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Executive Summary

GREAT LAKES WATER LEVELS INTEGRATED ASSESSMENT REPORT

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For more information on this project, please go to: http://graham.umich.edu/emopps/water-levels

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EXECUTIVE SUMMARY

Great Lakes water levels have been much in the news over the last few years. After a decade of downward trends, water levels on Lakes Michigan and Huron reached historic low levels in January 2013.[1] Then during 2013 and 2014 the same lakes came close to setting another record as they experienced the second-largest gain over a 24-month period since water levels began to be recorded.[2,3] Water levels since then have remained above the long-term recorded average, and the U.S. Army Corps of Engineers (USACE) official outlook forecasts continued trends higher in 2018.[4]

These recent changes in water levels and the nearly century of data showing cyclical water level fluctuations underscore the dynamic nature of the Great Lakes system. Many of the large and diverse group of interests connected to the lakes are accustomed to dealing with, and may even depend upon, a certain degree of water level change. However, water level conditions outside the range experienced more recently as well as uncertainty in future water levels can present significant challenges for individuals, businesses, and communities living with the lakes in the present.

Variation across the Great Lakes in terms of existing water level regulation, degree of observed change, and shoreline uses makes the question of how best to deal with changing water levels particularly challenging. Therefore, there is a need to explore alternative strategies for mitigating the harm and maximizing the benefits of water level variation in the Great Lakes. International Joint Commission (IJC) reference studies over the last three decades have identified various options that could help the region adapt to water level changes.[5] Some of these options, such as shoreline management, stand in contrast to lake-wide water level control structures in that they are inherently site-specific, and thus allow different localities to address impacts and issues specific to their geography, development, and shoreline uses. In practice, however, location-specific shoreline management and policy options have not been widely adopted throughout the region. A major challenge in implementation, in addition to variability and uncertainty in water levels, is determining the appropriate integrated mix of options that take into consideration local conditions, multiple objectives, and jurisdictional constraints.

Overcoming these obstacles requires a new approach that emphasizes creative solutions and engagement with decision-makers, and that couples place-based work with a broader regional perspective. It should build upon existing efforts, bring in best-available science, and recognize the dynamic nature of the Great Lakes system made more evident by the recent reversal in water level trends. To help decision makers address the challenges and opportunities posed by Great Lakes water level variability, the University of Michigan's Graham Sustainability Institute initiated the Great Lakes Water Levels Integrated Assessment (IA).[6]

PURPOSE

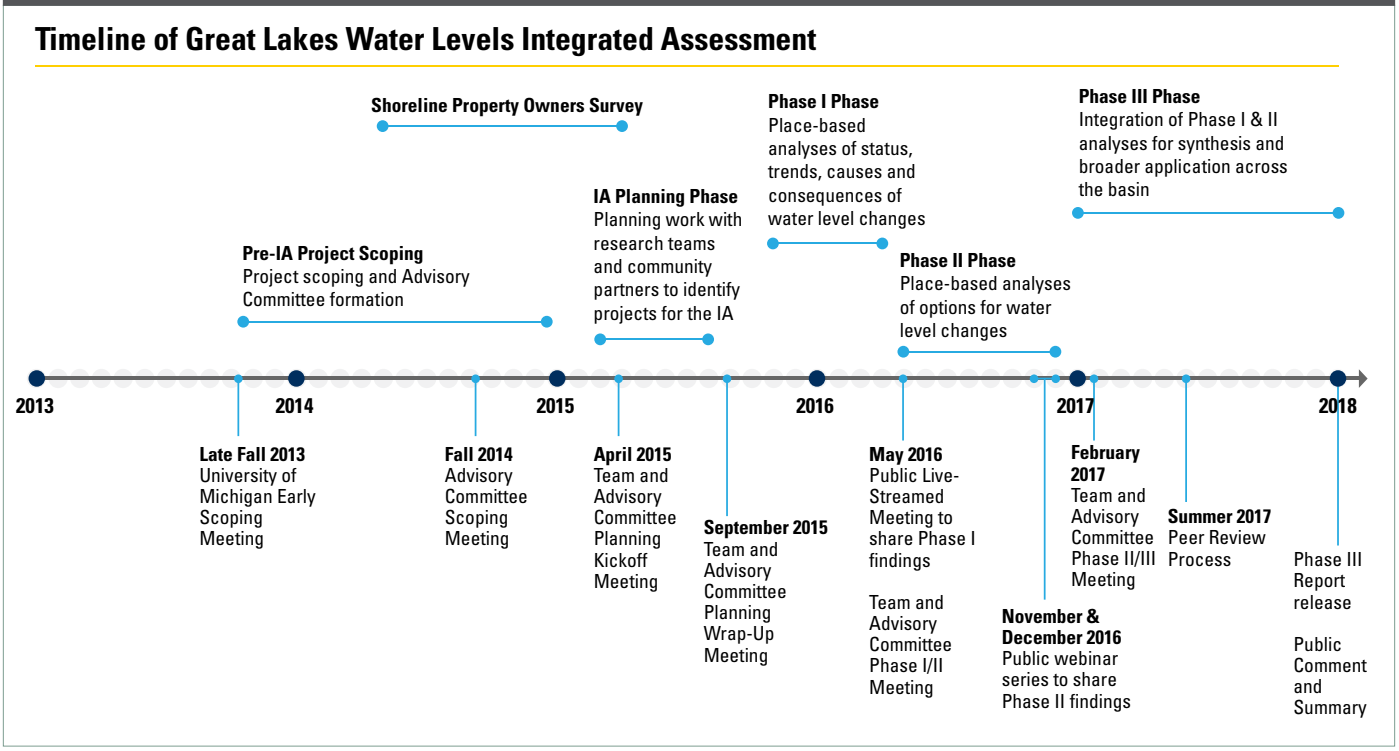
The purpose of the IA has been to develop information, tools, and partnerships to help decision makers address the challenges and opportunities posed by variability in Great Lakes water levels. The IA aimed to transform extensive existing research about water levels, flows, and impacts into practical, adaptive strategies to address issues facing shoreline property owners and managers. The IA was informed by a binational advisory committee,[7] who provided input and advice reflecting the views of key stakeholder groups. To focus the work, the following guiding question was developed in consultation with the advisory committee:

> *What environmentally, socially, politically, and economically feasible policy options and management actions can people, businesses, and governments implement in order to adapt to current and future variability in Great Lakes water levels?*

To respond to the question, the IA focused on Lakes Michigan and Huron and took both a place-based and regional approach. Place-based teams collaborated with specific communities to assess specific, integrated, and feasible options related to water level variability. This report integrates and builds upon the local projects to demonstrate variation and similarities among the communities' needs and identify insights for the basin more broadly.

The project adopted an IA approach as the organizing framework. IA is a deliberative process where experts summarize and synthesize existing scientific data and information to guide decision making. By engaging representatives from a wide range of impacted sectors and perspectives on a given issue, IAs collaboratively define problems, address diverse perspectives, use and share best-available information, and establish partnerships with the goal of analyzing options for making positive change.[8]

Figure 1: IA Timeline



PROCESS

The IA was divided into three phases. The first two phases were focused on specific localities. During Phase I, teams used existing data and information to develop an overview synthesis report on the status, trends, causes, and consequences of changing water levels as they relate to the key issues in the community they were working with. Each report then outlined the future research and planning each group intended to complete, whether that involved further community outreach, ordinance drafting, or geological mapping. Results from this work were shared at a public meeting (in person and live streamed) in May of 2016[9] and posted to the project website.[6]

In Phase II the research teams worked in collaboration with their partners to identify and analyze viable policies and adaptive actions that meet local objectives. Phase II reports outlined the full findings of each group. These included the options proposed by communities and researchers, the feedback to those options, and the challenges and opportunities of each option. Each group also presented webinars on their findings, which generated widespread public participation and feedback.[10]

This Phase III report seeks to integrate the findings of each group regarding the unique challenges and opportunities faced by each community to identify opportunities for the region. While relying primarily on material from the previous IA phases, the report also includes additional material to support findings and clarify topics of relevance. The hope is that this report can inform communities facing similar situations as to how to approach water level variability, given the environmental, social, political, and economic characteristics of their community.

IA TEAMS

Wisconsin Team

David Hart of Wisconsin Sea Grant headed a team of researchers from Wisconsin Sea Grant, the University of Wisconsin-Madison, and the University of Wisconsin-Milwaukee.

This team focused on communities along the shore of Lake Michigan located immediately north of the city of Milwaukee, Wisconsin in Milwaukee and Ozaukee counties, with a primary focus on the influence of changing water levels on coastal bluff erosion. Their goals were to synthesize existing resources and to engage community residents and officials in discussions about their hopes and concerns around the future of their coastal bluffs. Through several public meetings and stakeholder interviews, the team developed a wide range of options for addressing these challenges, and gauged community feedback to these options.

In addition to partners at the local and county level, the team coordinated with regional and state organizations and agencies working on coastal issues, such as the Southeastern Wisconsin Regional Planning Commission and Wisconsin Coastal Management Program, Department of Natural Resources, and Division of Emergency Management.

Ontario Team

Lynne Peterson, a local government and integrated policy consultant, led a team including researchers from the University of Toronto's Ecological Modelling Lab, Environment and Climate Change Canada, and University of Guelph, a former municipal chief administrative officer and a former

Figure 2: Map of the IA place-based projects

Ontario municipal finance and planning policy expert.

The team focused on Huron County, Ontario with 100 kilometers (62 miles) of shoreline along Lake Huron, and worked directly with the Huron County Water Protection Steering Committee. The team's goals were to review issues arising from both low and high water level extremes on Lake Huron and to identify regulatory and non-regulatory options for living with water level variability for review by Huron County, local municipalities, conservation authorities, non-profit organizations, harbor organizations, local residents, and businesses.

Through a series of workshops, presentations, and additional discussions with key stakeholders, the team developed a series of policy and adaptive management proposals. In addition to the Water Protection Steering Committee, key participants were the Lake Huron Centre for Coastal Conservation, the Ausable-Bayfield Conservation Authority, the Maitland Valley Conservation Authority, the Bluewater Shoreline Residents Association, and the Ashfield-Colborne Lakefront Association.

Southern Michigan Team

Richard Norton of the University of Michigan Taubman School of Architecture and Urban Planning led a team of researchers from the University of Michigan, Michigan Technological University, and the non-profit planning and community development firm LIAA.

The team worked directly with of the City of Grand Haven and Grand Haven Charter Township along the southern Michigan shore of Lake Michigan. The team sought to build on previous land use planning efforts and to identify options for actually implementing master plans or shoreland area management plans.

Northern Michigan Team

Frank Marsik of the University of Michigan College of Engineering led researchers from the University of Michigan and Michigan State University. This team developed a collaborative approach to work directly with the Little Traverse Bay Bands of Odawa Indians (LTBB) and the Grand Traverse Band of Ottawa and Chippewa Indians (GTB). The LTBB and GTB have reservation lands in the northwest lower peninsula of Michigan along Lake Michigan, as well as hunting, fishing, and gathering rights within a larger area spanning the upper and lower peninsulas of Michigan and Lakes Michigan-Huron and Superior.

The team sought to facilitate the integration of western science approaches and Indigenous Traditional Knowledge approaches into the consideration of climate change effects on lake levels in Tribal plans.

WATER LEVEL VARIABILITY & DIVERSE INTERESTS

Great Lakes Water Budgets

Many factors influence Great Lakes water levels, including precipitation, evaporation, run-off, water flow through connecting channels, diversions into and out of the system, consumptive water use, dredging, and water level regulation. Air temperature, wind, and vertical movement of the earth's crust also factor in.[15,16] A water budget is a concept that describes the relationship between inputs and outputs of water through a region, and it can help to clarify the causes of long-term fluctuations in water levels. When inputs (precipitation, runoff, groundwater, inflows from upstream, and diversions in) exceed the outputs (evaporation, outflow from the lake, diversions out) for a significant period of time, lake level rises. While the concept is simple, understanding the water balance still continues to be a scientific challenge and requires ongoing analyses.

The three main factors affecting water levels are precipitation, runoff, and evaporation.[15] Human factors also influence water levels in the Great Lakes, although to a much lesser degree than natural factors. Diversions bring water into and take water out of the lakes, although the net effect is a small input to the system, as the combined average amount of water diverted into Lake Superior at Ogoki and Long Lac is greater than the combined amount of diversions out of the Great Lakes Basin.[17] To put these in perspective, over the period of 1953-2010, precipitation added an average of 3,100 cubic meters of water per second (CMS) to Lakes Michigan and Huron and evaporation removed 2,700 CMS, while the Ogaki and Log Lac diversions added 160 CMS to the system and the Illinois diversion removed 90 CMS.[17] Additional human influences play even more limited roles in influencing water levels. For example, general consumptive uses, reflecting varied purposes, have little effect on overall water levels.[18]

BOX: IMAGES FROM THE PLACE-BASED PROJECT TEAMS

Figure 3: Photograph illustrating coastal bluffs within the Wisconsin project area[11]

The image shows both unarmored and armored shoreline.

Figure 5: Photograph of residential development along the shoreline in the City of Grand Haven, Michigan within the Southern Michigan project area[13]

Figure 4: Map illustrating the high proportion of properties facing erosion failure risks in a stretch of shoreline within the Ontario project area[12]

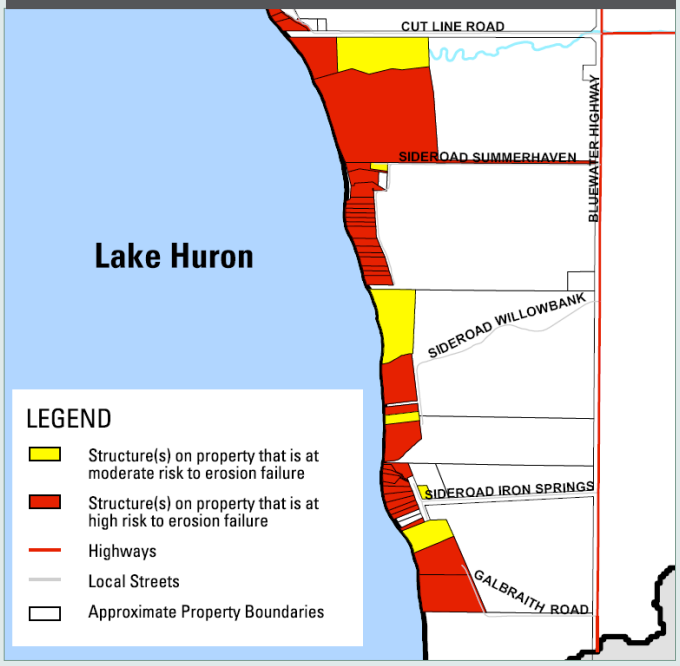
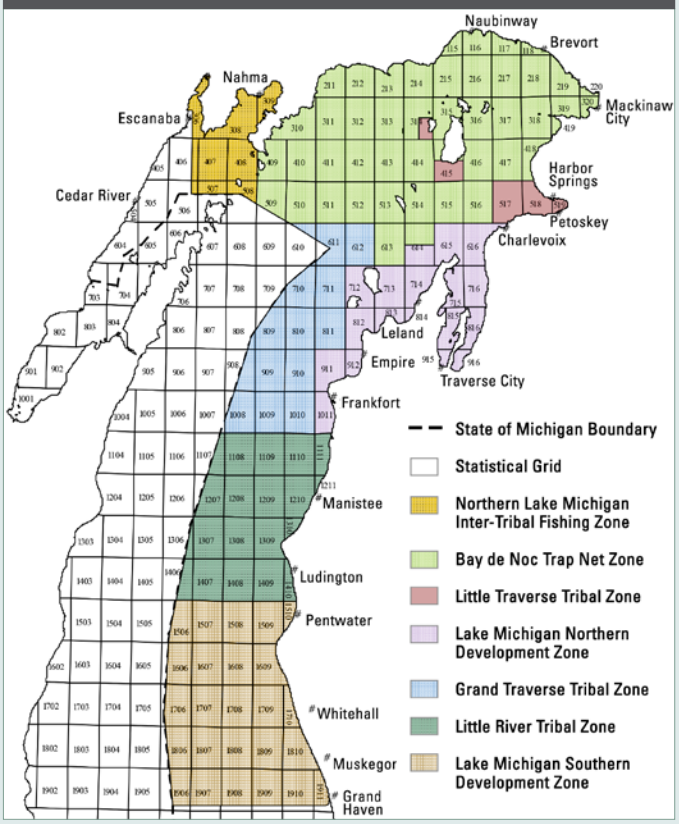


Figure 6: Map of 2000 Consent Decree Tribal commercial fishing zones that were considered by the Northern Michigan project team[14]



2000 Consent Decree
Federal court order that represents a negotiated agreement between the U.S., the State of Michigan, and five Native American Tribes, which details how fishing in the 1836 Treaty waters will be allocated, managed, and regulated through 2020.

The IJC provides oversight at three control structures that impact international water levels and flows on the Great Lakes and St. Lawrence River. These are located in the St. Marys River, Niagara River, and St. Lawrence River, near the outlets of Lake Superior, Lake Erie, and Lake Ontario, respectively.[19]

Changes Over Time

The combination of the Great Lakes' large size and small outflow channels results in a largely self-regulating system that tends to buffer changes and keep lake levels within typical ranges over long periods. It also means that extremely high or low levels and flows can persist for a considerable time after the factors that caused them have changed.[20]

The magnitude of water level changes varies depending on the lake and the time scale considered. Over the course of a year water levels typically vary approximately 30-50 centimeters (cm) or 12-20 inches. Over longer time scales, monthly water levels range from about 60-90 cm (2-3 feet) above or below the long-term averages for the month.[21] The historical range of recorded annual average water levels on Lakes Michigan and Huron, for instance, is close to 2 meters (6.5 feet).[22]

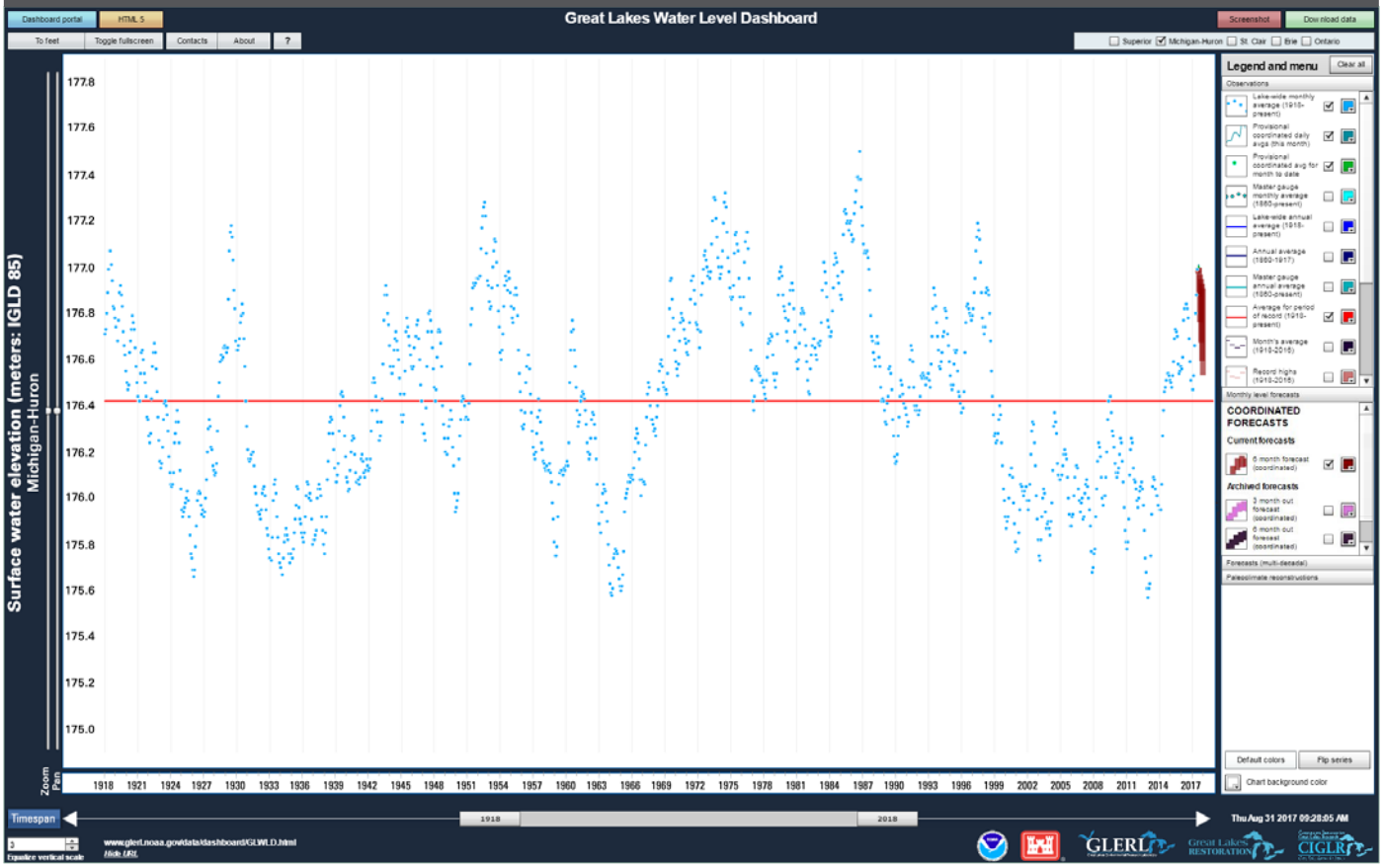
Regular seasonal changes in water levels are caused by corresponding seasonal patterns in the various inputs to and outflows from the system, with annual minimum water levels occurring in the winter and annual maximum water levels in the late spring.

Continuing high or low water supply conditions contribute to larger long-term fluctuations. Several-year periods of high or low levels are a normal feature of Great Lakes water levels dynamics, but they are very difficult to predict. Review of long-term water levels on Lakes Michigan and Huron from 1918 to the present (Figure 7) reveals periods of lows in the 1920s, mid-1930s, mid-1960s, and 2000s to 2013, with periods of highs in the early 1950s, early 1970s, mid-1980s, and mid-1990s. While they may be difficult to predict, extreme lake levels are not an unusual phenomenon.

Another factor affecting water levels over time is glacial isostatic adjustment (GIA), which is the ongoing movement of the earth's crust as it rebounds following the retreat of the glaciers at the end of the last ice age. GIA is effectively tilting the basin southward over time, and as a result, affecting how water levels changes are experienced across the region; falling water levels will be more prominent in northern areas, and rising water levels will be greater in southern areas.[20]

Climate change poses additional challenges to understanding and adapting to fluctuating Great Lakes water levels. In its extensive analysis of climate impacts on future water levels, the International Upper Great Lakes Study by IJC concluded that "lake levels are likely to continue to fluctuate, but still remain within the relatively narrow historical range. While lower levels are likely, the possibility of higher levels cannot be dismissed. Both possibilities must be considered."[20]

Figure 7: GLERL Great Lakes Water Level Dashboard – Lakes Michigan and Huron water levels, 1918-present [3]



Blue dots denote monthly lakewide average water levels from 1918-present. The solid red line shows the long-term average from 1918-2016. The USACE 6-month forecast is shown as dark red probability bands on the far right. Accessed August 3, 2017.

Shoreline Property Owners and Managers

A large and diverse group of interests are affected by and connected to the lakes—through their business or livelihoods, recreation, infrastructure, and values—even if they don't live immediately along their shores.

This IA focuses primarily on issues facing shoreline property owners and managers. As of 2012 an estimated 93,400 properties along the upper Great Lakes shorelines and connecting channels, and projections suggest that most of the Lake Michigan and Huron shorelines will be developed as residential in the next 50 years.[20]

Property owners often have preferences for water levels at their particular location. Depending on physical characteristics of a specific location, this group can experience negative impacts from both high and low water levels. Since the 1950s the most prevalent negative impacts during high water levels have been damages to land and structures from storm-related flood and erosion damage, as well as bluff and beach erosion; loss of beach access as beaches are narrowed or eliminated; and the related socio-economic impacts. In areas where boats are the primary means of access to the water (such as rocky coastal environments in Georgian Bay, sheltered embayments, and drowned rivermouth areas like Saugatuck, Michigan), low water levels may result in more difficult and costly use of or access to property. In other areas, low water levels may provide a wider more attractive beach for recreation. It is worth noting that water level changes in the opposite direction bring corresponding positive benefits. Moreover, coastal zone interests may also experience, directly or indirectly, the effects on other interests—whether related to water quality, the economy, infrastructure, ecosystems or recreation.

OPTIONS FOR WATER LEVEL VARIABILITY

There exists a wide array of options that communities and shoreline property owners can implement in order to adapt to current and future variability in Great Lakes water levels. Many of these options are not new. Going back decades, the IJC and others have completed extensive studies identifying and assessing options around Great Lakes water level fluctuations. One key challenge, as those studies noted, is identifying and tailoring the suite of options according to unique local conditions and interests.

As described briefly, during Phase II of the IA, the four place-based research teams proposed and assessed a variety of options and strategies for their partner communities to consider. To support other communities and interest groups in thinking through ways to approach variable water levels, this chapter organizes and explores the options the teams considered during their Phase II work.

The options are grouped into four broad categories that include the most common options among the teams:

- **Planning and Coordination**
- **Shoreline Stabilization**
- **Land Use and Shoreline Management Policies**
- **Education and Outreach**

Subcategories are listed below. The full report provides additional descriptions and select detailed examples of these options as analyzed by the research groups.

The IA does not seek to duplicate previous reports that comprehensively enumerate potential options, nor does it provide detailed technical guidance or analyses of the options. Rather, it aims to organize examples from the Phase II place-based work to illustrate what select options might look like and highlight some of the associated challenges or opportunities to be considered. For a full list of the options generated during Phase II refer to Appendix A of the full report.

Lastly, this IA recognizes that no single measure will be sufficient. Responding to variable water levels will require a suite of measures that consider the characteristics of the shoreline, natural systems, built environment, interest groups, and political and legal factors. In addition, even these suites of options cannot completely eliminate potential negative impacts of water level fluctuations. They do, however, have the potential to address specific issues and to assist communities and interests in adapting to and living with variability.

Planning and Coordination

The Adaptive Management Plan for the IJC reiterated that "no one agency manages the issues associated with water level impacts and, therefore, a more intensive level of collaboration is needed than has been seen to date on the issue."[23] Not surprisingly, coordination emerged as an important theme for all four IA teams. Given the place-based nature of the projects, many of the options for coordination that the teams explored are focused more locally, addressing opportunities among and within jurisdictions, and among different organizations and individuals. The teams looked at options across these subcategories:

- **Coordinating among jurisdictions**
- **Working with other partners**
- **Planning across departments**
- **Coordinating funding**
- **Collaborating with neighbors**

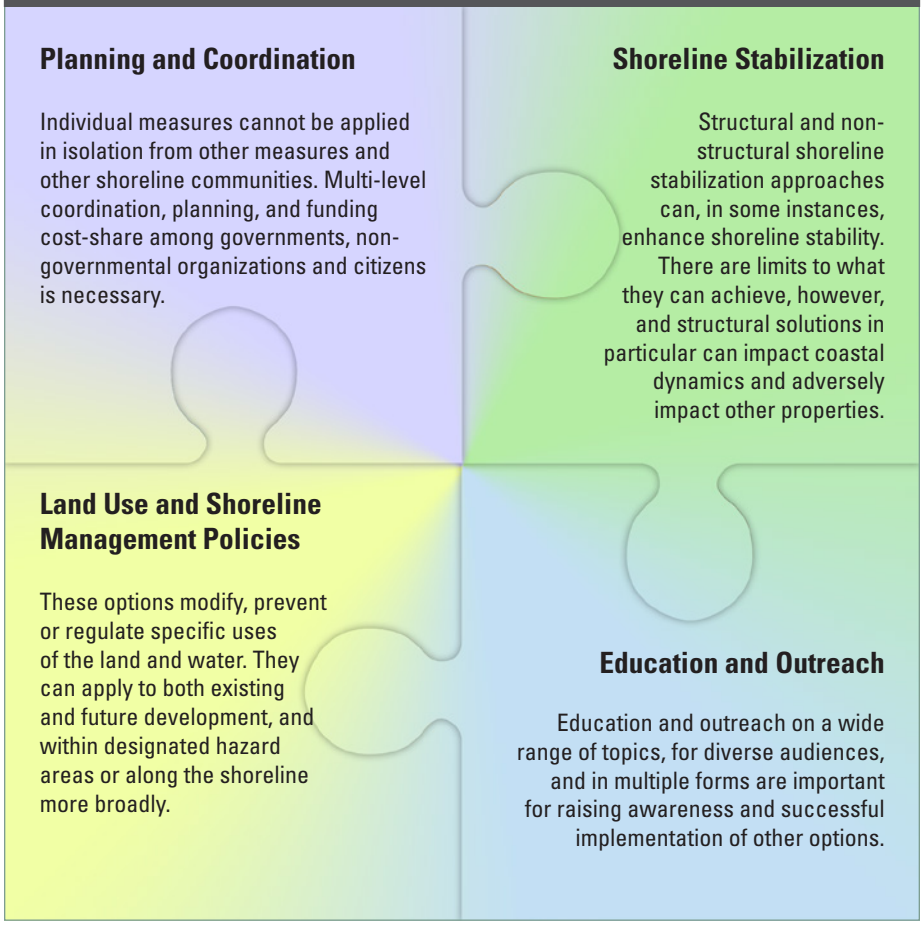
Shoreline Stabilization and Protection

Another category of response options the teams addressed is direct modification of the shoreline to reduce erosion and improve stability. This includes:

- **Structural approaches**
- **Non-structural approaches**
- **Gray-green infrastructure**

Where the shoreline has already been developed intensively, structural shore protection may be considered the only

Figure 8: Categories of water level variability response options explored through the IA



Responding to variable water levels will require a suite of measures that consider the characteristics of the shoreline, natural systems, built environment, interest groups, and political and legal factors. The categories of response options here are often interrelated, and they do not represent a comprehensive list of options. Rather, they represent the most common options identified by the place-based teams during Phase II of the IA.

available option. It is important, however, to recognize the limits of this approach. Even well-designed stabilization structures may still adversely affect adjacent property as well as shoreline areas a considerable distance away, often leading to an ongoing cycle of more armoring, more erosion, and more armoring—with impacts increasing with the shore hardening.

Approaches using plants, rather than hard construction materials, can also serve to reinforce the soil, improve water drainage, prevent erosion and dewater wet soils. There are limits to these approaches as well; where there is ongoing toe erosion, these measures can only enhance stability in the short-term, and over the medium to long-term they have no effect on changing the recession rate.[24]

Land Use and Shoreline Management Policies

This category of options includes those focused on modifying, preventing or regulating specific uses of the land and water. These options can affect both existing and future development, and they can apply within designated hazards areas along the shoreline or more broadly. The report divides these into two subcategories. The first discusses land use planning and development requirements, while the second looks at options related to permitting processes more generally. What unites these options is a primary reliance on regulations or other mandatory requirements.

- **Land use planning and development requirements**
- **Permitting**

Examples within these related to setbacks, stormwater management and soil erosion control, ordinance review procedures, permitting requirements, and public notice and comment processes.

Outreach and Education

All of the place-based IA teams explored options related to outreach and education, but the topics addressed, audiences targeted, and forms of the outreach resources or tools varied based on the needs of the given community. The teams considered a range of opportunities, including;

- **Keeping property owners informed**
- **Engaging youth**
- **Providing resources and engagement opportunities**
- **Mapping and visualization**

Other Topics

Other approaches included in the report include emergency planning; construction standards; acquisition, conservation and relocation strategies; and real estate disclosure.

Takeaways

Although described separately, the categories of response measures and the specific options described within them are often interrelated. For instance, planning and coordination are important for most of the options in the other categories, from considering structural or non-structural approaches to aligning and funding outreach efforts. Education and outreach approaches are important for building support for and implementing potential regulations or incentives, while land use and permitting requirements may affect the need and ability to pursue different stabilization approaches. The complex, multi-level governance system in the basin ensures that jurisdictional considerations are unavoidable for many options.

As mentioned previously, no single measure will be sufficient. The place-based IA teams identified ranges of opportunities for their partner communities to consider, and there are additional options beyond those

discussed here. In general terms, however, living with Great Lakes water level variability will require a combination of approaches that seek to prevent negative impacts, mitigate the effects of unavoidable negative impacts, respond to emergency impacts, and on the positive side, capitalize on the benefits associated with inevitable changes.

OVERARCHING THEMES

While the primary focus of the IA was to identify place-based adaptive strategies and options for water level variability in the Great Lakes, several common themes can be identified when examining the work of the research teams. These themes are reminders of conditions that may be critical for the success of any suite of strategies, or overall approach to identifying strategies, that a community takes.

Capacity

At the local level, capacity is variable, and efforts should be cognizant of capacity needs and develop strategies to meet them. As noted previously, while a significant amount of data and information are available on a range of water level issues it can require a substantial amount of work and expertise to convert those resources into actionable items at the local level. A good understanding of capacity can also provide insights on where partnerships can be particularly useful.

Context

When implementing policy options, context matters. Significant effort is needed to move general policy recommendations to locally-specific adaptive management strategies.

Jurisdiction

It is critical to understand the relevant authorities for decision making, particularly when multiple authorities (local, state, provincial, etc.) are involved, as is often the case with the Great Lakes resource issues.

Key Institutions

Efforts should be made to identify and engage critical partners and key institutions. Depending on the context, a key institution may be a property owners association, a local community organization, or a planning commission. Determining how to best apply limited resources and time can hinge on engaging key institutions.

Public Input

To find acceptable solutions, it is critical to solicit input from stakeholders, and competing perspectives should be sought out in a thoughtful manner. How stakeholder input is conducted can be as influential to an outcome as the methods of data collection and analysis. The work of all four of the research teams provides important insights on the value of and approaches to this engagement.

Uncertainty

Although uncertainty may be unavoidable to a certain extent, it need not preclude action. Tools such as scenario planning or approaches like adaptive management can help to develop and refine adaptive approaches in light of incomplete information.

PUBLIC PERCEPTION, INFORMATION, AND ENGAGEMENT

This overall study, as well as the four-placed based teams' work, recognizes that public perception of the issue of water levels, along with the validity of approaches to address the issue, is critical for adaptation to current and future Great Lakes water level variability. The diversity of views among the many interests in the region who are affected differently by water levels views can contribute to lack of agreement as to what the problem even is, let alone approaches for addressing it.

Access to information can help build understanding and acceptance, and all four teams included educational strategies in their analyses. Yet, while better information is important, it is not necessarily sufficient. It is important to remember that perceptions of risk among the public and technical experts often vary. Research emphasizes that neither groups' assessment is right or wrong, but instead they evaluate risks using different criteria. Moreover, coastal homeowners' decisions are also affected by values, beliefs, personal and property attributes, social norms, and other factors. These situations where parties disagree about an issue or misunderstand each other's perspective call for more engaged forms of public participation so that parties feel that their concerns are heard.

LIMITATIONS

Prior to the start of the IA, much discussion on this topic was focused on control measures to address concerns about low water levels in Lakes Michigan and Huron.[25] Now with higher overall levels, the discussion in some areas has focused to increasing the flow of water, particularly with respect to Lake Ontario.[26,27] While important discussions, water level regulation approaches are outside the focus of a place-based analysis of adaptive strategies. Moreover, the relatively quick change in the public discourse around water levels—from a focus on lows to highs—during just the course of this project underscores the dynamic nature of the Great Lakes system and the rationale for this IA's focus on variable water levels.

The scope of the IA was further bounded both geographically and topically, with a focus on Lakes Michigan and Huron and issues facing primarily shoreline property owners and managers. As a result, there are certainly topics of concern that are not addressed by the work of the teams and this report. However, it is the hope of this project that many of the topics that are addressed in the report, as well as the approaches taken by the teams, will have relevance to other Lake Michigan and Huron communities and communities along Lakes Superior, Erie, and Ontario.

Lastly, the assessment does not provide detailed technical guidance or effectiveness analyses, nor did it involve implementation funding for the place-based teams. Certainly both technical and financial resources are critical to successful adaptation, and in

the case of the latter, some of the options addressed in the report aim to meet those needs.

NEXT STEPS

Although this project concludes, efforts around adaptation to water levels continue. It is our hope that the place-based work will inform local decision-making and that this Phase III report will assist other communities' thinking around options to consider.

A goal of this IA is that its engagement efforts would help to sustain work around the issue after the project ends. In the past, interest has peaked around periods of particularly high or low levels, but diminished when trends reversed. The framing of the issue around variability, rather than just highs or lows, reflects the dynamics of the lakes, uncertainty around the effects of climate change, and a desire to improve resilience over the long term.

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