Master‘s Thesis

# Extreme Water Levels in the Great Lakes

## Assessing a Proposal for Adaptive Management

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Ísafjörður, February 2014

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*Extreme Water Levels in the Great Lakes - Assessing a Proposal for Adaptive Management*

45 ECTS thesis submitted in partial fulfilment of a Master of Resource Management degree in Coastal and Marine Management at the University Centre of the Westfjords, Suðurgata 12, 400 Ísafjörður, Iceland

Degree accredited by the University of Akureyri, Faculty of Business and Science, Borgir, 600 Akureyri, Iceland

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Printing: Háskólaprent, Reykjavík, February 2014.

## Declaration

I hereby confirm that I am the sole author of this thesis and it is a product of my own academic research.

Robert E. Salisbury

# Abstract

In March 2012, after 5 years of study, and at a cost of $14.6 million U.S., the International Upper Great Lakes Study Board ("IUGLS") issued its Final Report to the International Joint Commission ("IJC") entitled 'Lake Superior Regulation: Addressing Uncertainty in Upper Great Lake Water Levels' ("IUGLS Final Report"). The IUGLS Final Report proposed an adaptive management ("AM") strategy to address extreme water level conditions in the Great Lakes-St. Lawrence River system. Following issuance of the IUGLS Final Report, the IJC directed preparation of an AM Plan. Consequently, this work reviewed the AM Plan and background material as an AM Proposal and assessed adherence to identified AM strategy selection criteria. Starting with a review of the context for the IJC determination of strategy for managing water level uncertainty, seminal literature regarding AM theory enabled selection criteria to be identified. These informed the development of an assessment framework which was subsequently used to evaluate the AM Proposal. From this assessment, issues emerged regarding problem definition, stakeholder engagement and cost benefit. Consequently, it was concluded that the AM Proposal, as drafted, does not demonstrate sufficient agreement with AM selection criteria for it to be recommended. Specifically, the AM Proposal was found to require a more robust consideration of the AM value proposition for stakeholders, their management information needs, and capacity to adopt AM management practices. It was concluded that if the AM Plan remains in its current form, it will simply add to conclusions found in the literature that AM rarely gets beyond policy description. Further study is recommended, particularly at stakeholder level, to determine whether an AM strategy for water level management on the scope and scale of the Great Lakes-St. Lawrence River System can avoid the lack of implementation exhibited by other AM initiatives.

*..................................................Thanks Mar.*

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# Acronyms

| | |
|---|---|
| AM | adaptive management |
| AMG | Adaptive Management Group |
| AMTWG | Adaptive Management Technical Working Group |
| BWT | International Boundary Waters Treaty, 1909 |
| CBA | cost benefit analyses |
| CZMA | U.S. Coastal Zone Management Act, 1972 |
| DOI | U.S. Department of the Interior |
| EIA | environmental impact assessment |
| EIS | environmental impact statement |
| GCDAMP | Glen Canyon Dam Adaptive Management Program |
| GCM | Global Climate Models |
| ICZM | integrated coastal zone management |
| IGLD | International Great Lakes Datum |
| IIASA | International Institute for Applied Systems Analysis |
| IJC | International Joint Commission |
| IMD | identified management decision |
| ILSBC | International Lake Superior Board of Control |
| ISLRBC | International St. Lawrence River Board of Control |
| IUGLS | International Upper Great Lakes Study (Board) |
| LAB | Great Lakes – St. Lawrence River Levels Advisory Board |
| NBS | net basin supply |
| RCM | Regional Climate Models |
| RMP | resource management problem |
| SCOPE | Scientific Committee on Problems of the Environment |
| SMS | safe minimum standards |
| UNEP | United Nations Environmental Program |

# Acknowledgements

Countless wall plaques and posters have echoed Mark Twain's sentiments that twenty years from now you will be more disappointed by the things you didn't do than the things you did. I wanted to spend a year in Iceland and to secure a better understanding about the management of our vulnerable coastal and marine resources. But that was merely a dream until my wife Marlene encouraged me to take action. Thanks again Mar for all of your love, support and encouragement for this great adventure.

My two children, Sarah and Daniel also deserve a note of thanks. I know it was not easy to explain to those who asked what Dad was doing in Iceland or why he had gone back to university at such an "advanced" age.

My year in Iceland, which culminated in the writing of this thesis, was exactly the experience I was looking for. I cannot thank enough the citizens of Ísafjarðarbær for their great hospitality and tolerance for a foreign student in their midst. In particular I want to thank my friends, staff and fellow students at the University Centre of the Westfjords for their collegiality, help and the great fun I had while I was living in Ísafjörður.

Finally, special thanks must go to my supervisor, Professor Mike Philips, Program Director, Dagný Arnarsdóttir, and Instructor, Albertína Friðbjörg Elíasdóttir for their collective and individual advice and guidance throughout this thesis project. Their confidence that I could get it done provided much needed encouragement at times when I was not so sure.

It turns out that Mark Twain was entirely correct that throwing off the bowlines and sailing away from safe harbour, leads to discoveries of far greater value than provided by the effort it takes to maintain the status quo. But no voyage is a solitary act, and I gratefully acknowledge with thanks all of the support I have received.

# 1 Introduction

***For in their interflowing aggregate, those grand freshwater seas of ours,--Erie, and Ontario, and, Huron, and Superior, and Michigan,--possess an ocean-like expansiveness, with many of the ocean's noblest traits…***

**Moby Dick by Herman Melville**

The Great Lakes comprised of Lakes Superior, Huron, Michigan, Erie and Ontario, long a source of awe, wonder, and literary comment, are a significant resource for human habitation, industry and commerce. Spanning the border between Canada and the United States in the northeastern part of the North American continent, the inland sea created by these five lakes, is notable for holding about one fifth of the earth's surface fresh water (Fuller, Shear, & Wittig, 1995). Approximately 95% of the surface fresh water available to North America rests in these lakes (Grady, 2011). 33 million people inhabit the shores of the Great Lakes (EPA, 2013). The Great Lakes and their surrounding coasts are of such importance that they are defined by U.S. Federal Statute to be a part of the U.S. "coastal zone" subject to the Coastal Zone Management Act (CZMA, 1972).

Carved out by the glaciers of the last Ice Age, the Great Lakes originally contained only glacial melt water but are now replenished by a vast watershed. The Great Lakes, amongst other resource services, provide drinking water, hydro electrical power, marine transportation, fishery and recreation to many communities both coastal and inland. These resource services are in addition to the wide and diverse varieties of aquatic plants and animals supported by these lakes (Fuller et al., 1995).

The water levels of the Great Lakes fluctuate from season to season, year to year. The variable water levels of the Great Lakes are a function of a number of natural and anthropogenic modified processes. Winds, primarily from the west, distribute moisture in the form of precipitation directly into the lakes and their tributaries. The Great Lakes lose water through outflow downstream to the St. Lawrence River, and by evaporation and evapotranspiration **(Figure 1.1)**. Anthropogenic influences on these processes include diversion of tributaries both into and out of the Great Lakes, water intakes and outfalls, and structural changes to the natural flow patterns of the lake system caused by dredging, dams, and other coastal structures. Changes in climate also affect water levels. A warming climate increases evaporation from the Great Lakes and their tributaries, as well as increasing evapotranspiration from plants located in marshes, shorelines, and the lands surrounding the lakes. (Assel, Quinn, & Sellinger, 2004; Fuller et al., 1995)

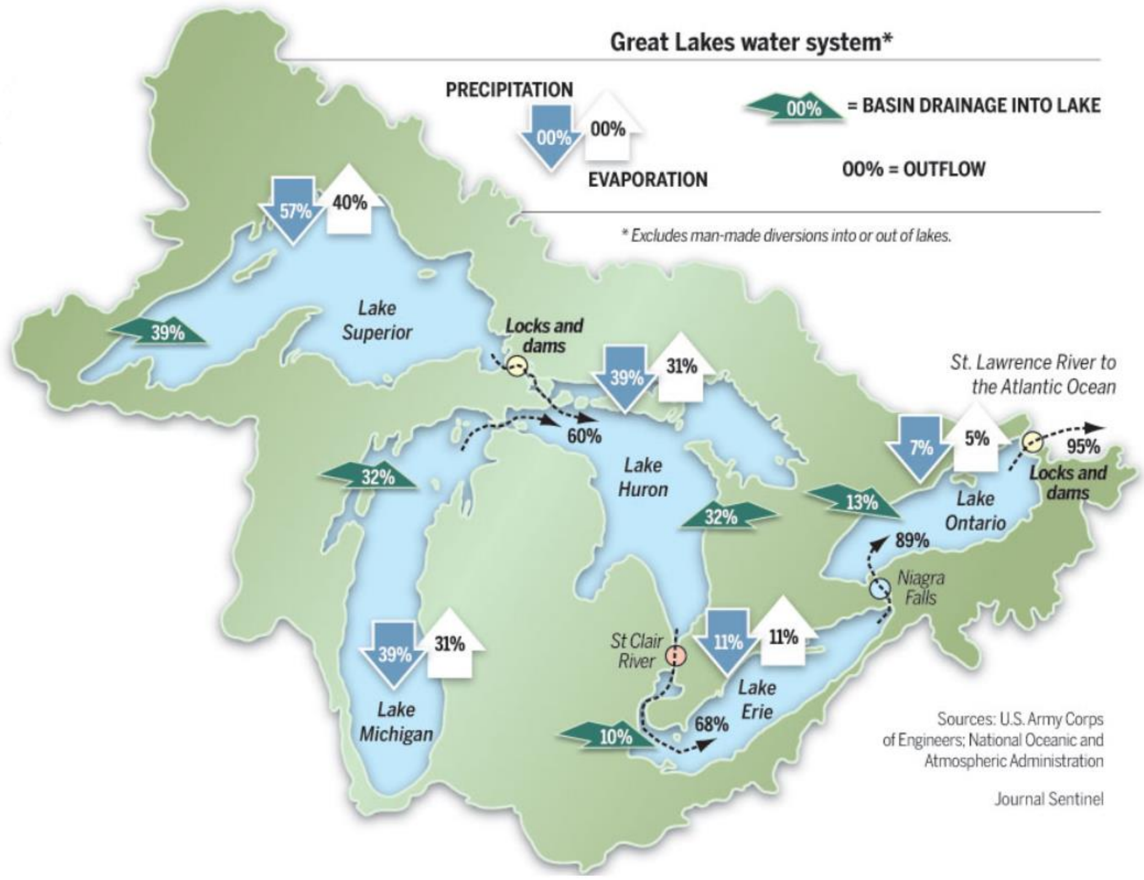



***Figure 1.1*** Graphic illustrating Hydrological Cycle and Flow Patterns for the Great Lakes. **Source:** http://www.jsonline.com/news/wisconsin/does-lake-michigans-record-low-water-level-mark-beginning-of-new-era-for-great-lakes-216429601.html (Egan, 2013)

Since the 1990's, the water levels in the Great Lakes have been dropping. In January 2013, Lake Huron and Lake Michigan reached their lowest water levels ever recorded since consistent measurement started in 1918 (Gronewold, Clites, Smith, & Hunter, 2013; The United States Army Corps of Engineers, 2013). Low water levels in the Great Lakes have significant environmental, social and economic impacts. Fish habitat and spawning areas are destroyed. Invasive vegetation grows in exposed mudflats and expanding shore areas. Inaccessibility due to low water conditions curtails recreation and tourism activities. Shipping on the Great Lakes is more costly and restricted due to load limitations caused by shallow navigation channel drafts and harbour dredging surcharges (Egan, 2012; Georgian Bay Forever, 2012; IUGLS, 2012; Millerd, 2011).

In March 2012, after 5 years of study, and at a cost of $14.6 million U.S., the International Upper Great Lakes Study Board ("IUGLS") issued its Final Report to the International Joint Commission ("IJC") entitled 'Lake Superior Regulation: Addressing Uncertainty in Upper Great Lake Water Levels' ("IUGLS Final Report"). The IUGLS Final Report proposed a long-term adaptive management ("AM") strategy to address extreme water level conditions in the Great Lakes-St. Lawrence River system (IUGLS, 2012). In March 2013, the International Great Lakes-St. Lawrence River Adaptive Management Task Team convened by the IUGLS, and at the direction of the IJC, issued in draft 'An Adaptive Management Plan for Addressing Extreme Water Levels' (IJC, 2013b). The draft AM plan with minor amendment was released by the IJC on May 30, 2013 ("AM Plan") for final public comment prior to recommendation to the Canadian and United States governments (IJC, 2013a). Pending formal recommendation of the AM Plan, the IJC has accepted the IUGLS proposals regarding an AM strategy and in turn has issued advice to the governments of Canada and the United States to the effect that AM is the way forward to address future extreme water levels in the Great Lakes.

## 1.1 Purpose and Structure of Thesis

The purpose of this thesis is to assess whether the AM strategy proposal to address extreme water levels in the Great Lakes is consistent with AM strategy selection criteria. While the phrase "adaptive management" can bring to mind a range of management possibilities, AM has both theoretical definition and structural requirements when the term is used in context to describe a resource management strategy. Significant demands will be made by an AM strategy where there is both limited capacity and limited financial supports for Great Lakes resource management. As an implemented resource management decision informing strategy, AM has not exhibited significant success when used for projects on the scope and scale of managing Great Lakes water levels.

This assessment will accordingly address the research question: “Are the International Upper Great Lakes Study recommendations for an adaptive management strategy as contained in the Final Report to the International Joint Commission entitled ‘Lake Superior Regulation: Addressing Uncertainty in Upper Great Lake Water Levels’ and the proposed ‘Adaptive Management Plan’ derived from those recommendations, supported by appropriate strategy selection criteria?” In other words, does the IJC’s proposal for an AM strategy to manage and address extreme water levels on the Great Lakes accord with identified selection criteria for AM? By engaging in this assessment to determine whether the IJC’s AM proposal is consistent with AM theory, the intent is to provide both useful commentary about the AM Plan as currently drafted and to assist in the determination of whether such a strategy is appropriate for implementation.

This thesis is structured into four parts following this introduction as Chapter 1. Chapter 2 addresses the background and structure of bilateral governance of the Great Lakes by Canada and the United States. Chapter 2 also provides the context and summary of content for the IJC AM strategy proposal. Chapter 3 provides a review of the seminal literature regarding AM and identifies theory compliant content and implementation issues. Following the introduction to context and theory content, Chapter 4 describes the method of content analysis that was used to assess the IJC’s AM proposal and in particular, the proposed plan for AM. Chapter 5 evaluates results following application of the assessment framework to the IJC’s AM strategy proposal. Finally, Chapter 6 discusses specific issues identified in Chapter 5 and provides conclusions regarding the appropriateness of the proposed AM strategy and plan to address extreme water levels on the Great Lakes.

This thesis has as a focus the definition and application of AM strategy selection criteria to an actual AM proposal. This is a unique approach not found in the literature that generally either addresses AM theory or assesses AM implementation results. The approach is limited to identification and application of AM selection criteria and, accordingly, does not include recommendations or analysis of specific stakeholder problems or objectives regarding management of Great Lake extreme water levels.

# 2 Background and Context

Organized as a bi-national commission in accordance with the International Boundary Waters Treaty ("BWT") (BWT, 1909), the IJC is responsible for preventing and resolving disputes regarding boundary waters between Canada and the United States. Accordingly, the IJC has a mandate to monitor, regulate and propose responses to water level regulation issues in the Great Lakes system. In fulfilling this mandate, the IJC established the IUGLS in 2007 to make reports and recommendations about the regulation of water levels in the upper Great Lakes (Lakes Superior, Huron, Michigan, Erie and their connecting water courses). No agency currently has the legislated authority to implement an AM bi-lateral strategy for the Great Lakes (IUGLS, 2012).

The terms "regulation" and "regulate" as used by the IJC and the IUGLS refer to the IJC's mandate to establish water level and flow plans at three control structures located on the Great Lakes and St. Lawrence River. Those control structures are located on the St. Marys River downstream of Lake Superior, the Niagara River downstream of Lake Erie, and on the St. Lawrence River downstream of Lake Ontario **(Figure 2.1)**. Of the three control structures, only the St. Marys River and St. Lawrence River control structures impact Great Lake water levels and their impact is limited to Lake Superior and Lake Ontario (IUGLS, 2012).

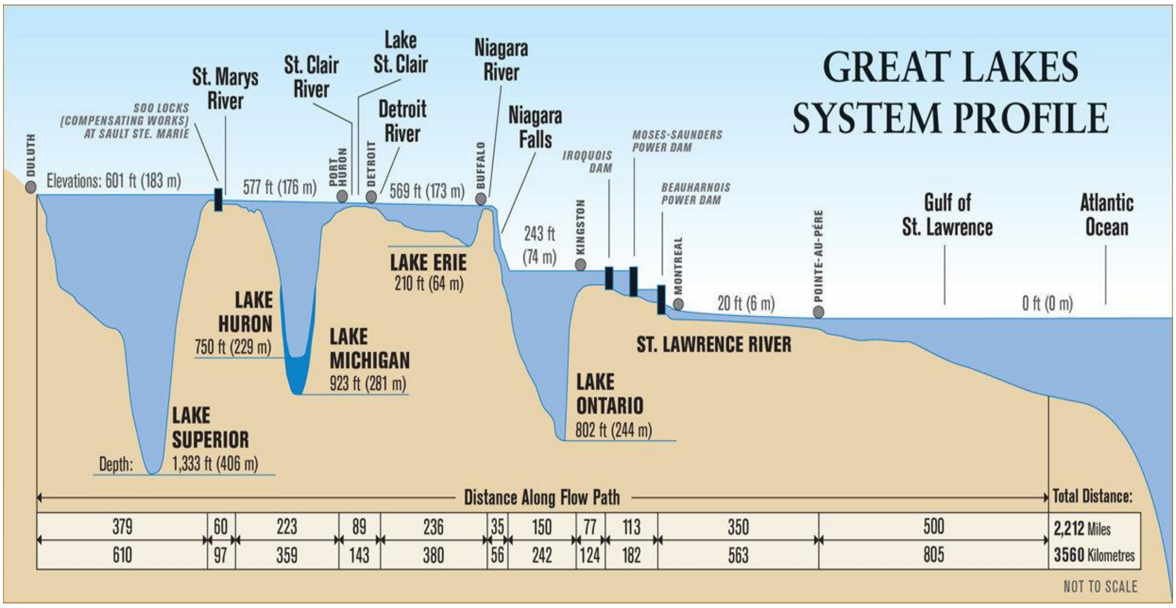



***Figure 2.1*** Profile of Great Lakes showing water surface elevations at chart datum International Great Lakes Datum (IGLD) 1985. **Source:** (IUGLS, 2012, pg. 3) as adapted by Bridge, The Center for Michigan http://bridgemi.com/2013/10/up-or-down-which-way-are-great-lakes-water-levels-headed/.

The IUGLS Final Report reflected a direction from the IJC to the IUGLS that it “study” extreme water levels, determine causes and impacts, and make recommendations for strategies to help decision makers, the private sector and governments. Implicit in that direction was a presumption that further “study” was required. The IUGLS concluded, in part, after 5 years of study that:

> In terms of understanding the lake system relative to lake levels the unavoidable conclusion is that the Great Lakes basin is a complex system whose dynamics are only partially understood. (IUGLS, 2012, pg. 61)

The IUGLS concluded that a number of identified factors influence water levels in the Great Lakes. The identified factors included climate change, which has resulted in increased evaporation from the lakes and changes in precipitation patterns, changes in flow rates in connecting waters between the Great Lakes, and isostatic adjustment that has caused basin tilt (IUGLS, 2012).

In recommending an AM strategy, the IUGLS reflected federal, state and provincial agency policies in both the U.S. and Canada that endorsed and promoted AM as a resource management strategy. The AM strategy proposal was also consistent with previous commentaries regarding recommended Great Lakes resource management strategies (Karkkainen, 2006).

There is little information about how or why AM was selected as a management strategy for consideration and recommendation by the IUGLS. Most of the published literature from the IUGLS described only a purpose and approach to AM.

The IUGLS Final Report described the recommended AM strategy:

> … [It] is intended to assist water level managers, coastal zone managers and others having to adapt to future extreme water levels. Through a structured, collaborative iterative approach to improved monitoring, modelling and assessment, these decision makers can be better equipped to anticipate changing water levels and better prepared (sic) to respond. They will be able to implement, review, adjust and revise actions to address future extremes as new information and knowledge become available and/or as water level conditions change. (IUGLS, 2012, pg. 165)

The IUGLS Final Report estimated that the proposed AM strategy would require an initial investment of $1.5 to $2.5 million ($U.S.) per annum. This was the cost estimate for the first five years of the program and the IUGLS estimated that funding could be reduced subsequent to the initial five-year program (IUGLS, 2012).

The AM Plan provided more detailed cost estimates and concluded:

> The start-up tasks for the entire AM Plan (including the AM Committee) for the U.S. components are estimated to total approximately ~$4.8 million U.S. along with up to $1.1 million U.S. for each U.S. pilot site. Canadian estimates are ~$5.3 million Canadian along with up to $1.1 million Canadian for each Canadian pilot site. For just the high priority tasks, both the U.S. and Canadian contribution estimates would be reduced to ~$3.4 million along with up to $890K for each pilot site. (IJC, 2013a, pg. 57)

The AM Plan proposed that funding, for what was described as the "adaptation side" of the AM Plan, would be secured from participating agencies that would contribute their existing resources to the "priorities of the AM Plan" (IJC, 2013a). No such financial or resource commitments were secured as part of the AM Plan drafting process.

As background research in preparation of the IUGLS Final Report, estimates of the current impact of low water levels in the Upper Great Lakes for some operations, such as hydroelectric production were prepared. In other economic areas, such as recreational boating and marina operations, no such extensive costing was undertaken due to perceived limitations in research resources (IUGLS, 2010).

Some attempts have been made by various municipalities around the Great Lakes to measure the current economic impact of extremely low water levels. For example, it was estimated that for the 2013 recreational boating season on Georgian Bay (part of Lake Huron), the 44 surrounding municipalities would have costs of $20 million Canadian arising from the maintenance and repair of infrastructure damaged by low water levels. Owners of cottages and residences on Georgian Bay were estimated to be spending up to $500 million Canadian in 2013 for mitigation efforts such as dock installations and water intake pipe extensions to address low water levels. (Georgian Bay Mayor's Group, 2013)

The IUGLS recommendation of an AM strategy very much assumed that there is little that can be done in the near term to regulate extreme water levels in the Great Lakes. The AM strategy as described in the IUGLS recommendations concluded that, regardless of whether regulation and/or hard engineering initiatives might actually address extreme water levels in the Great Lakes, on-going monitoring and modelling efforts as anticipated by an AM strategy would be useful (IUGLS, 2012).

On April 15, 2013, the IJC issued its ‘Advice to Governments on the Recommendations of the International Upper Great Lakes Study’ that supported the IUGLS recommendations for an AM strategy. In contrast to the IUGLS Final Report findings that structural options should not be explored, the IJC stated:

> The Commission recommends that the Governments undertake further investigation of structural options to restore water levels in Lake Michigan-Huron by 13 to 25 cm (about 5 to 10 in). The low end of the range addresses compensation for the early 1960s channelization and the higher end would offset the additional change in conveyance capacity that has been estimated by the Study Board to have occurred since then.
>
> The Commission recognizes that the change in conveyance capacity since 1963 cannot be attributed directly to a particular human action and thus any restoration actions will warrant further deliberation by the Governments.
>
> The Commission encourages the Governments to focus on an option that would not result in a permanent restoration change that could exacerbate

> future high water levels, but rather one that could primarily provide relief during low water periods.
>
> The Commission also recommends that the Governments undertake a comprehensive benefit-cost analysis and a detailed environmental study that includes upstream and downstream impacts of potential structural restoration options as part of this more comprehensive investigation. (IJC, 2013c, pg.11)

As at January 2014, the IJC had not issued a final AM Plan proposal in the form of further Advice to Governments as the AM Plan was still under consideration. Lana Pollack, the U.S. chair of the IJC did not sign the April 15, 2013 Advice to Governments as she believed the recommendations to explore structural options detracted from the IUGLS's findings on climate change and the need for an AM strategy (IJC, 2013f).

In introducing its AM strategy, the IUGLS utilized the definitional work of its working group which adopted the U.S. Department of the Interior ("DOI") / National Research Council definition for AM:

> Adaptive management [is a decision process promoting] flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders. (Leger & Read, 2012, pg. 1; Williams, Szarp, & Shapiro, 2007, pg. v)

The IUGLS did not explicitly problem scope issues surrounding water level management in the Great Lakes to determine whether an AM strategy is an appropriate strategy to address identified problem(s). The IUGLS did not describe any exploration of strategies as alternatives to AM to achieve its stated objectives.

## 2.1 Treaty and Regulation

The BWT (BWT, 1909) was entered into by Canada and the United States as a dispute avoidance and resolution mechanism regarding the use of boundary waters. The Preamble to the BWT expressed that purpose:

> The United States of America and His Majesty the King of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas, Emperor of India, being equally desirous to prevent disputes regarding the use of boundary waters and to settle all questions which are now pending between the United States and the Dominion of Canada involving the rights, obligations, or interests of either in relation to the other or to the inhabitants of the other, along their common frontier, and to make provision for the adjustment and settlement of all such questions as may hereafter arise, have resolved to conclude a treaty in furtherance of these ends…. (BWT, 1909, Preamble)

The definition of boundary waters was expressed in the Preliminary Article of the BWT:

> For the purpose of this treaty boundary waters are defined as the waters from main shore to main shore of the lakes and rivers and connecting waterways, or the portions thereof, along which the international boundary between the United States and the Dominion of Canada passes, including all bays, arms, and inlets thereof, but not including tributary waters which in their natural channels would flow into such lakes, rivers, and waterways, or waters flowing from such lakes, rivers, and waterways, or the waters of rivers flowing across the boundary. (BWT, 1909, Prelim Art.)

In keeping with the primary focus of the BWT, which is navigation rights and apportionment of non-navigational water use, Articles I and II addressed those concerns, while Article IV provided a very limited anti-pollution provision with no description of an enforcement mechanism (Hall, 2008).

The BWT was negotiated and drafted a number of years after the dispute between the United States and Mexico over the U.S. diversion efforts on the Rio Grande. That dispute had resulted in the then U.S. Attorney General, Judson Harmon, expressing a view, that became known as the Harmon Doctrine. The Harmon Doctrine provided that a sovereign state has absolute jurisdiction over an international watercourse within its borders without regard to downstream implications in another jurisdiction (McCaffrey, 1996; DeWitt, 1993). Article II of the BWT preserved for both the U.S. and Canada the right to divert waters within their respective jurisdictions subject to the recourse to the same legal remedies for an injured party as if such injury took place in the country where the diversion occurred.

It is within Article III of the BWT that uses, obstructions or diversions, affecting natural levels of the Great Lakes as boundary waters, were addressed. Article III of the BWT provided in part:

> It is agreed that, in addition to the uses, obstructions, and diversions heretofore permitted or hereafter provided for by special agreement between the Parties hereto, no further or other uses or obstructions or diversions, whether temporary or permanent, of boundary waters on either side of the line, affecting the natural level or flow of boundary waters on the other side of the line shall be made except by authority of the United States or the Dominion of Canada within their respective jurisdictions and with the approval, as hereinafter provided, of a joint commission, to be known as the International Joint Commission. (BWT, 1909, Art. III)

Article IV of the BWT addressed the permission of works, dams or other obstructions in waters flowing from boundary waters that could raise natural water levels within the Great Lakes. Article IV of the BWT provided in part:

> …they will not permit the construction or maintenance on their respective sides of the boundary of any remedial or protective works or any dams or other obstructions in waters flowing from boundary waters or in waters at a lower level than the boundary in rivers flowing across the boundary, the effect of which is to raise the natural level of waters on the other side of the boundary unless the construction or maintenance thereof is approved by the aforesaid International Joint Commission. (BWT, 1909, Art. IV)

Article VII of the BWT established the IJC, with 3 commissioners appointed by the President of the United States, and 3 commissioners appointed by the Federal Government of Canada. Article VIII vested the IJC with the jurisdiction to pass upon all cases involving the use, obstruction, or diversion of waters that are subject to Articles III and IV.

Article VIII of the BWT constrained the decision-making authority of the IJC regarding approval of use, obstruction or diversion of waters to an order of precedence. Under this Article, IJC decisions must give preference in the following descending order:

1. Uses for domestic and sanitary purposes;
2. Uses for navigation, including the service of canals for navigation;
3. Uses for power and for irrigation purposes. (BWT, 1909, Art. VIII)

Decisions by the IJC are made on the basis of a simple majority. In the event of a tied decision along national lines, the governments of Canada and the United States are to address the issue subject to stalemate by other means.

The IJC's reference powers were set out in Article IX, and as noted previously, issues or matters that are the subject of reference before the IJC can result in conclusions and recommendations, but these are not binding on either the governments of Canada or the United States.

## 2.2 Extreme Water Levels in the Great Lakes and the IJC

The IJC by treaty has authority to issue Orders of Approval for projects that can affect the natural levels of boundary waters. When asked jointly by the governments of Canada and the United States, the IJC also engages in studies called references to both study and make recommendations regarding boundary water issues. The recommendations arising from reference studies are not binding on the Canadian or United States governments. (BWT, 1909; IJC, 2013g)

When, in 1914, the IJC by Order of Approval allowed the development of further hydroelectric power generation on the St. Marys River it established the International Lake Superior Board of Control ("ILSBC") (IJC, 2013d). The ILSBC has a 2-person board, with one member from the United States and one member from Canada. The ILSBC is responsible for overseeing the implementation of a regulation plan approved by the IJC that governs the release of water from Lake Superior (IJC, 2013d). Similarly, when the IJC approved the construction of the Moses-Saunders Dam in 1952, an Order of Approval was issued by the IJC that charged the International St. Lawrence River Board of Control ("ISLRBC") with overseeing the implementation of a regulation plan that governs the release of water from Lake Ontario (IJC, 2013e). The ISLRBC has a 10-member board, with 5 representatives respectively from Canada and the United States (IJC, 2013e).

Since the 1960's, there have been multiple references concerning Great Lakes Water Levels as well as several studies directed by the IJC. The studies identified by the IJC include:

- 1964-1973 Regulation of Great Lakes Water Levels Reference Study (under 1964 reference)
- 1977-1981 Great Lakes Diversions and Consumptive Uses Reference Study (under 1977 reference)
- 1977-1983 Limited Regulation of Lake Erie Study (under 1977 reference)
- 1987-1993 Water Levels Reference Study (under 1986 reference)
- 1999-2000 Report on the Protection of the Waters of the Great Lakes (under 1999 reference)
- 2001-2006 Lake Ontario – St Lawrence River Study (under 2000 IJC directive)
- 2007-2012 International Upper Great Lakes Study (under 2007 IJC directive)
  (IJC, 2013a, pg. 4)

In 2007 the IUGLS started work on two reports that were directed by the IJC to fulfil two stated major objectives:

> 1. Examine physical processes and possible on-going changes in the St. Clair River and their impacts on levels of Lake Michigan-Huron and, if applicable, evaluate and recommend potential remedial options (Report 1); and
>
> 2. Review the regulation of Lake Superior outflows and assess the need for improvements to address both the changing conditions of the upper Great Lakes and the evolving needs of the many interests served by the system (Report 2). (IUGLS, 2009, pg. 8)

The IUGLS established an Adaptive Management Group ("AMG") in 2009 to develop an AM strategy to be recommended in the second report to the IJC. The AMG was comprised of Canadian and United States representatives from government or government supported agencies including Environment Canada, Ontario Ministry of Natural Resources, Ontario Centre for Climate Impacts and Adaptation Resources, Fisheries and Oceans Canada, National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, Great Lakes Fishery Commission, U.S. Army Corps of Engineers, Great Lakes Observing System, and The Nature Conservancy. (Leger & Read, 2012)

In its second report to the IJC, released in March 2012 and entitled 'Lake Superior Regulation: Addressing Uncertainty in Upper Great Lakes Water Levels', the IUGLS stated that with the concurrence of the IJC, the second IUGLS study was expanded to include an examination of "… the role of adaptive management in helping interests in the upper Great Lakes basin better anticipate and respond to future extreme water levels" (IUGLS, 2012, pg. 187).

The 'Final Report to the International Upper Great Lakes Study Board by the Adaptive Management Technical Work Group' ("AMTWG Final Report") was released in May of 2012. It described six core elements of a recommended AM strategy to "assist water level managers, coastal zone managers and others having to adapt to future extreme water levels" (IUGLS, 2012, pg. 165) in the Great Lakes as:

1. strengthening hydroclimate monitoring and modelling to improve estimates of the Great Lakes water balance;
2. tracking key performance indicators and changes in vulnerabilities to water levels;
3. ensuring more comprehensive information management and distribution;
4. improving tools and processes for decision makers to evaluate their actions;
5. establishing a collaborative regional Great Lakes-St. Lawrence River system risk assessment pilots for dealing with water level risk and water level extremes, and;
6. promoting the integration of water quality and quantity. (Leger & Read, 2012, pg. iii)

In adopting and expressing those identified core elements of a recommended AM strategy in its second report to the IJC, the IUGLS noted that the administration of such a strategy might require modification of the existing governance structures within the IJC and possibly changes to the IJC's mandate. These core elements for an AM strategy are uncontroversial and do not question or challenge existing stakeholder management goals or mandates. The second report was directed by the IJC to be focused on the upper Great Lakes and the specific influence of Lake Superior water level regulation. However, the recommended AM strategy was comprehensive and proposed that for non-regulated water level issues all of the Great Lakes-St. Lawrence River System be addressed by a Great Lakes-St. Lawrence River Levels Advisory Board ("LAB"). (IUGLS, 2012)

In May of 2012, the IJC, by directive, set up the Great Lakes-St. Lawrence River Adaptive Management Task Team ("Task Team"). The mandate of the Task Team was to draft an AM plan to address extreme water levels in the Great Lakes-St. Lawrence River System. In March 2013, the Task Team released a draft AM Plan for public comment, and in May

2013, the proposed AM Plan was released by the IJC for further public comment to be filed before the end of August 2013 (IJC, 2013a; IJC, 2013b).

## 2.3 Adaptive Management Plan Proposal

The IUGLS and IJC concluded that extreme water levels, being defined as water levels outside the historical levels experienced over the past 100 years on the Great Lakes (both above the maximum and below the minimum IGLD levels), will likely continue to occur in the future (IJC, 2013a; IUGLS, 2012). It was the view of the IUGLS and IJC that there were only two ways to address this predicted likelihood "…either by managing water levels through dams or other structures, and/or by managing how we respond to the impacts of those water level changes" (IJC, 2013a, pg. i). Regulation plans that established the permitted outflows from the control structures on the St. Marys River and on the St. Lawrence River were found to be of limited utility in addressing extreme water levels that are primarily the consequence of climatic conditions (IJC, 2013a; IUGLS, 2012).

An AM strategy was proposed by the IJC:

> Because the climate is changing and our ability to alter lake levels through lake regulation is limited, a broader, more comprehensive approach to manage the impacts of changing lake levels is needed. (IJC, 2013a, pg. i)

The IUGLS and the IJC concluded that system change can go unnoticed absent adequate monitoring, and that current models were not useful in predicting either the likelihood, timing or duration of extreme water level events (IJC, 2013a, pg. 13). After coming to these conclusions, the IJC identified the purposes of the AM strategy to be:

> 1.For on-going review of the Regulation Plans: Adaptive management will be used to monitor the effectiveness of implemented regulation plans in meeting intended objectives and to assess changing conditions and determine if the regulation plan may require adjustments based on what is learned over time/or as conditions change; and
>
> 2. For Improving Responses to Extreme Water Levels: Adaptive management will be utilized to provide an improved collaborative, systematic and iterative approach to inform on-going decision-making at all levels of government, by stakeholders and by the general public in response to changing water level conditions. This would be to ensure a strong continuous scientific basis for developing and evaluating options to issues posed by water level conditions, recognizing the limitation in

> regulating water levels and flows via existing or new structures to address risks of extreme water levels. (IJC, 2013a, pg. 6)

The AM strategy was not identified by the IJC as a strategy to either identify/modify regulation plan objectives or to engage in experimentation with regulation plans and processes.

The AM Plan was proposed to address its stated purposes through the creation of two bodies, an AM Committee reporting to the Boards of Control to handle assessment and evaluation of the regulation of outflows from Lake Superior and Lake Ontario, and the LAB to address extreme water levels outside of the limits of control by regulation **(Figure 2.2)**. The IJC stated:

> The IJC would convene the LAB but the LAB would rely on the willingness of agencies and stakeholders to collaborate under its auspices to inform decisions and implement the AM Plan. The LAB would engage agencies, organizations and institutions from across the Great Lakes-St. Lawrence River system in five system-wide networks for the following thematic areas:
>
> I. Hydroclimate Monitoring and Modelling
>
> II. Performance Indicators and Risk Assessment
>
> III. Evaluation and Decision Tools
>
> IV. Information Management and Distribution
>
> V. Outreach and Engagement (IJC, 2013a, pg. iii)

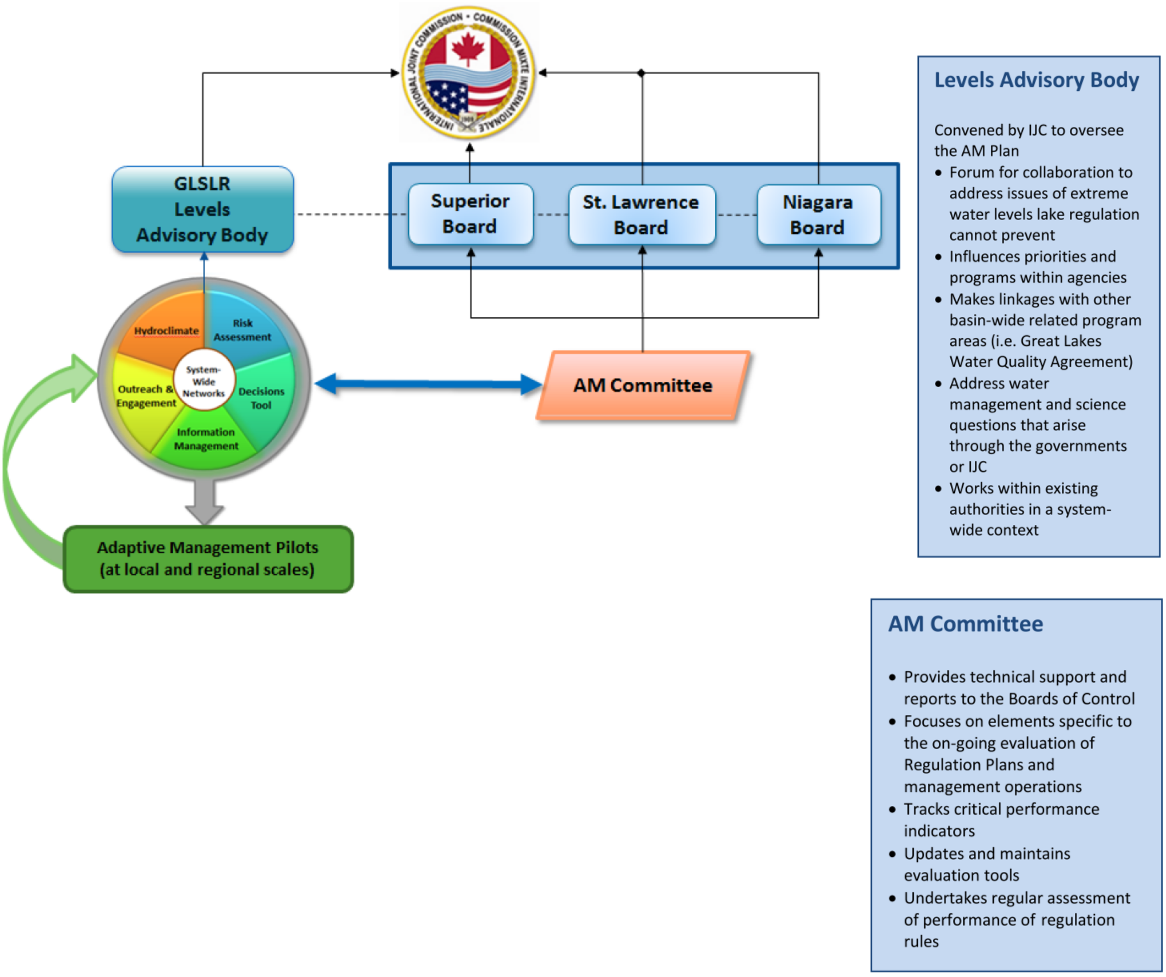



***Figure 2.2*** AM Committee and LAB Framework proposed in the AM Plan. **Source:** (IJC, 2013a, pgs. 23, 32)

# 3 Theory and Application of Adaptive Management – Seminal Literature

Adaptive management (AM) is a theory of natural resource management that has both definition and specific requirements for content in a management plan (Rist, Campbell, & Frost, 2013; Halbert, 1993). Many of the principles of AM were articulated in articles and texts well before the 1970's. However, it was during the 1970's that C.S. Holling, a Canadian ecologist, sought to incorporate management systems theory into environmental assessment practises to address uncertainty and surprise in the management of natural resources. In 1974, the Scientific Committee on Problems of the Environment ("SCOPE") held a workshop to deal with growing concerns and questions about environmental impact assessment practices. SCOPE was a scientific international non-government organization that sought to analyse and provide commentary about environmental issues. What emerged from the 1974 workshop were a number of questions about the utility of environmental impact assessment practices in predicting environmental conditions and about management planning for future conditions (Holling, 1978).

## 3.1 'Adaptive Environmental Assessment and Management'

In 1978, the International Institute for Applied Systems Analysis ("IIASA"), as part of a series of texts on applied systems analysis, and under the sponsorship of the United Nations Environmental Program ("UNEP"), published a text 'Adaptive Environmental Assessment and Management' edited by C.S. Holling. This text described a theory for AM and recommended specific procedures and techniques in its application (Holling, 1978). A central message of the 1978 IIASA text was that the environmental assessment process should be replaced with one that considered any particular project as an "experimental probe". Environmental impact assessments often predict a project's impact with more certainty than is reliable, and surprises in realized impacts are the result (Glasson, Therivel, & Chadwick, 2012; Culhane, 1987).

AM theory calls for the project itself to be the focus of on-going monitoring and responsive adaptation. Pre-project assessments regarding potential environmental impacts, in accordance with AM theory should be treated as experimental hypotheses rather than reliable assessments of predicted impact and consequences (Holling, 1978). With this construct, resource management became an exercise in addressing future uncertainty by learning to handle unexpected results through experiencing, monitoring and recording such results, and learning from them.

While in another context, an unexpected or surprising result in resource management might be considered as a failure in management, experiencing the unexpected consequences of a management decision is an essential component of an AM strategy. This is a concept within AM theory which is often overlooked by proponents of a colloquial concept of adaptive management which fails to recognize that in AM theory, resource management is an experiment in which unexpected results are to be anticipated and treated not as failures but as learning opportunities. Two explicit articulations of this aspect of AM theory and the theoretical explanation of the benefits of the unexpected described in the 1978 IIASA text were:

> Insulation from small disasters leaves one ill-prepared and vulnerable to larger ones." (Holling, 1978, pg. 135) and;
>
> We do, however, believe that there is one axiom that underlies any design for uncertainty. This axiom states: There exists a serious trade-off between designs aimed at preventing failure and designs that respond and survive when that failure does occur. (Holling, 1978, pg. 138)

In introducing AM, or what the 1978 IIASA text called "adaptive environmental management and assessment", twelve myths, or fallacies of policy belief regarding management and environmental impact assessment were enumerated:

> Myth 1 The central goal for design is to produce policies and developments that result in stable social, economic, and environmental behaviour….
>
> Myth 2 Development programs are fixed sets of actions that will not involve extensive modification, revision, or additional investment after the development occurs….
>
> Myth 3 Policies should be designed on the basis of economic and social goals with environmental concerns added subsequently as constraints during a review process….

> Myth 4 Environmental concerns can be dealt with appropriately only by changing institutional constraints….
>
> Myth 5 Environmental assessment should consider all possible impacts of the proposed development….
>
> Myth 6 Each new assessment is unique. There are few relevant background principles, information, or even comparable past cases….
>
> Myth 7 Comprehensive “state of system” surveys (species lists, soil conditions, and the like) are a necessary step in environmental assessment….
>
> Myth 8 Detailed descriptive studies of the present condition of system parts can be integrated by systems analysis to provide overall understanding and predictions of systems impacts….
>
> Myth 9 Any good scientific study contributes to better decision making….
>
> Myth 10 Physical boundaries based on watershed areas or political jurisdictions can provide sensible limits for impact investigations….
>
> Myth 11 Systems analysis will allow effective selection of the best alternative from several proposed plans and programs….
>
> Myth 12 Ecological evaluation and impact assessment aim to eliminate uncertainty regarding the consequences of proposed developments…. (Holling, 1978, pgs. 2 – 5)

According to the 1978 IIASA text, fundamental conditions for the application of AM and project design as experimentation were that a project must not destroy the experimenter and that capacity to start again must be preserved in the event of project failure. There also had to be, as a condition of AM application, an acknowledged willingness to start again if the project fails (Holling, 1978). Ecological systems were described as “dirty, changing, growing, and declining” (Holling, 1978. pg. 35). Ecological systems were also considered to demonstrate four properties namely; “…organized connection between parts, spatial heterogeneity, resilience and dynamic variability” (Holling, 1978 pg. 35). The 1978 IIASA text postulated that human systems demonstrate the same four properties and that in particular, individuals, institutions and society demonstrate resilience with multiple regions of stability that required testing by occasional change if rigidity is to be avoided (Holling, 1978).

The 1978 IIASA text sought to unify a theory of environmental systems and social systems so that improved environmental assessment practices could be realized. The resulting recommended changes to environmental assessment practices from this text were:

- Project design should incorporate environmental considerations at the outset and on an equal footing with economic and social factors.
- Broader constituencies than simply "stakeholders" and formal experts need to participate in project design.
- Information received from design incorporated project monitoring regarding environmental impact has value that needs to be recognized in project benefit valuation.
- Management action should be considered as much an experiment and opportunity to learn as scientific research.
- Project design should include both monitoring design and anticipated remedial response based on system feedback.
- Project design should include explicit recognition that there is an economic trade-off between a design that seeks to avoid the unexpected and "less capital intensive mechanisms that monitor and ameliorate the unexpected."
- Project design incorporating AM theory implies that changes in institutions and legislation will be necessary. (Holling, 1978)

Holling concluded in the 1978 IIASA text that a precise list of project design principles in keeping with AM theory is unknown and will likely remain so until the environmental assessment perspective that seeks prediction and control is replaced by one that considers uncertainty a fundamental aspect of environmental resource management. Carl Walters, who was a past Deputy Leader of IIASA's Ecology Project, next took up the task of articulating project design principles which incorporated AM theory in the 1986 IIASA text 'Adaptive Management of Renewable Resources' ("1986 IIASA text") (Walters, 1986).

## 3.2 'Adaptive Management of Renewable Resources'

The 1986 IIASA text stated that AM involves 3 essential tasks:

- Identifying a strategic range of alternative hypotheses, consistent with experience, which suggest the potential for different environmental responses outside the range of historical experience.
- Determining management policies that will take into account existing uncertainties, data gathering and learning processes about the managed system, and that will also take into account the uncertainties that future decision makers will be required to address in light of current decisions.
- Improving the monitoring of system change and, responsive project design to observed change that avoids adverse economic or social consequences. (Walters, 1986)

Following the AM process envisioned by Walters, policy articulation was less assured that uncertainties could simply be addressed by better data or more comprehensive modelling. This was described as an attitudinal change, and the attributes of an Adaptive management attitude were compared and contrasted with a Conventional management attitude in the 1986 IIASA text in the following chart **(Figure 3.1)**:

| Conventional | | Adaptive | |
|---|---|---|---|
| (1) | Seek precise predictions | (1a) | Uncover range of possibilities |
| (2) | Build prediction from detailed understanding | (2a) | Predict from experience with aggregate responses |
| (3) | Promote scientific consensus | (3a) | Embrace alternatives |
| (4) | Minimize conflict among actors | (4a) | Highlight difficult trade-offs |
| (5) | Emphasize short-term objectives | (5a) | Promote long-term objectives |
| (6) | Presume certainty in seeking best action | (6a) | Evaluate future feedback and learning |
| (7) | Define best action from set of obvious alternatives | (7a) | Seek imaginative new options |
| (8) | Seek productive equilibrium | (8a) | Expect and profit from change |

***Figure 3.1*** Comparison of Conventional Policy Analysis Attitudes with AM Policy Analysis Attitudes. **Source:** (Walters, 1986. Table 11.1, pg. 351)

According to the 1986 IILSA text, models, which are useful in the application of an AM strategy for resource management, are intentionally kept simple. Simple models would encourage debate about policy options and allow a focus on imaginative alternatives rather than the complexity of confounded causal relationships that will likely become more uncertain over time (Walters, 1986). The 1986 IILSA text dealt extensively with resource harvesting issues and the application of AM to resource status quo policies which created a domain of increasing uncertainty about management outcomes. The theory expressed is that intentional policy change that results in moderate disturbances to resource stocks, with limits placed on disturbance before dangerous scenarios result, produce feedback that is informative for future policy direction (Walters, 1986).

AM theory requires that significant changes be made in resource management approaches and policies as incremental change does not provide the necessary feedback to inform and educate decision makers. Additionally, AM theory advances the proposition that the acquisition of more data and/or constructing more complex models is not effective in eliminating uncertainty. Identification of the major uncertainties and policy decisions that will form the hypotheses to be tested is considered in AM theory to be the means by which further knowledge can be acquired to 'resolve' but never eliminate uncertainty. (Walters, 1986)

## 3.3 'Compass and Gyroscope'

In 1993, Professor Kai N. Lee, while the Director of the Center of Environmental Studies at Williams College in Williamstown, Massachusetts, published a text on AM titled 'Compass and Gyroscope' ("Lee's text") (Lee, 1994). Lee's text identified Holling, and the 1978 IILSA text, as providing the original formulation of AM (Lee, 1994). Lee's text identified Walters, and the 1986 IILSA text, as codifying AM through the development of a technical framework for ecosystem modelling (Lee, 1994). Lee described an approach reliant on AM for resource management that would achieve what he called an environmentally sustainable economy. Lee focused on utilizing an AM strategy to develop better management decisions based on enhanced learning about the relationship between human conduct and the environment. Lee paired this discussion with his consideration of the political changes necessary for a sustainable civilization. The pairing of AM theory with Lee's ideas about necessary political change was described as social learning.

Knowledge about the natural environment through AM was realized on “terms” that are governable (Lee, 1994).

Lee introduced into AM theory the explicit recognition of bounded rationality. As a resource management approach, AM was promoted by Lee as a necessary strategy if scientific uncertainty was to be prevented from paralyzing management action. Sparse data, limited theory, and lack of reliable predictability were described as attributes of large ecosystems and accordingly models were rarely accurate enough to be relied upon for quantitative projection. The utility of large ecosystem models was to systematize assumptions (scientific, social and political) so that they could be tested against experience. Ecosystem models were, according to Lee, constructs that reflect negotiation and compromise between competing interests. (Lee, 1994)

Lee’s concept of competing interests in a given environmental resource management issue was reflected in the title of his text. The status quo, which Lee opined was reflective of political and economic interests, acted as a gyroscope, resistant to change. Science acted as a compass pointing towards an ideal. These two countervailing forces constituted what Lee envisioned as the basis of a necessary conflict, which if properly bounded, could be managed. Lee’s text makes reference to a described standard definition of “sustainable development” using the UNEP definition, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Lee, 1994). However, Lee viewed sustainable development as normative, something akin to freedom or justice (Lee, 1994). This view resulted in Lee’s extraordinary conclusion that the declaration of a forest in Queensland, Australia as a World Heritage Site, free from logging, was a failure to recognize a bounded rationality. The policy declaration of an environmentally protected area which precluded experimenting with resource extraction to determine sustainable limits was, in Lee’s opinion, inconsistent with AM and the development of social learning (Dlhopolsky, 1995).

## 3.4 ‘Adaptive Management – The U.S. Department of the Interior Technical Guide’

As noted, the IUGLS promoted AM as a resource management strategy and in doing so relied upon the U.S. Department of the Interior (“DOI”) definition of adaptive management (Leger & Read, 2012, pg. 1; Williams et al., 2007, pg. v). The DOI, in ‘Adaptive

Management – The U.S. Department of the Interior Technical Guide' ("DOI Technical Guide"), traced AM as a resource management strategy from the 1978 IILSA text, the 1986 IILSA text and Lee's text (Williams et al., 2007). The DOI Technical Guide introduced its description of AM with the comment that:

> Adaptive management as described here is infrequently implemented, even though many resource planning documents call for it and numerous resource managers refer to it. (Williams et al., 2007, pg.1)

The specific AM process described by the DOI Technical Guide is comprised of two phases, a Set-up phase comprised of five steps, and an Iterative phase comprised of four steps:

Set-up phase

- Step 1 - Stakeholder Involvement - Ensure stakeholder commitment to adaptively manage the enterprise for its duration
- Step2 – Objectives – Identify clear, measurable, and agreed-upon management objectives to guide decision making and evaluate management effectiveness over time
- Step 3 – Management actions – Identify a set of potential management actions for decision making
- Step 4 – Models – Identify models that characterize different ideas (hypotheses) about how the system works
- Step 5 – Monitoring plans – Design and implement a monitoring plan to track resource status and other key resource attributes

Iterative phase

- Step 6 – Decision making – Select management actions based on management objectives, resource conditions, and enhanced understanding
- Step 7 – Follow-up monitoring – Use monitoring to track system responses to management actions
- Step 8 – Assessment – Improve understanding of resource dynamics by comparing predicted vs. observed change in resource status
- Step 9 – Iteration – Cycle back to Step 6 and, less frequently, to Step 1 (Williams et al., 2007, pg. 53)

The DOI Technical Guide description of the AM process is an example of the Decision-Theoretic School of AM theory (McFadden et al., 2011). Another school is the Resilience-Experimentalist School (McFadden et al., 2011). The distinction between the two schools principally depends upon a different emphasis on stakeholder engagement in defining objectives and management actions. In the Resilience-Experimentalist School, greater emphasis is placed on stakeholders having shared models and a shared understanding of the attributes and processes of a resource system before defining objectives and determining management decision alternatives. In the Decision-Theoretic School, model design comes after stakeholders participate in defining the management problem and objectives (McFadden et al., 2011). In keeping with its Decision-Theoretic School structure, the DOI Technical Guide began with a Problem-Scoping Key intended for use by resource managers to determine whether an identified management problem lends itself to an AM strategy (Williams et al, 2007, pg. iv; **Appendix A**).

The DOI Technical Guide postulated that AM, as a resource management strategy, is most useful when there is uncertainty about the outcomes or impacts of a management decision, but management objectives are well defined and the influence that management action can have on system behaviour is significant. Where management action has limited ability to influence a natural system, other management strategies such as hedging or scenario planning is more appropriate (Williams et al., 2007). Graphically, this was illustrated by the DOI **(Figure 3.2)**:

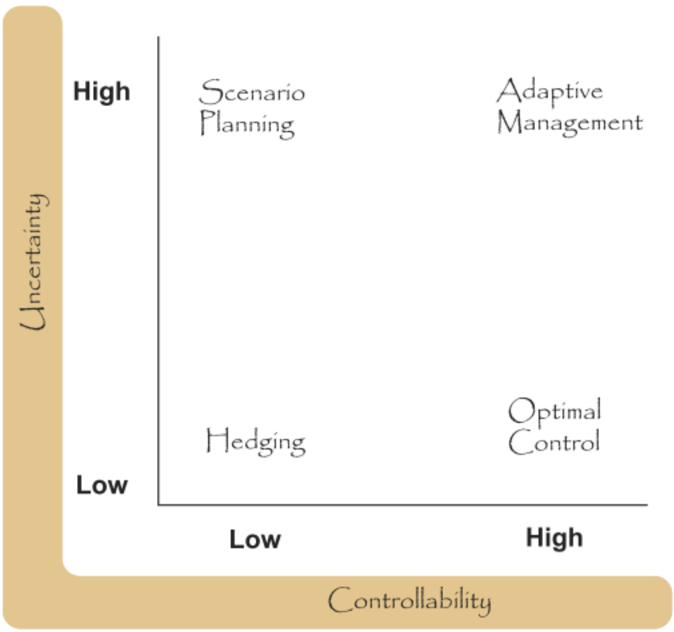



***Figure 3.2*** DOI Technical Guide diagram of decision making approaches for resource system management showing the influence of uncertainty and controllability. **Source:** (Williams et al., 2007, pg. 6)

Selection of AM as a decision assisting strategy requires critical examination of the uncertainty or unpredictability of management impact, and must include an examination of the degree of management control on a resource system. Surprisingly, the IJC has assumed, when it adopted the DOI definition of AM, that AM has utility not only when uncertainty is high, but also when management influence is understood to be very low.

In contrast to the DOI, the IJC graphically illustrated its belief that AM can address highly uncertain resource management impacts that exhibit a high degree of uncontrollability **(Figure 3.3)**:

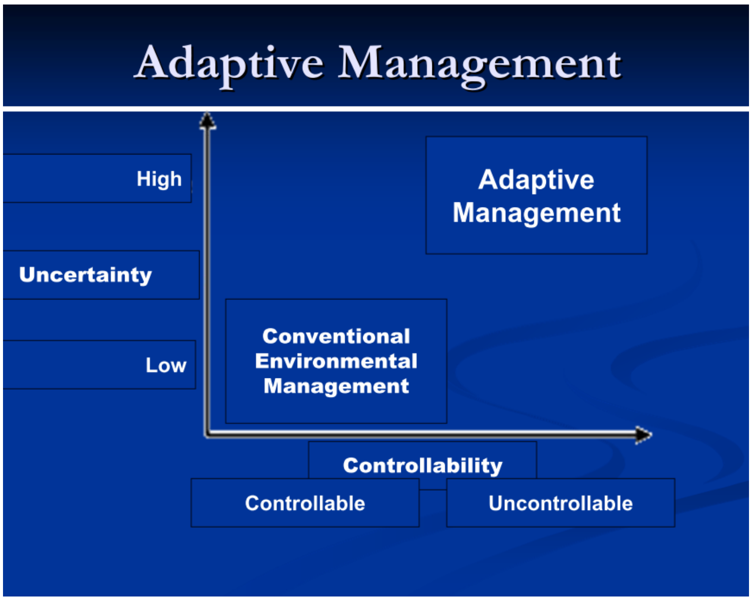



***Figure 3.3*** Findings of the Near shore Workshops by the Great Lakes Regional Office of the IJC regarding application of AM to high uncertainty, uncontrollable issues. **Source:** (Gannon, 2008, slide 14)

This expression of an understanding that AM is an appropriate strategy for managing highly uncertain and highly uncontrollable impacts, while inconsistent with AM theory, is likely reflective of the fact that AM is being advanced by the IJC not as a direct resource management strategy, but as a strategy to manage risk. Where environmental conditions are highly uncertain, and resource controllability is extremely limited, the IJC appears to be proposing that application of scenario planning calls for risk management using AM.

A particular management project which utilizes AM is considered successful in accordance with the DOI Technical Guide if:

- Stakeholders are involved and committed to the process
- Progress is made toward achieving management objectives
- Results from monitoring and assessment are used to adjust management decisions
- Implementation is consistent with applicable laws. (Williams et al., 2007, pg. 57)

The DOI Technical Guide did not describe in detail the content of an AM plan, but a DOI adaptive management website contains case studies as examples of adaptive management plans consistent with the DOI Technical Guide's recommendations (U.S. DOI, 2013; Williams et al., 2007). Of note is the case study titled 'Glen Canyon Dam Adaptive Management Program' ("GCDAMP") which the DOI advanced as an example of an appropriate AM strategy selection and implementation.

The GCDAMP was the outcome of an environmental impact statement ("EIS") that recommended AM to manage the impacts of the Columbia River Glen Canyon Dam on downstream resources. In particular, the EIS found that the Glen Canyon Dam was affecting the resources in the Glen Canyon National Recreation Area and the Grand Canyon National Park. In 2005, the Secretary of the Interior's designee to the GCDAMP boasted that according to Carl Walters, the GCDAMP was "…one of the three instances in the world of a successful implementation of adaptive management" (Gabaldon, 2005). Such an assertion begs the question; "Why has adaptive management proven to be of such limited success in its implementation in other instances?" A number of papers have questioned the claim that the GCDAMP represented a successful instance of AM implementation (Camacho, Susskind, & Schenk, 2010; Susskind, Camacho, & Schenk, 2012).

The GCDAMP had the explicit goals of reducing conflict, increasing learning and improving environmental conditions. The Glen Canyon Dam continues to be a source of significant litigation, the dam operates under a flow regime that is virtually unchanged from what was in existence prior to the GCDAMP, policy change in water management is not apparent as a consequence of learning, and it is unclear whether any of the experiments in modified flow condition management have shown a significant reduction of uncertainties regarding resource management (Susskind et al., 2012). The GCDAMP experience illustrates how the application of an AM strategy to a project of major scale (but comparatively much smaller than that of the Great Lakes) is unlikely to secure universal recognition of success.

## 3.5 Adaptive Management – Unfulfilled Promises

AM has become ubiquitous as the recommended or “go to” resource management strategy for programs and policies throughout Canada and the United States (Kwasniak, 2010; Ruhl & Fischman, 2010). Definitions of AM as recommended for various projects and programs range from those that amount to little more than sloganeering of the phrase, ‘learning by doing,’ to programs and policies that contain an extensive retelling of the theories and formal definitional nuances reflected in the original work of Holling (1978) and Walters (1986).

Rist et al. (2013) described specific components, as outlined by Holling (1978) and Walters (1986), which are required for an AM strategy to be compliant with theory:

1. Participation of those outside the management institution in order to manage conflict and increase the pool of contributions to potential management solutions,
2. Defining and bounding of the management problem, including the setting of management objectives,
3. Representing existing understanding through system models that include assumptions and predictions as a basis for further learning,
4. Identifying uncertainty and alternative hypotheses based upon experience,
5. Implementation of actions/policies to allow continued resource management or production while learning (reducing uncertainty),
6. Monitoring of the effect of implementing new policies,
7. Reflection on, and learning from monitoring results, comparison with original expectation in order to revise models and/or management actions based on what has been learned, and
8. Iterative repetition of this cycle (points 1-6 above) so that management reduces uncertainties and leads to improved management outcomes over time. (Rist et al., 2013, pg. 6)

Doremus (2010) argued that AM simply describes a range of potential management strategies that have the common features of: “iterative decision making and commitment to learning over time” (Doremus, 2010, pg. 1464). Care must be taken with this broader definition of AM to ensure that by the term ‘iterative’, it is understood that decision making is a repeated process that is informed and influenced by prior learning. The term “learning” must also be defined as a formal process derived from monitoring, otherwise one could argue that virtually all systems of management "learn" over time. It is the consideration of monitored results in comparison with model prediction that results in formal learning (Rist et al., 2013).

As a management decision informing strategy, AM is understood to require a comparatively greater investment of expert analytical skills, time and capital expenditure than other management decision support strategies (Rogers, 1998; Walters, 1997b). Institutions charged with resource management and protection may be less than committed to an AM strategy used solely as an information delivery/coordination tool, if the time, effort and cost of engagement are not perceived as generating additional information of significant value. Walters (1997a) asserted that in adopting an AM strategy the management question should always be: "…will policy A do better than policy B in terms of performance measure C?" (Walters, 1997b). The value decision when consideration is given to the adoption of an AM strategy is a measure of determining;

- whether the costs of AM are warranted for securing/organizing more data,
- whether formal institutional learning can realistically be anticipated as a result, and finally
- whether management decisions informed by such learning will demonstrate improvements of corresponding or greater value to the required investment (Doremus, 2010)

Walters, at a presentation in 2012, acknowledged once again that AM has exhibited significant failures in implementation, and he spoke about the emergence of three variations of AM theory in practice:

- AM Lite: management knowledge is assumed to be basically correct, AM as a strategy supports monitoring and policy correction when identified as required.
- AM for Optimists: management knowledge is assumed to be basically correct as in the case of AM Lite, but "Probing" experiments are undertaken to determine whether there are opportunities for policy improvement. Management and experimental probes are separate and distinct.

- AM with Humility: Nothing can be assumed, in keeping with AM as originally envisioned, every management policy decision is considered an experimental hypothesis. (Ross, 2012)

The six core elements of a recommended AM strategy as described in the 'Final Report to the International Upper Great Lakes Study Board by the Adaptive Management Technical Work Group' ("AMTWG Final Report") and the limitation of experimentation to Pilot Projects suggests that the IUGLS and IJC are proposing an AM Lite strategy.

McFadden et al. (2011) reviewed available literature on AM to assess the degree of implementation of the two identified schools of AM being Resilience Experimentalist and Decision Theoretic. It was concluded that the Decision Theoretic School of AM showed greater reported implementation than the Resilience Experimentalist School. Implementation of management action within an AM framework, regardless of school, remained low in comparison to the extensive number of articles that addressed AM as a theory or simply recommended an AM strategy to address a particular resource management problem (McFadden et al., 2011).

Rist et al. (2013) in a study of 187 worldwide papers of reported AM initiatives that were published in 2009, found only 15 of the papers surveyed reported on actual implementation or application of AM to a resource management problem. On average each of the 15 papers, which reported actual implementation, identified less than 5 of the 8 components of AM required of an AM theory compliant initiative. The most common omissions were stakeholder participation and management iteration. (Rist et al., 2013)

In the literature about AM, there is a growing expression of concern regarding the lack of theory compliant AM implementation or real world AM implementation success stories (Rist et al., 2013; Allen & Gunderson, 2011; McFadden et al., 2011; Huitema et al., 2009). As early as 1997 Carl Walters noted that AM, as a resource management strategy, rarely moved beyond policy articulation or modelling exercises to actual implemented management level decisions/experiments on spatial and temporal scales large enough to reveal system impacts (Walters, 1997b). Walters concluded that AM "flounders" in complex institutional settings and he considered as failures a number of major AM projects such as the Florida Everglades, Columbia River, and Upper Mississippi River (Walters, 1997b).

The focus on institutional or governance challenges in the implementation of AM, while it is thematic in the AM literature, cannot be considered as being unique to AM as it is a concern expressed about many resource management strategies and projects (Rist et al., 2013; Allen & Gunderson, 2011). It is, however, surprising to note that neither the IUGLS in recommending an AM strategy, nor the IJC in accepting that recommendation, made mention of the well discussed concern that AM has exhibited significant failures as a management decision informing strategy when implemented. For extremely complex issues, such as extreme water levels that are influenced or caused by climate change, AM may have limited application. AM, in theory, can be utilized to simply identify model deficiencies, but improved system models do not necessarily lead to improved resource management (Allen & Gunderson, 2011).

McFadden et al. (2011) found that there are multiple barriers to the successful implementation of an AM strategy:

> Such barriers include modelling difficulties, institutional rigidity, high financial costs, stakeholder dissension, and high political risks. (McFadden et al., 2011, pg. 1358)

Given those barriers and the lack of demonstrable successes for actual implemented AM strategies, particularly on large spatial or temporal scales, it is suggested that the cost of an AM strategy must be presented with a clear valuation of the learning and management improvement anticipated. If there is a good probability of securing useful information through an AM strategy that can reasonably be expected to change or impact on resource management decisions, then the risk of implementing an AM strategy that will not be considered successful might be worth taking. Great uncertainties regarding the impact of management decisions or the existence of significant consequences if management decisions are not appropriate, do not individually support a value proposition for an AM strategy (Failing, Horn, & Higgins, 2004).

An obvious impediment to the successful implementation of an AM strategy occurs where management is subject to conservation or resource management imperatives due to law or policy that precludes any capacity for genuine experimentation. While that would appear to be the context in which the IJC exercises its regulation authority, the impacts of water regulation and extreme water levels on the Great Lakes could still, in theory, provide an opportunity for other agencies to utilize AM provided the learning process is relevant to their management scope and scale. Surveys of smaller scope and scale AM initiatives indicate some successes where a focus on problem identification and the identification of clear objectives was institutionally supported and advanced by internal leadership (Greig, Marmorek, Murray, & Robinson, 2013).

# 4 Method

As discussed, AM is a resource management strategy that has been the subject of an extensive literature starting from the time it was initially described by C.S. Holling and Carl Walters in the 1970's and 1980's (Rist et al., 2013; Walters, 1986; Holling, 1978). While there are a number of definitions of AM advanced by various authors and organizations, AM is fundamentally a theory for resource management that seeks to support management decisions in the face of scientific uncertainty. AM theory treats learning how to manage a resource as an essential goal of management. Accordingly management decisions are connected to experimental hypotheses that remain subject to re-evaluation based on monitored system response (Rist et al., 2013; McFadden et al., 2011). In AM theory, understanding and knowledge about a resource or system subject to management is accepted as being incomplete. System response to management, while predictively modelled, is anticipated to be uncertain. For an AM strategy to be effective, issues and problems must be clearly identified and goals articulated. From problem identification and articulation of goals, an iterative cycle ensues wherein management alternatives are considered in the context of system models. Management action(s) selected from alternatives presented by modelling, once implemented, are monitored to determine whether impacts and results are consistent with models. The learning realized from this process results in model improvement, the start of a new cycle with re-examination of problems, and re-articulation of goals (Stringer et al., 2006; Walters, 1986).

AM is generally not regarded as an appropriate resource management strategy for highly complex problems arising from climate change where iterative time span cycles are lengthy, spatial scope is extensive, and despite the IJC's apparent interpretation, controllability and management influence are low (Allen & Gunderson, 2011; Gregory et al., 2006). However AM could still, in theory, be utilized to resolve uncertainties arising from model inadequacies for systems influenced by climate change (Allen & Gunderson, 2011). Models are emerging which suggest that AM could also simultaneously address structural uncertainty and uncertainty in management objectives (Williams, 2012).

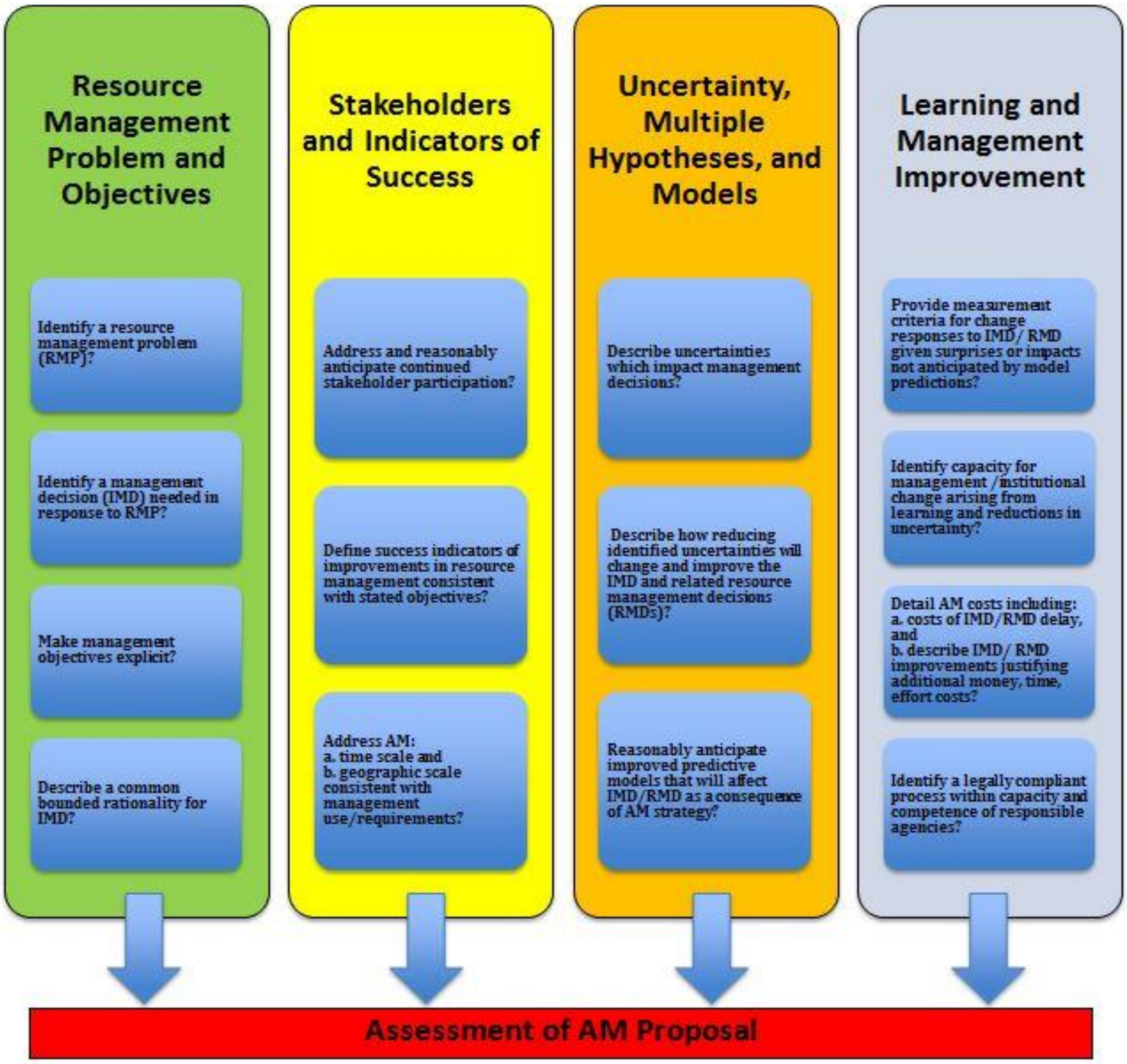
The method used in this thesis commenced with a review of the seminal literature regarding AM theory. Gregory, Ohlson, & Arvai (2006) determined that a resource management issue or problem should be assessed to determine whether AM was an appropriate decision informing strategy. A detailed analysis of anticipated costs and benefits was recommended as an adjunct to such an assessment (Doremus, 2010). However, no journal articles could be found that examined or addressed the actual application of described AM selection criteria to an actual AM proposal or plan. The literature to date either addressed AM as a theory and proposed selection criteria or examined the results of AM as implemented.

The review of the seminal literature regarding AM theory did however identify proposed AM selection criteria. Examples of proposed AM selection criteria were provided by Gregory et al. (2006) **(Appendix A),** the Problem Scoping Key by Williams et al., (2007) **(Appendix A),** and the nine AM "pathologies" contributing to implementation failure which Allen and Gunderson (2011) identified as:

1. Lack of stakeholder engagement…
2. Experiments are difficult…
3. Surprises are suppressed…
4. Prescriptions are followed…
5. Action procrastination: Learning and discussion remain the only ingredients…
6. Learning is not used to modify policy and management…
7. Avoiding hard truths: decision makers are risk averse…
8. Process lacks leadership and direction…
9. Focus on planning not action…
   (Allen & Gunderson, 2011, pgs. 1381-1383)

From the AM literature I created a synthesis of questions for assessing an AM proposal which incorporated the criteria identified by Gregory et al. (2006) and Williams et al. (2007), considered the pathologies identified by Allen & Gunderson (2011), and addressed the likelihood of successful implementation as discussed by Rist et al. (2013), McFadden et al. (2011), Holling (1978), and Walters (1986). The questions I created for assessing an actual proposal for AM are described in a table **(Table 4.1)**:

***Table 4.1*** 14 Key AM Selection Criteria Questions to Consider in the Assessment of an AM Strategy Proposal




I then considered and applied each of the 14 questions to assess the AM Plan (IJC, 2013a), the IUGLS Final Report (IUGLS, 2012), and the AMTWG Final Report (Leger & Read, 2012) treated collectively as the AM Proposal. Using this assessment method to examine written content, I sought to determine whether the AM Proposal contained evidence or data which would affirmatively answer the 14 Key AM Selection Criteria Questions necessary for theory compliant AM strategy recommendation. The results of that assessment were presented in a simple chart form and assessed more extensively thereafter. The discursive assessment included consideration of stakeholder written commentary filed with the IJC in response to the AM Proposal.

A range of "Met", "Partially Met", and "Not Met" was utilized to consider each of the 14 questions based upon a review of the documents which made up the AM Proposal. The method I created can be succinctly described as a desktop documentation analysis of content to determine whether complete consideration of identified selection criteria, consistent with AM theory, was evident in the AM Proposal to support the recommendation of an AM decision informing strategy regarding the management of extreme water levels on the Great Lakes.

In making a determination between whether specific identified selection criteria was "Met" or only "Partially Met" by the AM Proposal content, it is acknowledged that the process undertaken lacks absolute precision. The final conclusion that none of the identified selection criteria was ever completely satisfied by the AM Proposal documentation is reflective of comments within the AM Proposal documentation. The method as applied determined for example that the AM Proposal's "objectives" were identified to be "collaborative, systematic and iterative approach to inform on-going decision-making" and the AM Proposal's "indicators of success" were identified to be "will be further scoped out by the LAB". In the first instance, the AM Proposal recognized the need to identify objectives, but effectively articulated the objective to be simply engagement in AM. That was assessed as being incomplete. In the second instance, the AM Proposal recognized the need to specify indicators of success, but proposed to scope those out at a later time. This was also assessed as being incomplete. In all such instances, the AM Proposal selection criteria were assessed as only being "Partially Met."

The AM Proposal was not structured to provide explicit and direct answers to the specific questions identified in the method as described. AM was simply assumed by the IJC to be the appropriate strategy in light of the uncertainties presented by extreme water levels. Accordingly, a discursive content assessment framework examining the themes identified by and relating to the 14 Key AM Selection Criteria Questions Assessment process **(Table 4.1)** was created. I identified for purposes of a discursive assessment the key elements of a proposal that would indicate AM is appropriate for selection as a decision support strategy as discussed by Rist et al. (2013), McFadden et al. (2011), Walters (1986) and Holling (1978). I identified those key elements to be:

- Definition of the issue or problem that requires a decision
- Definition of the objectives of the decision making process
- Identification and involvement of stakeholders
- Determination of the measurement and recognition criteria for identifying achievement of defined objectives
- Identification of information critical to the management decision that is uncertain, unknown or subject to multiple hypotheses or alternative management action
- Identification of the models or scenarios that are available or could be generated to predict management decision outcomes and provide assessment monitoring and evaluation criteria
- Determination of whether monitoring and assessment of decision outcomes and or experiments based upon identified modelling framework is achievable and will be informative
- Determination of whether future decisions can be informed and changed as a consequence of decision outcome monitoring and assessment (Rist et al., 2013; McFadden et al., 2011; Walters, 1986; Holling, 1978)

Each of those identified key elements was considered and discussed in turn with respect to the content as found in the AM Proposal documentation.

The assessment of the application of the 14 Key AM Selection Criteria Questions Assessment process **(Table 4.1)** and the more discursive consideration of key elements was relied upon for purposes of discussion and conclusions.

The IJC recommended that in addition to an AM strategy, a detailed environmental study be undertaken regarding potential structural restoration options utilizing what the IJC described as a benefit-cost analysis. Accordingly, following the desktop assessment of the AM Proposal using the described method, I provided my discussion, based upon economic theory, as to the merits of combining an AM strategy with the proposed benefit-cost analysis of structural restoration options.

As noted in the Introduction, I did not attempt to extend the assessment method to address or make recommendations about what might or should have been included in the AM Proposal documentation specific to stakeholder problems or objectives, or otherwise recommend specific amendments to the AM Plan. Such recommendation would require the introduction of stakeholder identification analysis techniques that are beyond the scope and capacity of this work, but would form an important basis for further study.

# 5 Assessment of the IJC's Adaptive Management Proposal

The analytical framework for the assessment of the AM Plan as a proposal is structured in accordance with the method described in Chapter 4. The AM Plan (IJC, 2013a), the IUGLS Final Report (IUGLS, 2012), and the AMTWG Final Report (Leger & Read, 2012) considered as the AM Proposal were assessed initially utilizing the 14 Key AM Selection Criteria Questions **(Table 4.1)**. Those findings are presented as a table **(Table 5.1)**, the results being considered in more detail under the following headings:

- Definition of the Management Problem
- Definition of the Management Objectives
- Stakeholders
- Indicators of Success
- Identification of Uncertainty and Multiple Hypotheses
- Models as a Means to Reduce Uncertainty
- Learning from Results
- Management Improvement

## 5.1 AM Proposal Assessment Considerations (14 Key Questions)

***Table 5.1*** Application of 14 Key AM Selection Criteria Questions to the AM Proposal

| **Does the AM proposal:** | **Fully Met** | **Partially Met** | **Not Met** |
|---|---|---|---|
| **1. Identify a resource management problem (RMP)?** | | * | |
| **2. Identify a management decision (IMD) needed in response to RMP?** | | * | |
| **3. Make management objectives explicit?** | | * | |
| **4. Describe a common bounded rationality for IMD? (Common understanding of what is unknown or uncertain)** | | | * |
| **5. Describe uncertainties which impact management decisions?** | | * | |
| **6. Describe how reducing identified uncertainties will change and improve the IMD and related resource management decisions (RMDs)?** | | | * |
| **7. Detail AM costs including:<br>a. costs of IMD/RMD delay, and<br>b. describe IMD/ RMD improvements justifying additional money, time, effort costs?** | | | * |
| **8. Address AM:<br>a. time scale and<br>b. geographic scale consistent with management use/requirements?** | | | * |
| **9. Address and reasonably anticipate continued stakeholder participation?** | | * | |

| Does the AM proposal: | Fully Met | Partially Met | Not Met |
|---|---|---|---|
| **10. Reasonably anticipate improved predictive models that will affect IMD/RMD as a consequence of AM strategy?** | | * | |
| **11. Provide measurement criteria for change responses to IMD/ RMD given surprises or impacts not anticipated by model predictions?** | | | * |
| **12. Define success indicators of improvements in resource management consistent with stated objectives?** | | * | |
| **13. Identify capacity for management /institutional change arising from learning and reductions in uncertainty?** | | | * |
| **14. Identify a legally compliant process within capacity and competence of responsible agencies?** | | * | |

## 5.2 Definition of Management Problem

Problem definition is critical to resolution. As noted, AM is a management decision informing process that explicitly recognizes that management decisions and policies should not be construed as solutions but as hypotheses subject to testing. Management practices and policies, subject to an AM strategy, change as a consequence of deliberate learning that is derived from the structured monitoring of system feedback. In keeping with AM theory, new information and learning redefines objectives throughout the iterative process of AM. A problem that is amenable to a prediction and control strategy has markedly different characteristics to those exhibited by a problem that is appropriate for the application of AM. When an impact or result is not consistent with prediction or policy, using prediction and control management, a typical management response is to question whether management protocols were correctly followed and to look for other explanations in the nature of unforeseen events that interfered with management success. An AM strategy treats unanticipated impacts including major disruptions as healthy, demonstrative of system resilience and as a fortunate learning opportunity. To define a “problem” as amenable to an AM strategy frames both the problem and its resolution.

The AMTWG Final Report (Leger & Read, 2012) described the "problem" to be addressed by an AM strategy as follows:

> Recognizing the dynamic and ever changing nature of the Great Lakes-St. Lawrence River System and the inherent challenges of designing a single regulation plan that will be optimal for all possible future conditions including climate change, the Study Board decided early in the Study that the best mechanism for addressing future uncertainties was adaptive management. (Leger & Read, 2012, pg. 3)

The IUGLS Final Report (IUGLS, 2012) described the "problem" in this manner:

> The initial analysis establishing the limits of Lake Superior regulation delivered two important conclusions. First, given climate variability, the limits of regulation, and the need to balance the needs of a wide range of interests, a new regulation plan would be able to provide only small improvements over plan 1977A [current regulation plan for Lake Superior outflow] in terms of addressing water level risks in the upper Great Lakes. Second, a significant portion of the risks associated with changing water levels and flows would not be addressed unless a coordinated complementary adaptive management plan was implemented. (IUGLS, 2012, pg. 17)

Finally, the AM Plan (IJC, 2013a) described two key "purposes" of the AM strategy arising from the limited ability to alter lake levels through regulation that implies that regulation capability is a "problem":

> Water level extremes can be addressed in two ways, by managing water levels through dams or other structures, and/or by managing how we respond to the impacts of those water level changes. The current approach for managing water levels is the regulation by the IJC of outflows from Lake Superior and Lake Ontario through dams on the St. Marys River at Sault Ste. Marie and at the Moses-Saunders Dam at Cornwall/Massena on the St. Lawrence River. Outflows are controlled according to regulation rules that specify how much water can be let out under a range of conditions. However, as noted earlier, the ability to alter lake levels through the regulation plans is limited, especially for the upper Great Lakes, and is dominated by changes in water supply driven by precipitation and temperature. Based on this, the Task Team identified two key purposes for the IJC to be engaged in adaptive management:
>
> 1. For on-going review of the Regulation Plans: Adaptive management will be used to monitor the effectiveness of implemented regulation plans in meeting intended objectives and to assess changing conditions and determine if the regulation plan may require adjustments based on what is learned over time and/or as conditions change.; and

> 2. For Improving Responses to Extreme Water Levels: Adaptive management will be utilized to provide an improved collaborative, systematic and iterative approach to inform on-going decision-making at all levels of government, by stakeholders and by the general public in response to changing water level conditions. This would be to ensure a strong continuous scientific basis for developing and evaluating options to issues posed by water level conditions, recognizing the limitation in regulating water levels and flows via existing or new structures to address risks of extreme water levels. (IJC, 2013a, pg. 6)

So what is the problem that the AM Plan was intended to address? The AMTWG Final Report (Leger & Read, 2012) indicated that the problem was designing a regulation plan that would be optimal for all possible future conditions that are anticipated to include, at times, extreme water levels. The IUGLS Final Report (IUGLS, 2012) concluded that changes to existing regulation plans would only have limited impact on addressing water level risks and, accordingly, the identified problem is one of addressing extreme water level risks that could not be dealt with by regulation. Finally, the AM Plan (IJC, 2013a) itself did not explicitly describe a "problem" as the description was of two purposes for the AM Plan. The first purpose was to monitor water regulation to determine whether it was meeting intended objectives and assess whether water regulation might require adjustment as conditions change. The second purpose described in the AM Plan was to improve responses by others to extreme water levels while recognizing the limitation of water level regulation using existing or new structures.

What emerges from an examination of the progression in the identification of the "problem" to that of the identified two key purposes for the AM Plan, is that the AM strategy is being advanced, from the perspective of the IJC's regulation mandate, as a decision support strategy to effect a predict and control mandate. In recognition of that mandate, an objective of the AM Plan is to secure acknowledgement from stakeholders that the impact of the IJC's regulation efforts, which are defined by rules made in accordance with the BWT, and other potential water course structural changes are of limited utility as a response to extreme water levels.

Given its origins as a theory applicable to the management of natural resource yields, AM is more often discussed in the literature as having application to problems such as the determination of better forestry, agricultural or fish stock management practices that will produce the highest sustainable yield. The management uncertainty for sustainable yield problems is in determining which management practice or practices amongst a number available should be selected for the intended objectives. AM assists in an on-going decision process of selection and re-selection of practices by acknowledging learning as being an important objective of a management decision, and from the outset, specifying the measurement and monitoring of outcomes in light of those explicitly described objectives (Williams & Brown, 2012).

If the problem being addressed is simply one of determining which regulation plan will meet water level regulation objectives in compliance with the BWT and existing Orders of Approval, the problem becomes framed by those objectives. As noted, regulation objectives are a function of the various Orders of Approval issued by the IJC. For example, the Orders of Approval issued by the IJC with respect to the compensating works on the St. Mary's River call for the compensating works to be operated in a fashion that results in the level of Lake Superior not exceeding or falling below levels stated in the Order. In the IUGLS Final Report (IUGLS, 2012) there was a conclusion that recently experienced low water levels on Lakes Michigan and Huron could not be restored to levels within their historic ranges simply by operation of the compensating works on the St. Mary's River. The Orders of Approval and regulation plan mean that Lake Superior water levels must be maintained within a specified level range, with secondary consideration to outflow impacts on Lakes Michigan and Huron. An AM decision informing strategy will have little to no impact on the day-to-day management of the compensating works on the St. Mary's River and this is reflected in the organizational structure of the proposed AM Committee and the LAB. The expectation of the AM Plan is that there are no management choices to be made at the compensation works other than comply with the regulation rules as approved by the IJC.

If the problem being addressed by the AM Plan is the selection of management responses by agencies other than the IJC, and for responses other than the regulation of water levels, then framing the problem becomes problematic. The stated purpose in the AM Plan raises questions about "whose response" and "whose management." In effect, by concluding that a water regulation response within the mandate of the IJC would be the subject of regulation rules that are understood to be relatively ineffective in "responding" to extreme water level conditions, a framing shift has occurred (Bardwell, 1991). By stating that a purpose of the AM Plan was to improve the response of others, the problem becomes framed as one that suggests the problem(s), however and whenever defined, arise not by operation of IJC's command and control mandate, but because of limited access to information, lack of coordination, lack of collaboration and model deficiencies experienced by others. This leads to the proposal of an AM Plan under which the IJC seeks to assume AM coordination responsibilities beyond its current mandate. There is, however, no stated intent by the IJC to have its regulation management considered as an experimental hypothesis, or to have the IJC assume responsibility for exercising management of the responsibilities of others, in a top down sense. The framing results in no questioning of the role the IJC plays in the regulation of water levels, the AM Plan assumes this will continue as is. Implicit in this is a conclusion that current regulation objectives as expressed by the BWT and policy are consistent with the objectives of stakeholders.

In commenting upon the draft AM Plan, Willie Taylor, the Director of Environmental Policy and Compliance for the United States Department of the Interior ("DOI") wrote:

> It is not so much an adaptive management plan per se, as it is a proposal for the International Joint Commission (IJC) to undertake a role in conducting adaptive management across an equally wide range of scenarios throughout the Great Lakes – St. Lawrence System, spanning water regulation plans to regional or even local-scale projects. The AM Plan also proposes a new organizational structure in support of these activities. (Taylor, April 15, 2013)

Taylor went on to comment that such a far-reaching proposal as reflected by the AM Plan called for much great inter agency input. Implicit in his comments as a stakeholder and representative of one of the agencies that would be called upon to "respond" to extreme water levels was a lack of recognition of the "problem" being addressed by the AM Plan. This is reflected in Taylor's comments:

> …we [DOI] recommend that the increased breadth of the responsibilities, including the proposed Levels Advisory Board and related regional activities and pilot projects, be subject to more in-depth analysis. It may be a valid criticism that "collaboration" may not be happening to an ideal degree among all potentially involved parties. And many of the proposed activities and roles described in the AM Plan may be beneficial. But a clearer picture should be presented of the IJC's role, vis-a-vis the roles and jurisdictional responsibilities and limitations, including budgets and resources, of the respective governmental, institutional and NGO participants. (Taylor, April 15, 2013)

The lack of a clearly articulated problem regarding management uncertainty appropriate for an AM strategy may be reflective of an institution's inability to be engaged in adaptive management given its statutory obligations (Ruhl, 2005). The IJC was not probing its own mandate or the prioritization of precedent established by the BWT. The AM Plan will not lead to any fundamental questioning of existing governance or institutional authorities. The AM Plan stated:

> This Adaptive Management Plan is designed to work through organizations and their existing authorities to prioritize tasks, leverage resources, and engage current programs and resources if they exist to undertake specific tasks. There is no formal authority over agency participation or their decisions. Involvement is based on the concept that it is more effective and efficient to work collaboratively and that better, more sustainable outcomes will result. (IJC, 2013a, pgs. 10-11)

The IJC and the Boards of Control under its direction have no authority or jurisdiction to prioritize environmental concerns, for example, at the expense of the preferences agreed upon in compliance with the BWT.

Most institutions charged with environmental management responsibilities for the Great Lakes would likely welcome easier access to environmental data and greater inter agency collaboration. But AM is not necessarily or by definition a collaborative management process. The unasked questions include; "what is the value of this information access and coordination?" and "does this coordination and access require the elaborate institutional structures proposed by the AM Plan?" It is not apparent that stakeholders, in any sense applicable to AM theory, identified access to information and lack of collaboration as a problem that interfered with their ability to select from amongst management alternatives.

The scientific quest for more data was identified by Holling as frequently "utterly useless for constructing a management model, even when the data are scientifically sound" (Holling, 1978, pg. 63). As well, in AM theory, it is not collaboration or cohesiveness that necessarily leads to management learning. An AM strategy calls for an expectation amongst stakeholders that management decisions will result in surprising and at times environmentally degrading outcomes. The less than clear problem(s) identified by the AM Plan are not likely to attract stakeholder commitment to a process that will expose either individual agency or collective management ignorance. An AM strategy requires decision makers to have both the capacity and willingness to take the risk of acknowledging that management decisions are being made in the absence of full confidence that those decisions are correct or will be effective in meeting stated objectives (Gregory et al., 2006).

## 5.3 Definition of Management Objectives

As noted, the AM Plan explicitly identified its objectives. In AM theory, the term "objectives" is synonymous with management goals (Walters & Hilborn, 1978). The objectives identified in the AM Plan were:

- Optimizing the efficiency of regulation plans in achieving stated regulation plan objectives in the face of changing conditions, and
- Improving non-regulation responses to water level extremes by decision-makers at all levels of government, by stakeholders and by the general public. (IJC, 2013a).

These stated objectives are complex and lack definition. Unlike simple crop or resource harvest objectives, it is difficult to identify the basis for an optimization analysis that would direct the monitoring and measurement for achievement of these objectives, or even identify management strategy alternatives to improve management results.

AM is not a strategy for the resolution of conflicts in management objectives (Williams et al., 2007). As noted in the DOI AM Technical Guide:

> All too frequently, a decision making process is undertaken without agreement about scope, objectives, and management alternatives. Without this agreement, any management strategy likely will be viewed as reflecting unshared objectives and inappropriate or unnecessary limitations on management. The prospects for conflict increase dramatically in such a situation. (Williams et al., 2007, pg. 22)

The Shipping Federation of Canada, which represents the owners, operators and agents of ocean going ships which utilize Canadian ports on the Great Lakes reviewed the AM Plan, provided commentary to the IJC on the AM Plan, and specifically commented on the AM Plan's objectives:

> With respect to the second committee, the Levels Advisory Board, we understand that this group will be tasked with implementing the Adaptive Management Plan to Great Lakes-St. Lawrence River system-wide

> initiatives, as resources and opportunities arise, in order to keep current on the system trends and changes. Not only is this a very large mandate for existing institutions (which already have their own mandates) to undertake, but the engagement of stakeholders, government agencies and non-governmental organizations will be highly dependent on the funds that are available for such activities. Indeed, given the budgetary restrictions that government agencies in both Canada and the United States are currently facing, we fear that the LAB's ability to address the system-wide components of the Adaptive Management Plan may be severely constrained. (Gravel, 2013)

In the original draft of the IUGLS Final Report (IUGLS, 2012), the first recommendation made by the IUGLS to the IJC in the chapter entitled 'Addressing Future Extreme Water Levels: The Role of Adaptive Management' was for the establishment of the LAB (IUGLS, 2011). Utilization of an AM strategy was the second recommendation.

In Peer Review, the draft IUGLS Final Report's AM proposal was commented upon as follows:

> …the report was somewhat difficult to follow because the phrases vulnerability assessment and adaptive management seemed to be used interchangeably. In the end, what was presented was more of a risk-based decision making process rather than an adaptive strategy. These are quite different….a call for a new advisory board may appear a bit of a damp squib to the public. Think it would be better to reverse the order of recommendations 2 and 1. (Johnson & Halliday, 2011)

The IUGLS Final Report addressed the Peer Review comments by reversing the order of the original recommendation for a new advisory board so that it came after the AM strategy proposal. Risk-based decision-making was identified as the basis for the AM strategy proposal. This reorganization does not resolve the confusion in the AM Proposal between a strategy to address risks due to uncertainty and lack of control, that requires a scenario based risk analysis strategy, with an AM strategy which monitors management decision impact.

A management objective of utilizing AM:

> … to provide an improved collaborative, systematic and iterative approach to inform on-going decision-making at all levels of government, by stakeholders and by the general public in response to changing water level conditions… (IJC, 2013a, pg. 6)

raises concerns not simply about costs, funding and jurisdiction, but more fundamentally it raises questions about the tractability of such a strategy given geographic scale and stakeholder breadth (Failing et al., 2004).

AM, as an environmental management decision support strategy, requires the articulation of well-defined ecological objectives (Gregory et al., 2006). The stated objectives of the AM Plan really are nothing more than the statement of an objective to institute an AM approach. Put differently, the IJC's concerns appear to be that governments, stakeholders and the general public are not acting collaboratively, systematically and iteratively "enough" to make informed decisions and this requires improvement through an AM strategy. While the strategy is in response to changing water level conditions, the stated objectives are not necessarily (or defined as) ecological objectives.

The stated objectives of the AM Plan are also reflective of the different meanings AM has for various actors engaged in resource management. Governments embrace AM for the promise of greater system wide models that will allow at least the appearance of scientifically based policy and decision-making. Resource managers, responsible for specific management initiatives, seek predictive tools. AM has held out the promise of reducing predictive uncertainty. Finally, the scientific community finds comfort in AM for its experimental approach and recognition that ecosystem dynamics are often poorly understood and that monitoring and data collection, the work of scientists, becomes keenly relevant.

Lee (1999) noted that it was common for environmental problems to be prescribed a cure of "planning." Lee concluded, that AM, as a form of planning,

> …has been framed so as to win favour with those who are nominally in charge of stewardship – typically government managers or harvest regulators and private landowners. When these stewards' legitimacy is under attack, adaptive management has at times appeared to be a way to deflect criticism by opening the way to trying novel ideas. (Lee, 1999, pg. 13)

The DOI Technical Guide stated that an AM strategy not only required explicit objectives, but objectives must be measureable, so that success or failure could be assessed, and objectives must be project relevant (Williams et al., 2007). It was noted by Leger & Read (2012) that the IUGLS directed the AMG not to identify or propose any adaptive responses to extreme water levels in their AM strategy as this was not within IJC authority or mandate. Such proposals would be left to those agencies involved with a coastal zone management mandate (Leger & Read, 2012). It was as if to say the IJC had decided that an AM decision informing strategy was the best way forward without considering what decisions or objectives such a decision informing strategy might entail. This stated constraint in the drafting of the AM Plan makes any in depth analysis of the extent of measurable and project relevant objectives relatively pointless.

## 5.4 Stakeholders

The IJC's recommendation to use AM as a decision informing strategy was premised on the stated rationale that, by using AM, government, stakeholder and general public decision making would be better informed to respond to extreme water level conditions (IJC, 2013a; IJC, 2013b). While not explicitly stated as such, this rationale can be characterized as the IJC identifying poor information access/exchange amongst governments, stakeholders and the general public as being a problem. One stated objective of the AM Plan was to have the Great Lakes-St. Lawrence River community "equipped to make informed decisions on changing water levels and climate conditions" (IJC, 2013a, pg. 9).

As discussed in section 2.3 of this thesis, a key component of the AM Plan was the proposed creation of two new groups. A Boards of Control Adaptive Management Committee (AM Committee) was proposed to report to the existing water regulation boards being the Superior Board, the St. Lawrence Board and the Niagara Board. The AM Committee would be responsible for mid-term to long-term (not within year events) assessment and evaluation of current water level regulation plans. The evaluation by the AM Committee would be specific to water level conditions and their impact that can be controlled, or are the consequence of water level regulation. A second group, the LAB was proposed to develop and evaluate solution efforts that address water level conditions and their impacts that cannot be controlled by regulation, or are not the consequence of water level regulation. (IJC, 2013a)

Throughout the supporting material giving rise to the AM Plan, and within the AM Plan itself, it was acknowledged that it would be agencies that fall outside the authority of the IJC that would be responsible for implementing any AM strategy to address extreme water levels (IJC, 2013a; Leger & Read, 2012). The LAB as proposed would be comprised of existing senior officials from Canada and the U.S. already engaged in Great Lakes water level issues (IJC, 2013a). As such, there would be heavy reliance on the agencies, organizations and governments backing the participation of these senior officials on the LAB to identify stakeholders and to solicit their engagement.

The development of an AM strategy by the IUGLS did not involve a formalized stakeholder identification process. Outreach activities aimed at developing the AM strategy emphasised an expectation of eventual participation by federal, provincial, state, regional government and non-government agencies (Leger & Read, 2012). The AM Plan in addition to identifying and suggesting certain federal, state, and provincial representatives/agencies for LAB membership or association, described stakeholder groups proposed for LAB participation as consisting of "…shipping, industry, environmental, riparian, rec. boating, etc. (sic)" and possibly a "public layperson" (IJC, 2013a, pg. 34).

The literature supports the view that the best AM plans are the result of multi-stakeholder participation (Allen & Gunderson, 2011; Reed, 2008). Normative claims promote multi-stakeholder participation as an element of democratization. Given the problem implied by the IUGLS appropriate for an AM strategy, that being one of poor information access/exchange amongst governments, stakeholders and the general public regarding water level conditions, the pragmatic argument is simply that multi-stakeholder participation would lead to better information access/exchange. It was this pragmatic argument that dominated the discourse in the AM Plan, but this description was advanced absent stakeholder participation in the drafting process.

Walters and Holling (1990) emphasized the need for stakeholder engagement and participation at the outset in identifying the problems, objectives, policies to be probed, and outcomes to be monitored using an AM strategy (Henriksen & Barlebo, 2008; Walters & Holling, 1990). Taylor's comments on behalf of the DOI, as noted, suggested that at least from the DOI's perspective, the AM Plan as a proposal required more comprehensive involvement from agencies ultimately responsible for execution and involvement. Gravel, on behalf of The Shipping Federation of Canada echoed those sentiments when she wrote:

> In view of the breadth and scope of the document, we would have expected that interested stakeholders would have been given more than

> thirty days in which to provide their comments. (Gravel, 2013, pg. 3 of April 19, 2013 attachment)

The observations by Taylor and Gravel, and the absence of a systematic stakeholder identification and engagement process by the IUGLS in the preparation of the AM Plan raises again the question of what management system or systems will be subject to any AM Plan fostered by the IJC. Who are the stakeholders affected by such management? While there was not a lot of public response during the limited commentary period, one citizen wrote:

> The document I just tried to read is almost impossible to get through – and I am a pretty patient reader. Yes, yes, I know this is “a complex issue with so many governmental groups involved”. I have direct experience as a citizen group member of multiple DNR/IJC projects, over 9 years, so I know! But to study and assess and coordinate at the level this document attempts to address is a recipe for complete inability to take action, and swiftly, which is what is needed here. When you want to stop a bathtub from emptying, you close the main drain. (DeMyer, 2013)

While Allen & Gunderson (2011), Gregory et al. (2006) and Williams et al. (2007) emphasized the importance of stakeholder engagement; concerns about and examples of the need for effective stakeholder engagement are not unique to an AM strategy (Foster & Jonker, 2005). The AM Plan arose as a proposal after extensive study and the conclusion that the water level regulation capabilities of the IJC were not physically sufficient to address extreme water levels in the Great Lakes. For the IJC to assume it could solicit a broad mandate to coordinate, support and foster AM amongst stakeholders who would essentially volunteer to be subject to such direction subsequent to the drafting of the AM Plan appears to exhibit a top down perspective that is counter intuitive. There is little in the AM Plan and supporting documentation to support a conclusion that stakeholders are prepared to have an expanded IJC coordination function integrated into their respective individual management mandates and operations.

## 5.5 Indicators of Success

The AM Plan stated the following about the indicators of successful implementation:

> …a clear framework must be established for determining the effectiveness of adaptive management towards meeting outcomes through clear metrics that demonstrate progress towards meeting overall goals. These metrics will be further scoped out by the LAB with input from contributing agencies, organizations, and the IJC, but should be

> consistent with specific milestones. For example, measure of success might include all agencies and organizations of [sic] fully engaged and collaborating on the AM Plan. It could be measured by successes in solving longstanding issues through the AM Pilots that have not been resolved through existing mechanisms. It could be that stakeholder [sic] are fully engaged and have ways of accessing information and ways to inform the decision-making process and complaints by stakeholders are reduced. The overall success of the AM Plan will be that the process is being effective in influencing decisions aimed at reducing impacts of extreme water levels in a cost effective, efficient and sustainable way. (IJC, 2013a. pg. 56)

It is difficult to orient the stated indicators of success in the AM Plan with AM theory and existing AM selection criteria guidelines. A plan for AM should provide, in addition to articulated goals and objectives, a description of the indicators that will show the measurement of progress towards achievement of objectives. Full engagement of "all agencies and organizations" in collaboration in the plan itself, would not necessarily be an indicator of success unless progress is made towards meeting management objectives, monitored results influence management decisions, and management conduct is legally compliant (Williams et al., 2007).

If the overall objective of the AM Plan is simply full stakeholder engagement with "…ways of accessing information and ways to inform the decision-making process and complaints by stakeholders are reduced," (IJC, 2013a, pg. 56) this continues to beg the question about what are the expectations or objectives of the AM Plan in changing environmental management policy and practice. By concluding that overall success will be a measure of the effectiveness of the AM process in influencing decisions, which (the decisions themselves) are aimed at "…reducing impacts of extreme water levels in a cost effective, efficient and sustainable way," (IJC, 2013a, pg. 56) the AM Plan has entered the realm of tautological rhetoric.

AM is a strategy for informing management decision making. Engaging in AM or measuring the level of stakeholder engagement in the strategy is not an indicator of strategy success. The success of an AM strategy could be measured on the basis of considering alternative strategy results. The comparator being the impacts of management action, in the case of addressing extreme water levels, realized through management decision processes that are not informed by an AM strategy.

It is of concern that reduction of stakeholder complaints is specifically identified as an indicator of success in the AM Plan. As Lee (1994) pointed out, referencing Holling (1978), "the reason boundaries exist where they do is that they are tested periodically" (Lee, 1994). Lee suggests that conflict drives learning, and that cooperation/collaboration does not necessarily result in better management (Lee, 1994). A reduction in stakeholder complaints about the IJC's exercise of its water regulation mandate while it may be of importance institutionally to the IJC would not indicate whether the AM Plan was improving management decision-making.

The Council of Great Lakes Governors, as the Secretariat for the Great Lakes-St. Lawrence River Water Resources Regional Body and the Great Lakes-St. Lawrence River Basin Water Resources Council wrote the following in April 2013 in response to the IUGLS/IJC's request for comments regarding the indicators of success in the AM Plan:

> …we continue to encourage a set of clearer metrics in order to evaluate the success or failure of the adaptive management plan. General goals related to "improved understanding" and information availability are appropriate but should be supplemented with more specific performance metrics extrapolated from the regulation plans and specifically developed for more comprehensively evaluating the adaptive management plan. While these may be further developed at a later time, it would be useful to telegraph some of the potential metrics that could be used in order to inform future work—for example, incidence of flooding/erosion; protection of infrastructure; navigability; protection of beaches and wetlands; and hydropower generation. As the plan states, adaptive management will require a long-term commitment by many entities, and it will be important to track progress and make changes to the plan itself as implementation moves forward. (Naftzger, 2013, pg. 1)

Indicators of success serve the function of focussing an AM strategy on stated goals and directing relevant monitoring activity. It is in the consideration of the monitored impacts of alternative strategies in comparison to modelled predictions that results in management learning. Objectives need to be clear for measurement to be instructive. It is also important to identify which and whose management system is responsible for generating the conduct or action being monitored.

If an objective of the AM Plan is "… to provide an improved collaborative, systematic and iterative approach to inform on-going decision-making" (IJC, 2013a, pg. 6), and a success indicator is "improved understanding" of the nature and consequences of extreme water conditions, this is an indicator quite unlike an ecological system management metric. This "state of knowledge" metric, to have any basis for analysis, would require baseline data regarding the information available and utilized by stakeholder decision makers at the outset of the AM strategy. This metric would also require data about the state of knowledge of the stakeholder decision maker at some monitored point in the AM cycle. To evaluate the benefit or success of the AM strategy as described, some basis for comparison of the decisions made without the knowledge acquired during the AM cycle with those made with the acquired knowledge would have to be made. Determination of whether it is improved collaboration, an improved system of knowledge management, or simply decision reconsideration will be necessary to determine which aspect of the AM strategy lead to a measurable and improved change in management. To put this in context, if individual stakeholders are currently largely ignorant about the hydrological conditions that are giving rise to unpredictable water levels and changes in water levels, a greater understanding of the processes leading to such unpredictability may not be of significant assistance in management decision support if future conditions are, by model definition, unpredictable.

Making the collective engagement of stakeholders in a described process of AM an indicator of success for the AM Plan is reflective of some of the analysis that preceded the AM Plan (IJC, 2013a), and the IUGLS Final Report (IUGLS, 2012). In 2011 the AMTWG received a report prepared by Dr Michael Donahue titled 'Implementing a Non-Regulation Adaptive Response to Water Level-Related Impacts: An Institutional/Governance Analysis' (Donahue, 2011). In Donahue's report he referred to AM as a "philosophy" and described the success of an AM strategy as "…fundamentally dependent upon the ability of Basin institutions to exhibit their own form of adaptation" (Donahue, 2011, pg. 4). This confusion of AM with adaptation continued throughout Donahue's report in which he described a "Long-Term Adaptive Management Program" as being developed through the performance of a number of tasks related to "adaptive risk management" research, assessment, tool identification, expert systems approaches and the "identification/assessment of adaptive risk management measures with an emphasis on mechanisms for coordinated institutional response" (Donahue, 2011, pgs. 5 & 6). Donahue concluded that local government primarily make responses to the impacts of extreme water levels, in practice. From this conclusion Donahue asserted that there was a need for a formal, bi-national agreement to "facilitate the design, application and evaluation of adaptive response measures" which would use the IJC, or other bi-national institution to maintain,

> … a "tool kit" of proven adaptive response methodologies; advocating and guiding their application on pilot and System-wide scales; convening and coordinating multiple jurisdictions at the bi-national level; and monitoring and evaluating the performance of individual measures, and
>
> Establish a Bi-national Coordinating Committee with broad agency representation to oversee the Adaptive Management Program and "harmonize" adaptive response approaches among various levels of government and jurisdictions. (Donahue, 2011, pg. 47)

Tool kits and harmonized management response is antithetical to AM theory and falls into what Allen & Gunderson (2011) would describe as a pathology of AM. It cannot be overstated that a top down directed approach that seeks to "harmonize" management approaches, whether adaptive or not, assumes the existence of identifiable best practices which avoid the risks necessary for the learning benefits of AM to be realized.

Indicators of successful adaptive response measures are noted to be difficult to envision, measure and track (Ford, Berrang-Ford, Lesnikowski, Barrera, & Heymann, 2013). Outcome measurement, whereby measurement from a baseline is undertaken to ascertain progress to reduce vulnerability to climate change impacts, is difficult particularly due to the time scale differences between anticipated future climate change induced events and the need for current evaluation of management actions, iteration and institutional learning that is required of an AM strategy. A satisfactory engineering response to current low water conditions may indicate very little about capacity or preparedness for future water level extremes. For this reason, some authors have proposed utilizing adaptation reporting as a proxy (Ford et al., 2013). Given the lack of standards for such proxy measurement, and the inherent unknowns about the physical manifestation of climate change impacts, indicators that measure adaptive response on the basis of readiness, policies, programs or described adaptation action, in other words process measurement, would still provide an incomplete assessment for comprehensive management learning.

## 5.6 Identification of Uncertainty and Multiple Hypotheses

The uncertainty identified in the AM Plan is described as "uncertainty in managing the risk associated with lake level changes" (IJC, 2013a). As noted, the IUGLS concluded that the hydrology of the Great Lakes and the various factors influencing water levels is only partially understood. The AM Plan in its introductory section stated:

> There is strong evidence that extreme water levels (both high and low) outside the historical range are plausible, and in fact Lake Michigan-Huron set new record low water levels in January 2013 (based on 1918-2012 period of record)(DFO, 2013; Environment Canada, 2013; USACE, 2013b). There is considerable stakeholder concern and media attention over the current low water levels, their cause, and actions being taken to address them. Better tracking and understanding of these changes can help reduce uncertainty and inform solutions. (IJC, 2013a, pg. 4)

The IUGLS Final Report (IUGLS, 2012), in particular, commented on the inability of current models to provide reliable predictions in the near or long term about variable water levels in the Great Lakes in general, or specifically predict the occurrence and likelihood of water level extremes. For this reason, the IUGLS Final Report recommended regulation plans for the Upper Great Lakes that would be robust enough to account for continued potential extremes. The principal reason for this uncertainty is the lack of correspondence between model calculated Net Basin Supply ("NBS") and actual monitored water levels. Arguably, it is not simply the various models for future climatic and other contributing events affecting NBS that form the multiple hypotheses that could have been articulated in the AM Plan. What appears to be missing is the expression of a hypothesis, to be tested, that better data regarding hydrological factors, and better understanding of the Great Lakes hydrological system itself through improved models, will reduce uncertainty and make for better decisions at an operative level. This was advanced as a conclusion rather than a hypothesis in the AM Plan and supporting material.

AM theory calls for the explicit identification of uncertainties and was intended to be used as a management decision informing strategy to reduce but not resolve identified uncertainties. There is a difference between risk and uncertainty. In economic and management term usage, risk usually describes a quantity, that while perhaps unknown, is "susceptible" to measurement (Knight, 1921). Uncertainty describes an existing or future state that is impossible to accurately or completely describe (Knight, 1921). A strategy of compiling and relying upon best available knowledge to make resource management decisions to mitigate risk, even with an expressed willingness to change any decision when new or better information becomes available, is not by definition, AM. This is a trial and error approach to risk management. The informed and explicit selection of such a management strategy may be appropriate where the assurance of a best outcome, based on best current knowledge is required as a matter of policy or law. An AM strategy effectively discounts “state of knowledge” decision making in favour of long-term learning.

Deconstructing the statement “uncertainty in managing the risk associated with lake level changes”, suggests that the AM Plan was premised on the assumption that lake level change impacts are measurable, whereas management is uncertain. By confusing the uncertainty as being in the management of the risk associated with lake level changes, the far more obvious uncertainty, that of climate change and its impact on lake levels becomes obscured. Explicit recognition of that uncertainty, and analysis of the potential for the reduction of that uncertainty through hydroclimatic monitoring and modeling in the AM Plan, could have made arguments for or against the AM Plan as opposed to other management strategies much clearer.

The IUGLS Final Report (IUGLS, 2009) illustrated the elements of its AM strategy as follows **(Figure 5.1)**:


***Figure 5.1*** IUGLS Final Report illustration of the Elements of an Adaptive Management Strategy. **Source:** (IUGLS, 2009, pg. 159)

While implementation of adaptive response is necessarily an issue of governance, the urge or impetus for an adaptive response is usually the consequence of an environmental response or impact. In effect, the IJC has come to the realization that its capacity for water level regulation has been surpassed by the Great Lakes hydrological system's response to climate change. Assuming that an AM strategy will generate "solutions", while allowing the continued regulation of the Great Lakes as prioritized in the BWT, indicates at the very least a lack of identification of a significant uncertainty relevant to a management decision.

## 5.7 Models as a Means to Reduce Uncertainty

Regarding climate change modelling the IUGLS Final Report stated:

> The Study's analysis of future climate change scenarios found that while low water extremes appear to be more likely, high water level extremes over the coming century are also plausible and should not be dismissed. Decision making for addressing these potential risks into the future needs to be informed by improved science and outputs from GCMs and RCMs, better attribution of observed trends in climate, as well as improved understanding of the extent of current and future climate related risks. (IUGLS, 2009, pg. 161)

In the literature regarding climate change there has been growing recognition that for more than 30 years, regardless of improved models and modelling processes, there has been little to no improvement in the ability of climate models to predict future climatic conditions or the impact of climatic variables such as air and water temperature (Roe & Baker, 2007). Global Climate Models ("GCM") are generally considered to be more accurate than Regional Climate Models ("RCM"), but both suffer from non-reducible predictive uncertainties. That reality continues to apply to climate change impact predictions regardless of whether they are based upon chaos-theoretical process models or the less frequently used random walk (stochastic) process models.

The expressed view of the IUGLS that improved climate models will lead to better adaptive response decisions represents a form of false reductionism. More data, and more detailed models, while giving the appearance of being more "real" due to the nature of model structure, do not make the models more predictively accurate (Desai, Hulme, Lempert, & Pielke, 2009).

The AM Plan calls for improved use of precipitation data, improved runoff estimation, improved connecting channel flow estimation, and improved thermal expansion and contraction estimation, all with a view to improving hydrologic prediction for the Great Lakes and the forecasting of NBS (IJC, 2013a). The coupling of these improved hydrologic models with improved climate models (both GCM and RCM) lead the AM Plan to assert; "[i]mproved climate models will allow for improved risk assessment and prudent planning" (IJC, 2013a, pg. 40).

This expression of the use of models as a pathway to certitude misses a critical step for an AM strategy as it requires "large-scale management experiments that directly reveal process impacts at the space-time scales where future management will actually occur" (Walters, 1997b). Management by experiment is really the essence of an AM theory compliant strategy. A strategy that focuses on securing the "best model", rather than using models to formulate hypotheses for management experiments, and in turn relying on the "best model" to point the way towards the "best policy" falls short of realizing on the promise of AM theory (Walters, 1997b).

Regardless of differences between models in how dynamic environmental systems are described or understood, if a given management action is predicted to have comparable results or system impact by competing models, there is no strategic point in trying to refine a model or make a determination based upon "more data", experimentation, or monitoring to determine which model is more accurate (Williams et al., 2007). The management of municipal infrastructure in a Great Lakes coastal community faced with low water levels provides a good example. Various hydrologic models can weight differently the importance of factors affecting NBS in the Great Lakes, but virtually all models predict that current water level regulation capabilities will not maintain historic lake level range and extreme water levels can be anticipated. There is little use a municipality can make of the knowledge as to how much isostatic rebound, climate change, channel flow change or run off change contributed to the situation. While monitoring and improved models can serve a number of scientific functions, the aim of AM theory is to provide management with decision informing information that in context is specific, timely, and relevant. It is not the primary role of AM to engage stakeholder resources in data acquisition for purposes such as RCM refinement, particularly where resource management funding and capacity is limited. AM should not be utilized as a back door approach to addressing a lack of scientific research programs.

## 5.8 Learning from Results

Institutional learning is described by Donahue in his report as a function of the IJC going from occasional studies to continual learning and having a significant role in promoting consistency amongst agencies in the implementation of adaptive response measures (Donahue, 2011). Those conclusions are expressed in the AM Plan:

> The IJC has an on-going need for understanding hydroclimate and climate change science in the Great Lakes - St. Lawrence River Basin to allow for on-going assessment of implemented regulation plans for both Lake Superior and Lake Ontario outflows and to understand system-wide climate changes in context of water management decisions now and in the future. The IJC can play a lead facilitation role working with governments to set priorities. (IJC, 2013a, pg. 40)

Institutional learning is distinct from technical learning which together form the double loop learning cycles anticipated by AM theory (Williams & Brown, 2012). There is relatively little discussion in the AM Plan about formal learning. The AM Plan described AM as a structured process that "improves management by learning from the outcomes of previous policies and practices" (IJC, 2013a, pg. ii). The AM Plan described AM as "learning while doing" (IJC, 2013a, pg. 11) and mentions learning from AM Pilots (IJC, 2013a, pg. 50), but that is the extent of any reference to learning in a document that ran to some 82 pages. There is a similar paucity of reference to learning in the IUGLS Final Report (IUGLS, 2012), and the AMTWG Final Report (Leger & Read, 2012).

Managing to learn is fundamental to AM theory. Lee wrote extensively about the value and cost of learning using AM and iterative cycles (Lee, 1994). A plan for AM which does not formally describe an intended learning framework or lacks in particular structure about an explicit learning strategy will fail to realize the "point" of an AM strategy. Collaboration, which the AM Plan identified as an objective, is really just one process of many to facilitate management learning (Armitage, Marschke, & Plummer, 2008).

AM theory was developed in the belief that extensive study and analysis to determine the "correct" decision, before making same (front end knowledge), results in rigid adherence to policy and institutional inflexibility. Defending management decisions impedes institutional learning and prevents genuine regard to system feedback (back end knowledge). AM in both its active variants as management by experiment, and its passive variants which demonstrate simply a willingness to change policy in the face of monitored outcomes, requires real capacity for learning and the ability to change policy direction if the strategy is to be of value. From a manager's perspective, AM in practice means that not only must there be available policy choices and the capacity to select amongst policies, the selection of a given policy or management decision is only temporary, and subject to change based upon what is learned.

Doremus (2010) argued that, as a management decision informing strategy, AM should only be used when the additional costs of AM could be justified by the anticipated and predetermined value of management learning. She stated:

> What is needed is a kind of broad-brush cost-benefit analysis evaluating the tradeoffs inherent in choosing an adaptive approach. In most cases, that will boil down to estimating the expected value of learning for achieving management objectives, and comparing that added value to the costs and complications it will impose. That is not an easy task, and we should not expect anything like precise quantification. The analysis itself will, of course, consume agency resources. But I am convinced it will be worth it, leading to more self-conscious management even if the choice is not to undertake an adaptive approach. (Doremus, 2010, pg. 1479)

AM, as a theory is intended in its application to result in learning about ecological processes and to change institutional arrangements (Williams et al., 2007). As the DOI Technical Guide described it:

> …the use of adaptive management in resource management almost always requires a fundamental shift from the status quo. For example, it typically is necessary to rethink the nature of risk aversion that characterizes decision making in most Federal agencies, and to explicitly recognize uncertainty as a key attribute of natural resource management. Without a willingness to embrace uncertainty, adaptive management is unlikely to succeed. (Williams et al., 2007, pg. 38)

Virtually all ecological systems, which are being managed, demonstrate significant uncertainties about their future state, which in turn makes the impact of management decisions uncertain. Normative assertions about the value of learning, and in particular learning about ecosystems subject to climate change scenarios, does not constitute a structured learning framework or provide the analysis required to determine whether the value of learning justifies its expense.

## 5.9 Management Improvement

The AM Plan did not directly describe the specific management improvement anticipated if the AM Plan was implemented. As noted, adaptive management and adaptation are used interchangeably throughout the AM Plan (IJC, 2013a), the IUGLS Final Report (IUGLS, 2012), and the AMTWG Final Report (Leger & Read, 2012). By implication, the AM Plan identifies institutional adaptation as management improvement. In the IUGLS Final Report, institutional adaptation is described:

> Institutional adaptations can range from modest efforts (e.g., new collaborative arrangements, establishing new priorities, exercising unused authorities, redirecting or seeking additional funding) to more ambitious efforts (e.g., securing new legislative or regulatory authority, establishing a new international agreement and/or institution, establishing/ funding major new monitoring and modelling programs). (IUGLS, 2012, pg.158)

To a significant degree, the description of management improvement anticipated by the AM Plan assumes that by engaging in the described elements of AM, improved management is axiomatic. The IUGLS Final Report stated further:

> Better coordinated data and information related to hydro-climate and climate change is required by coastal zone managers and decision makers to identify and advance means to induce and promote adaptive actions. Applying adaptive actions, in turn, implies a commitment to monitoring, modelling, observing changes and regularly evaluating strategies to manage resources in light of uncertainty and new conditions…. information and education are powerful components of adaptive management. They contribute to both anticipating and preventing lake level-induced damage, particularly when focused on understanding risk, the limits of regulation, inherent uncertainties and system vulnerability. (IUGLS, 2012, pg.158)

AM theory was developed prior to climate change being identified as a significant source of uncertainty in resource management (Doremus, 2010). A particular problem climate change presents to the application of an AM strategy is the timing of the iterative learning cycles and management changes in response to learning, with the timing of the climate induced changes in the resource. The DOI suggested approach is to use scenario-planning techniques that would result in management improvement through the learning derived from scenario adequacy testing against observed conditions (Williams & Brown, 2012, pg. 76).

With water resources, a suggested approach by the DOI is classical experimentation or sequential updating of model confidence using Bayesian statistical analysis (Williams & Brown, 2012, pg. 76). Extreme water levels for the Great Lakes exhibit the uncertainties of climate change as well as the uncertainties of hydrological cycles. The necessary learning to achieve management improvement using the DOI guidelines for AM will be a complex analysis which incorporates scenarios for climate change tested against observed conditions, with updated hydrological models based on Bayesian statistical analysis. For management to improve through learning, the timing of this analysis must be in advance of system change so that improved management can be implemented ahead of any system changes. It is the timing of the changes in management in advance of system change, which in turn must be monitored in real time that becomes incredibly difficult if the unpredictable sequence and impact of climate change as currently understood and modeled is accurate.

# 6 Discussion and Conclusions

***Öll segl eiga ei við öll skip (All sails do not suit every ship)***

**Icelandic Proverb**

The AM strategy addressed in the AM Plan focused on improved anticipation and response to future extreme water levels (IUGLS, 2012). The proposed AM Plan advocated better models, better monitoring and better information sharing and analysis of initiative/project outcomes amongst stakeholders as the means to improve overall resource management performance. The ‘predict, monitor and manage’ interpretation of AM is considered by EIA practitioners as a sensible way to address predictive uncertainty (Glasson et al., 2012). The AM Plan assumed that improved resource management could largely be accomplished utilizing existing management structures and resources.

AM is a relatively simple process to describe in theory as a natural resource management decision informing strategy. A management decision is made to select from a number of identified and available management options, predictive modelling is used to anticipate the system impact of a chosen management option, the impacts of that selection decision are monitored and adjustments or re-selection of options are made based upon management learning from monitored results and model adjustment. Distinctions are made between so called passive AM, where one management decision is followed and monitored at a time, and active AM, where a number of alternative decisions are tested simultaneously as experiments and compared with a control to identify factors that are affecting a resource system (Linkov et al., 2006).

The distinction between AM and “traditional management” was described and illustrated by Linkov (2006) as follows **(Figure 6.1)**;

> During the adaptive management process, in contrast to traditional management, change is welcome, learning is emphasized, and even goals and objectives for the project may be revisited and revised. (Linkov et al., 2006, pg. 1080)

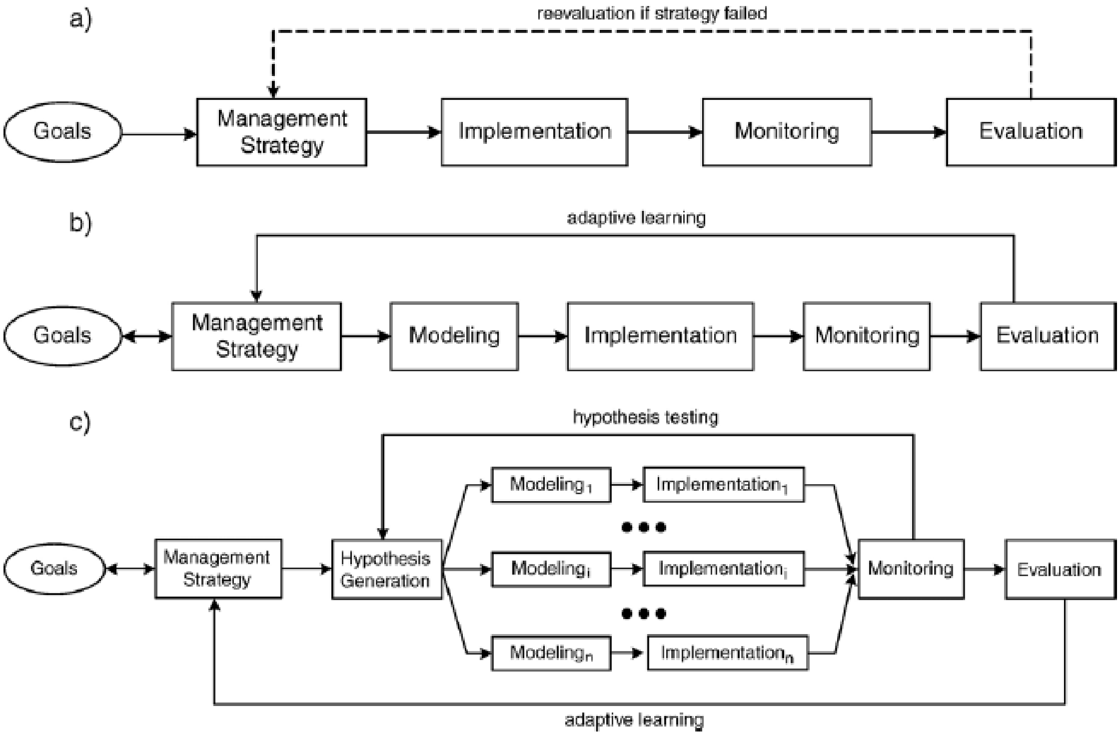



***Figure 6.1*** (a) Traditional management process; (b) Passive AM process; (c) Active AM process. **Source:** (Linkov et al., 2006, pg. 1080)

The AM Plan fails to satisfy all of the described selection criteria for a theory compliant AM strategy. This conclusion is subjective and based on an analysis of the AM Plan following application of the 14 Key AM Selection Criteria Questions Assessment process **(Table 4.1)** and the subsequent discursive assessment. As no specific potential management decisions or choices were identified in the AM Plan, it is not clear whether the AM Plan is supportive of a passive or an active AM strategy. If, for example, an identified decision uncertainty had been whether or not to dredge a commercial harbour on the Great Lakes, which due to limited draft caused by low water levels was experiencing limited commercial shipping loads, a passive AM process would suggest a singular management strategy (such as dredge/no dredge) be selected, modelled, implemented, monitored and evaluated. If the AM Plan is promoting an active AM process, similar harbours might be treated differently to test whether dredging, pier extensions, changed ship design (lighter barging), or doing nothing (a potential control) provide greater environmental, economic and social benefits.

In AM theory, system feedbacks based upon monitoring of the impacts experienced due to a chosen management decision are intended to improve system models and reduce uncertainty. If the assumed harbour draft problem is used as an extended example, it is difficult to identify how the monitored impacts of a selected management decision will lead to improved system models. Put another way, a problem presented by an incomplete understanding of the hydrology of the Great Lakes and the impact of climate change, amongst other factors affecting water levels, is that it is currently not possible to accurately predict where lake levels will be at any future point. A stakeholder, operating a commercial harbour on the Great Lakes, faced with current draft limitations cannot predict whether dredging now is the optimum management choice. If lake levels were to return to their historic range in the near term, then the harbour that chose to dredge would have unnecessarily impacted on the environment and have incurred significant costs for little or no benefit. While monitoring the impact of dredging might lead to improved dredging techniques, it would not necessarily contribute to an improved understanding of the resource system or result in improved system models regarding the hydrology of the Great Lakes, or the impacts of climate change.

The conclusion that the AM Plan was not rigorously considered using AM strategy selection criteria, would suggest a prescription of reconsideration using AM selection criteria. The weakness in that conclusion is that there is very little information to suggest that the relatively few, and much smaller scale successfully implemented AM strategies, owe their success to careful application of the recognized AM selection criteria. Consideration of the14 Key AM Selection Criteria Questions **(Table 4.1)** would however clarify what role an AM strategy could play in stakeholder management decision-making. As currently sketched, the AM Plan appears not to make AM an encompassing management strategy, but simply an adjunct.

If the problem identified by the IJC is simply one of how to improve inter agency resource management coordination and information dissemination, there may be no need to encumber the resolution of that problem with an over-arching strategy as described in the AM Plan.

## 6.1 Problem Definition

Problem definition is critical, and the initial step in determining whether an AM strategy is warranted. Problems are constructs, that is, they do not exist independent of context or the perspective of the institution or individuals who are describing something as a problem. The problem generally identified by the AM Plan is one of improving anticipation and response to future extreme water levels on the Great Lakes. Institutionally, a problem for the IJC is that it is charged with the task of undertaking a reference to provide policy advice to alleviate against the impacts of fluctuating water levels that are assumed by the reference question to be manageable. The reference question was: "How to manage fluctuating lake levels in the face of uncertainty over future water supplies to the basin while seeking to balance the needs of those interests served by the system?" (IUGLS, 2012, pg. i).

Predecessor studies to the IUGLS Final Report (IUGLS, 2012) had concluded that regulation had limited impact on extreme water levels in the Great Lakes (IJC, 2013b). In a sense, the reference problem presented to the IJC reflects a paradox of enhancement. The question creates an expectation that fluctuating lake levels given existing or proposed regulation structures "can be managed," and further, that the interests of those served by the system "can be balanced."

There is little information on how or why AM was identified as a strategy by the IUGLS to address the reference question. It cannot be asserted based upon any available documentary information that the IUGLS or the IJC objectively adopted AM as a strategy to deflect focus from the reality of their own jurisdictional and regulation capacity limitations. However, once identified as a strategy, AM easily provides a framework for redefining a problem as being an issue of predictive uncertainty requiring improved models, formal monitoring, learning, and responsive management adjustment.

It is suggested that in addition to the nine pathologies identified by Allen & Gunderson (2011) regarding AM, an addition or extension to the pathology of action procrastination becomes evident in the AM Plan. In the absence of any identified possible management actions to be tried or considered within the capacity and jurisdiction of an institution to address a complex problem, AM can be promoted as a "fill the void strategy." As a pathology, AM exhibits institutional mandate expansion and a requirement for additional funding, while providing the apparent comfort of status quo governance structures.

It would also not be accurate to suggest that the identified failure of the IUGLS and the IJC to completely identify the problem(s) and objective(s) consistent with AM theory in the AM Plan is the consequence of any lack of effort. While AM theory calls for such definition, climate change influences on resource systems create “wicked” (Rittel & Webber, 1973) (lacking clearly understood definition, messy, complex, and ultimately unsolvable) problems as:

> The formulation of a wicked problem is the problem! The process of formulating the problem and of conceiving a solution (or re-solution) are identical, since every specification of the problem is a specification of the direction in which a treatment is considered. (Rittel & Webber, 1973, pg. 161)

Presenting the IJC with the referenced task of “managing” lake levels, in the context of acknowledged uncertainties about NBS and climate change influence virtually assures that the prescriptive institutional response will be to seek ways to maintain an existing governance mandate while adapting to a changed and unpredictable resource system. The question defines the solution that calls for stakeholder adaptation to the limitations of regulation (Billé, 2009). The fact that the problem is not, or arguably cannot, be better defined in order to evaluate whether an AM strategy is appropriate is a reflection of the wicked characteristics of strategizing for climate change adaptation (Termeer, Dewulf, & Breeman, 2013).

## 6.2 Stakeholder Engagement

The AM Plan and the AMTWG recognised that it is a stakeholder community that was not directly involved in the drafting and creation of the AM Plan that would have to deliver on the AM strategy. A role of the LAB as proposed by the AM Plan is:

> …take the lead in fostering effective information management and the application of adaptive management methods, since these activities will be critical to the success of the local AM Pilots. (IJC, 2013a, pg. 54)

AM Pilots are proposed by the AMTWG as the approach to engage stakeholders on a regional or localized scale (IJC, 2013a). The concept was described in the AM Plan:

> This scaled-down approach enables participants to more effectively "test drive" adaptive management's iterative tasks with minimal risk, to collectively identify information or knowledge gaps, to collaboratively test alternatives and to modify the management action or decision accordingly. As these scaled-down efforts succeed, more objectives may be added and successfully accomplished. Hence, by creating a series of small wins inherent to the overall pilot process, participants gain greater confidence and experience with the process and, accept additional process improvements, while outside observers are attracted to become participants. (IJC, 2013a, pg. 49)

The project approach to secure stakeholder engagement has been the subject of significant literature in the area of ICZM implementation (Billé, 2009; Julien & Billé, 2010). There is an acknowledged implementation advantage for the pilot project approach, principally due to limited scale and lack of challenge to existing political, economic and social structures. But it is the initial ease of project implementation due to scale, encouraged by an institution from outside a stakeholder community, which raises concerns about replication, scaling up, and the absence of any legal obligation to change if small-scale projects demonstrate existing policy inadequacies.

The AM Plan and the over-arching role assumed by the proposed LAB effectively prescribe how local stakeholders would proceed if they wish to receive whatever benefits are at the disposal or direction of the IJC. Despite advocating an AM approach, the AM Plan still envisions small projects having "wins." In AM theory, it is more likely that small pilot project failures, from a traditional management delivery perspective, will be most informative and advance system wide management learning. The challenge remains to engage stakeholders in pilot projects that should welcome demonstrated failures about the assumptions of existing policies and practices in pilot demonstrations while remaining compliant with legal obligations.

An initial and better focus for the AM Proposal should have been on the uncertainties of stakeholders and their sphere of management. This is a different approach than focusing principally on the limitations of water level regulation and uncertainties of forecasting models as experienced by the IJC. It is an old "saw" but environmental management has more to do with managing people than it does with managing the environment. It is clear from the IUGLS Final Report (IUGLS, 2012) that citizen stakeholders perceived the issues to be about the failure of the IJC to "do something" about extreme water levels. Accordingly there was a public expectation that changes in regulation regimes and the introduction of further flow restriction and compensation structures was what the IJC should be considering.

While it is beyond the scope of this thesis to explore Bayesian networks (also called probability networks) to address stakeholder engagement in extreme water level management issues, the technique of utilizing Bayesian networks as a first step before management process selection would have brought together stakeholders to identify variables of importance which relate to their relevant decision making mandates. Problem identification, which is missing from the AM Plan, could have been made apparent through the identification of the relationships amongst variables and expressions of probabilistic dependencies (Bromley, Jackson, Clymer, Giacomello, & Jensen, 2005). Such an approach would not start from the premise that AM is the strategy to be utilized by stakeholders to address extreme water levels. The approach would be to integrate knowledge amongst stakeholders, identify the problem domain and consider decision-making process choices. Ideally the approach would allow for full consideration of the relationships amongst existing governance structures, available support, social and economic activities and environmental concerns. It might well be that following such a process, stakeholders would identify AM as the decision support approach, but this would be the consequence of stakeholder selection and consideration. Stakeholders would actively participate in the selection of a decision support strategy and consequently engagement in and support for the selected strategy would be a more likely outcome. Part of the management learning process would include learning about decision support strategy selection.

## 6.3 Cost Benefit

The IUGLS in the IUGLS Final Report (IUGLS, 2012) concluded:

> …considerable uncertainty remains regarding the future climate and its impact on Great Lakes hydrology. This uncertainty, along with environmental concerns, institutional requirements and the high costs pose significant challenges for moving forward with multi-lake regulation. Furthermore, there may be adaptive measures that could more effectively address risks related to extreme water level conditions. (IUGLS, 2012, pg. 190)

Effectively the IUGLS was saying that it concluded, absent rigorous stakeholder engagement, that climate change impacts and Great Lakes hydrology are so uncertain that there is no point in considering changes in regulation regimes and/or the introduction of further expensive flow restriction and compensation structures. This implies that the IUGLS did not have full confidence in an AM strategy and predicated its recommendations by closing the door on possible system wide engineering measures. As stated, the IUGLS arrived at this conclusion from a risk and cost benefit analysis perspective that "…there may be adaptive measures that could be more…" effective.

On April 15, 2013, the IJC issued its 'Advice to Governments on the Recommendations of the International Upper Great Lakes Study' (IJC, 2013c). In that document, in addition to recommending an AM strategy, the IJC recommended a detailed environmental study regarding potential structural restoration options to restore levels in Lake Huron and Lake Michigan and engage in a benefit-cost analysis. This was in marked contrast to the IUGLS sole recommendation of an AM strategy.

There are a number of possible methods that could be used to estimate and describe the costs of introducing or not introducing further structural restoration options. One approach would be to attempt to estimate the current cost/benefits of no system wide water level regulation or further flow restriction and compensation structures, and then develop a model for projecting or anticipating those costs based upon future water level predicted conditions. An alternative approach would be to attempt to model a cost for the current value of the regret for not addressing Great Lakes water levels previously and the resultant current situation. As with the current and projected cost model, the level of regret model could in theory be used to project future regret costs using assumptions about future water levels and their impact. Those practices giving rise to the regret cost analysis would include the activities that contributed to climate change, the coastal development practices and the dredging practices which have impacted Great Lake water levels.

Keller, Robinson, Bradford, and Oppenheimer (2007) suggested that a measure of regret due to suboptimal policy choice in addressing CO2 emissions could be modeled as a cost. They proposed a model wherein management strategies could be compared initially on the basis of "relevant trade-offs and observations about past value judgments" (Keller et al., 2007). By application of this model to CO2 emission abatement, a conclusion was reached that the delay in starting initiatives to achieve defined targets, described as procrastination, must be considered as a purchase cost.

Economics provides a number of analytical tools for evaluating management policy and the selection of a particular management method, such as AM. The most widely used economic decision analytic tool is cost-benefit analysis ("CBA"). CBA is an informational tool which assists in making a decision such as whether a course of management action should proceed. Simply put, CBA asks the question: "Do the benefits outweigh the costs?" CBA takes into account externalities and non-monetary costs as well as monetary costs but seeks to monetize, for comparison purposes, all costs using a common value system. Anticipated future benefits and costs are discounted using a present cost valuation. Some costs and benefits are estimated as only having a certain degree of probability or chance of occurrence, accordingly, in the CBA process, the degree of probability acts as a further discounting factor in the present value calculation of future costs and benefits.

Uncertainties and lack of complete information challenge the application of CBA. Where variances of either or both costs and benefits are not finite, CBA is not a useful analytical tool (Tol, 2003). While uncertainty about the costs and benefits of management action can lead to inaction or selection of an approach that simply calls for further study, that too can be considered as a cost.

As noted, the IUGLS concluded that climate change plays a significant role in explaining current extreme low water levels in the Great Lakes (IUGLS, 2012). Tol (2003) argued, "…it seems as if the uncertainty about climate change is too large to apply cost-benefit analysis." His reasoning was that for CBA to be of utility in assessing management choices, potential states and consequential impacts have to be finite (Tol, 2003). He was addressing climate change on a global scale, but if his argument is correct, it suggests that all geographic specific subsets experiencing the impact of global climate change, such as the Great Lakes, share infinite potential states and consequential infinite impacts due to climate change.

Future water level conditions on the Great Lakes are unknown and largely unpredictable. For this reason, CBA has serious limitations for analysing whether an AM strategy and/or the introduction of further flow restrictions and compensation structures for managing extreme water levels on the Great Lakes is appropriate.

Safe Minimum Standards ("SMS") is an alternative economic approach to CBA that utilizes defined thresholds as triggers. An SMS approach would require predefined management preservation action in the event certain resource states are realized. Such predefined action would be taken, as triggered, unless it could be demonstrated that the social benefits that will be lost absent continued or further development of a resource net of the expected benefits of preservation exceed an acceptable level (Crowards, 1998). SMS is intended to act as a policy shifting mechanism to prevent irreversible consequences arising from the continuance of an inappropriate management strategy. Tol dismisses SMS as being arbitrary, undemocratic and not sensitive to people's preferences. (Tol, 2003).

Accurate water level records have been recorded for the Great Lakes for close to 100 years (The United States Army Corps of Engineers, 2013). This would suggest that there are readily available indicators of minimum and maximum level extents that could not be construed as being established arbitrarily. Such a justification for action does not address Tol's criticism of SMS as being insensitive to people's preferences. It could be that water levels other than those within the range experienced for the last 100 years on the Great Lakes might be preferred. As well, some might argue that 100 years is too short a period of time to provide useful indicators of acceptable levels.

It is arguable that a proposal that relies only on an AM strategy to monitor the consequences of no additional water level regulation efforts in the Great Lakes, despite current historic low water level events, constitutes procrastination that is political in nature (Allen & Gunderson, 2011). Allen & Gunderson (2011) also noted that a pathology of AM is that it facilitates the avoidance of hard truths. Small experiments, such as those referred to as pilot projects in the AM Plan, can go on indefinitely without addressing difficult and hard questions about management.

The IUGLS suggested that there are a number of concerns regarding the introduction of physical elements that would allow actual regulation of Great Lake Levels below Lake Superior. Those concerns included cost, uncertainty about effectiveness, potential harm to the environment and inhabitants downstream, and an expectation that Great Lake water levels are cyclical and might return to their historical levels of their own accord (IUGLS, 2012). A mechanism to control upper Great Lake water levels below Lake Superior beyond the dam structures at Sault Ste. Marie does not physically exist, and the potential of actual water level regulation remains largely unexplored.

SMS has long been considered an add-on to CBA. SMS in application is vulnerable to similar issues in addressing unknown, unpredictable or potentially infinite variables. Crowards' (1998) modified approach to SMS emphasized resource preservation (i.e. efforts to maintain water levels within historic extremes) absent established greater loss of social benefit. Adoption of this approach could serve to moderate the impact of any pathology of procrastination that may have given rise to the selection of an AM management strategy.

As a formula, a summary of Crowards (1998) expressed an SMS approach in this manner:

> EBp is the expected benefit from preserving the resource
>
> PBd is the expected private benefit from allowing development
>
> UBp is the uncertain benefit of preservation
>
> Accordingly the Maximum Possible Loss of not allowing development UBp + EBp – PBd
>
> Minimax decision rule would be to adopt SMS unless UBp + EBp – PBd < 0
>
> Modified Minimax is to assume that UBp cannot be quantified but that it would be extremely large
>
> SMS should be adopted unless PBd – EBp > X where X is some 'large' amount which it is 'unacceptable' for society to go without
>
> The whole basis of the proposed SMS approach is that x, the probability of large future losses, is not known
>
> UBp represents future losses defined as being uncertain and unquantifiable. The cost to society of avoiding these possibly large future losses is the net benefit of forgone development, PBd – Ebp
>
> The decision rule then becomes one of accepting development only if the net benefits of development (PBd - EBp) exceed the unknown xUBp
>
> If x is assumed to be 0, then it's simply a Cost Benefit Analysis for determination of whether development should be accepted (Crowards, 1998)

Crowards' (1998) approach to SMS can be adapted further. Assuming that some probability can be attached to the possibility of unlimited or unquantifiable losses due to extreme water levels below or above defined thresholds, an opportunity cost analysis can be made. This analysis would require that the "do not regulate further" water levels option be chosen only so long as the opportunity costs of the "do not regulate further" option are less than the opportunity costs of the “further regulation” option. If it can be determined that there are no unquantifiable benefits associated with the “further regulation” option then a decision to introduce or not introduce further structural restoration and/or changed regulation priorities reverts to a CBA analysis.

This SMS approach avoids the infinite variable issue that can arise when using only CBA analysis. While the AM Plan simply anticipates that stakeholders will be engaged in adaptive responses to extreme water levels, the addition of a CBA/SMS approach, which gives consideration to introducing further engineered flow restriction, introduces a SMS rule to action as a component of the initial stakeholder engagement process. As an interventional question stakeholders would be asked, "Is there a water level limit at which an engineering and water regulation response is required?" In the AM Plan only coping zones for adaptive responses are addressed.

Effectively SMS could be used to “bound” the decision to utilize an AM monitoring strategy. Where such management action results in extreme water levels beyond identified thresholds, which in turn would raise the spectre of unknowable or unquantifiable damages, an SMS rule to action would call for a change in the management strategy. This proposal would not interfere with efforts to utilize AM to explore all requisite cycles of experimentation that could identify future adaptive management possibilities. An AM strategy could not then be effectively an excuse to avoid hard decisions to actively manage resources using traditional management techniques that are compliant with precautionary principles.

## 6.4 Conclusions

The DOI, the Shipping Federation of Canada, the Council of Great Lakes Governors and members of the public all expressed similar views. The AM Proposal lacks specific performance metrics, is difficult to understand, and appears to propose a costly process without sufficient consideration being given to available and realizable resources or stakeholder engagement and capacity. The Niagara Region (with shorelines on both Lake Ontario and Lake Erie) in bringing the AM Plan to the attention of its Regional Council succinctly commented:

> Implementing adaptive management could incur significant costs for shoreline communities. The proposed AM Plan does not contain any

> descriptions, provisions or call to address the potential need for attenuation, adaptation and mitigation measures, whether it be additional costs incurred by municipalities and/or regional governments or economic impacts to businesses and homes in shoreline communities. (Robson, 2013, pg. 2)

The Government of Niagara Region report goes on to support a call for federal funding (in their case Canadian federal funding) for municipalities to increase the "capability of stakeholders to participate in the design and application of adaptive management." (Robson, 2013, pg. 3)

A management strategy that elicits a stakeholder response of "we need more funds so that we can be technically competent to participate" risks dissipating stakeholder commitment and energy. AM, as a decision informing strategy, is not appropriate unless the value of management learning can be shown to justify the additional costs for such a strategy. It is unrealistic to suggest that, simply as a consequence of the IJC promoting AM as an answer to the inadequacies of regulation in the face of extreme water levels; there will be significant stakeholder contributions of existing resources to a new and additional program burden.

The "value" of AM is derived from management learning and the application of that knowledge to improve management decision-making. It is not sufficient justification to embark on such a strategy to simply enumerate the uncertainties in the knowledge about the natural and anthropogenic influences on the Great Lakes system that give rise to extreme water levels. Absent better definition by stakeholders as to their management problems and objectives, it is unclear what information relevant to their decision making capacity is missing that can be provided utilizing an AM strategy. Accordingly, it is recommended that engaging stakeholders in problem and objective identification as suggested by Questions 1 to 6 of the 14 AM Selection Criteria Questions **(Table 5.1)** will make whatever is the value proposition of the AM Proposal apparent.

The "learning" that leads to changed and improved management through an explicit and formal process is a hallmark of AM theory. If the proponents of a proposed strategy of AM fail to identify how management will learn and apply critical new knowledge then it will be difficult either to establish that an AM strategy is necessary, or if implemented, that any improved management action will be the result of such a strategy. A robust focus on

Questions 7-10 of the 14 AM Selection Criteria Questions **(Table 5.1)**, will allow the AM Proposal to more convincingly advance an argument that stakeholders have the capacity to both learn and modify their decisions if relevant uncertainties are reduced. If this cannot be established, then a more prescriptive "best practices" risk avoidance strategy based on scenario planning which the AM Proposal at times confuses with AM is the more appropriate strategy.

The identification and recognition of the "capacity for management change" which is the area addressed by Questions 11-14 of the 14 AM Selection Criteria Questions **(Table 5.1)** constitutes the third area which must be thoroughly considered before recommending an AM strategy. The current mandate of the IJC limits its capacity to experiment with water level regulation. There is an expectation from governments and stakeholders that water regulation can in some manner address extreme water level impacts while the scientific conclusion is that this capacity is extremely limited. The IJC through the AM Proposal is calling for stakeholders to acknowledge the limitations of regulation and adapt to the challenge of extreme water levels in the future. The likely risks of continued extreme water level conditions do not warrant an AM strategy if stakeholders because of policy, law or capacity are not capable of experimenting with different management options. This has been a long-standing challenge to AM theory. If an agency by law has an absolute obligation to conserve habitat or preserve a species, for example, it cannot engage in AM experimentation that fails to meet those obligations, in the same way that the IJC cannot promote regulation plans that do not comply with the orders of precedence under the BWT.

Application of Gregory's criteria (Gregory et al., 2006), William's problem scoping key (Williams et al., 2007), and/or the 14 AM Selection Criteria Questions **(Table 5.1)** to the contents of the AM Plan all generate a similar conclusion. The AM Plan and supporting documentation provides a less than complete or compelling determination that an AM decision informing strategy will be useful in addressing the management of extreme water levels on the Great Lakes. It is not possible, absent further inquiry of stakeholders, to determine whether an AM strategy could be successfully implemented to address extreme water levels on the Great Lakes and, as is suggested, further study is required.

At a theoretical level, the necessary criteria for appropriate selection of an AM strategy can be well understood and articulated. The AM Plan if it is advanced beyond a proposal will not provide a basis for measuring whether successful implementation is contingent upon application of defined selection criteria. The risk is significant that the AM Plan, if it remains in its current form, will simply add to conclusions found in the literature that AM rarely gets beyond policy description and that successful implementation, however defined, is similarly rare. A more rigorous application of selection criteria in re-crafting the AM plan as a proposal might allow for a unique opportunity to assess whether AM theory, if implemented in practice, provides an approach that measurably improves management performance. Equally appropriate, such application of selection criteria might lead to the conclusion that, given its spatial and temporal scale, extreme water levels in the Great Lakes does not lend itself to management by AM.

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# Appendix A

AM Criteria Questions (Gregory et al., 2006, pg. 2414)

| Topic-area consideration | Criteria questions |
|---|---|
| Spatial and temporal scale | |
| Duration | Is the project timeline to obtain verified results compatible with management decision-making requirements? |
| Spatial extent and complexity | If spatial extent or complexity is large, are there opportunities to apply AM on a subset of the problem and scale up? |
| External effects | Have potential issues related to background trends and cumulative effects of management actions been addressed in the AM design? |
| Dimensions of uncertainty | |
| Parameter uncertainty | Has the AM design been pared down to focus on only those uncertainties most likely to influence management decisions? |
| Structural uncertainty | Are there profound structural uncertainties? If so, how will surprise outcomes be managed? |
| Stochastic uncertainty | How do low-probability random natural and other causal events affect the AM design and expected outcomes? |
| Confidence in assessments | If the confidence in the proposed AM design is low, can expert judgment or other techniques help? |
| Costs, benefits, and risks | |
| Specifying benefits and costs | Can all the costs and benefits (and risks) be documented and communicated in a manner understandable to all stakeholders? |
| Magnitude of effects | Will the information collected through AM have sufficient predictive ability to make a difference to managers? |
| Multiple objectives | Does the design and assessment of AM plans explicitly address the multiple goals of stakeholders (rather than only scientists)? |
| Perceived risks of failure | Can stopping rules and clear thresholds identify and/or minimize the perceived risks of failures, to species and to institutions? |
| Stakeholder and institutional support | |
| Leadership | Is there explicit policy guidance and leadership support for AM? Will stakeholders see AM as an effective way to deal with uncertainty? |
| Flexibility in decision making | Is there sufficient management flexibility (and continuity) to incorporate new information in revised experimental designs? |
| Avoidance of taboo trade-offs | Does the proposed AM design involve any trade-offs that might be considered taboo by some stakeholders? |
| Institutional capacity | Are sufficient analytical skills available (staff or contractors) to design, evaluate, and monitor AM plans? |

DOI Problem Scoping Key for determining whether AM is an appropriate strategy. (Williams et al., 2007, pg. iv)

## Problem-Scoping Key for Adaptive Management

The following key can help in dissecting a particular management problem and determining whether adaptive management is an appropriate approach to decision making. If the answer to any question in the key is negative, then an approach other than adaptive management is likely to be more appropriate.

1. Is some kind of management decision to be made?
   (see Sections 1.1, 2.1, 2.3, 3.1, and 5.5)
   No – decision analysis and monitoring are unnecessary when no decision options exist.
   Yes – go to step 2.

2. Can stakeholders be engaged?
   (see Sections 1.1, 1.2, 2.1, 3.1, and 4.2)
   No – without active stakeholder involvement an adaptive management process is unlikely to be effective.
   Yes – go to step 3.

3. Can management objective(s) be stated explicitly?
   (see Sections 1.2, 2.1, 2.2, 2.3, 3.1, 4.2 and 5.1)
   No – adaptive management is not possible if objectives are not identified.
   Yes – go to step 4.



4. Is decision making confounded by uncertainty about potential management impacts?
   (see Sections 1.1, 1.2, 2.1, 3.1, 4.1, 4.2 and 5.2)
   No – in the absence of uncertainty adaptive management is not needed.
   Yes – go to step 5.

5. Can resource relationships and management impacts be represented in models?
   (see Sections 1.2, 3.1, 4.2, and 5.1)
   No – adaptive management cannot proceed without the predictions generated by models.
   Yes – go to step 6.

6. Can monitoring be designed to inform decision making?
   (see Sections 2.1, 2.3, 3.1, and 4.2)
   No – in the absence of targeted monitoring it is not possible to reduce uncertainty and improve management.
   Yes – go to step 7.

7. Can progress be measured in achieving management objectives?
   (see Sections 1.1, 3.1, 4.1, and 4.2)
   No – adaptive management is not feasible if progress in understanding and improving management is unrecognizable.
   Yes – go to step 8.

8. Can management actions be adjusted in response to what has been learned?
   (see Sections 1.2, 2.1, 3.1, 4.1, 4.2, 5.3, and 5.4)
   No – adaptive management is not possible without the flexibility to adjust management strategies.
   Yes – go to step 9.

9. Does the whole process fit within the appropriate legal framework?
   (see Sections 2.3, 2.4, 3.2, 4.1, and 4.2)
   No – adaptive management should not proceed absent full compliance with the relevant laws, regulations, and authorities.
   Yes – all of the basic conditions are met, and adaptive management is appropriate for this problem.