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Diagnosis of sustainability of trans-boundary water governance in the Great Lakes basin

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ABSTRACT

Trans-boundary water governance is crucial for addressing water-related issues caused by a growing population in combination with increasing demand, human intervention, conflict and above all climate change impacts on water resources. A literature review demonstrates that there is indeed a positive relationship between governance and the mitigation of tensions and meeting of sustainability goals in a given basin. Understanding the impacts of trans-boundary water governance from a sustainability perspective is very important. In this paper, Gibson's Sustainability Criteria are used to assess the sustainability performance of the trans-boundary water governance in the Great Lakes basin. The findings reveal that the trans-boundary water governance in this region is particularly weak in addressing Gibson's Sustainability Criteria factors of *Intra-Generational Equity*, *Inter-Generational Equity*, *Precautionary and Adaptation*, and *Immediate and Long-Term Integration* but successful in fostering *Livelihood Sufficiency and Opportunity*, *Resource Maintenance and Efficiency*, *Principle of Democracy and Civility* and many aspects of *Socio-Ecological System Integrity*. It is expected that the findings of this study will have implications for understanding the sustainability of present and future trans-boundary water governance around the world.

1. Introduction

Trans-boundary waters, defined as aquifers, lakes and river basins shared by two or more countries, are the most common natural resources among nations (Brels, Coates, & Loures, 2008). Around the world there are 263 trans-boundary river basins, and 145 countries have territory within trans-boundary lake or river basins (UNECE/UNESCO, 2015). All of them are primarily managed by international water agreements. Approximately 295 international water agreements have been negotiated and signed since 1948 (UNECE/UNESCO, 2015), including the United Nations Economic Commission for Europe (UNECE) Water Convention, a legal framework for trans-boundary water cooperation worldwide which has been globally available since 2003 (UNECE/UNESCO, 2015).

Fresh water is vital to sustainable development and a fundamental requirement for the planet's social, economic and environmental systems (Espey & Towfique, 2004; UNDESA, 2015). Not only is it a vital element for healthy ecosystems (UN Water, 2018), but it is also important for planetary health, helps to prevent the global burden of disease and is at the center of climate systems, human society and adaptation (UNDESA, 2015).

However, fresh water is under tremendous threat since its availability is changing around the world (Rodell et al., 2018). In "Ecosystems and Human Well-Being: Wetland and Water Synthesis of Millennium Ecosystem Assessment," Butchart, Dieme-Amting, Gitay, Raaymakers, and Taylor (2005) stated that world water supplies are already being degraded or used unsustainably. In the present world situation, the global demand for water has been increasing continuously at a rate of about 1% per year over the past decades and will keep increasing in the future (WWAP, 2018). The Organisation for Economic Co-operation and Development (OECD)'s 2012 Global Environmental Outlook's Baseline Scenario projects that an additional 2.3 billion people will experience severe water stress in many parts of the world by 2050, especially in North and South Africa as well as South and Central Asia (Kitamori, Manders, Dellink, & Tabeau, 2012). Another report by the World Water Assessment Programme (WWAP, 2016) shows that in a business-as-usual scenario the world could face a 40% global water deficit by 2030. It is obvious that most trans-boundary water basins will feel these stresses.

Only 35% of the total water in the world is freshwater, and less than 1% is readily usable by humans (WWF, 2010). A major portion of this 1% is shared by common basin water resources among 145

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nations. If the current uses of water resources continue, in the future, there is a growing potential of crises and associated conflicts around the world, especially in developing countries, over the scarcity of water resources and its management and consumption practices (Sivakumar, 2011). Trans-boundary water has the potential to cause social turbulence and lead to conflict within and among countries. Trans-boundary water crises and conflict have many dimensions and are complex and tough to manage (Sivakumar, 2011) in a changing metacoupled world (Liu, 2017). For example, there have already been conflicts between China and India (Postel, 2014), India and Bangladesh (Yoffe, Wolf, & Giordano, 2003) and Ethiopia and Egypt (Barnaby, 2009) over trans-boundary water resources. The crisis in Syria is a good example of how water can be a factor that triggers conflict (Gleick, 2014).

Trans-boundary water treaties based on legal and institutional frameworks can make effective instruments to deal with these challenges. Since 1948, approximately 295 international water treaties have been negotiated and signed, and there have been only 37 incidents of acute conflict over water during the same period. Since 2003, the UNECE Water Convention (a legal framework for trans-boundary water cooperation) has been available worldwide to assist in developing trans-boundary water treaties (UNECE/UNESCO, 2015). Nevertheless, there are no trans-boundary water agreements in many regions of the world, particularly in Southeast Asia, South Asia, Central America, the northern part of the South American continent, the southern Balkans as well as in different parts of Africa where new water infrastructure is being constructed or planned, leaving these regions in a vulnerable situation (De Stefano, Petersen-Perlman, Sproles, Eynard, & Wolf, 2017).

However, not all treaties are successful. Often the countries do not follow these treaties, especially in developing regions. Many countries' trans-boundary water basins are in constant tension, but a successful treaty can effectively resolve the tension and also provide mutually supporting social, economic and environmental benefits and help to ensure long-run sustainability of the regions.

In this respect, it is very important to assess the sustainability effects of successful trans-boundary water governance in order to see how it helps manage critical trans-boundary water resources to promote cooperation and sustainable development. Trans-boundary water governance in the Great Lakes (GL) basin is considered to be a successful trans-boundary water management model (Botts & Muldoon, 2008), but there are some questions about how it is supporting sustainability in particular. Therefore, the objective of this study is to provide a diagnosis of the sustainability of the trans-boundary water governance in the GL basin.

2. Overview of trans-boundary water governance in the Great Lakes basin

The water resources of the GL basin are currently governed by one major treaty and two major agreements. The first of these, the *Boundary Waters Treaty* (BWT), was signed in 1909 at the federal government level (Hall, 2008; Lemarquand, 1986; Patrick, 2017; Schulte, 2012) and was followed by two agreements: the 1972 *Great Lakes Water Quality Agreement* (GLWQA) (Botts & Muldoon, 2008) and, more recently, the *Great Lakes-St. Lawrence River Sustainable Water Resources Agreement* in 2005 (Patrick, 2017; Petrash, 2007; Schulte, 2012). Apart from the treaty and agreements, the *Great Lakes Charter* of 1985 (Patrick, 2017; Schulte, 2012), *Great Lakes Annex* of 2001 (Edstrom, Brown, Monschein, & Brunner, 2001; Patrick, 2017; Schulte, 2012) and *Great Lakes–St. Lawrence River Basin Water Resources Compact* of 2008 (Patrick, 2017; Saeger, 2007; Schulte, 2012) also assist in governing the GL basin water resources and ecosystem. The *Great Lakes–St. Lawrence River Basin Sustainable Water Resources Agreement* is designed to protect and restore the lakes (Patrick, 2017; Schulte, 2012), while the main objective of the *Great Lakes Charter* and *Annex* is to develop a collaborative water-management system for the GL trans-boundary resources (Patrick, 2017; Schulte, 2012). The *Great Lakes–St. Lawrence River Basin Water Resources Compact* is legally responsible for implementing the commitments made in the *Great Lakes–St. Lawrence River Basin Sustainable Water Resources Agreement* (Patrick, 2017; Saeger, 2007; Schulte, 2012).

The BWT was designed to resolve existing and prevent future disputes over the use of the 150 lakes, rivers, and connecting waterways along the 8800 km of the US-Canadian border (Hall, 2008; Manno & Krantzberg, 2008). The GLWQA was signed by Prime Minister Pierre Trudeau and President Richard Nixon in 1972 (Hall, 2008; Manno & Krantzberg, 2008) and subsequently amended in 1978 and 1987 in light of new research findings regarding pollution threats to the GL basin (Manno & Krantzberg, 2008). The GLWQA is considered the major model for environmental management in trans-boundaries around the world (Botts & Muldoon, 2008). The non-binding *Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement* was signed by the governors of the states bordering the GL (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin) and the premiers of Ontario and Quebec (CGLF, 2011; Hall, 2008). This agreement provides a framework for each province and state to pass laws to protect the waters of the Great Lakes-St. Lawrence River Basin (Ontario MNR, 2009).

Through the BWT and the GLWQA, Canada and the United States formalized a trans-boundary water governance system to define and implement priorities for the basin. This system includes two major governance bodies: the International Joint Commission (IJC) was created under the guidance of BWT (Schulte, 2012) and the Bi-national Executive Committee (BEC) was founded under GLWQA (EPA & EC, 2013). In spite of this, governance of the water resources in the GL basin is very complex since eight US states and two Canadian provinces (Hall, 2008) as well as all the local governments and municipalities within the basin have shared responsibilities (Chaloux & Paquin, 2012).

IJC has the role of alter, recommendation and assist the US and Canada government in achieving common goals over trans-boundary water treaty and agreements (Krantzberg, Bratzel, & MacDonald, 2006). As the authority, IJC issues orders of approval and references. In the capacity of orders of approval, IJC approves the "conditions on the application and operation of projects, such as dams, diversions or bridges that would affect the natural level of boundary waters" (IJC, 2019:1). For references, IJC "studies and recommends solutions to transboundary issues when asked to do so by the national governments" (IJC, 2019:1). IJC performs the activities of "regulating shared water uses," "improving water quality," "improving air quality" and "investigating issues and recommending solutions" (IJC, 2019:1).

The BEC was created after the 1987 amendments to the GLWQA (Manno & Krantzberg, 2008). Its many roles and responsibilities include setting priorities and strategic directions and coordinating bi-national programmes and activities (Binational. , 2019; Manno & Krantzberg, 2008) as well as evaluating progress under the GLWQA by providing advice, comment or other input for the preparation of various bi-national reports and presentations (EPA & EC, 2013).

The five Great Lakes consisting of Lake Superior, Lake Michigan, Lake Huron, Lake Erie, and Lake Ontario are shown in Fig. 1. They represent the largest surface freshwater system found anywhere in the world (Hall, 2008). Together with the St. Lawrence River, they contain one-fifth of the world's surface freshwater (IJC, 2019). The GL provide drinking water for about forty million people on both sides of the border, in other words, one in every three

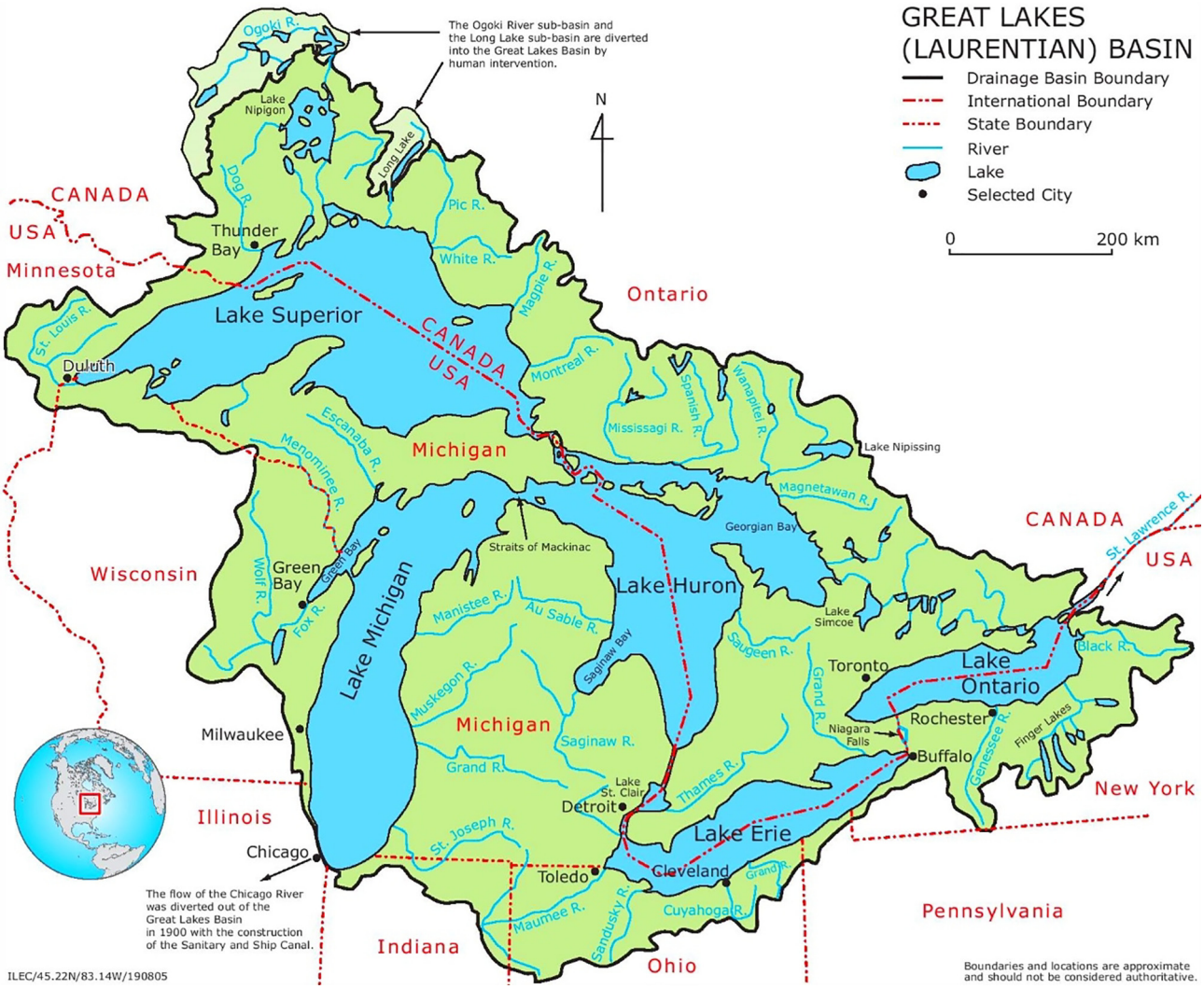

Fig. 1. Great Lakes, Source: On The World Map (2019).

Canadians and one in every ten Americans (Hall, 2008; Manno & Krantzberg, 2008). Every day, 56 billion gallons (212 billion litres) of GL water are utilized for industrial, municipal, and agricultural uses (IJC), 2005). The natural environment of the GL is incredibly rich. One-third of the basin is used for agriculture. There are more than 3500 species of plants and animals in the GL basin, including more than 250 species of fish (IJC, 2019).

3. Methodology

Water-related projects, programmes and treaties should fulfill various aspects of sustainability which can be assessed in a number of different ways. Procedures for evaluating sustainability include the triple bottom line (Ahi & Searcy, 2015); principles (Pintér, Hardi, Martinuzzi, & Hall, 2018; Talukder & Blay-Palmer, 2017); category (vanLoon, Patil, & Hugar, 2005); criteria (Gibson, Hassan, Holtz, Tansey, & Whitelaw, 2005); and the United Nations' Sustainable Development Goals (SDGs) (UNDP, 2015) approaches.

In the triple bottom line approach, three pillars of sustainability are assessed: society, economics and environment (Ahi & Searcy, 2015). This approach is usually applied in ways that distinguish between positive and adverse effects (gains and losses) in each of the three pillars. The Bellagio STAMP principles include objectives related to the desired results of initiatives, but also involve process and institutional considerations. vanLoon et al. (2005)'s categories are desired agricultural system qualities. Gibson's sustainability criteria (GSC) reflect requirements for progress towards sustainability (Gibson et al., 2005), whereas the UN's SDGs are essentially objectives.

In this study, the capacity of the trans-boundary water governance arrangements in the GL basin to address sustainability is assessed using Gibson's sustainability criteria (Gibson et al., 2005), which are described in Section 3.1. GSC arose out of a need for decision criteria in the pursuit of sustainability in environmental impact assessment. Sustainability assessment transcends traditional disciplinary boundaries, which Gibson's sustainability assessment framework is able to reflect. This framework has the capacity to effectively and thoroughly integrate ecological, economic and social pillars of sustainability in decision-making (Gibson et al., 2005). Integrating these three areas of concern is very important for sustainability assessment (Morrison-Saunders & Therivel, 2006).

3.1. Gibson's sustainability criteria (GSC)

GSC are grouped in eight categories (see part A of Fig. 2). A brief description of these categories is given below.

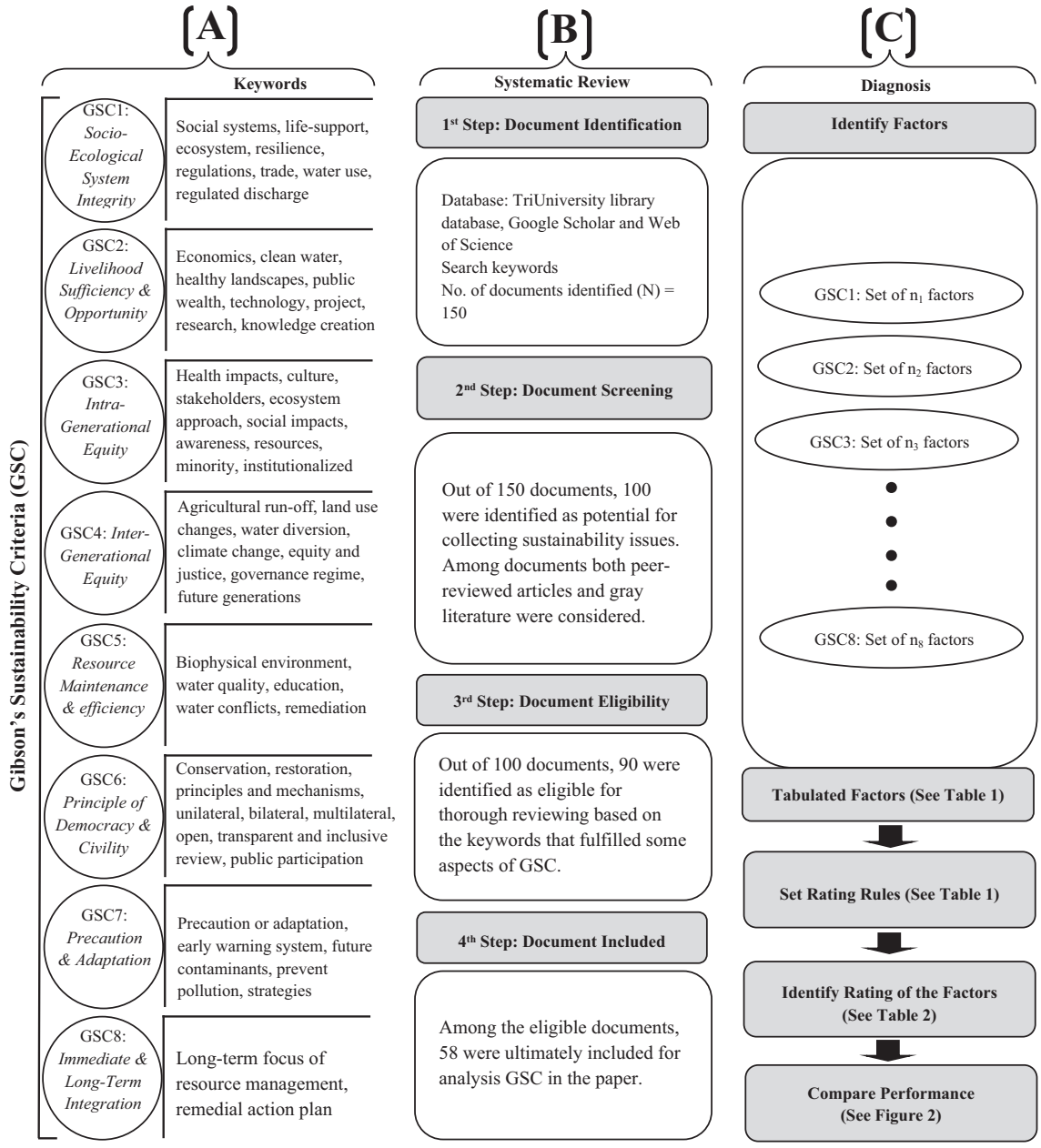

Fig. 2. Methodological Flow Chart of the Research.

GSC1: Social-Ecological System Integrity "fundamentally addresses the maintenance of the relationship between human systems and biophysical, environmental systems for human and ecological well-being" (Gibson, 2006:174).

GSC2: Livelihood Sufficiency and Opportunity "ensures that everyone and every community has enough for a decent life and that everyone has opportunities to seek improvements in ways that do not compromise future generations' possibilities for sufficiency and opportunity" (Gibson, 2006:174).

GSC3: Intra-Generational Equity "ensures that sufficiency and effective choices for all are pursued in ways that reduce dangerous gaps in sufficiency and opportunity (and health, security, social recognition, political influence, and so on) between the rich and the poor" (Gibson, 2006:174).

GSC4: Inter-Generational Equity relates to "present options and actions that are most likely to preserve or enhance the opportunities and capabilities of future generations to live sustainably" (Gibson, 2006:174).

GSC5: Resource Maintenance and Efficiency "provides a larger base for ensuring sustainable livelihoods for all, while reducing threats to the long-term integrity of socio-ecological systems by reducing extractive damage, avoiding waste and cutting overall material and energy use per unit of benefit" (Gibson, 2006:174).

GSC6: Principle of Democracy and Civility "builds the capacity indicate that motivation and habitual inclination of individuals, communities and other collective decision-making bodies to apply sustainability requirements through more open and better informed deliberations, greater attention to fostering reciprocal awareness and collective responsibility, and more integrated use of administrative, market, customary and personal decision-making practices" (Gibson, 2006:174).

GSC7: Precaution and Adaptation is "related to uncertainty, avoid even poorly understood risks of serious or irreversible damage to the foundations for sustainability, plan to learn, design for surprise, and manage for adaptation" (Gibson, 2006:174).

GSC8: Immediate and Long-term Integration refers to applying "all criteria of sustainability at once, seeking mutually supportive benefits and multiple gains" (Gibson, 2006:174).

3.2. Data collection and setting the factors for sustainability analysis

A brief presentation of the whole methodological process of the research is portrayed in Fig. 2 and explained below. For data collection, the keywords related to GSC and the capacity of the trans-boundary water governance to address sustainability in the Great Lakes basin were identified to find relevant literature (keywords are shown in Fig. 2, part [A]). In part [B] of Fig. 2, the steps for the systematic review processes are listed. Articles were collected based on these keywords and by following the steps proposed by Moher, Liberati, Tetzlaff, and Altman (2009) for a systematic literature review. In the first step of data collection, documents related to the water governance and sustainability of the GL basin were identified using deductive (theoretical) thinking. A systematic review allows the objectives of the study to be addressed by classifying, assessing and integrating the findings from the literature. The database of the Tri-University (University of Guelph, University of Waterloo and Wilfrid Laurier University) Group of Libraries, which contains more than seven million items, was used for the literature search and to create a database for systematic review. In addition, Google Scholar was utilized to flag and review literature related to the topic. The collected articles were screened, and eligible ones were included in the second, third and fourth steps of the systematic review process.

To assess the sustainability of the trans-boundary water governance in the GL basin based on Gibson's criteria, a set of factors for each criterion was identified as shown in part [C] of Fig. 2 and listed in the second column from the left in Table 1. These factors were selected based on the authors' judgments and were aligned with the appropriate GSC according to its inherent meaning. The factors that have been identified here against each GSC are considered to have equal importance. After identifying the factors, a rating system was developed for each factor as shown in the third column in Table 1. The water governance performance with respect to a specific factor was rated "2" if creditable action taken to address the factor was present, "1" if partially present, and "0" if absent. Here, "partially present" indicates that the water governance performance for the factor under consideration is indirectly fulfilled, meaning the performance only somewhat or imperfectly achieved the goal of the factor. Based on the rating of the factors, the overall score of each GSC was calculated by summing the score of all of the factors connected to the GSC. Notice in the right column in Table 2 that the preferred performance is 2 points for each factor. Hence, the preferred performance for each GSC is determined by multiplying two times the number of factors identified in that category. According to this rating system, the preferred total scores for *Socio-Ecological System Integrity*, *Livelihood Sufficiency and Opportunity*, *Intra-Generational Equity*, *Inter-Generational Equity*, *Resource Maintenance and Efficiency*, *Principal of Democracy and Civility*, *Precaution and Adaptation*, *Immediate and Long-Term Integration* criteria are 10, 8, 12, 8, 8, 10, 10 and 4, respectively. For each GSC, one can compare the actual score to the preferred one. For example, as shown in the fourth column from the left in Table 2, the total actual score for GSC1, (*Socio-Ecological System Integrity*) is 2 + 1 + 2 + 1 + 1 = 7 out of a preferred score of 10.

4. HYPERLINK "SPS:id::Sec5" Results

As pointed out in Section 3.2, Table 1 provides the list of factors for each of the eight GSCs and the rating system used for evaluating each factor. Table 2 contains the results of the analysis; the third column from the left lists the evaluations for all of the factors. The column on the right in Table 2 shows the preferred score, which is 2 for each factor. Fig. 3 interprets the findings given in Table 2 graphically: Fig. 3[A] displays the actual score, or performance, for each of the eight GSCs and Fig. 3[B] the preferred performance.

Notice in the two Radar Graphs in Fig. 3 that each web boundary emanating from the center presents a specific score from 0 to 12. As determined in the sample calculation presented at the end of Section 3.2, GSC1 has an actual score of 7, with an ideal or preferred score of 10. The scores of 7 and 10 are marked in the Radar Graph under the GSC shown at the top in Fig. 3[A] and [B], respectively. From the graphical comparisons, one can see that the *Livelihood Sufficiency and Opportunity*, *Resource Maintenance and Efficiency* and *Principle of Democracy and Civility* GSCs obtained preferred scores, meaning the factors selected for these three GSCs were fully met by the GL trans-boundary water governance. As mentioned above, *Socio-Ecological System Integrity* scored 7 out of 10. The GSCs *Intra-Generational Equity*, *Inter-Generational Equity*, *Precaution and Adaptation* and *Immediate and Long-Term Integration* scored 5, 3, 4 and 2 when compared to the preferred scores of 12, 8, 10 and 4, respectively. The lowest scores were for *Inter-Generational Equity* and *Immediate and Long-Term Integration*. The rationales of the performances of sustainability by different GSCs against the factors are discussed in Section 5.

5. Discussion

The existing trans-boundary water governance of the GL is described in Section 2, the methodology for evaluating the sustainability of the water governance system using GSC is outlined in Section 3 and the assessment of the GL governance system is presented in Section 4 along with a comparison to the preferred situation. The goal of this section is to explain how the factors listed in the second column in Tables 1 and 2 for each of the eight GSCs are satisfied within the scope of the trans-boundary water governance system and where improvements are needed.

5.1. GSC1: socio-ecological system integrity

As can be seen in the second column from the left in Tables 1 and 2, five factors are identified for assessing to what extent the Gibson Sustainability Criterion *Socio-Ecological System Integrity* is fulfilled by the GL trans-boundary water governance. Among the five factors, "establish regulations and practices to protect *Socio-Ecological System Integrity*" and "ensure clean and accessible bodies of water for healthy society and ecosystem" were fully covered by GL water governance, whereas "strictly regulate discharge of industrial and municipal wastewater effluent", "promote ecosystem resilience" and "support re-organisation of social and human systems to preserve life-support functions of the ecosystem" were only partially covered.

As mentioned in Section 2, BWT and its governance body, the IJC, along with subsequent new treaties, agreements and institutions have served as the basis for establishing and implementing regulations and practices in the GL basin to protect *Socio-Ecological System Integrity* (IJC, 2019). For example, the GLWQA was negotiated pursuant to the 1909 BWT to protect the water of the GL from chemical, physical and biological pollution in order

Table 1
Factors to Assess Sustainability of the GL Trans-Boundary Water Governance.

GSC	Factors	Rating Rules	Justification
Socio-Ecological System Integrity	Establish regulations and practices to protect *Socio-Ecological System Integrity*.	P = 2; PP = 1; A = 0	All these factors are essential for maintaining complex adaptive systems for long-term socio-ecological integrity.
	Strictly regulate discharge of industrial and municipal wastewater effluent.	P = 2; PP = 1; A = 0	
	Ensure clean and accessible bodies of water for healthy society and ecosystem.	P = 2; PP = 1; A = 0	
	Promote ecosystem resilience.	P = 2; PP = 1; A = 0	
	Support re-organisation of social and human systems to preserve life-support functions of the ecosystem.	P = 2; PP = 1; A = 0	
Livelihood Sufficiency and Opportunity	Ensure water availability for economic activities (agricultural activities, hydro power generation, industrial activities, fisheries, sports, recreation facilities) without any disruption.	P = 2; PP = 1; A = 0	These factors of the trans-boundary water governance are important for the maintenance of economic interests.
	Recognize waters as shared public wealth.	P = 2; PP = 1; A = 0	
	Identify and accelerate water-related projects and technologies that enhance the movement of both goods and people.	P = 2; PP = 1; A = 0	
	Support international enterprises and trade by water transportation.	P = 2; PP = 1; A = 0	
Intra-Generational Equity	Health impacts related to uses of GL resources are addressed.	P = 2; PP = 1; A = 0	These factors are required to reduce gaps in sufficiency and opportunity in health, security, social recognition, political influence, etc. between the rich and the poor.
	Effects on the culture of the people living in the GL basin are addressed.	P = 2; PP = 1; A = 0	
	Comprehensive social impact assessment was considered.	P = 2; PP = 1; A = 0	
	Institutional attention was given to address social impacts.	P = 2; PP = 1; A = 0	
	Women and ethnic minorities were given opportunities in decision making.	P = 2; PP = 1; A = 0	
	Full awareness programme was implemented in using resources.	P = 2; PP = 1; A = 0	
Inter-Generational Equity	Have a mandate with an explicit commitment to equity and justice for future generations.	P = 2; PP = 1; A = 0	These factors incorporate formalized mechanisms for assessing and predicting – to the best of present abilities – the impact of a proposed project, plan, or programme on future generations.
	Present a plan to carry out a formal assessment of long-term future impacts when approving RAPs and other projects.	P = 2; PP = 1; A = 0	
	Include formal proxy representatives for future generations in governance bodies.	P = 2; PP = 1; A = 0	
	Support civic pride and personal and spiritual well-being by ensuring healthy landscapes.	P = 2; PP = 1; A = 0	
Resource Maintenance and Efficiency	Ensure management of biophysical environment, especially water quality, by an ecosystem approach.	P = 2; PP = 1; A = 0	These factors address the issues related to Resource Maintenance and Efficiency.
	Strongly committed to protecting ecosystems.	P = 2; PP = 1; A = 0	
	Remediation for highly polluted areas.	P = 2; PP = 1; A = 0	
	Holistic education about resource management.	P = 2; PP = 1; A = 0	
Principle of Democracy and Civility	Ensure stakeholders' participation in ecosystem conservation and restoration.	P = 2; PP = 1; A = 0	The proposed factors are needed to ensure socio-ecological civility and democracy.
	Jurisdiction to resolve water conflicts.	P = 2; PP = 1; A = 0	
	Possesses an excellent education tool to increase understanding of water issues.	P = 2; PP = 1; A = 0	
	Ensure public participation in the decision-making process.	P = 2; PP = 1; A = 0	
	Committed to an open, transparent and inclusive review process of agreement.	P = 2; PP = 1; A = 0	
Precaution and Adaptation	Include language that suggests precaution or adaptation.	P = 2; PP = 1; A = 0	These factors reflect different aspects of socio-ecological civility and democracy.
	Acknowledge uncertainty and not precautionary in motive.	P = 2; PP = 1; A = 0	
	Establish an early warning system to anticipate the emergence of future contaminants and their effects.	P = 2; PP = 1; A = 0	
	Encourage preventative action to prevent pollution and otherwise harmful discharge into the lakes.	P = 2; PP = 1; A = 0	
	Present strategies for dealing with an uncertain future and adaptation plan.	P = 2; PP = 1; A = 0	
Immediate and Long-Term Integration	Long-term focus of resource management.	P = 2; PP = 1; A = 0	The proposed factors are related to Immediate and Long-Term Integration.
	Remedial action planning is incorporated.	P = 2; PP = 1; A = 0	

Note: In this Table, GSC = Gibson's Sustainability Criteria, P = Present; PP = Partially Present; A = Absent.

to maintain a healthy ecosystem (GLWQA, 1987; Manno & Krantzberg, 2008). Strictly regulating the discharges of industrial and municipal wastewater effluent is considered a means to ensure a sound ecosystem and associated good water quality. Not properly regulating discharges threatens *Socio-Ecological System Integrity* with negative consequences such as (1) restrictions on fish and

Table 2
Score Obtained by the Factors of GSCs for Diagnosis the Sustainability of Water Governance.

GSC	Factors	Score Obtained	Preferred Score
Socio-Ecological System Integrity	Establish regulations and practices to protect *Socio-Ecological System Integrity*.	2	2
	Strictly regulate discharge of industrial and municipal wastewater effluent.	1	2
	Ensure clean and accessible bodies of water for healthy society and ecosystem.	2	2
	Promote ecosystem resilience.	1	2
	Support re-organisation of social and human systems to preserve life-support functions of the ecosystem.	1	2
Livelihood Sufficiency and Opportunity	Ensure water use for economic activities (agricultural activities, hydro power generation, industrial activities, fisheries, sports, recreation facilities) without any disruption.	2	2
	Recognize waters as shared public wealth.	2	2
	Identify and accelerate water-related projects and technologies that enhance the movement of both goods and people.	2	2
	Support international enterprises and trade by water transportation.	2	2
Intra-Generational Equity	Health impacts related to uses of GL resources are addressed.	1	2
	Effects on the culture of the people living in the GL basin are addressed.	1	2
	Comprehensive social impact assessment was considered.	0	2
	Institutional attention was given to address social impacts.	1	2
	Women and ethnic minorities were given opportunities in decision making.	1	2
	Full awareness programme was implemented in using resources.	1	2
Inter-Generational Equity	Have a mandate with an explicit commitment to equity and justice for future generations.	1	2
	Present a plan to carry out a formal assessment of long-term future impacts when approving RAPs and other projects.	0	2
	Include formal proxy representatives for future generations in governance bodies.	0	2
	Support civic pride and personal and spiritual well-being by ensuring healthy landscapes.	2	2
Resource Maintenance and Efficiency	Ensure management of biophysical environment, especially water quality, by an ecosystem approach.	2	2
	Strongly committed to protecting ecosystems.	2	2
	Remediation for highly polluted areas.	2	2
	Holistic education about resource management.	2	2
Principle of Democracy and Civility	Ensure stakeholders' participation in ecosystem conservation and restoration.	2	2
	Jurisdiction to resolve water conflicts.	2	2
	Possesses an excellent education tool to increase understanding of water issues.	2	2
	Ensure public participation in the decision-making process.	2	2
	Committed to an open, transparent and inclusive review process of agreement.	2	2
Precaution and Adaptation	Include language that suggests precaution or adaptation	0	2
	Acknowledge uncertainty and not precautionary in motive.	0	2
	Establish an early warning system to anticipate the emergence of future contaminants and their effects.	1	2
	Encourage preventative action to prevent pollution and otherwise harmful discharge into the lakes.	2	2
	Present strategies for dealing with an uncertain future and adaptation plan.	1	2
Immediate and Long-Term Integration	Long-term focus of resource management.	0	2
	Remedial action planning is incorporated.	2	2

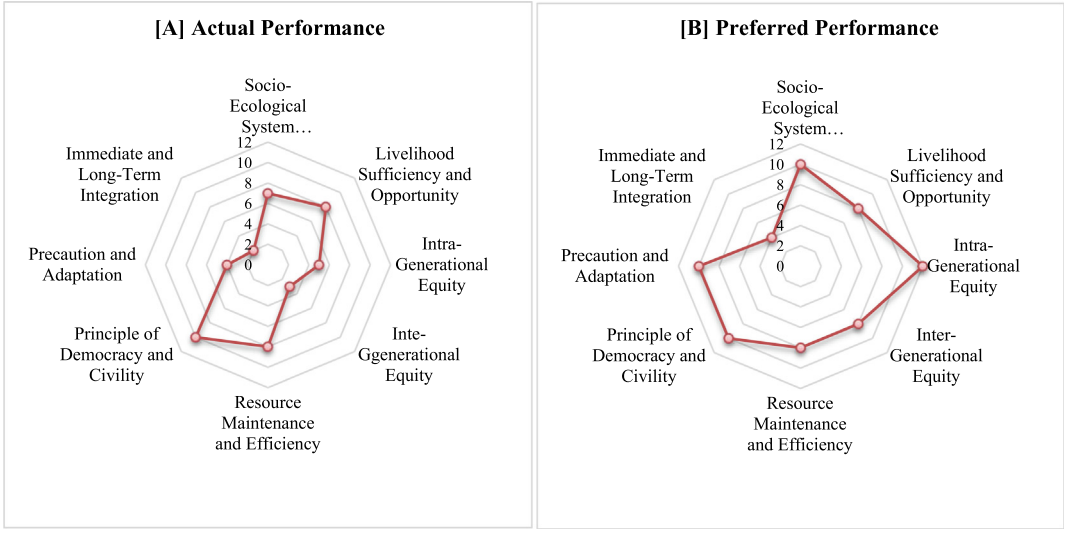

Fig. 3. Comparison of Sustainability in Terms of Actual and Preferred Performance of Trans-Boundary Water Governance.

shellfish consumption; (2) nutrient enrichment leading to eutrophication or undesirable algal growth; (3) isolated and rare incidences of water-borne diseases caused by sewage contamination of drinking water supplies; (4) added costs to agricultural, industrial and municipal users for treatment of unacceptable water; (5) degradation/loss of fish and wildlife habitat; (6) reduced

aquatic and wildlife populations and so forth (EC, 2008). The release of industrial and municipal wastewater effluent is of great concern for water-related *Socio-Ecological System Integrity* in the GL basin. Despite regulation at all levels of government regarding waste discharge, the GL serves as the final waste disposal receptor for point and nonpoint source wastes from industries, municipalities, agriculture and urban areas (Sproule-Jones, 2008). Accordingly, the trans-boundary water governance system has the mandate to ensure safe, clean and healthy water in the GL basin, which helps to preserve ecological integrity (Forslund et al., 2009; IJC, 2000; Norman & Bakker, 2005).

Water-related ecosystem resilience maintains ecological flows of water and provides ecological services for the long-term sustainability of coupled socio-ecological systems (Bunch, Morrison, Parkes, & Venema, 2011). Ecosystem resilience helps to maintain critical ecological functions when ecosystems undergo disturbances (Sasaki, Furukawa, Iwasaki, Seto, & Mori, 2015). In the GL trans-boundary water governance system, ecosystem resilience is not directly mentioned, but all the regulations are envisioned to maintain it. Trans-boundary water governance allows for water level regulation, which has impacts on water availability and ecosystem resilience (Wantzen et al., 2008).

The GL trans-boundary water governance was visionary as it transcended political boundaries to focus on GL ecosystems (Botts, Muldoon, Botts, & von Moltke, 2001). In an indirect way, water governance supports the re-organisation of social and human systems to preserve the life-support functions of the ecosystem and the social systems that depend on having sound ecological systems in the basin (Sierra, 2006). Water governance should ensure ecological system integrity, but it often has competing objectives, some of which are noted in the following GSCs.

5.2. GSC2: livelihood sufficiency and opportunity

Four factors were identified to assess the performance of the GL trans-boundary water governance with respect to the *Livelihood Sufficiency and Opportunity* criterion of GSC (see Tables 1 and 2). All four factors were fully covered by the GL trans-boundary water governance system.

As can be seen by the scores in Table 2, the trans-boundary water governance ensures water use for economic activities without any disruption (JIC, 2000). Undisrupted water use depends on the health of the ecosystems of the GL. A healthy ecosystem supports the basic elements of the livelihoods and culture of an area (MEA, 2005). Ensuring a healthy ecosystem is one of the prime objectives of GL trans-boundary water governance. Thus, in many ways, water governance is supporting the livelihoods of different stakeholders in the basin. For instance, the GL Fish Health Committee strives to prevent the introduction and dissemination of communicable fish diseases (GLFC, 2011), which ensures the livelihoods of those who depend on different types of fisheries. Undisrupted GL water is used for multibillion-dollar businesses including a range of manufacturing industries, energy generation, agriculture, forest products, tourism, sports and commercial fishing (IJC, 2000). Five million people in the GL basin participate in sport fishing, commercial fishing and Native American fishing, which forms a US$4 billion a year industry (David & Ashley, 2007). In addition, 30% of USA and 25% of Canadian agricultural production take place (IJC, 2005) in the GL basin and are highly dependent on GL water. The basin water also serves as a strong marine transportation system (Stewart, 2006) that provides many job opportunities. However, invasive species, fishing and recreational activities disrupt the local ecosystem dynamics of GL and can cause problems for society and livelihoods (Atkinson & Domske, 2015).

The trans-boundary water governance system recognizes water as a shared public resource (Crane, 2012), emphasizes the responsibilities of the USA and Canada to manage it and helps to identify and accelerate water-related projects and technologies that enhance the movement of both goods and people (IJC, 2000; Norman & Bakker, 2005). The GL also serves as a strong water transportation system (Stewart, 2006) which offers many job opportunities. Trans-boundary water governance through various actions supports international enterprises and trade by water transportation (Walker, 2015).

5.3. GSC3: intra-generational equity

To assess the *Intra-Generational Equity* criterion of GSC, six factors were considered as noted in Tables 1 and 2. Among these six factors, five were partially covered by GL trans-boundary governance: "health impacts related to uses of GL resources are addressed", "effects on the culture of the people living in the GL basin are addressed", "institutional attention was given to address social impacts", "women and ethnic minorities were given opportunities in decision making" and "full awareness programme was implemented in using resources". The factor called "Comprehensive social impact assessment was considered" was not covered directly or indirectly by the GL trans-boundary governance, as indicated by a score of 0.

Health impacts related to uses of GL resources are not addressed directly by the GL trans-boundary water governance system. Pollution of the GL impacts fish stocks in many ways, such as by decreasing fish stocks (HPTF, 2004; Johnson, Hicks, & De Rosa, 1999) and increasing the presence of toxic substances that result in the issuance of fish consumption advisories (Gandhi, Drouillard, Arhonditsis, Gewurtz, & Bhavsar, 2016). This has impacted the fish consumers of the GL basin in two ways. Firstly, if the consumers do not follow consumption advisories they are exposed to toxic substances and secondly, the ethnic minorities who have free access to the GL fish stocks lose a free source of nutritious and protein-rich food (HPTF, 2004; Johnson et al., 1998). The authors have observed that catching and consuming GL fish is increasing among new immigrants in Ontario. This can create a serious health issue for them because of the concentration of various pollutants in fish. Among ethnic minorities, those with lower incomes and education levels and women have lower awareness of the fish consumption advisories (Connelly & Knth, 1995; Tilden et al., 1997), which can lead to serious health consequences for them in the long run.

Nothing is specifically mentioned in the GL trans-boundary water governance documents about preserving the culture of the ethnic groups living in the GL basin. Nevertheless, the governance system supports First Nation cultures in indirect ways. Shared GL fisheries (Gaden, Goddard, & Read, 2013), which are a part of the traditional food and culture of the ethnic minorities living in the GL basin, are managed by a multi-jurisdictional governance system, which to some extent preserves the culture of the ethnic minorities. Cultural life of the community is one of the elements of sustainability and an important aspect of *Intra-Generational Equity*. Trans-boundary water governance involves having ethnic groups in discussions related to GL issues (IJC, 2000). This ensures to some extent the diversity in natural and cultural resources enjoyed by these groups (Summers & Smith, 2014).

Comprehensive social impact assessment was not entertained in GL trans-boundary water governance. Comprehensive social impact assessment is an important way to involve the affected communities and other stakeholders in the process of designing the governance system (Vanclay, 2003). The lack of scope for addressing comprehensive social impact assessment may lead to broader neglect of social justice and equity. However, some institu-

tional attention was given to social impacts in GL trans-boundary water governance as the policymakers and stakeholders analyse the social impacts during the decision-making process to facilitate social equity in the GL basin (BWT, 1909; GLWQA, 1987).

The GL trans-boundary water governance does not include guidelines or conditions regarding the age, gender and ethnicity of the commissioners, the appointment of whom is left to the discretion of the Canadian Governor in Council and the United States President with approval from the Senate (BWT, 1909; GLWQA, 1987). From the literature review, it is not possible to conclude with high certainty that the commissioners have been disproportionately of white ethnicity and male gender, and that women and ethnic minorities have been inequitably excluded from decision-making positions within scope of the GL trans-boundary water governance system. However, the GL trans-boundary water governance offers several opportunities for stakeholder participation in decision-making situations such as public hearings, conferences, roundtable discussions, and meetings (IJC, 2019; Krantzberg, 2009). As George (1999) suggests, such events are far more accessible to socially advantaged groups with financial means, sufficient time, educational background and knowledge. As a result, the outcome of these processes often reflects the opinion of more influential social groups (George, 1999).

A full awareness programme for using the resources of the GL was not specifically mentioned in the GL trans-boundary water governance system. However, the activities of the trans-boundary water governance in many ways directly or indirectly create social and ecological awareness for using water resources in sustainable ways within the GL basin ecosystem (Norman & Bakker, 2005).

5.4. GSC4: inter-generational equity

Four factors were taken into account to assess the *Inter-Generational Equity* aspect of the GL trans-boundary water governance. The factor "Have a mandate with an explicit commitment to equity and justice for future generations" was partially covered, while the factor "support civic pride and personal and spiritual well-being by ensuring healthy landscapes" was fully satisfied by the GL trans-boundary water governance. "Present a plan to carry out a formal assessment of long-term future impacts when approving Remedial Action Plans (RAPs) and other projects" as well as "include formal proxy representatives for future generations in governance bodies" were not covered by the GL trans-boundary water governance. *Inter-Generational Equity* mandates require the consideration of long-term impacts (Padilla, 2002) of the development of plans, programmes and policies to ensure the well-being of future generations, but they are not directly mentioned in the GL trans-boundary water governance.

The GL trans-boundary water governance has a mandate with an explicit commitment to equity and justice for future generations in an indirect way (IJC, 2019). One of the main purposes of the GL trans-boundary water governance is to ensure safe, clean and healthy water (IJC, 2000; Norman & Bakker, 2005). This objective maintains some sort of equity and justice for future generations. While some efforts to restore ecological integrity have been made under the GL trans-boundary water governance, the degradation caused by present human activities (e.g., agricultural run-off, water diversion, overfishing, and climate change) all threaten to degrade the natural environment (Chu, Barker, Gutowsky, & de Kerckhove, 2018), which is then unable to provide the same economic opportunities and quality of life for future generations. The GL trans-boundary water governance does not include references to the equitable treatment of future generations; rather, it focuses on the fair distribution of the natural capital of the GL basin between the USA and Canada (BWT, 1909). It also urges restoration of the ecological integrity of the basin (GLWQA, 1987), which indeed will benefit future generations.

The GL trans-boundary water governance has no plan to carry out a formal assessment of long-term future impacts when approving RAPs and other projects, or to directly consider or justify the extent to which their impacts might unfairly burden future generations (IJC, 2019). The decision-making process of the water governance does indirectly consider future generations, but a governance system that advances intergenerational equity would include formal proxy representatives for future generations in the governance mandates. This would ensure that the voice of future generations is, at least to a degree, reflected in present-day decisions.

The programmes and activities of the GL trans-boundary water governance system in many ways ensure healthy landscapes that make communities safer and more liveable by tempering the effects of natural events and human activity. They also serve as a source of civic pride and personal and spiritual well-being.

5.5. GSC5: resource maintenance and efficiency

The *Resource Maintenance and Efficiency* criterion of GSC was assessed using four factors as can be seen in Tables 1 and 2. All the factors were fully covered by the GL trans-boundary water governance. The factor "Ensure management of biophysical environment, especially water quality, by an ecosystem approach" was fulfilled since the GLWQA established an ecosystem approach to water resources that corresponds well with sustainability principles (Manno & Krantzberg, 2008). The phrase "ecosystem approach" is a management philosophy stating that humans participate in the natural world rather than dominating it, which means having a humans-in-system rather than a "system-in-man" approach (Krantzberg & Houghton, 1996; Mackenzie, 1993). The focus of this approach is on ecological integrity, remediation of stress on natural systems, self-sustaining ecosystems, natural ecological boundaries and holistic education about resource management (Mackenzie, 1993). The governance system takes into account ecosystem protection and is considered to be a pioneer in employing the ecosystem approach (Botts & Muldoon, 2005; Valiante, 2008).

The other three factors ("strongly committed to protecting ecosystems", "remediation for highly polluted areas" and "holistic education about resource management") were fully covered by the GL trans-boundary water governance systems (Botts & Muldoon, 2008; Edstrom et al., 2001; Petrash, 2007).

5.6. GSC6: principle of democracy and civility

Five factors were considered to assess the *Principle of Democracy and Civility* criterion of GSC. All of the five factors are fully covered by the GL trans-boundary water governance. However, in the literature review it was difficult to determine the extent of attention paid to the issues of democracy and civility in the trans-boundary water governance system due to its complex system of shared governance.

Different stakeholders like governments, businesses and industries, First Nations, non-governmental organizations, teachers and many other interested individuals have combined their efforts in teams, task forces and volunteer groups under the GL trans-boundary water governance for ecosystem conservation and restoration (IJC, 2017). The GL trans-boundary water governance provides the principles and mechanisms to resolve current disputes and prevent future ones, mainly those concerning water quantity and water quality along the boundary between Canada and the United States (IJC, 2019). On the basis of the trans-boundary water governance system, officials at the federal, state, and provincial levels respect each other's authority and accept

each other's intentions to undertake unilateral, bilateral, or multilateral initiatives even if there have been serious differences of opinion regarding priorities and approaches to some issues related to water resources (Findlay & Telford, 2006). However, there are a large and diverse number of rules in the governance regime of the GL (Sproule-Jones, 2008) that often make it difficult to effectively manage trans-boundary water governance. For example, Michigan could pass a law prohibiting businesses from dumping a certain toxic chemical into Lake Erie, but if Ontario, Ohio, Pennsylvania and New York do not pass similar laws, then the water quality of Lake Erie will still suffer (Findlay & Telford, 2006).

The trans-boundary water governance system possesses an excellent education tool to increase awareness and understanding of water issues. For example, as part of an initiative by the IJC, the *St. Croix River: State of the Watershed Report 2008* was prepared to inform, educate and support the development of a common understanding of natural resources in both Maine and New Brunswick (ISCRWB and IJC, 2008).

The trans-boundary water governance system ensures public participation in the decision-making process. Governance invites public participation and advice when the stakeholders undertake studies to shape policies (Valiante, 2008; IJC, 2019). Through GL trans-boundary water governance, the US and Canadian governments are committed to an open, transparent and inclusive review process of agreement which allows for the involvement of all interested parties (state, provincial and municipal governments and other authorities) in trans-boundary environmental issues (IJC, 2019).

5.7. GSC7: precaution and adaptation

The *Precaution and Adaptation* criterion of GSC was evaluated with respect to four factors (see Tables 1 and 2) among which "encourage preventative action to prevent pollution and otherwise harmful discharge into the lakes" and "establish an early warning system to anticipate the emergence of future contaminants and their effects" were covered fully and partially, respectively. In contrast, the factors "Include language that suggests precaution or adaptation" and "acknowledge uncertainty and not precautionary in motive" were not covered by the GL trans-boundary water governance.

The GL trans-boundary water governance does not include language that suggests that the precautionary/adaptive principle should be taken into account in its reports and recommendations (deFur & Kaszuba, 1998). Nonetheless, it very clearly sets out rules for trans-boundary conduct – what activities each country is allowed to execute – but it does not take into consideration the future of the Great Lakes or acknowledge that the current characteristics of the Lakes may change. It implements adaptive measures by specifying limits on contaminant levels but does not provide multiple strategies for dealing with uncertainty resulting from a changing climate and emerging pollutants (Hanson, 2016).

The GL trans-boundary water governance does consider the future of the Great Lakes by making projections of future pollutant (mostly phosphorus) levels and by recommending the establishment of an early warning system to anticipate the emergence of future contaminants and their effects (GLWQA, 1987). It does not encourage preventative action in the face of uncertainty but only prevents the degradation of GL ecosystems. However, it does encourage preventative action on a larger scale from which the water quality of GL may suffer.

5.8. GSC8: immediate and long-term integration

Two factors, "long-term focus of resource management" and "remedial action planning is incorporated", were selected to assess the performance of *Immediate and Long-term Integration*, as indicated in Tables 1 and 2. The first factor was not taken into account by the GL trans-boundary water governance. However, the second factor was fully covered.

The GL trans-boundary water governance has mainly focused on short-term goals with measurable results (Botts & Muldoon, 2008) rather than long-term resource management. However, the *Great Lakes Water Quality Agreement* has the goal to restore the environmental integrity of 43 highly contaminated "Areas of Concern" around the Great Lakes Basin by creating Remedial Action Plans (RAPs) (Mackenzie, 1993). Notably, the RAPs called for interaction and cooperation among all levels of government, the general public, and industry to restore and maintain areas of mutual concern. RAPs were intended to encourage stakeholder participation at the local level due to the perception that government agencies were not doing enough to clean up pollution hot spots (Beierle & Konisky, 2001). Although RAPs are "reactive" to environmental degradation and focus on remediation, they have attempted to incorporate sustainability-based planning.

6. Conclusions

This research demonstrates that there have been many successes in water-related sustainability of the GL basin through trans-boundary water governance. Nonetheless, GL trans-boundary water governance should concentrate on addressing some sustainability issues such as ecosystem resilience, habitat conservation, risks to threatened species, long-term adaptation, immediate and long-term integration of water resource management and intra- and inter-generational equity. The findings of this study can be viewed as a learning point or reference point which can form the basis to formulate, upgrade or coordinate existing and future trans-boundary water governance systems around the world to ensure the sustainability of trans-boundary water resources management.

The GL are sensitive to climate change and have huge social implications for both Canada and the USA. Accordingly, ensuring the sustainability of GL water resources management through trans-boundary water governance is crucial to mitigating ongoing and forthcoming disputes over shared water resources. Climate change will continue to detrimentally affect the world's shared freshwater resources (Earle et al., 2015). Therefore, tension over shared water resources will increase around the world, thereby triggering serious conflict (Uitto & Duda, 2002) and jeopardizing livelihoods and social well-being (Michel & Pandya, 2009). Appropriate trans-boundary water governance can reduce many conflicts and ensure sustainability in the shared basin areas. Hence, understanding the sustainability aspects of bilateral water governance can be very helpful. However, trans-boundary water governance is an ecologically and geographically overlapping administrative area that must be properly managed in light of various sustainability criteria.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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