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Low Water Theme Report

February 18, 2010
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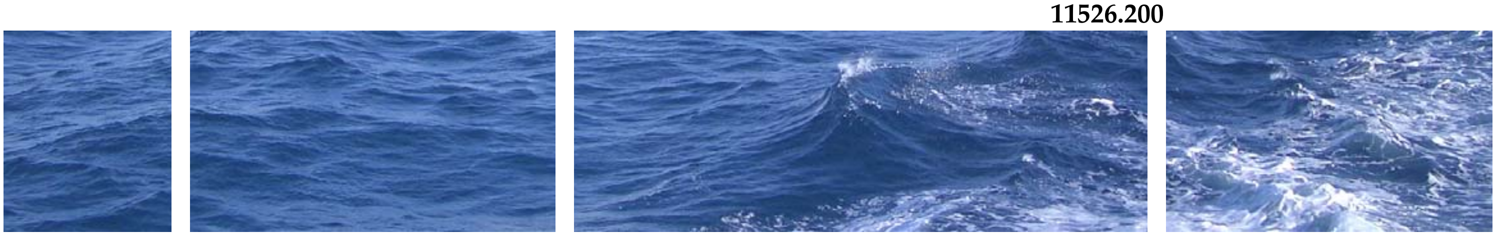

N a v i g a t i n g   N e w   H o r i z o n s

Low Water Theme Report

Prepared for

International Joint Commission
Coastal Zone Technical Working Group

Prepared by

Baird

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1.0 INTRODUCTION

This report was prepared for the Coastal Zone Technical Working Group (CZTWG) for the International Joint Commission's (IJC) five-year International Upper Great Lakes Study (IUGLS). The report, which describes low water impacts on shorelines, is one of four descriptive theme reports (the others being: Flooding, Erosion and Shore Protection) that were prepared for the IUGLS. The study area includes Lake Superior, Lake Michigan-Huron, Lake St. Clair and Lake Erie. The focus of the CZTWG analysis of regulation impacts is on the open lake and embayment shoreline, not the connecting channels.

1.1 Scope of Study

The Low Water Theme Report summarizes the current understanding of low water level impacts on the upper Great Lakes shorelines. The report includes: a description of how low water levels affect the shorelines of the Great Lakes and a review of previous studies and literature. Figure 1.1 provides a schematic diagram of how natural fluctuations in lake levels can impact beach width fronting a seawall and residential development.

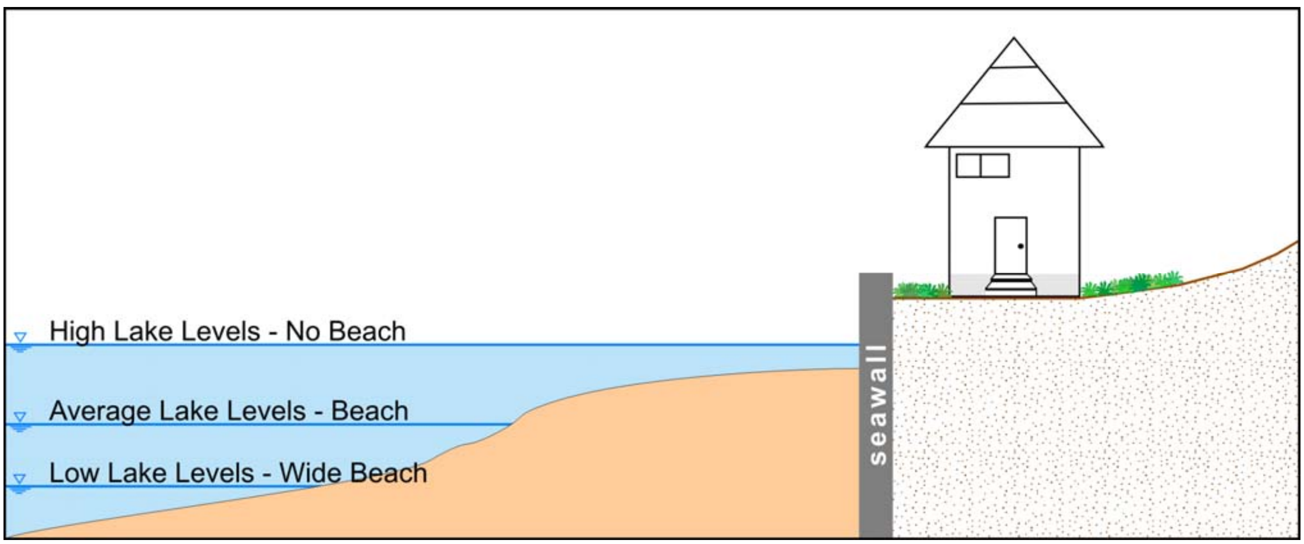

Figure 1.1 Water Level Impacts on Beach Width

The Low Water Performance Indicator (PI) will evaluate the physical processes and impacts associated with low water along both private lands (riparian landowners) and public shorelines (provincial, state or national park lands). Typical mitigation or restoration activities (e.g. dredging for recreational boat access, vegetation clearing for improved aesthetics, etc.) completed in these areas as a result of low water could also be considered in the Low Water PI.

Damage or failure of shore protection structures located on public or private land will not be considered in the low water impact analysis, since they are included in the Shore Protection PI.

1.2 Low Water Level Impacts and Benefits

Water levels in the Great Lakes fluctuate on an annual basis as well as in response to longer cycles (decadal or climactic cycles). Annually, water levels rise in the spring when runoff to the lake is high due to melting snow and evaporation rates are low due to cool lake and warm air temperatures. Peak levels occur in the summer as more water flows into the lakes than out. During the fall and winter, when evaporation is high due to warm lake and cool air temperatures and new precipitation inputs are generally lower than the spring, the lake levels drop and reach annual lows.

Longer-term water level fluctuations can occur over several years to decades. During wet and cool years, lake levels rise, while during hot and dry years, lake levels decline. Figure 1.2 shows the monthly mean water levels between 1918-2008 for the three main lake systems. For the three lakes shown, Lake Superior has the smallest range of monthly mean water levels (range of 1.19 m) while Lake St. Clair has the largest range of monthly mean water levels (range of 2.08 m).

High lake levels occurred in the early 1950s, early 1970s, mid-1980s, and mid-1990's while low lake levels occurred in the late 1920s, mid-1930s, mid-1960s, and from the late 1990s until present. Along shorelines with shallow nearshore bathymetry (or gentle nearshore slopes), small water level fluctuations can change the shoreline extent and characteristics significantly. For example, previously submerged portions of the lake bottom become an extension of riparian "backyards" and often dramatically change the aesthetic conditions and access to the lake. Refer to Figure 1.3 for an example of low water conditions on Lake St. Clair. During average and high lake levels, the riparian owners are able to access the lake for swimming from their seawalls, launch personal watercraft and dock small boats during fair weather. During low water this access is lost and replaced with emergent vegetation and rotting algae mats.

Figure 1.4 highlights low water impacts on the granite shoreline of Macey's Bay, near Honey Harbour on Georgian Bay. Boat docks are completely inoperable during low water and grey water intake lines are significantly compromised. Dredging costs can increase significantly for both private land owners and commercial marinas. Nearshore water quality can also be negatively affected by low water in sheltered areas or embayments with limited circulation or natural inflow from upland watersheds (Schiefer, 2003).

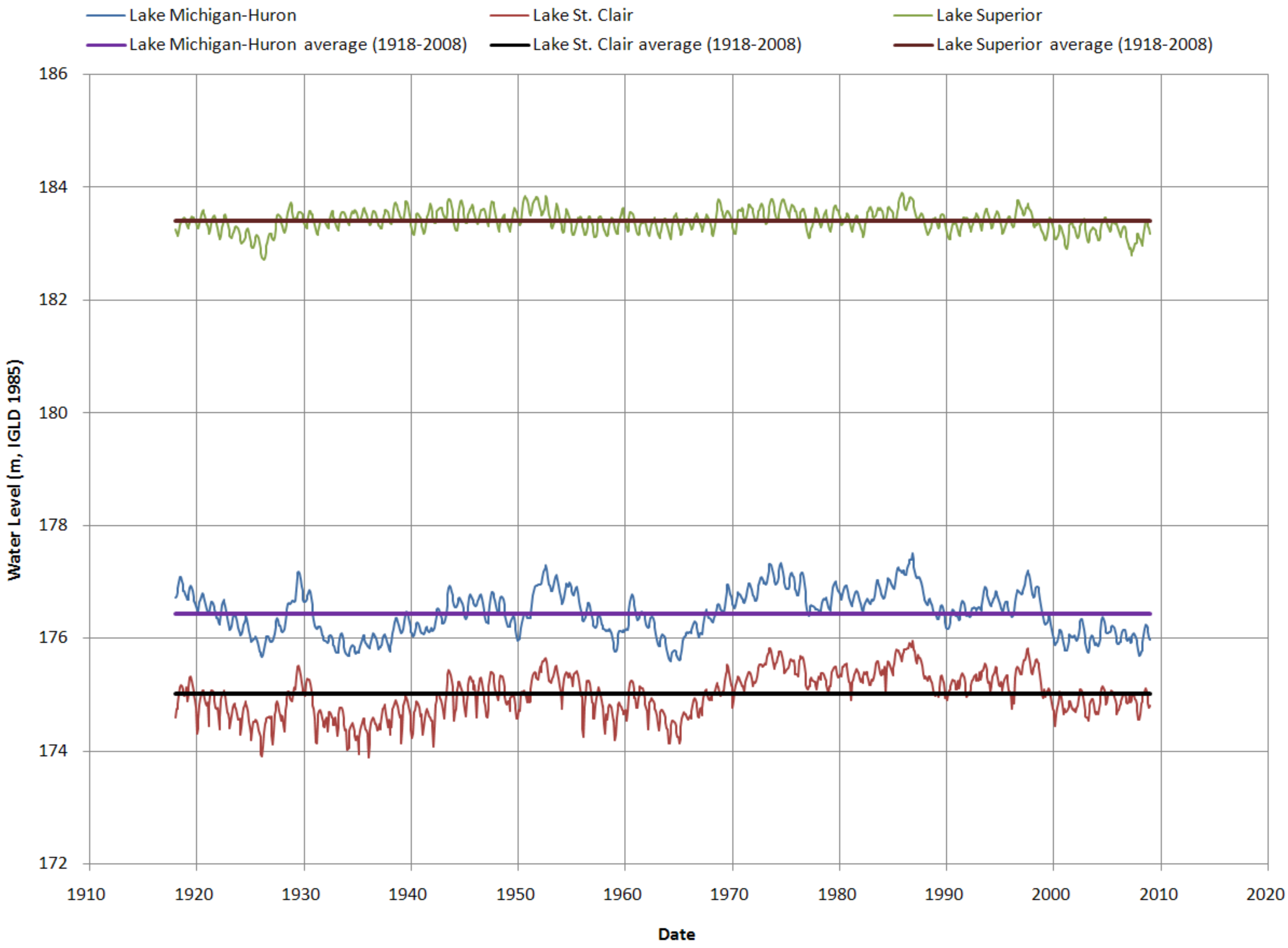

Figure 1.2 Upper Great Lake Monthly Mean Lake Levels (1918-2008) (USACE, 2009)

Figure 1.3 Low Water Impacts on Riparian Property Located on Lake St. Clair

Figure 1.4 Low Water Impacts on Macey's Bay, near Honey Harbour, Georgian Bay

When low water levels occur along undeveloped shorelines (sheltered, embayed or open coast areas), positive changes to physical habitat can occur, including: beach and dune recovery, increased vegetation growth, and creation of new early succession terrestrial habitat in previously submerged areas, to mention a few.

For open coast beach areas along developed shorelines, periods of falling or low water levels are beneficial in many ways, including: increases in beach width as lake levels drop, cross-shore migration of sand from the lake to the beach, which further widens the beach and provides additional sediment for dune growth, more recreational space for beach users, and storage of sand in the beach and foredune, which provides a natural buffer against storm erosion during the next period of high lake levels.

In addition, periods of low water along open coastlines can lead to the loss of hydrostatic pressure for shore protection structures and increased toe erosion, both of which can lead to costly maintenance. In some cases, increased beach width is perceived negatively by riparian landowners and thus low water conditions have a negative impact on their enjoyment of their property. Collectively, the impacts and benefits of low water periods throughout the study area will be explored in the following sections of this report.

2.0 LOW WATER LEVEL SHORELINE IMPACTS

Section 2.0 of the report will describe low water impacts for two generalized categories of coastline (1) sheltered shorelines with shallow nearshore bathymetry, and (2) exposed shorelines with steep nearshore bathymetry.

2.1 Sheltered Shorelines with Shallow Nearshore Bathymetry

Water level fluctuations can drastically alter the shoreline position in areas that have shallow nearshore bathymetry or low sloping topography. During low water level periods, large expanses of shorelines that were previously submerged can become exposed. The nearshore landscape can be altered noticeably during prolonged periods of low levels, as have been present on the Great Lakes for the last ten years.

In undeveloped areas, these changes can be beneficial to the environment. Figure 2.1 illustrates the land progradation and formation of deltas that can occur around river mouths during periods of persistent low water levels. The mouth of the Ford River, which drains into the northern part of Green Bay from Delta County, MI is shown at three different times between 1998 and 2006. The top photo, shows the area in April 1998, after the high lake levels experienced in the mid-1990s. The middle photo shows the progradation of the delta in June 2003, after five years of low water levels as well as the widening of the beach to the east. The bottom photo shows the area in August 2006 after another three years of low water levels. The delta was colonized by vegetation and stabilized after the prolonged low water level period creating new terrestrial habitat areas.

In developed areas, the effects of prolonged low water levels are sometimes not desirable. Shallower water levels and increased vegetation growth, which can affect water accessibility (unusable boat ramps, muddy conditions, etc.) and aesthetics (change in view, stagnant water, smell, etc.) are generally nuisances to riparian landowners and other users of the lake (commercial/recreational boaters, fishermen, etc.). Figure 2.2 shows how the shoreline in Saginaw Bay changed in response to the low water levels between 1998 and 2005. The top two photos show the lakeward migration of the shoreline between April 1998 and June 2005 in Arenac County, MI. Also evident is the beach widening, vegetation growth and the channel dredging for recreational boat navigation in response to the shallower water levels. The bottom two photos show the lakeward migration of the shoreline in Bay County, MI between April 1999 and August 2005. Increase in the area covered by vegetation and dredging activities in response to the prolonged low water levels are also observed.

April 1998

June 2003

August 2006

Figure 2.1 Landscape Changes Due to Extended Low Water Period at the Ford River, Delta County, MI, Northern Green Bay (1998-2006)

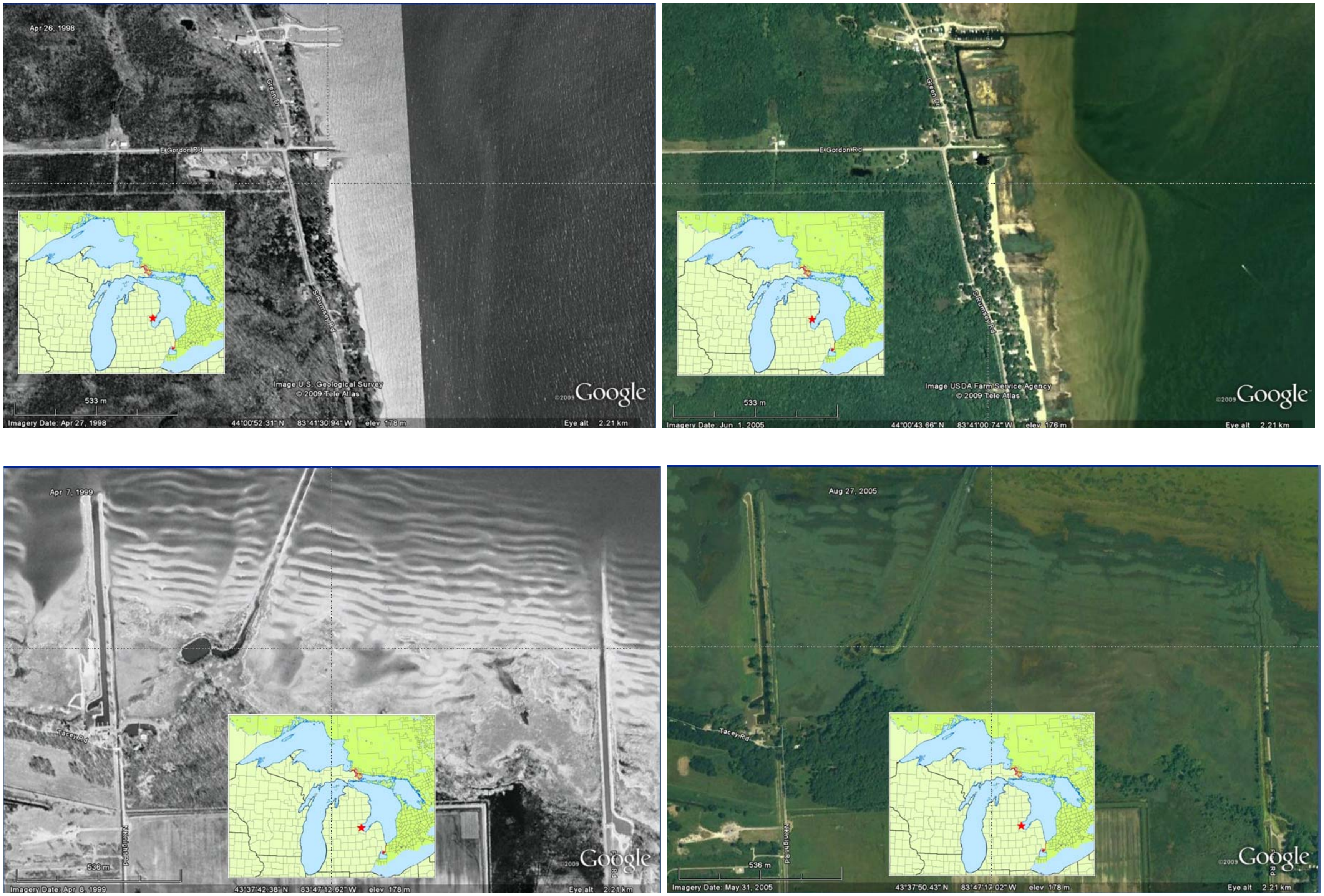

Figure 2.2 Low Water Impacts in Saginaw Bay Due to Extended Low Water Period. Top Figures: Arenac County, MI: April 1998 & June 2005. Bottom Figures: Bay County, MI: April 1999 & August 2005.

These negative impacts are observed in many of the embayed areas around the Upper Great Lakes which feature shallow nearshore bathymetry (Green Bay, Saginaw Bay, Georgian Bay, Lake St. Clair). Figure 2.3 shows the extensive dredging around northwest Collingwood, in Simcoe County, Ontario on Georgian Bay in June 2007. In some areas, where the bottom of the lakes are covered by bedrock, this type of adaptation requires channel blasting.

Figure 2.3 Dredging in Response to Low Water Levels in Northwest Collingwood, Simcoe County, Ontario (June 2007)

Figure 2.4 presents a ground level picture of a stranded residential boat slip on Lake St. Clair during the present low water regime, along with excessive weed growth and algae accumulation along residential seawalls in Figure 2.5.

Figure 2.4 Residential Boat Slip Stranded from Lake St. Clair During Low Water (1999)

Figure 2.5 Excessive Vegetation Growth and Algae Accumulation During Low Water, Lake St. Clair (1999)

2.2 Exposed Shorelines with Steep Nearshore Conditions

Open coast shorelines, which generally feature steeper nearshore bathymetry and more wave energy are not as sensitive to prolonged periods of low water levels. In these areas, the change in shoreline position due to falling or low lake levels is generally not as dramatic as areas with a gentle nearshore slope. Impacts on navigational channels are also less severe than in sheltered environments with gentle nearshore bathymetry.

Exposure of these shorelines to high wave energy also reduces the potential for fine sediment accumulation, such as silts and clays, in the shallow nearshore zone and along the beach. Further, the energetic nearshore environment also prohibits the growth of submerged and emergent aquatic vegetation. Therefore, the combination of these factors reduces the potential for the growth and deposition of aquatic vegetation during periods of low water levels.

Prolonged periods of low water levels can be beneficial to exposed shorelines and the environment. For example: 1) lower water levels widen the exposed portion of the beach, which provides natural erosion protection, 2) a wider dry beach increases sediment supply to the foredune and often results in dune recovery/rebuilding, 3) enhances recreational opportunities for beach users, and 4) completes the cycle of beach erosion and low water recovery that sustains the dynamic habitat found along sandy beaches and barrier beaches throughout the Great Lakes.

Figure 2.6a to d presents a sequence of photographs looking south along the barrier beach at Hillman Marsh, on Lake Erie. During high lake levels in 1998, the barrier beach was almost completely inundated and a breach developed. Refer to the conditions in Figure 2.6a during a mild storm on Lake Erie. Once the storm conditions subsided, the glacial till beneath the sandy barrier and root mats from the eroded vegetation were exposed and are documented in Figure 2.6b. By

2004, following six years of low to average water levels on Lake Erie, the sand beach had returned. Refer to Figure 2.6c. By 2006, it was even wider (Figure 2.6d). These photographs document the significant influence lake levels have on this barrier beach, which is migrating inland due to natural and anthropogenic factors. Further, it highlights the significant impacts water levels have on the visitor experience to this beach, the amount of usable beach area, and terrestrial habitat for native species.

Figure 2.6a Hillman Marsh Barrier Beach During Storm Conditions and High Water (1998)

Figure 2.6b Hillman Marsh Barrier Beach During High Water (Eroding Clay Substrate in Foreground)

Figure 2.6c Sand Beach Returns to Hillman Marsh Barrier During Low Water (2004)

Figure 2.6d Beach Width Increases During Prolonged Low Water (2006)

Figure 2.7 documents embryo dune growth in 2004 on Lake Michigan, south of Michigan City, at the base of a very old eroding relic dune (>1,000 years old). The marram grass has stabilized the aeolian deposit and will continue to support dune building while water levels remain low to average. The growth of this embryo dune diversifies the beach habitat and provides a natural buffer against storm erosion.

Figure 2.7 Embryo Dune Growth South of Michigan City Harbor (August 10, 2004)

Figure 2.8 documents the beach and dune conditions south of Michigan City Harbor. The backshore is a combination of dunes and sandy bluffs, protected with an armour stone revetment. Without shore protection, this shoreline would erode during high lake level conditions, which is why the riparian land owners have constructed the revetment. During low water conditions, there is a beach lakeward of the revetment, which increases the recreational benefits of this shoreline and buffers the shore protection from direct wave attack. Although there are beach benefits to this shore during average to low lake level conditions, when high lake levels return the beach will likely erode and the waters edge will be defined by the shore protection.

Figure 2.8 Revetment at the Base of Eroding Dune, South of Michigan City Harbor (August 10, 2004)

In Figure 2.9, a waterfront home is separated from the lake by a very large concrete seawall, which protects the property from storm activity during high lake levels. During the low water conditions in 2004, a wide beach was present in front of the seawall, which highlights the low water benefits for this stretch of shoreline.

Figure 2.9 Seawalls Protecting Waterfront Development North of Michigan City (August 10, 2004)

3.0 LITERATURE REVIEW AND PREVIOUS STUDIES

Section 3.0 of the report will review relevant literature and related studies for the Low Water Performance Indicator.

3.1 Previous Large Lake Impact Studies

Previous large lake studies have not focused specifically on low water impacts for riparian property, since the impetus for these studies has often been hazardous conditions associated with high lake levels. However, there was some valuable research done on low water impacts for sandy beaches in the Lake Michigan Potential Damages Study. Further, the influence of lake levels on recreational beach width was investigated during the IJC Lake Ontario – St. Lawrence River Study. Both are described below.

3.1.1 Lake Michigan Potential Damages Study

The Lake Michigan Potential Damages Study did not specifically study low water impacts on private property, however, it did investigate the impacts of low water periods or lake level cycles on sandy beaches. Specifically, a methodology was developed to quantify the cross-shore transport of sand (e.g. from beach to nearshore and from nearshore to beach) during rising and falling water levels for temporal periods spanning several years to decades. Figures 3.1 and 3.2 highlight the predictive ability of the tool, known as the Profile Shift Module of the FEPS (Baird, 2003). The theory for the cross-shore re-distribution of sand is based partially on the work of Per Bruun (1983 and 1987) and augmented with in-lake data that documented cross-shore transport of sand during rising and falling lake levels (Hands, 1979 and 1984; Baird, 2001). The predictive capabilities of the tool were validated during a detailed sediment budget study for the sandy coastlines in Allegan and Ottawa Counties, Lake Michigan (Baird, 2003).

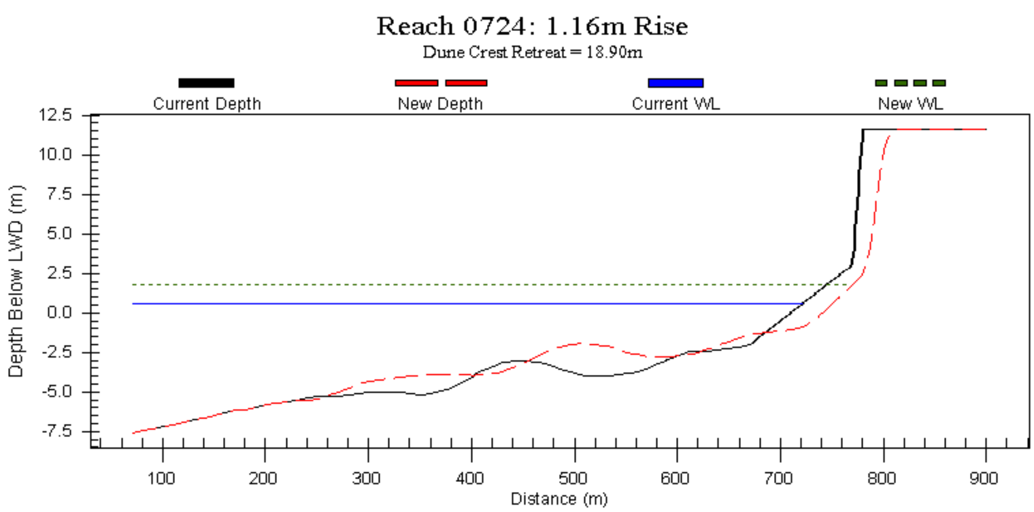

Figure 3.1 Dune Erosion and Cross-shore Re-distribution of Sand During Rising Lake Levels

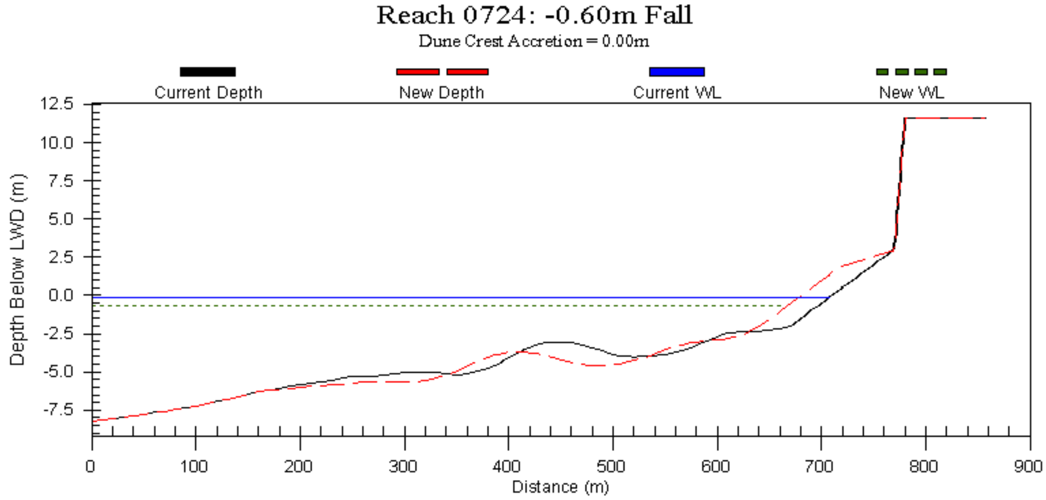

Figure 3.2 Beach Recovery During Falling Lake Levels

The inputs for the Profile Shift Module include: 1) a 2D beach profile, extending lakeward of the depth of closure and landward of the dune crest, 2) toe of beach on x-axis, 3) toe of dune on x-axis, 4) lake level when profile data was collected, and 5) future lake level condition/scenario. Based on the water level difference (i.e. delta between #4 and #5), the nearshore bar is shifted vertically and horizontally as seen in Figures 3.1 and 3.2, while maintaining the overall profile volume. This is a key advancement of the tool over the original Bruun theory, which did not integrate dune erosion when maintaining the overall profile volume. For example, as demonstrated in Figure 3.1, a 1.16 m rise in lake levels results in the landward shift of the nearshore bar and sufficient dune erosion to maintain the original profile volume. Consequently, the model predicts less erosion for larger dunes during a period of rising lake levels than for smaller dunes.

During a period of falling lake levels, as seen in Figure 3.2, the nearshore bar migrates offshore and decreases in elevation. This profile adjustment to the lower lake level regime creates excess sediment in the nearshore and thus the beach increases in volume and width. This response has been observed throughout the Great Lakes since the period of low to average lake levels began in 1998.

3.1.2 Beach Performance Indicator, Lake Ontario

In 2005, Baird completed a visitor survey for two beaches (Sandbanks Provincial Park in Prince Edward County, Ontario, and Hamlin State Park in Monroe County, New York) on Lake Ontario for the Beach Performance Indicator, which was investigated during the IJC's Lake Ontario-St. Lawrence Study. The purpose of the survey was to determine how beach visitation would be affected by changes in beach width due to fluctuating lake levels. Figure 3.1 shows a beach profile at Sandbanks with flags representing various water level elevations along the profile (elevations on Y2 axis) and the visitation distribution for beach users at each elevation (Y1 axis) based on the survey results. As the pink line indicates, visitation was predicted to be sensitive to water levels and thus beach width, with a drop in total visitation for both extreme high and low lake levels. When lake levels were between 1.5 and 0.5 m above Low Water Datum, visitation was above 90% based on the survey.

Economic and visitation data were obtained from: (1) Ontario Parks Park User Surveys and Park Statistic reports, and (2) the New York State Office of Parks, Recreation and Historic Preservation visitation records. The published data indicates the annual recreational value of Canadian beaches on Lake Ontario ranges from $23.5 to $32 million, while the annual recreational value of U.S. beaches on Lake Ontario ranges from $58 to $77 million.

Since the beach survey determined future visitation would be sensitive to lake levels and thus beach width, it can be concluded water levels play an important role on the economic benefits generated by beaches within the limits of the Upper Great Lakes study. Therefore, by extension, the inclusion of low water impacts on recreational beaches, whether municipal/public or part of the State, Provincial or Federal parks system, is important.

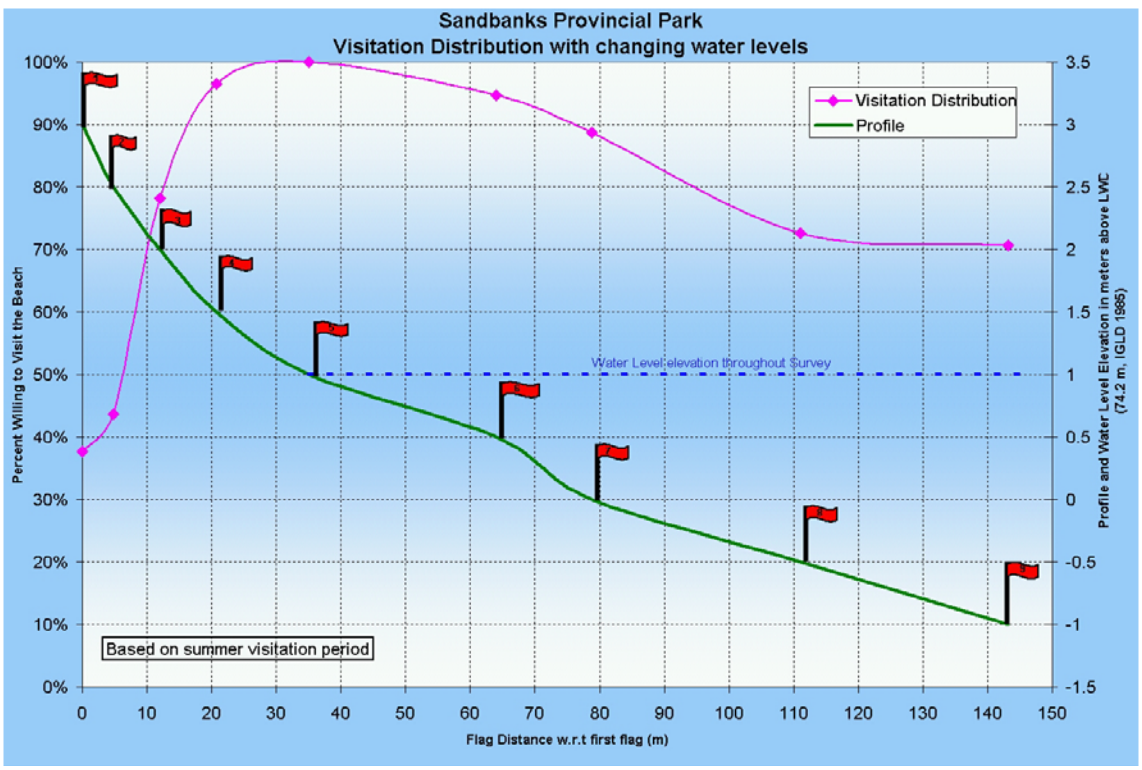

Figure 3.3 Sandbanks Provincial Park Visitation Distribution as a Function of Water Level (Elevation Along Y2 Axis with Flags Representing Varying Water Level Elevation. Visitation Distribution Along Y1 Axis for Water Levels at Each Flag)

3.2 Other Studies

Two additional studies are reviewed that document the economic value of Great Lakes beaches and the role of beach width on market values for ocean front property.

3.2.1 Value of Lake Erie Beaches (1999)

Researchers from Ohio State University and the Ohio Sea Grant Extension Program conducted an economic study at two beaches on Lake Erie: Maumee Bay State Park beach, and Headlands State Park Beach (Ohio Sea Grant College Program, 1999). They surveyed beach users and found that on average, expenditures for single day trip users ranged from $21/trip at Headlands to $34/trip at Maumee (or $3.3 million/year at Headlands and $6.2 million/year at Maumee in local economic expenditures). They also completed a travel cost model and determined that the value of satisfaction at the beaches is $3.5 million at Headlands and $6.1 million at Maumee. Considering the beach area, the study found that each acre of beach is worth $2.3 million at Headlands and $5.5 million at Maumee (combining the economic and satisfaction values). This is significantly higher than riparian owned land which averaged $24,000-$29,000/acre in the area. By extension, considering the sensitivity of beach width and visitation to water level fluctuations, the beaches in the study area will be sensitive to both high and low water levels.

3.2.2 Effect of Beach Width on Market Values (1994)

As mentioned previously, wider beaches can reduce erosion, provide larger zones of transition habitat and more recreational area, as well as provide enhanced storm protection for communities located shoreward of beaches. Rinehard and Pompe (1994) used a hedonic model to look at the effect beach width has on coastal property values along two beaches in South Carolina: Garden City and Surfside Beach. Their study indicated that beach width has a positive effect on the price of nearby housing (a 10% increase in beach width increases nearby home values by 2.6%), with the largest effects seen on houses located near the beach. Similar effects may exist for waterfront property along the open coast of the Great Lakes.

3.3 2008 CDM Federal Programs Corporation Scoping Report

CDM conducted an extensive literature review for the U.S. Army Corps of Engineers and the CZTWG of the IUGLS to define the potential impacts of low water on riparian landowners and the associated methodologies for evaluating those impacts. From a review of sixty-seven documents, it was concluded that properties with more lake-frontage (proximity), easier access and better views of the lake, have higher price premiums associated with them. It was also concluded that lower water levels lead to lower property values.

Many of the reviewed documents assessed the impact of low water levels on housing prices around reservoirs or other small bodies of water. The observed trend of a decline in property values with decreasing water level may be representative of shorelines located in the embayments around the

Great Lakes (e.g. Green Bay and Saginaw Bay) or locations that feature a gentle nearshore slope and low wave action.

One study reviewed by CDM (No. 26, Beach Quality and the Enhancement of Recreational Property Values, by Pompe and Rinehart (1993) describes how property values in South Carolina increase with increasing beach width (which may be analogous with a situation of falling lake levels). A one foot width increase of beach increased values of developed and undeveloped lots by $558 and $754, respectively. This trend of increasing property values with increasing beach width appears to be most representative of waterfront property along the open coast of the Great Lakes.

Ultimately, further lake-specific technical studies are required to establish the trends for the upper Great Lakes study area. Given the vast geography and range of shoreline conditions (e.g. geology, nearshore slope, and wave exposure), it is possibly that the impacts of low water on property values will vary throughout the system.

4.0 SUMMARY OF KEY FINDINGS

Low water can impact shorelines positively (habitat creation, beach width increases, increased property values) or negatively (decrease aesthetics, poor water accessibility, and lower property values). Based on the initial review completed for this report, two general conclusions are provided: (1) areas with gently sloping nearshore bathymetry, low wave energy (e.g. embayments) and developed shorelines will be impacted negatively by periods of low water, and (2) exposed beach shorelines with a steep nearshore slope and high wave energy will benefit from periods of low water.

Beach visitation generates significant economic benefits within the Great Lakes and beach width and visitation have been linked to lake level fluctuations. Therefore, the impacts of low water levels on the beaches within National, State or Provincial Parks should be considered in future studies. There will be impacts to beaches outside these government parks too, however, without visitation statistics, it is difficult to make quantitative predictions about impacts due to lake level fluctuations.

In addition to impacts on beaches and property values, other low water impacts in the coastal zone include navigation channel sedimentation and increased dredging costs, negative impacts to commercial and industrial lands due to restricted access, drinking water intakes and outfalls, and industrial operations that withdraw and discharge water into the lakes. To put all of these impacts in context, further technical studies should focus on a wide range of shore types and land uses throughout the study area.

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