Economic Impacts of Water Levels on the Upper Great Lakes

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1.0 Introduction

The Great Lakes and the basin they drain occupy some 292,000 square miles (756,000 km²)—an area larger than the state of Texas. The lakes themselves cover 94,250 square miles (244,100 km²), making them collectively the world’s largest body of freshwater. Lake Superior, with an area of 31,700 square miles (82,100 km²), is the world’s largest freshwater lake. The five lakes descend in a series of steps, from Lake Superior’s surface elevation of 600 feet (183 m) above sea level to Lake Ontario’s 250 feet (76 m).

For over a decade the water levels in the Great Lakes have been on a steady decline. This has created considerable economic concerns by some stakeholders who have experienced negative impacts as a result and was a contributing factor to the initiation of the Upper Great Lakes Study. Given the importance of this issue to a number of interests, and in particular shoreline property and recreational boating interests, the Study Board has made considerable effort to adequately assess the impacts of low water levels. However, this has not proven to be an easy task. The Recreational Boating, Tourism and Cruise Ships Technical Working Group (TWG) were assigned the responsibility of assessing conditions and advising the Study Board on a path forward. Given the importance of this issue to the public, the purpose of this peer review is to assess the approach taken by the Recreational Boating, Tourism and Cruise Ships TWG, the validity of their findings, conclusions and guidance to the Study Board.

Below average water level conditions were observed on the Upper Great Lakes in the years leading up to the start of the International Upper Great Lakes Study (IUGLS), particularly on Lake Superior and Lakes Michigan-Huron. The low water levels were, and continue to be, a source of concern for most commercial and recreational boaters in the Upper Great Lakes.

The area of assessment is defined as Lake Erie, Lake Huron, Lake Michigan and Lake Superior. This assessment included data collection in 17 identified Areas of Study (AOS) to be representative and extrapolated to include the entire assessment area.

Data collection occurred across the international border and collated into a single multi-dimensional report.

2.0 Performance Indicators

The Recreational Boating, Cruise Ship and Tourism Technical Working Group (TWG) evaluated and assessed a number of different scenarios on how best to address the
tasks laid out in the Terms of Reference. After much debate and consultations with both industry advisors and Upper Great Lakes Study plan authors, the TWG identified four (4) performance indicators, two of which were directly related to recreational boating and the effects that changing water-levels currently is, or might have, on the overall multi-billion dollar industry on the Great Lakes. Those two performance Indicators are:

1) Number of unusable marina slips resulting from water-level fluctuation based on the physical surveys of approximately 17000 boat slips in 17 zones around the Great Lakes, excluding Lake Ontario
2) Economic Impact of fluctuating water-levels on marina operators within the Great Lakes Basin excluding Lake Ontario.

The approach taken was thought to be the best way of assessing the impacts given a very limited budget, the lack of data that was available on the recreational boating industry especially in Ontario and the time-frame that was allowed to complete the tasks.

3.0 Methodologies Used for all Segments of Recreational Boating Analysis

3.1 Literature Review and Technical Working Group Consultation
The design of the field work, both the questionnaire and the depth measurements, was aided by the knowledge gained from performing a literature review, along with consultations with the members of the Recreational Boating and Tourism Technical Working Group (TWG). The goal of the fieldwork was to assess the vulnerability of marinas to fluctuations in water levels. The field research team was comprised of Dan Waddell and Greg Ross, herein referred to as “the team”. During the beginning of the work term, a literature review of online and library sources was performed concerning the topics of recreational boating, water levels, adaptation, and climate change as related to the Great Lakes. Documents, journal articles, and websites from this literature review and additional metadata were compiled into a database.

The survey was designed to collect data that would be compatible with the results obtained by previous studies that had also investigated the effects of changing water levels on recreational boating in the Great Lakes. The major studies that informed the survey design were the 2001 analysis “Economic Impact of Lake Michigan Levels on Recreational Boating and Charter Fishing in Five Counties” (Mahoney, Stynes and Pistus, 2001), the 2005 International Joint Commission-sponsored report, “Estimating the Economic Impact of Changing Water Levels on Lake Ontario and the St. Lawrence River for Recreational Boaters and Associated Businesses” (Connelly, Bibeault, J. Brown and T. Brown, 2005), and the 2008 US Army Corps of Engineers’ report, “John Glenn Great Lakes Basin Program, Great Lakes Recreational Boating Main Report-Final” (USACE 2008). These studies influenced the format of the questionnaire (See-Attitudinal Questionnaire design: below).

3.2 Description of sample areas: Areas of Survey (AOS)
Seventeen locations were chosen by the TWG to represent significant regions of the upper Great Lakes’ recreational boating and tourism industries. These seventeen locations acted as the center-points for 80 km diameter circles, referred to as “areas of
survey” (AOS). These seventeen circles were represented visually on Google Earth, to be used to identify marinas.

The seventeen AOS were selected according to several criteria: In terms of eco-regions, sites were chosen to give an even representation of both the Great Lakes Forest Region and the Boreal Forest Region. Geologically, an even representation of both Precambrian Shield (granite) and Escarpment (primarily limestone bottoms) rock formations was desired. AOS selection was also designed to encompass a maximum concentration of ports/marinas, and aimed for equal representation in terms of regional susceptibility to fluctuating water levels. The Chicago area was not selected because that area has very deep waters. The TWG selected areas significantly impacted by fluctuating water levels historically. The TWG also wanted to ensure that at least two sites were selected on each major body of water. Finally, one site on the U.S. side was selected at the request of a Public Interest Advisory Group (PIAG) member.

3.2.1 Sample Sites

![Figure 1: The 17 Areas of Survey](image-url)
In total, seventeen areas of survey (AOS) were visited along the shores of Lakes Erie, Huron, Michigan, and Superior.

3.3 Sample selection: Marinas identified to be surveyed within the AOS’s

Five resources were used to identify marinas within each AOS: Google Earth software, Google web search, YellowPages.ca (http://www.yellowpages.ca/), the Ontario Marina Operators Association’s online Ontario Boating Destination Guide (http://www.marinasontario.com/destination_guide.asp) and Reference USA database of U.S. businesses (accessed through the Royal Oak Public Library http://www.referenceusa.com/).

Google Earth software was used to scan the shoreline visually (bird’s eye perspective) for dockage and other infrastructure characteristics of marina facilities. Once a marina was identified visually, its location was recorded by a place-mark, which was then saved in My Places. The place-marks were grouped according to the AOS in which they were located.

The Fly To search engine feature was also used to locate marinas near cities and towns within the AOS as well as to provide basic contact information. For example, the terms “Parry Sound Marina” were used to cross reference the locations and identities of marinas found visually, or found through the other identification resources (see below).

The four other resources were used to search for marinas listed in and around towns and cities located within a given AOS. These resources were also used to gather detailed contact information as well as cross-reference information found using the other resources. Detailed contact information was transcribed onto an Excel spreadsheet named “Master Marina Inventory.”

In order to be included in the identified marina sample set, a given marina had to be open to the public, have dockage, and had to use its dockage to either accommodate transient or seasonal patrons. As a result, most contractors and repair shops were excluded.

3.4 Contact with respondents: Letter of Introduction, Scheduling Meetings

A Letter of Introduction was mailed out to all of the identified marinas. This letter explained the purpose of the study, and asked the marina operator to participate by completing the questionnaire and by giving permission to take depth measurements. It was also explained that the letter would be followed up by a phone call to confirm participation and schedule visits.

The marina operator was assured of confidentiality. If an operator indicated that they did not wish to participate in the survey, then no further contact was made and their refusal was noted as such.

Some operators gave permission to take depth measurements, but were too busy to complete the questionnaire at the time of the meeting. In this case, the operator was
asked if they would be available to complete the questionnaire over the phone at a later date. If so, a follow-up phone call was made during the desired time period to conduct the interview.

Once in the field, it was discovered that some of the marinas listed in the sample set had gone out of business, or had been misidentified. Some marinas were located in a different location than had been determined with Google Earth. In addition, some new marinas which had not been identified in the sample set were discovered during the field visits, often as a result of speaking with other marina operators that were surveyed. Where possible, contact information was obtained and a meeting was set up.

As many marinas as possible were surveyed, but not all marinas identified were surveyed due to time constraints. The 149 marinas identified on the Canadian side prior to fieldwork were sent the letter of introduction. Depth measurements were taken at 89 marinas, and 78 marina operators completed the questionnaire. The same process was followed for the U.S. AOS.

3.5 Fieldwork Data: Physical Depth Measurements
Slip depths at marinas were recorded with the Lowrance LCX-112C Sonar/GPS Chartplotter. Michel Gugen of Fisheries and Oceans Canada provided training on the use of the sounder and manipulation of measurement data using software.

The transducer attached to the LCX-112C, when placed into a body of water measured the depth. The LCX-112C also has a GPS unit that provided the coordinates of where each of the measurements was taken. The LCX-112C records other data when measurements are taken, but only depth, location and time were pertinent to the survey. The unit was mounted to a dolly while a car battery, which powered the unit, rested on the bottom of the same dolly. The transducer was attached to an approximately four foot long (1.2 meter) piece of wood. The transducer was able to move independently from the dolly as it was attached to the mounted LCX-112C by a single wire; approximately 4 meters long. Once a depth reading was found, it was recorded as a data point by saving a waypoint on the LCX-112C’s internal drive.

A waypoint was recorded for each slip, unless the depth was 2.7 meters or greater\(^2\). The depth of the slip, however, was noted to be greater than 2.7 meters. This cut-off depth allowed for quicker movement around marinas and freed time to survey a greater number of marinas in total. Slips having a depth of greater than 2.7 meters were considered to be safe slips and would still be usable if water-levels dropped by a meter or 3 feet.

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\(^2\) This cut-off depth was chosen because it translates to about 9 feet. With a 3 foot loss in water levels, at least 6 feet would remain in the slip. Six feet is the approximate average draft of a sailboat, the most vulnerable vessel to shallow water levels due to their deep keels. If a given slip could lose 3 feet and still accommodate a sailboat, it was considered safe and its depth was not recorded.
Once all the required waypoints were recorded for a given marina, the data was transferred from the LCX-112C's internal drive to the removable SD card. At this point a Lowrance USR (.usr) file was saved onto the removable SD card and transferred to a computer for analysis and manipulation.

Once the .usr file was transferred from the SD card to a computer, a program called GPS Babel was used to convert the .usr file into a format that is readable by Microsoft Excel: Garmin MapSource (.txt). Added to the spreadsheet was the difference (in meters) between the water level and the standard benchmark elevation used in navigational charts; chart datum\(^3\). The appropriate measurements at the time of the survey were chosen from the Fisheries and Oceans Canada website, “Tides, Currents, and Water Levels” where elevations are recorded at the nearest water level gauge. This measurement was used to calculate each slip’s elevation above the International Great Lake Datum (IGLD 1985). The formula used to calculate the slips bottom elevation was: Lake Chart Datum + Chart Datum Adjustment – Recorded Slip Depth. Also added to the spreadsheet were the total numbers of slips at the marina as well as the slips measured at the marina. (Refer to Appendix A)

These slip bottom elevations were then used to count the number of slips rendered unusable given three “slip-loss” scenarios of one (0.3m), two (0.6m) and three (0.9m) foot (meter) drops in the water level. All drops are subtracted from each Lake’s 2009 average elevation of the months in which measurements were taken. From this average water level three one foot (0.3m) intervals were subtracted to create the three scenarios of water level loss. These drops were chosen to represent potential changes in water levels based on long-term water level records. Furthermore, it is common to refer to water levels in one foot intervals, as these terms would be familiar to the marina operators. If the difference between the scenario water level and the slip elevation was less than two feet (0.6m), it was counted as lost and unusable. The decision to use a depth of two feet (0.6m) as the cut-off point for a functioning slip was based on the reasoning that at a depth lower than two feet (0.6m), it can become difficult for marinas to accommodate power boats with outboard motors (which typically have the shallowest draft requirements for common Great Lakes boats), let alone other types of boats which require deeper drafts. This decision may under report slip loss at marinas that rely on larger boats for business.

Also, the LCX-112C was equipped with a ‘Navionics’ chip that contained nautical charts of the Great Lakes. These charts contained enough detail to view the depths of access channels of the surveyed marinas. The access channel depths, adjusted to chart datum, were subjected to the same water level loss scenarios as the slip measurements.

\(^3\) All surveyed features on a navigational chart are positioned on some horizontal datum system. On the Great Lakes, water level and chart datum elevations are presently referenced to International Great Lakes Datum 1985 (http://www.waterlevels.gc.ca/english/VerticalDatums.shtml). The height of the water level above or below chart datum was obtained from the Fisheries and Oceans Canada website, “Tides, Currents, and Water Levels” found at http://www.waterlevels.gc.ca/.
described above. If a given marina’s access channel total depth dropped below 2 feet, all slips at the marina were considered lost.

The number of slips lost given each drop and rise scenario, were counted for each marina. The data from all of the marinas within a given AOS were combined on an AOS summary spreadsheet. This spreadsheet contains the total number of slips measured in the AOS, the total number of slips at the surveyed marinas in the AOS and a total of how many slips would be lost at the surveyed marinas based on each scenario. Regional vulnerability graphs were created by combining the data of all the surveyed marinas in a given AOS. The bar graph compares the surveyed marinas in the AOS directly, while the pie chart provides the overall vulnerability of the surveyed marinas in the AOS. This process was repeated until the same graphs were reproduced for each AOS where depth measurements were taken.

3.6 Questionnaire response data:
The questionnaire was designed to gather information that could be used to describe four sub- performance indicators: (Refer to Appendix C)

3.6.1 Past Experience with water levels: Damages and Adaptations. Damages sustained and adaptations that were undertaken as a result. The real BASELINE conditions under which marinas have operated in the context of past changes in water levels, to be used to evaluate the significance of hypothetical damages that may occur as a result of future changes in levels. Operators recounted their experience with historic episodes of changes in the water level with reference to the level at the time of the interview. To be comparable, their answers are referred to standardized water level elevations (explained in 3.6.2).

3.6.2 Adaptive Capacity and Threshold Vulnerabilities. Describes the various adaptations that marinas would be hypothetically able to use when dealing with changes in water levels. How effective are these adaptations? Do they suffer from threshold limitations? (From Pages 3 to 7 of questionnaire). The operators were asked to consider six hypothetical changes in water level starting from the level at the time of the survey. To be comparable, their answers are referenced to standardized elevations that were designed to approximate the level at the time of the surveys for each lake. These standardized elevations were constructed by taking the average of the monthly-average elevations during the time-frames in which surveys were conducted on each of the Lakes. The monthly average water level elevations for 2009 on lakes Erie, Huron and Superior were obtained from the monthly bulletins, "Water Levels: Great Lakes and Montreal Harbour Monthly Bulletin" from the Canadian Hydrographic Service webpage: http://www.waterlevels.gc.ca/C&A/back-arrieres_e.html. These standardized elevations are in turn referred to a horizontal benchmark used in navigational charts; the International Great Lakes Datum 1985. All surveyed features on a navigational chart are positioned on some horizontal datum system. On the Great Lakes, water level and chart datum elevations are presently referenced to International Great Lakes Datum 1985 (http://www.waterlevels.gc.ca/english/VerticalDatums.shtml). In Table 13, the
appropriate standardized monthly average elevations for Lakes Erie, Michigan/Huron and Superior (in blue) are compared to the individual elevations during the surveys.

3.6.3 Impediments to Adaptation. What stands in the way of performing necessary adaptations? Some examples given were the difficulty involved in obtaining dredging permits, or insufficient funding to undertake a necessary adaptation such as rebuilding seawalls. (From Page 7 of questionnaire).

3.6.4 Adaptive Management Strategies. Opinions expressed by respondents which may aid in the development of an adaptive management strategy. For example, many respondents suggested that governments design an ‘emergency’ grant or loan to aid marinas with the cost of dredging during periods of unusually low water levels. (From Pages 7 and 8 of questionnaire).

In addition, the questions from page 1 of the Questionnaire were designed to provide data that describes basic characteristics of the given marina including dockage, the type and size of boats that a given marina usually serves, services offered, operating season, and how many years a marina had been in operation. The same boat size categories were used as in the 2008 USACE report (USACE 2008, p6).

Also, once in the field, the question: “What are the three major factors that affect your business?” on page 7 of the Questionnaire, under the heading “Perception Questions”, was modified. The question lists four factors that might affect a given marina operator’s business (Water Levels, State of the Economy, Gas Prices and Other), and was intended for the surveyor to note which of these factors affects the marina according to the operator’s response. However, during the interviews operators were asked to rank the factors from, largest impact on their marina to smallest. For example, a marina could say water levels was the most important factor but gas prices had a larger impact than other (weather), while state of the economy had the smallest effect on the marina year to year. The design on the questionnaire was consistent with social survey design principles and was reviewed by the TWG and pretested on a marina operator. Revisions for clarity were completed.

From the questionnaire data, tables and graphs were created and analyzed according to the four performance indicators described above: Marina Characteristics, Adaptive Capacity and Threshold Vulnerabilities, Impediments to Adaptation, and Adaptive Management. Individual reports were created for each of the 10 AOS (which can be found in the Appendices), followed by the main report, where the different AOS are organized into regions, and analyzed comparatively on a regional and Lake-wide basis.

3.7 Fieldwork Data: Transcribing Attitudinal Questionnaire Data
Data written on the questionnaires was transcribed into an Excel spreadsheet titled ‘Survey Master Good’. However, some marina operators chose not to respond to certain questions, resulting in some inconsistencies in the attitudinal data. (Refer to Appendix C)
3.8 Economic Analysis
Monetary valuations were performed on both the data obtained from the interviews, and the physical depth measurements. The former attributed cost values to the damages and adaptations reported in the operators’ responses to the three hypothetical drop scenarios. The latter attributed cost values to the slips that were deemed lost given the three drop scenarios; both according to the depth measurements as well as the operators’ slip-loss estimates obtained from the interviews. Both sets of valuations are described below: (Refer to Appendix B)

3.9 Damages and adaptations estimates:
- The estimation of costs from the damages and adaptations reported in the operators’ responses to the three hypothetical low water scenarios required three pieces of information.
  A. The damages and adaptations reported with accompanying monetary cost estimates.
  B. The damages and adaptations reported without same.
  C. Historical expenditures on dredging and dock modifications from the operators’ accounts of their reactions to past episodes of low water levels.
- Due to the lack of monetary cost estimates in A, average costs were calculated for dredging and dock modifications reported in B and C. Average dredging costs were sorted by four different marina size categories (>100 slips, 100-200 slips, 201-400 slips, and >400 slips).
- These average cost values were then imputed for the dredging and dock modifications reported in B. With these first round imputations included, costs were then totaled for the three low water scenarios for each AOS and for Lakes Erie, Michigan/Huron, and Superior. U.S. operators’ accounts of past expenditures on dredging and dock modifications were then added to the costs used for the Canadian marinas, and new averages were calculated and used for the first round imputations for the U.S. marinas.
- However, even with the first round imputations, these estimates failed to include valuations for many of the damages and adaptations reported. As a result, an undervaluation was assumed.
- To get a rough idea of the potential magnitude of the undervaluation, a second round of imputations was performed using low-certainty prices for the damages and adaptations that were remaining without costs after the first round imputations. Ranges of potential cost increases by percentage were created.
- The estimates for the high water scenarios were not performed due to the lack of information in the responses.

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4 The costs reported in C were adjusted for inflation to 2009 constant Canadian dollars.

5 The cost estimates with the first round imputed average costs for dredging and dock modifications did not include the following adaptations: installing floating docks, extending docks, extending launch ramp, and repairing seawalls.
3.10 **Slip-loss revenue estimates:**
- The estimation of lost revenue from unusable slips due to low water levels required four pieces of information.
  - The physical depth measurements.
  - Slip loss estimates produced by the marina operator completing the questionnaire.
  - The average boat size, in feet, at each marina\(^6\) (obtained from Questionnaire).
  - Slip rental rate per-foot of boat dockage\(^7\).
- These pieces of information were used to calculate two separate slip-loss revenue estimates (Physical Depth Measurements vs. Operators’ response estimates). The average boat size was multiplied by the average per-foot slip rental rates to obtain revenue rates per-slip for the appropriate areas of survey and regions\(^8\).
- For the Physical depth measurement estimates, the number of slips lost at each marina for each of the three low water scenarios was then multiplied by the appropriate revenue rate per-slip. A 100 percent occupancy rate was assumed for the slip inventory\(^9\).
- For the Operators’ response estimates, the number of slips lost for each of the three low water scenarios was also multiplied by the appropriate revenue rate per-slip.
- The two resulting sets of lost revenue estimates were then compared.

3.11 **Combined costs:**
- To get rough overall estimates for the three low water scenarios, the cost estimates for the damages and adaptations (including the first and second round of imputations) were combined with the physical depth measurement slip-loss revenue estimates by Lake.
- An overall estimate of cost per surveyed marina for each of the Lakes was also created.

4.0 **Results and Findings**

4.1 **Coping Zones**
- From the field research undertaken by the TWG, Coping Zones were developed that were an indication of water-level preferences by marina operators on all four of the Great Lakes. The zones indicated a range of water-levels that marina operators felt would and would not impact their business. The sampling and surveys demonstrated that while there are localized unique physical limitations and aspects that hamper adaptation under extreme lake level conditions, there was a remarkable similarity in the outcomes – i.e.

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\(^6\) Due to gaps in the data, only an AOS wide average for boat size could be calculated. This average was calculated from the marina operators’ answers to the questionnaire.

\(^7\) Again, due to gaps in the data, the rental rate average could only be calculated by region. This average was calculated using listed slip rates per-foot that were posted on marina websites, as we did not have the foresight to include a question in the survey to collect this data.

\(^8\) The Erie region used five listed prices to calculate the average cost per foot of dockage, the South Huron region also used five, the Georgian Bay region used 15, and the North Channel region used seven. A proxy was used for the Superior region due to a lack of listed prices online.

\(^9\) A 93 percent occupancy rate was used in the Lake Ontario Study.
the lake level ranges that created economic difficulties. This is a critical piece of information for consideration by regulators. (Refer to Appendix D)

4.2 Observations and Estimates

- Due to the lack of information on recreational boating on the Ontario side of the border, estimates had to be made based on the best available information. In order to ensure that the studies undertaken by the Recreational Boating Technical Working Group were deemed to be valuable, both by the Plan Authors and the Peer Review Panel, the TWG has put qualifiers on all information that was either assumed or estimated. However, information gathered verbally was checked against other studies such as the John Glenn Study undertaken by the U.S. Army Corps of Engineers in 2008 and for the most part seemed to reflect those of our study findings.

- This section was developed by the TWG Co-leads using information gathered from the International Upper Great Lakes Study; Recreational Boating Final Report 2010 ( Appendix A) and the International Upper Great Lakes Study: Recreational Boating Economic Analysis 2010 (Appendix B), both of which were produced by the Recreational Boating, Cruise Ship and Tourism Technical Working Group using two paid university graduates as field researchers.

- The two studies noted above only addressed the direct finding within the 17 study zones.

This section is an attempt to extrapolate information from those findings to cover the whole study area and provide readers with an indication of the significance of changing water-levels to marine operators who make their living providing services to recreational boaters. The information being presented are estimates only so as to provide numerical and financial parameters of the potential impacts using the three water-level scenarios.

The number of slips identified within the study area in the U.S. is as follows:

<table>
<thead>
<tr>
<th>State</th>
<th>Slips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minnesota</td>
<td>607</td>
</tr>
<tr>
<td>Illinois</td>
<td>8,487</td>
</tr>
<tr>
<td>Indiana</td>
<td>2,883</td>
</tr>
<tr>
<td>Michigan</td>
<td>54,056</td>
</tr>
<tr>
<td>New York**</td>
<td>2,000</td>
</tr>
<tr>
<td>Ohio</td>
<td>39,915</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>3,224</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>8,287</td>
</tr>
<tr>
<td><strong>Total Slips</strong></td>
<td><strong>120,066</strong></td>
</tr>
</tbody>
</table>

This number is based on approximately 1200 marinas surveyed during the John Glenn Study in 2008.

** New York slips were estimated based on the fact that only 15 marinas were identified as being on Lake Erie. Most of New York State marinas are found on the Niagara River and on Lake Ontario.
The number of slips estimated within the study area in Ontario Canada is as follows:

The Ontario Marina Operators Association indicated that they have a membership of 114 marinas who operate 19,905 slips within the study area. They estimate that 70% of the total marinas within the study area are members of their association. Extrapolating numbers from this estimate, it is predicted that there are approximately 162 marinas with 28,500 slips on the Ontario side within the study area.

Using the above information as a baseline, the following assumptions have been made.

In the U.S., the survey team identified 7049 slips in the 7 zones of which 4,347 were actually depth measured. (The ones not measured were deeper than 2.7 meters and deemed not to be effected by a three foot drop in water depth). This equated to approximately 62% of the slips that could be affected by water-level fluctuations of up to .9 meter (3 feet) but still may be usable for smaller pleasure craft. (See Table 49 of the Recreational Boating Final Report) However, the survey results indicated that 784 slips of those measured would be unusable (less than .6 meters in depth). This indicates that approximately 11% of the slips observed/counted would not be usable if current water-levels were to drop by .9 meters. Using these numbers and percentages to determine slip loss across the UGLS area, it is projected that: if a .3 meter drop would occur, 1801 slips would be lost on the U.S. side of the Great Lakes (120,066 X1.5% = 1801). If a .6 meter drop were to occur survey results show that 4322 slips would become unusable. (120,066 X3.6% = 4322). One could conclude that 13,207 slips on the U.S. side would be unusable in the event of a .9 meter water drop from current 2009 levels. (120,066 X 11% = 13,207).

On the Canadian side, the results of a .9 meter water drop are more pronounced. The survey team physically measured 9615 slips of a total of 14,025 in the 10 pre-selected zones. This equated to approximately 68% of the slips that would be affected if a .9 meter water-drop was to occur. The survey results also indicated that 3115 slips would be unusable with a .9 meter water drop from 2009 levels within the sample area. (See Table 48 of the Recreational Boating Final Report) This equated to 22% of the total slips within the 10 study zones being unusable.

If a .3 meter drop was to happen it is estimated that 798 slips would be lost or 2.8% (28,500 X 2.8% = 798). In the event of a .6 meter water-level drop from current levels, it is estimated that 7.9% of the slips would be unusable that equated to 2251 slips (28,500 X 7.9% = 2251). If a .9 meter drop were to occur, 22.2 % of the slips would be unusable that equated to 6327 slips (28,500 X 22.2% = 6327).

4.3 **Financial Impacts**

Using the above noted assumptions, the authors have tried to determine/estimate a range of economic impacts resulting from the three scenarios estimated above.

4.3.1 **Total Slip Loss Revenue for the Complete Study Area.**

The approach takes for this exercise was to identify the number of slips observed within the 17 sample zones as a percentage of the overall slips identified within the complete study area. This was done by looking at the percentages of surveyed slips in both Canada and the United States. Approximately 50% of all slips on the Canadian side of the study area were surveyed but only about 6% of the total U.S. slips were surveyed.
Based on the findings and calculations from the Recreational Boating Study we projected slip loss revenue in both Canada and the U.S. and then combined those numbers. This was done for the three scenarios of a one foot, two foot and three foot drop in water-levels from the current 2009 water-levels observed.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Canada</th>
<th>United States</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Foot</td>
<td>$1,260,000.00</td>
<td>$3,930,000.00</td>
<td>$5,190,000.00</td>
</tr>
<tr>
<td>2 Feet</td>
<td>$3,840,000.00</td>
<td>$9,700,000.00</td>
<td>$13,540,000.00</td>
</tr>
<tr>
<td>3 Feet</td>
<td>$10,362,000.00</td>
<td>$30,699,000.00</td>
<td>$41,060,000.00</td>
</tr>
</tbody>
</table>

4.3.2 Damages and Adaptation Costs

This exercise was much more subjective. In order to get an indication of the magnitude of the costs that might be incurred in order to ensure the viability of marinas within the Upper Great Lakes, the initial study developed a range of costs both at the high end and low end as described on page 11 of this report. In order to maximize accuracy, calculations were done by lake, since costs seemed to differ substantially from lake to lake. The following projections were developed:

<table>
<thead>
<tr>
<th>Lake Erie</th>
<th>1 Foot</th>
<th>2 Feet</th>
<th>3 Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.</td>
<td>$1,342,000.00</td>
<td>$3,178,000.00</td>
<td>$7,265,000.00</td>
</tr>
<tr>
<td>Min.</td>
<td>$670,900.00</td>
<td>$360,480.00</td>
<td>$989,851.00</td>
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</table>

<table>
<thead>
<tr>
<th>Lake Huron</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.</td>
<td>$5,917,000.00</td>
<td>$10,265,000.00</td>
</tr>
<tr>
<td>Min.</td>
<td>$1,085,000.00</td>
<td>$6,926,000.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lake Superior</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.</td>
<td>$0</td>
<td>$1,748,000.00</td>
</tr>
<tr>
<td>Min.</td>
<td>$0</td>
<td>$194,000.00</td>
</tr>
</tbody>
</table>

**Totals**

| Max.      | $7,259,000.00 | $30,923,000.00 | $58,057,000.00 |
| Min.      | $1,756,000.00 | $7,480,000.00  | $13,679,000.00 |

4.3.3 Combined Estimated Costs

In order to determine the total costs of changing water-levels, we added the damage and adaptation costs to the slip loss revenues. This gives an indication of the total potential costs to marina operators within the complete Upper Great Lakes Study area.

**Total Costs ***

| Max.      | $12,450,000.00 | $36,254,000.00 | $99,117,000.00 |
| Min.      | $6,948,000.00  | $21,017,000.00 | $54,738,000.00 |

*** These are estimates only based on extrapolation of estimates and verbal information taken from the Upper Great Lakes Study Report 2010.
5.0 Next Steps and Recommendations

In gathering data for the study, there were some glaring gaps where there were no known existing databases to seek information. An extensive literature review was undertaken and the lack of information regarding the recreational boating industry on the Canadian side of the Great Lakes was concerning. Of particular concern was the fact that there was no electronic boat registration data base readily available in Canada despite the fact that powerboats have been manually registered for several decades. Also, no database could be found identifying Ontario marinas unless they belonged to an association.

In order to get a better understanding of this multi-billion dollar industry, it is being proposed that the following datasets and studies be initiated and maintained for future studies and work.

**Databases**

- Watercraft registration information (electronic) – Canada
- Marina database (electronic) – U.S. and Canada
  - Facilities open to public
  - Facilities closed to public (yacht clubs, dockominiums, lake associations, etc.)
- Boat launch database (electronic) – U.S. and Ontario
  - Facilities open to public
  - Facilities closed to public (yacht clubs, dockominiums, lake associations, etc.)

**Studies/surveys (5 year cycles)**

- Boat launch use
- Marina use
- Recreational boat spending (direct and indirect benefits)
- Boating Industry Job Creation & Retention
- Recreational Boat Types and Use
- Climate Change Impacts to Recreational Boating (one cycle)
Appendix ‘A’

IUGLS: Recreational Boating Final Report
(125 pages)
International Upper Great Lakes Study: Recreational Boating Final Report
This report was produced by the Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) at MIRARCO in accordance with the contract that exists between the Great Lakes Observing System (GLOS) and the Mining Innovation, Rehabilitation and Applied Research Corporation. This report was produced in support of the Tourism, Recreational Boating and Cruise Ship Technical Working Group of the International Upper Great Lakes Study.

GLOS: W26HM400150014
Project Number: MPA/MIRARCO-01

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Executive Summary

This report summarizes the results of a two part survey administered to provide an assessment of the vulnerability of the upper Great Lakes marina industry to fluctuations in water levels of approximately one meter, both up and down, from the long term average water elevation during the boating season (May to October). Personal interviews with marina owners and operators as well as depth measurements at slips were completed at a total of seventeen areas of survey (AOS) spread along Lakes Erie, Huron and Superior; ten in Canada and seven in the United States of America. Based on the responses to questionnaires completed by 111 marina owner/operators (77 Canadian, and 34 U.S.A.), this report summarizes regional industry characteristics of the different sample areas, their experience with historical episodes of fluctuating water levels, as well as their responses to different scenarios of water level fluctuations pertaining to damages and adaptations. Physical depth measurements from 125 marinas (88 Canadian, and 37 U.S.A.) yielded regional slip-loss estimates for three incremental one foot (0.3m) drop scenarios below the 2009 average elevation during the boating season. Using the physical depth measurements, each marina’s set of slip measurements were subjected to three scenarios of one foot (0.3m) interval drops below the host Lake’s 2009 average elevation for the months during which surveys were completed. The number of slips with less than two feet (0.6m) of water after a one foot (0.3m), two foot (0.6m) and three foot (0.9m) drop from this average were considered to be unusable. Finally, this measure, as well as the costs reported in the operators’ responses, was used to generate rough economic loss estimates related to the three drop scenarios.

From the physical measurements,

All nine of the U.S. and Canadian regions experience a threshold increase in slip losses between the two and three foot drop scenarios (175.8m-175.5m on Lake Michigan/Huron; 173.8m-173.5m on Lake Erie; and 182.8m-182.5m on Lake Superior).

The two most southern Canadian regions (Erie and South Huron), along with two of the U.S. regions on Lakes Michigan and Huron (Holland and Alpena/Bay City) are more vulnerable to slip losses given the water level drop scenarios than the five other regions (The Canadian regions of Georgian Bay, North Channel, and Superior; and the U.S. regions of Toledo/Sandusky and North U.S.).

Given the three foot (0.9m) drop scenario from the appropriate average water level elevation, the U.S. regions of Alpena/Bay City and Holland suffer significantly worse slip losses than the North U.S. and Toledo/Sandusky regions (21% and 20% vs. 12% and 1%, respectively). On the Canadian side, the Erie and South Huron regions suffer significantly worse slip losses than the Georgian Bay, North Channel, and Superior regions (31% and 25% vs. 16%, 15% and 5%, respectively).

The marinas in the Toledo/Sandusky region suffer almost no slip losses (1%). However, in the process of recording depth measurements there, field researchers observed that a significant proportion of the
marinas were vulnerable to shallow access channels despite the fact that most of their slips remained deep enough to dock boats given the drop scenarios. In many cases, a ‘bottleneck’ effect could prevent access to the marinas given a significant drop in the water level; which could render 100% of their slips unusable. Similar vulnerabilities exist within the Holland, Alpena, Bay City, Baraga, and Turkey Point AOS; but affect smaller proportions of the marinas than in the Toledo/Sandusky AOS.

From the personal interviews with 111 marina operators,

A majority of the marinas within all of the regions have been affected by historic periods of low water levels between 1995 and 2008. At least half of these marinas were able to adapt by dredging, performing dock modifications, and installing floating docks.

In contrast, periods of high water levels had proven to be more of a nuisance than a serious problem for most of the marinas, except for a concentration of those located on the eastern end of Lake Erie where high water had led to increased flooding and ice damage from wind seiches during the mid 1980’s.

According to the survey respondents, a hypothetical drop of three feet (-0.9m), from the elevation during the interview, would create a significantly larger proportion of unusable slips, damages to launch ramps, seawalls, and docks, increased aquatic weed growth and inadequate access channel depths when compared to a two foot drop (-0.6m). The results indicate that the North Channel, Erie¹, South Huron, Alpena/Bay City, and Holland regions would be more vulnerable to the same drop scenario than the Superior, North U.S., Georgian Bay and Toledo/Sandusky regions.

Many of the Canadian operators stressed that they would have difficulty accommodating sailboats, or other large boats (>21ft) that require deeper draft (~1.5m) in access channels and dockage under the three feet drop (-0.9m) scenario.

In response to the three foot (0.9m) water level drop scenario, about half of the Canadian operators would be likely to dredge. More than half of the U.S. operators would dredge as well.

A large proportion of marinas in the Erie and South Huron regions would likely suffer flooding and ice damage given the two (0.6m) or three foot (0.9m) rise scenarios. However, the same rise scenarios would significantly affect only a small proportion of the marinas within the Georgian Bay, North Channel and Superior regions². In fact, several of the operators in these regions said that a three foot rise would actually increase revenues by allowing them to accommodate larger cruise and sailboats. Except for two

¹ Within the Erie region, the Turkey Point AOS would be exceptionally vulnerable to drops in the water level, as most of its marinas lie within the shallow Inner Bay of Long Point Bay, a renowned sports-fishing destination.
² At a two foot rise, a small minority of marinas in these three regions would incur damages to docks and seawalls. At a three foot rise, these issues would be slightly amplified, but still quite manageable for the majority.
U.S. marinas\(^3\), a relatively small proportion would be significantly affected by even a three foot (0.9m) rise in the water level. Most of the U.S. marinas would be quite resilient.

Approximately half of the marinas surveyed on Lake Erie would go out of business if the water level were to drop by three feet (-0.9m) from the 174.4 meter elevation to 173.5m, with a significant threshold increase appearing between the 173.8m and 173.5m elevations. Most of the operators would prefer the water level to remain at the 174.4m elevation.

On Lake Michigan/Huron, about half of the marinas in the Little Current, Port Huron, Goderich, Bay City, Holland, and Menominee AOS’s would go out of business if the water level were to drop by three feet (-0.9m) from the average elevation during the surveys (176.4m) to 175.5m. This represents significant threshold vulnerability for most of the marinas on the Lake between the 175.8m and 175.5m elevations. However, only a minority of the marinas in the Midland (26%), Richard’s Landing (25%), and Alpena (0%) would go out of business at 175.5m. Most of the operators would prefer the water level to be one foot (0.3m) higher than the 2009 average elevation of 176.4m, at 176.7m.

On Lake Superior, all of the marinas in the Baraga and Ontonagon AOS’s would go out of business if the water level were to drop three feet (0.9m) from the August 2009 average elevation of 183.4m to 182.5m. This represents significant threshold vulnerability between the 182.8m and 182.5m elevations; although neither of the marinas that completed questionnaires in the Thunder Bay AOS would be affected. Most of the operators would prefer the water level to be one foot (0.3m) higher than the 2009 average elevation of 183.4m, at 183.6m.

From the economic analysis,

As expected, a critical threshold increase in costs exists from the two foot (0.6m) drop to the three foot (0.9m) drop scenarios on both the Canadian and American sides.

Given a three foot drop from the appropriate average elevation, minimum cost estimates per surveyed marina are as follows: $53,000 per marina on Lake Erie, $83,000 per marina on Lake Michigan/Huron, and $61,000 per marina on Lake Superior. These estimates apply only to those marinas that participated in the survey, and thus should not be taken as a complete representation of all commercial marinas on each Lake\(^4\).

\(^3\) Given a three foot (0.9m) rise, one of the three marinas in the Toledo/Sandusky region would go out of business due to shoreline erosion, and one of the two marinas in the Menominee AOS would lose 100% of their slips due to their inability to finance the installation of floating docks in order to adapt.

\(^4\) Thirty five marinas were surveyed on Lake Erie, 83 were surveyed on Lake Michigan/Huron, and 5 were surveyed on Lake Superior.
1.0 Regional Descriptions

Figure 1: The 17 Areas of Survey

In total, seventeen areas of survey (AOS) were visited along the shores of Lakes Erie, Huron, Michigan, and Superior.
Canadian Regional Descriptions

Erie Region

Areas of Survey (AOS): Port Colborne, Turkey Point, Kingsville

The marinas surveyed in the Lake Erie region are clustered near the mouth of the Niagara River, near the outlet of the Grand River, inside Long Point Bay’s Inner Bay, and around the city of Windsor at the mouth of the Detroit River (Port Colborne, Turkey Point, Kingsville AOS Analyses Appendices). The Turkey Point and Port Colborne AOS are situated on the eastern end of the lake while the Kingsville AOS is near the western end. Apart from the several marinas clustered near the city of Windsor, most are located near rural communities. Many of the marinas double as trailer parks and accommodate angling enthusiasts drawn to Lake Erie’s shallow waters which are renowned for sport-fishing.

South Huron Region

Areas of Survey (AOS): Sarnia, Goderich

The marinas surveyed in the South Huron Region are clustered around Sarnia at the mouth of the St Clair River, and in the mouths of the Maitland River in Goderich, and the Bayfield River in Bayfield (Sarnia and Goderich AOS Analyses Appendices). The two AOS within this region are not homogenous. The main difference is that the marinas in the Sarnia AOS are clustered around a larger urban center (Sarnia), while those in the Goderich AOS, situated further north, are located in rural communities. However, marinas in both of the AOS accommodate a large proportion of sailboats. This region faces competition from marinas on the nearby U.S. side of southern Lake Huron.

Georgian Bay Region

Areas of Survey (AOS): Midland, Parry Sound

The marinas surveyed in the Georgian Bay Region are situated around Severn Sound, Honey Harbour, Parry Sound, and the town of Pointe-au-Barril (Midland and Parry Sound AOS Analyses Appendices). The marinas in the Parry Sound AOS accommodate more cottage commuters, while the marinas in the Midland AOS cater more to transient and seasonal boaters. However, both AOS are located within waters that are very popular destinations for transient boaters. Attractions include the 30,000 Islands, Parry Sound, Killbear Provincial Park, Severn Sound, Honey Harbour and Wasaga Beach.
North Channel Region

Areas of Survey (AOS): Little Current, Richards Landing

The marinas surveyed in the North Channel Region are situated in the town of Killarney, around Manitoulin Island, the outlet of the Spanish River, around St Joseph Island, and in the city of Sault Ste Marie (Little Current and Richards Landing AOS Analyses Appendices). Many are situated in popular tourism and boating areas, including Killarney Provincial Park, Manitoulin Island, the Spanish River, the North Channel, St Joseph Island, and the Sault Locks.

Superior Region

Areas of Survey (AOS): Thunder Bay

The marinas surveyed in the Superior Region were clustered around the city of Thunder Bay, with one of the marinas being situated on the southern extent of Sleeping Giant Provincial Park. The rugged beauty of the region’s shoreline makes it a popular destination for transient sailors, and one that is enjoyed enthusiastically by local boaters.
U.S. Regional Descriptions

**Figure 2: Areas of Survey in the U.S.**

**Toledo/Sandusky Region**

**Areas of Survey (AOS): Toledo/Sandusky**

The marinas surveyed in the Toledo/Sandusky Region were clustered around the cities of Toledo and Sandusky Michigan, in and around Maumee Bay and Sandusky Bay at the east end of Lake Erie.

**Figure 3: Toledo/Sandusky Region**
Alpena/Bay City Region
Areas of Survey (AOS): Alpena, Bay City
The marinas surveyed in the Alpena/Bay City Region are located along Saginaw Bay and Thunder Bay; both of which feeds into Lake Huron.

Holland Region
Areas of Survey (AOS): Holland
The marinas surveyed in the Holland Region are located along Lake Macatawa, which feeds into Lake Michigan.
North U.S. Region
Areas of Survey (AOS): Menominee, Baraga, Ontonagon
The marinas surveyed in the North U.S. Region are located along Green Bay, which feeds into Lake Michigan; along L’anse Bay which feeds into Lake Superior; and the town of Ontonagon, on Lake Superior.

Figure 6: North U.S. Region
2.0 Marina Characteristics

In this section, the different regions are analyzed in terms of industry characteristics obtained from the interviews with marina operators. During the survey, marina operators completed the questionnaires, providing information describing their marina’s slip distribution, dry storage capacity, sizes and types of boats accommodated, services offered, operating season, and significant factors that affect their business. It should be noted however, that the following marina characteristics only represent the marinas that completed questionnaires. Also, the sample of marinas for each region may not be representative of the industry in those areas.

Table 1: Number of Canadian marinas that completed questionnaires and depth measurements

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Marinas that Completed Questionnaires</th>
<th>Marinas with Completed Depth Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>Port Colborne</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Turkey Point</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Kingsville</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>South Huron</td>
<td>Port Huron</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Goderich</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>Midland</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Parry Sound</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>North Channel</td>
<td>Little Current</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Richards Landing</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Superior</td>
<td>Thunder Bay</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

For the most part, the Canadian regions are evenly represented in terms of the amount of respondents who completed questionnaires within each AOS (Table 1). The Erie, Georgian Bay, and North Channel regions each completed twenty or more questionnaires. This amount is a relatively larger amount than those completed by the South Huron and Superior regions. Respondents in these two regions completed an average of three questionnaires per AOS; which is small compared to the average of ten questionnaires completed per AOS in the Erie, Georgian Bay and North Channel regions.

---

5 As can be seen in Table 1, depth measurements were completed at more marinas than questionnaires.
6 This issue applies in particular to the Thunder Bay AOS, where depth measurements were completed at the city’s largest marina, but a questionnaire was not. Although questionnaire data was obtained from two other marinas in the area, the data set does not provide a strong representative sample compared to data sets from the other four regions.
7 With the exception of the North Channel Region, where respondents in the Little Current AOS over represent those in the Richards Landing AOS by three to two.
In the U.S., the Toledo/Sandusky and Holland areas had far more marinas that completed depth measurements than the other areas of survey (AOS) (Table 2). Also, significantly more questionnaires were completed in the Holland AOS than any other AOS. Participation was particularly low in the two AOS on Lake Superior (Baraga and Ontonagon).

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Marinas that Completed Questionnaires</th>
<th>Marinas with Completed Depth Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena/Bay City</td>
<td>Alpena</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Bay City</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>Toledo/Sandusky</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Holland</td>
<td>Holland</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>North U.S.</td>
<td>Menominee</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Baraga</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Ontonagon</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

### 2.1 Distribution of Wet Slips, Transient Slips and Storage Capacity

The distribution of wet slips is displayed in Tables 3 and 4. In Canada, the South Huron, Erie, and Georgian Bay regions have significantly higher numbers of wet slips per marina than the Superior or North Channel Regions. In the former three regions, the numbers of wet slips are concentrated in the Sarnia, Turkey Point and Midland AOS. The South Huron region has the highest average and median number of wet slips per marina, as well as the highest number of minimum wet slips per marina. Slips in the South Huron region are concentrated in the Sarnia AOS; which outnumber those in the Goderich AOS by more than two to one.

The Georgian Bay and Erie regions also have a high number of average and median wet slips per marina. Within the Erie region, the Turkey Point AOS has between three and four times the average number of wet slips per marina than the other two AOS in the region\(^8\). Similarly, in the Georgian Bay region, the Midland AOS has almost twice the average wet slips per marina than the Parry Sound AOS. The North Channel and the Superior regions have noticeably fewer wet slips than the other three regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average (Median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>4</td>
<td>750</td>
<td>189 (115)</td>
</tr>
</tbody>
</table>

\(^8\) Marinas in Turkey Point provide 2372 of the region’s wet slips, while Port Colborne and Kingsville have 941 and 662 respectively.
In the U.S., the Toledo/Sandusky region has the highest amount of average wet slips per marina, followed by the Alpena/Bay City region, the Holland region, and the North U.S. region. The latter has significantly less wet slips per marina than the other three regions.

Table 4: Distribution of wet slips per marina in the U.S.

<table>
<thead>
<tr>
<th>Region</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average (Median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena/Bay City</td>
<td>41</td>
<td>453</td>
<td>192 (128)</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>40</td>
<td>2250</td>
<td>890 (380)</td>
</tr>
<tr>
<td>Holland</td>
<td>35</td>
<td>450</td>
<td>154 (97)</td>
</tr>
<tr>
<td>North U.S.</td>
<td>5</td>
<td>253</td>
<td>73 (40)</td>
</tr>
</tbody>
</table>

The distribution of transient slips is displayed in Tables 5 and 6. In Canada, the South Huron, North Channel and Georgian Bay regions offer relatively more transient dockage than the other two regions. The transient slips are not evenly distributed among these three region’s AOS. In fact, the highest concentrations of transient dockage are found in the Sarnia and Little Current AOS. The former has more than double the average amount of transient slips per marina than the latter.

All five of the regions contain some marinas with little or no transient slips. More than half of the marinas in the Georgian Bay and Erie regions offer no transient dockage at all. Regions that experience large flows of transient boat traffic may be vulnerable to significant drops in the water level if larger cruise and sail boats, requiring deeper draft, are unable to find adequate access and/or dockage. These large transient boats represent a significant portion of gas revenue and docking fees for regions with high transient traffic.

Table 5: Distribution of transient slips per marina in Canada

<table>
<thead>
<tr>
<th>Region</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average (Median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>0</td>
<td>60</td>
<td>10 (0)</td>
</tr>
<tr>
<td>South Huron</td>
<td>0</td>
<td>150</td>
<td>35 (23)</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>0</td>
<td>200</td>
<td>18 (0)</td>
</tr>
</tbody>
</table>

9 However, it should be noted that a questionnaire was not completed by the largest marina in the Superior region, which may offer a large number of transient slips. The South Huron region has the highest average, with only one of its eight marinas offering no transient slips.

10 In the South Huron region, the Sarnia AOS offers almost four times the amount of average transient slips per marina than the Goderich AOS. In the North Channel region, the Little Current AOS has almost twice the average amount of transient slips per marina than the Richards Landing AOS. In the Georgian Bay region, the Midland AOS has almost twice the average amount of transient slips per marina than the Parry Sound AOS. This may be attributed to the fact that many of the Parry Sound AOS marinas cater to cottage commuters.

11 The Sarnia AOS has 56 transient slips per marina while the Little Current AOS has 24 per marina.
In the U.S., the Alpena/Bay City region has more transient slips per marina than the other three regions, although the Holland and North regions do have an average of seven transient slips per marina. The Toledo/Sandusky region has no transient slips, but this may be due to the fact that of the ten marinas surveyed there, only three completed questionnaires.

Table 6: Distribution of transient slips per marina in the U.S.

<table>
<thead>
<tr>
<th>Region</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average (Median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena/Bay City</td>
<td>0</td>
<td>83</td>
<td>26 (12)</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>0</td>
<td>0</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Holland</td>
<td>0</td>
<td>20</td>
<td>7 (5)</td>
</tr>
<tr>
<td>North U.S.</td>
<td>5</td>
<td>10</td>
<td>7 (7)</td>
</tr>
</tbody>
</table>

The distribution of dry-land storage capacity is displayed in Tables 7 and 8. In Canada, marinas surveyed in the Georgian Bay and South Huron regions store much higher numbers of boats per marina on land than the other three regions. However, there is almost four times the amount of boats stored in the Georgian Bay region than in the South Huron region. Within the South Huron Region, storage capacity is concentrated in the Sarnia AOS. In contrast, the Erie and North Channel regions have relatively low storage capacities. A marina’s capacity to store boats on land is, to an extent, dependent on their ability to launch and haul boats from out of the water. Capacity to undertake this process can become reduced during periods of significant fluctuations in water levels. Launch ramps and travel lift slips used for these operations may become too shallow during periods of low water levels just as they can become obstructed or damaged during flooding caused by ice jams or wind seiches. As a result, regions that specialize in the boat storage business may be more vulnerable to significant fluctuations than other regions.

Table 7: Storage capacity per marina in Canada

<table>
<thead>
<tr>
<th>Region</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average (Median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>0</td>
<td>150</td>
<td>40 (20)</td>
</tr>
<tr>
<td>South Huron</td>
<td>0</td>
<td>250</td>
<td>115 (115)</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>0</td>
<td>1000</td>
<td>147 (90)</td>
</tr>
<tr>
<td>North Channel</td>
<td>0</td>
<td>400</td>
<td>54 (0)</td>
</tr>
<tr>
<td>Superior</td>
<td>100</td>
<td>200</td>
<td>150</td>
</tr>
</tbody>
</table>

12 The Superior region may in fact have a higher storage capacity, but questionnaire data from the region is incomplete as it excludes a marina known to be significant to the area.

13 The Georgian Bay region stores 3813 boats annually, while the South Huron region stores 920.

14 The Sarnia AOS has an average storage capacity of 145 boats per marina, whereas the Goderich AOS has an average capacity of 85 boats per marina.
In the U.S., the Toledo/Sandusky region has a significantly higher average storage capacity per marina than the other three regions. The Holland region has the second highest storage capacity, followed by the Alpena/Bay City region. According to the six questionnaires completed in the North U.S. region’s three AOS, they have no storage capacity whatsoever\(^\text{15}\).

**Table 8: Storage capacity per marina in the U.S.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average (Median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena/Bay City</td>
<td>0</td>
<td>100</td>
<td>14 (0)</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>0</td>
<td>450</td>
<td>193 (130)</td>
</tr>
<tr>
<td>Holland</td>
<td>0</td>
<td>260</td>
<td>43 (0)</td>
</tr>
<tr>
<td>North U.S.</td>
<td>0</td>
<td>0</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

### 2.2 Boat Type and Size

The main types of boats accommodated by the marinas in each region are displayed in tables 9 and 10. In Canada, all five of the regions accommodate cruising and sail boats. Along with these, the Erie, North Channel and Superior regions specialize in accommodating boats used for sport fishing\(^\text{16}\). Although some of the other regions do house cottage commuter boats\(^\text{17}\), the primary focus of the Georgian Bay marinas is to service cottage commuters, especially within the Parry Sound AOS. The Erie region accommodates the most diverse range of boat types, with at least one-third of its marinas accommodating pontoon and personal water craft (PWC), in addition to their mainstays of fishing, cruise and sail boats. The ability to accommodate sail boats or larger cruise boats can be reduced during periods of low water levels, as these types of boats require deeper access channels and dockage.

**Table 9: Proportion of marinas that accommodate different boat types by region in Canada**

<table>
<thead>
<tr>
<th>Region</th>
<th>Cruising</th>
<th>Sail</th>
<th>Fishing</th>
<th>Cottage Commuter</th>
<th>Power</th>
<th>Pontoon</th>
<th>PWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>South Huron</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Channel</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accommodated by</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;66% of Marinas</td>
<td>A</td>
</tr>
<tr>
<td>33% to 66% of Marinas</td>
<td>B</td>
</tr>
<tr>
<td>&lt;33% of Marinas</td>
<td></td>
</tr>
</tbody>
</table>

---

\(^{15}\) However, this may be in fact false, given the possibility that respondents misunderstood the survey question.  
\(^{16}\) Boats used for recreational or sport fishing are referred to as ‘fishing’ boats.  
\(^{17}\) Several respondents explained that cottage commuter boats were typically used to access remote cottages on island or on the shoreline of the Georgian Bay region. One respondent explained that a typical “3000 islands regular cottage owner” would have three boats: One 24-28 footer, one 18-20 footer, and one 14-16 foot aluminum runabout. They explained that the average size used to be 18 feet 11 years ago. Now the average is a 20 foot deep hull fiberglass, with 15 inches of draft.
In the U.S., more than 66% of marinas in all four regions accommodate cruising, sail, and fishing boats. For the most part, between 33% and 66% of marinas in all four regions also accommodate pontoon boats and personal water craft as well\textsuperscript{18}. None of the regions have marinas that accommodate cottage commuters\textsuperscript{19}.

### Table 10: Proportion of marinas that accommodate different boat types by region in the U.S.

<table>
<thead>
<tr>
<th>Region</th>
<th>Cruising</th>
<th>Sail</th>
<th>Fishing</th>
<th>Cottage Commuter</th>
<th>Power</th>
<th>Pontoon</th>
<th>PWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena/Bay City</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Holland</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>North U.S.</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
</tbody>
</table>

The typical boat sizes accommodated by the different regions are displayed in Tables 11 and 12. All of the Canadian regions accept boats between 16 and 40 feet long at most of their marinas\textsuperscript{20}. Other than in the Erie region, at least one-third of the marinas in the rest of the regions accommodate boats that are greater than 40 feet\textsuperscript{21}.

### Table 11: Proportion of marinas that accommodate different boat sizes by region in Canada

<table>
<thead>
<tr>
<th>Region</th>
<th>&lt;12ft</th>
<th>12-15ft</th>
<th>16-20ft</th>
<th>21-28ft</th>
<th>29-40ft</th>
<th>40+ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Huron</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Channel</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior</td>
<td>B</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The typical boat sizes accommodated by the different regions are displayed in Tables 11 and 12. All of the Canadian regions accept boats between 16 and 40 feet long at most of their marinas\textsuperscript{20}. Other than in the Erie region, at least one-third of the marinas in the rest of the regions accommodate boats that are greater than 40 feet\textsuperscript{21}.

### Table 11: Proportion of marinas that accommodate different boat sizes by region in Canada

<table>
<thead>
<tr>
<th>Region</th>
<th>&lt;12ft</th>
<th>12-15ft</th>
<th>16-20ft</th>
<th>21-28ft</th>
<th>29-40ft</th>
<th>40+ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Huron</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>B</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Channel</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior</td>
<td>B</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{18} More than 66% of marinas in the Alpena/Bay City region accommodate pontoon boats. More than 66% of marinas in the Toledo/Sandusky region accommodate personal water craft.

\textsuperscript{19} It is likely that most respondents reported power boats as cruising boats (this survey attempted to distinguish cruising boats without sleep cabins as ‘power boats’, which was a source of confusion for both respondents and fieldworkers.

\textsuperscript{20} Except for the Georgian Bay region, in which about half of the marinas do not accommodate boats longer than 28 feet. Also, the Superior Region specializes in boats that are 29 feet and longer, and half of its marinas do not accommodate boats that are smaller than 28 feet.

\textsuperscript{21} Only half of the marinas in the Georgian Bay and North Channel regions can house boats longer than 40 feet.
More than 66% of the marinas in all four U.S. regions accept boats between 21 and 40 feet long (except for the Alpena/Bay City and North U.S. regions). The Toledo/Sandusky region accepts the widest range of sizes, followed by the Holland region. The Alpena/Bay City region tends to accept longer boats (29 to 40+ feet), while the North region tends to accept boats between 21 and 28 feet long.

Table 12: Proportion of marinas that accommodate different boat sizes by region in the U.S.

<table>
<thead>
<tr>
<th>Region</th>
<th>Boat Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;12ft</td>
</tr>
<tr>
<td>Alpena/Bay City</td>
<td></td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>A</td>
</tr>
<tr>
<td>Holland</td>
<td>B</td>
</tr>
<tr>
<td>North U.S.</td>
<td></td>
</tr>
</tbody>
</table>

Accommodated by
- >66% of Marinas: A
- 33% to 66% of Marinas: B
- <33% of Marinas: A

2.3 Services

Services offered by region are displayed in Tables 13 and 14. A majority of marinas within all Canadian regions provide fuel and pump-out services, but very few provide boat and motor rentals. Access to fuel docks can become a problem for larger boats during periods of low water, which can significantly reduce revenue for some marinas. If there is not enough water for a marina to operate its travel lift, it may not be able to offer storage to larger boats; which could also significantly reduce revenue.

Table 13: Proportion of marinas that offer different services by Canadian region

<table>
<thead>
<tr>
<th>Region</th>
<th>Dry Storage</th>
<th>Food Liquor</th>
<th>Travel Lift</th>
<th>Boat Motor Rentals</th>
<th>Boat Motor Sales</th>
<th>Marine Supplies</th>
<th>Repairs</th>
<th>Fuel</th>
<th>Pump-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>South Huron</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>North Channel</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior</td>
<td>A</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Offered by
- >66% of Marinas: A
- 33% to 66% of Marinas: B
- <33% of Marinas: A

The Georgian Bay region offers the broadest array of services when compared to the other regions, especially in the Midland AOS, where a majority of marinas offer all categories of service except for boat

22 However, only 65% of the marinas in the Erie region provide fuel and pump-out services.
and motor rentals. The region specializes in dry storage, boat sales, marine supplies and repairs. Furthermore, it is the only region in which more than 33 percent of marinas offer boat and motor sales\(^23\), and the only region in which more than 66 percent of marinas provide marine supplies and repairs. Eighty-eight percent of the respondents in the Georgian Bay area said that they compete against other local marinas for recreational spending.

Marina operators in the South Huron region also indicated a high degree of competition with other marinas for recreational spending\(^24\). However, unlike the Georgian Bay respondents, several explained that they compete against marinas on the nearby U.S. side of Southern Lake Huron. A strong majority of the marinas in the South Huron region provide dry storage.

Competition among marinas was less extreme in the North Channel and Erie regions\(^25\). Some of the respondents in the Little Current AOS mentioned that the provision of niche services, combined with greater distances between the marinas, acted to reduce intra-area competition. The North Channel region provides the least amount of services compared to the other regions, and the Erie region provides relatively few services per marina, especially within the Kingsville AOS.

Competition among marinas is perhaps the least in the Superior region, where the two respondents who completed questionnaires identified themselves as the sole providers of specific marine services within the local area, and to a lesser extent within an even larger geographical region. For example, one of the marinas sells parts that are not available at other marinas within travelling distance\(^26\), as well as performing repairs on “large boats from around the entire surrounding area, and many of the boats that park at the municipal Prince Arthur’s marina”.

In the U.S., at least 33% to 66% of marinas within all four regions provide fuel and pump-out services; however, very few provide boat and motor rentals or boat and motor sales. The three marinas surveyed in the Toledo/Sandusky region offer the broadest array of services when compared to the other regions, while the six marinas surveyed in the North U.S. region offer the fewest. Within the Alpena/Bay City, Toledo/Sandusky regions, all five of the operators surveyed in the Bay City AOS, and all three of the operators surveyed in the Toledo/Sandusky AOS said that they compete against other marinas or yacht clubs for recreational spending\(^27\). Similarly, 80% of the fifteen operators surveyed in the Holland region also said that they compete against other marinas. In contrast, only one of the six operators surveyed in the North U.S. region said that they compete against other marinas.

---

\(^{23}\) In the Georgian Bay region, 46% of marinas offer boat and motor sales.

\(^{24}\) Some respondents in the Goderich AOS mentioned that they compete with nearby marinas for some services but not others. For example, one marina competes against neighboring marinas for transient traffic, but is referred to for haul out services by the same competitors.

\(^{25}\) In these regions 75% of respondents said that they compete against local marinas for recreational spending.

\(^{26}\) He claimed that “we are the only dealer between here and Toronto for certain parts. Big retail customers come from all over for parts”. He also noted that a large proportion of his repair business was done on pontoon boats, which are quite popular on inland lakes.

\(^{27}\) In addition, two of the Toledo/Sandusky operators said that they compete against golf courses.
Table 14: Proportion of marinas that offer different services by U.S. region

<table>
<thead>
<tr>
<th>Region</th>
<th>Dry Storage</th>
<th>Food Liquor</th>
<th>Travel Lift</th>
<th>Boat Motor Rentals</th>
<th>Boat Motor Sales</th>
<th>Marine Supplies</th>
<th>Repairs</th>
<th>Fuel</th>
<th>Pump out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena/Bay City</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Holland</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>North U.S.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Offered by

<table>
<thead>
<tr>
<th>Proportion</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;66% of Marinas</td>
<td>A</td>
</tr>
<tr>
<td>33% to 66% of Marinas</td>
<td>A</td>
</tr>
<tr>
<td>&lt;33% of Marinas</td>
<td>B</td>
</tr>
</tbody>
</table>

2.4 Operating Season

The operating seasons of the marinas by region are shown in Tables 15 and 16. The table shows the median start-of-season and median end-of-season by region (in lighter shade). For the Canadian marinas that completed questionnaires, the start of the operating season ranges from early April to late May, while the end of the season ranges from Late October to early November. Along with the longest operating season (early April to late November), a higher proportion of marinas stay open year round in the Georgian Bay region compared to the other four regions. This longer season is perhaps related to the fact that many of these marinas run repair shops and provide winter storage (as discussed above in the Services section).

For the U.S. marinas that completed questionnaires, the start of the operating season ranges from early April to late May, while the end of the season ranges from early September to late November. The North U.S. Region has the latest median start-of-season in early May, as well as the earliest median end-of-season in late September. The other three regions share the median end-of-season in late October.

Respondents were also asked when they experienced periods of concentrated business, referred to as their ‘busy season’ (Tables 17 and 18). In Canada, busy seasons ranged from early April (Erie and Georgian Bay regions) to late November (Erie and Georgian Bay regions). All five of the regions experience busy periods in the summer months of July and August. The Erie and South Huron regions have the longest busy seasons (early June to late August, and late June to early September, respectively). The summer months are occupied by serving transient and seasonal customers, selling supplies and performing boat repairs and routine infrastructure maintenance. Adequate depth in slips and access channels are vital during this time.

28 In the Georgian Bay region, 31% of marinas stay open year round compared to 14% in the Erie region, 13% in the South Huron Region, and 5% in the North Channel Region.

29 It should also be noted that a significant amount of marinas in the South Huron, Georgian Bay and Erie regions have busy seasons that span between May and October.
The spring and fall are also busy periods for those marinas that launch boats at the start of the season and haul them out at the end. Provision of launching and haul-out services can be a significant task for marinas that deal with larger sail or cruise boats, or that provide large amounts of dockage and dry land storage. This strain is characteristic of many of the marinas found in the Georgian Bay, Erie, and South Huron regions (See the Distribution of Wet Slips, Transient Slips and Storage Capacity section above). Launching and haul-out operations can be delayed or prevented by several natural processes, including significant fluctuations in water levels. For example, many of the marinas in the Erie region are vulnerable to flooding and ice damage caused by wind seiches. Similarly, several of the marinas in the South Huron region are vulnerable to flooding and damage to infrastructure caused by ice jams in nearby river mouths and outlets. When they occur, these conditions can delay a given marina’s opening season, or force an early haul-out; both cut the season short.

The U.S. marinas’ busy seasons are shown in table 18. Based on the regional median start-of-season to median end-of-season, the Alpena/Bay City region has the longest busy season, running from early April to late October. The Toledo/Sandusky region has the shortest busy season, running from early April to late July; and the Holland and North U.S. regions share the same busy season, running from early May to late September.

---

30 Two marinas in the South Huron and Georgian Bay region cited ‘put in’ and ‘haul out’ periods as busy in addition to the summer busy season. However, other operators in all of the regions had explained that these periods were important during the questionnaire.

31 According to Wikipedia, Lake Erie is particularly prone to wind-caused seiches because of its shallowness and elongation (http://en.wikipedia.org/wiki/Seiche#Lake_seiches).
### Table 15: Canadian Operating Season\(^{32}\)

<table>
<thead>
<tr>
<th>Region</th>
<th>Open Year</th>
<th>Ice Out</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Ice In</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Round</td>
<td></td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
<td>Late</td>
<td></td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
<td>Late</td>
</tr>
<tr>
<td>Erie</td>
<td>Earliest Start</td>
<td>Median</td>
<td>Latest Start</td>
<td></td>
<td>Early End</td>
<td>Median</td>
<td></td>
<td>Latest End</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Huron</td>
<td>Earliest Start</td>
<td>Median</td>
<td>Latest Start</td>
<td></td>
<td>Early End</td>
<td>Median</td>
<td></td>
<td>Latest End</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>Earliest Start</td>
<td>Median</td>
<td>Latest Start</td>
<td></td>
<td>Earliest End</td>
<td>Median</td>
<td></td>
<td>Latest End</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Channel</td>
<td>Earliest Start</td>
<td>Median</td>
<td>Latest Start</td>
<td></td>
<td>Earliest End</td>
<td>Median</td>
<td></td>
<td>Latest End</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Superior</td>
<td>Both Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 16: U.S. Operating Season

<table>
<thead>
<tr>
<th>Region</th>
<th>Open Year</th>
<th>Ice Out</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Ice In</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Round</td>
<td></td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
<td>Late</td>
<td></td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
<td>Late</td>
</tr>
<tr>
<td>Alpena Bay City</td>
<td>Earliest Start</td>
<td>Median</td>
<td>Latest Start</td>
<td></td>
<td>Earliest End</td>
<td>Median</td>
<td>Latest End</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toledo Sandusky</td>
<td>Earliest Start</td>
<td>Median</td>
<td>Latest Start</td>
<td></td>
<td>Earliest End</td>
<td>Median</td>
<td>Latest End</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holland</td>
<td>Earliest Start</td>
<td>Median</td>
<td>Latest Start</td>
<td></td>
<td>Earliest End</td>
<td>Median</td>
<td>Latest End</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North U.S.</td>
<td>Earliest Start</td>
<td>Median</td>
<td>Latest Start</td>
<td></td>
<td>Earliest End</td>
<td>Median</td>
<td>Latest End</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{32}\) Not all of the marinas are open year round. Refer to the individual AOS analyses in Appendix for specific details.
### Table 17: Canadian Busy Season

<table>
<thead>
<tr>
<th>Region</th>
<th>Put In</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Haul Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>Median Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Median End</td>
</tr>
<tr>
<td>South Huron</td>
<td>Median Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Median Start</td>
<td>Median End</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>Median Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Median Start</td>
<td>Median End</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Channel</td>
<td>Median Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Median Start</td>
<td>Median End</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 18: U.S. Busy Season

<table>
<thead>
<tr>
<th>Region</th>
<th>Put In</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Haul Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena Bay City</td>
<td>Median Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Median Start</td>
<td>Median End</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toledo Sandusky</td>
<td>Median Start</td>
<td></td>
<td></td>
<td>Median End</td>
<td></td>
<td></td>
<td>Median End</td>
<td>Median End</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holland</td>
<td>Median Start</td>
<td></td>
<td></td>
<td>Median End</td>
<td></td>
<td></td>
<td>Median End</td>
<td>Median End</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North U.S.</td>
<td>Median Start</td>
<td></td>
<td></td>
<td>Median End</td>
<td></td>
<td></td>
<td>Median End</td>
<td>Median End</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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2.5 Factors that Affect Business

Operators were asked to rank four factors that might affect their business in terms of revenue. These factors were: water levels, state of the economy, gas prices, and weather. The first and second factors ranked for importance by region are displayed in Tables 19 and 20.

Table 19: Ranked factors that affect business (revenue) by region and AOS in Canada

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>First Ranked Factor</th>
<th>Second Ranked Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>Port Colborne</td>
<td>Water Levels</td>
<td>Economy</td>
</tr>
<tr>
<td></td>
<td>Turkey Point</td>
<td>Weather</td>
<td>Water Levels</td>
</tr>
<tr>
<td></td>
<td>Kingsville</td>
<td>Water Levels</td>
<td>Gas Prices</td>
</tr>
<tr>
<td>South Huron</td>
<td>Port Huron</td>
<td>Weather</td>
<td>U.S. Economy</td>
</tr>
<tr>
<td></td>
<td>Goderich</td>
<td>Weather</td>
<td>U.S. Economy</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>Midland</td>
<td>Weather</td>
<td>Economy</td>
</tr>
<tr>
<td></td>
<td>Parry Sound</td>
<td>Water Levels</td>
<td>Economy</td>
</tr>
<tr>
<td>North Channel</td>
<td>Little Current</td>
<td>Water Levels</td>
<td>Weather</td>
</tr>
<tr>
<td></td>
<td>Richards Landing</td>
<td>Weather</td>
<td>Economy</td>
</tr>
<tr>
<td>Superior</td>
<td>Thunder Bay</td>
<td>Water Levels</td>
<td>?</td>
</tr>
</tbody>
</table>

In Canada, weather has a strong influence on boating activity in the South Huron, Georgian Bay and North Channel regions. During periods of poor weather, both transient and seasonal boating traffic slows down; reducing sales of fuel, marine supplies and boat repairs. Many of the operators in the Erie region explained that water levels affect their business on a regular basis as a result of wind seiches and seasonal fluctuations.

A majority of the marinas in the South Huron region are dependent upon the relationship between the Canadian and U.S. economies. Their businesses compete with marinas on the U.S. side of Lake Huron, and therefore fare better when the exchange rate is favorable to the U.S. dollar. Several of the marinas in Sarnia, Goderich and Bayfield depend on the strength of the U.S. economy for recreational spending by U.S. customers. U.S. boaters are also important to some of the marinas in the Richards Landing AOS.

One-quarter of the marinas surveyed are owned and operated by local municipal governments. Although there are municipal marinas in all five of the regions, they make up a greater proportion within the North Channel and Superior regions. These marinas often rely on government funding to perform necessary dredging, dock modifications and other adaptations to fluctuating water levels. Some of the smaller marinas noted that they were unable to compete against municipally funded marinas.

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33 The operators' perceptions of the influence of poor weather on business should be understood in the context of a rainy summer this year. See the individual AOS analysis (APPENDIX) for further detail.
In the U.S., all AOS’s ranked their top significant factors evenly except for the Holland AOS (which ranked the U.S. economy first and water levels second). For the Alpena/Bay City, Toledo/Sandusky, and North U.S. regions, the top voted factors are the state of the U.S. economy, water levels, and gas prices.

### Table 20: Ranked factors that affect business (revenue) by region and AOS in the U.S.

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Tied for first ranked factor</th>
<th>Tied for first ranked factor</th>
<th>Tied for first ranked factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena/Bay City</td>
<td>Alpena</td>
<td>U.S. economy</td>
<td>gas prices</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bay City</td>
<td>Water Levels</td>
<td>Gas prices</td>
<td>U.S. economy</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>Toledo/Sandusky</td>
<td>U.S. economy</td>
<td>Gas prices</td>
<td></td>
</tr>
<tr>
<td>North U.S.</td>
<td>Baraga</td>
<td>Water Levels</td>
<td>U.S. economy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ontonagon</td>
<td>Water Levels</td>
<td>U.S. economy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Menominee</td>
<td>Water Levels</td>
<td>U.S. economy</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>First ranked factor</th>
<th>Second ranked factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holland</td>
<td>U.S. economy</td>
<td>Water Levels</td>
</tr>
</tbody>
</table>

### 3.0 Performance Indicators

#### 3.1 Past Experience with Water Levels: Damages and Adaptations

This section describes how the marinas have been affected by historic episodes of fluctuating water levels. These experiences provide a baseline that can be used to evaluate the significance of hypothetical consequences that are likely to result from future changes in the water level.\(^{34}\)

During the interviews, operators were asked to recount their past experience with fluctuating water levels under Plan 1977A. Questions were designed to discern how operators were able to adapt to historic episodes of low and high water levels. Their responses describe the damages that were sustained, the adaptations that were undertaken in response as well as the effectiveness of those adaptations.

### 3.11 Historic Lows

The main features of the operators’ past experiences with historical episodes of low water levels by region are summarized in Tables 21 and 22. The sizes of the drops in the water level are referred to the

---

\(^{34}\) The operators’ predictions of hypothetical damages and adaptations will be discussed in the next section, Adaptive Capacity and Threshold Vulnerabilities.
individual elevations at the time of the surveys. However, to be comparable, the answers are referred to
the average water level elevation (in meters), by lake, during the months in which surveys were
conducted, which are referred to International Great Lakes Datum 1985\textsuperscript{35} (Referring questionnaire
answers to standardized elevations as well as to IGLD 1985 is discussed in greater detail in the next
section: 4.0 Performance Indicator 2 -Adaptive Capacity and Threshold Vulnerabilities).

As table 21 shows, a majority of the Canadian marinas within all of the regions were affected by periods
of low water levels between 1995 and 2008. Operators informed us that during that time period, water
levels were between one and four feet lower than the level at the time of the interview. For many, the
worst lows occurred in the 1999-2000 season. Within some of the regions, some AOS were affected
more than others. Within the Erie region, the Turkey Point and Kingsville areas were affected more than
the Port Colborne area; possibly due to greater wind seiches at the eastern end of Lake Erie\textsuperscript{36}. Within
the Georgian Bay and North Channel regions, the low water episodes of 1999 to 2008 affected a greater
proportion of marinas in the Midland and Little Current AOS than the others\textsuperscript{37}. Some respondents in the
Georgian Bay region claimed that several marinas went out of business as a result of the low water in
the 1999 season. This may have added a survivorship bias to the marina sample.

In all five of the regions, at least half of the marinas were able to adapt to the low water by dredging.
Nearly all of the marinas in the Erie and South Huron regions had dredged in the late nineties. About half
of the marinas in the Georgian Bay and North Channel regions had dredged as well. Within the North
Channel region, a higher proportion of marinas in the Little Current AOS had dredged than in the
Richards Landing AOS. Responses to the questionnaire indicate that marinas in the Richards Landing
AOS have a relatively lower capacity to dredge as a result of financial constraints and the presence of
bedrock in many of their basins, which may explain why the area did not dredge as much as the others.

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Size of Drop?</th>
<th>Proportion affected?</th>
<th>When?</th>
<th>Proportion that dredged?</th>
<th>Average cost</th>
<th>Proportion that modified docks?</th>
<th>Average cost</th>
</tr>
</thead>
</table>

\textsuperscript{35} All surveyed features on a navigational chart are positioned on some horizontal datum system. On the Great
Lakes, water level and chart datum elevations are presently referenced to International Great Lakes Datum 1985
(http://www.waterlevels.gc.ca/english/VerticalDatums.shtml). The appropriate monthly average elevations for Lakes
Erie, Huron and Superior are compared to the individual elevations during the surveys in Table 14. (The monthly
average water level elevations for 2009 on lakes Erie, Huron and Superior were obtained from the monthly bulletins,
“Water Levels: Great Lakes and Montreal Harbour Monthly Bullentin” from the Canadian Hydrographic Service

\textsuperscript{36} As will be discussed below, periods of low water levels on Lake Erie may have been offset somewhat in the Port
Colborne area, as it is situated in the eastern end of the lake, where predominant winds tend to force the water up on
a regular basis.

\textsuperscript{37} Within the two regions, The Parry Sound and Richards Landing areas had not been affected as much as the
Midland and Little Current areas.
Although some marinas dredge regularly as part of their annual upkeep, many of the respondents referred to major emergency dredging operations which had been undertaken in response to the period of low water in the late 1990s and early 2000s. Operators in the Midland, Little Current and Richards Landing areas of survey explained that much of the dredging had been accomplished with the help of a federal grant program where one-third of outside labor costs could be recovered from the federal government. Some operators claimed that their marinas were too small to take advantage of the grant as the cost of using outside labor would have been more expensive than using internal labor despite the assistance.

In Honey Harbour, Bayfield, Kingsville and Windsor, several groups of marinas share common harbours, bays or access channels. These groups of marinas were able to reduce costs by dredging cooperatively. For the two groupings of marinas located inside the river outlets in Bayfield and Kingsville, cooperative dredging is part of their annual maintenance. Each year, they share the cost of dredging silt and gravel that washes downstream. As a result, the dredging that they did in the late nineties should not be considered ‘emergency dredging’.

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38 See Port Colborne’s individual AOS analysis for further details (Appendix).

39 One of these marinas dredges annually as part of routine maintenance. They remove silt that is washed down the coast during the off season.

40 Three of the marinas split the cost of dredging; they are all situated in the same river outlet in Bayfield ON, where gravel silts in naturally.

41 Many operators claimed that the dredge fund was achieved through the lobbying efforts of the Ontario Marine Operators Association (OMOA), an organization representing many of the marinas that were surveyed.

42 Some respondents explained that the Provincial Government was supposed to cover another one third of the costs, but failed to do so in the end.
Many of the regions were also able to adapt to low water levels by performing dock modifications. Marinas in the South Huron region performed dock modifications to deal with the low water levels of the late nineties. Less than half of the marinas in the Georgian Bay region incorporated dock modifications. Within the North Channel region, more than half of the marinas in the Richards Landing AOS performed dock modifications; which may be linked to their low capacity to dredge. These dock modifications consisted mostly of either installing floating docks or adjusting the floating docks mechanisms. Forty percent of these marinas also substituted smaller boats into slips that had been intended for larger ones. Only a minority of marinas in the Erie region performed dock modifications.

As can be seen in Table 21, the adaptations undertaken in response to the low water of the late 1990s entailed significant costs. The average dredging cost per marina ranged from $15,000 to $90,000. Although few respondents reported the cost of performing dock modifications, half of the marinas in the Midland AOS spent an average of $35,000 per marina. As one respondent explained,

"We've spent thousands chasing water levels."

Table 22: Historical periods of low water levels by U.S. region and AOS

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Size of Drop?</th>
<th>Proportion affected?</th>
<th>Proportion that dredged?</th>
<th>When?</th>
<th>Proportion that modified docks?</th>
<th>Average cost</th>
<th>Proportion that installed floating docks?</th>
<th>Average cost</th>
<th>Average cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena Bay City</td>
<td>Alpena (2)</td>
<td>n/a</td>
<td>50%</td>
<td>50%</td>
<td>n/a</td>
<td>80%</td>
<td>$40,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bay City (5)</td>
<td>0.3-1.2m</td>
<td></td>
<td></td>
<td></td>
<td>2005-2008</td>
<td>60%</td>
<td>$500,000</td>
<td>80%</td>
<td>$57,000</td>
<td>40%</td>
</tr>
<tr>
<td>Toledo Sandusky</td>
<td>Toledo Sandusky (3)</td>
<td>0.45m</td>
<td>100%</td>
<td>100%</td>
<td>1999-2000</td>
<td>33%</td>
<td>$200,000</td>
<td></td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Holland</td>
<td>Holland (15)</td>
<td>0.3-1.5m</td>
<td>100%</td>
<td>80%</td>
<td>1995-2008</td>
<td>60%</td>
<td>$73,000</td>
<td>60%</td>
<td>$206,000</td>
<td>20%</td>
</tr>
<tr>
<td>North U.S</td>
<td>Baraga (3)</td>
<td>0.3-0.6m</td>
<td>100%</td>
<td>67%</td>
<td>2006-2009</td>
<td>67%</td>
<td>$2,500</td>
<td>67%</td>
<td>$4,000</td>
<td></td>
</tr>
</tbody>
</table>

43 Examples of dock modifications include: extending docks out into deeper waters, or modifying steps or ramps to increase the accessibility of floating docks that lie low when the water level drops. Many docks are designed to be adjustable to fluctuations in water levels. Performing such adjustments can be costly in terms of labor intensity and time.
44 Note, only one of three reported expenditures on dredging.
45 Note, only two of four reported expenditures on dock modifications.
46 Note, only one of three reported expenditures on dredging.
47 Note, only one of two reported expenditures on dredging.
48 Note, only one of three reported expenditures on dock modifications.
In the U.S., a majority of the marinas within all of the regions were affected by periods of low water levels between 1995 and 2009 (Table 22). Operators informed us that during that time period, water levels were between one (0.3) and five feet (1.5m) lower than the level at the time of the interview.

Between 50% and 100% of the marinas in all of the other AOS’s were able to dredge in order to adapt to these drops in the water level; spending an average of $163,000 per marina (except for the Ontonagon and Menominee AOS’s found in the North U.S. region).

Also, between 33% and 80% of operators in all four regions (except the Alpena AOS) adapted through dock modifications\(^{49}\); spending an average of $142,000 per marina.

Some operators also adapted by installing floating docks; ranging between 20% and 50% of the marinas in the Bay City, Holland and Menominee AOS’s.

A minority of operators also adapted by rebuilding facilities (walkways or gas docks), and by substituting smaller boats (with less draft) into slips that were normally used for larger boats\(^{50}\).

### 3.12 Historical Highs

The past experiences with historical episodes of high water levels by region are displayed in Tables 23 and 24. In Canada, past periods of high water levels have proven to be more of a nuisance than a serious problem, except for the Erie region. Respondents on Lake Erie explained that predominant winds can push water levels up by eight or ten feet due to the lake’s shallow waters and elongated shape. These seiches are usually worse during the winter storm season. During the winter, rising water can break up ice, which is then pushed up on shore by powerful winds, causing significant damage to docks, shore walls, pilings, buildings, landscaping and other infrastructure. Predominant winds tend to push water towards the eastern end of the lake. It is no surprise then to note that the effects of high water levels were more of a concern to respondents in the Port Colborne and Turkey Point AOS than the Kingsville AOS, given their locations.

Marinas in the Port Colborne AOS have been affected by wind seiche flooding and ice damage on an annual basis, and have adapted by modifying docks, electrical and water systems to be removable for

\(^{49}\) Examples of dock modifications include: extending docks out into deeper waters, or modifying steps or ramps to increase the accessibility of floating docks that lie low when the water level drops. Many docks are designed to be adjustable to fluctuations in water levels. Performing such adjustments can be costly in terms of labor intensity and time.

\(^{50}\) See the individual AOS reports in the appendix.
the winter, as well as relocating fuel docks to avoid ice damage. In the Turkey Point AOS, sustained high water levels in the mid eighties resulted in wind seiche flooding that washed out walkways and seawalls at most of the marinas. Operators were able to adapt by rebuilding higher walkways and seawalls. Half of the marinas in the South Huron region also modified docks and seawalls as a result of flooding in the mid eighties.

As can be seen in Table 12, the adaptations described above had been quite costly for the Port Colborne and Turkey Point areas. If boater spending remains constant, and marinas are unable to raise prices to cover adaptive spending, then such spending comes out of their year-end profit. One respondent explained that,

“There’s not a lot of profit in marinas where the water levels fluctuate.”

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>Port Colborne</td>
<td>2.4-3m&lt;sup&gt;51&lt;/sup&gt;</td>
<td>75%</td>
<td>Annually</td>
<td>38%</td>
<td>Dock modifications, electrical system modifications, fuel dock modifications</td>
<td>$100,000</td>
</tr>
<tr>
<td>Turkey Point</td>
<td>0.9-1.2m&lt;sup&gt;52&lt;/sup&gt;</td>
<td>83%</td>
<td>1973-87 &amp; 2009</td>
<td>83%</td>
<td>Rebuilt seawalls, raised walkways&lt;sup&gt;53&lt;/sup&gt;</td>
<td>$45,000&lt;sup&gt;54&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Kingsville</td>
<td>n/a&lt;sup&gt;55&lt;/sup&gt;</td>
<td>0%</td>
<td>1989</td>
<td>0%</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Huron</td>
<td>Port Huron</td>
<td>0.9-1.2m</td>
<td>50%</td>
<td>1985-86</td>
<td>50%</td>
<td>Dock modifications, rebuilt seawalls</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Goderich</td>
<td>n/a</td>
<td>100%</td>
<td>1986 &amp; 1994</td>
<td>50%</td>
<td>Very few</td>
<td>n/a</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>Midland</td>
<td>n/a&lt;sup&gt;56&lt;/sup&gt;</td>
<td>50%</td>
<td>1985-86</td>
<td></td>
<td>Very few</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Parry Sound</td>
<td>0.6-1.8m</td>
<td>55%</td>
<td>1985-86</td>
<td></td>
<td>Very few</td>
<td>n/a</td>
</tr>
<tr>
<td>North</td>
<td>Little Current</td>
<td>n/a&lt;sup&gt;57&lt;/sup&gt;</td>
<td>25%</td>
<td>1985-86</td>
<td></td>
<td>Very few</td>
<td>n/a</td>
</tr>
</tbody>
</table>

<sup>51</sup> Two respondents in this AOS reported that the rises can be eight and ten feet during wind seiches.

<sup>52</sup> High water levels during the late eighties had made the marinas more vulnerable to common wind seiches that can change the water level by two or more feet, in both directions, in only a few hours. Seiches can cause serious flooding, ice damage, and reduce slip and access channel depths temporarily.

<sup>53</sup> Inconsistent fluctuations in Lake Erie’s water level were identified as having reduced the effectiveness of adaptive planning. As a result, operators in the Turkey Point AOS had been reluctant to invest in adaptations, despite the damages and inconvenience caused by periods of high water levels.

<sup>54</sup> Two of the three respondents that had rebuilt walkways and other infrastructure had spend $40,000 and $50,000. One of the operators that had extended seawalls to be higher reported that the cost had been “significant”.

<sup>55</sup> One respondent in the Kingsville AOS reported that water levels had been three feet higher in 1989 than the level at the time of the interview.

<sup>56</sup> Only three respondents reported that water levels were 3ft, 4ft, and 6ft higher during the late eighties and mid nineties than at the time of the interview.

<sup>57</sup> Only one respondent reported that water levels were 3ft higher during 1986 than at the time of the interview.
Similarly, in the U.S. past periods of high water have not been as harmful as the low water levels. Four of the seven AOS were affected in the late 1980’s, mid 1990’s and in 2009 (Alpena, Toledo/Sandusky, Holland and Menominee AOS’s). Only one of the two marinas affected in the Toledo/Sandusky AOS adapted by spending $40,000 on seawalls. Three of the five marinas affected in the Holland AOS adapted by modifying\textsuperscript{60} and extending docks.

| Table 24: Historical periods of high water levels by U.S. region and AOS |
|-------------------|-----------------|----------|-----------------|-------------------|------------------|
| Alpena/Bay City   | Alpena (2)      | 0.6-1.2m      | 40%               | 1990’s and 2009    |                               |              |             |             |
|                   | Bay City (5)    |             |                   |                    |                               |              |             |             |
| Toledo/Sandusky   | Toledo/Sandusky (3) | 0.45m      | 67%               | 1970’s             | 33%                           | Seawalls $40,000 |             |
| Holland           | Holland (15)    | 1.5-1.8m\textsuperscript{61} | 33%               | 1986 and 1993      | 20%                           | Dock modifications $9,000 | Extend docks |
| North U.S.        | Baraga (3)      |             |                   |                    |                               |              |             |             |
|                   | Ontonagon (1)   |             |                   |                    |                               |              |             |             |
|                   | Menominee (2)   | 0.9m         | 100%              | 1985-86 and 1995   |                               |              |             |             |

\textbf{3.13 Effectiveness of Past Adaptations}

When the Canadian operators were asked whether the adaptations described above had provided a suitable long term solution to dealing with fluctuating water levels, most of the respondents in the Georgian Bay region were confident that they had. Several respondents in the Parry Sound AOS attributed their resilience to the naturally deep waters and steep rocky shores characteristic of the area. About two thirds of respondents in the South Huron and North Channel regions were confident in their capacity to survive future fluctuations. However, within these two regions, many of the operators in

\textsuperscript{58} Only one respondent reported that water levels were 2ft higher during 1996-97 than at the time of the interview.  
\textsuperscript{59} One of the two respondents interviewed in the Superior region claimed that shoreline erosion had been the main concern during the high water period in 1999.  
\textsuperscript{60} Two of the marinas in the Holland AOS adapted by spending $15,000 and $3,000 on their respective dock modifications.  
\textsuperscript{61} Note, only one of the five affected reported a magnitude.
both the Port Huron and Richards Landing areas explained that their confidence in the long term effectiveness of their adaptations was contingent on the assumption that future fluctuations in water levels would remain within long term average highs and lows. As one operator described,

“In a sense the adaptations are band-aid. They could function as long term solutions if the water stays in between the long term averages”

Many of the operators in the Erie region (specifically the Port Colborne and Turkey Point AOS) felt that the adaptations that they had undertaken in the past would only provide a short term solution. Respondents in both areas expressed that Lake Erie’s inconsistent water levels had reduced the effectiveness of preventative adaptations. One operator explained that he was “not planning any major expenditure due to the long term uncertainty of water levels”. The two operators that completed questionnaires in the Superior region were split on the issue, as one faced increasing silting of an access channel without the capacity to dredge it.

When the U.S. operators were asked whether the adaptations described above had provided a suitable long term solution to dealing with fluctuating water levels, only the Alpena/Bay City region had a majority of operators (57%) who felt that they had. A third or less of the operators in the other three regions felt the same way. Instead, between 50% and 67% of the latter three regions’ (Toledo/Sandusky, Holland, and North U.S.) operators felt that the adaptations described above had instead provided only a short term solution to dealing with fluctuating water levels. As one respondent from the Holland AOS explained,

“If the water remains at similar levels the solutions will be long term. However, if the water levels change greatly, they will be short term”

In any case, roughly half of the respondents in all four U.S. regions considered their current adaptive strategy to be ‘suitable’.

3.2 Hypothetical damages and adaptations

This section describes how hypothetical low and high water level scenarios would be likely to affect the different regions. During the interviews, respondents were asked a series of ‘what if?’ questions related to six hypothetical scenarios of water levels raising or lowering at one, two and three foot intervals. The questions were intended to determine how a given scenario would affect a marina in terms of damages to infrastructure, number of slips rendered unusable, and adaptations which operators would likely undertake in reaction. When set against the background of the historical experiences described in the last section, this information can be used as a rough assessment of regional adaptive capacity.
The operators were asked to imagine the six hypothetical changes in water level starting from the level at the time of the survey. To be comparable, their answers are referenced to standardized elevations that were designed to approximate the level at the time of the surveys for each lake. These standardized elevations were constructed by taking the average of the monthly-average elevations during the timeframes in which surveys were conducted on each of the Lakes. These standardized elevations are in turn referred to a horizontal benchmark used in navigational charts; the International Great Lakes Datum 1985. In Tables 25 and 26, the appropriate standardized monthly average elevations for Lakes Erie, Michigan/Huron and Superior (in blue) are compared to the individual elevations during the surveys.

Table 25: Water level elevations during Canadian surveys compared to 2009 average water level elevations

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Chart Datum (m)</th>
<th>Elevation During Surveys (m)</th>
<th>2009 Average Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>Port Colborne</td>
<td>173.5</td>
<td>Average: 174.4</td>
<td>174.4</td>
</tr>
<tr>
<td>Erie</td>
<td>Turkey Point</td>
<td>173.5</td>
<td>Min: 174.3 Max: 174.5</td>
<td>174.4</td>
</tr>
<tr>
<td>Erie</td>
<td>Kingsville</td>
<td>173.5</td>
<td>Average: 174.4 Min: 174.3 Max: 174.5</td>
<td>174.4</td>
</tr>
<tr>
<td>South Huron</td>
<td>Port Huron</td>
<td>176</td>
<td>Average: 176.7 Min: 176.5 Max: 176.9</td>
<td>176.4</td>
</tr>
<tr>
<td>South Huron</td>
<td>Goderich</td>
<td>176</td>
<td>Average: 176.4 Min: 176.3 Max: 176.4</td>
<td>176.4</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>Midland</td>
<td>176</td>
<td>Average: 176.4 Min: 176.3 Max: 176.5</td>
<td>176.4</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>Parry Sound</td>
<td>176</td>
<td>Average: 176.4 Min: 176.3 Max: 176.4</td>
<td>176.4</td>
</tr>
<tr>
<td>North Channel</td>
<td>Little Current</td>
<td>176</td>
<td>Average: 176.4 Min: 176.3 Max: 176.5</td>
<td>176.4</td>
</tr>
<tr>
<td>North Channel</td>
<td>Richards Landing</td>
<td>176</td>
<td>Average: 176.1 Min: 176 Max: 176.2</td>
<td>176.4</td>
</tr>
<tr>
<td>Superior</td>
<td>Thunder Bay</td>
<td>183.2</td>
<td>Average: 183.4 Min: 183.4 Max: 183.4</td>
<td>183.4</td>
</tr>
</tbody>
</table>

Table 26: Water level elevations during U.S. surveys compared to 2009 average water level elevations

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Chart Datum (m)</th>
<th>Elevation During Surveys (m)</th>
<th>2009 Average Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena/Bay City</td>
<td>Alpena</td>
<td>176.0</td>
<td>Average: 176.2 Min: 176.2 Max: 176.2</td>
<td>176.4</td>
</tr>
<tr>
<td>Alpena/Bay City</td>
<td>Bay City</td>
<td>176.0</td>
<td>Average: 176.3 Min: 176.3 Max: 176.3</td>
<td>176.4</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>Toledo/Sandusky</td>
<td>173.5</td>
<td>Average: 173.8 Min: 173.8 Max: 173.8</td>
<td>174.4</td>
</tr>
<tr>
<td>Holland</td>
<td>Holland</td>
<td>176.0</td>
<td>Average: 176.4 Min: 176.3 Max: 176.5</td>
<td>176.4</td>
</tr>
<tr>
<td>North U.S.</td>
<td>Baraga</td>
<td>183.2</td>
<td>Average: 183.1 Min: 183.1 Max: 183.1</td>
<td>183.4</td>
</tr>
<tr>
<td>North U.S.</td>
<td>Ontonagon</td>
<td>183.2</td>
<td>Average: 183.1 Min: 183.1 Max: 183.1</td>
<td>183.4</td>
</tr>
<tr>
<td>North U.S.</td>
<td>Menominee</td>
<td>176.0</td>
<td>Average: 176.2 Min: 176.2 Max: 176.2</td>
<td>176.4</td>
</tr>
</tbody>
</table>


3.21 Historic Context

Before discussing the results of the scenarios, the magnitude of these six hypothetical changes in water level should be understood relative to the actual historical behavior of the different lake levels. The all time high and low water level elevations, as well as the all time annual average elevation, all time average during the months when surveys were conducted, and the annual average for the past ten years for Lakes Erie, Michigan/Huron and Superior are shown in comparison to the six scenarios in Tables 27, 28, and 29 below.

As is shown in Table 27, Lake Erie’s average elevation (June and July 2009) was 0.1 meter above the long term average for the months of June and July, and 0.4 meters above the annual average over the past ten years. Given the recent episodes of low water, many of the operators may have experienced lows equivalent to or greater than the hypothetical scenarios. A three foot drop would still be 0.2 meters above the all time low (1934). Also, the high scenarios may have been perceived as more significant than they would have had the survey been conducted during a time period when water levels were closer to the ten year average. For example a three foot rise would be 0.4 meters above the all time high for Lake Erie.

Table 27: Historical Context of Scenarios on Lake Erie

<table>
<thead>
<tr>
<th>Lake Erie</th>
<th>Elevation (m)</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Time High (1986)</td>
<td>174.9</td>
<td>175.3</td>
</tr>
<tr>
<td>Long Term Average (June/July)</td>
<td>174.3</td>
<td>175.0</td>
</tr>
<tr>
<td>Long Term Average (Annual)</td>
<td>174.1</td>
<td>174.7</td>
</tr>
<tr>
<td>10 Year Average</td>
<td>174.0</td>
<td>174.4</td>
</tr>
<tr>
<td>All Time Low (1934)</td>
<td>173.3</td>
<td>174.1</td>
</tr>
<tr>
<td>Chart Datum</td>
<td>173.5</td>
<td>173.8</td>
</tr>
</tbody>
</table>

As is shown in Table 28, Lake Michigan/Huron’s average elevation (May through August 2009) was 0.2 meters below the long-term average for May through August. Although the water level was below the long term average, the low water scenarios may have been reminiscent of the episodes of low water experienced by many of the operators over the past decade. The average elevation for 2009 was 0.4 meters above the annual average over the past ten years. A three foot drop would be 0.2 meters below the all time low (1964). A three foot rise would be equivalent to the all time high (1986).

Table 28: Historical Context of Scenarios on Lake Michigan/Huron

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64 All measurements were obtained from http://www.waterlevels.gc.ca. ‘Long Term Averages (month/month)’ were calculated by averaging the all time average elevations of the months during which the surveys were completed on a given lake.

65 Described in the last section, Performance Indicator 1.

66 Described in the last section, Performance Indicator 1.
As is shown in Table 29, Lake Superior’s average elevation (Aug 2009) was 0.1 meter below the long term average for the month of August, and 0.1 meter above the annual average over the past ten years. Given the recent episodes of low water\(^{67}\), the operators may have experienced lows equivalent to or greater than the hypothetical scenarios. A three foot drop would be 0.4 meters above the All Time Low (1926). Operators would not have experienced high water levels equivalent to the three foot rise scenario, which would be 0.6 meters above the All Time High (1986).

Table 29: Historical Context of Scenarios on Lake Superior

<table>
<thead>
<tr>
<th>Lake Superior</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Time High (1986)</td>
<td>177.3</td>
</tr>
<tr>
<td>Long Term Average (May thru Aug)</td>
<td>176.6</td>
</tr>
<tr>
<td>Long Term Average (Annual)</td>
<td>176.4</td>
</tr>
<tr>
<td>10 Year Average</td>
<td>175.0</td>
</tr>
<tr>
<td>All Time Low (1964)</td>
<td>175.7</td>
</tr>
<tr>
<td>Chart Datum</td>
<td>175.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>177.3</td>
</tr>
<tr>
<td>177.0</td>
</tr>
<tr>
<td>176.7</td>
</tr>
<tr>
<td>176.4</td>
</tr>
<tr>
<td>176.1</td>
</tr>
<tr>
<td>175.8</td>
</tr>
<tr>
<td>175.5</td>
</tr>
</tbody>
</table>

3.22 Low Water Scenarios

The Canadian responses to the three drop scenarios are displayed for each region in Tables 30 through 34. These responses give an indication as to how the three low water scenarios would affect the different regions in terms of damages to infrastructure, amount of slips rendered unusable, and adaptations which operators would be likely to perform in reaction.

A one foot drop would affect the North Channel region more than the other regions\(^{68}\). Forty percent of its marinas would suffer slip losses of up to 33%, whereas less than one third of marinas in the other regions would lose the same amount. More than double the amount of marinas in the South Huron region would have dock damages than compared to the North Channel region. To adapt, almost 40% of marinas in the South Huron region would dredge, whereas less than a quarter would dredge in the Erie and North Channel regions. Little dredging would likely go on in the Georgian Bay region.

---

\(^{67}\) Described in the last section, Performance Indicator 1.

\(^{68}\) A one foot drop would affect 70% of marinas in the North Channel region, and only half or less than half of the marinas in the South Huron, Erie and Georgian Bay regions. The Superior regions would not be affected.
A two foot drop would impact almost all of the marinas in the South Huron, North Channel and Erie regions, as well as almost three-quarters of the marinas in the Georgian Bay region. More marinas in the North Channel region would suffer the slip losses (65%), than the Georgian Bay (46%), Erie (40%) and South Huron regions (25%). The magnitude of these slip losses would be greater in the North Channel, Erie and South Huron regions than in the Georgian Bay region. One-quarter of the marinas in the North Channel region would loose between one and two-thirds of their slips, while 40% of the marinas would lose up to one-third. About 10% of marinas in the Erie and South Huron regions would lose between one and two-thirds of their slips. Most of the marinas that would lose slips in the Georgian Bay region would lose up to one-third.

The South Huron region would suffer the most damage to docks (38%), followed by the North Channel (20%) and Georgian Bay (15%) regions. Launch ramps would become unusable in ten to fifteen percent of the marinas in the Georgian Bay and Erie regions. Thirty five percent of marinas in the North Channel region could suffer from reduced sales. In response, almost half of the marinas in the Erie (42%), South Huron (38%) and North Channel (35%) regions would dredge. Several respondents in the North Channel region said that they would like to dredge, but would be unable to due to the presence of bedrock as well as financial limitations. About a quarter of the marinas in the Georgian Bay region would dredge as well. Fifteen percent of marinas in the North Channel region would also adapt by undertaking dock modifications.

A three foot drop would affect most of the marinas within all of the regions. As one respondent put it, a three foot drop would be “catastrophic” for many of the marinas. Slip losses would be significant in all four the regions. Significantly more marinas in the North Channel region would suffer slip loss (85%) than the other regions (between 50% and 65%). Forty percent of marinas in the North Channel region would lose more than 66% of their slips, followed by the Erie region, where a quarter of the marinas would lose the same proportion. Within the Erie region, consequences would be especially severe in the Turkey Point AOS, where several of the marinas are situated on the shallow Inner Bay of Long Point Bay, which is a popular sports fishing destination. In addition, significant amounts of marinas in all four of the regions would have slip losses of up to two third of their dockage. Damage to docks would be greatest in the South Huron region (50%), followed by the North Channel (25%), Georgian Bay (23%) and Erie (10%) regions. Around a quarter of the marinas in the South Huron and Erie regions would suffer damage to seawalls. Low water levels can remove back-pressure necessary to support seawalls; requiring them to be dug lower and reconstructed. Some marinas in the Georgian Bay and North Channel region would be unable to use their launch ramps. To adapt, around half of the marinas in all of the regions would dredge, with the most dredging going on in the South Huron region (63%) and the least in Georgian Bay (38%). Along with dredging, between ten and twenty percent of the marinas in the South Huron and North Channel regions would perform other adaptations such as installing floating docks, undertake dock modifications, and repair seawalls.

To varying degrees, the low water scenarios would cause marinas in all of the regions to have difficulty accommodating sailboats or other large boats (21+ feet) that require deeper draft in access channels.
Several operators explained that to a large extent, their businesses rely on expenditures from larger cruise and sail boat customers. One respondent in the South Huron region joked that given a significant drop in water level, his yacht club would turn into a “small powerboat club”. Regions that specialize in accommodating larger boats and sailboats may experience particular thresholds in their vulnerability to dropping water levels.

As questionnaires were only completed for two of the four marinas surveyed in the Superior region, the following responses may not accurately represent the region. One operator in the Superior region would be affected by two and three foot drops, losing more than two thirds of their slips. No adaptations would be undertaken in response.

### Table 30: Erie region responses to water level drop scenarios

<table>
<thead>
<tr>
<th></th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for June and July 2009: 174.4m</td>
<td>174.1m</td>
<td>173.8m</td>
<td>173.5m</td>
</tr>
<tr>
<td>Response (Out of 21 Surveyed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Damages</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondents Affected</td>
<td>9 of 21</td>
<td>17 of 21</td>
<td>19 of 21</td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td>2 of 21</td>
<td>2 of 21</td>
<td>2 of 21</td>
</tr>
<tr>
<td>Dock Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>1 of 21</td>
<td>2 of 21</td>
<td>3 of 21</td>
</tr>
<tr>
<td>Walkway Damage</td>
<td></td>
<td>1 of 21</td>
<td>1 of 21</td>
</tr>
<tr>
<td>Fuel Dock Access Restricted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Aquatic Weed Growth</td>
<td>1 of 21</td>
<td>1 of 21</td>
<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales Lost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Slip Loss</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;0% to 33% Slip Loss</td>
<td>1 of 21</td>
<td>6 of 21</td>
<td>4 of 21</td>
</tr>
<tr>
<td>Marinas with 33% to 66% Slip Loss</td>
<td></td>
<td>2 of 21</td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;66% Slip Loss</td>
<td>2 of 21</td>
<td>5 of 21</td>
<td></td>
</tr>
<tr>
<td><strong>Adaptations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondents who would Dredge</td>
<td>4 of 21</td>
<td>9 of 21</td>
<td>11 of 21</td>
</tr>
</tbody>
</table>

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69 Accommodating sailboats or other large boats requiring deeper draft would become an issue for a minority of marinas in the Georgian Bay region, as well as many of the marinas in the Erie region at a one foot drop, and for many of the marinas in the South Huron and North Channel regions at a two foot drop.
### Table 31: South Huron region responses to water level drop scenarios

<table>
<thead>
<tr>
<th>South Huron Region</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m</td>
<td>176.1m</td>
<td>175.8m</td>
<td>175.5m</td>
</tr>
<tr>
<td>Response (Out of 8 Surveyed)</td>
<td>4 of 8</td>
<td>7 of 8</td>
<td>8 of 8</td>
</tr>
<tr>
<td>Damages</td>
<td>3 of 8</td>
<td>3 of 8</td>
<td>4 of 8</td>
</tr>
<tr>
<td>Dock Damage</td>
<td>2 of 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Walkway Damage</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Fuel Dock Access Restricted</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Increased Aquatic Weed Growth</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Sales Lost</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Slip Loss</td>
<td>3 of 8</td>
<td>3 of 8</td>
<td>5 of 8</td>
</tr>
<tr>
<td>Marinas with &gt;0% to 33% Slip Loss</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>3 of 8</td>
</tr>
<tr>
<td>Marinas with 33% to 66% Slip Loss</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>3 of 8</td>
</tr>
<tr>
<td>Marinas with &gt;66% Slip Loss</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>3 of 8</td>
</tr>
<tr>
<td>Adaptations</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Respondents who would Dredge</td>
<td>3 of 8</td>
<td>3 of 8</td>
<td>5 of 8</td>
</tr>
<tr>
<td>Adapt with Floating Docks</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Adapt with Dock Modifications</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Adapt with Seawalls</td>
<td>1 of 8</td>
<td>1 of 8</td>
<td>1 of 8</td>
</tr>
</tbody>
</table>

### Table 32: Georgian Bay region responses to water level drop scenarios

<table>
<thead>
<tr>
<th>Georgian Bay Region</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 of 21</td>
<td>1 of 21</td>
<td>1 of 21</td>
</tr>
<tr>
<td></td>
<td>Average Water Level Elevation for May thru August 2009: 176.4m</td>
<td>176.1m</td>
<td>176.8m</td>
</tr>
<tr>
<td>-----------------------</td>
<td>---------------------------------------------------------------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td><strong>Response (Out of 26 Surveyed)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondents Affected</td>
<td>10 of 26</td>
<td>19 of 26</td>
<td>25 of 26</td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td>3 of 26</td>
<td>4 of 26</td>
<td>5 of 26</td>
</tr>
<tr>
<td>Dock Damage</td>
<td>4 of 26</td>
<td>6 of 26</td>
<td></td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>1 of 26</td>
<td>1 of 26</td>
<td></td>
</tr>
<tr>
<td>Walkway Damage</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Dock Access Restricted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Aquatic Weed Growth</td>
<td></td>
<td>1 of 26</td>
<td>1 of 26</td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td>1 of 26</td>
<td>1 of 26</td>
</tr>
<tr>
<td>Sales Lost</td>
<td>1 of 26</td>
<td>1 of 26</td>
<td></td>
</tr>
<tr>
<td>Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;0% to 33% Slip Loss</td>
<td></td>
<td>4 of 26</td>
<td>10 of 26</td>
</tr>
<tr>
<td>Marinas with 33% to 66% Slip Loss</td>
<td></td>
<td>2 of 26</td>
<td>2 of 26</td>
</tr>
<tr>
<td>Marinas with &gt;66% Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondents who would Dredge</td>
<td></td>
<td>2 of 26</td>
<td>6 of 26</td>
</tr>
<tr>
<td>Adapt with Floating Docks</td>
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<td>1 of 26</td>
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<tr>
<td>Adapt with Dock Modifications</td>
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<td>2 of 26</td>
</tr>
<tr>
<td>Adapt with Seawalls</td>
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<td>1 of 26</td>
<td></td>
</tr>
</tbody>
</table>

Table 33: North Channel region responses to water level drop scenarios

<table>
<thead>
<tr>
<th>North Channel Region</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m</td>
<td>176.1m</td>
<td>176.8m</td>
<td>175.5m</td>
</tr>
<tr>
<td><strong>Response (Out of 20 Surveyed)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondents Affected</td>
<td>14 of 20</td>
<td>17 of 20</td>
<td>19 of 20</td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td>1 of 20</td>
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</tr>
<tr>
<td>Dock Damage</td>
<td>3 of 20</td>
<td>4 of 20</td>
<td>5 of 20</td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>1 of 20</td>
<td></td>
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<tr>
<td>Walkway Damage</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Dock Access Restricted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Aquatic Weed Growth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td>1 of 20</td>
<td>1 of 20</td>
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<tr>
<td>Sales Lost</td>
<td>7 of 20</td>
<td>8 of 20</td>
<td></td>
</tr>
<tr>
<td>Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;0% to 33% Slip Loss</td>
<td></td>
<td>8 of 20</td>
<td>8 of 20</td>
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<td>Marinas with 33% to 66% Slip Loss</td>
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<td>4 of 20</td>
</tr>
<tr>
<td>Marinas with &gt;66% Slip Loss</td>
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<tr>
<td>Adaptations</td>
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<tr>
<td>Respondents who would Dredge</td>
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<tr>
<td>Adapt with Floating Docks</td>
<td></td>
<td>1 of 20</td>
<td></td>
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</table>
Table 34: Superior region responses to water level drop scenarios

<table>
<thead>
<tr>
<th>Superior Region</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for August 2009: 183.4m</td>
<td>183.1m</td>
<td>182.8m</td>
<td>182.5m</td>
</tr>
<tr>
<td>Response (Out of 2 Surveyed)</td>
<td>1 of 2</td>
<td>1 of 2</td>
<td>1 of 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Damages</th>
<th>Respondents Affected</th>
<th>1 of 2</th>
<th>1 of 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Launch Ramp Damage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dock Damage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seawall Damage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Walkway Damage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fuel Dock Access Restricted</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased Aquatic Weed Growth</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sales Lost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slip Loss</th>
<th>Marinas with &gt;0% to 33% Slip Loss</th>
<th>1 of 2</th>
<th>1 of 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Marinas with 33% to 66% Slip Loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marinas with &gt;66% Slip Loss</td>
<td>1 of 2</td>
<td>1 of 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adaptations</th>
<th>Respondents who would Dredge</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adapt with Floating Docks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adapt with Dock Modifications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adapt with Seawalls</td>
<td>1 of 2</td>
</tr>
</tbody>
</table>

The U.S. responses to the three drop scenarios are displayed by region in Tables 35 through 38. A one foot (0.3m) drop from the appropriate average water level elevations would affect the Toledo/Sandusky and Holland regions more than the Alpena/Bay City or North U.S. regions. A minority of the marinas in the former two regions would suffer damages including increased aquatic weed growth and accelerated shoreline erosion. One third of the marinas in both regions would have 33% or less of their slips rendered unusable. In response, around half of the operators would dredge in the Holland region. All three of the marinas that completed questionnaires in the Toledo/Sandusky region would like to dredge, but only two would be able to afford it. These same damages and reactions would persist in the Toledo/Sandusky region for the two (0.6m) and three foot (0.9m) drops as well.
A two foot (0.6m) drop from the appropriate average water level elevation would affect the Holland region more than the other three regions. In the Holland region, between 20% and 40% of the marinas would suffer damages to docks, walkways, and launch ramps, increased aquatic weed growth and inadequate access channel depths. 53% of the marinas would lose up to 33% of their slips, and 27% would lose between 33% and 66%. To adapt, 80% of the operators would dredge.

In the Alpena/Bay City region, 29% of the operators would suffer damages to launch ramps and inadequate access channel depths. They would react by installing floating docks. Two of the six marinas in the North U.S. region would suffer from increased aquatic weed growth. Half would dredge and one-third would undertake dock modifications.

A three foot (0.9m) drop from the appropriate average water level elevation would cause significant damages to a majority of marinas in all four of the regions. About half of the marinas in all four regions would suffer damages including damage to docks, walkways, and launch ramps; increased aquatic weed growth, and accelerated shoreline erosion. Inadequate access channel depths would occur at a majority of the marinas in the Toledo/Sandusky region, 71% of the Alpena/Bay City region, 60% of the Holland region, and 33% of the North U.S. region. The loss of up to 33% of total slips per marina would occur at about half of the marinas in the Holland region, and at roughly 30% of the marinas in the Alpena/Bay City and Toledo/Sandusky regions. The loss of between 33% and 66% of total slips per marina would occur at 27% of the marinas in the Holland region, and at one of the seven marinas in the Alpena/Bay City region. Within the North U.S. region, all three of the marinas in the Baraga AOS would lose 100% of their slips. The loss of more than 66% of total slips per marina would occur at one of the three marinas that completed questionnaires in the Toledo/Sandusky region, and at two of the fifteen marinas in the Holland region.

To adapt, many of the marinas would dredge, including 80% of the Holland region, 71% of the Alpena/Bay City region, and 67% of the Toledo/Sandusky and North U.S. regions. Operators would also undertake dock modifications in half of the North U.S. region, and 40% of the Holland region. Operators would also install floating docks at 57% of the Alpena/Bay City region, 27% of the Holland region, and 33% of the North U.S. region. Two of the six operators in the North U.S. region would also extend existing docks.

### Table 35: Toledo/Sandusky region responses to water level drop scenarios

<table>
<thead>
<tr>
<th>Toledo/Sandusky region</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for June and July 2009: 174.4m</td>
<td>174.1m</td>
<td>173.8m</td>
<td>173.5m</td>
</tr>
<tr>
<td>Response (Out of 3 Surveyed)</td>
<td>3 of 3</td>
<td>3 of 3</td>
<td>3 of 3</td>
</tr>
</tbody>
</table>

70 Within the North U.S. region, one of the two operators in the Menominee AOS said that they would like to dredge in the case of a three foot (0.9m) drop, but would be unable to afford it due to the presence of bedrock in their basin.
# Alpena/Bay City Region Responses to Water Level Drop Scenarios

**Table 36: Alpena/Bay City region responses to water level drop scenarios**

<table>
<thead>
<tr>
<th>Alpena/Bay City</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m</td>
<td>176.1m</td>
<td>175.8m</td>
<td>175.5m</td>
</tr>
<tr>
<td>Response (Out of 7 Surveyed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damages</td>
<td>Respondents Affected</td>
<td>2 of 7</td>
<td>3 of 7</td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td>2 of 7</td>
<td>2 of 7</td>
<td>2 of 7</td>
</tr>
<tr>
<td>Dock Damage</td>
<td>1 of 7</td>
<td>1 of 7</td>
<td>4 of 7</td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>1 of 7</td>
<td>1 of 7</td>
<td>1 of 7</td>
</tr>
<tr>
<td>Walkway Damage</td>
<td></td>
<td>3 of 7</td>
<td></td>
</tr>
<tr>
<td>Fuel Dock Access Restricted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Aquatic Weed Growth</td>
<td>1 of 7</td>
<td>1 of 7</td>
<td>2 of 7</td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td>1 of 7</td>
<td>1 of 7</td>
<td>2 of 7</td>
</tr>
<tr>
<td>Access Channel Issue</td>
<td>1 of 7</td>
<td>2 of 7</td>
<td>5 of 7</td>
</tr>
<tr>
<td>Sales Lost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slip Loss</td>
<td>Marinas with &gt;0% to 33% Slip Loss</td>
<td>1 of 7</td>
<td>2 of 7</td>
</tr>
<tr>
<td>Marinas with 33% to 66% Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;66% Slip Loss</td>
<td>1 of 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptations</td>
<td>Respondents who would Dredge</td>
<td>1 of 7</td>
<td>5 of 7</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Adapt with Floating Docks</td>
<td>2 of 7</td>
<td>4 of 7</td>
<td></td>
</tr>
<tr>
<td>Adapt with Dock Modifications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapt with Seawalls</td>
<td>1 of 7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 37: Holland region responses to water level drop scenarios

<table>
<thead>
<tr>
<th>Holland region</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m</td>
<td>176.1m</td>
<td>175.8m</td>
<td>175.5m</td>
</tr>
<tr>
<td>Response (Out of 15 Surveyed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondents Affected</td>
<td>8 out of 15</td>
<td>13 out of 15</td>
<td>15 out of 15</td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td>1 out of 15</td>
<td>3 out of 15</td>
<td>3 out of 15</td>
</tr>
<tr>
<td>Dock Damage</td>
<td>5 out of 15</td>
<td>7 out of 15</td>
<td></td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>1 out of 15</td>
<td>2 out of 15</td>
<td>2 out of 15</td>
</tr>
<tr>
<td>Walkway Damage</td>
<td>1 out of 15</td>
<td>3 out of 15</td>
<td>3 out of 15</td>
</tr>
<tr>
<td>Fuel Dock Access Restricted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Aquatic Weed Growth</td>
<td>3 out of 15</td>
<td>6 out of 15</td>
<td>6 out of 15</td>
</tr>
<tr>
<td>Access Channel Issue</td>
<td>2 out of 15</td>
<td>4 out of 15</td>
<td>9 out of 15</td>
</tr>
<tr>
<td>Accelerated Shoreline Bluff Erosion</td>
<td>1 out of 15</td>
<td>2 out of 15</td>
<td>2 out of 15</td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td>1 out of 15</td>
<td>3 out of 15</td>
<td></td>
</tr>
<tr>
<td>Sales Lost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;0% to 33% Slip Loss</td>
<td>5 of 15</td>
<td>8 of 15</td>
<td>6 of 15</td>
</tr>
<tr>
<td>Marinas with 33% to 66% Slip Loss</td>
<td>1 of 15</td>
<td>4 of 15</td>
<td>4 of 15</td>
</tr>
<tr>
<td>Marinas with &gt;66% Slip Loss</td>
<td>2 of 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondents who would Dredge</td>
<td>6 out of 15</td>
<td>12 out of 15</td>
<td>12 out of 15</td>
</tr>
<tr>
<td>Adapt with Floating Docks</td>
<td>1 out of 15</td>
<td>2 out of 15</td>
<td>4 out of 15</td>
</tr>
<tr>
<td>Adapt with Dock Modifications</td>
<td>3 out of 15</td>
<td>4 out of 15</td>
<td>6 out of 15</td>
</tr>
<tr>
<td>Extend docks</td>
<td>1 out of 15</td>
<td>1 out of 15</td>
<td>1 out of 15</td>
</tr>
<tr>
<td>Adapt with Seawalls</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 38: North U.S. region responses to water level drop scenarios

<table>
<thead>
<tr>
<th>North U.S. Region</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m (Menominee); Average Water Level Elevation for August 2009: 183.4m (Baraga &amp; Ontonagon)</td>
<td>176.1m; 183.1m</td>
<td>175.8m; 182.8m</td>
<td>175.5m; 182.5m</td>
</tr>
</tbody>
</table>

Response (Out of 6 Surveyed)

<table>
<thead>
<tr>
<th>Damages</th>
<th>1 of 6</th>
<th>6 of 6</th>
<th>6 of 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondents Affected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td>1 of 6</td>
<td>3 of 6</td>
<td></td>
</tr>
<tr>
<td>Dock Damage</td>
<td>1 of 6</td>
<td>4 of 6</td>
<td></td>
</tr>
<tr>
<td>Seawall Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walkway Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Dock Access Restricted</td>
<td>2 of 6</td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Increased Aquatic Weed Growth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access Channel Issue</td>
<td>1 of 6</td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Accelerated Shoreline Bluff Erosion</td>
<td>1 of 6</td>
<td>1 of 6</td>
<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td></td>
<td>1 of 6</td>
</tr>
<tr>
<td>Sales Lost</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Slip Loss

<table>
<thead>
<tr>
<th>Marinas with &gt;0% to 33% Slip Loss</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Marinas with 33% to 66% Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;66% Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adaptations

<table>
<thead>
<tr>
<th>Respondents who would Dredge</th>
<th>3 of 6</th>
<th>4 of 6</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Adapt with Floating Docks</td>
<td>1 of 6</td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Adapt with Dock Modifications</td>
<td>2 of 6</td>
<td>3 of 6</td>
<td></td>
</tr>
<tr>
<td>Extend Docks</td>
<td>1 of 6</td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Adapt with Seawalls</td>
<td></td>
<td>1 of 6</td>
<td></td>
</tr>
</tbody>
</table>
3.23 High Water Scenarios

The responses to the three high water scenarios are displayed by region in Tables 39 through 46 below. When compared to the results from the low water scenarios, it is apparent that most marinas would be more resilient to the effects of high water than they are to low water; although specific vulnerabilities exist in some Canadian regions\(^1\).

\(^1\) Except for the Erie and South Huron regions, a relatively small proportion of the Canadian marinas would be significantly affected by the higher water levels. At a two foot increase, a small minority of marinas in the other regions would incur damages to docks, seawalls, and experience reduced demand for winter storage. At a three foot rise, these issues would be slightly amplified, but still quite manageable for a majority of the marinas. Several of the operators in the Georgian Bay, North Channel and Superior regions explained that even a three foot rise would increase their bus

3.22 Low Water Scenarios

The Canadian responses to the three drop scenarios are displayed for each region in Tables 30 through 34. These responses give an indication as to how the three low water scenarios would affect the different regions in terms of damages to infrastructure, amount of slips rendered unusable, and adaptations which operators would be likely to perform in reaction.

A one foot drop would affect the North Channel region more than the other regions\(^1\). Forty percent of its marinas would suffer slip losses of up to 33%, whereas less than one third of marinas in the other regions would lose the same amount. More than double the amount of marinas in the South Huron region would have dock damages than compared to the North Channel region. To adapt, almost 40% of marinas in the South Huron region would dredge, whereas less than a quarter would dredge in the Erie and North Channel regions. Little dredging would likely go on in the Georgian Bay region.

A two foot drop would impact almost all of the marinas in the South Huron, North Channel and Erie regions, as well as almost three-quarters of the marinas in the Georgian Bay region. More marinas in the North Channel region would suffer the slip losses (65%), than the Georgian Bay (46%), Erie (40%) and South Huron regions (25%). The magnitude of these slip losses would be greater in the North Channel, Erie and South Huron regions than in the Georgian Bay region. One-quarter of the marinas in the North Channel region would lose between one and two-thirds of their slips, while 40% of the marinas would lose up to one-third. About 10% of marinas in the Erie and South Huron regions would lose between one and two-thirds of their slips. Most of the marinas that would lose slips in the Georgian Bay region would lose up to one-third.

The South Huron region would suffer the most damage to docks (38%), followed by the North Channel (20%) and Georgian Bay (15%) regions. Launch ramps would become unusable in ten to fifteen percent of the marinas in the Georgian Bay and Erie regions. Thirty five percent of marinas in the North Channel region could suffer from reduced sales. In response, almost half of the marinas in the Erie (42%), South Huron (38%) and North Channel (35%) regions would dredge. Several respondents in the North Channel region said that they would like to dredge, but would be unable to due to the presence of bedrock as well as financial limitations. About a quarter of the marinas in the Georgian Bay region would dredge as well. Fifteen percent of marinas in the North Channel region would also adapt by undertaking dock modifications.
A three foot drop would affect most of the marinas within all of the regions. As one respondent put it, a three foot drop would be “catastrophic” for many of the marinas. Slip losses would be significant in all four regions. Significantly more marinas in the North Channel region would suffer slip loss (85%) than the other regions (between 50% and 65%). Forty percent of marinas in the North Channel region would lose more than 66% of their slips, followed by the Erie region, where a quarter of the marinas would lose the same proportion. Within the Erie region, consequences would be especially severe in the Turkey Point AOS, where several of the marinas are situated on the shallow Inner Bay of Long Point Bay, which is a popular sports fishing destination. In addition, significant amounts of marinas in all four of the regions would have slip losses of up to two thirds of their dockage. Damage to docks would be greatest in the South Huron region (50%), followed by the North Channel (25%), Georgian Bay (23%) and Erie (10%) regions. Around a quarter of the marinas in the South Huron and Erie regions would suffer damage to seawalls. Low water levels can remove back-pressure necessary to support seawalls; requiring them to be dug lower and reconstructed. Some marinas in the Georgian Bay and North Channel region would be unable to use their launch ramps. To adapt, around half of the marinas in all of the regions would dredge, with the most dredging going on in the South Huron region (63%) and the least in Georgian Bay (38%). Along with dredging, between ten and twenty percent of the marinas in the South Huron and North Channel regions would perform other adaptations such as installing floating docks, undertake dock modifications, and repair seawalls.

To varying degrees, the low water scenarios would cause marinas in all of the regions to have difficulty accommodating sailboats or other large boats (21+ feet) that require deeper draft in access channels and dockage. Several operators explained that to a large extent, their businesses rely on expenditures from larger cruise and sail boat customers. One respondent in the South Huron region joked that given a significant drop in water level, his yacht club would turn into a “small powerboat club”. Regions that specialize in accommodating larger boats and sailboats may experience particular thresholds in their vulnerability to dropping water levels.

As questionnaires were only completed for two of the four marinas surveyed in the Superior region, the following responses may not accurately represent the region. One operator in the Superior region would be affected by two and three foot drops, losing more than two thirds of their slips. No adaptations would be undertaken in response.

Table: Erie region responses to water level drop scenarios
<table>
<thead>
<tr>
<th>Erie Region</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for June and July 2009: 174.4m</td>
<td>174.1m</td>
<td>173.8m</td>
<td>173.5m</td>
</tr>
<tr>
<td>Response (Out of 21 Surveyed)</td>
<td>9 of 21</td>
<td>17 of 21</td>
<td>19 of 21</td>
</tr>
<tr>
<td>Damages</td>
<td>2 of 21</td>
<td>2 of 21</td>
<td>2 of 21</td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>1 of 21</td>
<td>2 of 21</td>
<td>3 of 21</td>
</tr>
<tr>
<td>Walkway Damage</td>
<td>1 of 21</td>
<td>1 of 21</td>
<td></td>
</tr>
<tr>
<td>Fuel Dock Access Restricted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Aquatic Weed Growth</td>
<td>1 of 21</td>
<td>1 of 21</td>
<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales Lost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;0% to 33% Slip Loss</td>
<td>1 of 21</td>
<td>6 of 21</td>
<td>4 of 21</td>
</tr>
<tr>
<td>Marinas with 33% to 66% Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;66% Slip Loss</td>
<td>2 of 21</td>
<td>5 of 21</td>
<td></td>
</tr>
<tr>
<td>Adaptations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondents who would Dredge</td>
<td>4 of 21</td>
<td>9 of 21</td>
<td>11 of 21</td>
</tr>
<tr>
<td>Adapt with Floating Docks</td>
<td>1 of 21</td>
<td>1 of 21</td>
<td></td>
</tr>
<tr>
<td>Adapt with Dock Modifications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapt with Seawalls</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table: South Huron region responses to water level drop scenarios

<table>
<thead>
<tr>
<th>South Huron Region</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m</td>
<td>176.1m</td>
<td>175.8m</td>
<td>175.5m</td>
</tr>
<tr>
<td>Response (Out of 8 Surveyed)</td>
<td>4 of 8</td>
<td>7 of 8</td>
<td>8 of 8</td>
</tr>
<tr>
<td>Damages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondents Affected</td>
<td>3 of 8</td>
<td>3 of 8</td>
<td>4 of 8</td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>Walkway Damage</td>
<td>Fuel Dock Access Restricted</td>
<td>Increased Aquatic Weed Growth</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------</td>
<td>----------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marinas with &gt;0% to 33% Slip Loss</td>
<td></td>
<td></td>
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<tr>
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<td>Marinas with 33% to 66% Slip Loss</td>
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<td>Adapt with Floating Docks</td>
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### Table: Georgian Bay region responses to water level drop scenarios

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<th>Georgian Bay Region</th>
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<tr>
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<td>Walkway Damage Restricted</td>
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### Table: North Channel region responses to water level drop scenarios

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<td>175.8m</td>
<td>175.5m</td>
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<td>Marinas with 33% to 66% Slip Loss</td>
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<td>Marinas with &gt;66% Slip Loss</td>
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### Table: Superior region responses to water level drop scenarios

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<td>Dock Damage</td>
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<tr>
<td>Seawall Damage</td>
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<td>Walkway Damage</td>
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<tr>
<td>Increased Aquatic Weed Growth</td>
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The U.S. responses to the three drop scenarios are displayed by region in Tables 35 through 38. A one foot (0.3m) drop from the appropriate average water level elevations would affect the Toledo/Sandusky and Holland regions more than the Alpena/Bay City or North U.S. regions. A minority of the marinas in the former two regions would suffer damages including increased aquatic weed growth and accelerated shoreline erosion. One third of the marinas in both regions would have 33% or less of their slips rendered unusable. In response, around half of the operators would dredge in the Holland region. All three of the marinas that completed questionnaires in the Toledo/Sandusky region would like to dredge, but only two would be able to afford it. These same damages and reactions would persist in the Toledo/Sandusky region for the two (0.6m) and three foot (0.9m) drops as well.

A two foot (0.6m) drop from the appropriate average water level elevation would affect the Holland region more than the other three regions. In the Holland region, between 20% and 40% of the marinas would suffer damages to docks, walkways, and launch ramps, increased aquatic weed growth and inadequate access channel depths. 53% of the marinas would lose up to 33% of their slips, and 27% would lose between 33% and 66%. To adapt, 80% of the operators would dredge. In the Alpena/Bay City region, 29% of the operators would suffer damages to launch ramps and inadequate access channel depths. They would react by installing floating docks. Two of the six marinas in the North U.S. region would suffer from increased aquatic weed growth. Half would dredge and one-third would undertake dock modifications.

A three foot (0.9m) drop from the appropriate average water level elevation would cause significant damages to a majority of marinas in all four of the regions. About half of the marinas in all four regions would suffer damages including damage to docks, walkways, and launch ramps; increased aquatic weed growth, and accelerated shoreline erosion. Inadequate access channel depths would occur at a majority of the marinas in the Toledo/Sandusky region, 71% of the Alpena/Bay City region, 60% of the Holland region, and 33% of the North U.S. region. The loss of up to 33% of total slips per marina would occur at about half of the marinas in the Holland region, and at roughly 30% of the marinas in the Alpena/Bay City and Toledo/Sandusky regions. The loss...
of between 33% and 66% of total slips per marina would occur at 27% of the marinas in the Holland region, and at one of the seven marinas in the Alpena/Bay City region. Within the North U.S. region, all three of the marinas in the Baraga AOS would lose 100% of their slips. The loss of more than 66% of total slips per marina would occur at one of the three marinas that completed questionnaires in the Toledo/Sandusky region, and at two of the fifteen marinas in the Holland region.

To adapt, many of the marinas would dredge, including 80% of the Holland region, 71% of the Alpena/Bay City region, and 67% of the Toledo/Sandusky and North U.S. regions. Operators would also undertake dock modifications in half of the North U.S. region, and 40% of the Holland region. Operators would also install floating docks at 57% of the Alpena/Bay City region, 27% of the Holland region, and 33% of the North U.S. region. Two of the six operators in the North U.S. region would also extend existing docks.

### Table Error! Main Document Only: Toledo/Sandusky region responses to water level drop scenarios

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<th>Toledo/Sandusky region</th>
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<td>Seawall Damage</td>
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<td>Walkway Damage</td>
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<tr>
<td>Fuel Dock Access Restricted</td>
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<tr>
<td>Increased Aquatic Weed Growth</td>
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<tr>
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<tr>
<td>Sales Lost</td>
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<td>Accelerated Shoreline Bluff Erosion</td>
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<td>Adapt with Dock Modifications</td>
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<td>Table: Alpena/Bay City region responses to water level drop scenarios</td>
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<td>Marinas with &gt;0% to 33% Slip Loss</td>
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Global Page 77
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<td>6 out of 15</td>
<td></td>
</tr>
<tr>
<td>Extend docks</td>
<td>1 out of 15</td>
<td>1 out of 15</td>
<td>1 out of 15</td>
<td></td>
</tr>
<tr>
<td>Adapt with Seawalls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table: North U.S. region responses to water level drop scenarios
<table>
<thead>
<tr>
<th>Average Water Level Elevation for May thru August 2009: 176.4m (Menominee); Average Water Level Elevation for August 2009: 183.4m (Baraga &amp; Ontonagon)</th>
<th>176.1m; 183.1m</th>
<th>175.8m; 182.8m</th>
<th>175.5m; 182.5m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response (Out of 6 Surveyed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damages Respondents Affected</td>
<td>1 of 6</td>
<td>6 of 6</td>
<td>6 of 6</td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td>1 of 6</td>
<td>3 of 6</td>
<td></td>
</tr>
<tr>
<td>Dock Damage</td>
<td>1 of 6</td>
<td>4 of 6</td>
<td></td>
</tr>
<tr>
<td>Seawall Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walkway Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Dock Access Restricted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Aquatic Weed Growth</td>
<td>2 of 6</td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Access Channel Issue</td>
<td>1 of 6</td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Accelerated Shoreline Bluff Erosion</td>
<td>1 of 6</td>
<td>1 of 6</td>
<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sales Lost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;0% to 33% Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with 33% to 66% Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marinas with &gt;66% Slip Loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptations Respondents who would Dredge</td>
<td>3 of 6</td>
<td>4 of 6</td>
<td></td>
</tr>
<tr>
<td>Adapt with Floating Docks</td>
<td>1 of 6</td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Adapt with Dock Modifications</td>
<td>2 of 6</td>
<td>3 of 6</td>
<td></td>
</tr>
<tr>
<td>Extend Docks</td>
<td>1 of 6</td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Adapt with Seawalls</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.23 High Water Scenarios

The responses to the three high water scenarios are displayed by region in Tables 39 through 46 below. When compared to the results from the low water scenarios, it is apparent that most marinas would be more resilient to the effects of high water than they are to low water; although specific vulnerabilities exist in some Canadian regions.71

Within the Erie region, the effects of a two foot rise would be concentrated in the Turkey Point and Port Colborne AOS, where many of the marinas are vulnerable to flooding and ice damage attributed to wind seiches, which can be amplified during periods of high water. Respondents explained that an increase in water levels would not harm day to day operations, but would make the whole marina more susceptible to water surges during periods of high winds. This issue was only expected to occur with a two foot water level rise or higher. Also, respondents already accommodate a one foot rise in water levels during routine maintenance and modifications, whereas a two foot rise would incur more costly adaptations.
Within the Erie region, the effects of a two foot rise would be concentrated in the Turkey Point and Port Colborne AOS, where many of the marinas are vulnerable to flooding and ice damage attributed to wind seiches, which can be amplified during periods of high water. Respondents explained that an increase in water levels would not harm day to day operations, but would make the whole marina more susceptible to water surges during periods of high winds. This issue was only expected to occur with a two foot water level rise or higher. Also, respondents already accommodate a one foot rise in water levels during routine maintenance and modifications, whereas a two foot rise would incur more costly adaptations such as increased labor costs or the installation of new walkways. At a three foot rise, wind surges become more than a concern and are considered a major impediment to operating a successful business.

Similarly, several marinas in the South Huron region are vulnerable to flooding and damage to infrastructure caused by ice jams in nearby river mouths and outlets. In the Port Huron AOS, a three foot rise would cause half of the marinas to lose a significant portion of their slips\(^72\). Half of the marinas would also have issues with flooding\(^73\). One respondent explained that the flooding that would occur in the case of a three foot rise would be a “disaster” and “hard to contemplate”.

<table>
<thead>
<tr>
<th>Table 39: Erie region responses to water level rise scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie Region</td>
</tr>
<tr>
<td>Average Water Level Elevation for June and July 2009: 174.4m</td>
</tr>
<tr>
<td>Response (Out of 21 Surveyed)</td>
</tr>
<tr>
<td>Damages</td>
</tr>
<tr>
<td>Damages</td>
</tr>
<tr>
<td>Dock Damage</td>
</tr>
<tr>
<td>Seawall Damage</td>
</tr>
<tr>
<td>Walkway Damage</td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
</tr>
<tr>
<td>Shoreline Erosion</td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
</tr>
<tr>
<td>Flooding Related to Seiches</td>
</tr>
</tbody>
</table>

such as increased labor costs or the installation of new walkways. At a three foot rise, wind surges become more than a concern and are considered a major impediment to operating a successful business.

iness volume, allowing many to accommodate larger cruise and sailboats. Some operators attributed their resilience to the naturally steep and rocky shores that are characteristic of the three northern regions.

\(^72\) One marina would lose 100% of their slips, while another would lose 50%.
\(^73\) One marina said they would have to build a barrier to prevent flooding. Another said that they would have flooding of their buildings and walkways used to access slips; necessitating the construction of catwalks to reach their floating docks, at an estimated cost of $100,000.
### Table 40: South Huron region responses to water level rise scenarios

<table>
<thead>
<tr>
<th>South Huron Region</th>
<th>One Foot Rise</th>
<th>Two Foot Rise</th>
<th>Three Foot Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m</td>
<td>176.7m</td>
<td>177.0m</td>
<td>177.3m</td>
</tr>
<tr>
<td>Response (Out of 8 Surveyed)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Damages</th>
<th>Response (Out of 8 Surveyed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondents Affected</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Dock Damage</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Walkway Damage</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td></td>
</tr>
<tr>
<td>Shoreline Erosion</td>
<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td>1 of 8</td>
</tr>
<tr>
<td>Flooding Related to Seiches</td>
<td></td>
</tr>
</tbody>
</table>

### Table 41: Georgian Bay region responses to water level rise scenarios

<table>
<thead>
<tr>
<th>Georgian Bay Region</th>
<th>One Foot Rise</th>
<th>Two Foot Rise</th>
<th>Three Foot Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m</td>
<td>176.7m</td>
<td>177.0m</td>
<td>177.3m</td>
</tr>
<tr>
<td>Response (Out of 26 Surveyed)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Damages</th>
<th>Response (Out of 26 Surveyed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respondents Affected</td>
<td>1 of 26</td>
</tr>
<tr>
<td>Dock Damage</td>
<td>2 of 26</td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>1 of 26</td>
</tr>
<tr>
<td>Walkway Damage</td>
<td>2 of 26</td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td></td>
</tr>
<tr>
<td>Shoreline Erosion</td>
<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
</tr>
</tbody>
</table>
Table 42: North Channel region responses to water level rise scenarios

<table>
<thead>
<tr>
<th>North Channel Region</th>
<th>One Foot Rise</th>
<th>Two Foot Rise</th>
<th>Three Foot Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m</td>
<td>176.7m</td>
<td>177.0m</td>
<td>177.3m</td>
</tr>
<tr>
<td>Response (Out of 20 Surveyed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damages</td>
<td>Respondents Affected</td>
<td>4 of 20</td>
<td>9 of 20</td>
</tr>
<tr>
<td>Dock Damage</td>
<td>1 of 20</td>
<td>3 of 20</td>
<td></td>
</tr>
<tr>
<td>Seawall Damage</td>
<td>2 of 20</td>
<td>2 of 20</td>
<td></td>
</tr>
<tr>
<td>Walkway Damage</td>
<td>1 of 20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoreline Erosion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flooding Related to Seiches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptations</td>
<td>Adapt with Dock Modifications</td>
<td>2 of 20</td>
<td>3 of 20</td>
</tr>
<tr>
<td></td>
<td>Adapt by Rebuilding Facilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adapt by Extending Docks</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the U.S., most of the marinas would be quite resilient to high water levels. At a two foot (0.6m) rise in the water level a minority of marinas in the Toledo/Sandusky, Holland regions, and Baraga AOS would experience shoreline erosion, incur damages to docks, seawalls, and launch ramps. To adapt, the operators would rebuild seawalls, modify existing docks, install floating docks, and rebuild facilities (e.g. gas docks or walkways). At a three foot (0.9m) rise from the appropriate average elevations, these issues would be slightly amplified, but still quite manageable for a majority of the marinas.

Table 43: Toledo/Sandusky region responses to water level rise scenarios

<table>
<thead>
<tr>
<th>Toledo/Sandusky region</th>
<th>One Foot Rise</th>
<th>Two Foot Rise</th>
<th>Three Foot Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for June and July 2009: 174.4m</td>
<td>174.7m</td>
<td>175.0m</td>
<td>175.3m</td>
</tr>
<tr>
<td>Response (Out of 3 Surveyed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damages</td>
<td>Respondents Affected</td>
<td>1 out of 3</td>
<td>1 out of 3</td>
</tr>
<tr>
<td>Dock Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seawall Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walkway Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoreline Erosion</td>
<td>1 out of 3</td>
<td>1 out of 3</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
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<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flooding Related to Seiches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapt with Dock Modifications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapt by Rebuilding Facilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapt by Extending Docks</td>
<td>1 out of 3</td>
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<td></td>
</tr>
</tbody>
</table>

### Table 44: Alpena/Bay City region responses to water level rise scenarios

<table>
<thead>
<tr>
<th>Alpena/Bay City region</th>
<th>One Foot Rise</th>
<th>Two Foot Rise</th>
<th>Three Foot Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m</td>
<td>176.7m</td>
<td>177.0m</td>
<td>177.3m</td>
</tr>
<tr>
<td>Response (Out of 7 Surveyed)</td>
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</tr>
<tr>
<td>Damages</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Respondents Affected</td>
<td>1 of 7</td>
<td>5 of 7</td>
<td></td>
</tr>
<tr>
<td>Dock Damage</td>
<td></td>
<td>4 of 7</td>
<td></td>
</tr>
<tr>
<td>Seawall Damage</td>
<td></td>
<td>1 of 7</td>
<td></td>
</tr>
<tr>
<td>Walkway Damage</td>
<td></td>
<td>1 of 7</td>
<td></td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td></td>
<td>1 of 7</td>
<td></td>
</tr>
<tr>
<td>Shoreline Erosion</td>
<td></td>
<td>1 of 7</td>
<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flooding Related to Seiches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapt with Dock Modifications</td>
<td>1 of 7</td>
<td>3 of 7</td>
<td></td>
</tr>
<tr>
<td>Adapt by Rebuilding Facilities</td>
<td></td>
<td>2 of 7</td>
<td></td>
</tr>
<tr>
<td>Adapt by Extending Docks</td>
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<td>4 of 7</td>
<td></td>
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</tbody>
</table>

### Table 45: Holland region responses to water level rise scenarios

<table>
<thead>
<tr>
<th>Holland region</th>
<th>One Foot Rise</th>
<th>Two Foot Rise</th>
<th>Three Foot Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for</td>
<td>176.7m</td>
<td>177.0m</td>
<td>177.3m</td>
</tr>
</tbody>
</table>
### Table 46: North region responses to water level rise scenarios

<table>
<thead>
<tr>
<th>North U.S. Region</th>
<th>One Foot Rise</th>
<th>Two Foot Rise</th>
<th>Three Foot Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Water Level Elevation for May thru August 2009: 176.4m (Menominee); Average Water Level Elevation for August 2009: 183.4m (Baraga &amp; Ontonagon)</td>
<td>176.7m; 183.7m</td>
<td>177.0m; 184.0m</td>
<td>177.3m; 184.3m</td>
</tr>
<tr>
<td>Response (Out of 6 Surveyed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondents Affected</td>
<td>1 of 6</td>
<td>3 of 6</td>
<td></td>
</tr>
<tr>
<td>Dock Damage</td>
<td></td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Seawall Damage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walkway Damage</td>
<td></td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Launch Ramp Damage</td>
<td>1 of 6</td>
<td></td>
<td>1 of 6</td>
</tr>
<tr>
<td>Shoreline Erosion</td>
<td>1 of 6</td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Reduced Demand for Winter Storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flooding Related to Seiches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapt with Dock Modifications</td>
<td>1 of 6</td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Adapt by Rebuilding Facilities</td>
<td></td>
<td>2 of 6</td>
<td></td>
</tr>
<tr>
<td>Adapt with Floating Docks</td>
<td></td>
<td></td>
<td>1 of 6</td>
</tr>
<tr>
<td>Adapt by Rebuilding Seawall</td>
<td></td>
<td>3 of 6</td>
<td></td>
</tr>
<tr>
<td>Adapt by Extending Docks</td>
<td></td>
<td></td>
<td>1 of 6</td>
</tr>
</tbody>
</table>
3.24 “Out of Business” Water Levels

Operators were asked at which change in water level their business would no longer be viable. Figures 6, 7 and 8 show the number of marinas in each AOS on lakes Erie, Michigan/Huron, and Superior that would go out of business if the water level were to change to different elevations, starting from the 2009 average elevations used above. Lake Erie’s average elevation for June and July 2009 was 174.4 meters. Lake Michigan/Huron’s average elevation for May through August 2009 was 176.4 meters. Lake Superior’s average elevation for August 2009 was 183.4 meters.

On Lake Erie, just over half of the marinas in all four of the AOS would go out of business if the water level were to drop to the 173.5m elevation (a three foot (0.9m) drop from the 2009 average for June and July of 174.4m)(Figure 6). A significant threshold exists between the 173.8 and the 173.5 meter elevations in terms of the amount of marinas that would go out of business. Also, more than half of the marinas in the Kingsville AOS would go out of business if the water level were to rise by three feet (0.9m) from the average elevation for June and July, 2009 (174.4m).

![Lake Erie: Marinas Out of Business due to 0.3m fluctuations in water level](image)

*Figure 7: Lake Erie marinas Out of Business due to 0.3m fluctuations in water level by AOS*
On Lake Michigan/Huron, at least half of the marinas in the Port Huron, Goderich, Little Current, Bay City, Holland, and Menominee AOS’s would go out of business if the water level were to drop by three feet (0.9m) from the average elevation for May through August, 2009 (176.4m) to the 175.5m elevation (Figure 7). This represents significant threshold vulnerability for most of the marinas on lake Michigan/Huron between the 175.8m and 175.5m elevations. However, with this elevation only a minority of the marinas in the Midland (26%), Richard’s Landing (25%), and Alpena (0%) AOS’s would go out of business.

If the water level were to rise up three feet (0.9m) from the 2009 average elevation of 176.4m to the 177.3m elevation, then the proportion of marinas per AOS that would go out of business are as follows: 50% in Port Huron and Menominee; 40% in Bay City; 33% in Holland; 27% in Parry Sound; and 25% in Richard’s Landing.

Figure 8: Lake Michigan/Huron marinas Out of Business due to 0.3m fluctuations in water level
On Lake Superior, all of the marinas in the Baraga and Ontonagon AOS’s would go out of business if the water level were to drop three feet (0.9m) from the August 2009 average elevation of 183.4m to 182.5m (Figure 8). This represents significant threshold vulnerability between the 182.8m and 182.5m elevations; although neither of the marinas in the Thunder Bay AOS would be affected.

![Lake Superior: Marinas Out of Business due to 0.3m fluctuations in water level](image)

**Figure 9: Lake Superior marinas Out of Business due to 0.3m fluctuations in water level by AOS**

### 3.25 Preferred Water Levels

Operators were also asked to identify their preferred water level. Figures 9, 10 and 11 show the number of marinas in each AOS on Lakes Erie, Michigan/Huron, and Superior that prefer a given water level elevation.

On Lake Erie, most of the operators would like the water level to remain at the average elevation for the months of June and July 2009, 174.4 meters (Figure 9). However, one quarter of the respondents would prefer it to be one foot (0.3m) higher at 174.7m.
On Lake Michigan/Huron, a majority of the respondents would prefer the water level to be one foot (0.3m) higher than the 2009 average elevation of 176.4, at the 176.7m elevation (Figure 10). Also, a significant proportion of operators would prefer it to be either at the 176.4m elevation, or two feet (0.6m) higher, at the 177m elevation.
On Lake Superior, three of the six respondents would prefer the water level to be one foot (0.3m) higher than the 2009 average elevation of 183.4m, at the 183.7m elevation (Figure 11). Two of the six would prefer it to be two feet (0.6m) higher, at the 184m elevation.

Figure 12: Lake Superior: preferred water levels by AOS
3.3 Impediments to Adaptation

Respondents were asked a series of questions intended to identify factors that impede their capacity to adapt to changes in water levels. In their answers, both Canadian and U.S. operators focused on the difficulties associated with obtaining dredging permits, namely the bureaucratic “red tape” and paperwork involved in the process.

As one Canadian operator explained,

“The number of authoritative bodies that have to be dealt with is frustrating”

In Canada, a significantly higher proportion of operators in the Turkey Point, Port Huron, Goderich, and Richards Landing AOS cited difficulties associated with dredging permits as an impediment to adaptation. Some expressed having trouble completing dredging within the timeframe allotted by the permit as a result of delays from poor weather (Port Huron AOS) or a limited supply of local contractors (Turkey Point AOS). Government organizations regulate the dredging of many of the marinas’ access channels and basins in order to protect endangered ecosystems or fish spawning grounds. One operator explained that,

“We pay for a water lot and can’t touch it”

Also, several marinas in the Georgian Bay and North Channel regions have difficulty dredging due to the time and costs involved with blasting bedrock in their access channels and basins, especially in the Richards Landing AOS where a significantly higher proportion of respondents identified it as an impediment to adaptation. As one respondent explained,

“The presence of rocks in the channel creates a permit issue for timing. Once a rock is discovered, it requires a new permit to blast, and this may take too long”

One of the two operators interviewed in the Thunder Bay AOS explained that the presence of contaminated soil in their access channel from past industrial uses has made it prohibitively costly to properly dispose of material dredged from the river bottom.

The majority of U.S. operators who responded to the question indicated that difficulties associated with obtaining dredging permits impede their ability to adapt. The proportion of these respondents who

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74 For specific details, refer to the individual AOS analyses Appendix.
75 For example, several of the marinas in the Turkey Point AOS depend on the shallow Long Point Bay for access to their marinas, which is protected crown land and cannot be dredged.
cited ‘dredging permits’, by AOS, are as follows: 100% in the Toledo/Sandusky and Alpena AOS’s; 67% in the Baraga AOS; 50% in the Menominee AOS; 40% in the Bay City AOS; and 20% in the Holland AOS.

### 3.4 Adaptive Management Suggestions

Respondents were asked a series of questions intended to provide information that could be incorporated into the design of programs that would enable marinas to adapt to fluctuating water levels. The suggestions are organized by region and AOS in Table 47.

In Canada, many of the operators suggested that the government provide some form of emergency financial assistance during times of extreme fluctuations in the water level. According to one respondent,

“**Assistance would be desired, for dredging and dock modifications, IF at the time there is a significant drop in water levels**”

Given an episode of significantly low water levels, some marinas may not be able to afford expensive adaptations such as dredging or dock modifications, despite the fact their survival could very well depend on it. One respondent explained that,

“**Not every little guy can afford steel floating docks and dredging**”

As the table shows, the highest proportion of respondents who made suggestions for government funding were in the Georgian Bay region, followed by the North Channel Region, the Erie region, and lastly the South Huron region. Within the Georgian Bay region, nearly all of the respondents in the Midland AOS made suggestions, providing the widest array of funding applications. Within the Erie region, significantly more respondents in the Kingsville AOS made suggestions than the other two AOS. Questionnaire data was incomplete for the Superior region.

Also, several of the respondents in the Port Colborne AOS expressed doubt or a lack of trust in the government’s ability to aid them in adapting to changing water levels. As one respondent explained,

“**[It] wouldn’t matter what you did, you wouldn’t win. Haven’t seen them help anyone other than General Motors**”

Within the South Huron and North Channel Regions, respondents from the Goderich and Richards Landing AOS made suggestions related to the negative effects of the exchange rate and border-crossing regulations on business from U.S. boaters. A respondent from the Goderich AOS explained that

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76 However, the one operator who did respond to this section of the questionnaire mentioned that he was uncertain of the reliability of government funding as a result of prior experience. See the Thunder Bay AOS analysis appendix for further details.
“The Canadian dollar needs to be at 0.8 [of the U.S. dollar] to compete with the American side”

Respondents from both AOS said that they had lost business from larger cruise boats (Goderich AOS) and sports-fishermen (Richards Landing AOS) from the nearby state of Michigan as a result of the recent increase in paperwork necessary to cross the border.

Although the questions were intended to provide information concerning government support for adaptations to changing water levels, several responses were made in the Port Colborne AOS concerning the government’s perceived role in the regulation of the water level on Lake Erie\(^{77}\) as well as several responses in the Parry Sound AOS concerning the government’s perceived role in the regulation of the water level on Lake Huron\(^{78}\). In both sets of responses, regulation of the St Clair river system was a recurring focus. These are comments made by marina operators and do not reflect this report’s findings or recommendations.

In the U.S., a minority of the respondents (four) said that they knew of existing government funding available to them in order to assist in adaptation to changes in water levels (Two of the three respondents in the Toledo/Sandusky AOS, as well as both of the respondents in the Alpena AOS).

However, many of the operators suggested that the government provide some form of financial aid for dredging and infrastructure upkeep. The proportions of respondents by AOS who made these suggestions are as follows: 40% in the Holland AOS; 33% in the Toledo/Sandusky AOS; and 20% in the Bay City AOS. Also in related to the topic of dredging, two of the three respondents in the Baraga AOS suggested,

“Simpler steps in permitting for dredging and upgrading”, requesting “personnel to help [them] walk through the permitting process and to answer questions when they arise”.

\(^{77}\) Some of the respondents expressed conflicting views as to how the government should be regulating Lake Erie’s water levels. It was suggested that the government regulate the water level to ensure enough draft for haul out in the fall. Low water in the fall can create difficulties for marina operators as they try to haul out boats using launch ramps or travel lifts that require a certain draft. One respondent blamed the government for dropping the water level in the fall before storm season, claiming that, “they drop it in October; they say they don’t. They do it to protect the lakeshore properties in the storm season”. However, this operator may not have been as susceptible to damages related to high water as others in the area.

Indeed, many marinas in this area are vulnerable to high water levels, and feel that the government should be responsible for preventing episodes of high water. A respondent suggested that the government should lower Lake Erie’s water level using its control structures. They claimed that the IJC’s dredging of the St Claire River has resulted in the rise in water level. They also claimed that man-made obstructions in the mouth of the Niagara River have made the natural choke point even narrower, adding to the high water levels.

\(^{78}\) Some respondents claimed that significant fluctuations in water levels were partially a man made problem, urging the government to “get a grip” on Lake Huron’s water levels. One respondent expressed that “throwing money at us won’t solve a long term problem”.

Some claimed that past dredging in the St. Claire River was to blame for recent low water levels, and requested that the government use control structures to reduce the outflow from Lake Huron. One respondent requested that the government “put a cork in the St. Claire River”. Another suggested that “somebody needs to be sued for not taking care of the outlet”
In addition, respondents in the Bay City AOS suggested improved state/private facility interaction to keep public access available; and that taxes be lowered in order to allow for growth and expansion of marina businesses.

Nine of the fifteen respondents in the Holland AOS made a variety of suggestions as well, asking for planning and silt control, funding for dock modifications, ice damage protection, building permits for floating docks, the clean-up of water and shoreline, and financial assistance from both the federal and state governments similar to Act 51 that is normally used for road work projects.

Table 47: Suggestions for government assistance by region and AOS

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Respondents</th>
<th>Suggestions for Funding</th>
<th>Suggested by % of AOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>Port Colborne</td>
<td>8</td>
<td>Tax Breaks</td>
<td>13%</td>
</tr>
<tr>
<td>Erie</td>
<td>Turkey Point</td>
<td>6</td>
<td>Emergency Dredging</td>
<td>17%</td>
</tr>
<tr>
<td>Erie</td>
<td>Kingsville</td>
<td>7</td>
<td>Emergency Dredging</td>
<td>57%</td>
</tr>
<tr>
<td>South Huron</td>
<td>Port Huron</td>
<td>4</td>
<td>Flood/Dredge Funding</td>
<td>50%</td>
</tr>
<tr>
<td>South Huron</td>
<td>Goderich</td>
<td>4</td>
<td>Currency Exchange Control, Reduce Passport Restrictions</td>
<td>50%</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>Midland</td>
<td>15</td>
<td>Emergency Dredging, Dock Modifications, Seawall Construction, Tax Breaks</td>
<td>93%</td>
</tr>
<tr>
<td>Georgian Bay</td>
<td>Parry Sound</td>
<td>11</td>
<td>Emergency Dredging, Dock Modifications</td>
<td>73%</td>
</tr>
<tr>
<td>North Channel</td>
<td>Little Current</td>
<td>12</td>
<td>Emergency Dredging, Dock Modifications, Erosion Control</td>
<td>50%</td>
</tr>
<tr>
<td>North Channel</td>
<td>Richards Landing</td>
<td>8</td>
<td>Emergency Dredging, Dock Modifications</td>
<td>75%</td>
</tr>
<tr>
<td>North Channel</td>
<td>Richards Landing</td>
<td>8</td>
<td>Passport Restrictions</td>
<td>13%</td>
</tr>
<tr>
<td>Superior</td>
<td>Thunder Bay</td>
<td>2</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Alpena/Bay City</td>
<td>Bay City</td>
<td>5</td>
<td>Improved state/private facility interaction to keep public access</td>
<td>20%</td>
</tr>
<tr>
<td>Alpena/Bay City</td>
<td>Bay City</td>
<td>5</td>
<td></td>
<td>20%</td>
</tr>
<tr>
<td>Alpena/Bay City</td>
<td>Bay City</td>
<td>5</td>
<td>Dredging and Infrastructure Assistance</td>
<td>20%</td>
</tr>
<tr>
<td>Alpena/Bay City</td>
<td>Alpena</td>
<td>2</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>Toledo/Sandusky</td>
<td>3</td>
<td>Dredging and Infrastructure Assistance</td>
<td>33%</td>
</tr>
<tr>
<td>Holland</td>
<td>Holland</td>
<td>15</td>
<td>Dredging and Infrastructure Assistance</td>
<td>40%</td>
</tr>
<tr>
<td>Holland</td>
<td>Holland</td>
<td>15</td>
<td>Planning and silt control, funding for dock modifications, ice damage protection, building permits for floating docks, clean up of water and shoreline, &amp; federal and state cooperative funding.</td>
<td>60%</td>
</tr>
<tr>
<td>North</td>
<td>Baraga</td>
<td>3</td>
<td>Simplified dredging/permitting process, personnel to assist</td>
<td>67%</td>
</tr>
<tr>
<td>North</td>
<td>Ontonagon</td>
<td>1</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>North</td>
<td>Menominee</td>
<td>3</td>
<td></td>
<td>0%</td>
</tr>
</tbody>
</table>
4.0 The Physical Measurements

Physical slip depth measurements were taken in every region. Of the 221 marinas identified in the Areas of Survey (148 Canadian, 73 U.S.), 125 were physically surveyed (88 Canadian, 37 U.S.). A waypoint was recorded for each slip, unless the depth was 2.7 meters or greater at the time of the survey. This cut-off depth was chosen because the depth translates to approximately nine feet. With a three foot loss in water levels, at least six feet would remain in these slips. Six feet is the approximate average draft of a sailboat, the most vulnerable vessel to shallow water levels due to their deep keels. If a given slip could lose three feet and still accommodate a sailboat, it was considered safe and its depth was not recorded. The depth of the slip, however, was noted to be greater than 2.7 meters. A total of 13,804 slips were measured (9,457 Canadian, 4,347 U.S.) out of a possible 21,014 or 66 percent (13,965 Canadian, 7,049 U.S).

The measured marinas do not necessarily form a representative sample of the marina industry in the individual AOS’s or Regions.

The slips were then subjected to the same three low water level scenarios – one (0.3), two (0.6) and three (0.9) foot (meter) drops from the 2009 average water level elevations for the months in which measurements were recorded on each Lake. For Erie this elevation is 174.4m, for Lake Huron it is 176.4m and for Lake Superior it is 183.4m. These levels were chosen to represent potential changes in water levels based on both the long-term records and long-term forecasts from climate change models. In conducting these slip-loss scenarios, a given slip was considered to be unusable if the distance between the slip’s bottom elevation and the scenario elevation were less than two feet (0.6m). The two foot (0.6m) cut-off point for a functioning slip was chosen based on the reasoning that at a depth lower than two feet, a slip begins to have difficulty accommodating even small boats with outboard motors; which typically have the shallowest draft requirements when compared to all other boat types commonly used on the Great Lakes. However, it should be noted that a significant proportion of Great Lakes slips may be considered as unusable at a depth well before the two foot (0.6m) cut-off by a given marina, depending on its target clientele. As a result, the measurements, and the scenarios applied to them necessarily fail to capture the damages associated with slip-loss occurring at water depths greater than two feet (0.6m).

In running the three slip-loss scenarios, the number of slips lost for each scenario is totaled for each marina and then presented graphically. Individual marina results are then aggregated by Region to show vulnerability to water level drops on a regional scale. Tables 48 and 49 display the number of slips lost in each region and AOS, and enables damages between regions to be quickly compared. The following bar graphs compare the surveyed marinas in the Region with each other, while the pie charts provide the overall vulnerability each Region. The bar graphs also show how a region’s results might be skewed due to either a large marina or a small sample size.
Table 48: Overall loss of slips at surveyed marinas in Canada, organized by Region and Area of Survey

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Total Slips</th>
<th>Slips Measured</th>
<th>Lost at 1 Foot Drop (173.9m)</th>
<th>Lost at 2 Foot Drop (173.6m)</th>
<th>Lost at 3 Foot Drop (173.3m)</th>
<th>Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erie</td>
<td>Port Colborne</td>
<td>883</td>
<td>804</td>
<td>6</td>
<td>49</td>
<td>171</td>
<td>712</td>
</tr>
<tr>
<td></td>
<td>174.2m</td>
<td>Turkey Point</td>
<td>2566</td>
<td>1961</td>
<td>96</td>
<td>321</td>
<td>930</td>
</tr>
<tr>
<td></td>
<td>Kingsville</td>
<td>1325</td>
<td>1248</td>
<td>58</td>
<td>142</td>
<td>390</td>
<td>935</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>4774</td>
<td>4013</td>
<td>160</td>
<td>512</td>
<td>1491</td>
<td>3283</td>
</tr>
<tr>
<td></td>
<td>% Of Total Slips</td>
<td>84%</td>
<td>3%</td>
<td>11%</td>
<td>31%</td>
<td>69%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Total Slips</th>
<th>Slips Measured</th>
<th>Lost at 1 Foot Drop (176.2m)</th>
<th>Lost at 2 Foot Drop (175.9m)</th>
<th>Lost at 3 Foot Drop (175.6m)</th>
<th>Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Huron</td>
<td>Port Huron</td>
<td>1436</td>
<td>966</td>
<td>40</td>
<td>109</td>
<td>446</td>
<td>990</td>
</tr>
<tr>
<td></td>
<td>176.4m</td>
<td>Goderich</td>
<td>680</td>
<td>411</td>
<td>4</td>
<td>18</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2116</td>
<td>1377</td>
<td>44</td>
<td>127</td>
<td>519</td>
<td>1597</td>
</tr>
<tr>
<td></td>
<td>% Of Total Slips</td>
<td>65%</td>
<td>2%</td>
<td>6%</td>
<td>25%</td>
<td>75%</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Total Slips</th>
<th>Slips Measured</th>
<th>Lost at 1 Foot Drop (176.2m)</th>
<th>Lost at 2 Foot Drop (175.9m)</th>
<th>Lost at 3 Foot Drop (175.6m)</th>
<th>Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgian Bay</td>
<td>Midland</td>
<td>3723</td>
<td>2105</td>
<td>87</td>
<td>257</td>
<td>642</td>
<td>3081</td>
</tr>
<tr>
<td></td>
<td>Parry Sound</td>
<td>1648</td>
<td>731</td>
<td>38</td>
<td>122</td>
<td>225</td>
<td>1423</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>5371</td>
<td>2836</td>
<td>125</td>
<td>379</td>
<td>867</td>
<td>4504</td>
</tr>
<tr>
<td></td>
<td>% Of Total Slips</td>
<td>53%</td>
<td>2%</td>
<td>7%</td>
<td>16%</td>
<td>84%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Total Slips</th>
<th>Slips Measured</th>
<th>Lost at 1 Foot Drop (176.2m)</th>
<th>Lost at 2 Foot Drop (175.9m)</th>
<th>Lost at 3 Foot Drop (175.6m)</th>
<th>Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Channel</td>
<td>Little Current</td>
<td>811</td>
<td>727</td>
<td>21</td>
<td>73</td>
<td>151</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>Richards Landing</td>
<td>693</td>
<td>565</td>
<td>9</td>
<td>15</td>
<td>73</td>
<td>620</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1504</td>
<td>1292</td>
<td>30</td>
<td>88</td>
<td>224</td>
<td>1280</td>
</tr>
<tr>
<td></td>
<td>% Of Total Slips</td>
<td>86%</td>
<td>2%</td>
<td>6%</td>
<td>15%</td>
<td>85%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Total Slips</th>
<th>Slips Measured</th>
<th>Lost at 1 Foot Drop (183.2m)</th>
<th>Lost at 2 Foot Drop (182.9m)</th>
<th>Lost at 3 Foot Drop (182.6m)</th>
<th>Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior</td>
<td>Thunder Bay</td>
<td>260</td>
<td>97</td>
<td>2</td>
<td>4</td>
<td>14</td>
<td>246</td>
</tr>
<tr>
<td></td>
<td>183.5m</td>
<td>Total</td>
<td>260</td>
<td>97</td>
<td>2</td>
<td>14</td>
<td>246</td>
</tr>
<tr>
<td></td>
<td>% Of Total Slips</td>
<td>37%</td>
<td>1%</td>
<td>2%</td>
<td>5%</td>
<td>95%</td>
<td></td>
</tr>
</tbody>
</table>

*Note these are cumulative totals*
Table 49: Overall loss of slips at surveyed marinas in the U.S., organized by Region and Area of Survey

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Total Slips</th>
<th>Slips Measured</th>
<th>Lost at 1 Foot Drop (176.1m)</th>
<th>Lost at 2 Foot Drop (175.8m)</th>
<th>Lost at 3 Foot Drop (175.5m)</th>
<th>Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpena Bay City</td>
<td>Alpena</td>
<td>252</td>
<td>252</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>243</td>
</tr>
<tr>
<td>176.4m</td>
<td>Bay City</td>
<td>835</td>
<td>835</td>
<td>20</td>
<td>76</td>
<td>216</td>
<td>619</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1087</strong></td>
<td><strong>1087</strong></td>
<td><strong>20</strong></td>
<td><strong>76</strong></td>
<td><strong>225</strong></td>
<td><strong>862</strong></td>
</tr>
<tr>
<td>% Of Total Slips</td>
<td></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>2%</strong></td>
<td><strong>7%</strong></td>
<td><strong>21%</strong></td>
<td><strong>79%</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Total Slips</th>
<th>Slips Measured</th>
<th>Lost at 1 Foot Drop (176.1m)</th>
<th>Lost at 2 Foot Drop (175.8m)</th>
<th>Lost at 3 Foot Drop (175.5m)</th>
<th>Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holland</td>
<td>Holland</td>
<td>2358</td>
<td>2358</td>
<td>56</td>
<td>135</td>
<td>461</td>
<td>1897</td>
</tr>
<tr>
<td>176.4m</td>
<td>Total</td>
<td>2358</td>
<td>2358</td>
<td>56</td>
<td>135</td>
<td>461</td>
<td>1897</td>
</tr>
<tr>
<td>% Of Total Slips</td>
<td></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>2%</strong></td>
<td><strong>6%</strong></td>
<td><strong>20%</strong></td>
<td><strong>80%</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Region</th>
<th>AOS</th>
<th>Total Slips</th>
<th>Slips Measured</th>
<th>Lost at 1 Foot Drop (174.1m)</th>
<th>Lost at 2 Foot Drop (173.8m)</th>
<th>Lost at 3 Foot Drop (173.5m)</th>
<th>Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toledo Sandusky</td>
<td>Toledo Sandusky</td>
<td>3006</td>
<td>304</td>
<td>0</td>
<td>4</td>
<td>29</td>
<td>2977</td>
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<td>2977</td>
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<td></td>
<td><strong>10%</strong></td>
<td><strong>0%</strong></td>
<td><strong>0%</strong></td>
<td><strong>0%</strong></td>
<td><strong>1%</strong></td>
<td><strong>99%</strong></td>
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<th>Slips Measured</th>
<th>Lost at 1 Foot Drop (183.1m;176.1m)</th>
<th>Lost at 2 Foot Drop (182.8m;175.8m)</th>
<th>Lost at 3 Foot Drop (182.5m;175.5m)</th>
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<td><strong>7%</strong></td>
<td><strong>12%</strong></td>
<td><strong>88%</strong></td>
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</table>

*Note these are cumulative totals*
4.1 Erie Region

In the Erie Region, physical depth measurements were taken at 25 marinas within the Port Colborne, Turkey Point, and Kingsville AOS. At these marinas, 84 percent of the slips were less than 2.7 meters in depth at the time that the measurements were taken. Figure 13 displays the number of slips that were measured.

![Erie Region: Slip Depths](image)

Figure 13: Slips under 2.7m in the Erie Region

The number of slips, in the Erie Region that would have a water level of less than 0.6 m, or two feet, after a theoretical drop of one foot (0.3m), two feet (0.6m) and three feet (0.9m) is displayed in Figure 14. These drops are subtracted from the 2009 average elevation of the months in which measurements were taken on Lake Erie: 174.4. The water level, at the time of measuring, fluctuated between 174.3 and 174.5 metres on Lake Erie. The individual marinas’ vulnerability to the water drop scenarios is displayed in Figure 15.

![Erie Region: Slip Loss at Scenarios](image)

Figure 14: Number of slips lost at the 3 scenarios of water level drops

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79 On the Great Lakes, water level and chart datum elevations are presently referenced to International Great Lakes Datum 1985 (http://www.waterlevels.gc.ca/english/VerticalDatums.shtml)
Figure 15: Slip losses at individual marinas, in the Erie Region, at the 3 scenarios of water level changes.
4.2 South Huron Region

In the South Huron Region, physical depth measurements were taken at nine marinas within the Port Huron and Goderich AOS. At these marinas, 65 percent of the slips were less than 2.7 meters in depth. Figure 16 displays the number of slips that were measured.

![Figure 16: Slips in the South Huron region under 2.7m](image)

The amount of slips, in the South Huron region that would have a water level of less than 0.6 m, or two feet, after a theoretical drop of one foot (0.3m), two feet (0.6m) and three feet (0.9m) is displayed in Figure 17 below. These drops are subtracted from the 2009 average elevation of the months in which measurements were taken on Lake Huron: 176.4. The water level, at the time of measuring in the South Huron region, fluctuated between 176.3 and 176.9 meters. The individual marinas’ vulnerability to the water drop scenarios is displayed in Figure 18.

![Figure 17: Number of slips lost at the 3 scenarios for water level drops](image)
Figure 18: Slip losses at individual marinas, in the Erie Region, at the 3 scenarios of water level changes
4.3 Georgian Bay Region

In the Georgian Bay Region, physical depth measurements were taken at 27 marinas within the Midland and Parry Sound AOS. At these marinas 53 percent of the slips were less than 2.7 meters in depth at the time that the measurements were taken. Figure 19 displays the number of slips that were measured.

![Georgian Bay Region: Slip Depths](image1)

**Figure 19: Slips in Georgian Bay region under 2.7m**

The number of slips in the Georgian Bay region that would have a water level of less than 0.6 m, or two feet, after a theoretical drop of one foot (0.3m), two feet (0.6m) and three feet (0.9m) is displayed in Figure 20. These drops are subtracted from the 2009 average elevation of the months in which measurements were taken on Lake Huron: 176.4. The water level, at the time of measuring, fluctuated between 176.3 and 176.5 metres in the Georgian Bay region. The individual marina’s vulnerability to the water drop scenarios is displayed in Figure 21.

![Georgian Bay Region: Slip Loss at Scenarios](image2)

**Figure 20: Number of slips lost at the 3 scenarios for water level drops in the Georgian Bay region**
Figure 21: Slip losses at individual marinas, in the Georgian Bay Region, at the 3 scenarios of water level changes.
4.4 North Channel Region

In the North Channel Region, physical depth measurements were taken at 23 marinas within the Little Current and Richard’s Landing AOS. At these marinas 86 percent of the slips were less than 2.7 meters in depth. Figure 22 displays the number of slips that were measured.

The number of slips in the North Channel Region that would have a water level of less than 0.6 m, or two feet, after a theoretical drop of one foot (0.3m), two feet (0.6m) and three feet (0.9m) is displayed in Figure 23. These drops are subtracted from the 2009 average elevation of the months in which measurements were taken on Lake Huron: 176.4. The water level, at the time of measuring, fluctuated between 176.0 and 176.5 metres in the North Channel Region. The individual marinas’ vulnerability to the water drop scenarios is displayed in Figure 24.
Figure 24: Slip losses at individual marinas, in the North Channel Region, at the 3 scenarios of water level changes
4.5 Superior Region

In the Superior Region, physical depth measurements were taken at three marinas within the Thunder Bay AOS. At these marinas 37 percent of the slips were less than 2.7 meters in depth at the time of the measurements. Figure 25 displays the number of slips that were measured. Given the small sample size, these results are most likely less conclusive than the results for other regions.

The number of slips in the Superior Region that would have a water level of less than 0.6 m, or two feet, after a theoretical drop of one foot (0.3m), two feet (0.6m) and three feet (0.9m) is displayed in Figure 26. These drops are subtracted from the 2009 average elevation of the months in which measurements were taken on Lake Superior: 183.4m. The water level remained at this elevation during the measurements. The individual marinas’ vulnerability to the water drop scenarios is displayed in Figure 27.
Figure 27: Slip losses at individual marinas, in the Superior Region, at the 3 scenarios of water level changes
4.6 Toledo/Sandusky Region

In the Toledo/Sandusky Region, physical depth measurements were taken at 10 marinas within the Toledo/Sandusky AOS. At these marinas, 7% of the slips were less than 2.7 meters in depth at the time that the measurements were taken (Figure 28). Out of a total of 3006 slips, 304 were measured.

![Toledo Sandusky AOS: Slip Depths](image)

Figure 28: Slips under 2.7m in the Toledo/Sandusky Region

The number of slips, in the Toledo/Sandusky Region that would have a water level of less than 0.6 m, or two feet, after a theoretical drop of one foot (0.3m), two feet (0.6m) and three feet (0.9m) is displayed in Figure 29. These drops are subtracted from the 2009 average elevation of the months in which measurements were taken on Lake Erie: 174.4. The water level, at the time of measuring, was 173.8 meters on Lake Erie\(^8^0\). The individual marinas' vulnerability to the water drop scenarios is displayed in Figure 30. It should be noted however, that in the process of recording depth measurements, field researchers observed that a significant proportion of the marinas were vulnerable to shallow access channels despite the fact that most of their slips remained deep enough to dock boats given the drop scenarios. In many cases, a ‘bottleneck’ effect could prevent access to the marinas given a two (0.6m) or three foot (0.9m) drop in the water level; which would be equivalent to a 100% slip loss.

![Toledo Sandusky AOS Slip Loss](image)

Figure 29: Number of slips lost at the 3 scenarios of water level drops

Figure 30: Slip losses at individual marinas, in the Toledo/Sandusky Region, at the 3 scenarios of water level changes
### 4.7 Alpena/Bay City Region

In the Alpena/Bay City Region, physical depth measurements were completed at nine marinas within the Alpena and Bay City AOS’s. At these marinas, 71 percent of the slips were less than 2.7 meters in depth. Figure 31 displays the number of slips that were measured.

![Figure 31: Slips in the Alpena/Bay City region under 2.7m](image)

The amount of slips, in the Alpena/Bay City region that would have a water level of less than 0.6 m, or two feet, after a theoretical drop of one foot (0.3m), two feet (0.6m) and three feet (0.9m) is displayed in Figure 32 below. These drops are subtracted from the 2009 average elevation of the months in which measurements were taken on Lake Huron: 176.4m. The water level, at the time of measuring in the Alpena/Bay City region, fluctuated between 176.2 and 176.3 meters. The individual marinas’ vulnerability to the water drop scenarios is displayed in Figure 33. It should be noted that five of the seven operators who completed questionnaires indicated that their marinas would have insufficient access channel depth given the three foot (0.6m) drop scenario. In many cases, insufficient access channel depth creates a ‘bottleneck’ effect; preventing access to 100% of a given marina’s slips. Readers should keep in mind that these slip losses are not reflected in figures 32 and 33.

![Figure 32: Number of slips lost at the 3 scenarios for water level drops](image)
Figure 33: Slip losses at individual marinas, in the Alpena/Bay City region, at the 3 scenarios of water level changes
4.8 Holland Region

In the Holland Region, physical depth measurements were taken at fourteen marinas within the Holland AOS. At these marinas 73% of the slips were less than 2.7 meters in depth at the time that the measurements were taken. Figure 34 displays the number of slips that were measured.

![Holland AOS: Slip Depths](image)

**Figure 34: Slips in Holland region under 2.7m**

The number of slips in the Holland region that would have a water level of less than 0.6 m, or two feet, after a theoretical drop of one foot (0.3m), two feet (0.6m) and three feet (0.9m) is displayed in Figure 35. These drops are subtracted from the 2009 average elevation during May through August 2009 on Lake Michigan/Huron: 176.4m. The water level, at the time of measuring, fluctuated between 176.3 and 176.5 meters in the Holland region. The individual marina’s vulnerability to the water drop scenarios is displayed in Figure 36. It should be noted that 27% of the 15 operators who completed questionnaires indicated that their marinas would have insufficient access channel depth given the two foot (0.6m) drop scenario. Given a three foot (0.9m) drop, this proportion would grow to 60%. In many cases, insufficient access channel depth creates a ‘bottleneck’ effect; preventing access to 100% of a given marina’s slips. Readers should keep in mind that these slip losses are not reflected in figures 35 and 36.

![Holland AOS Slip Loss](image)

**Figure 35: Number of slips lost at the 3 scenarios for water level drops in the Holland region**
Figure 36: Slip losses at individual marinas, in the Holland Region, at the 3 scenarios of water level changes.
4.9 North U.S. Region

In the North U.S. Region, physical depth measurements were taken at six marinas within the Baraga, Ontonagon, and Menominee AOS. At these marinas, 78 percent of the slips were less than 2.7 meters in depth. Figure 37 displays the number of slips that were measured.

![North U.S. Region: Slip Depths](image)

Figure 37: Slips under 2.7m in the North U.S. region

The number of slips in the North U.S. Region that would have a water level of less than 0.6 m, or two feet, after a theoretical drop of one foot (0.3m), two feet (0.6m) and three feet (0.9m) is displayed in Figure 38. These drops are subtracted from the 2009 average elevation during May through August on Lake Michigan/Huron (Menominee AOS): 176.4m; and during August on Lake Superior (Baraga and Ontonagon AOS); 183.4m. The water level, at the times of measuring was 176.18m on Lake Michigan/Huron, and 183.13m on Lake Superior. The individual marinas’ vulnerability to the water drop scenarios is displayed in Figure 39. Note that slip losses would only occur at two of the seven marinas (within the Baraga and Ontonagon AOS). It should be noted that two of the six operators who completed questionnaires indicated that their marinas would have insufficient access channel depth given the three foot (0.9m) drop scenario. These two marinas are located in the Baraga AOS. In some cases, insufficient access channel depth creates a ‘bottleneck’ effect; preventing access to 100% of a given marina’s slips. Readers should keep in mind that these slip losses are not reflected in figures 38 and 39.
Figure 38: Number of slips lost at the 3 scenarios for water level drops in the North U.S. Region
Figure 39: Slip losses at individual marinas, in the North U.S. Region, at the 3 scenarios of water level changes.
Physical Measurements Conclusion

The two most southern Canadian regions (Erie and South Huron), along with two of the U.S. regions on Lakes Michigan and Huron (Holland and Alpena/Bay City) are more vulnerable to slip losses given the water level drop scenarios than the five other regions (The Canadian regions of Georgian Bay, North Channel, and Superior; and the U.S. regions of Toledo/Sandusky and North U.S.).

Given the three foot (0.9m) drop scenario from the appropriate average water level elevation, the U.S. regions of Alpena/Bay City and Holland suffer significantly worse slip losses than the North U.S. and Toledo/Sandusky regions (21% and 20% vs. 12% and 1%, respectively). On the Canadian side, the Erie and South Huron regions suffer significantly worse slip losses than the Georgian Bay, North Channel, and Superior regions (31% and 25% vs. 16%, 15% and 5%, respectively).

All nine of the U.S. and Canadian regions experience a threshold increase in slip losses between the two and three foot drop scenarios (175.8m-175.5m on Lake Michigan/Huron; 173.8m-173.5m on Lake Erie; and 182.8m-182.5m on Lake Superior). On the U.S. side, the percentage increase in losses across this threshold is larger for the Alpena/Bay City and Holland regions (14%), than the North U.S. and Toledo/Sandusky regions (5% and 1% respectively). On the Canadian side, the percentage increase is larger for the Erie and South Huron regions (20% and 19%) than the Georgian Bay, North Channel and Superior regions (9%, 9%, and 3%).

On Lake Erie, slip losses under the three foot (0.9m) drop scenario are highest in the Turkey Point AOS (36%), followed by the Kingsville AOS (29%), the Port Colborne AOS (19%), and the Toledo/Sandusky AOS (1%).

On Lake Michigan/Huron, slip losses under the three foot (0.9m) drop scenario are highest in the South Huron AOS (31%), followed by the Bay City AOS (26%), the Holland AOS (20%), the Little Current AOS (19%), the Midland AOS (17%), the Parry Sound AOS (14%), the Goderich and Richard’s Landing AOS’s (11%), the Menominee AOS (6%), and the Alpena AOS (4%).

On Lake Superior, slip losses under the three foot (0.9m) drop scenario are highest in the Baraga AOS (51%), followed by the Thunder Bay AOS (5%), and the Ontonagon AOS (0%).

The marinas in the Toledo/Sandusky region suffer almost no slip losses (1%). However, in the process of recording depth measurements there, field researchers observed that a significant proportion of the marinas were vulnerable to shallow access channels despite the fact that most of their slips remained deep enough to dock boats given the drop scenarios. In many cases, a ‘bottleneck’ effect could prevent access to the marinas given a significant drop in the water level; which could render 100% of their slips unusable. Similar vulnerabilities exist within the Holland, Alpena, Bay City, Baraga, and Turkey Point AOS; but affect smaller proportions of the marinas than in the Toledo/Sandusky AOS.
Economic Analysis

Fluctuating water levels affect marinas’ ability to operate and in turn affect their finances. To estimate the magnitude of this economic loss, a combination of the questionnaire responses and the physical data were used. Each AOS had an economic loss value estimated for the three water level drop scenarios. These scenarios use the same water levels that were described earlier in the report as the base condition. The starting elevation was 174.4m for Lake Erie, 176.4m for all Lake Huron and 183.4m for all Lake Superior. From these starting elevations, three water level drops of one-foot (0.3m) intervals were applied. The estimated economic loss experienced by the marinas under each scenario is comprised of three components: damages, adaptations and lost slip revenue. Each component will be introduced individually and later merged to give an overall estimate. When each component is introduced, the assumptions and limitations of the component’s estimations will be highlighted and discussed. The goal of this exercise is to create an estimate of the overall magnitude of economic loss at each water level scenario for the marinas surveyed. As losses will be aggregated some accuracy will be lost. Also, these estimates were completed only for marinas that were surveyed and are therefore not necessarily representative of the industry as a whole.

Adaptation and Damages Cost Estimates

When water levels fluctuate, damage to equipment and infrastructure often results. Costs are incurred by these damages in the form of lost future revenues, capital losses, and repairs. As marina operators cannot control fluctuations in the water level, they must attempt to avoid related damages by undertaking adaptations; which also incur costs.

In this section we look at cost estimates that were described in the operators’ accounts of both historical and hypothetical damages and adaptations that had resulted in the past, or would hypothetically result in the future, from fluctuations in the water level.  

Although the aim is to construct an economic valuation of these consequences, neither data set reflects the full extent of the damages, or the complex relationship between water level impacts and business decisions that would actually take place in the real world. The information obtained from the interviews with marina operators is noisy, complicated, and often inconsistent. For example, many of the operators did report specific damages and adaptations without accompanying cost estimates (Tables 1 and 2). Some operators also explained that they would be able to reduce costs by using in-house labor and equipment rather than hiring a contractor, or by accommodating smaller boats than they normally would. These efficiencies may not be fully reflected in the response data. In addition, many of the

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81 During the interviews, operators were asked to recount their past experience with fluctuating water levels under plan 1977A (3.0 Performance Indicator 1- Past Experience with Water Levels, historical damages and adaptations, in the main body of the report), as well as a series of ‘what if?’ questions related to six hypothetical scenarios of one foot, two foot and three feet intervals of drops and rises of the water level. They were also asked to provide cost estimates for these damages and adaptations when possible (4.0 Performance Indicator 2 -Adaptive Capacity and Threshold Vulnerabilities).

82 For example, some operators predicted that their marinas would become unable to accommodate certain boat sizes and types (See the main report), but were unable to estimate the associated monetary impact on sales or revenue.
operators said that they would go out of business after considering the three foot drop scenario (-0.9m). After this point in the interview, these operators were less likely to report further hypothetical damages and adaptations; perhaps because such details were considered irrelevant in light of the idea of going out of business. In any case, all of the factors described above contribute to the uncertainty involved in estimating an accurate valuation of the impacts that would likely result from hypothetical changes in the water level.

**Sample Description**
The damages and adaptations that were reported with costs by the Canadian operators are in 2009 constant Canadian dollars. To be comparable, the historical expenditures that these operators reported were adjusted for inflation to 2009 constant Canadian dollars as well, using the Bank of Canada’s online inflation calculator (http://www.bankofcanada.ca/en/rates/inflation_calc.html). Likewise, the damages and adaptations reported with costs by the U.S. operators were adjusted for inflation to 2009 U.S. dollars, and then converted to 2009 Canadian dollars using the Bank of Canada’s average exchange rate for 2009: $1USD=$1.14187729 CAD (http://www.bankofcanada.ca/pdf/nraa09.pdf).

In the operators’ responses to the drop scenarios, monetary cost estimates are missing for 92% of the damages reported by Canadian operators, and for 100% of those reported by U.S. operators (Table 50)). Costs are also missing for 66% of the adaptations reported by Canadian operators, and for 90% of those reported by U.S. operators (Table 50). Response rates for the rise scenarios are even worse (Table 51). As a result, the numerical sum of these estimates does a poor job of representing the costs that would be likely to accumulate as we move across the hypothetical scenarios (A complete listing of the cost estimates provided in the responses to the six scenarios are summarized in the section ‘operator response tables’ in the appendix).
### Table 50 Hypothetical drop scenarios response sample description

<table>
<thead>
<tr>
<th>CAN response</th>
<th>Operators interviewed</th>
<th>Operators that reported damages</th>
<th>Total Damages Reported</th>
<th>Damages Reported with Cost</th>
<th>Operators that reported adaptations</th>
<th>Total Adaptations Reported</th>
<th>Adaptations Reported with cost</th>
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### Table 51 Hypothetical rise scenarios response sample description

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<th>Operators interviewed</th>
<th>Operators that reported damages</th>
<th>Total Damages Reported</th>
<th>Damages Reported with Cost</th>
<th>Operators that reported adaptations</th>
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<th>Total Damages Reported</th>
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</table>
First-Round Imputations: Average dredging and dock modification cost estimates

To generate figures that can do a better job at conveying a representative monetary valuation of the response data, we can impute average costs for the two most common adaptations found in our response data that were accompanied by cost estimates: dredging and dock modifications. Shown in tables 52 and 54, these average cost estimates were obtained from both the historical and hypothetical Canadian response data.

Although very few cost estimates were obtained from the U.S. hypothetical responses, a substantial amount of dredging and dock modification costs were reported in the historical responses. After the first round imputation was performed on the Canadian Data using the average cost estimates shown in tables 53 and 55, the additional U.S. costs reported were added to the Canadian data in order to generate new average cost estimates to be used in a first round imputation on the U.S. data. Note that the average cost for dock modifications is significantly higher once the U.S. historical costs are added (Table 54 vs. Table 55).

Median dredging and dock modification costs were constructed from a combination of both a) the cost estimates found in the responses to the three hypothetical drop scenarios, and b) the marina operators’ accounts of their past expenditures that had been undertaken in response to historical drops in the water levels (Tables 3 and 4). Hypothetical and historical cost estimates for dredging were sorted according to the following size categories (<100 slips, 100 to 200 slips, 201 to 400 slips, and >400 slips) (Table 30), while those for dock modifications were not (Table 31).
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<tr>
<td>Hypothetical CAN</td>
<td>$5,000 TP</td>
<td>$100,000 PC</td>
<td>$75,000 TP</td>
<td>$50,000 TP</td>
</tr>
<tr>
<td>Historical CAN</td>
<td>$5,000 GOD</td>
<td>$100,000 GOD</td>
<td>$20,000 PS</td>
<td>$111,000 TP</td>
</tr>
<tr>
<td></td>
<td>$100,000 PS</td>
<td>$80,000 MID</td>
<td>$90,000 TP</td>
<td>$106,000 MID</td>
</tr>
<tr>
<td></td>
<td>$13,000 GOD</td>
<td>$154,000 PC</td>
<td>$122,000 MID</td>
<td>$111,333</td>
</tr>
<tr>
<td></td>
<td>$5,000 MID</td>
<td>$107,000 KV</td>
<td>$18,000</td>
<td>$18,000</td>
</tr>
<tr>
<td></td>
<td>$122,000 PS</td>
<td>$72,000 MID</td>
<td>$56,000 LC</td>
<td>$111,333</td>
</tr>
<tr>
<td></td>
<td>$60,000 LC</td>
<td>$143,000 PS</td>
<td>$5,000 LC</td>
<td>$143,000 PS</td>
</tr>
<tr>
<td></td>
<td>$35,000 RL</td>
<td>$100,000</td>
<td>$137,500</td>
<td>$108,500</td>
</tr>
</tbody>
</table>

Max | $155,000 | $250,000 | $250,000 | $200,000 |
Min | $1,000 | $40,000 | $20,000 | $18,000 |
Average | $44,474 | $101,222 | $140,250 | $111,333 |
Median | $25,000 | $100,000 | $137,500 | $108,500 |
Table 53: Average hypothetical and historical dredging costs used for U.S. data

<table>
<thead>
<tr>
<th>U.S. Dredging</th>
<th>marina size: &lt;100 slips</th>
<th>100-200 slips</th>
<th>201-400 slips</th>
<th>&gt;400 slips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothetical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAN</td>
<td>$5,000 TP</td>
<td>$100,000 PC</td>
<td>$75,000 TP</td>
<td>$50,000 TP</td>
</tr>
<tr>
<td>Historical</td>
<td>$5,000 GOD</td>
<td>$100,000 GOD</td>
<td>$20,000 PS</td>
<td>$18,000 TP</td>
</tr>
<tr>
<td>CAN</td>
<td>$100,000 PS</td>
<td>$80,000 MID</td>
<td>$90,000 TP</td>
<td>$111,000 TP</td>
</tr>
<tr>
<td>Hypothetical</td>
<td>$6,000 TP</td>
<td>$100,000 PS</td>
<td>$153,000 TP</td>
<td>$183,000 TP</td>
</tr>
<tr>
<td>U.S.</td>
<td>$16,000 KV</td>
<td>$80,000 PS</td>
<td>$238,000 GOD</td>
<td>$106,000 MID</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$71,000 KV</td>
<td>$45,000 LC</td>
<td>$174,000 MID</td>
<td>$204,277 HL</td>
</tr>
<tr>
<td></td>
<td>$13,000 GOD</td>
<td>$154,000 PC</td>
<td>$122,000 MID</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$155,000 MID</td>
<td>$107,000 KV</td>
<td>$39,969 HL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$49,000 MID</td>
<td>$46,000 PH</td>
<td>$680,924 BC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$21,000 MID</td>
<td>$40,000 GOD</td>
<td>$40,855 HL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$122,000 PS</td>
<td>$72,000 MID</td>
<td>$147,057 HL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$1,000 PS</td>
<td>$122,000 MID</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$56,000 LC</td>
<td>$63,000 PS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$60,000 LC</td>
<td>$143,000 PS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$5,000 LC</td>
<td>$111,000 PS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$95,000 RL</td>
<td>$106,000 LC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$35,000 RL</td>
<td>$34,259 HL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$57,099 HL</td>
<td>$228,395 HL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$57,099 HL</td>
<td>$11,420 HL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$5,710 BA</td>
<td>$47,264 AL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$284,549 TS</td>
<td>$11,379 HL</td>
<td></td>
<td>$204,277 HL</td>
</tr>
<tr>
<td></td>
<td>$24,305 HL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$236,321 HL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$2,954 BA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Max          | $284,549               | $250,000      | $680,924      | $204,277   |
Min          | $1,000                 | $11,379       | $20,000       | $18,000    |
Average      | $58,194                | $93,683       | $159,730      | $124,611   |
Median       | $30,000                | $100,000      | $122,000      | $111,000   |
### Table 54: Average hypothetical and historical dock modification costs used for Canadian data

<table>
<thead>
<tr>
<th>Dock Modifications</th>
<th>Cost Estimates ($)</th>
<th>AOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothetical CAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$66,000</td>
<td>LC</td>
</tr>
<tr>
<td></td>
<td>$20,000</td>
<td>RL</td>
</tr>
<tr>
<td></td>
<td>$30,000</td>
<td>MID</td>
</tr>
<tr>
<td>Historical CAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$5,000</td>
<td>MID</td>
</tr>
<tr>
<td></td>
<td>$3,000</td>
<td>RL</td>
</tr>
<tr>
<td></td>
<td>$31,000</td>
<td>MID</td>
</tr>
<tr>
<td></td>
<td>$12,000</td>
<td>TP</td>
</tr>
<tr>
<td></td>
<td>$6,000</td>
<td>MID</td>
</tr>
<tr>
<td></td>
<td>$106,000</td>
<td>MID</td>
</tr>
</tbody>
</table>

|                | Max                | $106,000 |
|                | Min                | $3,000   |
| Average        | $31,000            |
| Median         | $20,000            |

### Table 55: Average hypothetical and historical dock modification costs used for U.S. data

<table>
<thead>
<tr>
<th>Dock Modifications U.S.</th>
<th>Cost Estimates</th>
<th>AOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothetical CAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$66,000</td>
<td>LC</td>
</tr>
<tr>
<td></td>
<td>$20,000</td>
<td>RL</td>
</tr>
<tr>
<td></td>
<td>$30,000</td>
<td>MID</td>
</tr>
<tr>
<td>Historical CAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$5,000</td>
<td>MID</td>
</tr>
<tr>
<td></td>
<td>$3,000</td>
<td>RL</td>
</tr>
<tr>
<td></td>
<td>$31,000</td>
<td>MID</td>
</tr>
<tr>
<td></td>
<td>$12,000</td>
<td>TP</td>
</tr>
<tr>
<td></td>
<td>$6,000</td>
<td>MID</td>
</tr>
<tr>
<td></td>
<td>$106,000</td>
<td>MID</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$15,361</td>
<td>BC</td>
</tr>
<tr>
<td></td>
<td>$136,185</td>
<td>BC</td>
</tr>
<tr>
<td></td>
<td>$940,846</td>
<td>HL</td>
</tr>
<tr>
<td></td>
<td>$1,772</td>
<td>HL</td>
</tr>
<tr>
<td></td>
<td>$94,528</td>
<td>HL</td>
</tr>
<tr>
<td></td>
<td>$3,545</td>
<td>HL</td>
</tr>
<tr>
<td></td>
<td>$3,545</td>
<td>HL</td>
</tr>
<tr>
<td></td>
<td>$2,845</td>
<td>HL</td>
</tr>
<tr>
<td></td>
<td>$57,099</td>
<td>HL</td>
</tr>
<tr>
<td></td>
<td>$25,432</td>
<td>HL</td>
</tr>
<tr>
<td></td>
<td>$6,706</td>
<td>HL</td>
</tr>
<tr>
<td></td>
<td>$4,726</td>
<td>BA</td>
</tr>
<tr>
<td></td>
<td>$341,374</td>
<td>ME</td>
</tr>
</tbody>
</table>

|                | Max                | $940,846 |
|                | Min                | $1,772   |
| Average        | $86,953            |
| Median         | $17,680            |
Tables 56, 57, and 58 show the Lake-wide cost estimate totals by AOS for the drop scenarios including these first-round imputations: the average dredging and dock modification estimates imputed in place for those dredging and dock modifications that were reported without accompanying cost values\(^8\). The cost estimate totals for the rise scenarios are not discussed due to the lack of information.

As Table 56 shows, Lake Erie would experience a threshold increase in costs of about 78% (~$575,000 to ~$625,000), if the water level were to drop from one foot (174.1m) to two feet (173.8m) below the average water level elevation for June and July 2009 (174.4m). If the water level were to drop another foot (0.3m) to the 173.5m elevation, they would suffer an increase in costs of about 10% ($132,000).

**Table 56 Lake Erie cost estimate totals by AOS for drop scenarios, with imputed average dredging and dock modification costs**

<table>
<thead>
<tr>
<th></th>
<th>One Foot Drop (174.1m)</th>
<th>Two Foot Drop (173.8m)</th>
<th>Three Foot Drop (173.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOS</td>
<td>Cost Range ($)</td>
<td>Cost Range ($)</td>
<td>Cost Range ($)</td>
</tr>
<tr>
<td>Port Colborne</td>
<td>$101,222</td>
<td>$352,444 to $402,444</td>
<td>$352,444 to $402,444</td>
</tr>
<tr>
<td>Turkey Point</td>
<td>$340,250</td>
<td>$531,583</td>
<td>$531,583</td>
</tr>
<tr>
<td>Kingsville</td>
<td>$44,474</td>
<td>$176,696</td>
<td>$308,918</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>$284,341</td>
<td>$284,341</td>
<td>$284,341</td>
</tr>
<tr>
<td>Lake Erie</td>
<td>$770,286</td>
<td>$1,345,064 to $1,395,064</td>
<td>$1,477,286 to $1,527,286</td>
</tr>
</tbody>
</table>

Similarly, Lake Huron would experience a threshold increase in costs of ~147% (~$2,330,000) if the water level were to drop from one foot (176.1m) to two feet (175.8m) below the average water level elevation for June and July 2009 (176.4m) (Table 57).

**Table 57 Lake Huron cost estimate totals by AOS for drop scenarios, with imputed average dredging and dock modification costs**

<table>
<thead>
<tr>
<th></th>
<th>One Foot Drop (176.1m)</th>
<th>Two Foot Drop (175.8m)</th>
<th>Three Foot Drop (175.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOS</td>
<td>Cost Range ($)</td>
<td>Cost Range ($)</td>
<td>Cost Range ($)</td>
</tr>
<tr>
<td>Port Huron</td>
<td>n/a</td>
<td>n/a</td>
<td>$651,222</td>
</tr>
<tr>
<td>Goderich</td>
<td>$55,000 to $80,000</td>
<td>$161,000</td>
<td>$161,000</td>
</tr>
<tr>
<td>Midland</td>
<td>$244,522</td>
<td>$736,022</td>
<td>$890,246</td>
</tr>
<tr>
<td>Parry Sound</td>
<td>n/a</td>
<td>$186,474</td>
<td>$393,000</td>
</tr>
<tr>
<td>Little Current</td>
<td>$251,696 to $261,696</td>
<td>627,170 to 637,170</td>
<td>671,643 to 681,643</td>
</tr>
<tr>
<td>Richards Landing</td>
<td>$31,000</td>
<td>$183,222</td>
<td>$334,170</td>
</tr>
<tr>
<td>Alpena</td>
<td>$0</td>
<td>$0</td>
<td>$93,683</td>
</tr>
<tr>
<td>Bay City</td>
<td>$0</td>
<td>$333,635</td>
<td>$842,223</td>
</tr>
<tr>
<td>Holland</td>
<td>$983,666</td>
<td>$1,523,742</td>
<td>$1,664,631</td>
</tr>
<tr>
<td>Menominee</td>
<td>$0</td>
<td>$159,730</td>
<td>$159,730</td>
</tr>
<tr>
<td>Lake Michigan/Huron</td>
<td>$1,565,884 to $1,600,884</td>
<td>$3,910,995 to $3,920,995</td>
<td>$5,871,548 to $5,861,548</td>
</tr>
</tbody>
</table>

\(^8\) Those responses that had been reported without accompanying cost estimates are denoted by ‘n/a’ under the ‘Cost range’ columns in the ‘Economic Analysis Operator Response Tables’ in the Appendices.
If the water level were to drop another foot (0.3m) to the 175.5m elevation, they would suffer an increase in costs of about 50% (~$1,950,553).

On Lake Superior, the Baraga and Ontonagon AOS’s would experience an increase in costs of $237,809 if the water level were to drop from one foot (183.1m) to two feet (182.8m) below the average water level elevation for August 2009 (183.4m) (from zero losses at a the 183.1m elevation) (Table 58). If the water level were to drop another foot (0.3m) to the 182.5m elevation, only the Baraga AOS would suffer an increase in costs of about 61% ($145,147).

Table 58 Lake Superior cost estimate totals by AOS for drop scenarios, with imputed average dredging and dock modification costs

<table>
<thead>
<tr>
<th>AOS</th>
<th>One Foot Drop (183.1m) Cost Range ($)</th>
<th>Two Foot Drop (182.8m) Cost Range ($)</th>
<th>Three Foot Drop (182.5m) Cost Range ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thunder Bay</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Baraga</td>
<td>$0</td>
<td>$179,616</td>
<td>$324,762</td>
</tr>
<tr>
<td>Ontonagon</td>
<td>$0</td>
<td>$58,194</td>
<td>$58,194</td>
</tr>
<tr>
<td>Lake Superior</td>
<td>$0</td>
<td>$237,809</td>
<td>$382,956</td>
</tr>
</tbody>
</table>

**Estimating the magnitude of the undervaluation: Second-Round Imputations**

Despite the first-round imputations of average costs for dredging and dock modifications, the lake-wide cost estimate totals shown in Tables 56, 57, and 58 still fail to include costs for 90% of the damages reported by Canadian operators; 100% of the damages reported by U.S. operators; 12% of the adaptations reported by Canadian operators; and 34% of the adaptations reported by U.S. operators. As a result, they likely undervalue the economic impact of the damages and adaptations that were reported in response to the three drop scenarios.

To get an idea of the magnitude of this undervaluation, a second set of average costs can be imputed for most of these remaining damages and adaptations that are still missing values. Although some of the remaining damages and adaptations were accompanied by cost estimates, there were not enough to create average estimates with comparable certainty to those that were created for dredging and dock modifications. Despite this setback, imputing these responses with average cost estimates derived from the small proportion that did provide cost estimates can at least provide a rough idea of the magnitude of the undervaluation.

---

85 The cost estimates summarized in Table ??? do not include both the following damages: dock, breakwall, launch ramp, walkways, increased weed growth, reduced demand for winter storage, and accelerated shoreline erosion, or and the following adaptations: installing floating docks, extending docks, extending launch ramp, and repairing seawalls.
A small proportion of the responses did provide cost estimates for damage to docks, increased weed growth, seawall repair, launch ramp repair, dock extension, and the installation of floating docks; summarized in Table 59\textsuperscript{86}.

<table>
<thead>
<tr>
<th>Damage/Adaptation</th>
<th>Cost range ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dock Damage</td>
<td>2,000</td>
</tr>
<tr>
<td>Increased weed growth</td>
<td>1,300</td>
</tr>
<tr>
<td>Seawall repair</td>
<td>50,000 to 300,000</td>
</tr>
<tr>
<td>Launch Ramp repair</td>
<td>50,000 to 100,000</td>
</tr>
<tr>
<td>Extend Docks/Install floating docks</td>
<td>50,000 to 200,000</td>
</tr>
</tbody>
</table>

When the set of costs shown in Table 59 are imputed for the missing monetary values that were not included in the first round valuations, increases occur in the cost estimate totals per scenario. These increases range from 4\% to 71\% on Lake Erie; 9\% to 108\% on Lake Huron; and 44\% to 289\% on Lake Superior (Tables 60, 61, and 62). It should be noted that even after the second round imputations, these percentage increases in costs per scenario still fail to include valuations for 50\% of the damages, and 8\% of the adaptations reported by U.S. operators, as well as 19\% of the damages reported by Canadian operators.

<table>
<thead>
<tr>
<th>Lake Erie</th>
<th>One Foot Drop (174.1m)</th>
<th>Two Foot Drop (173.8m)</th>
<th>Three Foot Drop (173.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% increase</td>
<td>13% to 26%</td>
<td>4% to 34%</td>
<td>10% to 71%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lake Huron</th>
<th>One Foot Drop (176.1m)</th>
<th>Two Foot Drop (175.8m)</th>
<th>Three Foot Drop (175.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% increase</td>
<td>9% to 48%</td>
<td>23% to 34%</td>
<td>27% to 108%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lake Superior</th>
<th>One Foot Drop (183.1m)</th>
<th>Two Foot Drop (182.8m)</th>
<th>Three Foot Drop (182.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% increase</td>
<td>n/a</td>
<td>44% to 170%</td>
<td>68% to 289%</td>
</tr>
</tbody>
</table>

Although this second round of imputations introduces significant uncertainty, they do show that the first round cost estimates likely undervalue the economic significance of the total damages and adaptations reported by a significant margin.

Slip Revenue Lost

The final component to be added to the overall economic impact analysis is the lost dockage fees when slips become unusable at the three water drop scenarios. Two different estimates of this economic loss were created. The first estimate is based on the physical measurements, which counts a given slip as unusable when it has less than two feet (0.6m) of water depth. The second estimate is derived from the questionnaire data, where marina operators estimated the number of slips they would lose given each of the hypothetical drop scenario.

To obtain an estimate of the economic value associated with slips lost due to a drop in the water level, two values are required. The first is the dockage fee per foot for the lost slip; the second is the size of boat that was going to occupy the lost slip. However, not every marina provided a breakdown of their slip sizes, or a reliable estimate of the size of the boats to which they cater. Because we could not find the per foot dockage fee of the specific slips that would be lost, an average price was calculated for each region. Also we did not know what size of boat would be displaced when the slip became unusable, therefore another average was created. The use of these averages is at best an approximation of revenue lost.

Table 63 shows the slip rental revenue lost at the three different water level drop scenarios in each Canadian AOS; while Table 64 shows those in the U.S. AOS. Only one season of damages is listed as slips lost may be restored by future dredging. The restored slips would then return to providing rental income. The first estimate is based on the physical measurements, which counts a slip as unusable when it has less than two feet (0.6m) of water after being subjected to the new water level elevation. The second estimate refers to slip loss based on the marina operators’ survey responses with respect to the three different drop scenarios. Both slip loss estimates are then multiplied by the same estimates of seasonal slip rental revenue for each AOS. The amount of lost slips at each water level scenario and at each marina was multiplied by the average rental revenue generated per slip in the AOS. The economic impact of the water level changes for each marina in an AOS was totaled. These water level scenarios are identical to the scenarios used in the main report.

It is difficult to extrapolate from these numbers to the complete Great Lakes marina industry, as the true population of marinas for each lake is not known. Also, it is difficult to compare the results from one region against another as some regions have been more thoroughly surveyed than others.

On the Canadian side, both the physical depth measurements and the marina operator responses provide almost identical cost values (Table 63), whereas on the American side, the operators’ responses overestimate the physical depth measurements (Table 64).
Table 63: Canada: Overall economic loss from lost slips due at 3 water level drop scenarios

<table>
<thead>
<tr>
<th>AOS by Region</th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Physical Depth Measurement Slip Loss Valuations</td>
<td>Operators’ Responses Slip Loss Valuations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 Foot Drop</td>
<td>2 Foot Drop</td>
<td>3 Foot Drop</td>
<td>1 Foot Drop</td>
<td>2 Foot Drop</td>
<td>3 Foot Drop</td>
</tr>
<tr>
<td>Erie Region Total</td>
<td>$181,080</td>
<td>$571,520</td>
<td>$1,658,580</td>
<td>$15,400</td>
<td>$231,680</td>
<td>$1,542,500</td>
</tr>
<tr>
<td>Turkey Point</td>
<td>$105,600</td>
<td>$353,100</td>
<td>$1,023,000</td>
<td>$15,400</td>
<td>$196,900</td>
<td>$264,000</td>
</tr>
<tr>
<td>Kingsville</td>
<td>$69,600</td>
<td>$170,400</td>
<td>$468,000</td>
<td>$0</td>
<td>$24,000</td>
<td>$960,000</td>
</tr>
<tr>
<td>Port Colborne</td>
<td>$5,880</td>
<td>$48,020</td>
<td>$167,580</td>
<td>$0</td>
<td>$10,780</td>
<td>$318,500</td>
</tr>
<tr>
<td>South Huron Total</td>
<td>$79,680</td>
<td>$230,760</td>
<td>$942,960</td>
<td>$179,520</td>
<td>$364,920</td>
<td>$706,080</td>
</tr>
<tr>
<td>Port Huron</td>
<td>$72,000</td>
<td>$196,200</td>
<td>$802,800</td>
<td>$158,400</td>
<td>$315,000</td>
<td>$583,200</td>
</tr>
<tr>
<td>Goderich</td>
<td>$7,680</td>
<td>$34,560</td>
<td>$140,160</td>
<td>$21,120</td>
<td>$49,920</td>
<td>$122,880</td>
</tr>
<tr>
<td>Georgian Bay Total</td>
<td>$341,910</td>
<td>$1,035,450</td>
<td>$2,378,430</td>
<td>$276,300</td>
<td>$830,160</td>
<td>$2,377,890</td>
</tr>
<tr>
<td>Midland</td>
<td>$242,730</td>
<td>$717,030</td>
<td>$1,791,180</td>
<td>$75,330</td>
<td>$407,340</td>
<td>$1,701,900</td>
</tr>
<tr>
<td>Parry Sound</td>
<td>$99,180</td>
<td>$318,420</td>
<td>$587,250</td>
<td>$200,970</td>
<td>$422,820</td>
<td>$675,990</td>
</tr>
<tr>
<td>North Channel Total</td>
<td>$25,494</td>
<td>$76,538</td>
<td>$189,462</td>
<td>$98,952</td>
<td>$204,064</td>
<td>$411,880</td>
</tr>
<tr>
<td>Little Current</td>
<td>$18,816</td>
<td>$69,408</td>
<td>$135,296</td>
<td>$66,304</td>
<td>$120,960</td>
<td>$272,384</td>
</tr>
<tr>
<td>Richards Landing</td>
<td>$6,678</td>
<td>$11,130</td>
<td>$54,166</td>
<td>$32,648</td>
<td>$83,104</td>
<td>$139,496</td>
</tr>
<tr>
<td>Superior Total</td>
<td>$1,624</td>
<td>$3,248</td>
<td>$11,368</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Thunder Bay</td>
<td>$1,624</td>
<td>$3,248</td>
<td>$11,368</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Grand Total</td>
<td>$629,788</td>
<td>$1,917,516</td>
<td>$5,180,800</td>
<td>$570,172</td>
<td>$1,630,824</td>
<td>$5,038,350</td>
</tr>
</tbody>
</table>
Table 64: U.S.: Overall economic loss from lost slips due at 3 water level drop scenarios

<table>
<thead>
<tr>
<th>AOS by Region</th>
<th>Physical Depth Measurement Slip Loss Valuations</th>
<th>Operators’ Responses Slip Loss Valuations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Foot Drop</td>
<td>2 Foot Drop</td>
</tr>
<tr>
<td>Toledo/Sandusky Total</td>
<td>$0</td>
<td>$4,409</td>
</tr>
<tr>
<td>Alpena/Bay City Total</td>
<td>$42,491</td>
<td>$161,464</td>
</tr>
<tr>
<td>Alpena</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Bay City</td>
<td>$42,491</td>
<td>$161,464</td>
</tr>
<tr>
<td>Holland Total</td>
<td>$151,967</td>
<td>$366,350</td>
</tr>
<tr>
<td>North U.S. Total</td>
<td>$41,019</td>
<td>$48,810</td>
</tr>
<tr>
<td>Menominee</td>
<td>$41,019</td>
<td>$41,019</td>
</tr>
<tr>
<td>Baraga</td>
<td>$0</td>
<td>$7,790</td>
</tr>
<tr>
<td>Ontonagon</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Grand Total</td>
<td>$235,477</td>
<td>$581,032</td>
</tr>
</tbody>
</table>

According to the physical depth measurement valuations, the Georgian Bay Region would face the largest economic impact of approximately 2.3 million dollars, followed by the Erie and Holland regions at ~1.7 million and ~1.2 million, respectively. In fact, most of the U.S.’s grand total costs are sustained by the Holland region. However, it should be noted that more regions were surveyed in these regions than the others.\(^{87}\)

\(^{87}\) The number of marinas that completed depth measurements by region are as follows: 28 in Georgian Bay, 25 in Erie, 23 in North Channel, 14 in Holland, 10 in Toledo/Sandusky, 9 in South Huron, 6 in Alpena/Bay City, 5 in North U.S., and 3 in Superior.
As expected, a critical threshold increase in costs exists from the two foot (0.6m) drop to the three foot (0.9m) drop scenarios on both the Canadian and American sides. Percentage increases in costs are 170% and 216% respectively (increases of $3,262,384 and $1,257,190 from the two foot (0.6m) drop cost totals). It is interesting to note that when compared to the interview responses, the three foot (0.9m) drop scenario also coincided with several of the marinas’ out-of-business mark (See ‘Out of Business’ in the main report). From the perspective of many of the operators, a three foot (0.9m) drop would imply that all slips be considered as lost despite sufficient water depth of two feet (0.6m). This condition could not be discerned by examining the physical measurement data alone.

These estimates help complete the picture of the costs incurred by low water levels to the marina industry. When coupled with the cost data obtained from the operators’ accounts of damages and adaptations, these slip-loss revenue losses represent another aspect of the significance of fluctuations in water to Great Lakes marinas.

### Combined Costs

Summing the cost values of physical slip loss, damages and adaptations provides a closer estimate of the true economic impact of declining water levels (Table 65). The ‘damages and adaptations’ costs include the second-round low certainty imputations discussed above[^88]. At the maximum end of the range, the marinas on Lakes Michigan/Huron suffer the highest combined costs at the three foot (0.9m) drop scenario, at approximately $12 million, followed by those on Lake Erie at ~$3 million, and Lake Superior at ~$2 million.

<table>
<thead>
<tr>
<th></th>
<th>Total Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Foot Drop</td>
</tr>
<tr>
<td>Lake Erie</td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$381,354</td>
</tr>
<tr>
<td>min</td>
<td>$281,217</td>
</tr>
<tr>
<td>Lake Michigan/Huron</td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$1,450,985</td>
</tr>
<tr>
<td>min</td>
<td>$823,490</td>
</tr>
<tr>
<td>Lake Superior</td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$1,624</td>
</tr>
<tr>
<td>min</td>
<td>$1,624</td>
</tr>
</tbody>
</table>

[^88]: See ‘Estimating the magnitude of the undervaluation: second-round imputations’ found above in the ‘damages and adaptation cost estimates’ section.
### Damages and Adaptations Costs

<table>
<thead>
<tr>
<th>Lake</th>
<th>Total</th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lake Erie</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAN (Erie region)</td>
<td>$181,080</td>
<td>$575,929</td>
<td>$1,690,544</td>
<td></td>
</tr>
<tr>
<td>U.S. (Toledo Sandusky region)</td>
<td>0</td>
<td>4,409</td>
<td>31,964</td>
<td></td>
</tr>
<tr>
<td><strong>Lake Michigan/Huron</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAN (South Huron region)</td>
<td>$79,680</td>
<td>230,760</td>
<td>942,960</td>
<td></td>
</tr>
<tr>
<td>CAN (Georgian Bay region)</td>
<td>341,910</td>
<td>1,035,450</td>
<td>2,378,430</td>
<td></td>
</tr>
<tr>
<td>CAN (North Channel region)</td>
<td>25,494</td>
<td>76,538</td>
<td>189,462</td>
<td></td>
</tr>
<tr>
<td>U.S. (Alpena/Bay City region)</td>
<td>42,491</td>
<td>161,464</td>
<td>477,218</td>
<td></td>
</tr>
<tr>
<td>U.S. (Holland region)</td>
<td>151,967</td>
<td>366,350</td>
<td>1,251,016</td>
<td></td>
</tr>
<tr>
<td>U.S. (Menominee AOS)</td>
<td>41,019</td>
<td>41,019</td>
<td>41,019</td>
<td></td>
</tr>
<tr>
<td><strong>Lake Superior</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAN (Thunder Bay AOS)</td>
<td>1,624</td>
<td>3,248</td>
<td>11,368</td>
<td></td>
</tr>
<tr>
<td>U.S. (Baraga AOS)</td>
<td>0</td>
<td>7,790</td>
<td>37,004</td>
<td></td>
</tr>
<tr>
<td>U.S. (Ontonagon AOS)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Again, this data only represents those marinas that were surveyed, and thus should not be taken as a complete representation of all commercial marinas on each lake. However, an average cost per surveyed marina can be found by dividing each Lake’s total cost by the number of marinas surveyed there. These values can be seen in Table 66, where the number of marinas surveyed in each Lake or country is shown in brackets. At the three foot (0.9m) drop scenario, Lake Superior has the highest total cost per marina, at $231,023. However, they have the lowest physical slip revenue lost per marina, and the highest damages and adaptations cost per marina. Lakes Michigan/Huron has the highest physical slip revenue lost per marina at $63,616.

---

89 Thirty five marinas were surveyed on Lake Erie, 83 were surveyed on Lake Michigan/Huron, and 5 were surveyed on Lake Superior.
Table 66: Total Estimated Cost Per Surveyed Marina

<table>
<thead>
<tr>
<th>Total Estimated Cost PER MARINA</th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Erie (35)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$10,896</td>
<td>$30,007</td>
<td>$79,283</td>
</tr>
<tr>
<td>min</td>
<td>$8,035</td>
<td>$17,992</td>
<td>$52,522</td>
</tr>
<tr>
<td>Lake Michigan/Huron (83)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$17,482</td>
<td>$39,093</td>
<td>$139,886</td>
</tr>
<tr>
<td>min</td>
<td>$9,922</td>
<td>$33,869</td>
<td>$82,716</td>
</tr>
<tr>
<td>Lake Superior (5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$325</td>
<td>$83,063</td>
<td>$231,023</td>
</tr>
<tr>
<td>min</td>
<td>$325</td>
<td>$23,135</td>
<td>$61,756</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical Slip Rental Revenue Lost PER MARINA</th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Erie (35)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$5,174</td>
<td>$16,455</td>
<td>$48,301</td>
</tr>
<tr>
<td>CAN (25)</td>
<td>$7,243</td>
<td>$22,861</td>
<td>$66,343</td>
</tr>
<tr>
<td>U.S. (10)</td>
<td>$0</td>
<td>$441</td>
<td>$3,196</td>
</tr>
<tr>
<td>Lake Michigan/Huron (83)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$8,224</td>
<td>$23,031</td>
<td>$63,616</td>
</tr>
<tr>
<td>CAN (60)</td>
<td>$7,451</td>
<td>$22,379</td>
<td>$58,514</td>
</tr>
<tr>
<td>U.S. (23)</td>
<td>$10,238</td>
<td>$24,732</td>
<td>$76,924</td>
</tr>
<tr>
<td>Lake Superior (5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$325</td>
<td>$2,208</td>
<td>$9,674</td>
</tr>
<tr>
<td>CAN (3)</td>
<td>$541</td>
<td>$1,083</td>
<td>$3,789</td>
</tr>
<tr>
<td>U.S. (2)</td>
<td>$0</td>
<td>$3,895</td>
<td>$18,502</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Damages and Adaptations Costs PER MARINA</th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Erie (35)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$5,722</td>
<td>$13,552</td>
<td>$30,982</td>
</tr>
<tr>
<td>min</td>
<td>$2,861</td>
<td>$1,537</td>
<td>$4,221</td>
</tr>
<tr>
<td>Lake Huron (83)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$9,258</td>
<td>$16,062</td>
<td>$76,271</td>
</tr>
<tr>
<td>min</td>
<td>$1,698</td>
<td>$10,838</td>
<td>$19,100</td>
</tr>
<tr>
<td>Lake Superior (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$0</td>
<td>$80,855</td>
<td>$221,349</td>
</tr>
<tr>
<td>min</td>
<td>$0</td>
<td>$20,927</td>
<td>$52,082</td>
</tr>
</tbody>
</table>
Methodology

**Literature Review and Technical Working Group Consultation**

The design of the field work, both the questionnaire and the depth measurements, was aided by the knowledge gained from performing a literature review, along with consultations with the members of the Recreational Boating and Tourism Technical Working Group (TWG). The goal of the fieldwork was to assess the vulnerability of marinas to fluctuations in water levels. The field research team was comprised of Dan Waddell and Greg Ross, herein referred to as “the team”. During the beginning of our work term, a literature review of online and library sources was performed concerning the topics of recreational boating, water levels, adaptation, and climate change as related to the Great Lakes. Documents, journal articles, and websites from this literature review and additional metadata were compiled into a database.

The survey was designed to collect data that would be compatible with the results obtained by previous studies that had also investigated the effects of changing water levels on recreational boating in the Great Lakes. The major studies that informed the survey design were the 2001 analysis “Economic Impact of Lake Michigan Levels on Recreational Boating and Charter Fishing in Five Counties” (Mahoney, Stynes and Pistus, 2001), the 2005 International Joint Commission-sponsored report, “Estimating the Economic Impact of Changing Water Levels on Lake Ontario and the St. Lawrence River for Recreational Boaters and Associated Businesses” (Connelly, Bibeault, J. Brown and T. Brown, 2005), and the 2008 US Army Corps of Engineers’ report, “John Glenn Great Lakes Basin Program, Great Lakes Recreational Boating Main Report-Final” (USACE 2008). These studies influenced the format of the questionnaire (See-Attitudinal Questionnaire design: below).

**Description of sample areas: Areas of Survey (AOS)**

Seventeen locations were chosen by the TWG to represent significant regions of the upper Great Lakes’ recreational boating and tourism industries. These seventeen locations acted as the center-points for 80 km diameter circles, referred to as “areas of survey” (AOS). These seventeen circles were represented visually on Google Earth, to be used to identify marinas.

The seventeen AOS were selected according to several criteria: In terms of eco-regions, sites were chosen to give an even representation of both the Great Lakes Forest Region and the Boreal Forest Region. Geologically, an even representation of both Precambrian Shield (granite) and Escarpment (primarily limestone bottoms) rock formations was desired. AOS selection was also designed to encompass a maximum concentration of ports/marinas, and aimed for equal representation in terms of regional susceptibility to fluctuating water levels. The Chicago area was not selected because that area has very deep waters. The TWG selected areas significantly impacted by fluctuating water levels historically. The TWG also wanted to ensure that at least two sites were selected on each major body of water. Finally, one site on the U.S. side was selected at the request of a Public Interest Advisory Group (PIAG) member.
Sample selection: Marinas identified to be surveyed within the AOS’s

Five resources were used to identify marinas within each AOS: Google Earth software, Google web search, YellowPages.ca (http://www.yellowpages.ca/), the Ontario Marina Operators Association’s online Ontario Boating Destination Guide (http://www.marinasontario.com/destination_guide.asp) and Reference USA database of U.S. businesses (accessed through the Royal Oak Public Library http://www.referenceusa.com/).

Google Earth software was used to scan the shoreline visually (bird’s eye perspective) for dockage and other infrastructure characteristics of marina facilities. Once a marina was identified visually, its location was recorded by a Placemark, which was then saved in My Places. The Placemarks were grouped according to the AOS in which they were located.

The Fly To: search engine feature was also used to locate marinas near cities and towns within the AOS as well as to provide basic contact information. For example, the terms “Parry Sound Marina” were used to cross reference the locations and identities of marinas found visually, or found through the other identification resources (see below).

The four other resources were used to search for marinas listed in and around towns and cities located within a given AOS. These resources were also used to gather detailed contact information as well as cross-reference information found using the other resources. Detailed contact information was transcribed onto an Excel spreadsheet named “Master Marina Inventory” (See APPENDIX 4 Master Marina Inventory).

In order to be included in the identified marina sample set, a given marina had to be open to the public, have dockage, and had to use its dockage to either accommodate transient or seasonal patrons. As a result, most contractors and repair shops were excluded.

Contact with respondents: Letter of Introduction, Scheduling Meetings

A Letter of Introduction was mailed out to all of the identified marinas. This letter explained the purpose of the study, and asked the marina operator to participate by completing the questionnaire and by giving permission to take depth measurements. It was also explained that the letter would be followed up by a phone call to confirm participation and schedule visits (See APPENDIX 5 Letter of Introduction). The letter was followed up by a phone call to confirm participation and schedule visits. The marina operator was assured of confidentiality. If an operator indicated that they did not wish to participate in the survey, then no further contact was made and their refusal was noted as such.

Some operators gave permission to take depth measurements, but were too busy to complete the questionnaire at the time of the meeting. In this case, the operator was asked if they would be available to complete the questionnaire over the phone at a later date. If so, a follow-up phone call was made during the desired time period to conduct the interview.

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90 The letter also suggested that a boat would be used to take depth measurements. However, due to difficulties obtaining insurance, no boat was used.
Once in the field, it was discovered that some of the marinas listed in the sample set had gone out of business, or had been misidentified. Some marinas were located in a different location than had been determined with Google Earth. In addition, some new marinas which had not been identified in the sample set were discovered during the field visits, often as a result of speaking with other marina operators that were surveyed. Where possible, contact information was obtained and a meeting set up.

As many marinas as possible were surveyed, but not all marinas identified were surveyed due to time constraints. The 149 marinas identified prior to fieldwork were sent the letter of introduction. Depth measurements were taken at 89 marinas, and 78 marina operators completed the questionnaire.

**Fieldwork Data: Physical Depth Measurements**

Slip depths at marinas were recorded with the Lowrance LCX-112C Sonar/GPS Chartplotter. Michel Gugen of Fisheries and Oceans Canada provided training on the use of the sounder and manipulation of measurement data using software.

The transducer attached to the LCX-112C, when placed into a body of water measured the depth. The LCX-112C also has a GPS unit that provided the coordinates of where each of the measurements was taken. The LCX-112C records other data when measurements are taken, but only depth, location and time were pertinent to the survey. The unit was mounted to a dolly while a car battery, which powered the unit, rested on the bottom of the same dolly. The transducer was attached to an approximately four foot long (1.2 meter) piece of wood. The transducer was able to move independently from the dolly as it was attached to the mounted LCX-112C by a single wire; approximately 4 meters long (Figure 1).

The unit and the battery, all on the dolly, were wheeled through marinas. One person moved the dolly, while the other held the post to which the transducer was attached. The dolly was wheeled to each slip at each marina and then the transducer was placed 10 centimeters into the water and a measurement was recorded. During the measurement the transducer was placed in the middle of the slip and approximately a foot from the side of the slip. It should be noted that the resolution of the depth measurements is somewhat limited by the variability in depth across the bottom of a given slip. This variability may be greater or less depending on the bottom material (silt or rock), or whether the slip has been partially or fully dredged. In any case, significant variability was rarely apparent, and measurement placements were chosen with this issue in mind. Once a depth reading was found, it was recorded as a data point by saving a waypoint on the LCX-112C’s internal drive.

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91 For example, some slips that had been designed for sailboats had been partially dredged with a trench down the middle to allow the boats’ keel to pass.
A waypoint was recorded for each slip, unless the depth was 2.7 meters or greater\textsuperscript{92}. The depth of the slip, however, was noted to be greater than 2.7 meters. This cut-off depth allowed for quicker movement around marinas and freed time to survey a greater number of marinas in total.

Once all the required waypoints were recorded for a given marina, the data was transferred from the LCX-112C’s internal drive to the removable SD card. At this point a Lowrance USR (.usr) file was saved onto the removable SD card and transferred to a computer for analysis and manipulation.

Once the .usr file was transferred from the SD card to a computer, a program called GPS Babel was used to convert the .usr file into a format that is readable by Microsoft Excel: Garmin MapSource (.txt). Added to the spreadsheet was the difference (in meters) between the water level and the standard benchmark elevation used in navigational charts; chart datum\textsuperscript{93}. The appropriate measurements at the time of the survey were chosen from the Fisheries and Oceans Canada website, “Tides, Currents, and Water Levels” where elevations are recorded at the nearest water level gauge. This measurement was used to calculate each slip’s elevation above the International Great Lake Datum (IGLD 1985).

\textsuperscript{92} This cut-off depth was chosen because it translates to about 9 feet. With a 3 foot loss in water levels, at least 6 feet would remain in these slips. Six feet is the approximate average draft of a sailboat, the most vulnerable vessel to shallow water levels due to their deep keels. If a given slip could lose 3 feet and still accommodate a sailboat, it was considered safe and its depth was not recorded.

\textsuperscript{93} All surveyed features on a navigational chart are positioned on some horizontal datum system. On the Great Lakes, water level and chart datum elevations are presently referenced to International Great Lakes Datum 1985 (http://www.waterlevels.gc.ca/english/VerticalDatums.shtml). The height of the water level above or below chart datum was obtained from the Fisheries and Oceans Canada website, “Tides, Currents, and Water Levels” found at http://www.waterlevels.gc.ca/.
The formula used to calculate the slips elevation was: Lake Chart Datum + Chart Datum Adjustment – Recorded Slip Depth. Also added to the spreadsheet were the total numbers of slips at the marina as well as the slips measured at the marina. These slip elevations were then used to count the number of slips rendered un-useable given three “slip-loss” scenarios of one (0.3m), two (0.6m) and three (0.6m) foot (meter) drops in the water level. All drops are subtracted from each Lake’s 2009 average elevation of the months in which measurements were taken. From this average water level three one foot (0.3m) intervals were subtracted to create the three scenarios of water level loss. These drops were chosen to represent potential changes in water levels based on long-term water level records. Furthermore, it is common to refer to water levels in one foot intervals, as these terms would be familiar to the marina operators. If the difference between the scenario water level and the slip elevation was less than two feet (0.6m), it was counted as lost and unusable. The decision to use a depth of two feet (0.6m) as the cut-off point for a functioning slip was based on the reasoning that at a depth lower than two feet (0.6m), it can become difficult for marinas to accommodate power boats with outboard motors (which typically have the shallowest draft requirements for common Great Lakes boats), let alone other types of boats which require deeper drafts. This decision may under report slip loss at marinas that rely on larger boats for business.

Also, the LCX-112C was equipped with a ‘Navionics’ chip that contained nautical charts of the Great Lakes. These charts contained enough detail to view the depths of access channels of the surveyed marinas. The access channel depths, adjusted to chart datum, were subjected to the same water level loss scenarios as the slip measurements described above. If a given marina’s access channel total depth dropped below 2 feet, all slips at the marina were considered lost.

The number of slips lost given each drop and rise scenario were counted for each marina. The data from all of the marinas within a given AOS were combined on an AOS summary spreadsheet. This spreadsheet contains the total number of slips measured in the AOS, the total number of slips at the surveyed marinas in the AOS and a total of how many slips would be lost at the surveyed marinas based on each scenario. Regional vulnerability graphs were created by combining the data of all the surveyed marinas in a given AOS. The bar graph compares the surveyed marinas in the AOS directly, while the pie chart provides the overall vulnerability of the surveyed marinas in the AOS. This process was repeated until the same graphs were reproduced for each AOS where depth measurements were taken.

**Questionnaire response data**

The questionnaire was designed to gather information that could be used to describe four performance indicators:

A. **Past Experience with water levels:** Damages and Adaptations. Damages sustained and adaptations that were undertaken as a result. The real BASELINE conditions under which marinas have operated in the context of past changes in water levels, to be used to evaluate the significance of hypothetical damages that may occur as a result of future changes in levels. *(From Page 2 of questionnaire, APPENDIX 2).* Operators recounted their experience with historic episodes of changes in the water level with reference to the level at the time of the interview.
To be comparable, their answers are referred to standardized water level elevations (explained in the next performance indicator).

B. **Adaptive Capacity and Threshold Vulnerabilities.** Describes the various adaptations that marinas would be hypothetically able to use when dealing with changes in water levels. How effective are these adaptations? Do they suffer from threshold limitations? (*From Pages 3 to 7 of questionnaire*). The operators were asked to consider six hypothetical changes in water level starting from the level at the time of the survey. To be comparable, their answers are referenced to standardized elevations that were designed to approximate the level at the time of the surveys for each lake. These standardized elevations were constructed by taking the average of the monthly-average elevations during the time-frames in which surveys were conducted on each of the Lakes. The monthly average water level elevations for 2009 on lakes Erie, Huron and Superior were obtained from the monthly bulletins, “Water Levels: Great Lakes and Montreal Harbour Monthly Bullentin” from the Canadian Hydrographic Service webpage: [http://www.waterlevels.gc.ca/C&A/back-arrieres_e.html](http://www.waterlevels.gc.ca/C&A/back-arrieres_e.html). These standardized elevations are in turn referred to a horizontal benchmark used in navigational charts; the International Great Lakes Datum 1985. All surveyed features on a navigational chart are positioned on some horizontal datum system. On the Great Lakes, water level and chart datum elevations are presently referenced to International Great Lakes Datum 1985 ([http://www.waterlevels.gc.ca/english/VerticalDatums.shtml](http://www.waterlevels.gc.ca/english/VerticalDatums.shtml)). In Table 13, the appropriate standardized monthly average elevations for Lakes Erie, Michigan/Huron and Superior (in blue) are compared to the individual elevations during the surveys.

C. **Impediments to Adaptation.** What stands in the way of performing necessary adaptations? Some examples given were the difficulty involved in obtaining dredging permits, or insufficient funding to undertake a necessary adaptation such as rebuilding seawalls. (*From Page 7 of questionnaire*).

D. **Adaptive Management Strategies.** Opinions expressed by respondents which may aid in the development of an adaptive management strategy. For example, many respondents suggested that governments design an ‘emergency’ grant or loan to aid marinas with the cost of dredging during periods of unusually low water levels. (*From Pages 7 and 8 of questionnaire*).

In addition, the questions from page 1 of the Questionnaire were designed to provide data that describes basic characteristics of the given marina including dockage, the type and size of boats that a given marina usually serves, services offered, operating season, and how many years a marina had been in operation. The same boat size categories were used as in the 2008 USACE report (USACE 2008, p6).

Also, once in the field, the question: “What are the three major factors that affect your business?” on page 7 of the Questionnaire, under the heading “Perception Questions”, was modified. The question lists four factors that might affect a given marina operator’s business (Water Levels, State of the Economy, Gas Prices and Other), and was intended for the surveyor to note which of these factors
affects the marina according to the operator’s response. However, during the interviews operators were asked to rank the factors from, largest impact on their marina to smallest. For example, a marina could say water levels was the most important factor but gas prices had a larger impact than other (weather), while state of the economy had the smallest effect on the marina year to year. (See APPENDIX 2 questionnaire).

The design on the questionnaire was consistent with social survey design principles and was reviewed by the TWG and pretested on a marina operator. Revisions for clarity were completed.

From the questionnaire data, tables and graphs were created and analyzed according to the four performance indicators described above: Marina Characteristics, Adaptive Capacity and Threshold Vulnerabilities, Impediments to Adaptation, and Adaptive Management. Individual reports were created for each of the 10 AOS (which can be found in the Appendices), followed by the main report, where the different AOS are organized into regions, and analyzed comparatively on a regional and Lake-wide basis.

Fieldwork Data: Transcribing Attitudinal Questionnaire Data
Data written on the questionnaires was transcribed into an Excel spreadsheet titled ‘Survey Master Good’. However, some marina operators chose not to respond to certain questions, resulting in some inconsistencies in the attitudinal data.

Economic Analysis
Monetary valuations were performed on both the data obtained from the interviews, and the physical depth measurements. The former attributed cost values to the damages and adaptations reported in the operators’ responses to the three hypothetical drop scenarios. The latter attributed cost values to the slips that were deemed lost given the three drop scenarios; both according to the depth measurements as well as the operators’ slip-loss estimates obtained from the interviews. Both sets of valuations are described below:

Damages and adaptations estimates:
- The estimation of costs from the damages and adaptations reported in the operators’ responses to the three hypothetical low water scenarios required three pieces of information.
  A. The damages and adaptations reported with accompanying monetary cost estimates.
  B. The damages and adaptations reported without same.
  C. Historical expenditures on dredging and dock modifications from the operators’ accounts of their reactions to past episodes of low water levels.
- Due to the lack of monetary cost estimates in A, average costs were calculated for dredging and dock modifications reported in B and C. Average dredging costs were sorted by four different marina size categories (>100 slips, 100-200 slips, 201-400 slips, and >400 slips).
- These average cost values were then imputed for the dredging and dock modifications reported in B. With these first round imputations included, costs were then totaled for the three low...

94 The costs reported in C were adjusted for inflation to 2009 constant Canadian dollars.
water scenarios for each AOS and for Lakes Erie, Michigan/Huron, and Superior. U.S. operators’ accounts of past expenditures on dredging and dock modifications were then added to the costs used for the Canadian marinas, and new averages were calculated and used for the first round imputations for the U.S. marinas.

- However, even with the first round imputations, these estimates failed to include valuations for many of the damages and adaptations reported. As a result, an undervaluation was assumed.
- To get a rough idea of the potential magnitude of the undervaluation, a second round of imputations was performed using low-certainty prices for the damages and adaptations that were remaining without costs after the first round imputations. Ranges of potential cost increases by percentage were created.
- The estimates for the high water scenarios were not performed due to the lack of information in the responses.

Slip-loss revenue estimates:

- The estimation of lost revenue from unusable slips due to low water levels required four pieces of information.
  - The physical depth measurements.
  - Slip loss estimates produced by the marina operator completing the questionnaire.
  - The average boat size, in feet, at each marina (obtained from Questionnaire).
  - Slip rental rate per-foot of boat dockage.

- These pieces of information were used to calculate two separate slip-loss revenue estimates (Physical Depth Measurements vs. Operators’ response estimates). The average boat size was multiplied by the average per-foot slip rental rates to obtain revenue rates per-slip for the appropriate areas of survey and regions.

- For the Physical depth measurement estimates, the number of slips lost at each marina for each of the three low water scenarios was then multiplied by the appropriate revenue rate per-slip. A 100 percent occupancy rate was assumed for the slip inventory.

- For the Operators’ response estimates, the number of slips lost for each of the three low water scenarios was also multiplied by the appropriate revenue rate per-slip.

- The two resulting sets of lost revenue estimates were then compared.

---

95 The cost estimates with the first round imputed average costs for dredging and dock modifications did not include the following adaptations: installing floating docks, extending docks, extending launch ramp, and repairing seawalls.

96 Due to gaps in the data, only an AOS wide average for boat size could be calculated. This average was calculated from the marina operators’ answers to the questionnaire.

97 Again, due to gaps in the data, the rental rate average could only be calculated by region. This average was calculated using listed slip rates per-foot that were posted on marina websites, as we did not have the foresight to include a question in the survey to collect this data.

98 The Erie region used five listed prices to calculate the average cost per foot of dockage, the South Huron region also used five, the Georgian Bay region used 15, and the North Channel region used seven. A proxy was used for the Superior region due to a lack of listed prices online.

99 A 93 percent occupancy rate was used in the Lake Ontario Study.
Combined costs:
- To get rough overall estimates for the three low water scenarios, the cost estimates for the damages and adaptations (including the first and second round of imputations) were combined with the physical depth measurement slip-loss revenue estimates by Lake.
- An overall estimate of cost per surveyed marina for each of the Lakes was also created.

Recap
This methodology outlines the processes that were followed in designing the survey, selecting marinas to be sampled, contacting those marinas, and in taking depth measurements and conducting interviews with the marina operators. It also outlines the processes that were followed in manipulating the data that was collected in the field for subsequent analysis.
Appendix ‘B’

IUGLS: Recreational Boating Economic Analysis
(39 pages)
International Upper Great Lakes Study: Recreational Boating Economic Analysis
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Economic Analysis

Fluctuating water levels affect marinas’ ability to operate and in turn affect their finances. To estimate the magnitude of this economic loss, a combination of the questionnaire responses and the physical data were used. Each AOS had an economic loss value estimated for the three water level drop scenarios. These scenarios use the same water levels that were described earlier in the report as the base condition. The starting elevation was 174.4m for Lake Erie, 176.4m for all Lake Huron and 183.4m for all Lake Superior. From these starting elevations, three water level drops of one-foot (0.3m) intervals were applied. The estimated economic loss experienced by the marinas under each scenario is comprised of three components: damages, adaptations and lost slip revenue. Each component will be introduced individually and later merged to give an overall estimate. When each component is introduced, the assumptions and limitations of the component’s estimations will be highlighted and discussed. The goal of this exercise is to create an estimate of the overall magnitude of economic loss at each water level scenario for the marinas surveyed. As losses will be aggregated some accuracy will be lost. Also, these estimates were completed only for marinas that were surveyed and are therefore not necessarily representative of the industry as a whole.

Adaptation and Damages Cost Estimates

When water levels fluctuate, damage to equipment and infrastructure often results. Costs are incurred by these damages in the form of lost future revenues, capital losses, and repairs. As marina operators cannot control fluctuations in the water level, they must attempt to avoid related damages by undertaking adaptations; which also incur costs.

In this section we look at cost estimates that were described in the operators’ accounts of both historical and hypothetical damages and adaptations that had resulted in the past, or would hypothetically result in the future, from fluctuations in the water level1.

Although the aim is to construct an economic valuation of these consequences, neither data set reflects the full extent of the damages, or the complex relationship between water level impacts and business decisions that would actually take place in the real world. The information obtained from the interviews with marina operators is noisy, complicated, and often inconsistent. For example, many of the operators reported specific damages and adaptations without accompanying cost estimates2 (Tables 1 and 2). Some operators also explained that they would be able to reduce costs by using in-house labor and equipment rather than hiring a contractor, or by accommodating smaller boats than they normally would. These efficiencies may not be fully reflected in the response data. In addition, many of the operators said that they would go out of business after considering the three foot drop scenario (-0.9m). After this point in

1 During the interviews, operators were asked to recount their past experience with fluctuating water levels under plan 1977A (3.0 Performance Indicator 1- Past Experience with Water Levels, historical damages and adaptations, in the main body of the report), as well as a series of ‘what if?’ questions related to six hypothetical scenarios of one foot, two foot and three feet intervals of drops and rises of the water level. They were also asked to provide cost estimates for these damages and adaptations when possible (4.0 Performance Indicator 2 -Adaptive Capacity and Threshold Vulnerabilities).

2 For example, some operators predicted that their marinas would become unable to accommodate certain boat sizes and types (See the main report), but were unable to estimate the associated monetary impact on sales or revenue.
the interview, these operators were less likely to report further hypothetical damages and adaptations; perhaps because such details were considered irrelevant in light of the idea of going out of business. In any case, all of the factors described above contribute to the uncertainty involved in estimating an accurate valuation of the impacts that would likely result from hypothetical changes in the water level.

Sample Description
The damages and adaptations that were reported with costs by the Canadian operators are in 2009 constant Canadian dollars. To be comparable, the historical expenditures that these operators reported were adjusted for inflation to 2009 constant Canadian dollars as well, using the Bank of Canada’s online inflation calculator (http://www.bankofcanada.ca/en/rates/inflation_calc.html). Likewise, the damages and adaptations reported with costs by the U.S. operators were adjusted for inflation to 2009 U.S. dollars, and then converted to 2009 Canadian dollars using the Bank of Canada’s average exchange rate for 2009: $1USD=$1.14187729 CAD (http://www.bankofcanada.ca/pdf/nraa09.pdf).

In the operators’ responses to the drop scenarios, monetary cost estimates are missing for 92% of the damages reported by Canadian operators, and for 100% of those reported by U.S. operators (Table 1). Costs are also missing for 66% of the adaptations reported by Canadian operators, and for 90% of those reported by U.S. operators (Table 1). Response rates for the rise scenarios are even worse (Table 2). As a result, the numerical sum of these estimates does a poor job of representing the costs that would be likely to accumulate as we move across the hypothetical scenarios (A complete listing of the cost estimates provided in the responses to the six scenarios are summarized in the section ‘operator response tables’ on page 21, in tables 18 to 27).
### Table 1 Hypothetical drop scenarios response sample description

<table>
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<th>CAN response</th>
<th>Operators interviewed</th>
<th>Operators that reported damages</th>
<th>Total Damages Reported</th>
<th>Damages Reported with Cost</th>
<th>Operators that reported adaptations</th>
<th>Total Adaptations Reported</th>
<th>Adaptations Reported with cost</th>
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### Table 2 Hypothetical rise scenarios response sample description

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<th>Total Damages Reported</th>
<th>Damages Reported with Cost</th>
<th>Operators that reported adaptations</th>
<th>Total Adaptations Reported</th>
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<td>% of total adaptations reported</td>
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First-Round Imputations: Average dredging and dock modification cost estimates

To generate figures that can do a better job at conveying a representative monetary valuation of the response data, we imputed average costs for the two most common adaptations found in our response data that were accompanied by cost estimates: dredging and dock modifications\(^3\). Shown in tables 3, and 5, these average cost estimates were obtained from both the historical and hypothetical Canadian response data.

Although very few cost estimates were obtained from the U.S. hypothetical responses, a substantial amount of dredging and dock modification costs were reported in the historical responses. After the first round imputation was performed on the Canadian data using the average cost estimates shown in tables 4 and 6, the additional U.S. costs reported were added to the Canadian data in order to generate new average cost estimates to be used in a first round imputation on the U.S. data. It should be noted that the average cost for dock modifications is significantly higher once the U.S. historical costs are added (Table 5 vs. Table 6).

\(^3\) Median dredging and dock modification costs were constructed from a combination of both a) the cost estimates found in the responses to the three hypothetical drop scenarios, and b) the marina operators’ accounts of their past expenditures that had been undertaken in response to historical drops in the water levels (Tables 3 and 4). Hypothetical and historical cost estimates for dredging were sorted according to the following size categories (<100 slips, 100 to 200 slips, 201 to 400 slips, and >400 slips)(Table 30), while those for dock modifications were not (Table 31).
### Table 3 Average hypothetical and historical dredging costs used for Canadian data

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<th>Dredging</th>
<th>Marina size: &lt;100 slips</th>
<th>Marina size: 100-200 slips</th>
<th>Marina size: 201-400 slips</th>
<th>Marina size: &gt;400 slips</th>
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<td></td>
<td>$13,000</td>
<td>GOD</td>
<td>$154,000</td>
<td>PC</td>
</tr>
<tr>
<td></td>
<td>$5,000</td>
<td>GOD</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$155,000</td>
<td>MID</td>
<td>$107,000</td>
<td>KV</td>
</tr>
<tr>
<td></td>
<td>$49,000</td>
<td>MID</td>
<td>$46,000</td>
<td>PH</td>
</tr>
<tr>
<td></td>
<td>$21,000</td>
<td>MID</td>
<td>$40,000</td>
<td>GOD</td>
</tr>
<tr>
<td></td>
<td>$122,000</td>
<td>PS</td>
<td>$72,000</td>
<td>MID</td>
</tr>
<tr>
<td></td>
<td>$1,000</td>
<td>PS</td>
<td>$122,000</td>
<td>MID</td>
</tr>
<tr>
<td></td>
<td>$56,000</td>
<td>LC</td>
<td>$63,000</td>
<td>PS</td>
</tr>
<tr>
<td></td>
<td>$60,000</td>
<td>LC</td>
<td>$143,000</td>
<td>PS</td>
</tr>
<tr>
<td></td>
<td>$5,000</td>
<td>LC</td>
<td>$111,000</td>
<td>PS</td>
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<tr>
<td></td>
<td>$95,000</td>
<td>RL</td>
<td>$106,000</td>
<td>LC</td>
</tr>
<tr>
<td></td>
<td>$35,000</td>
<td>RL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>$155,000</td>
<td></td>
<td>$250,000</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>$1,000</td>
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<td>$40,000</td>
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</tr>
<tr>
<td>Average</td>
<td>$44,474</td>
<td></td>
<td>$101,222</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>$25,000</td>
<td></td>
<td>$100,000</td>
<td></td>
</tr>
</tbody>
</table>
Table 4: Average hypothetical and historical dredging costs used for U.S. data

<table>
<thead>
<tr>
<th>U.S. Dredging</th>
<th>marina size: &lt;100 slips</th>
<th>marina size: 100-200 slips</th>
<th>marina size: 201-400 slips</th>
<th>marina size: &gt;400 slips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost Estimates ($)</td>
<td>AOS</td>
<td>Cost Estimates ($)</td>
<td>AOS</td>
</tr>
<tr>
<td>Hypothetical CAN</td>
<td>$5,000</td>
<td>TP</td>
<td>$100,000</td>
<td>PC</td>
</tr>
<tr>
<td>Historical CAN</td>
<td>$25,000</td>
<td>GOD</td>
<td>$250,000</td>
<td>PH</td>
</tr>
<tr>
<td>Hypothetical U.S.</td>
<td>$5,000</td>
<td>GOD</td>
<td>$100,000</td>
<td>GOD</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$100,000</td>
<td>PS</td>
<td>$80,000</td>
<td>MID</td>
</tr>
<tr>
<td>Hypothetical U.S.</td>
<td>$6,000</td>
<td>PS</td>
<td>$100,000</td>
<td>PS</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$16,000</td>
<td>KV</td>
<td>$80,000</td>
<td>PS</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$71,000</td>
<td>KV</td>
<td>$45,000</td>
<td>LC</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$13,000</td>
<td>GOD</td>
<td>$154,000</td>
<td>PC</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$5,000</td>
<td>GOD</td>
<td>$103,000</td>
<td>KV</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$155,000</td>
<td>MID</td>
<td>$107,000</td>
<td>KV</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$49,000</td>
<td>MID</td>
<td>$46,000</td>
<td>PH</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$21,000</td>
<td>MID</td>
<td>$40,000</td>
<td>GOD</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$122,000</td>
<td>PS</td>
<td>$72,000</td>
<td>MID</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$1,000</td>
<td>PS</td>
<td>$122,000</td>
<td>MID</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$56,000</td>
<td>LC</td>
<td>$63,000</td>
<td>PS</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$60,000</td>
<td>LC</td>
<td>$143,000</td>
<td>PS</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$5,000</td>
<td>LC</td>
<td>$111,000</td>
<td>PS</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$95,000</td>
<td>RL</td>
<td>$106,000</td>
<td>LC</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$35,000</td>
<td>RL</td>
<td>$34,259</td>
<td>HL</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$57,099</td>
<td>HL</td>
<td>$228,395</td>
<td>HL</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$57,099</td>
<td>HL</td>
<td>$11,420</td>
<td>HL</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$5,710</td>
<td>BA</td>
<td>$47,264</td>
<td>AL</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$284,549</td>
<td>TS</td>
<td>$11,379</td>
<td>HL</td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$24,305</td>
<td>HL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$236,321</td>
<td>HL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historical U.S.</td>
<td>$2,954</td>
<td>BA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Max | $284,549 | $250,000 | $680,924 | $204,277 |
Min | $1,000 | $11,379 | $20,000 | $18,000 |
Average | $58,194 | $93,683 | $159,730 | $124,611 |
Median | $30,000 | $100,000 | $122,000 | $111,000 |
Table 5: Average hypothetical and historical dock modification costs used for Canadian data

<table>
<thead>
<tr>
<th>Dock Modifications</th>
<th>Cost Estimates ($)</th>
<th>AOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothetical CAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>$66,000</td>
<td>LC</td>
</tr>
<tr>
<td>R</td>
<td>$20,000</td>
<td>RL</td>
</tr>
<tr>
<td>M</td>
<td>$30,000</td>
<td>MID</td>
</tr>
<tr>
<td>H</td>
<td>$5,000</td>
<td>MID</td>
</tr>
<tr>
<td>R</td>
<td>$3,000</td>
<td>RL</td>
</tr>
<tr>
<td>M</td>
<td>$31,000</td>
<td>MID</td>
</tr>
<tr>
<td>T</td>
<td>$12,000</td>
<td>TP</td>
</tr>
<tr>
<td>M</td>
<td>$6,000</td>
<td>MID</td>
</tr>
<tr>
<td>H</td>
<td>$106,000</td>
<td>MID</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td>$106,000</td>
</tr>
<tr>
<td>Min</td>
<td></td>
<td>$3,000</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>$31,000</td>
</tr>
<tr>
<td>Median</td>
<td></td>
<td>$20,000</td>
</tr>
</tbody>
</table>

Table 6: Average hypothetical and historical dock modification costs used for U.S. data

<table>
<thead>
<tr>
<th>Dock Modifications U.S.</th>
<th>Cost Estimates</th>
<th>AOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothetical CAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>$66,000</td>
<td>LC</td>
</tr>
<tr>
<td>R</td>
<td>$20,000</td>
<td>RL</td>
</tr>
<tr>
<td>M</td>
<td>$30,000</td>
<td>MID</td>
</tr>
<tr>
<td>H</td>
<td>$5,000</td>
<td>MID</td>
</tr>
<tr>
<td>R</td>
<td>$3,000</td>
<td>RL</td>
</tr>
<tr>
<td>M</td>
<td>$31,000</td>
<td>MID</td>
</tr>
<tr>
<td>T</td>
<td>$12,000</td>
<td>TP</td>
</tr>
<tr>
<td>M</td>
<td>$6,000</td>
<td>MID</td>
</tr>
<tr>
<td>H</td>
<td>$106,000</td>
<td>MID</td>
</tr>
<tr>
<td>H</td>
<td>$15,361</td>
<td>BC</td>
</tr>
<tr>
<td>H</td>
<td>$136,185</td>
<td>BC</td>
</tr>
<tr>
<td>H</td>
<td>$940,846</td>
<td>HL</td>
</tr>
<tr>
<td>H</td>
<td>$1,772</td>
<td>HL</td>
</tr>
<tr>
<td>H</td>
<td>$94,528</td>
<td>HL</td>
</tr>
<tr>
<td>H</td>
<td>$3,545</td>
<td>HL</td>
</tr>
<tr>
<td>H</td>
<td>$3,545</td>
<td>HL</td>
</tr>
<tr>
<td>H</td>
<td>$2,845</td>
<td>HL</td>
</tr>
<tr>
<td>H</td>
<td>$57,099</td>
<td>HL</td>
</tr>
<tr>
<td>H</td>
<td>$25,432</td>
<td>HL</td>
</tr>
<tr>
<td>H</td>
<td>$6,706</td>
<td>HL</td>
</tr>
<tr>
<td>H</td>
<td>$4,726</td>
<td>BA</td>
</tr>
<tr>
<td>H</td>
<td>$341,374</td>
<td>ME</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td>$940,846</td>
</tr>
<tr>
<td>Min</td>
<td></td>
<td>$1,772</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>$86,953</td>
</tr>
<tr>
<td>Median</td>
<td></td>
<td>$17,680</td>
</tr>
</tbody>
</table>
Tables 7, 8, and 9 show the lake-wide cost estimate totals by AOS for the drop scenarios including these first-round imputations: the average dredging and dock modification estimates imputed in place for those dredging and dock modifications that were reported without accompanying cost values\(^4\). The cost estimate totals for the rise scenarios are not discussed due to the lack of information.

As Table 7 shows, Lake Erie would experience a threshold increase in costs of about 78% (~$575,000 to ~$625,000), if the water level were to drop from one foot (174.1m) to two feet (173.8m) below the average water level elevation for June and July 2009 (174.4m). If the water level were to drop another foot (0.3m) to the 173.5m elevation, they would suffer an increase in costs of about 10% ($132,000).

Table 7 Lake Erie cost estimate totals by AOS for drop scenarios, with imputed average dredging and dock modification costs

<table>
<thead>
<tr>
<th>AOS</th>
<th>One Foot Drop (174.1m)</th>
<th>AOS</th>
<th>Two Foot Drop (173.8m)</th>
<th>AOS</th>
<th>Three Foot Drop (173.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Colborne</td>
<td>$101,222</td>
<td>Port Colborne</td>
<td>$352,444 to $402,444</td>
<td>Port Colborne</td>
<td>$352,444 to $402,444</td>
</tr>
<tr>
<td>Turkey Point</td>
<td>$340,250</td>
<td>Turkey Point</td>
<td>$531,583</td>
<td>Turkey Point</td>
<td>$531,583</td>
</tr>
<tr>
<td>Kingsville</td>
<td>$44,474</td>
<td>Kingsville</td>
<td>$176,696</td>
<td>Kingsville</td>
<td>$308,918</td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>$284,341</td>
<td>Toledo/Sandusky</td>
<td>$284,341</td>
<td>Toledo/Sandusky</td>
<td>$284,341</td>
</tr>
<tr>
<td>Lake Erie</td>
<td>$770,286</td>
<td>Lake Erie</td>
<td>$1,345,064 to $1,395,064</td>
<td>Lake Erie</td>
<td>$1,477,286 to $1,527,286</td>
</tr>
</tbody>
</table>

Similarly, Lake Huron would experience a threshold increase in costs of ~147% (~$2,330,000) if the water level were to drop from one foot (176.1m) to two feet (175.8m) below the average water level elevation for June and July 2009 (176.4m) (Table 8).

Table 8 Lake Huron cost estimate totals by AOS for drop scenarios, with imputed average dredging and dock modification costs

<table>
<thead>
<tr>
<th>AOS</th>
<th>One Foot Drop (176.1m)</th>
<th>AOS</th>
<th>Two Foot Drop (175.8m)</th>
<th>AOS</th>
<th>Three Foot Drop (175.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Huron</td>
<td>n/a</td>
<td>Port Huron</td>
<td>n/a</td>
<td>Port Huron</td>
<td>$651,222</td>
</tr>
<tr>
<td>Goderich</td>
<td>$55,000 to $80,000</td>
<td>Goderich</td>
<td>$161,000</td>
<td>Goderich</td>
<td>$161,000</td>
</tr>
<tr>
<td>Midland</td>
<td>$244,522</td>
<td>Midland</td>
<td>$736,022</td>
<td>Midland</td>
<td>$890,246</td>
</tr>
<tr>
<td>Parry Sound</td>
<td>n/a</td>
<td>Parry Sound</td>
<td>$186,474</td>
<td>Parry Sound</td>
<td>$393,000</td>
</tr>
<tr>
<td>Little Current</td>
<td>$251,696 to $261,696</td>
<td>Little Current</td>
<td>627,170 to 637,170</td>
<td>Little Current</td>
<td>671,643 to 681,643</td>
</tr>
<tr>
<td>Richards Landing</td>
<td>$31,000</td>
<td>Richards Landing</td>
<td>$183,222</td>
<td>Richards Landing</td>
<td>$334,170</td>
</tr>
<tr>
<td>Alpena</td>
<td>$0</td>
<td>Alpena</td>
<td>$0</td>
<td>Alpena</td>
<td>$93,683</td>
</tr>
<tr>
<td>Bay City</td>
<td>$0</td>
<td>Bay City</td>
<td>$333,635</td>
<td>Bay City</td>
<td>$842,223</td>
</tr>
<tr>
<td>Holland</td>
<td>$983,666</td>
<td>Holland</td>
<td>$1,523,742</td>
<td>Holland</td>
<td>$1,664,631</td>
</tr>
<tr>
<td>Menominee</td>
<td>$0</td>
<td>Menominee</td>
<td>$159,730</td>
<td>Menominee</td>
<td>$159,730</td>
</tr>
</tbody>
</table>

\(^4\) Those responses that had been reported without accompanying cost estimates are denoted by ‘n/a’ under the ‘Cost range’ columns in the ‘Economic Analysis Operator Response Tables’ in the Appendices.)
If the water level were to drop another foot (0.3m) to the 175.5m elevation, they would suffer an increase in costs of about 50% (~$1,950,553).

On Lake Superior, the Baraga and Ontonagon AOS’s would experience an increase in costs of $237,809 if the water level were to drop from one foot (183.1m) to two feet (182.8m) below the average water level elevation for August 2009 (183.4m) (from zero losses at a the 183.1m elevation) (Table 9). If the water level were to drop another foot (0.3m) to the 182.5m elevation, only the Baraga AOS would suffer an increase in costs of about 61% ($145,147).

Table 9 Lake Superior cost estimate totals by AOS for drop scenarios, with imputed average dredging and dock modification costs

<table>
<thead>
<tr>
<th>AOS</th>
<th>One Foot Drop (183.1m)</th>
<th>Two Foot Drop (182.8m)</th>
<th>Three Foot Drop (182.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost Range ($)</td>
<td>Cost Range ($)</td>
<td>Cost Range ($)</td>
</tr>
<tr>
<td>Thunder Bay</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Baraga</td>
<td>$0</td>
<td>$179,616</td>
<td>Baraga</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$324,762</td>
<td>$324,762</td>
</tr>
<tr>
<td>Ontonagon</td>
<td>$0</td>
<td>$58,194</td>
<td>Ontonagon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$58,194</td>
<td>$58,194</td>
</tr>
<tr>
<td>Lake Superior</td>
<td>$0</td>
<td>$237,809</td>
<td>Lake Superior</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$382,956</td>
<td>$382,956</td>
</tr>
</tbody>
</table>

Estimating the magnitude of the undervaluation: Second-Round Imputations

Despite the first-round imputations of average costs for dredging and dock modifications, the lake-wide cost estimate totals shown in Tables 7, 8, and 9 still fail to include costs for 90% of the damages reported by Canadian operators; 100% of the damages reported by U.S. operators; 12% of the adaptations reported by Canadian operators; and 34% of the adaptations reported by U.S. operators.5 As a result, they likely undervalue the economic impact of the damages and adaptations that were reported in response to the three drop scenarios.

To get an idea of the magnitude of this undervaluation, a second set of average costs can be imputed for most of these remaining damages and adaptations that are still missing values. Although some of the remaining damages and adaptations were accompanied by cost estimates, there were not enough to create average estimates with comparable certainty to those that were created for dredging and dock modifications. Despite this setback, imputing these responses with average cost estimates derived from the small proportion that did provide cost estimates can at least provide a rough idea of the magnitude of the undervaluation.

5 The cost estimates summarized in Table 3, 4, and 6 do not include both the following damages: dock, breakwall, launch ramp, walkways, increased weed growth, reduced demand for winter storage, and accelerated shoreline erosion, or and the following adaptations: installing floating docks, extending docks, extending launch ramp, and repairing seawalls.
A small proportion of the responses did provide cost estimates for damage to docks, increased weed growth, seawall repair, launch ramp repair, dock extension, and the installation of floating docks; summarized in Table 10.6.

Table 10 Low certainty cost estimates derived from remaining responses

<table>
<thead>
<tr>
<th>Damage/Adaptation</th>
<th>Cost range ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dock Damage</td>
<td>2,000</td>
</tr>
<tr>
<td>Increased weed growth</td>
<td>1,300</td>
</tr>
<tr>
<td>Seawall repair</td>
<td>50,000 to 300,000</td>
</tr>
<tr>
<td>Launch Ramp repair</td>
<td>50,000 to 100,000</td>
</tr>
<tr>
<td>Extend Docks/install floating docks</td>
<td>50,000 to 200,000</td>
</tr>
</tbody>
</table>

When the set of costs shown in Table 10 are imputed for the missing monetary values that were not included in the valuations shown in Tables 7, 8, and 9, increases occur in the cost estimate totals per scenario. These increases range from 4% to 71% on Lake Erie; 9% to 108% on Lake Huron; and 44% to 289% on Lake Superior (Tables 11, 12, and 13). It should be noted that even after the second round imputations, these percentage increases in costs per scenario still fail to include valuations for 50% of the damages, and 8% of the adaptations reported by U.S. operators, as well as 19% of the damages reported by Canadian operators.

Table 11 Percentage increase in cost totals for the three drop scenarios with low certainty imputations

<table>
<thead>
<tr>
<th>Lake Erie</th>
<th>One Foot Drop (174.1m)</th>
<th>Two Foot Drop (173.8m)</th>
<th>Three Foot Drop (173.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% increase</td>
<td>13% to 26%</td>
<td>4% to 34%</td>
<td>10% to 71%</td>
</tr>
</tbody>
</table>

Table 12 Percentage increase in cost totals for the three drop scenarios with low certainty imputations

<table>
<thead>
<tr>
<th>Lake Huron</th>
<th>One Foot Drop (176.1m)</th>
<th>Two Foot Drop (175.8m)</th>
<th>Three Foot Drop (175.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% increase</td>
<td>9% to 48%</td>
<td>23% to 34%</td>
<td>27% to 108%</td>
</tr>
</tbody>
</table>

Table 13 Percentage increase in cost totals for the three drop scenarios with low certainty imputations

<table>
<thead>
<tr>
<th>Lake Superior</th>
<th>One Foot Drop (183.1m)</th>
<th>Two Foot Drop (182.8m)</th>
<th>Three Foot Drop (182.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% increase</td>
<td>n/a</td>
<td>44% to 170%</td>
<td>68% to 289%</td>
</tr>
</tbody>
</table>

Although this second round of imputations introduces significant uncertainty, they nonetheless show that the cost estimates summarized in Tables 32 and 33 likely undervalue the economic significance of the total damages and adaptations reported by a significant margin.

---

Slip Revenue Lost
The final component to be added to the overall economic impact analysis is the lost dockage fees when slips become unusable at the three water drop scenarios. Two different estimates of this economic loss were created. The first estimate is based on the physical measurements, which counts a given slip as unusable when it has less than two feet (0.6m) of water depth. The second estimate is derived from the questionnaire data, where marina operators estimated the number of slips they would lose given each of the hypothetical drop scenario.

To obtain an estimate of the economic value associated with slips lost due to a drop in the water level, two values are required. The first is the dockage fee per foot for the lost slip; the second is the size of boat that was going to occupy the lost slip. However, not every marina provided a breakdown of its slip sizes, or a reliable estimate of the size of the boats to which it caters. Because we could not find the per foot dockage fee of the specific slips that would be lost, an average price was calculated for each region. Also we did not know what size of boat would be displaced when the slip became unusable, therefore another average was created. The use of these averages is at best an approximation of revenue lost.

Table 14 shows the slip rental revenue lost at the three different water level drop scenarios in each Canadian AOS; while Table 15 shows those in the U.S. AOS. Only one season of damages is listed as slips lost may be restored by future dredging. The restored slips would then return to providing rental income. The first estimate is based on the physical measurements, which counts a slip as unusable when it has less than two feet (0.6m) of water after being subjected to the new water level elevation. The second estimate refers to slip loss based on the marina operators’ survey responses with respect to the three different drop scenarios. Both slip loss estimates are then multiplied by the same estimates of seasonal slip rental revenue for each AOS. The amount of lost slips at each water level scenario and at each marina was multiplied by the average rental revenue generated per slip in the AOS. The economic impact of the water level changes for each marina in an AOS was totaled. These water level scenarios are identical to the scenarios used in the main report.

It is difficult to extrapolate from these numbers to the complete Great Lakes marina industry, as the true population of marinas for each lake is not known. Also, it is difficult to compare the results from one region against another as some regions have been more thoroughly surveyed than others.

On the Canadian side, both the physical depth measurements and the marina operator responses provide almost identical cost values (Table 14), whereas on the American side, the operators’ responses overestimate the physical depth measurements (Table 15).
Table 14: Canada: Overall economic loss from lost slips due at 3 water level drop scenarios

<table>
<thead>
<tr>
<th>AOS by Region</th>
<th>Physical Depth Measurement Slip Loss Valuations</th>
<th>Operators’ Responses Slip Loss Valuations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Foot Drop</td>
<td>2 Foot Drop</td>
</tr>
<tr>
<td>Erie Region Total</td>
<td>$181,080</td>
<td>$571,520</td>
</tr>
<tr>
<td>Turkey Point</td>
<td>$105,600</td>
<td>$353,100</td>
</tr>
<tr>
<td>Kingsville</td>
<td>$69,600</td>
<td>$170,400</td>
</tr>
<tr>
<td>Port Colborne</td>
<td>$5,880</td>
<td>$48,020</td>
</tr>
<tr>
<td>South Huron Total</td>
<td>$79,680</td>
<td>$230,760</td>
</tr>
<tr>
<td>Port Huron</td>
<td>$72,000</td>
<td>$196,200</td>
</tr>
<tr>
<td>Goderich</td>
<td>$7,680</td>
<td>$34,560</td>
</tr>
<tr>
<td>Georgian Bay Total</td>
<td>$341,910</td>
<td>$1,035,450</td>
</tr>
<tr>
<td>Midland</td>
<td>$242,730</td>
<td>$717,030</td>
</tr>
<tr>
<td>Parry Sound</td>
<td>$99,180</td>
<td>$318,420</td>
</tr>
<tr>
<td>North Channel Total</td>
<td>$25,494</td>
<td>$76,538</td>
</tr>
<tr>
<td>Little Current</td>
<td>$18,816</td>
<td>$65,408</td>
</tr>
<tr>
<td>Richards Landing</td>
<td>$6,678</td>
<td>$11,183</td>
</tr>
<tr>
<td>Superior Total</td>
<td>$1,624</td>
<td>$3,248</td>
</tr>
<tr>
<td>Thunder Bay</td>
<td>$1,624</td>
<td>$3,248</td>
</tr>
<tr>
<td>Grand Total</td>
<td>$629,788</td>
<td>$1,917,516</td>
</tr>
</tbody>
</table>
Table 15: U.S.: Overall economic loss from lost slips due at 3 water level drop scenarios

<table>
<thead>
<tr>
<th>AOS by Region</th>
<th>Physical Depth Measurement Slip Loss Valuations</th>
<th>Operators’ Responses Slip Loss Valuations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Foot Drop</td>
<td>2 Foot Drop</td>
</tr>
<tr>
<td>Toledo/Sandusky Total</td>
<td>$0</td>
<td>$4,409</td>
</tr>
<tr>
<td>Alpena/Bay City Total</td>
<td>$42,491</td>
<td>$161,464</td>
</tr>
<tr>
<td>Alepna</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Bay City</td>
<td>$42,491</td>
<td>$161,464</td>
</tr>
<tr>
<td>Holland Total</td>
<td>$151,967</td>
<td>$366,350</td>
</tr>
<tr>
<td>North U.S. Total</td>
<td>$41,019</td>
<td>$48,810</td>
</tr>
<tr>
<td>Menominee</td>
<td>$41,019</td>
<td>$41,019</td>
</tr>
<tr>
<td>Baraga</td>
<td>$0</td>
<td>$7,790</td>
</tr>
<tr>
<td>Ontonagon</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Grand Total</td>
<td>$235,477</td>
<td>$581,032</td>
</tr>
</tbody>
</table>

According to the physical depth measurement valuations, the Georgian Bay Region would face the largest economic impact of approximately 2.3 million dollars, followed by the Erie and Holland regions at ~1.7 million and ~1.2 million, respectively. In fact, most of the U.S.’s grand total costs are sustained by the Holland region. However, it should be noted that more regions were surveyed in these regions than the others.  

---

7 The number of marinas that completed depth measurements by region are as follows: 28 in Georgian Bay, 25 in Erie, 23 in North Channel, 14 in Holland, 10 in Toledo/Sandusky, 9 in South Huron, 6 in Alpena/Bay City, 5 in North U.S., and 3 in Superior.
As expected, a critical threshold increase in costs exists from the two foot (0.6m) drop to the three foot (0.9m) drop scenarios on both the Canadian and American sides. Percentage increases in costs are 170% and 216% respectively (increases of $3,262,384 and $1,257,190 from the two foot (0.6m) drop cost totals). It is interesting to note that when compared to the interview responses, the three foot (0.9m) drop scenario also coincided with several of the marinas’ out-of-business mark (See ‘Out of Business’ in the main report). From the perspective of many of the operators, a three foot (0.9m) drop would imply that all slips be considered as lost despite sufficient water depth of two feet (0.6m). This condition could not be discerned by examining the physical measurement data alone.

These estimates help complete the picture of the costs incurred by low water levels to the marina industry. When coupled with the cost data obtained from the operators’ accounts of damages and adaptations, these slip-loss revenue losses represent another aspect of the significance of fluctuations in water to Great Lakes marinas.

**Combined Costs**

Summing the cost values of physical slip loss, damages and adaptations provides a closer estimate of the true economic impact of declining water levels. Table 16 shows these estimated values. The ‘damages and adaptations’ costs include the second-round low certainty imputations discussed above. At the maximum end of the range, the marinas on Lakes Michigan/Huron suffer the highest combined costs at the three foot (0.9m) drop scenario, at approximately $12 million, followed by those on Lake Erie at ~$3 million, and Lake Superior at ~$2 million.

<table>
<thead>
<tr>
<th></th>
<th>Total Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Foot Drop</td>
</tr>
<tr>
<td><strong>Lake Erie</strong></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$381,354</td>
</tr>
<tr>
<td>min</td>
<td>$281,217</td>
</tr>
<tr>
<td><strong>Lake Michigan/Huron</strong></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$1,450,985</td>
</tr>
<tr>
<td>min</td>
<td>$823,490</td>
</tr>
<tr>
<td><strong>Lake Superior</strong></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$1,624</td>
</tr>
<tr>
<td>min</td>
<td>$1,624</td>
</tr>
</tbody>
</table>

8 See ‘Estimating the magnitude of the undervaluation: second-round imputations’ found above in the ‘damages and adaptation cost estimates’ section.
### Physical Slip Rental Revenue Lost

<table>
<thead>
<tr>
<th></th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lake Erie</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$181,080</td>
<td>$575,929</td>
<td>$1,690,544</td>
</tr>
<tr>
<td>CAN (Erie region)</td>
<td>$181,080</td>
<td>$571,520</td>
<td>$1,658,580</td>
</tr>
<tr>
<td>U.S. (Toledo Sandusky region)</td>
<td>$0</td>
<td>$4,409</td>
<td>$31,964</td>
</tr>
<tr>
<td><strong>Lake Michigan/Huron</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$682,561</td>
<td>$1,911,581</td>
<td>$5,280,105</td>
</tr>
<tr>
<td>CAN (South Huron region)</td>
<td>$79,680</td>
<td>$230,760</td>
<td>$942,960</td>
</tr>
<tr>
<td>CAN (Georgian Bay region)</td>
<td>$341,910</td>
<td>$1,035,450</td>
<td>$2,378,430</td>
</tr>
<tr>
<td>CAN (North Channel region)</td>
<td>$25,494</td>
<td>$76,538</td>
<td>$189,462</td>
</tr>
<tr>
<td>U.S. (Alpena/Bay City region)</td>
<td>$42,491</td>
<td>$161,464</td>
<td>$477,218</td>
</tr>
<tr>
<td>U.S. (Holland region)</td>
<td>$151,967</td>
<td>$366,350</td>
<td>$1,251,016</td>
</tr>
<tr>
<td>U.S. (Menominee AOS)</td>
<td>$41,019</td>
<td>$41,019</td>
<td>$41,019</td>
</tr>
<tr>
<td><strong>Lake Superior</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$1,624</td>
<td>$11,038</td>
<td>$48,372</td>
</tr>
<tr>
<td>CAN (Thunder Bay AOS)</td>
<td>$1,624</td>
<td>$3,248</td>
<td>$11,368</td>
</tr>
<tr>
<td>U.S. (Baraga AOS)</td>
<td>$0</td>
<td>$7,790</td>
<td>$37,004</td>
</tr>
<tr>
<td>U.S. (Ontonagon AOS)</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
</tbody>
</table>

### Damages and Adaptations Costs

<table>
<thead>
<tr>
<th></th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lake Erie</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$200,274</td>
<td>$474,322</td>
<td>$1,084,373</td>
</tr>
<tr>
<td>min</td>
<td>$100,137</td>
<td>$53,803</td>
<td>$147,729</td>
</tr>
<tr>
<td><strong>Lake Michigan/Huron</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$768,424</td>
<td>$1,333,138</td>
<td>$6,330,472</td>
</tr>
<tr>
<td>min</td>
<td>$140,930</td>
<td>$899,529</td>
<td>$1,585,318</td>
</tr>
<tr>
<td><strong>Lake Superior</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>$0</td>
<td>$404,275</td>
<td>$1,106,743</td>
</tr>
<tr>
<td>min</td>
<td>$0</td>
<td>$104,636</td>
<td>$260,410</td>
</tr>
</tbody>
</table>

Again, this data only represents those marinas that were surveyed, and thus should not be taken as a complete representation of all commercial marinas on each lake. However, an average cost per surveyed marina can be found by dividing each Lake’s total cost by the number of marinas surveyed there. These values can be seen in Table 17, where the number of marinas surveyed in each Lake or country is shown in brackets. At the three foot (0.9m) drop scenario, Lake Superior has the highest total cost per marina, at $231,023. However, they have the lowest physical slip revenue lost per marina, and the highest damages and adaptations cost per marina. Lakes Michigan/Huron has the highest physical slip revenue lost per marina at $63,616.

---

9 Thirty five marinas were surveyed on Lake Erie, 83 were surveyed on Lake Michigan/Huron, and 5 were surveyed on Lake Superior.
## Table 17: Total Estimated Cost Per Surveyed Marina

<table>
<thead>
<tr>
<th></th>
<th>Total Estimated Cost PER MARINA</th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Erie (35)</td>
<td>max</td>
<td>$10,896</td>
<td>$30,007</td>
<td>$79,283</td>
</tr>
<tr>
<td></td>
<td>min</td>
<td>$8,035</td>
<td>$17,992</td>
<td>$52,522</td>
</tr>
<tr>
<td>Lake Michigan/Huron (83)</td>
<td>max</td>
<td>$17,482</td>
<td>$39,093</td>
<td>$139,886</td>
</tr>
<tr>
<td></td>
<td>min</td>
<td>$9,922</td>
<td>$33,869</td>
<td>$82,716</td>
</tr>
<tr>
<td>Lake Superior (5)</td>
<td>max</td>
<td>$325</td>
<td>$83,063</td>
<td>$231,023</td>
</tr>
<tr>
<td></td>
<td>min</td>
<td>$325</td>
<td>$23,135</td>
<td>$61,756</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Physical Slip Rental Revenue Lost PER MARINA</th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Erie (35)</td>
<td>Total</td>
<td>$5,174</td>
<td>$16,455</td>
<td>$48,301</td>
</tr>
<tr>
<td></td>
<td>CAN (25)</td>
<td>$7,243</td>
<td>$22,861</td>
<td>$66,343</td>
</tr>
<tr>
<td></td>
<td>U.S. (10)</td>
<td>$0</td>
<td>$441</td>
<td>$3,196</td>
</tr>
<tr>
<td>Lake Michigan/Huron (83)</td>
<td>Total</td>
<td>$8,224</td>
<td>$23,031</td>
<td>$63,616</td>
</tr>
<tr>
<td></td>
<td>CAN (60)</td>
<td>$7,451</td>
<td>$22,379</td>
<td>$58,514</td>
</tr>
<tr>
<td></td>
<td>U.S. (23)</td>
<td>$10,238</td>
<td>$24,732</td>
<td>$76,924</td>
</tr>
<tr>
<td>Lake Superior (5)</td>
<td>Total</td>
<td>$325</td>
<td>$2,208</td>
<td>$9,674</td>
</tr>
<tr>
<td></td>
<td>CAN (3)</td>
<td>$541</td>
<td>$1,083</td>
<td>$3,789</td>
</tr>
<tr>
<td></td>
<td>U.S. (2)</td>
<td>$0</td>
<td>$3,895</td>
<td>$18,502</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Damages and Adaptations Costs PER MARINA</th>
<th>1 Foot Drop</th>
<th>2 Foot Drop</th>
<th>3 Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Erie (35)</td>
<td>max</td>
<td>$5,722</td>
<td>$13,552</td>
<td>$30,982</td>
</tr>
<tr>
<td></td>
<td>min</td>
<td>$2,861</td>
<td>$1,537</td>
<td>$4,221</td>
</tr>
<tr>
<td>Lake Huron (83)</td>
<td>max</td>
<td>$9,258</td>
<td>$16,062</td>
<td>$76,271</td>
</tr>
<tr>
<td></td>
<td>min</td>
<td>$1,698</td>
<td>$10,838</td>
<td>$19,100</td>
</tr>
<tr>
<td>Lake Superior (3)</td>
<td>max</td>
<td>$0</td>
<td>$80,855</td>
<td>$221,349</td>
</tr>
<tr>
<td></td>
<td>min</td>
<td>$0</td>
<td>$20,927</td>
<td>$52,082</td>
</tr>
</tbody>
</table>
## Operator Response Tables

### Table 18 Canadian marinas on Lake Erie: detailed operators’ cost estimates for the drop scenarios

<table>
<thead>
<tr>
<th>Erie (Erie)</th>
<th>Scenario</th>
<th>One Foot Drop</th>
<th>Two Foot Drop</th>
<th>Three Foot Drop</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOS</td>
<td>Cost Range</td>
<td>Cost Range</td>
<td>Cost Range</td>
<td></td>
</tr>
<tr>
<td>Port Colborne</td>
<td>Damage</td>
<td>Launch Ramp</td>
<td>180 slips</td>
<td>50,000 to $100,000</td>
</tr>
<tr>
<td></td>
<td>Adaptation</td>
<td>Dredging</td>
<td>180 slips</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>AOS Total</td>
<td>n/a</td>
<td>$~150,000 to $~200,000</td>
<td>$~150,000 to $~200,000</td>
</tr>
<tr>
<td>Turkey Point</td>
<td>Damage</td>
<td>Dock</td>
<td>357 slips</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Adaptation</td>
<td>Dredging</td>
<td>750 slips</td>
<td>$200,000</td>
</tr>
<tr>
<td></td>
<td>AOS Total</td>
<td>n/a</td>
<td>$200,000</td>
<td>$280,000</td>
</tr>
<tr>
<td>Kingsville</td>
<td>Damage</td>
<td>Launch Ramp</td>
<td>25 slips</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Adaptation</td>
<td>Dredging</td>
<td>56 slips</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>AOS Total</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Lake-wide</td>
<td>Total Cost</td>
<td>$200,000 to $~430,000</td>
<td>$~430,000 to $~480,000</td>
<td>$~430,000 to $~480,000</td>
</tr>
</tbody>
</table>
Table 19 U.S. marinas on Lake Erie: detailed operators’ cost estimates for the drop scenarios

<table>
<thead>
<tr>
<th>Erie (Toledo Sandusky)</th>
<th>Scenario:</th>
<th>One Foot Drop</th>
<th>Marina Size</th>
<th>Cost Range</th>
<th>Two Foot Drop</th>
<th>Marina Size</th>
<th>Cost Range</th>
<th>Three Foot Drop</th>
<th>Marina Size</th>
<th>Cost Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOS</td>
<td>174.4m</td>
<td>174.1m</td>
<td>173.8m</td>
<td></td>
<td>173.5m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toledo/Sandusky</td>
<td>Damage</td>
<td>Reduced demand for winter storage</td>
<td>40 slips</td>
<td>n/a</td>
<td>Reduced demand for winter storage</td>
<td>40 slips</td>
<td>n/a</td>
<td>Reduced demand for winter storage</td>
<td>40 slips</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Adaptation</td>
<td>Dredging</td>
<td>380 slips</td>
<td>n/a</td>
<td>Dredging</td>
<td>380 slips</td>
<td>n/a</td>
<td>Dredging</td>
<td>380 slips</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dredging</td>
<td>2250 slips</td>
<td>n/a</td>
<td>Dredging</td>
<td>2250 slips</td>
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Table 20 Canadian marinas on Lake Huron: detailed operators’ cost estimates for the drop scenarios

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<th>Huron (South Huron)</th>
<th>Scenario:</th>
<th>One Foot Drop</th>
<th>Marina Size</th>
<th>Cost Range</th>
<th>Two Foot Drop</th>
<th>Marina Size</th>
<th>Cost Range</th>
<th>Three Foot Drop</th>
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### Region Total Cost

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## Economic Analysis 2010

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<th>104 slips</th>
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## Economic Analysis 2010

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### Richards Landing

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Table 22 U.S. marinas on Lake Superior: detailed operators’ cost estimates for the drop scenarios

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Table 23 Canadian marinas on Lake Erie detailed operators’ cost estimates for the rise scenarios

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Global Page 174
### Economic Analysis 2010

#### Seawall

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#### Adaptation

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<td>Accelerated shoreline erosion and flooding of inland areas</td>
<td>220 slips</td>
<td>n/a</td>
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</table>

#### Kingsville

<table>
<thead>
<tr>
<th>AOS Total Cost</th>
<th>Marina Size</th>
<th>Cost Range</th>
<th>Date: 2010</th>
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</thead>
<tbody>
<tr>
<td>Launch Ramp</td>
<td>25 slips</td>
<td>n/a</td>
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</table>

#### Lake-wide

<table>
<thead>
<tr>
<th>AOS Total Cost</th>
<th>Marina Size</th>
<th>Cost Range</th>
<th>Date: 2010</th>
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</thead>
<tbody>
<tr>
<td>Launch Ramp</td>
<td>25 slips</td>
<td>n/a</td>
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### Table 24 U.S. marinas on Lake Erie detailed operators’ cost estimates for the rise scenarios

<table>
<thead>
<tr>
<th>Erie (Toledo Sandusky)</th>
<th>Scenario:</th>
<th>One Foot Rise</th>
<th>Marina Size</th>
<th>Cost Range</th>
<th>Two Foot Rise</th>
<th>Marina Size</th>
<th>Cost Range</th>
<th>Three Foot Rise</th>
<th>Marina Size</th>
<th>Cost Range</th>
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<tbody>
<tr>
<td>AOS</td>
<td>174.4m</td>
<td>174.7m</td>
<td>175.0 m</td>
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<td>Toledo Sandusky Damage</td>
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<td>40 slips</td>
<td>n/a</td>
<td>Accelerated erosion</td>
<td>40 slips</td>
<td>n/a</td>
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<td>40 slips</td>
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<td>Breakwalls</td>
<td>40 slips</td>
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Table 25 Canadian marinas on Lake Huron detailed operators’ cost estimates for the rise scenarios

<table>
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<th>Lake Huron (South Huron)</th>
<th>Scenario:</th>
<th>One Foot Rise</th>
<th>Marina Size</th>
<th>Cost Range</th>
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<th>Cost Range</th>
<th>Three Foot Rise</th>
<th>Marina Size</th>
<th>Cost Range</th>
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<tbody>
<tr>
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<td>Port Huron</td>
<td>Damage</td>
<td>Dock 100 slips</td>
<td>n/a</td>
<td>Dock</td>
<td>Dock 150 slips</td>
<td>n/a</td>
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<td>n/a</td>
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<td>Seawall</td>
<td>Seawall 100 slips</td>
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<td>Seawall 100 slips</td>
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<td>Reduced demand for storage</td>
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<td>177.0 m</td>
<td>177.3 m</td>
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<td>Dock</td>
<td>330 slips</td>
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<td>Seawall</td>
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<td>$30,000</td>
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<td>200 slips</td>
<td>$30,000</td>
<td>Dock modifications</td>
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<td>Rebuild facilities</td>
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</table>

| Parry Sound Damage       | Dock      | 200 slips     | n/a         | Dock       | 104 slips    | n/a         | Dock       | 200 slips      | n/a         |            |
|                          | Dock      | 200 slips     | n/a         | Dock       | 200 slips    | n/a         | Dock       | 200 slips      | n/a         |            |
|                          | Dock      | 200 slips     | n/a         | Dock       | 70 slips     | n/a         | Dock       | 130 slips      | n/a         |            |
|                          | Seawall   | 200 slips     | n/a         |            |             |             |            |                |             |            |
|                          | Walkway   | 200 slips     | n/a         |            |             |             |            |                |             |            |
| Adaptation               | Dock modifications | 200 slips | $30,000 | Dock modifications | 200 slips | $30,000 | Dock modifications | 200 slips | $30,000 | Dock modifications | 200 slips | $30,000 |
|                          | Rebuild facilities | 200 slips | n/a         |            |             |             |            |                |             |            |

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<thead>
<tr>
<th>AOS Total Cost</th>
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<th>Region Total Cost</th>
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MIRARCO
### Economic Analysis 2010

#### Table 26 U.S. marinas on Lake Huron detailed operators’ cost estimates for the rise scenarios

<table>
<thead>
<tr>
<th>Michigan Huron (Alpena Bay City)</th>
<th>Scenario:</th>
<th>One Foot Rise</th>
<th>Marina Size</th>
<th>Cost Range</th>
<th>Two Foot Rise</th>
<th>Marina Size</th>
<th>Cost Range</th>
<th>Three Foot Rise</th>
<th>Marina Size</th>
<th>Cost Range</th>
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<tbody>
<tr>
<td><a href="#">AOS</a></td>
<td>One Foot Rise</td>
<td>176.4m</td>
<td>176.7 m</td>
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<td>Michigan Huron (Alpena Bay City)</td>
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<td><a href="#">AOS</a></td>
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- Lake Huron (North Channel)
- Scenario:
  - One Foot Rise
  - Two Foot Rise
  - Three Foot Rise
- Marina Size:
  - AOS: 176.4m, 176.7 m, 177.0 m, 177.3 m
- Cost Range:
  - AOS: 176.4m, 176.7 m, 177.0 m, 177.3 m

<table>
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<tr>
<th>Little Current</th>
<th>Damage</th>
<th>Dock</th>
<th>192 slips</th>
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<tr>
<td>Adaptation</td>
<td>Dock modifications</td>
<td>63 slips</td>
<td>n/a</td>
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<tr>
<td>AOS Total Cost</td>
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<th>Richards Landing</th>
<th>Damage</th>
<th>Dock</th>
<th>20 slips</th>
<th>n/a</th>
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<td>Adaptation</td>
<td>Dock modifications</td>
<td>20 slips</td>
<td>n/a</td>
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<td>AOS Total Cost</td>
<td>n/a</td>
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</table>

**Global Page 178**
<table>
<thead>
<tr>
<th>Michigan Huron (Holland)</th>
<th>Scenario:</th>
<th>One Foot Rise</th>
<th>Two Foot Rise</th>
<th>Three Foot Rise</th>
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<tbody>
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<td>AOS</td>
<td>Average Water Level 176.4m</td>
<td>176.7 m</td>
<td>177.0 m</td>
<td>177.3 m</td>
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<tr>
<td>Holland</td>
<td>Damage</td>
<td>Dock 79 slips n/a</td>
<td>Dock 349 slips n/a</td>
<td>Dock 86 slips n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dock 52 slips n/a</td>
<td>Dock 86 slips n/a</td>
<td>Dock 52 slips n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dock 310 slips n/a</td>
<td>Dock 189 slips n/a</td>
<td>Dock 310 slips n/a</td>
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<td>Breakwalls 86 slips n/a</td>
<td>Breakwalls 189 slips n/a</td>
<td>Breakwalls 86 slips n/a</td>
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<td>Walkways 189 slips n/a</td>
<td>Walkways 189 slips n/a</td>
<td>Walkways 189 slips n/a</td>
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<tr>
<td>Adaptation</td>
<td>Walkways 310 slips</td>
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<td></td>
<td>Walkways 210 slips</td>
<td>n/a</td>
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<tr>
<td></td>
<td>Accelerated shoreline erosion 55 slips</td>
<td>n/a</td>
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<td></td>
<td>Accelerated shoreline erosion 52 slips</td>
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<td>Accelerated shoreline erosion 310 slips</td>
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<td>Floatind docks 349 slips</td>
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<td></td>
<td>Floatind docks 210 slips</td>
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<td>Dock modifications 79 slips</td>
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<td>Dock modifications 349 slips</td>
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<td>Dock modifications 210 slips</td>
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<td>Rebuild facilities 310 slips</td>
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<td>Breakwalls 86 slips</td>
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### Table 27 U.S. marinas on Lake Superior detailed operators’ cost estimates for the rise scenarios

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</tr>
</tbody>
</table>
Appendix ‘C’

Field Survey Questionnaire
(8 pages)
Date (dd/mm/yy): ______/_____/______ Time: ___________
Marina: __________________________ Name: ___________ Yrs __________
Location: __________________________ Coordinates: Lat: ______ Long: ______
Phone: (__________)

No. of Wet Slips (Transient): ______ (____) No. of Dry Slips: ______
Slip size (% of total) Slip size (% of total)

<table>
<thead>
<tr>
<th>&lt;12</th>
<th>12-15</th>
<th>16-20</th>
<th>21-28</th>
<th>29-40</th>
<th>41+</th>
</tr>
</thead>
</table>

What type of boats do you cater to?

<table>
<thead>
<tr>
<th>Cruising</th>
<th>Sail</th>
<th>Fishing</th>
<th>Personal Watercraft</th>
<th>Pontoon</th>
<th>Other: ________________</th>
</tr>
</thead>
</table>

Boat Size (%)

<table>
<thead>
<tr>
<th>&lt;12</th>
<th>12-15</th>
<th>16-20</th>
<th>21-28</th>
<th>29-40</th>
<th>41+</th>
</tr>
</thead>
</table>

Operating Season

<table>
<thead>
<tr>
<th>Open (dd/mm)</th>
<th>Closed (dd/mm)</th>
</tr>
</thead>
</table>

Money Season

<table>
<thead>
<tr>
<th>Start (dd/mm)</th>
<th>End (dd/mm)</th>
</tr>
</thead>
</table>

Sources of Revenue

<table>
<thead>
<tr>
<th>Dry Slip rentals</th>
<th>Winter Storage</th>
<th>Liquor/Bar</th>
<th>Food/Beverage</th>
<th>Travel Lift</th>
<th>Boat/Motor Rentals</th>
<th>Boat/Motor Sales</th>
<th>Marine Supplies</th>
<th>Repairs</th>
<th>Fuel/Pumpout</th>
</tr>
</thead>
</table>

What regional businesses do you compete against for recreational spending?

<table>
<thead>
<tr>
<th>Marina(s)</th>
<th>Yacht Club(s)</th>
<th>Golf Course(s)</th>
<th>Outfitter(s)</th>
<th>Other (specify):</th>
</tr>
</thead>
</table>

Comments

<table>
<thead>
<tr>
<th>Comments</th>
</tr>
</thead>
</table>

Is your business affected by seasonal river flows? Yes ☐ No ☐
Has your business ever been affected by:
Low Water Levels? Yes ☐ No ☐

If Yes:
Which Year(s)?

How big was the drop(s)(Ft)? (from where to where)?

What adaptations did you do in response?
☐ Dredging Cost:
☐ Floating Docks Cost:
☐ Dock modifications Cost:
☐ Rebuilding facilities (walkways, gas docks)
☐ Substitute Smaller Boats in slips Cost:

% of slips substituted:

What is your preferred Water Level? (Relative to today's current level i.e. 'A foot up', 'a foot down', etc.)

-5 -4 -3 -2 -1 0 1 2 3 4 5

High Water Levels? Yes ☐ No ☐

If Yes:
Which Year(s)?

How big was the drop(s)(Ft)? (from where to where)?

What adaptations did you do in response?
☐ Extended docks Cost:
☐ Breakwalls Cost:
☐ Rebuilding facilities (walkways, gas docks)
☐ Substitute Bigger boats in slips Cost:

% of slips substituted:

What are the Boat Sizes affected: (<12, 12-15,16-20,21-28,29-40,41+)

☐ Other: Cost:
☐ Other: Cost:
☐ Other: Cost:
☐ Other: Cost:
What is the water level at which you are no longer able to operate a viable marina? Lowest? Highest? (FT away from current level)

|   -5   |   -4   |   -3   |   -2   |   -1   |   0    |   1    |   2    |   3    |   4    |   5    |

Perception Questions

What are the three major factors that affect your business?

- Water Levels
- State of the Economy
- Gas Prices
- Other

Other:

Adaptive Management

To your knowledge, is there any Government Assistance available to your marina to adapt to impacts of changing water levels? (Funding, Technology)

Yes □ No □

What kinds of Assistance would you like to see made available to you in order to deal with the impacts of changing water levels?

Do you face any institutional barriers to desired adaptations? I.e. dredging permits?

<table>
<thead>
<tr>
<th>Available Assistance:</th>
<th>Wish list for Assistance:</th>
<th>Barriers to Adaptation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Funding:</td>
<td></td>
<td>□ dredging permits</td>
</tr>
<tr>
<td>□ technology:</td>
<td></td>
<td>□ physical limits (rock)</td>
</tr>
</tbody>
</table>
Earlier in our conversation you mentioned that in the past, you had undertaken x, y, and z adaptations in response to periods of low/high water. Do you see these as short term or long term solutions?

☐ Short term ☐ Long term

In your opinion, is your adaptive strategy suitable for high and low water levels?
<table>
<thead>
<tr>
<th>Would you be affected by a change in water levels of:</th>
<th>A One Foot Drop?</th>
<th>A Two Foot Drop?</th>
<th>A Three foot Drop?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes ☐</td>
<td>Yes ☐</td>
<td>Yes ☐</td>
<td></td>
</tr>
<tr>
<td>If so, how many unusable wet slips?</td>
<td># %</td>
<td># %</td>
<td># %</td>
</tr>
<tr>
<td>How many slips would become unusable for the size of boat they were designed for?</td>
<td># %</td>
<td># %</td>
<td># %</td>
</tr>
<tr>
<td>Boat Sizes affected: (&lt;12, 12-15,16-20,21-28,29-40,41+)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other damages?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Docks ☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breakwall ☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Launch Ramp ☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walkways ☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inadequate channel depths ☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased Aquatic Weed Growth ☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced demand for winter storage ☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerated shoreline bluff erosion and flooding of inland areas. ☐</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other ☐</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### What actions COULD you take in response?

<table>
<thead>
<tr>
<th>Action</th>
<th>Cost:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dredging</td>
<td></td>
</tr>
<tr>
<td>Floating Docks</td>
<td></td>
</tr>
<tr>
<td>Dock modifications</td>
<td></td>
</tr>
<tr>
<td>Rebuilding facilities</td>
<td></td>
</tr>
<tr>
<td>(walkways, gas dock, pumpout)</td>
<td></td>
</tr>
<tr>
<td>Substitute Smaller/Larger Boats in Slips</td>
<td></td>
</tr>
</tbody>
</table>

% of slips substituted:

Boat Sizes affected: (<12, 12-15, 16-20, 21-28, 29-40, 41+)

<table>
<thead>
<tr>
<th>Action</th>
<th>Cost:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended docks</td>
<td></td>
</tr>
<tr>
<td>Breakwalls</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

### What actions WOULD you do to adapt if you had the capacity?

<table>
<thead>
<tr>
<th>Action</th>
<th>Cost:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dredging</td>
<td></td>
</tr>
<tr>
<td>Floating Docks</td>
<td></td>
</tr>
<tr>
<td>Dock modifications</td>
<td></td>
</tr>
<tr>
<td>Rebuilding facilities</td>
<td></td>
</tr>
<tr>
<td>(walkways, gas dock, pumpout)</td>
<td></td>
</tr>
<tr>
<td>Substitute Smaller/Larger Boats in Slips</td>
<td></td>
</tr>
</tbody>
</table>

% of slips substituted:

Boat Sizes affected: (<12, 12-15, 16-20, 21-28, 29-40, 41+)

<table>
<thead>
<tr>
<th>Action</th>
<th>Cost:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended docks</td>
<td></td>
</tr>
<tr>
<td>Breakwalls</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Would you be affected by a change in water levels of:</td>
<td>A One Foot Rise?</td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>If so, how many unusable wet slips?</td>
<td>#</td>
</tr>
<tr>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>How many slips would become unusable for the size of boat they were designed for?</td>
<td>#</td>
</tr>
<tr>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Boat Sizes affected: (&lt;12, 12-15,16-20,21-28,29-40,41+)</td>
<td></td>
</tr>
<tr>
<td>Other damages? Cost?</td>
<td>☐ Docks</td>
</tr>
<tr>
<td>☐ Breakwall</td>
<td>☐ Breakwall</td>
</tr>
<tr>
<td>☐ Launch Ramp</td>
<td>☐ Launch Ramp</td>
</tr>
<tr>
<td>☐ Walkways</td>
<td>☐ Walkways</td>
</tr>
<tr>
<td>☐ Inadequate channel depths</td>
<td>☐ Inadequate channel depths</td>
</tr>
<tr>
<td>☐ Increased Aquatic Weed Growth</td>
<td>☐ Increased Aquatic Weed Growth</td>
</tr>
<tr>
<td>☐ Reduced demand for winter storage</td>
<td>☐ Reduced demand for winter storage</td>
</tr>
<tr>
<td>☐ Accelerated shoreline bluff erosion and flooding of inland areas.</td>
<td>☐ Accelerated shoreline bluff erosion and flooding of inland areas.</td>
</tr>
<tr>
<td>☐ Other</td>
<td>☐ Other</td>
</tr>
</tbody>
</table>
Appendix ‘D’

Coping Zones
(4 pages)
Coping Zones by similar areas of survey (AOS)

Interest: Recreational Boating - Marina Slips
Location: Lake Superior (Thunder Bay, Baraga and Ontanagon AOS)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Water Level Regime Characteristics</th>
<th>Other Factors</th>
<th>Sensitivity</th>
<th>Economic Consequence</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max ft (m)</td>
<td>Min ft (m)</td>
<td>Range</td>
<td>Frequency of extremes</td>
<td>Duration</td>
</tr>
<tr>
<td>Zone A</td>
<td>184.3</td>
<td>182.8</td>
<td>1.5m (five feet)</td>
<td>During 30 year snapshot of the boating season (April through November), 0% of months exceeded Max. and 0% of months are less than Min.</td>
<td>Can withstand this range with minimal damage</td>
</tr>
<tr>
<td>Zone B</td>
<td>There is a jump from Zone A to C between 184.3 and 184.6</td>
<td>182.5 (Zone B exists only between 182.8 and 182.5)</td>
<td>0.3m (one foot) on the lower end of Zone A</td>
<td>0% of months exceed Max. and 0% of months are less than Min.</td>
<td>Can withstand this range with minimal damage</td>
</tr>
<tr>
<td>Zone C</td>
<td>&gt;184.6</td>
<td>&lt;181.9</td>
<td>2.7m (nine feet)</td>
<td>0% of months exceed Max. and 0% of months are less than Min.</td>
<td>Quite resilient</td>
</tr>
</tbody>
</table>
Coping Zones by similar areas of survey (AOS)

**Indicators**

<table>
<thead>
<tr>
<th>Max ft (m)</th>
<th>Min ft (m)</th>
<th>Range</th>
<th>Frequency of extremes</th>
<th>Duration</th>
<th>Rate of Change</th>
<th>Seasonality</th>
<th>Slip Loss</th>
<th>Percentage of Marinas 'Out of Business'</th>
<th>Wind/Waves/Storm Surge</th>
<th>Other Factors</th>
<th>Sensitivity</th>
<th>Economic Consequence</th>
<th>Suggested indicators for assessing thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td>177.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Less than 5% (45% PH, 5% PS, 2% RL)</td>
<td>0%</td>
<td>Not Significant</td>
<td>Greater than 30% (45% PH, 31% PS, 26% RL)</td>
<td>? Unknown? Or Ranging from $7.6 to $1.1 million for combined costs of all marinas surveyed within the six Lake Huron AOS (54 marinas). A valuation of quantitative slip losses combined</td>
<td>Slip losses (Less than 5%), &amp; Interview responses regarding 'Out of Business' levels (4%) .</td>
</tr>
</tbody>
</table>

**Zone A**

- **177.3 (Port Huron AOS)** is more resilient by 0.3m, and Richard's Landing is less resilient at 175.5m. However, they are 0.9m (three feet) closer after 30 months exceed Max. and 19% of months are less than Min. Can withstand this range with minimal damage. Can withstand this range with minimal damage (April through November), 3% of months exceed Max. and 19% of months are less than Min. Can withstand this range with minimal damage.

**Zone B**

- **175.5 (Lake Huron/Michigan)** is more resilient by 0.3m, and Richard's Landing is less resilient at 177.3m. However, they are 1.5m (five feet) closer after 30 months exceed Max. and 0% of months are less than Min. Either extreme will cause significant damage until actions are taken to adapt. Many would not be able to survive through a season given either extreme. Many are especially vulnerable during Spring 'Launch'.

**Zone C**

- **175.3 (Lake Huron/Michigan)** is more resilient by 0.3m, and Richard's Landing is less resilient at 177.3m. However, they are 2.1m (seven feet) closer after 30 months exceed Max. and 0% of months are less than Min. Many would not be able to survive through a season given either extreme. Many are especially vulnerable during Spring 'Launch'. Any length of time in Zone C would make it difficult for many of the marinas to remain operational. The marinas to remain operational.

**Zone D**

- **175.3 (Lake Huron/Michigan)** is more resilient by 0.3m, and Richard's Landing is less resilient at 177.3m. However, they are 2.1m (seven feet) closer after 30 months exceed Max. and 0% of months are less than Min. Many would not be able to survive through a season given either extreme. Many are especially vulnerable during Spring 'Launch'. Any length of time in Zone C would make it difficult for many of the marinas to remain operational. The marinas to remain operational.

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Appendix D - Page 2
## Coping Zones by similar areas of survey (AOS)

### Interest: Recreational Boating-Marina Slips

### Location: Lake Huron (Goderich, Midland, Little Current and Alpina AOS)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Max ft (m)</th>
<th>Min ft (m)</th>
<th>Range</th>
<th>Frequency of extremes</th>
<th>Duration</th>
<th>Rate of Change</th>
<th>Seasonality</th>
<th>Slip Loss</th>
<th>Percentage of Marinas 'Out of Business'</th>
<th>Wind/Waves/Storm Surge</th>
<th>Other Factors</th>
<th>Adaptation</th>
<th>Sensitivity</th>
<th>Economic Consequence</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A</td>
<td>177.3</td>
<td>176.1</td>
<td>1.2m (four feet)</td>
<td>During 30 year snapshot of the boating season (April through November), 3% of months exceed Max. and 19% of months are less than Min.</td>
<td>Can withstand this range with minimal damage</td>
<td>Quick drops or rises are generally considered a negative as interest does not have time to adjust.</td>
<td>Less than 5% (1% GOD, 4% MID, 3% LC)</td>
<td>0%</td>
<td>Not Significant</td>
<td>Marinas affected with Min: 3/4 Goderich, 3/4 Little Current, 1/5 Midland. (Some Dock Dammage in MID and LC).</td>
<td>Honey Harbour access channel, Wasaga Beach, Spanish</td>
<td>Interest will take action to protect investment even within this zone, however, expenditures are within expectations.</td>
<td>Not Significant</td>
<td>Same as B, but amplified</td>
<td>Existing adaptation not sufficient. Dredging may allow some to survive. Many operators indicated that they would be 'Out of Business' by this point, and would</td>
</tr>
</tbody>
</table>

### Zone B

177.3 (Accordin to 'Out of Business' & 'Slip Loss' numbers, there is a jump from Zone A to Zone C after 177.3)

175.5 (There is a threshold at 175.6m, in terms of the amount of operator that responde d that they)

1.8m (six feet) 3% of months exceed Max. and 0% of months are less than Min. | Either extreme will cause significant damage until actions are taken to adapt. Many would not be able to survive through a season given either extreme. Many are especially vulnerable during Spring 'Launch' | A quick return to zone A regime would be beneficial. A further drop/rise, or prolonged period at this elevation could push interest to Zone C | Less than 5% (18% GOD, 30% MID, 21% LC) | Up to 30% (50% GOD, 27% MID, 58% LC) SIGNIFICANT THRESHOLD OCCURS BETWEEN 175.6m and 175.5m. | Not Significant | All marinas affected with Min. (Dock Dammage: 1/2 in GOD)/(Many would have trouble accommodating sailboats (and boats >21ft) in LC and GOD) (Reduced Sales: 2/3 in LC). Marinas affected with. | Property owners likely to take action to protect their investment. (Dredging: 3/Sfh in MID, 7/12 in LC, 3/4 in GOD) (1 out of 6 would perform Dock Modifications in LC). | Honey Harbour access channel, Trent-Severn Outlet, Wasaga Beach, Spanish, Little Current | Recovery of bedrock during dredging can cause significant delays in obtaining permits. | Not Significant | Same as B, but amplified | Existing adaptation not sufficient. Dredging may allow some to survive. Many operators indicated that they would be 'Out of Business' by this point, and would | Discovery of bedrock during dredging can cause significant delays in obtaining permits. | Zone B or greater. | Slip losses (Greater than 30%), & Interview responses regarding "Out of Business" levels (Up to 30%). |

### Zone C

177.6 (Midland is slightly more resilient, 177.9)

175.2 (However, more than 30% of operator said that they would go 'Out of Business' given a prolonged period)

2.4m (eight feet) 0% of months exceed Max. and 0% of months are less than Min. | Many would not be able to survive through a season given either extreme. Many are especially vulnerable during Spring 'Launch' and Fall 'Haunt-out'. | Any length of time in Zone C would make it difficult for many of the marinas to remain operational. | Same as B | Greater than 30% (38% GOD, 49% MID, 40% LC) | Not Significant | Same as B, but amplified | Existing adaptation not sufficient. Dredging may allow some to survive. Many operators indicated that they would be 'Out of Business' by this point, and would | Honey Harbour access channel, Trent-Severn Outlet, Wasaga Beach, Spanish, Little Current | Discovery of bedrock during dredging can cause significant delays in obtaining permits. | Not Significant | Same as B, but amplified | Existing adaptation not sufficient. Dredging may allow some to survive. Many operators indicated that they would be 'Out of Business' by this point, and would | Discovery of bedrock during dredging can cause significant delays in obtaining permits. | Zone B or greater. | Slip losses (Greater than 30%), & Interview responses regarding "Out of Business" levels (Greater than 30%). |

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**Appendix D - Page 3**
## Water Level Regime Characteristics

<table>
<thead>
<tr>
<th>Zone</th>
<th>Max (m)</th>
<th>Min (m)</th>
<th>Range</th>
<th>Frequency of extremes</th>
<th>Duration</th>
<th>Rate of Change</th>
<th>Seasonality</th>
<th>Slip Loss</th>
<th>Percentage of Marinas 'Out of Business'</th>
<th>Other Factors</th>
<th>Wind/Waves/Storm Surge</th>
<th>Other Factors</th>
<th>Sensitivity</th>
<th>Economic Consequence</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone A</td>
<td>174.7</td>
<td>174.1</td>
<td>0.6 m</td>
<td>2 ft</td>
<td>During 30 year snapshot of the boating season (April through November), 12% of months exceed Max. and 16% of months are less than Min.</td>
<td>Can withstand this range with minimal damage</td>
<td>Quick drops or rises are generally considered a negative as interest may need to adapt (dock adjustments).</td>
<td>Seiches (flooding and ice damage) are worse in the winter.</td>
<td>Less than 5% (PC 1%, TP 5%, KV 5%)</td>
<td>0%</td>
<td>An increase in water levels would not harm day to day operations, but would make the marinas more susceptible to water surges due to high seasonality.</td>
<td>One-third of marinas in Turkey Point AOS would dredge.</td>
<td>Shallow waters for marina and sports fishing in Long Point Bay's inner bay with lows. Amplified flooding and ice damage from seiches with highs.</td>
<td>One-third of marinas in Turkey Point AOS would dredge.</td>
<td>Three factors were identified as having reduced the ability to recover</td>
</tr>
<tr>
<td>Zone B</td>
<td>175.3</td>
<td>173.8</td>
<td>1.5 m</td>
<td>5 ft</td>
<td>0% of months exceed Max. and 0% of months are less than Min.</td>
<td>If prolonged: Between zero and 30% of marinas go out of business, and slip loss between five and 30%</td>
<td>Quick drops or rises are generally considered a negative as interest does not have time to adjust.</td>
<td>Seiches (flooding and ice damage) are worse in the off season</td>
<td>5% to 30% (PC 8%, TP 17%, KV 12%)</td>
<td>Up to 30% (13% PC, 0% TP, 14% KV)</td>
<td>Wind surges begin to become a major impediment to operating a successful business.</td>
<td>Most marinas affected with Min. (81%). Seventy-five percent of marinas affected with Max. Increased trouble accommodating sailboats. Minority will have launch ramps.</td>
<td>Minority will dredge in Port Colborne and Kingsville AOS. Two-thirds would dredge in Turkey Point AOS, plus more costly adaptations (new walkways).</td>
<td>Shallow waters for marina and sports fishing in Long Point Bay's inner bay with lows. Amplified flooding and ice damage from seiches with highs.</td>
<td>Inconsistent fluctuation in Lake Erie's water level were identified as having reduced the effectiveness of adaptive measures</td>
</tr>
<tr>
<td>Zone C</td>
<td>175.6</td>
<td>173.5</td>
<td>2.1 m</td>
<td>7 ft</td>
<td>0% of months exceed Max. and 0% of months are less than Min.</td>
<td>If prolonged: More than 30% of marinas go out of business, and slip loss greater than 30%</td>
<td>The quicker Zone C is reached from Zone B, the greater the damage will be as there will be little time to prepare or react.</td>
<td>Greater than 30% (PC 21%, TP 47%, KV 31%)</td>
<td>Greater than 30% (63% PC, 50% TP, 57% KV)</td>
<td>Greater than 30% (PC 21%, TP 47%, KV 31%)</td>
<td>Wind surges become a major impediment to operating a successful business.</td>
<td>Most marinas affected with Min. and Max. (90%). Increased trouble accommodating sailboats. Increased launch ramp issues.</td>
<td>Most marinas in Turkey Point would dredge (All located in Long Point Bay's inner bay), ~40% of marinas in Port Colborne and Kingsville would dredge as well.</td>
<td>Shallow waters for marina and sports fishing in Long Point Bay's inner bay with lows. Amplified flooding and ice damage from seiches with highs.</td>
<td>Inconsistent fluctuation in Lake Erie's water level were identified as having reduced the effectiveness of adaptive measures</td>
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