 2009). During war years, the Commission's programs were reduced but officials were still able to

Fig. 1. The Transboundary Water Resources Framework: Critical characteristics for sustainable management.

meet and schedule inspections, rising above the deterioration of bilateral relations between India and Pakistan.

Another requirement for an authority is that it manages multiple water purposes, as this type of authority has proven to be more successful (Sherk, 2005; Mandarano *et al*., 2008). For example, the Agences de l'Eau (Water Agencies) in France manage water resources to preserve and improve water quality, fight against pollution, improve knowledge of the resources, monitor the resources, and educate the public. They are also responsible for fiscal 'water' works within their hydrological basins and have been managing the water resources in their respective regions for over 20 years.

Once an authority has been identified, its administrative function needs to be outlined, which should include the aim of managing multiple water purposes. The administration part of governance helps the authority achieve its goals. This includes a regulation system and programs, an infrastructure (physical and technological), and often a conflict management process for addressing disputes among parties. The regulatory system gives the authority tools prescribing how decisions can be, and should be, reached and implemented. It should also include a rule compliance mechanism (Dietz *et al*., 2003) that acts as a deterrent to 'breaking the law'. The administration also hosts the different programs for water resource management, from biological monitoring of the system to public education. For example, the ICPR (ICPR, 1999) outlined in Article 10 its decision-making process, whilst Article 11 outlined implementation procedures. The ICPR's administration also coordinates six different working groups, which could be seen as programs, ranging from a group that focuses on micropollutants to one that focuses on the economy.

Physical and technological infrastructure can assist governance by developing a governing institution with basin-wide presence (Dietz *et al.*, 2003). Infrastructure can also facilitate effective communication among all governance levels (from local to transnational), provide tools for decision-analysis, and a place of work that is dedicated to their mission. An infrastructure solidifies the working of the authority but requires a dedicated budget. Without a permanent budget, the working of the administration can be dampened and priorities challenged. In creating a permanent budget, an administration can work efficiently and stay focused on the issues that come to hand. Having a permanent budget allows for more effective water management: an administration does not have to spend human resources applying for or finding money that would be used to fund research, staff, and facilities or even prescribing which programs should be funded or not.

Characteristics of sustainable water resource management

Pro-active governance: inclusive, transparent and flexible

Inclusive water governance needs to include all stakeholders within the basin. For example, interstate water resources require a form of governance that can achieve collaboration among different agencies at both the state and national level (Mandarano *et al*., 2008). Inclusive water governance also requires local 'civil society' to be involved (Biermann, 2007). These beliefs reinforce the 2000 Hague Ministerial Declaration, which stated public involvement and stakeholder interest have to be part of water resource management in order for governance to be effective (Rogers & Hall, 2003). Ostrum *et al*. (1999) also pointed out that management of freshwater resources depends on the cooperation of appropriate international institutions (when the resource is international) and national, regional, and local institutions.

Thus, involving civil society can create 'local watchdogs' that can monitor and support government actions and policies, help regulate public–private arrangements to overcome some of the institutional weakness at higher tiers of authority, and ease the resolution of water conflicts (Hall, 2005). For example, in Minnesota (US), watershed districts are required to have a Citizen Advisory Committee (CAC). According to the Watershed District Act (Minnesota Statute 103D 331), the CAC is made up of district residents and their role is to consider issues that are pertinent to the district, and review and comment on the working of the managers in charge of managing the watershed. The CAC is in this sense the 'local watch-dog'. By having stakeholders involved in water resource management, the credibility of the authority can be strengthened.

To further reinforce credibility, the institution should be open and transparent (GWP, 2009). Because water resources tend to be transboundary at local and national levels, vulnerable relationships can be created between authorities (Priscoli, 1998; Priscoli & Llamas, 2001; Zawahri, 2009). These vulnerabilities emerge when negative impacts occur and the cause(s) are not revealed to or accepted by the injured party. For example, the dumping of toxic materials upstream affects the riparian system downstream and creates tensions between the up and downstream governing authorities. In order to minimize these tensions, states must communicate (Priscoli, 1996, 1998; Zawahri, 2009) and resolve differing perspectives.

Stakeholders have a clearer image of what the governing system is doing when a transparent communication system is in place. It lessens the notion of mistrust and encourages interactions among parties. Furthermore, it is important for the institution to bridge the gap between the scientific, political and public spheres (Rofougaran & Karl, 2005). One way to bridge the gap is to ensure that the institutions clearly communicate with and educate the public on the reasons for their rulings. The bottled water debate is a clear example of how institutions responsible for distributing tap water have failed to communicate to their users on their effective water processing capabilities. Many citizens do not realize that bottled water is poorly regulated (Parag & Roberts, 2009), and is sometimes only tap water placed in a bottle (Splash Report, 2003). Parag & Roberts (2009) explain that increasing bottled water consumption is not only linked to better advertising by bottling companies but also 'the growing distrust of tap-water quality and the state's ability to protect the health of its citizens'. Parag & Roberts also suggest that public involvement, transparency and better science communication are some of the institutional and procedural changes required to restore trust. Clearly, if the institution responsible for distributing tap water had a more transparent communication system that was bridging the gap between science and the public, this mistrust and misuse of water resources could have possibly been avoided.

The administrative function of governance must be designed to permit flexibility. Participants, programs and rules/policies have to be flexible in order to meet the needs and changes in political ideologies at the state and federal levels (Mandarano *et al*., 2008), and also to respond quickly to new scientific findings (Dietz *et al.*, 2003; Biermann, 2007). Drieschova *et al*. (2008) argue that the tensions over the 1944 treaty between the US and Mexico are due to a lack of flexibility. The tensions grew because Mexico fell behind on its required water deliveries to the United States (Phillips, 2002). As per the treaty, Mexico had to make up the water deficit within the next five year 'billing' cycle. However, during that time, Mexico was still in drought. Disputes rose between the nations with regards to the timing of repayment. Thus, it is important for institutional regimes to be flexible in order to meet changing and unpredictable conditions, and therefore promote sustainable water management.

Finally, water administrations must have rules that clearly outline how the parties will address disputes (Hall, 2005; GWP, 2009). Conflict management processes facilitate cooperation/collaboration and promote peaceful resource management (Priscoli, 1996; Giordano *et al*., 2005; Zawahri, 2009). Zawahri (2009) discussed how the PIC has, for over 40 years, peacefully managed the Indus River System and used several conflict management processes to resolve conflicts once they arose. The PIC schedules a series of meetings in order for negotiations to be successful. In situations when they are unable to manage a conflict, they call upon a foreign secretary board to intervene. If that fails, a neutral expert attempts to negotiate. The next level of management is a court of arbitration of seven judges. Conflict management processes need to be fair and effective, as they are important components of robust institutions (Ostrum, 1990; Johnson & Nelson, 2004).

Sustainable management: monitoring to support an integrated approach

To increase sustainability over time, resource monitoring (both environmental and biological) has always been an important activity that can be used to support decision-making and the design of effective programs. However, today it is even more important as climate patterns are changing and impacts are less predictable. Monitoring of a resource can provide managers and stakeholders with early indications of resource health. Without environmental monitoring data, trends would not be identified and forecasting models could not be developed and used for prediction. In 1999, the World Bank funded the Water and Environmental Management of the Aral Sea Basin Project. One of the key components for the project was transboundary monitoring. Data from the monitoring stations were useful for more effective management of the irrigated systems. The monitoring component of the project was so successful that more funds were allocated to it and twelve additional international monitoring sites were constructed. Data from these stations are actively used to improve the timing and scheduling of irrigation releases (The World Bank, 2004).

Water-related problems are becoming increasingly complex, which demands an integrated ecosystem approach to management. A study by Hall *et al*. (1999) discovered that changes in biological communities were not only linked to climate but also urbanization and agriculture. Thus, it is important to have an integrated understanding of an ecosystem. As Falkenmark *et al*. (2004) explained, water scientists need to interact with a large number of other scientists, e.g., agricultural, medical, social, economic, ecological and environmental, along with water law makers and geophysical scientists. However, the dominant approach to water management is a single-discipline approach (Falkenmark *et al*., 2004). This approach does not allow a complete understanding of all aspects affecting a water resource, thus reducing the capacity for prediction and ultimately the prevention of adverse effects. Thus, in order for water resources to be managed in a sustainable way, all aspects of the water resource system must be considered and an integrated ecosystem approach must be used.

Case study: the International Joint Commission and the international Rainy Lake board of control

Rainy Lake–Namakan Reservoir characteristics

The Rainy Lake–Namakan Reservoir region is located in the border region of northern Minnesota near International Falls (USA) and northwestern Ontario (Canada) (see Figure 2 and Table 1 for physical

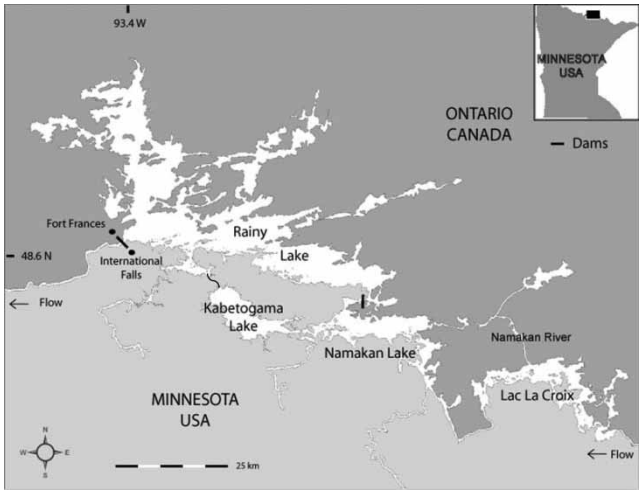

Fig. 2. Map of the Rainy Lake Basin located in the border region of Ontario, Canada and Minnesota, United States. Dams are denoted as black bars. There is an overflow connector, known as Gold Portage, from Rainy Lake at Black Bay to Kabetogama Lake, represented on the map by a curved line. (Source: National Park Service).

Table 1. Lake and watershed characteristics in the Rain Lake–Namakan Reservoir complex. (Data taken from Kallemeyn *et al*. (2003)).

Lake	Lake area (ha)	Watershed to lake area ratio	Maximum depth (m)	Mean depth (m)	Littoral area (%)	Volume ($m^3 \times 10^6$)	Renewal time (years)
Kabetogama	10,425	196.7	24.3	9.1	30	948.7	–
Namakan	10,170	192.7	45.7	13.6	20	1383.1	0.6*
Rainy	92,100	41.9	49.1	9.9	35	9117.9	1

*Renewal time is for Namakan Reservoir.

characteristics; see Kallemeyn *et al*., 2003, for further details). Lakes and reservoir in that area are all located on Precambrian rock formations underlain with schist (Boerboom, 1994) and are situated in the Northern Lakes and Forest ecoregion (Omernick, 1987). The lakes have complex basin morphometries and each has several depositional basins. One natural overflow (Gold Portage) also exists; the portage is between Black Bay, on the south west corner of Rainy Lake, and Kabetogama Lake.

History and establishment of the authority

In 1909, the Boundary Waters Treaty (BWT) between the United States and Canada established the International Joint Commission (IJC) as the authority with jurisdiction over shared water resources. The remit for the Authority was to prevent and resolve conflicts over the use and quality of freshwater (inland waters) shared by Canada and the USA. Since its inception, the IJC has created several boards to carry out its responsibilities (IJC, 2009a). One of these boards is the International Rainy Lake Board of Control (IRLBC). The IRLBC acts as the Administration for the Rainy Lake Basin

region (Figures 1 and 2). It was designed to help manage the border waters of Rainy Lake and Namakan Reservoir, both of which were impounded at the start of the twentieth century to ensure a minimal flow for power generation all year round. At first, the dams were operated in a 'manage as we go' fashion by the American and Canadian lumber companies who owned the dams. However, in 1925, after several damaging flood events, the IJC was asked to become involved through a formal request by the United States and Canada, known as a 'reference'.

Since 1925, the IJC has implemented a number of regulations (Table 2). The first new regulations were spelled out in the 1940 Convention, which assigned to the IJC the legal authority to examine and report on the Rainy Lake Basin under emergency conditions. Next, the 1949 Order, which was based on findings of the International Rainy Lake Board of Control (established in 1941), proposed regulations with regard to extreme water-level events in Rainy Lake. The 1949 Order required dam owners to manage the water-levels to closely mimic the single rule curve. The single rule curve provided a reference for minimum water-levels behind the dams throughout the year.

However, in 1957, a supplementary order was implemented in response to excessive spring runoff in 1950 and 1954. No change was made to the Rainy Lake single rule curve but a maximum rule curve was added for the Namakan Reservoir, creating a rule curve band (a minimum and maximum water level). Finally, due to high and low water events between 1957 and 1968, the 1970 Order implemented a rule curve band for Rainy Lake and amended the rule curves for Namakan Reservoir.

The 1970 order was sustained until 2000 when a new supplemental order was implemented. The modification to the order was initiated in 1991 when an *ad hoc* group, made up of United States and Canadian citizens and known as the Rainy–Namakan Water Level International Steering Committee, determined that the current (1970) order negatively impacted biological communities. The IRLBC played a major part in determining these impacts through studies that the commission had adopted to pursue. In response, the 2000 Order was adopted by the IJC stating that the Commission:

> *continue to carry out its responsibilities under the 1938 Convention for avoiding emergency conditions by instituting rule curves and other requirements which provide a careful balance between upstream and downstream concerns, and among the various interests, including environmental concerns, hydropower, flood risk, and boating. The draft Supplementary Order also takes into account improvements to water quality in the Rainy River allowing lower discharges under low-flow conditions than were previously desirable.* (IJC, 2000)

Furthermore, the 2000 Order stipulated that the biological communities and their habitats be monitored by resource management agencies to determine biological response to the new water-level manipulations. Since 2000, no modifications have been prescribed to the supplemental order. Instead, a Rule Curve Assessment Work Group was formed and, over the course of several workshops, developed monitoring programs, protocols and identified funding sources. Since 2000, a number of studies were implemented (IJC, 2008), most of which focused on the effects of water-level fluctuation on biological communities and specific organisms such as loons, muskrats, wetland vegetation, etc. (IRRWPB/IRLBC, 2006, 2007, 2008); other studies in the basin focused on mercury uptake in prey fish and trophic state indicators (IRLBC/IRRWPB, 2004).

In 2008, at a gap analysis workshop, managers, scientists, and local residents developed a plan of study for the coming years and raised concerns about the potential termination of monitoring stations and long-term studies. The importance of monitoring stations and long-term studies was reiterated during the International Lake of the Woods Water Quality Forum in 2008 and 2009, in part because

Table 2. Rainy Lake Basin administrative origins and history (1909 to 2009), and water regulation. Modified from Larry Kallemeyn (Personal communication, Kallemeyn (2007)).

Year	Decision/description
1909	Boundary Waters Treaty United States and Canada establish the International Joint Commission and define its role via the signing of the Boundary Waters Treaty
1909	International Dam Dam completed at International Falls/Fort Frances
1914	Canadian Dam and International Dam Dams completed at Kettle Falls
1925	Rainy Lake Reference United States and Canada issued the Rainy Lake Reference, requesting the IJC to make recommendations as to the regulation of Rainy Lake and other boundary waters
1934	Final report for the Rainy Lake Reference IJC submits the final report for the Rainy Lake Reference to the United States and Canada
1940	1940 Convention Governments ratify the report with the 1940 convention. The 1940 convention did not actually define any specifics for regulation but assigned the power to the IJC to determine when emergency conditions exist in the Rainy Lake basin and to adopt control measures as necessary
1941	Rainy Lake Board of Control The IJC establishes the International Rainy Lake Board of Control and directed it to examine and report on emergency issues
1949	The 1949 Order The IJC integrated the IRLBC findings into its Order of 8 June 1949. Order had a single rule curve (one line) for both Rainy Lake and Namakan Reservoir
1957	The 1957 Order The IJC issued a supplementary Order on 1 October 1957, in response to excessive spring runoff in 1950 and 1954. No change was made in the Rainy Lake rule curve but a maximum rule curve was added for Namakan Reservoir
1970	The 1970 Order The IJC issued a new supplementary Order on 29 July 1970. It established a rule curve band on Rainy Lake and amended the rule curves on Namakan Reservoir
1987	US Federal Regulatory Commission License US Federal Regulatory Commission license issued for the US portion of the dam at International Falls for 40 years. License required Rainy Lake water levels to be at the top of the 1970 Rule Curve for two weeks following ice-out
1987–1995	US Congress US Congress passes and President signs an act requiring the dam operators to utilize the Rainy Lake and Namakan Reservoir Water Level International Steering Committee's proposed rule curves in conjunction with the 1970 rule curves. In each instance in which an existing rule curve coincided with a proposed rule curve, the water level was to be maintained within the range. When the existing rule curve and proposed rule curve did not coincide, the water level was to be maintained at the limit of the existing rule curve that was closest to the proposed rule curve. The amendment, sponsored by Senator Wellstone, had a sunset provision that said it would remain in effect until the IJC reviewed and made a decision on the Steering Committee's recommendations
2000	2000 Order IJC issued a new supplementary Order on 5 January 2000 which implemented new rule curves for both Rainy Lake and Namakan Reservoir, directed the Companies to target the middle of the rule curves, and gave the IRLBC authority to direct the Companies to target elsewhere in the band

(*Continued.*)

Table 2. (*Continued.*)

Year	Decision/description
2001	Consolidated Order
	IJC adopted a consolidation as the authoritative text of the Commission's Order of June 1949, as amended, and replaced the individual Order and the Supplementary Orders of 1957, 1970, and 2000. The rule curves in the 2000 supplementary Order were not changed
2005	Integrated Watershed Initiative
	The International Rainy Lake Board of Control and the International Rainy River Water Pollution Board take part in the IJC's International Watershed Initiative

there was increasing evidence of climate change effects within the region (International Lake of the Woods Water Quality Forum, pers. comm., 2009).

Recently, on 17 June 2010, the US and Canadian governments 'requested that the IJC review and make recommendations regarding the bi-national management of the Lake of the Woods and Rainy River Basin and the IJC's potential role in this management' (IRLBC/IRRWPB, 2010). The region of concern includes the chain of lakes that fall under the working of the International Rainy Lake Board of Control. The IJC established the International Lake of the Woods Rainy River Watershed Task Force (ILWRRWTF) in July 2010. In the directive to the task force, the IJC highlights that the 'task force shall consult with the International Rainy Lake Board of Control and International Rainy River Pollution Board to seek their views so that each Board and Task Force may be aware of any activities of the other that might be useful to it in carrying out its responsibilities' (IJC, 2010). The ultimate task for it is to 'provide advice on potential structures and mechanisms for governance in the Lake of the Woods and Rainy River Watershed, as well as priority issues or activities to be addressed by or through such mechanisms' (ILWRRWTF, 2011a). In February 2011, the task force published an interim report describing the historical context of the task force, the roles and responsibilities of the various organizations in the region, accomplishments, and issues and concerns in the watershed. Some of the concerns relate to climate change and water monitoring efforts.

Climate change in Rainy Lake–Namakan Reservoir Region

As previously mentioned, the Rainy Lake–Namakan Reservoir Region, located in and near Voyageurs National Park on the US–Canadian border of Minnesota and Ontario, has not been immune to climate change. Moin (2008) and the IJC (2009b) indicated that the US–Canada border area may experience climate change. Serieyssol *et al*. (2009) showed that mean winter air temperature records from Kenora, Ontario, located less than 100 km north-west of International Falls, Minnesota, showed an increase in seasonal winter temperatures post-1970, and were correlated with biological changes in the border lakes. This change in winter temperature is reflected in earlier ice-out dates and later ice-in dates (Kallemeyn *et al*., 2003). Jensen *et al*. (2007) identified a similar trend in the Laurentian Great Lakes, as did Johnson & Stefan (2006) in Minnesota, and Kallemeyn *et al*. (2003) in Voyageurs National Park, where Rainy Lake and Namakan Reservoir are located.

Forecasting models predict Minnesota temperature increases of up to 2.2°Celsius by 2100 (EPA, 1997). Clearly, climate change is occurring in Minnesota (Johnson & Stefan, 2006) and will continue (EPA, 1997). In addition, the EPA anticipates Minnesota precipitation will increase by 15% in winter,

summer, and autumn (EPA, 1997). Recently, Serieyssol *et al*. (2010) identified an increase in precipitation during the autumn season at International Falls, Minnesota. These changes in temperature and precipitation may increase runoff and drought events in Minnesota (EPA, 1997). Furthermore, ecosystem boundaries could shift north and biological communities may change. Serieyssol *et al*. (2009, 2010) identified diatom community changes related to climate change. Clearly, climate change is occurring in the region and affecting the resources, but is the IJC prepared for it?

Recommendations for sustainable management in the Rainy Lake–Namakan Reservoir Region

In 2009, the Boundary Waters Treaty (BWT) of 1909 celebrated a 'century of cooperation protecting our shared waters' (IJC, 2009a). The BWT established the IJC to investigate, resolve and prevent boundary water disputes between the United States and Canada, and subsequently established the IRLBC in 1941 to help it carry out its responsibilities. In addition, the Board actively participates in the International Watershed Initiative (IWI) which 'promotes an integrated, ecosystem approach to issues arising in transboundary waters through enhanced local participation and strengthened local capacity'. Conflict management and an integrated ecosystem approach are important when dealing with climate change. However, long-term monitoring cannot be ignored when managing for sustainability. As a result, this investigation has been focused on: (1) conflict management; (2) the IWI approach; and (3) long-term monitoring. All three elements are important for the sustainable, conflict-free management of water resources, particularly in the Rainy Lake–Namakan Reservoir Region of the IJC.

Conflict management

Overall, only minor conflicts have occurred regarding the Rainy Lake–Namakan Reservoir. Most disputes have happened with regard to water-level changes and water quality. Disputes brought to the IJC have focused on the adverse effects of the regulated waters, specifically that the regulated waters have negatively affected aquatic biota since the dams were built (see Sharp, 1941; Johnson *et al*., 1966; Chevalier, 1977; Kraft, 1988; Kallemeyn *et al*., 2003). These concerns have been raised by the National Park Service, since the creation of the Voyageurs National Park in 1975 (Kallemeyn *et al*., 2003).

However, in 1991, water-level concerns were raised and could not be ignored, when the Rainy Lake and Namakan Reservoir International Steering Committee (RLNRISC) was formed. This committee was not affiliated with the IJC and included diverse stakeholders, including United States and Canadian representatives from private industry, the public, and government agencies (including scientific communities). The task of the committee was to reach a consensus about how the lakes in the Rainy Lake–Namakan reservoir should be managed.

The committee undertook extensive analysis of scientific data, discussion and public consultation (Kallemeyn *et al*., 2003). Two years later, the RLNRISC submitted their report to the IJC suggesting that the 1970 Order should be modified. Specifically, the committee wanted to see earlier and greater low- and high-water levels during the spring refill period, a reduction of the overall annual fluctuation (thus, less extreme low and high water levels), and recommended the Autumn drawdown to be more modest (IRLBC, 1999). A few months later, Boise Cascade Corporation, then owner of the dams and also a member of the RLNRISC, submitted a statement to the IJC against the modification of the 1970 Order. In 1995, the IJC requested that the IRLBC, the regional board supervising the

management of waters in that region, review the 1970 Order, they being the administrative body for that region under the IJC. Four years later, the IRLBC recommended that the 1970 Order be modified. In 2000, the IJC issued a new supplementary order. It is important to note that throughout this time period, the IJC's governance remained re-active to disputes. The IJC did not promote exchange between the public, industry and government; it was the stakeholders who initiated the interactions.

However, in 2003, in response to the dispute over water levels and consultation with stakeholders, the IJC finally recognized the importance of local stakeholders by expanding the IRLBC Board to include two local residents, one from Canada and the other from the United States. Thus, the Board went from two to four members with half of the membership representing local residents. To date, the Board still includes two local residents along with two members from government agencies.

Furthermore, the Board expanded their communication and outreach with the broader community. They initiated a quarterly website newsletter to inform the public of the Board's activities in 2003 (IRLBC/IRRWPB, 2004). They also redesigned their website, developed workshops, attended local water-related conferences, and continued to hold annual public meetings and publish semi-annual reports. Since 2006, the Board has worked to meet regularly with resource agencies. In addition, board members have had greater interaction amongst themselves, increasing their meetings from four in 2003 to seven in 2008. These pro-active gestures by the IJC promoted cooperation and collaboration between all involved parties. These processes were not only inclusive but also improved transparent communication, both key factors in managing conflicts. All these traits led to a collaborative decision-making process. In addition, these characteristics have been further reinforced in the working of the IRLBC, as they are now part of the International Watersheds Initiative (IJC, 2009b), which has reinforced the idea that the Board should hold regular public hearings.

Since July 2010, the IJC has also been involved in the region with the ILWRRWTF. The directive from the IJC to the task force emphasizes the importance of public outreach and consultation. The task force not only identified the various stakeholders in the region but also created a Citizen Advisory Group (CAG) composed of citizens, private sector and local government representatives and scientists, to name a few. In the recorded notes of the CAG meetings dated 25–28 October 2010, the CAG made a note to ask the task force if they had a communication/media plan (CAG, 2010). Shortly after, in their work plan dated 15 November 2010, the ILWRRWTF identified an information dissemination plan in addition to their public stakeholder engagement plan (ILWRRWTF, 2011a). Clearly, the task force is following the directive of the IJC and is increasing stakeholder involvement in the region. This approach is extremely important as it increases transparency in the working of the task force and is strengthening open communication, two important criteria in managing conflicts.

Integrated ecosystem approach

While conflict management is critical for water management, an integrated ecosystem approach is essential for sustainable management. The IJC developed the International Watersheds Initiative (IWI) 'to facilitate the development of watershed-specific responses to emerging challenges such as intensified population growth and urbanization, global climate change, changing uses of water, pollution from air and land, and introductions of exotic species' (IJC, 2009a). The idea of this approach was first introduced in 1997. It was further developed in consultation with different governmental levels: states and provinces, First Nations, and local authorities. In 2005, the Rainy River was chosen as one of the pilot projects.

Because the International Rainy River Water Pollution Board (IRRWPB) and the IRLBC work together closely, the IRLBC also became part of the IWI with the International Rainy River Water Pollution Board.

Since 2005, IJC commissioners have been working to strengthen this international watershed initiative, and meet yearly to develop and reinforce it. The IJC has also supported this integrated ecosystem approach by providing funding for a better understanding of how the reservoir and Rainy River function together. In 2006, the IRRWPB and IRLBC established an informal working group made up of relevant stakeholders. The working group was tasked with developing cooperative mechanisms to balance hydropower and ecosystem needs, particularly during the fish spawning period. The working group agreed to establish an annual 2.5 month period, during the spawning season, when no hydropower peakings would take place. Dam owners, natural resource specialist and other stakeholders were able to approach issues from all different angles.

Another example using an integrative approach took place at a 'Rule Curve' workshop, sponsored by the IJC in March 2008. Representative from all fields (natural and social sciences) were asked to develop a gap analysis of what studies needed to be done for the evaluation of the 2000 Order in 2015. The workshop included culture specialists, dam engineers, provincial and state natural resources representatives, and aquatic ecologists. This inclusiveness allowed for a better understanding of the watershed's ecosystem. Furthermore, in April 2008, both the International Rainy River Pollution Board and the IRLBC indicated to the IJC that they supported the merger of both boards. This merger would bring these two boards in the same watershed into one decision-making unit, which would allow a more comprehensive approach to water resources in the region.

It must also be noted that the IJC is still working on enhancing and strengthening the IWI boards. The IWI boards were developed to anticipate, prevent and resolve watershed disputes at a local level. This watershed approach recognizes the interconnections between land and water on a whole-basin scale. In 2009, the IJC determined that the IWI was effective and necessary, especially in light of emerging issues such as climate change. The IWI functions need to be flexible; each IWI board needs to be localized, so as to maximize local involvement (IJC, 2009b). IWI boards are also more cost-effective but will require further funding from the US and Canada, in order to develop the initiative. The IWI boards are cost-effective, in that they link the boards with local groups on both sides of the border. This allows communication to occur and ensures that duplicate projects are not implemented, and priority projects are initiated in an efficient matter.

Long-term monitoring

Integrated ecosystem approach is not the only element required for sustainable management; long-term monitoring is equally important. When the IJC stipulated in its 2000 Order that resources should be monitored, a committee was formed to oversee development and implementation of a long-term monitoring program (over 15 years). The committee soon realized that 'such a long-term monitoring program would require long-term commitments not only from the natural resource agencies, but also from industry, other agencies, and the public concerned with these significant water resources, and that obtaining the financial resources needed to support the program would be a significant and ongoing challenge' (Kallemeyn *et al.*, 2003). These concerns are consistently reflected in the joint semi-annual reports from the International Rainy River Water Pollution Board and the International Rainy Lake Board of Control (IRLBC, 2000; IRLBC/IRRWPB, 2002; 2004; 2005; 2006; 2007; 2008). Lack of financial support for monitoring stations was again reiterated as a concern during an IJC rule curve workshop (IJC, 2008).

Furthermore, even though the focus has been on physico-biological–chemical monitoring, socio-economic monitoring is still lacking (IRRWPB/IRLBC, 2009).

Although the IJC encourages long-term monitoring, it has not provided long-term financial support. It has instead reiterated that environmental and natural resource agencies must 'step up their support for IWI … by carrying out monitoring and analytical studies to provide essential baseline data and to discern and improve understanding of significant trends in transboundary basins' (IJC, 2009b). With the 2009 downturn in the economy, monitoring resources are threatened. It is important for the IJC to not only support monitoring efforts verbally but also financially. Biological, chemical, and socio-economic monitoring are all extremely important in decision-making. This concern was also referenced in the ILWRRWTF Interim report, dated 14 February 2011 (ILWRRWTF, 2011b). The IJC needs to start thinking of how to allocate some of their budget to support these efforts. Gaps in monitoring data could lead to inefficient and reactive decisions, rather than pro-active and sustainable policies.

Conclusions

Conflict management, an integrated ecosystem approach and long-term monitoring are essential characteristics for sustainable water management. These elements are especially important due to the potential impacts of climate change. The International Joint Commission in the Rainy Lake–Namakan Reservoir Region has been quite successful at incorporating these characteristics in its working environment. However, it does not fully support the implementation of long-term monitoring efforts. For several decades, the IJC has relied on federal and state agencies on both sides of the border to fund monitoring stations. In order to promote sustainable management, the IJC itself needs to consider long-term funding for monitoring of the resource.

The management of transboundary freshwater resources under potential climate change is a global challenge. Transboundary water-managing organizations such as the IJC will need to implement pro-active governance practices, and ensure that they obtain or support long-term monitoring data collection. The data are important for making sustainable decisions and are integral to making integrated ecosystem decisions. Without these elements, tensions could arise, unsustainable decisions be made, and valuable data be lost or not collected. All these scenarios could lead to the breakdown of an organization that has celebrated a century of cooperation protecting shared waters.

References

Bates, B. C., Kundzewicz, Z. W., Wu, S. & Palutikof, J. P.(eds.). (2008). *Climate change and water.* Technical Paper VI of the Intergovernmental Panel on Climate Change. IPCC Secretariat, Geneva, 210 pp.

Biermann, F. (2007). 'Earth system governance' as a crosscutting theme of global change research. *Global Environmental Change 17*, 326–337.

Boerboom, T. (1994). *Minnesota at a Glance*. Minnesota Geological Survey, St. Paul, Minnesota.

Chevalier, J. R. (1977). Changes in the walleye (*Stizostedion vitreum vitreum*) population in Rainy Lake and factors in abundance, 1924–75. *Journal of the Fisheries Research Board of Canada 34*, 1696–1702.

Citizen Advisory Group (2010). Summary of CAG meeting notes from October 25–28, 2010 meetings. Available at: http://www.ijc.org/conseil_board/rainy_river_watershed/sites/default/files/CAG%20Meeting%20Notes%20summary%20October2010.pdf (Accessed 28 March 2011).

Conca, K. (2006). *Governing Water*. MIT Press, Cambridge, MA.

Conca, K., Wu, F. & Mei, C. (2006). Global regime formation or complex institution building? The principled content of international river agreements. *International Studies Quarterly 50*(2), 263–285.

Dietz, T., Ostrom, E. & Stern, P. C. (2003). The struggle to govern the commons. *Science 302*, 1907–1912.

Draper, S. E. & Kundell, J. E. (2007). Impact of climate change on transboundary water sharing. *Journal of Water Resources Planning and Management 133*(5), 405–415.

Drieschova, A., Giordano, M. & Fischhendler, I. (2008). Governance mechanism to address flow variability in water treaties. *Global Environmental Change 18*, 285–295.

Environmental Protection Agency (1997). *Climate Change and Minnesota*. EPA 230-F-97-008W. Available at: http://yosemite.epa.gov/oar/GlobalWarming.nsf/UniqueKeyLookup/SHSU5BUTET/$File/mn_impct.pdf (Accessed 18 May 2009).

European Council (2000). *Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy*. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF (Accessed 29 March 2011).

Falkenmark, M., Gottschalk, L., Lundqvist, J. & Wouters, P. (2004). Towards integrated catchment management: increasing the dialogue between scientists, policy-makers and stakeholders. *Water Resources Development 20*(3), 297–309.

Fischer, A., Petersen, L., Feldkötter, C. & Huppert, W. (2007). Sustainable governance of natural resources and institutional change: an analytical framework. *Public Administration and Development 27*, 123–137.

Giordano, M. F., Giordano, M. A. & Wolf, A. T. (2005). International resource conflict and mitigation. *Journal of Peace Research 42*(1), 47–65.

Global Water Partnership (2009). *Toolbox for Integrated Water Resources Management*. GWP. Available at: http://www.gwptoolbox.org/

Hall, A. W. (2005). Water: water and governance. In: *Governance for Sustainable Development: a Foundation for the Future*. Ayre, G. & Callway, R. (eds.). Earthscan, UK. pp. 111–128.

Hall, R. I., Leavitt, P. R., Quinlan, R., Dixit, A. S. & Smol, J. P. (1999). Effects of agriculture, urbanization, and climate on water quality in the northern Great Plains. *Limnology and Oceanography 44*, 739–756.

Hall, R. I. & Smol, J. P. (1996). Paleolimnological assessment of long-term water-quality changes in south-central Ontario lakes affected by cottage development and acidification. *Canadian Journal of Fishing and Aquatic Science 53*, 1–17.

ICPR (International Commission for the Protection of the Rhine River) (1999). Convention on the Protection of the Rhine River. Available at: http://www.iksr.org/fileadmin/user_upload/Dokumente_en/convention_on_tthe_protection_of_the_rhine.pdf

International Joint Commission (2000). *Supplementary Order to the Order Prescribing Method of Regulating the Levels of Boundary Waters*, dated June 1949, as amended by Supplementary Orders dated 1 October 1957 and 29 July 1970. Available at: http://www.ijc.org/rel/news/rainyorderfinal.html (Accessed 7 May 2009).

International Joint Commission (2008). Rule Curve Monitoring Workshop, Fort Frances. Ontario, March 10–11, 2008.

International Joint Commission (2009a). Who We Are. Available at: http://www.ijc.org/en/background/ijc_cmi_nature.htm#eco (Accessed 23 April 2009).

International Joint Commission (2009b). *The International Watershed Initiative: Implementing a New Paradigm for Transboundary Basins*. Third Report to Governments on the International Watershed Initiative. IJC. Available at: http://www.ijc.org/php/publications/pdf/ID1627.pdf

International Joint Commission (2010). *Directive to the International Lake of the Woods and Rainy River Watershed Task Force*. Available at: http://www.ijc.org/conseil_board/rainy_river_watershed/sites/default/files/DIRECTIVE.pdf (Accessed 29 March 2011).

International Lake of the Woods and Rainy River Watershed Task Force (2011a). *Welcome*. Available at: http://www.ijc.org/conseil_board/rainy_river_watershed/welcome (Accessed 28 March 2011).

International Lake of the Woods and Rainy River Watershed Task Force (2011b). *Interim Report from 24 February 2011*. Available at: http://www.ijc.org/conseil_board/rainy_river_watershed/sites/default/files/Interim%20Report.pdf. (Accessed 28 March 2011).

International Law Association (1966). The Helsinki rules on the uses of the waters of international rivers. In *Report of the Fifty-Second Conference (Helsinki, 1966)*. International Law Association, London, UK.

International Law Association (2004). The Berlin rules on water resources. In *Report of the Seventy-First Conference (Berlin, 2004)*. International Law Association, London, UK.

International Rainy Lake Board of Control (1999). Annual Report for Years 1995–1999. Available at: http://www.ijc.org/rel/boards/rainylake/ann20000705_e.pdf (Accessed 27 July 2009).

International Rainy Lake Board of Control (2000). Annual Report. Available at: http://www.ijc.org/rel/boards/rainylake/ann20010321_e.pdf (Accessed 27 July 2009).

International Rainy Lake Board of Control/International Rainy River Water Pollution Board (2002). Annual Report. Available at: http://www.ijc.org/rel/boards/rainylake/rl20021031_e.pdf (Accessed 27 July 2009).
International Rainy Lake Board of Control/International Rainy River Water Pollution Board (2004). Spring Report, 2004. Available at: http://www.ijc.org/rel/pdf/IRLBC-IRRW_jointrpt_0203.pdf (Accessed 27 July 2009).
International Rainy Lake Board of Control/International Rainy River Water Pollution Board (2005). Fall Report. Available at: http://www.ijc.org/rel/pdf/IRRWPB-IRLBC-2005FallRept-Final.pdf (Accessed 27 July 2009).
International Rainy Lake Board of Control/International Rainy River Water Pollution Board (2006). Fall Report. Available at: http://www.ijc.org/rel/pdf/IRLBC-IRRWPB-Fall2006Rept.pdf (Accessed 27 July 2009).
International Rainy Lake Board of Control/International Rainy River Water Pollution Board (2007). Fall Report. Available at: http://www.ijc.org/rel/pdf/IRRWPB-IRLBC-Fall2007Rept-2007Sep26.pdf (Accessed 27 July 2009).
International Rainy Lake Board of Control/International Rainy River Water Pollution Board (2008). Fall Report. Available at: http://www.ijc.org/rel/pdf/IRLBC-IRRWPB-Fall2008Rept.pdf (Accessed 27 July 2009).
International Rainy Lake Board of Control/International Rainy River Water Pollution Board (2009). Spring Report. Available at http://www.ijc.org/rel/pdf/IRLBC-IRRWPB-Spring2009Rept-2009Mar12.pdf (Accessed 27 July 2009).
International Rainy Lake Board of Control/International Rainy River Water Pollution Board (2010). Fall Report. Available at http://www.ijc.org/rel/pdf/IRLBC-IRRWPB-Fall2010-Report.pdf (Accessed 15 March 2011).
Jensen, O. P., Benson, B. J., Magnuson, J. J., Card, V. M., Futter, M. N., Soranno, P. A. & Stewart, K. M. (2007). Spatial analysis of ice phenology trends across the Laurentian Great Lakes region during a recent warming period. *Limnology and Oceanography 52*, 2013–2026.
Johnson, F. H., Thomasson, R. D. & Caldwell, B. (1966). *Status of the Rainy Lake Walleye Fishery, 1965*. Minnesota Department of Conservation, Division of Game and Fish, Section of Research and Planning Investigational Report 292. Saint Paul, USA.
Johnson, K. A. & Nelson, K. C. (2004). Common property and conservation: the potential for effective communal forest management within a national park in Mexico. *Human Ecology 32*(6), 703–733.
Johnson, S. & Stefan, H. G. (2006). Indicators of climate warming in Minnesota: Lake ice covers and snowmelt runoff. *Climate Change 75*, 421–453.
Kallemeyn, L. (2007). Personal communication.
Kallemeyn, L. A., Holmberg, K. L., Perry, J. A. & Odde, B. Y. (2003). *Aquatic Synthesis for Voyageurs National Park*. U.S. Geological Survey, Information and Technology Report 2003–0001.
Kliot, N. (2000). A cooperative framework for sharing scarce water resources: Israel, Jordan, and the Palestinian authority. In *Water in the Middle East: A Geography of Peace*. Amery, H. A. & Wolf, A. T. (eds.). University of Texas Press, Austin, USA. pp. 191–217.
Kraft, K. J. (1988). *Effect of increased winter drawdown on benthic macroinvertebrates in Namakan Reservoir*. Voyageurs National Park, US Department of the Interior, National Park Service Research, Resources Management Report MWR-12, 76p.
Lettenmaier, D., Major, D., Poff, L. & Running, S. (2008). *Water resources: the effects of climate change on agriculture, land resources, water resources, and biodiversity*. A report by the U.S. Climate Change Science Program and the subcommittee on Global Change Research. Washington, DC, USA. 362 pp.
Mandarano, L. A., Featherstone, J. P. & Paulsen, K. (2008). Institutions for interstate water resources management. *Journal of the American Water Resources Association 44*(1), 136–147.
McKinnon, S. (2009). Unabated use of groundwater threatens Arizona's future. *The Arizona Republic*, 2 August 2009. Available at: http://www.azcentral.com/arizonarepublic/news/articles/2009/08/02/20090802bucket-groundwater.html (Accessed 17 August 2009).
Milly, P. C. D., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P. & Stouffer, R. J. (2008). Stationarity is dead: Whither water management? *Science 319*(5863), 573–574.
Moin, S. M. A. (2008). Climate change impacting Great Lakes Water. In Paper presented at *Ontario Climate Change Impacts Assessment Research, Adapting to Climate Change in the Niagara Region*. St. Catharines, Ontario, May 14, 2008.
Omernick, J. M. (1987). Map supplement: Ecoregions of the conterminous United States. *Annals of the Association of American Geographers 77*, 118–125.
Ostrom, E., Dietz, T., Dolšak, N., Stern, P., Stonich, S. & Weber, E. (eds.). (2003). *The Drama of the Commons*. National Academy Press, Washington DC.
Ostrum, E. (1990). *Governing the Commons: the Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge, UK.

Ostrum, E., Burger, J., Field, C. B., Norgaard, R. B. & Policansky, D. (1999). Revisiting the commons: local lessons, global challenges. *Science 284*, 278–282.

Parag, Y. & Roberts, J. T. (2009). A battle against the bottles: building, claiming, and regaining tap-water trustworthiness. *Society and Natural Resources 22*, 625–636.

Phillips, T. (2002). Behind the US–Mexico water treaty dispute. *Interim News 77*(7), 1–6.

Pienitz, R., Roberge, K. & Vincent, W. F. (2006). Three hundred years of human-induced change in an urban lake: paleolimnological analysis of Lac Saint-Augustin, Québec City. *Canadian Journal of Botany 84*, 303–320.

Priscoli, J. D. (1996). *Conflict resolution, collaboration and management in international water resource issues*. Working Paper no. 6, US Army Corps of Engineers.

Priscoli, J. D. (1998). Water and civilization: using history to reframe water policy debates and to build a new ecological realism. *Water Policy 1*, 623–636.

Priscoli, J. D. & Llamas, M. R. (2001). International perspective in ethical dilemmas in the water industry. In: *Navigation Rough Waters*. Davis, C. K. & McGinn, R. E. (eds.). American Water Works Association, Denver, CO, pp. 41–64.

Quinlan, R., Leavitt, P. R., Dixit, A. S., Hall, R. I. & Smol, J. P. (2002). Landscape effects of climate, agriculture, and urbanization on benthic invertebrate communities of Canadian prairie lakes. *Limnology and Oceanography 47*(2), 378–391.

Ramstack, J. M., Fritz, S. C. & Engstrom, D. R. (2004). Twentieth century water quality trends in Minnesota lakes compared with presettlement variability. *Canadian Journal of Fishing and Aquatic Science 61*, 561–576.

Rofougaran, N. L. & Karl, H. A. (2005). *San Francisquito Creek – the problem of science in environmental disputes: joint fact finding as a transdisciplinary approach toward environmental policy making*. US Geological Survey Professional Paper 1710. Available at: http://pubs.usgs.gov/pp/pp1710/.

Rogers, P. & Hall, A. (2003). *Effective water governance*. TEC Background Papers: 7. Elanders Novum, Sweden.

Roseneau, J. N. (2003). Governance in a new global order. In *Governing Globalization*. Held, D. & McGrew, A. (eds.). Polity Press, UK. pp. 70–86.

Schimel, D., Janetos, A., Backlund, P., Hatfield, J., Ryan, M., Archer, S. & Lettenmaier, D. (2008). *Synthesis: the effects of climate change on agriculture, land resources, water resources, and biodiversity.* A Report by the U.S. Climate Change Science Program and the subcommittee on Global Change Research. Washington, DC, USA. 362pp.

Serieyssol, C. A., Edlund, M. B. & Kallemeyn, L. W. (2009). Impacts of settlement, damming, and hydromanagement in two boreal lakes: a paleolimnological before–after control-impact study. *Journal of Paleolimnology 42*(4), pp. 497–513.

Serieyssol, C. A., Edlund, M. B., Kallemeyn, L. W. & Ramstack, J. (2010). Interactive effects of hydromanagement, land use and climate change on water quality of US–Canada borders waters.

Sharp, R. W. (1941). Report of the investigation of biological conditions of Lakes Kabetogama, Namakan, and Crane as influenced by fluctuating water levels. *Fisheries Research Investigational Report No. 30*, Department of Natural Resources, Saint Paul, Minnesota. 17 p.

Sherk, G. W. (2005). The management of interstate water conflicts in the twenty-first century: is it time to call uncle? *New York University's Environmental Law Journal 12*(3), 764–827.

Shiva, V. (2002). *Water Wars: Privatization, Pollution and Profit*. South End Press, Canada. 156 p.

Smol, J. P. (2008). *Pollution of Lakes and Rivers: A Paleoenvironmental Perspectives*. Second edition, Blackwell Publishing Ltd., Singapore.

Splash Report (2003). *Facts and figures: Bottled water. The United Nations International Year of Freshwater 2003*. Available at: http://www.wateryear2003.org/en/ev.php-URL_ID=5226&URL_DO=DO_TOPIC&URL_SECTION=201.html (Accessed 17 August 2009).

The World Bank (2004). *Aral Sea water and environment management project*. Report 27626. Available at: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2004/03/04/000012009_20040304125041/Rendered/PDF/27626.pdf (Accessed 19 August 2009).

United Nations (1997). Convention on the Law of Non-Navigational Uses of International Watercourses. Official Records of the General Assembly, Fifty-first Session, Supplement No. 49(A/51/49). United Nations.

Veeman, T. & Politylo, J. (2003). The role of institutions and policy in enhancing sustainable development and conserving natural capital. *Environment, Development and Sustainability 5*, 317–332.

Zawahri, N. A. (2009). India, Pakistan and cooperation along the Indus River system. *Water Policy 11*, 1–20.

Received 13 July 2010; accepted in revised form 4 April 2011. Available online 28 May 2011