Managing Coastal Hazard Risks On Wisconsin's Dynamic Great Lakes Shoreline

WISCONSIN COASTAL MANAGEMENT PROGRAM

MANAGING COASTAL HAZARD RISKS

ON

WISCONSIN'S

DYNAMIC GREAT LAKES SHORELINE

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Ozaukee County – 1987 photo source: Wisconsin DNR
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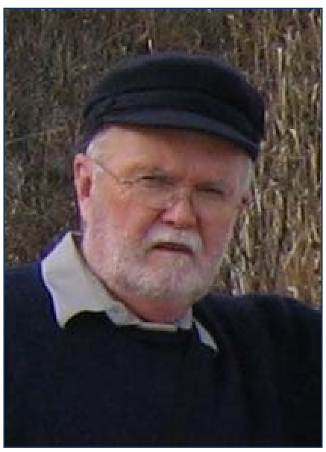
THE WISCONSIN COASTAL MANAGEMENT PROGRAM, part of the Wisconsin Department of Administration, and overseen by the **WISCONSIN COASTAL MANAGEMENT COUNCIL**, was established in 1978 to preserve, protect and manage the resources of the Lake Michigan and Lake Superior coastline for this and future generations.

Dedication

This report is dedicated to co-author Phil Keillor who passed away during the writing of this report. Phil was the first coastal engineer to graduate from the University of Wisconsin and was the Coastal Engineer for the Wisconsin Sea Grant Institute for 32 years. Rip currents and water levels; landslides and eroding shorelines; contaminated sediments and lakebed erosion: Phil became an expert on them all.

His passing reminds us of the risks in life. Phil died taking a risk – strapping two metal edges to his feet and skating on a frozen pond with his granddaughter. He never would have gotten on a bicycle without a helmet. Yet, ice skating was something he did so frequently as a child, that to him, it didn't carry the same feeling of risk.

This is ironic for someone who frequently talked about risk. He would tell a story of how he and his brother Garrison were sea kayaking in caves on Lake Superior. In the caves they had to duck their heads to get through. Shortly after they exited, a passing ship sent a five foot wave against the shore. Had that ship passed 15 minutes earlier, they could have been casualties of a hazard of which they were not aware.



In the same fashion, he felt landowners along Wisconsin's coasts weren't aware of the risks they were taking by building so close to unsafe bluffs – bluffs that could stand tall for decades and then have a 50 foot wide chunk tumble down to the beach in a matter of minutes.

Phil was steadfast and diligent in his efforts to be an information source to coastal landowners. He felt that when people were given their permit to build, they then assumed it was safe to build there. If there were coastal hazards that could impact their property, it was his job to provide them information on how to deal with those hazards.

After retiring from the University of Wisconsin Sea Grant in 2003, Phil remained active in the coastal engineering community including several projects with the Association of State Floodplain Managers (ASFPM). In addition to this report, he was co-author of ASFPM's Coastal No Adverse Impact Handbook. He also volunteered his time to help ASFPM develop policy on adaptation to climate change.

In the final stages of this project, Phil concentrated heavily on the impact of climate change on coastal hazards. He felt it was important to inform landowners of the increased risks from landslides and that a change in weather patterns could cause high lake levels to return. This project enabled Phil and me to discuss the hazards posed by Lakes Superior and Michigan with local officials who are charged with managing development in their jurisdictions. It provided a final opportunity for them to absorb a bit more of Phil's coastal knowledge.

Phil lived his life with integrity and passion. He cared deeply about family and the community in which he lived. I miss him and his calm presence. My mantra as I completed this report was:

"How would Phil do it?"

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Foreword

High Great Lakes water levels in the 1950s and again in the 1970s caused widespread bluff recession, damaging millions of dollars' worth of coastal development. The Wisconsin Coastal Management Program (WCMP) funded several studies following this damaging high lake level period, including the Wisconsin Shore Erosion Plan: An Appraisal of Options and Strategies by Springman and Born (1979). In that report they indicated that at that time about 150 miles of Wisconsin's Great Lakes shoreline had serious erosion problems and that between 1972 and 1976 there were damage losses of $16 million (50 million in today's dollars).

The Wisconsin Shore Erosion Plan identified erosion hazard areas, analyzed various structural and nonstructural damage reduction options, and recommended state policy to reduce erosion hazard damage. The focus of the plan was on before-the-fact strategies rather than after-the-fact emergency measures due to the fact that "erosion control or structural strategies have generally not proved cost-effective over the short and long term". The report stated that – "In spite of the controversial nature of structural approaches, e.g. cost effectiveness, adverse impacts, shoreline management implications, the present state policy framework does little to officially discourage structural approaches." The report highlighted the approach utilized by the California Coastal Commission wherein structural approaches can only be considered after all other non-structural options have been examined. However, it was recognized that there is a continuing amount of riparian and local government interest in structural approaches.

Non-structural options such as building setbacks and hazard area zoning were highlighted as viable options in developing and rural areas. The plan noted that one non-structural option, relocation, was receiving greater consideration for developed areas and that land and water management practices were increasingly being incorporated into preventive approaches. In particular, bluff dewatering and vegetative stabilization techniques were being used more frequently. The plan recommended coastal erosion setbacks in undeveloped areas and acquisition, relocation and hazard disclosure for developed areas.

Yanggen (1981) followed up the work of Springman and Born by developing a model coastal recession setback ordinance. While the Wisconsin legislature has not to date enacted legislation making coastal setbacks mandatory statewide, communities have been encouraged to adopt them to protect critical facilities, infrastructure, and new development from coastal hazards.

When high water levels on the Great Lakes returned in 1985, a number of counties amended their local ordinances to include provisions for increased setbacks in areas with unstable bluffs. The counties that took a progressive step toward managing risks were Douglas, Bayfield, Kewaunee, Manitowoc, Sheboygan, Ozaukee, and Racine.

The adoption of increased setbacks along the Great Lakes coastline has significantly reduced the risk to new development in the unincorporated areas of these counties. However, new development on the rest of Wisconsin's Great Lakes coastal bluffs is not subject to setbacks that address bluff instability or coastal recession.

The intent of this report is to assess coastal hazard risks, identify ways to ensure new development is adequately set back from coastal hazard areas, and recommend ways in which the risks to existing development along the coast can be reduced.

Introduction

Wisconsin is a water-rich State. The State has thousands of miles of streams, thousands of lakes, and is bordered on the west by the Mississippi and St. Croix Rivers. In addition, on the north and east, Wisconsin has several hundred miles of Great Lakes coastline. The focus of this report is on the unique hazards associated with the Great Lakes coastline.

The Great Lakes have long been a navigation corridor and have developed into one of the world's greatest inland waterway systems. Coastal areas are a popular destination for tourism and recreational activities. Wisconsin's natural coastline has a fringe of beaches are popular recreational areas. The State of Wisconsin and communities in the State have established 192 public beaches on Lakes Superior and Michigan. Nationwide people spend over $70 billion annually on visits to coastal beaches (Houston, 2008).

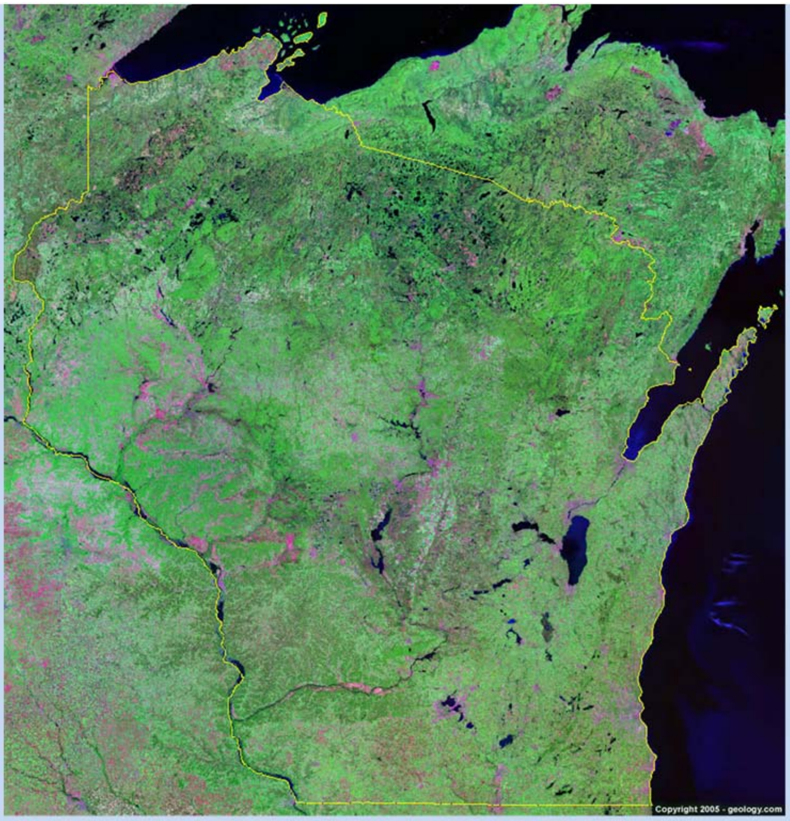


Figure 1 - Wisconsin Landcover

A bit over a third of the people in Wisconsin (2 million) live in the 15 coastal counties along Lake Michigan and Lake Superior. They are drawn to the lakes due to the economic and recreational opportunities the lakes provide. The Great Lakes coasts are attractive locations for second homes and investment properties. Property values along the coast are substantially greater than those of non-coastal properties.

Development pressure on the Great Lakes coastline continues to increase with larger and larger homes being built in this dynamic environment. However, living on the coast poses some risks. People living on Wisconsin's Great Lakes coastline are vulnerable to lake level changes, waves, storm surge, floods, ice shove and landslides.

This report assesses risks associated with coastal development on the Great Lakes and provides some guidance on managing those risks in light of a changing regional climate.

The Great Lakes System

The Great Lakes form the largest system of fresh surface water on earth, containing 18 percent of the world supply. Lake Superior, with an area of 31,700 square miles, has the largest surface area of any lake in the world. With a maximum depth of just over 1,330 feet, it is the deepest of the Great Lakes. Lakes Michigan and Huron are hydraulically connected at the Straits of Mackinac and therefore at times are identified as one lake (i.e. Lake Michigan-Huron).

Figure 2 - States/provinces of the Great Lakes basin

Water in the Upper Great Lakes descends 32 feet from Lake Superior through Lake Michigan-Huron to Lake Erie, and then into the Niagara River which plunges over Niagara Falls 325 feet into Lake Ontario. The four lakes above Niagara Falls are called the Upper Great Lakes. A portion of the water entering the Niagara River is diverted through turbines which generate an average of 24 million kilowatt hours of electricity annually.

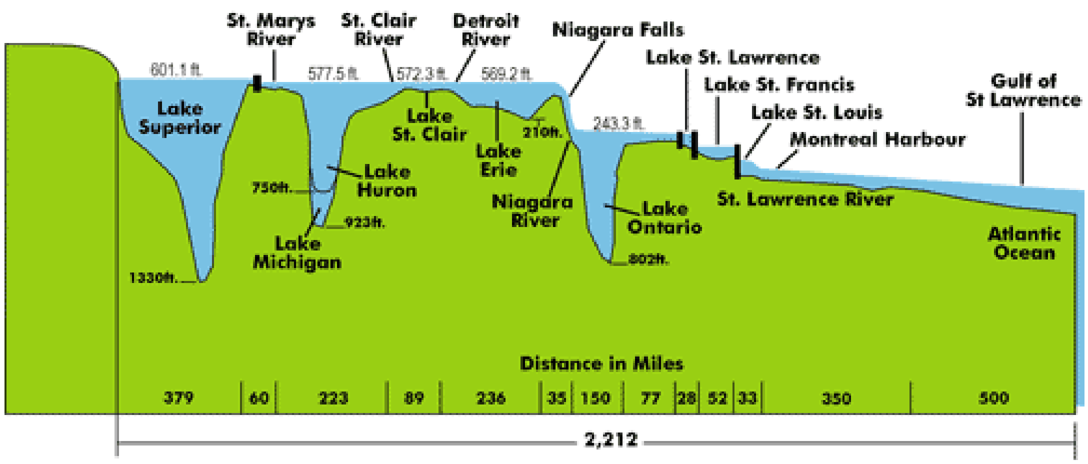
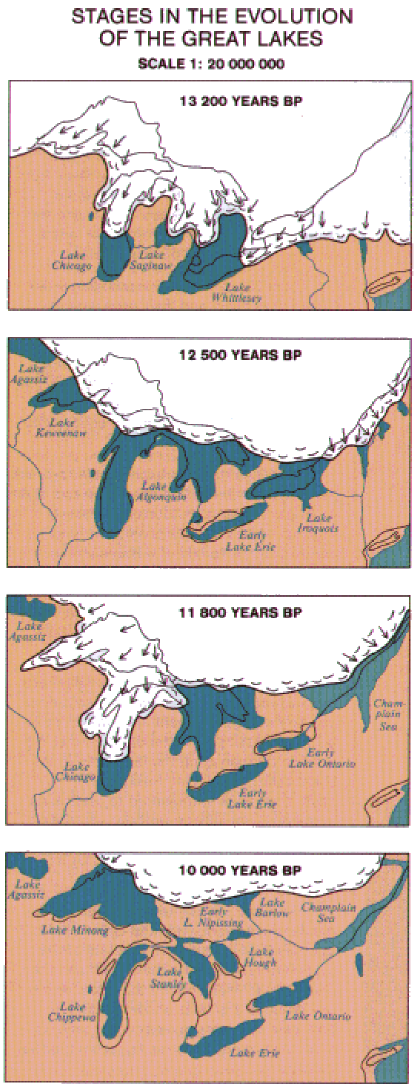


Figure 3 - Great Lakes System Profile

How the Great Lakes Were Formed



NOTE:
The maps on the left are "snapshots" of a continuously changing situation during the retreat of the Wisconsin icesheet. They should not be viewed as a simple sequence, since many intermediate stages are omitted. The letters BP denote before present.

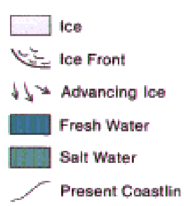


Figure 4 - Glacial extents

Figure 5 - Co-author Keillor next to glacial deposits on the Lake Michigan coast [Photo by Alan Lulloff]

Continental glaciers advanced over central North America beginning more than a million years ago. As they crept forward, these over-a-mile-thick glaciers gouged out the Great Lakes basins. Alternating warming and cooling periods caused the glaciers to repeatedly melt back and advance. When the last glaciers in the region melted between 14,000 and 10,000 years ago, they left behind deposits of sand, silt, clay and boulders (see Figure 5) in various mixtures in the region. Glacial till are sediments composed of a wide range of grain sizes deposited directly by the glacier.

The shores of the Great Lakes include wetlands, low-to-high cohesive bluffs, low-to-high rocky cliffs, river mouth barrier bars, low sandy banks and sand dunes. The glacial till that makes up much of this coastline range from cohesive deposits with significant amounts of clay to unconsolidated soils with considerable quantities of glacially mixed sand, gravel and rock chunks. All of which are highly erodible. In geologically young lacustrine systems of this nature, which are steep-sided and deep, erosive forces work to erode the edges, smooth the boundaries, and fill the middle of the lake.

Lake Superior bluffs and uplands have relatively high clay content that reduces stability. Therefore stable slope angles along Lake Superior are generally flatter than the coastline of Lake Michigan. The soils are young and are undergoing a high rate of natural erosion. When man settled in the area logging, construction and agricultural activities removed the established vegetation accelerating this already high rate of erosion in the Lake Superior watershed. (U.S.EPA 1980)

Great Lakes Coastal Dynamics

The Great Lakes shores are fundamentally different from ocean shores in a number of ways. First, the water is fresh, making the lakes a desirable source of drinking water. Second, while the tides are much smaller (~ 1 inch), depending on wind conditions and ice cover, periodic seiches can be significant (up to 10 feet). Third, unlike ocean coasts, where sea level is relatively constant or gradually trending higher, Great Lakes water levels vary annually and over multi–decade cycles. Varying water levels have a fundamental influence on the portion of the shore face that is exposed to wave energy and the exposure of bluffs to wave attack. The relatively short fetches on the Great Lakes produce erosive, choppy wave conditions during storms, but there are limited long-period swell waves that naturally rebuild beaches during calm conditions (Morang 2004).

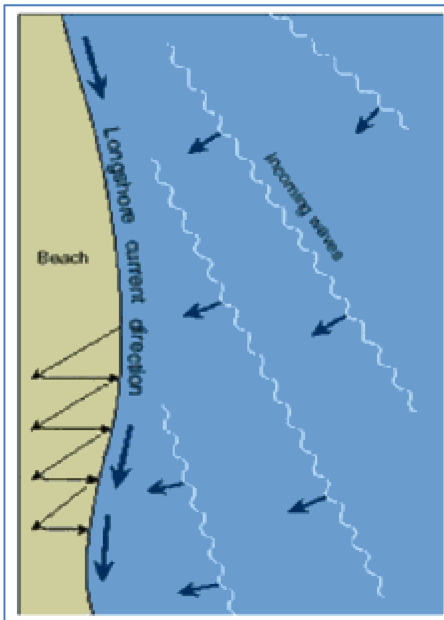
Beyond the erosive nature of the waves, the shoreline is highly vulnerable to shore erosion largely because much of the coastal landforms are made up of mixed, unconsolidated glacial materials such as gravels, lake-deposited clays, and tills. The Lake Michigan coastline includes bluffs ranging from five feet in Kenosha County to 80-100 feet near Whitefish Bay. Nearly one-half of the Lake Superior shoreline consists of high clay bluffs some near 200 feet high. Most of these bluffs are made of unstable glacial deposits. Bluff erosion and slumping result in a continuously changing shoreline. While this process provides sand that builds beaches it can undermine development constructed too close to a bluff.

Beach Behavior

Much of the coastline of the Great Lakes has a beach zone – a strip of unconsolidated material found at the margin of the coast. Orin Pilkey provided the following description of a beach in his 1996 book – *The Corps and the Shore*.

With almost incredible tenacity, a beach, a mere strip of easily moved sand, withstands the constant pounding of waves, the tug of currents and the tear of the wind. The beach is a perfect buffer. It retreats when things get tough during a storm and returns when the weather is calm. It shapes itself to best absorb the pounding storm waves and forms a different shape when the waves are small. It's a unique and amazingly flexible natural environment. It is so dynamic that changes of the shape and position of the beach are described as beach "behavior". A major goal of coastal engineering and coastal geology is to predict how beaches behave. All beaches exist in dynamic equilibrium involving four major controls: (1) wave energy; (2) quality and quantity of the sediment supply; (3) beach shape and location; and (4) water level. (Pilkey, 1996)

Beaches are an invaluable social, economic, natural and cultural resource. In addition to providing a great place to recreate, beaches and associated dunes act as buffers that absorb the energy of coastal storms thus reducing damage to public infrastructure, private development and coastal bluffs.



Sand is transported alongshore by currents formed when waves strike the beach at an angle. Sand is also carried along the shore in a zigzag pattern by waves rushing onto the beach and back to the lake.

Figure 6 - Waves cause littoral drift

Littoral Drift

The natural process of the transportation of soil particles (i.e. sand, silt, and clay) along the coastline creates a dynamic coastal environment. Wind, waves and storms keep these materials in constant motion in every direction on the beach. Soil particles are moved offshore to deeper water by bottom currents, which are usually storm-related. Wind blows sand from the beach into nearby dunes where it is trapped by dune vegetation. But by far the largest volume of soil particles is carried by longshore currents. Longshore currents are formed as waves strike the shoreline at an oblique angle, forcing some of the surf-zone water to move laterally. The movement of soil particles with longshore currents (called littoral drift) is influenced by the circulation patterns in the Great Lakes.

The currents and waves which transport these particles are driven by wind. The intensity of the winds generated by storms on the Great Lakes plays a primary role in determining the amount of erosion that occurs in any given year. Lake levels influence whether waves attack low on the beach face or high on the back beach (at the base of the erodible dune-bluff).

The strongest and fastest currents found in the Great Lakes are concentrated around the edge of the lakes in a narrow "breaking wave zone". This zone - which starts in water depths of 18 to 20 feet and extends to the beach - is the location of the greatest volume of soil particle transport. If waves approach the coast straight on—directly onto the beach—movement is primarily onshore and offshore. However, when storm waves approach the coast at an angle, water currents move along shore and can carry soil particles in the direction the waves are moving. Sand is an important beach building material in soil particles moving with littoral drift. The amount of sand that moves depends on sand availability, the size of the waves, and the length of time the waves are present to drive the water currents in one direction.

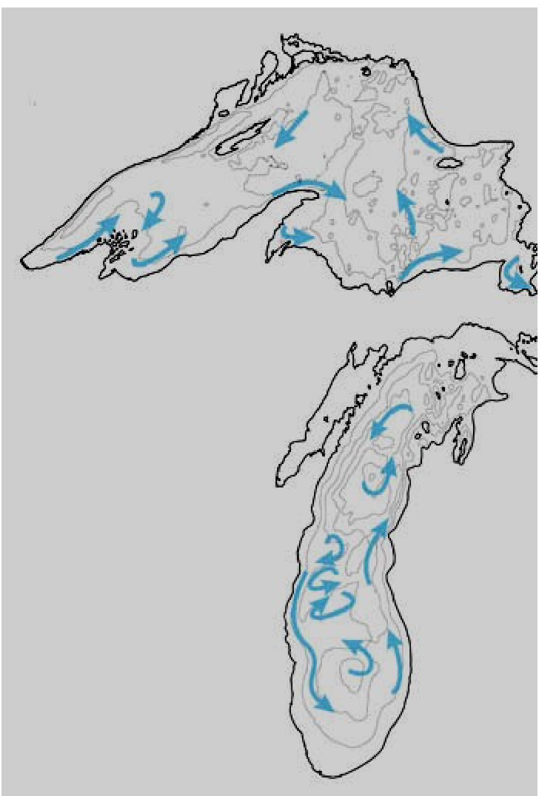


Figure 7 - Mean Summer Circulation - Lake Superior and Lake Michigan – [Source – Beletsky 1999]

Wisconsin's Lake Michigan coast is comprised of sandy beach and erodible bluffs from the Sturgeon Bay canal to the Illinois border. The littoral drift along this coastline is generally north to south. From the Sturgeon Bay Canal north to the tip of Door County and down through Green Bay, the coast is limited to bays and clay banks.

Like Lake Michigan, the Lake Superior coast has erodible bluffs - although portions of the Bayfield County coastline consists of exposed bedrock. Littoral drift on the Lake Superior shoreline is generally west to east.

Erosion and the Sediment Budget

Erosion is part of the natural littoral process. The source of most of the sand in the littoral zone is from the erosion of the bluffs and dunes. This sand builds and maintains beaches, offshore bars and the overall beach profile. These features dissipate wave energy, and help reduce coastal erosion.

As the Great Lakes coastline became urbanized after the mid-1800s, residents, industries, and municipalities attempted to arrest bluff erosion using various types of structures. Some of these protection measures worked temporarily, but they aggravated the erosion problem by reducing the supply of sediment that could be reworked and transported along the shore by waves. Equally significant are the jetties built at many harbors to keep sediments moving along the shoreline from filling navigation channels. The sediments accumulate updrift of these jetties preventing them from continuing their movement along the coast.

Before the industrial era, the material eroded from bluffs and supplied by rivers provided an abundant sand supply for Great Lakes beaches. As an example, when the first European settlers came to the southern shore of Lake Erie in 1796, the wide, continuous sandy beach of the lake was used as a road (Mather 1838). Today the southern shore of Lake Erie is heavily armored and with few beaches remaining. Most of the Great Lakes coasts are severely sand-starved compared to the conditions that existed 200 years ago.

In addition to the more obvious adverse consequences associated with narrower beaches, reductions in sand supply have an impact on the sand dunes and cohesive shore types that make up most of the erodible coastlines of the Great Lakes. On cohesive coasts, the loss of sand cover in the near shore exposes the underlying till to erosion of the lakebed. This allows more waves to reach the beach, causing the erosion to gradually progress to the beach and bluff in a process termed *profile adjustment*. Erosion of the lakebed (or downcutting) is a common phenomenon along cohesive shorelines of the Great Lakes (See Figure 8).

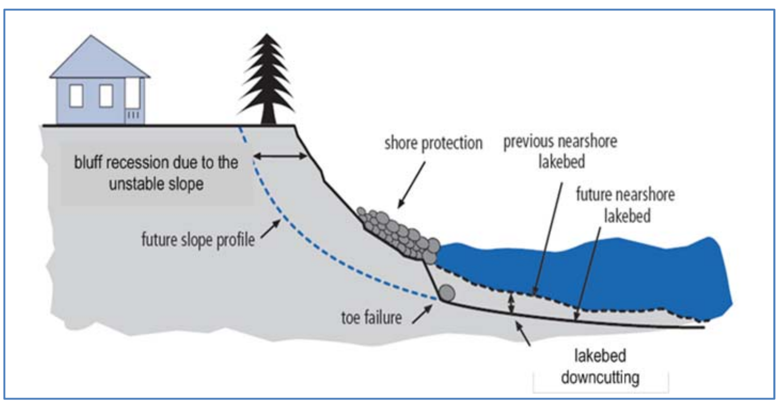


Figure 8 - Coastal Bluff with Lakebed Downcutting

The underwater erosion of the lakebed controls the rate at which erosion and recession of adjacent cohesive bluff and bank shorelines takes place. Recession of the bluff or bank occurs as a result of wave erosion at the toe. If this recession occurred without lakebed downcutting, a shallow platform would be left as the bluffs receded. Waves would then dissipate all their energy on this platform, thus reducing their ability to erode the bluff toe. However, in areas with lakebed made up of cohesive soils, lakebed and shoreline erosion proceed together, allowing large waves to reach the toe of the bluff. The rate of vertical erosion at a point on the profile can be predicted from the profile slope, where the steeper the slope, the greater the erosion rate. This accounts for the concave shape of most cohesive shore profiles. Erosion rates are the highest close to shore, where the slope is the steepest, and are lowest in deeper water offshore, where the slope decreases.

Fluctuation of Lake Levels

Historical records show Great Lakes water levels can vary significantly over several decades. Water levels in the Great Lakes fluctuate in response to precipitation patterns, regional climate changes and outflows from the basin. The National Oceanic and Atmospheric Administration (NOAA) has nine water level gages on Lake Michigan and Superior that have been recording still water levels since 1860.

Figure 9 - Water Level Gages on the Great Lakes (Note: DFO refers to Fisheries and Oceans Canada)

Over this 150 year timeframe, the differences between the record high and record low monthly mean lake levels are 6.2 feet (1.9 meters) for Lake Michigan-Huron and 3.8 feet (1.2 meters) for Lake Superior. Great Lakes water levels tend to follow a cyclical pattern. The Great Lakes system experienced high water levels in the 1870s, early 1950s, early 1970s, mid-1980s and mid-1990s. Low water levels were experienced in the late 1920s, mid-1930s, mid-1960s, and from the late 1990s until 2014.

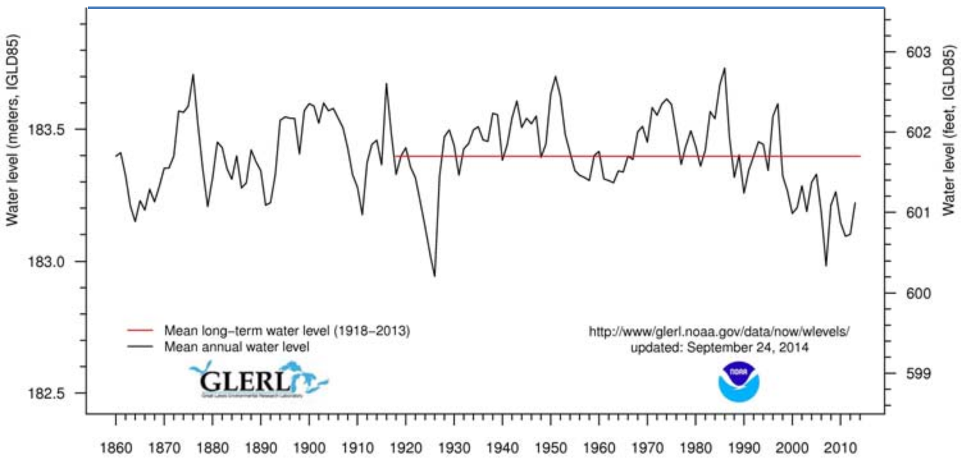
During periods of relatively low water levels (such as experienced recently), some of the areas of the exposed beach were underwater during the high water years in the 1980s. These areas experience a rebuilding as sand borne by wind and waves accumulates and forms ridges. Wind-blown seeds replant the newly-exposed beaches and ridges with vegetation.

Table 1 summarizes the time frames associated with some of the most dramatic water level changes that have occurred during 150 year monitoring record.

Total Change (feet)	Time Span	Annual Rate of Change (ft./yr.)	Period of Change
Lakes Michigan-Huron			
+ 3.5	17 months	+2.5	Feb. 1928 - July 1929
+3.1	18 months	+2.1	Feb. 1951 - Aug. 1952
+3.2	18 months	+2.1	Feb. 1959 - Aug. 1960
+5.6	8.5 years	+0.7	Jan. 1965 – July 1973
-4.8	3.5 years	-1.4	July 1929 – Jan. 1933
-4.0	2.3 years	-1.7	Oct. 1986 – Feb. 1989
-4.7	3.5 years	-1.3	Aug. 1997 – Dec. 2000
Lake Superior			
-3.3	2.5 years	-1.3	April 1926 – Oct. 1928
-2.8	4.5 years	-0.6	Aug. 1926 – Mar. 2001

Table 1 - Rapid Historic Lake Level Changes Source: NOAA Hydrograph for the Great Lakes

The following figures illustrate the dynamic nature of the water levels on Lake Superior and Lake Michigan-Huron. Water levels fluctuate less on Superior because it has an outflow control structure.

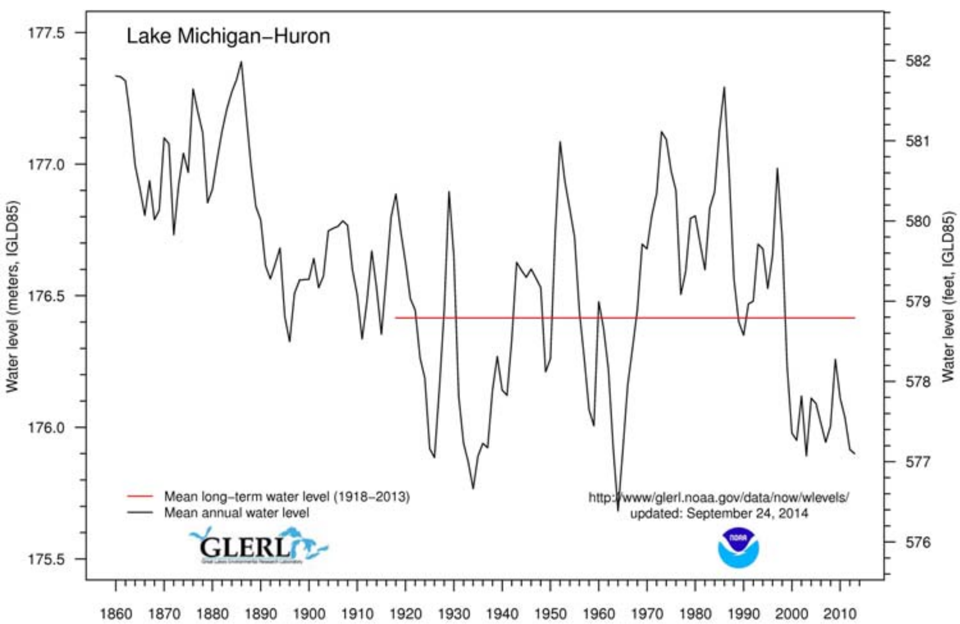


Highest Level: – 603.38 ft.
July 1986

Lowest Level: – 599.48 ft.
Winter 1926

Water Level Range – 3.9 feet

Figure 10 - Lake Superior Mean Annual Water Levels (IGLD85)



Highest Level: – 581.35 ft.
Summer 1986

Lowest Level – 576.02 ft.
Jan 2013

Water Level Range – 6.3 feet

Figure 11 - Lake Michigan Mean Annual Water Levels (IGLD85)

Figure 12 - Eagle Harbor - Ephram, WI

Low water levels can be problematic for navigation and water supply intakes, and limit riparian landowners' access to the lake. High lake levels, which occur roughly every ten to twenty years, cause widespread flooding and bluff erosion. During these high water periods, storm surge and storm waves can cause severe property damage and shoreline erosion. The threshold level for significant damages is 579 and 601.5 feet IGLD for Lake Michigan-Huron and Superior respectively (Springman and Born 1979). Areas on the Great Lakes that experience chronic flood and erosion damages were typically constructed during times of low lake levels. (OMNR 2001)

Storms

Low-pressure systems or cold fronts moving through the Great Lakes can generate large waves, storm surge (often called seiche on the Great Lakes) and rare, large-edge waves. These storms have caused hundreds of ship wrecks. The most famous is the sinking of the American Great Lakes freighter the SS Edmund Fitzgerald which sank in a Lake Superior storm on November 10, 1975. The storm caused near hurricane-force winds and waves up to 35 feet high.

Flooding

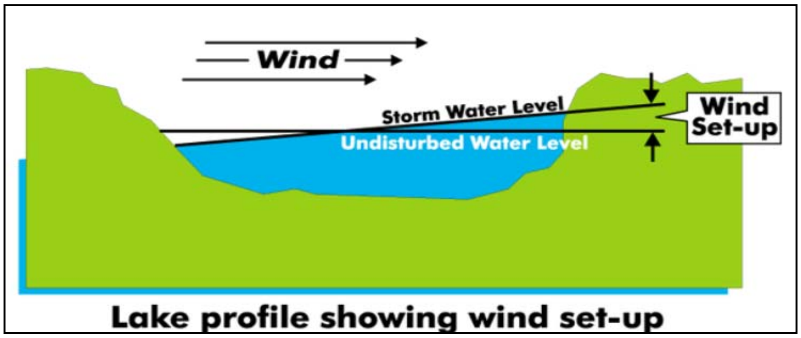


Figure 13 - Sustained winds cause water levels to rise downwind and lower up wind

Flooding affects all of Wisconsin's coastal counties. When lake levels are high, wind set-up, wave height, and wave run-up influence the severity of coastal flooding. Wind set-up, also known as storm surge, occurs when sustained high winds from one direction push the water level up at one end of a lake, which makes the level drop by a corresponding amount at the opposite end. As the storm passes the water sloshes back. This seiche effect on the Great Lakes is a result of quick-moving squall fronts generating the oscillation of the waters. Storm surges and damaging wave action and run-up are a function of wind speed, direction, duration and fetch (the distance waves travel before striking a coastline). In areas with flat slopes waves move inland as the lake bottom absorbs the wave energy and dampens wave heights. When waves strike a relatively steep structure, the waves can splash up and over the structure (called wave run-up).

Figure 14 - Wave run-up in Superior, WI

Along Lake Michigan, coastal flooding is a serious issue in southern Kenosha County and along the southern end and western shore of Green Bay where sustained winds out of the northeast can cause a significant storm surge at the southern end of Green Bay. On Lake Superior, northeasterly winds blowing down the length of the lake can cause flooding in the City of Superior, while winds blowing into Chequamegon Bay from the north can cause flooding in the City of Ashland. Flood hazards are depicted by the Federal Emergency Management Agency (FEMA) on maps called Flood Insurance Rate Maps (FIRMs). FIRMs include flood inundation, wind set-up, and in some cases wave heights or wave run-up.

Ice Shoves

During the winter, as the temperatures of the lakes fall, ice covers significant portions of the Great Lakes. Ice damage to shoreline property is often caused by the "shoving" action of an ice sheet. When rising air temperatures warm the ice, the expanding ice sheet pushes against the shore creating ridges (also known as "ice shoves" or "ice ramparts"). Alternate warming and cooling of an ice sheet can possess enough power to push houses off their foundations.

Figure 15 - Ice shoves on Green Bay [Photo by Dick Koch]

Another form of ice damage can occur during the breakup of lake ice in the spring. Complete melting of lake ice cover occurs first near shore. The ice sheet is free to float on the water and drift with the wind. When a wind-blown ice sheet collides with the shore, it can exert great pressure and push heaps of ice on shore. Mounds of wind-blown ice can pile up on the shoreline, leading to damage of property. Ice shoves and ice mounds are especially problematic during high water periods.

Figure 16 - Ice ramparts on Lake Superior [Photo by Alan Lulloff]

Ice ramparts frequently form on the Lake Superior shoreline. Ramparts typically form on shorelines exposed to powerful wind and waves that have a beach to initiate ice accretion. Sand, pebbles and cobbles are incorporated into ice ramparts during large-wave winter storm ice building episodes. During periods of melting these materials become concentrated on the surface, as can be seen in the photograph on the left.

Coastal Erosion

Much of the Wisconsin coastline consists of relatively high (50 to 200 feet) bluffs composed of glacial till and glacial lake deposits that are prone to landslides, surface rill, and soil creep. Landslides are prompted by heavy rainfall, stormwater runoff and groundwater outflow. Surface rills are shallow incisions into topsoil layers caused by surface runoff. Creep is the gradual downslope shifting of the soil prevalent in the clay bluffs along Lake Superior.

Bluffs are most vulnerable to failure when groundwater in the bluff is at its highest level. This is due to the fact that water in the bluff lubricates soil particles and reduces their stability. Below the groundwater table, water reduces the stability to half compared to unsaturated conditions (WCMP 1977). To determine the potential for bluff failure and the appropriate stable slope angle, slope stability analyses need to identify the highest groundwater level that a site will likely experience.

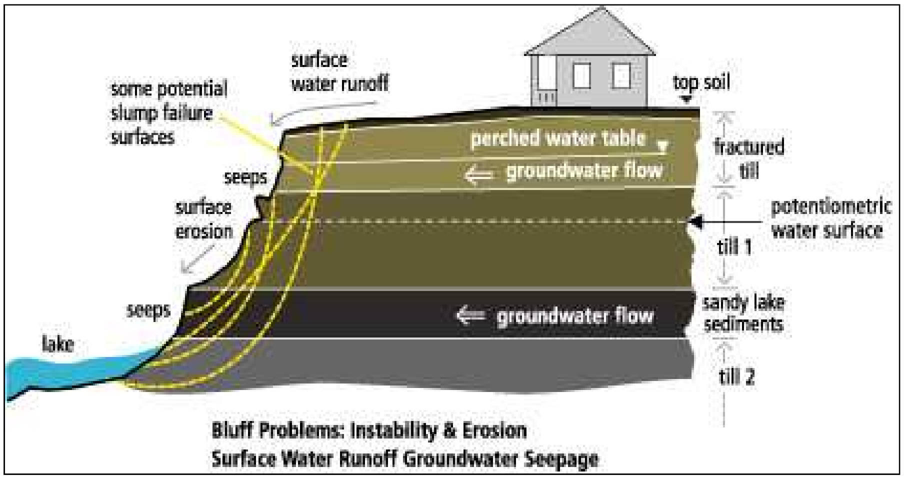


Figure 17 - Cross Section of Coastal Bluff

Another input in slope stability analyses is the safety factor desired for the analysis. A safety factor of 1.0 identifies a condition of “imminent collapse”. Where Infrastructure and large buildings are involved, safety factors higher than 1.0 should be used due to the significant consequences associated bluff failure in these situations. A factor of safety of 1.5 is generally used to define a stable slope, or alternatively to define the “safe” set-back distance for permanent structures or valuable infrastructure from an unstable slope. (Ottawa, 2013)

Shoreline erosion is less during periods of low water levels except in the nearshore zone. This relationship was documented in *An Assessment of Lake-Level Fluctuations on Beach and Shoreline Changes* (LaValle 2000). The results illustrated that over the 18-year period of the study, fluctuating lake levels were associated with shifts in shoreline position and the development of various aggradation and degradation states at the beach. A sustained rapid rise in lake levels initiates an erosional sequence which persists even after lake levels start to decline. When water levels remain low for long periods, the beach and shoreline adjust from unstable, erosional state to an aggradation state. (LaValle, 2000)

While the erosion of banks and bluffs on the shoreline decreases during periods of low lake levels and increases during high lake levels, the opposite is true of nearshore lakebed erosion. During periods of low lake levels, the nearshore lakebed at a given location is subject to higher water velocities from wave motion. The zone of wave breaking where erosion is highest occurs farther offshore than during high lake level periods. When high water levels return, the water depth close to shore is greater than it was during the previous high water period, increasing wave impacts on the shore.

Shoreline Recession

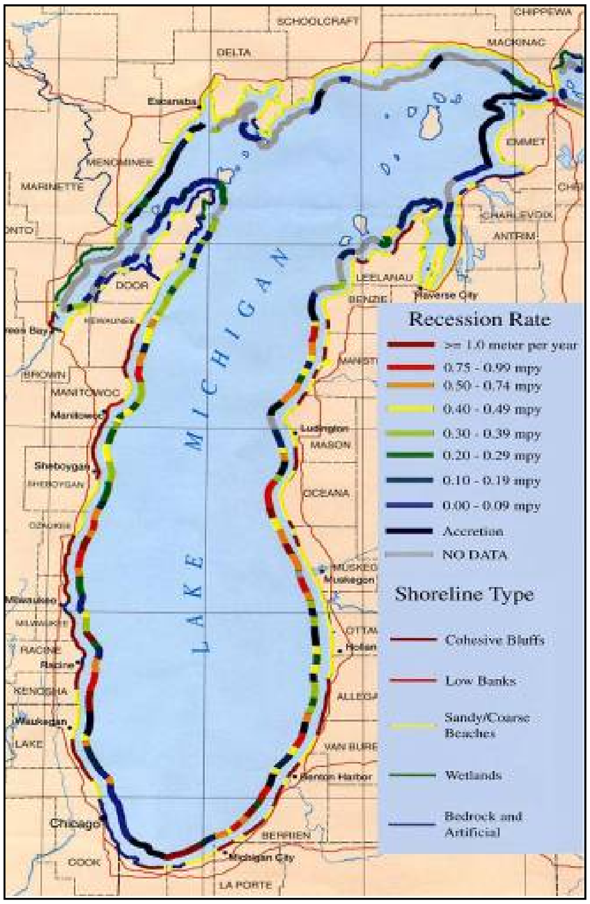


Figure 18 - Lake Michigan Recession Rates and Shoreline Types [Source - Pope el al., 1999]

The terms *erosion* and *recession* are often used interchangeably. However, they are not the same. Recession is the landward movement of a feature, such as a bluff or dune crest, while erosion is the wearing away of land or lake bottom. Recession is expressed as a distance or a change in distance, while erosion is expressed as a volume or a change in volume. Recession can be thought of as a consequence of erosion.

Shoreline recession rates are usually determined by comparing aerial photographs taken on different dates. In areas with cohesive bluffs, these comparisons can be misleading because of the length of time (lag) that usually occurs between erosion and bluff-top recession. Coastal erosion occurs over the area roughly from the face of the bluff out into the nearshore region to about the 30-foot water depth. As a result, erosion processes (particularly those that occur on the nearshore lake bottom) often do not become apparent as bluff crest recession until days, weeks, months, or even years have passed. Coastline recession, particularly bluff crest recession, does not occur at a constant rate. It is not uncommon for a reach of coastline to have no bluff crest recession for months or years and then experience severe bluff slumping over a period of days or weeks.

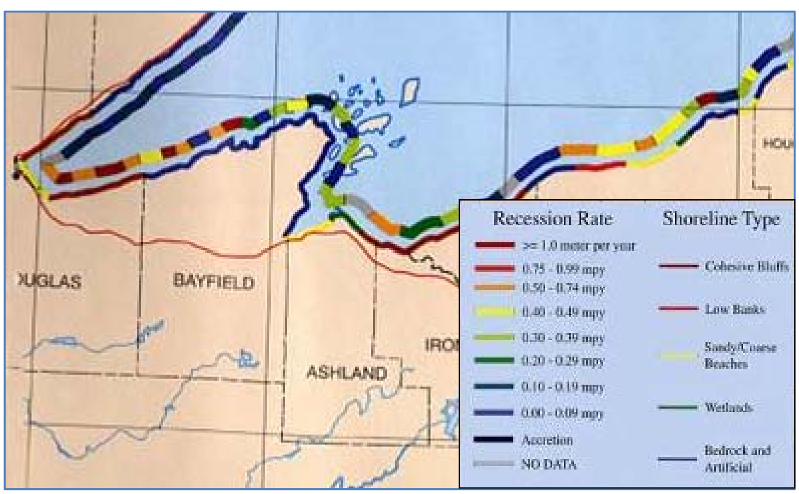


Figure 19 - Lake Superior Recession Rates and Shoreline Types [Source - Pope el al, 1999]

Shoreline recession along the Great Lakes coast is affected primarily by cyclically changing lake levels, disruption of longshore transport of beach-building material, intense rainfall events and storm-generated waves. Rates of bluff and dune recession along the shores of the Great Lakes vary from near zero to tens of feet per year because of annual variability in wave climate and lake levels (National Research Council, 1990).

The Climate of the Great Lakes

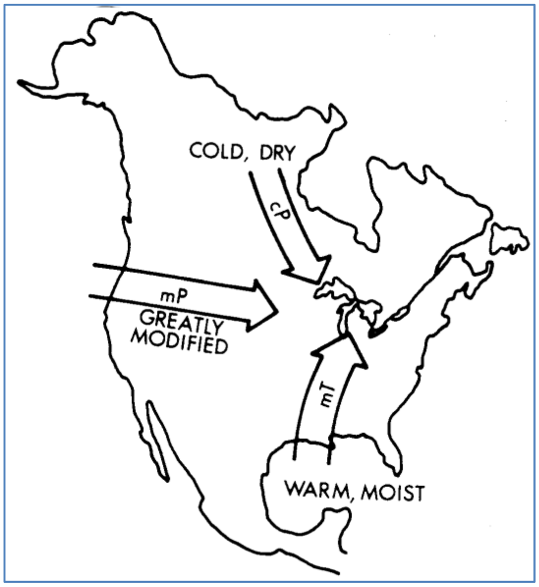


Figure 20 - Air Masses in the Great Lakes

The climate of Great Lakes is affected by three prominent air systems. There is a very dry and cold arctic system which comes from the north, another dry, but warm Pacific system that comes from the west, and finally, a warm, wet tropical system from the south and the Gulf of Mexico. The weather of the region is very changeable as a result of alternating flows of warm, humid air from the Gulf of Mexico and cold, dry air from the Arctic.

The Great Lakes themselves have a significant impact on the regional coastal climate, moderating temperatures and feeding moisture into the atmosphere. In the winter, this moisture condenses as snow when it reaches the land, creating heavy snowfall in some areas, known as "snow belts".

Impact of Climate on the Great Lakes Coast

In general, the most widely applicable statement that can be made about climate change in Wisconsin is that the State's residents are experiencing a trend towards wetter conditions with less extreme cold, but the number of extremely hot days during summer does not appear to have increased. The four seasons have experienced widely varying degrees of climate change, with the most pronounced warming having occurred in winter and spring, and nighttime low temperatures are increasing at a rate that is faster than daytime highs. The difference in the rate of warming between daytime and nighttime temperatures has caused the diurnal temperature range to compress by 0.35ºC (0.63 ºF) in springtime to as much as 1.2ºC (2.2 ºF) in summertime. Since 1950, the growing season has become longer by about 1 to 3 weeks across the interior portion of the central and northern parts of the State. (WICCI 2011)

This increase in temperature is most readily observed in reduced ice cover on lakes in the region and on the Great Lakes themselves. As storms (extra-tropical cyclones) follow storm tracks into the Great Lakes Basin, the storms bring heavy precipitation. What is being observed regarding heavy precipitation events is that the intensity is increasing.

These changes can have significant impacts in the region including but not limited to impacts on Great Lakes water levels. High Great Lakes water levels are believed to result from Great Lakes basin climate changes that increase precipitation (Meadows et al. 1997, citing Chagnon 1987). Low water levels are commonly attributed to reduced ice cover allowing more evaporation.

Ice Cover

There has been an overall decrease in the average duration of ice cover from the beginning of the record, with a much steeper decline in the average duration of ice cover beginning in 1970. (Magnuson et al. 2000). Since 1970, total annual ice cover on the Great Lakes has shown an overall decline of 71%, while the annual maximum ice cover shows an overall decline of 52% over the period 1973-2010 (38 years). It is important to note that while the trend is downward, ice cover on the great Lakes varies widely from year to year. The maximum ice coverage over all of the Great Lakes was 96% in 1979. The 2011-2012 ice cover maximum was only ~5%. This is the lowest ever observed in the satellite era (Wang, J. X. et al. 2012). On March 6, 2014, Great Lakes ice cover was 92.5% putting winter 2014 into 2nd in the record books for maximum ice cover.

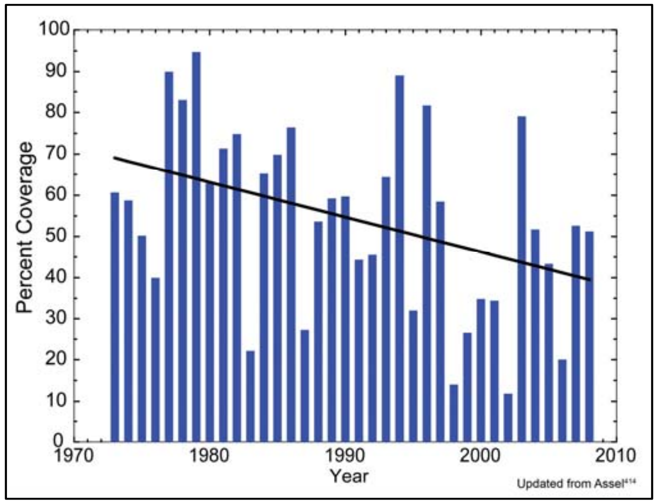


Figure 21 - Percent of Ice Coverage 1973 to 2010

Precipitation

The recent assessment report on weather extremes issued by the U.S. Climate Change Science Program states, "One of the clearest trends in the U.S. observational record is an increasing frequency and intensity of heavy precipitation events" (Karl et al. 2009). This result is consistent with the 50% rise in frequency of 4-inch daily rainfalls in the upper Midwest over the last century reported by Groisman et al (2001).

This increase in intensity of heavy precipitation events was responsible for most of the observed increase in overall precipitation during the last 50 years. In fact, there has been little change or a decrease in the frequency of light and moderate precipitation during the past 30 years, while heavy precipitation has increased. In addition, while total average precipitation over the nation as a whole increased by about 7 percent over the past century, the amount of precipitation falling in the heaviest one percent of rain events increased nearly 20 percent. This trend is predicted to continue, with the largest increases in the wettest places.

The map in Figure 22 shows the percentage increases in very heavy precipitation (defined as the heaviest one percent of all events) from 1958 to 2007 for each region. Noteworthy is the fact that the Great Lakes basin is in the two regions with the highest increases in heavy downpours.

Climate models project continued increases in the heaviest downpours during this century, while the lightest precipitation is projected to decrease. By the end of this century, heavy downpours that now occur every 20 years are projected to occur every 4 to 15 years. In addition to occurring more frequently, the intensity of heavy downpours is also expected to increase. This same heavy downpour is expected to be between 10 and 25 percent heavier by the end of the century than it is now.

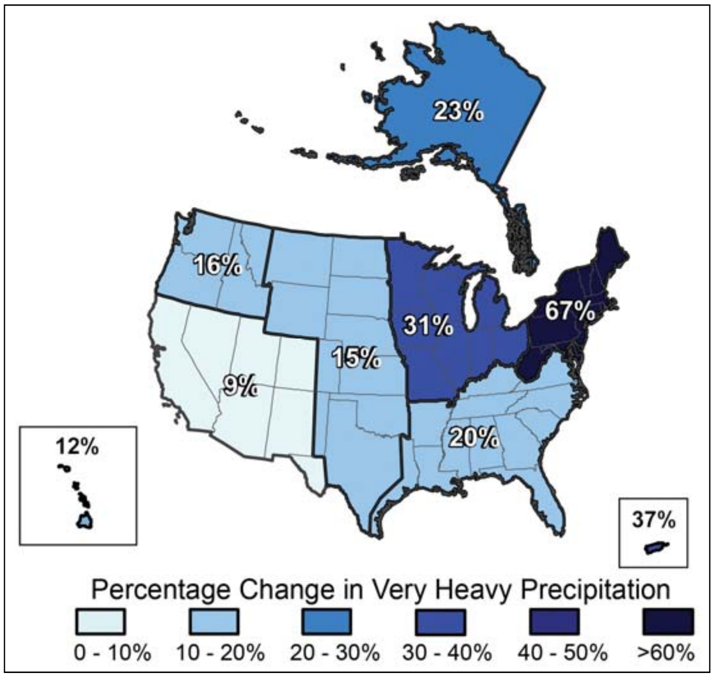


Figure 22 - Very Heavy Precipitation Events (1958-2007)
[Source: Karl el al. 2009]

"Precipitation has been increasing over the Great Lakes region over the last 100 years … most of those increases have come in the form of increased extreme precipitation events … the increases have come most dramatically during autumn since the mid-1960s." (Sousounis and Grover 2002, pages 502 and 503). Much of the summer precipitation in Wisconsin comes from evaporation in the region. In the other seasons, the State gets more moisture from long distances; from the Gulf of Mexico and even from the tropical Atlantic (Trenberth 2007). In the State, there has also been an increase in severe storms having a five percent likelihood of occurrence in any year.

A study conducted by the University of Wisconsin also concluded that storm intensity is likely to increase. Typically, heavy precipitation events of at least two inches occur roughly 12 times per decade (once every 10 months) in southern Wisconsin and 7 times per decade (once every 17 months) in northern Wisconsin. The University of Wisconsin study indicates that by the mid-21st century, Wisconsin may receive 2-3 more of these extreme events per decade, or roughly a 25% increase in their frequency. (WICCI 2011)

Impact on Future Water Levels

The Great Lakes basin is a complex system whose dynamics are only partially understood. There is a high degree of uncertainty about how climate change will affect future water levels over the next several decades. Despite these uncertainties, however, it is clear that lake evaporation is increasing and likely will increase for the foreseeable future, due to the lack of ice cover. It also clear that rainfall intensity is increasing. More intense rainfall will result in increased stormwater runoff.

In summary, climate in the upper Great Lakes basin during the next 30 years is likely to be characterized by an increase in:

- lake evaporation coupled with increased wind speeds and
- more frequent intense storms.

These changes will to some extent offset each other. How much increased stormwater runoff will offset the anticipated increases in evaporation is difficult to predict. While relatively lower water levels may occur, future water levels are predicted to remain consistent with historic long-term averages and will likely include high water periods. (IJC 2012)

Impact on Erosion of Cohesive Bluffs

Heavy precipitation events tend to destabilize bluffs. In addition to more heavy precipitation events, communities and homes that dot the bluffs around the Great Lakes will also be affected by warmer temperatures and more winter and spring precipitation that impact erosion rates. It is anticipated that these conditions will result in more deep rotational slumps, translational slides, mud flows, sheet wash, and soil creep when coupled with more freeze/thaw events. Table 5 summarizes selected climate changes and their anticipated effects on erosion. More intense precipitation events will increase erosion rates, particularly during winters without frozen soils, in summers and falls with drier soils, and during periods of drought.

Table 2. Selected climate changes and their anticipated effects on erosion of cohesive slopes

Climate change	Potential deep rotational slumps	Typical shallow translational slides	Solifluction (mud flows)	Sheetwash and rill erosion	Soil creep (mostly Lake Superior slopes)
Warmer, wetter winters, more freeze/thaw events	More failures only if shallow frost penetration thaws	More slides	More mud flows	More erosion	Even more erosion, weaker soils
Much warmer, wetter winters, no freeze/thaw	More failures	More slides	More mud flows	More rain impact, more erosion	Even more erosion, weaker soils
More extreme precip. events in winter with frozen soil (1)	No effect	No effect	No effect	No effect	No effect
More extreme precip. events in winter without frozen soil	More failures	More slides	More mud flows	More erosion	Even more erosion, weaker soils
More extreme precip. events with dryer summer, fall, soils	No effect	More slides	No effect	More erosion	Even more erosion, weaker soils
No ice cover on lakes (2)	More failures	More slides	No effect	No effect	No effect
Short-term drought (3)	No effect	More thin slides	More erosion	More erosion	Uncertain
Severe drought: years or longer (3)	Initial fewer failures, long term uncertain	More slides	More erosion	More erosion	Uncertain

1. Presumes face of slopes remain frozen during extreme precipitation events.
2. Presumes more wave attack with storm waves reaching bases of slopes.
3. Presumes occasional or rare extreme precipitation events. Uncertainty exists about the net effect of drought on slope stability.Sources: Chase (2007), Edil and Mickelson (2007).

Do landowners have the right to protect their shoreline in WI?

Public Interest Standard: The rights to protect your shoreline from natural processes in Wisconsin are defined by statute in Chapter 30, Wisconsin Statutes. Historically, a shoreline landowner had limited rights under common law to protect property so long as there was not interference with public use and there was limited intrusion into public waters.

These common law concepts are now embodied in Section 30.12, Wisconsin Statutes, which allows protection of shorelines where it is determined that the project will not "materially obstruct navigation" and will not "be detrimental to the public interest." Consideration under the "public interest" standard includes potential impacts on habitat, wetlands, natural scenic beauty, and navigation and its incidents, such as fishing, boating and swimming. (Cain, 2009)

Adverse Impacts on Others: Courts have long followed the maxim *Sic utere tuo ut alienum non laedas*, or "so use your own property that you do not injure another's property."

Answer: As long as the public interest standard is maintained and neighboring property is not adversely impacted.

Structural Shoreline Management

Shore-Parallel Structures

Seawalls and revetments are structures parallel to the shore intended to prevent storm waves from further damaging or moving the margins of eroding coastal land. Seawalls and revetments attempt to fix in place the edge of the land on a coast that would otherwise be receding, thus protecting fixed structures such as buildings. On a receding shore, however, seawalls and revetments contribute to the narrowing and eventual loss of beaches on the water side of the structures (Pope, 1997). Shore-parallel structures reduce the supply of sediments that builds beaches, while deflecting and increasing wave energy on neighboring shorelines. These two adverse impacts thus can increase erosion both at the base of the structure (which can cause structural failure) and down drift of it, negatively impacting adjacent properties.

Along with the loss of the beach, also compromised or lost is the public's right of passage protected by the Public Trust Doctrine. The beach area becomes so narrow that it no longer affords suitable space for walking, fishing and other public uses. Under the public trust doctrine, the State holds its navigable waters and underlying beds in trust for certain public uses. The public trust doctrine is essentially a common law doctrine, in that it is the creation of courts rather than legislatures. Case law in each State therefore defines how the Public Trust Doctrine is applied in each State.

Some coastlines consist of sand with underlying clay layers. If the sand is not being replenished, as it is washed away the underlying clay is exposed. Erosion of the clay bed can then undermine shore protection structures, hastening their failure. These pieces of failed shore protection structures join the slow movement of material along the coast. They create a visual blight for neighbors and beach visitors, as well as hazards for swimmers and beach walkers on neighboring properties.

Shore-Perpendicular Structures

Some of the controversial shoreline management structures are ones built perpendicular to the shore, which include solid piers, groins and jetties. All solid shore-perpendicular structures interrupt littoral drift, causing sand to build up beaches on one side and worsen erosion on properties on the down drift side.

Jetties

Figure 23 - Jetties on Lake Superior [Source: D. Mickelson]

Jetties are built to reduce the amount of sediment accumulation in navigation channels. These structures are called jetties because they are designed to increase flow velocities in the channel and jet sediments from the near shore into deep water. In addition, they interrupt the longshore movement of sand and other material in the littoral zone. Jetties usually extend far enough from the shoreline to completely block the movement of sand in the littoral zone (see photograph) and therefore have a significant impact on adjacent beaches. To mitigate the impact of jetties on adjacent beaches, artificial sand bypassing can be used. Sand bypassing is the hydraulic or mechanical movement of sand from an accreting area updrift of an obstruction to littoral transport to a downdrift eroding area. Dredged or mechanically moved material is placed on a beach immediately downdrift from the obstruction that then serves as a “feeder” beach to nourish beaches further downdrift.

Solid Piers

Solid piers are structures which are permanent (as opposed to temporary docks which are typically removed during the winter months.) These solid structures do not allow for the free, flow of water beneath them. The Wisconsin Department of Natural Resources (WDNR) completed and published an Environmental Assessment of *the Cumulative Physical, Biological, Socioeconomic, and Aesthetic Impacts of Solid Pier Structures on the Bed of Green Bay* (WDNR 2000)*.* The conclusions of this assessment regarding aquatic habitat were that the fish population would be negatively affected by the direct loss of natural spawning, nursery and food production areas in the littoral zone. Many game and forage species spawn in the shallow waters of the littoral zone. Loss of substrate reduces potential spawning success. Both adult and young life stages of many fish species rely on invertebrates found in the littoral zone as a food source. Because a decrease in macro invertebrate populations is also possible with this habitat loss, the carrying capacity of the fisheries community could be diminished. (WDNR 2000)

Groins

Groins are another type of shore protection structures built at right angles to the shore (see Figure 24). Their purpose is to encourage growth of beaches and to prevent existing beaches from eroding.

The Wisconsin Coastal Zone Management Program and the Bay-Lake Regional Planning Commission funded a project to provide the Wisconsin Department of Natural Resources (WDNR) with scientifically sound methodologies and training for evaluating impacts of groins and solid piers along Wisconsin's Lake Michigan shoreline and connecting bays. Special attention was given to addressing impacts on littoral drift, the potential for increased erosion or deposition, and size and spacing of groins. The training focused on the influence that bluff stratigraphy, profile shape, fetch length and sediment supply have on groin function.

Figure 24 - A Groin on Lake Michigan [Photo by Alan Lulloff]

The training provided the following guidance regarding groin construction:

Down Drift Impacts - Based on research conducted in Lake Michigan regarding the zone of impact of groins, one can expect accelerated erosion down drift and accretion up drift by up to four groin lengths. (Meadows et al. 1997b, Meadows et al. 1998) For groin fields the affected area can be up to six groin lengths. The training recommended that for applications proposing to install groins which extend above the existing beach, that the groin be placed 2.5 to four groin lengths' distance from adjacent property lines to minimize impacts to adjacent beaches.

Groin Height - Groin height plays a major role on the impact a groin will have on a shoreline. As a general rule the greater the groin height the greater the impact the groin will have on the shoreline. It is important to realize that groins extending only 18 inches above average water level may cause accelerated erosion on down drift beaches (Bennet 2001). The training recommended that the height of the groin be no higher than the design height of the beach. As can be seen in the above photograph, the groin pictured is excessively high.

Groin Width - Groins occupy public lakebed and can negatively impact aquatic habitat; therefore, groin width should be kept as narrow as structurally feasible. Groins with widths as narrow as six inches have been constructed along the shorelines of the Great Lakes using sheet piling, and wood groins 12 to 16 inches wide are also common. Again it is apparent that the width of the groin pictured is excessive.

Coastline Armoring in Wisconsin

In 1996 and 2007 the Wisconsin Coastal Management Program (WCMP) funded a collection of aerial oblique photographs of the Wisconsin Great Lakes coastline. The WCMP subsequently funded a comparison to conditions documented in historic 1976 aerial photography for Lake Michigan. Table 2 summarizes the length of Lake Michigan shoreline by county that was identified as being armored with shore protection structures on the 1976 and 2007 aerial oblique photographs.

Table 3 - Increase of Armoring on Wisconsin Lake Michigan Coastline (1976 to 2007)

	1976		*2007*		*Amount of Increase*	
County	***Miles***	***Percent***	***Miles***	***Percent***	***Miles***	***Percent***
Door	0.37	2.6%	1.71	11.9%	1.34	362.2%
Kewaunee	1.56	5.9%	2.29	9.1%	0.73	46.8%
Manitowoc	7.86	22.4%	9.48	26.6%	1.62	20.6%
Sheboygan	8.23	31.1%	8.56	32.3%	0.33	4.0%
Ozaukee	2.67	9.6%	7.56	27.3%	4.89	183.1%
Milwaukee	14.2	44.6%	19.96	62.7%	5.76	40.6%
Racine	8.38	56.5%	9.95	67.0%	1.57	18.7%
Kenosha	8.04	58.9%	11.72	85.7%	3.68	45.8%
Total	51.31	26.9%	71.23	37.6%	19.92	38.8%

Door, Ozaukee, Kewaunee, Kenosha and Milwaukee had the largest increases in coastline armoring in this ~30 year time frame.

Regulation of Shore Protection Structures

Because the Great Lakes are navigable waters of the United States, permits are required from the U.S. Army Corps of Engineers (USACE) pursuant to the Rivers and Harbors Act for the placement of piers, wharves, jetties, breakwaters, and similar shoreline structures. A permit is also required from the Wisconsin Department of Natural Resources pursuant to Chapter 30 of Wisconsin Statutes.

Some States have adopted rules to protect natural shorelines by prohibiting artificial shoreline armoring structures. In 1983, the State of Maine, to preserve its few sandy beaches, became the first State to declare that hard stabilization would not be allowed on its coastline. North Carolina followed suit in 1985. South Carolina prohibited structures in 1988 and required that existing seawalls be removed within 40 years. (Pilkey, 1996) Texas recommends the use of nonstructural methods for erosion control and discourages the use of groins, breakwaters, revetments, and seawalls that can modify the natural shoreline and create problems down drift of them. (Texas General Land Office, 2001)

Federal Guidance on Shore Protection Structures

The **U.S. Army Corps of Engineers**, in cooperation with the Great Lakes States, has developed a publication called *Living on the Coast* (USACE/Wisconsin Sea Grant 2003). This publication recognizes the impacts of lakebed erosion and provides guidance for coastal property owners:

- adapt to natural processes,
- restore natural shorelines, moderate erosion and
- use armoring only as a last resort.

"*Shore protection structures are controversial intrusions on the mobile margins of the coast. Such structures interfere with the natural contribution of beach-building material from the erosion of coastal slopes and the movement of that material along the coast. Shore protection structures are considered by some experts to be measures of last resort …*" (Pope, 1997)

The principal message of *Living on the Coast* is to do everything possible to avoid placing buildings and other structures where flooding, storm waves and erosion are likely to damage them or shorten their useful lives. For existing structures that are threatened, there are a number of options other than shore protection available to homeowners:

Manage water on the land. Surface water should be directed away from the bluff and prevented from running over the edge and down the face of a bluff. Ponding of water on land near coastal slopes should be minimized. Rain gardens and on-site waste disposal systems should be located as far from the bluff as possible. Rain gutter downspouts should be directed away from the bluff. Rain barrels should be used to provide as much of the plant watering needs on a property as possible.

Restore the natural shoreline by maintaining and enhancing vegetation on coastal slopes and retaining and nourishing beaches. Vegetation on coastal slopes stops surface erosion and may prevent shallow slides. Planting shrubs, grasses and other ground cover with deep roots on coastal slopes is preferred. Small trees that will not grow into large trees are recommended because large trees cause large, concentrated loads on slopes, partially offsetting the added strength their roots provide to slope soils. New trees should be planted on the mid to lower portions of a slope to minimize the risk of wind throw.

Beach retention is an important defense of coastal property against erosion by waves. Sand fencing and planting dune grasses are two methods to enhance sand accumulation.

Relocate threatened buildings. Moving a structure is often the most cost-effective and certain way of increasing a home's longevity. New buildings along the coast if designed properly can be relocated in the future if necessary.

The **Federal Emergency Management Agency Community Rating System (CRS)** rewards communities that are doing more than meeting the minimum requirements of the National Flood Insurance Program (NFIP) to help their citizens prevent or reduce flood losses. According to the FEMA CRS Manual - permanent shoreline stabilization projects may cause the loss of the public beach and increase erosion at adjacent properties by interrupting natural sand migration patterns. Communities that prohibit hardened shore protection structures receive points under the CRS program.

Beach Nourishment

An alternative method of reducing or temporarily stopping excessive erosion of the natural coast is to provide a "man-made" beach and dune-bluff. Feeding sand to a coast is referred to as "beach nourishment." Beach nourishment works by supplying sand needed for waves and currents to rebuild and maintain the natural protective beach and sand bar system. This involves bringing in clean sand from inland sources or reintroducing uncontaminated sand that has been removed from the littoral system.

Nourishment sand provides three important beneficial effects. First, beach nourishment sand directly protects the natural dune-bluffs from wave attack by serving as a sacrificial dune and beach buffer zone between the waves and the previously eroding natural coast. Second, beach nourishment reduces erosion on adjacent properties by supplying sand to the regional beach and sand bar system. Both the beach nourishment project site and the adjacent shoreline benefit from the placement of nourishment sand. Third, beach nourishment creates beaches that can be used for recreation.

A major problem with beach nourishment is getting quality sand. Sediments dredged from harbors to keep shipping channels open often cannot be used for beach nourishment because they are contaminated. On the Great Lakes, slightly more than half of the material dredged from the harbors and channels must be disposed in the 22 confined disposal facilities (CDFs) that have been constructed on the Great Lakes (Clark 2013). Confined Disposal Facilities are intended to provide a secure storage facility for contaminated sediments. Use of dredged sediments for beach nourishment is only allowed if the particle size and contaminant concentrations meet the criteria contained in Wisconsin NR 347.

Fortunately there are some sources of sand that are acceptable for beach nourishment. As mentioned previously, when a coastal structure traps sand on one side, creating erosion problems on the down drift side, the trapped sand can be dredged and by-passed around the structure. Figure 23 on page 19 shows the extent that sand can be trapped on the up drift side of a structure. Mechanical movement of sand places the same sand on the down drift shoreline that would have arrived there naturally if the structure was not present. Sand can also be obtained from inland sources and trucked to the beach.

An additional challenge associated with beach nourishment is that it is a temporary solution. With time, beach nourishment sand is completely mobilized as it moves down the shoreline providing protection to down drift property owners in the form of new beaches and sand bars. When all the beach nourishment sand is carried down drift, the project site must be renourished.

Coastal Land-use Management

Communities can use a variety of tools to manage land-use in coastal areas with receding high unstable bluffs. One such tool is a coastal shoreline protection overlay zone. This a set of special development considerations adopted by a local community that sits on top of the existing ordinance’s land use requirements and only applies in a legally defined zone. Along a coast, special development considerations often include coastal development setbacks and restrictions on shore protection structures. In addition, regulations protecting dunes, bluffs, sensitive habitat and view sheds are often enacted. Other methods of ensuring coastal development is not constructed at-risk include Purchase of Development Rights (PDR), conservation easements and publicly-owned conservancies.

Coastal Construction Setbacks in the U.S. and Canada

A number of States in the US and the Province of Ontario in Canada have adopted coastal management regulations and/or policies. Table 4 provides a comparison of State/provincial coastal erosion management provisions.

Table 4 - Coastal Development Setbacks: State/Province Summary

State/ Province	Planning Horizon (years)	Criteria	Minimum Setback Req. (ft.)	Additional Setback Req. (ft.)	Erosion Reference Feature	Setback Req.
Michigan	30				Bluff Top	Yes
Minnesota	50			25	Bluff Top	No
New York	40					Yes
Ohio	30					Yes
Ontario	100		30 meters	Dynamic Beach 75 ft.	Bluff Top	Yes
Pennsylvania	30	Residential			Bluff Top	Yes
	75	Commercial				
	100	Industrial	50			
Florida	30				MHW	Yes
Maine		Residential		75		
	100	General	250	25	HWL	Yes
North Carolina	30		60			
	60	>5000 sq. ft.	120			
	30	>3.5 ft./yr.		105	LOV	Yes
	30	Res < 6 units				
	60	Res > 6 units				
Rhode Island	60	Commercial			MHW	Yes
South Carolina	40				Base Line	Yes
Texas	60				LOV	No

Erosion Reference Feature = the feature from which the setback is measured
Setback = Planning Horizon x Recession Rate
LOV = Line of Vegetation
MHW = Mean High Water

Determining a recession setback - on a shoreline with a recession rate of two feet per year, using a planning horizon of 100 years the setback to address recession would be 200 feet.

On the Great Lakes, the State of Michigan has the most extensive set of regulations associated with coastal hazards. Michigan has developed sample coastal overlay language related to eroding bluffs, eroding sand coasts, and protecting dunes.

Hazard Identification and Mapping

The two primary coastal hazards on the Great Lakes are flooding and landslides. Flooding hazards are designated on the Federal Emergency Management Agency's Flood Insurance Rate Maps (FIRMs). FIRMs show the extent of the 1% annual chance floodplain, also known as the Special Flood Hazard Area (SFHA). Along coasts these maps identify the areas that have a 1% annual chance of being impacted by inundation and waves. Within the SFHA, floodplain management regulations apply and flood insurance is required for all property used to secure federally backed loans.

However, much of the Great Lakes shoreline consists of relatively high (50 to 200 foot) bluffs. Development along the coast in these areas is not susceptible to flooding directly, but instead is subject to undercutting and landslides. Coastal areas susceptible to landslides and recession are not identified on Flood Insurance Rate Maps. (See inset on the Upton Jones amendment to the National Flood Insurance Act.) Mapping coastal areas susceptible to landslides and recession usually involves identifying susceptible areas and classifying coastline reaches with related characteristics. Identifying coastal reaches with unstable bluffs and determining recession rates provides coastal communities and landowners with the information needed to avoid constructing buildings at risk.

The map of high risk erosion areas on the following page was developed by the State of Michigan. In order to monitor coastal erosion in Michigan, the Department of Environmental Quality conducts a study every ten years, one objective of which is to monitor and record erosion rates. If rates increase a foot or more in the area of study, the area is designated a "High Risk Erosion Area", whereupon structure setbacks become more regulated.

Upton Jones

Upton Jones was an amendment to the National Flood Insurance Act that modified the Federal Flood Insurance program by providing relocation and acquisition coverage for structures in imminent danger from an encroaching shoreline. This amendment enabled the Federal Flood Insurance Program to pay up to 40% of the policy to property owners who relocate structures in imminent danger and up to 110% of the insurance policy to property owners who demolish those structures and remove the debris. Erosion Hazard Mapping associated with this amendment designated 60 year and 30 year setback areas. The amendment sunsetted in 1989 and has not been reauthorized.

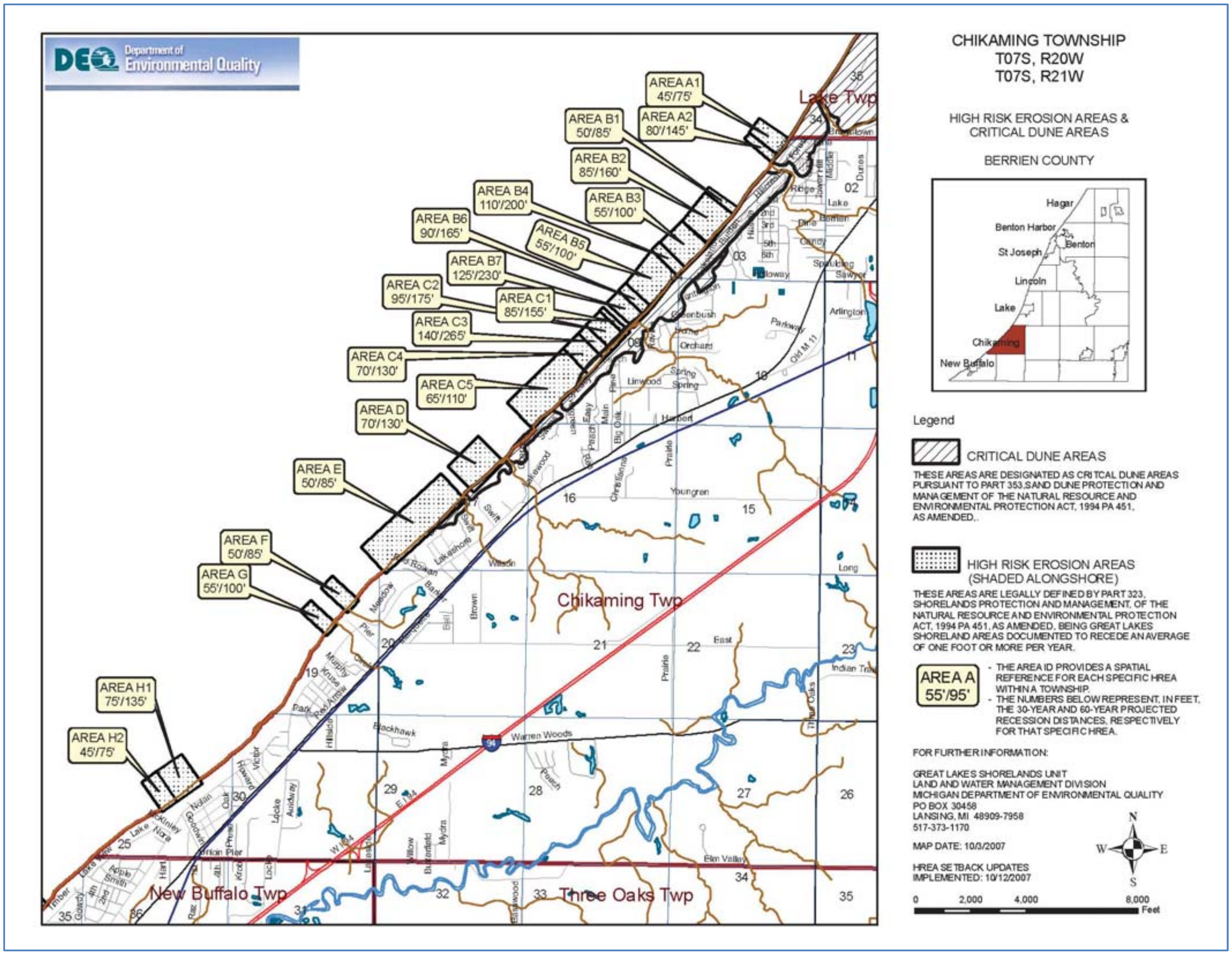


Figure 25 – Map of High Risk Erosion Areas - Chikaming Township, Michigan

Local Government Coastal Management Efforts in Wisconsin

All unincorporated areas in Wisconsin along the Great Lakes coastline have shoreland zoning in place that covers areas with 1,000 feet of the coastline. (In Wisconsin, the shoreland zone associated with all navigable waters includes areas within 500 feet of streams and 1,000 feet of lakes.)

The State standard for setbacks in the shoreland zone is 75 feet from the Ordinary High Water Mark (OHWM). Legally, the OHWM is defined as “the point on the bank or shore up to which the presence and action of water is so continuous as to leave a distinct mark either by erosion, destruction of terrestrial vegetation or other easily recognized characteristic.” (Diana Shooting Club v. Husting, 156 Wis. 261, 271 - 1914**)**

On the portions of the Wisconsin coast with bluffs, the OHWM is usually the toe of the bluff. A setback of 75 feet from the toe of a bluff could allow construction of a building on the face of the bluff (See Figure 26 below). Therefore, it is clear that Wisconsin's shoreland setback does not adequately address coastal hazards.

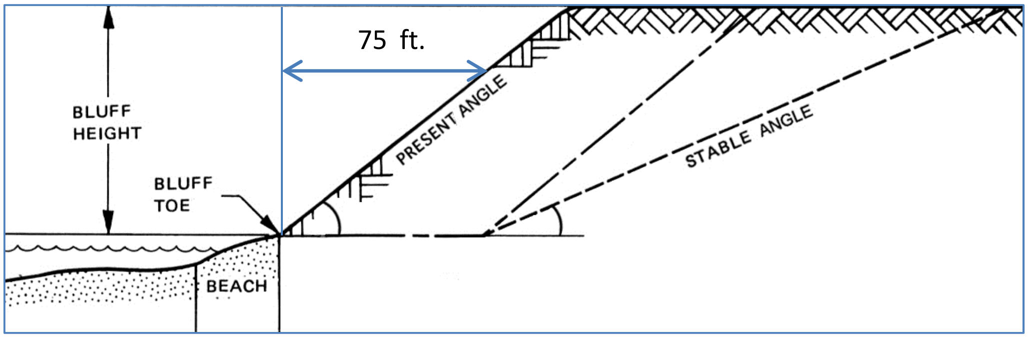


Figure 26 - Coastal Bluff with 75 ft. setback (based on a 100 ft. high bluff & 1 to 1 slope)

In the 1980s the Wisconsin Coastal Management Program began an effort to understand coastal erosion processes on the State's Great Lakes coasts, an effort which continues to the present. Along the way, the WCMP funded the development of a model coastal ordinance for construction setback distances above and beyond the setback required by Wisconsin's Shoreland Protection Act. The WCMP working with Wisconsin Sea Grant and the Wisconsin Department of Natural Resources promoted the adoption of this ordinance by coastal counties, an effort that was extremely (though not completely) successful. High lake levels in 1986 and 1987 reinforced the need to keep new development set back from unstable coastal bluffs.

Coastal communities in Wisconsin used several methods to address coastal hazards:

1) **Modifying the reference from which the setback is measured**

FEMA has developed regulations related to coastal erosion that define an "Erosion Reference Feature". Erosion reference features are the bluff crest and toe for coastal bluffs and the line of vegetation for coastal dune environments. Requiring buildings to be setback from the bluff crest instead of the OHWM was a relatively simple way for coastal communities to modify their shoreland zoning ordinance to address coastal hazards. Bayfield County modified their shoreland zoning ordinance in this fashion. Ozaukee County included this provision in their shoreland zoning ordinance to establish a minimum setback for bluffs, gullies and ravines in high bluff areas along the coast.

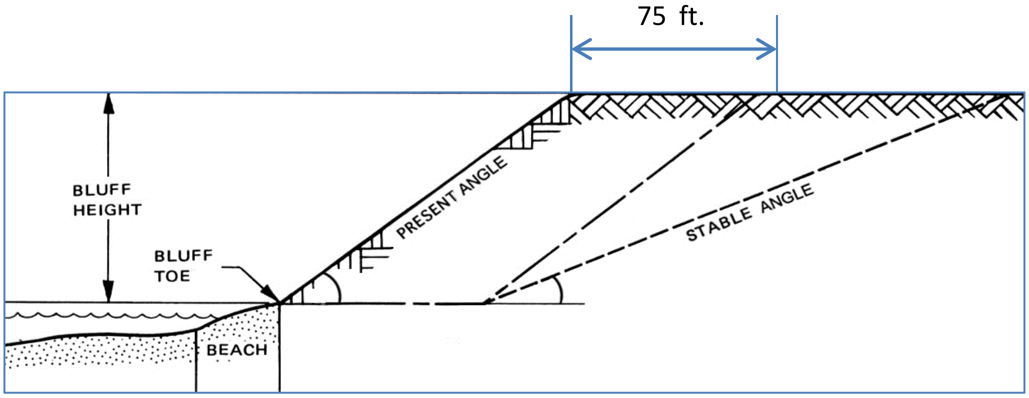


Figure 27 - Setback from top of bluff

2) Increasing the setback to address coastal hazards

Most of the more heavily-populated Lake Michigan communities with unstable eroding bluffs have adopted this approach. This includes Racine, Ozaukee, Sheboygan, Manitowoc and Kewaunee Counties.

Sheboygan and Manitowoc Counties have adopted the model ordinance with both stable slope and recession setback requirements for the bluff portions of their coastlines. The recession rate in both counties is assumed to be two feet per year.
Ozaukee County has adopted the model ordinance with the stable slope setback for the bluff portions of their coastline with a minimum of 75 feet from the bluff top. In addition, they require a 75 foot setback from the bluff top in ravines.
Racine County has adopted the stable slope setback and requires shore protection to be constructed.
Kewaunee County requires a 125 foot setback from the Ordinary High Water Mark where the coastal bluff is greater than 10 feet high.

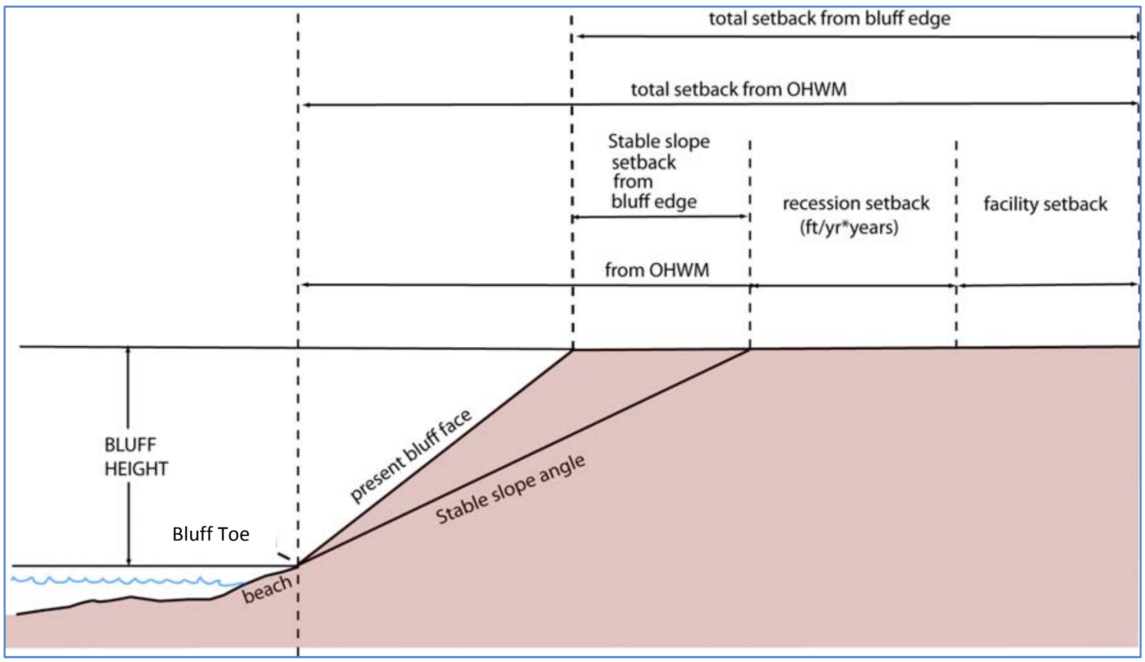


Figure 28 - Coastal Setback based upon recession rate and stable slope

3) Including coastal setback requirements in their general zoning ordinance.

Douglas County has adopted the following setback requirements in their general zoning ordinance associated with Lake Superior Coastal Waters:

"All permanent installations including soil absorption system, seepage pits and holding tanks; but not including piers and boathouses, shall be setback from all points along the bluff edge by the distance shown on the Lake Superior Shoreland Setback Table." The table includes bluff heights from 16 to 60 feet that establishes setbacks ranging from 170 to 399 feet depending upon bluff height and bluff slope.

Figure 29 - WI Counties with Coastal Regulations

The counties shown on the map in Figure 29 have taken measures to reduce the risk to development along their receding coasts. Of these, the four along Lake Michigan include the portions of the Great Lakes coastline with the greatest potential for development due to their proximity to the City of Milwaukee. In addition, Door County has adopted regulations that protect natural areas including dunes and ridge and swale complexes. The counties that have adopted all or part of the model ordinance have a variable setback based upon bluff height and/or recession rate. Those that include a recession rate component use a default rate of 2 feet per year.

Great Lakes Coastal Hazard Risks - Community Interviews

Figure 30 - Meeting with local officials in Manitowoc, WI [Photo by Alan Lulloff]

As part of this project, meetings were held with local officials representing regional planning commissions, coastal counties and communities along Wisconsin's Great Lakes coastline. Meetings were in the cities of Plymouth, Manitowoc, Milwaukee, Ashland and Superior.

What We Learned

Substantial existing development at risk – Setback regulations have effectively kept new houses away from unstable bluffs in Manitowoc, Sheboygan, Ozaukee and Racine counties. However, these counties have at-risk development that predates their ordinances. This was illustrated in 2000, when the Wisconsin Coastal Hazards Work Group conducted an evening meeting in Ozaukee County to discuss coastal setbacks. Even though lake levels were low at the time, over 100 people attended the meeting seeking information on how to stabilize bluffs on their property to prevent loss of their houses. The county subsequently conducted a workshop to provide at-risk property owners with technical information on methods to improve the stability of those bluffs.

Coastal Development Pressure - Coastal development is becoming increasingly upscale. Over the past two decades there has been a trend toward "mansionization" of the coastline on the Great Lakes. Mansionization refers to the conversion of older, smaller cottages to larger permanent homes, or the new construction of large permanent homes instead of the traditional lakeside cottages. Kenosha County staff reported that in some instances, two adjacent houses are purchased, raised and replaced with one very large structure. Three factors identified that have increased coastal development pressure are:

- Coastal redevelopment – In some Lake Michigan communities, industrial complexes along the coast are being redeveloped into upscale condominiums and/or commercial development.
- Living on the coast is viable to more people – telecommuting is becoming more common and improved interstate highways have reduced commuting times.
- The climate is changing - The Lake Superior coast is becoming more habitable. Warming summer waters allow swimmers to swim nearly all summer

Regenerated and revegetated coastal dunes and ridges are at risk. During this recent low water epoch, dunes and ridges are forming along the Wisconsin coastline. Coastal community staff indicated that there have been cases in which:

- property owners want the ordinary high water mark (OHWM) shifted lake ward so that they can build on these features, which were not present in the high lake level years of the 1970s and 1980s.
- property owners are building standard septic systems within the new primary dune areas.

- property owners with dunes and ridges, who were issued permits to remove invasive plant species, are destroying newly-emergent, natural vegetation, unaware that the natural vegetation is part of the rebuilding process for these future buffers against storms and returning high lake levels.

Below is a 2012 photograph of the Lake Michigan coastline that shows the beaches and dunes that had formed and the terrestrial vegetation that had become established during the recent prolonged low water level period. Note the rip rap in the left portion of the photograph that was placed during a high water period to protect a coastal home from wave attack. In the right portion of the photograph there is terrestrial vegetation that has not been destroyed by water action or waves.

Figure 31 - Lake Michigan Coastline in Sheboygan County, WI [Photo by Alan Lulloff]

Bluff slumping is an ongoing problem. High groundwater conditions along the Lake Michigan coast are causing increased bluff slumping. Efforts to re-fill slumps often fail. It was noted that some properties have groundwater seepage pouring out of the top of the bluff, immediately below the turf layer. There was support for limiting rain gardens, stormwater retention basins and infiltration in subdivisions near the coast. The stormwater management standards in Wisconsin NR115 do not address groundwater and surface water management in coastal hazard areas. There is a need for guidance materials and training on stormwater management near unstable bluffs, non-structural bluff stabilization and bluff de-watering techniques.

Groins and solid piers can adversely impact neighboring properties and nearshore habitat. An assessment of groins conducted in 1998 and in an environmental assessment of solid piers and groins in 2000 determined that groins have significant cumulative impacts. Specifically, they block littoral drift, negatively impact species that use and depend on nearshore habitat, and cause user conflicts in the nearshore area - canoers, kayakers, anglers, swimmers and waders are forced into deeper water to get around these structures (WDNR, 2000).

Major shoreline hardening projects are ongoing. Concordia College in Ozauke County implemented a major shore protection project in 2008 that involved: construction of a hardened shoreline, a re-grade of the bluff, addition of handicapped access consisting of concrete sidewalks with switchbacks, stormwater catch basins and piping, and a bike path along the shoreline.

Riparian boat access is problematic when lake levels remain low for extended periods. During low water periods, riparian land owners desire to dredge channels to enable boat access. The Wisconsin Department of Natural Resources conducted an environmental assessment in 2008 due to the significant number of applications for dredging permits in Green Bay. This assessment determined that these dredged channels interrupt littoral drift and therefore have a significant cumulative adverse impact on near shore habitat (WDNR 2008).

On-site waste disposal: The WI Uniform Plumbing Code does not presently restrict on-site waste disposal in coastal hazard areas.

In the photograph to the right an on-site waste disposal system (see circle) has been constructed in-between a house setback from a bluff and the edge of the bluff.

The homeowner ultimately moved the system to the front of the house when bluff slumping began occurring.

Figure 32 - House setback from the bluff edge [Source: D. Mickelson]

Statewide legislation: Some community officials recommended a uniform Statewide approach to coastal construction setbacks. They indicated that it would be difficult for county or community planning and zoning officials to propose increased setbacks.

Risk communication associated with coastal hazards is needed. Public information on coastal hazards including visualization demonstrations similar Wisconsin Sea Grant's lateral recession rate demo would be useful for educators, coastal landowners and realtors.

Adaptation Strategies for Managing Coastal Hazard Risks

The Great Lakes shoreline is a high energy environment. Storms moving through the Great Lakes cause storm surge and choppy waves. Great Lakes water levels vary annually and over multi – decade cycles. Varying water levels have a fundamental influence on the portion of the shore face that is exposed to wave energy and the exposure of bluffs to wave attack. Beyond the erosive nature of the waves, the shoreline is highly vulnerable to shore erosion largely because much of the coastal landforms are made up of mixed, unconsolidated glacial materials such as gravels, lake-deposited clays, and tills. Significant portions of the coastline consist of bluffs that are made of unstable glacial deposits. Bluff erosion and slumping result in continuously changing shoreline. During the winter, as the temperatures of the lakes fall, ice covers significant portions of the Great Lakes. The "shoving" action of ice is another factor that impacts the shoreline.

There has been significant change in the duration of ice cover and rainfall intensity over the past forty years on the Great Lakes making the dynamics of the system less predictable. While relatively lower water levels may occur due to reduced ice cover increased rainfall intensity will have the opposite effect – thus it is predicted that future water levels will likely include high water periods. More extreme and frequent precipitation events likely will cause bluffs to be less stable. Future soil conditions include the possibility of more surface and groundwater flow, warmer winters with more frequent thaws, more slope failures, and the desiccation of cohesive slopes during prolonged drought.

These are just a few examples that illustrate why a reevaluation of the effectiveness of current programs aimed at reducing risks to development in Wisconsin's Great Lakes coastal areas is warranted.

Where the Coastal Setback model ordinance (or variations of it) has been adopted in the State, the risk to new coastal development has been substantially reduced. However, there also have been some unintended consequences. One consequence was that in some cases property owners and property developers re-graded coastal slopes to stable angles. These re-grading projects accelerated the loss of natural vegetation and habitat along many coastal slopes. Many re-grading projects were accompanied by construction of shore protection structures. The combination of re-graded, stabilized slopes and massive shore protection structures has further diminished the already-low supply of sediments containing sand that nourish and sustain Wisconsin beaches.

The recommendations in this report reflect the common knowledge that coastal development has moved upscale during the decades of studying erosion of the State's coasts. Summer cottages built in the first half of the 20th century have been greatly expanded and winterized, or torn down and replaced with much larger four season dwellings. The approach described and recommended in this report takes into consideration the substantially increased investments made in Wisconsin coastal property in recent decades. The recommended planning horizon of 100 years fits with the useful lives of well-built wood frame houses in stable residential neighborhoods.

The recommendations in this report do not guarantee a risk-free level of coastal protection based on conservatively-safe setbacks to cover any conceivable contingency. The approach recommended is instead a trade-off that limits the size of the setback distance in order to reduce the incidence of unbuildable coastal lots, at the cost of some unknown risk of future building relocation or loss.

1. Coastal construction setbacks should be referenced to an Erosion Reference Feature

Issue: Some communities that have adopted setbacks in coastal areas have done so by amending their shoreland ordinance. The shoreland ordinance establishes setbacks in reference to the ordinary high water mark (OHWM). Unfortunately, the indicators associated with the OHWM can shift lakeward during long periods of low water conditions. If the boundaries in recession-prone jurisdictions with coastal construction setbacks are allowed to shift lakeward with the changing erosion/vegetation boundary, prolonged periods of low lake levels could prompt construction on beach ridges and dunes that will be rapidly destroyed if high water levels return.

Recommendation: Coastal construction setbacks should be referenced from an Erosion Reference Feature. Coastal communities with receding unstable bluffs that reference setbacks from the OHWM should instead reference the toe of the bluff. Minimum setbacks should be referenced to the top of the bluff.

> Recommended definition: Erosion Reference Feature is the receding edge of a bluff or eroding frontal dune, or if such a feature is not present, the highest recorded water level for the associated lake.

Rationale: The OHWM is the demarcation of the water resource not the hazard. Referencing coastal construction setbacks from an Erosion Reference Feature ties the setback directly to the hazard (e.g. bluff crest or bluff toe). An Erosion Reference Feature is defined in the NFIP regulations (See below) and is the reference most Great Lakes coastal states with coastal setback regulations utilize (See Table 1 on p. 24).

> 44 CFR 59.1 Definitions. Reference feature is the receding edge of a bluff or eroding frontal dune, or if such a feature is not present, the normal high-water line or the seaward line of permanent vegetation if a high-water line cannot be identified.

In 1914, the Wisconsin Supreme Court defined the OHWM as "the point on the bank or shore up to which the presence and action of the water is so continuous as to leave a distinct mark either by erosion, destruction of terrestrial vegetation or other easily recognized characteristic." On the Great Lakes, the bluffs on the coast are often unstable due to waves attacking the bluff toe during periods of high water. Since this provides distinct evidence of erosion, the OHWM in areas with bluffs is generally the toe of the bluff. Therefore changing the reference from the OHWM to the toe of the bluff maintains the intent of the coastal setback provisions currently in place. Several counties have minimum setbacks from the top of the bluff. These provisions can also remain unchanged.

Communities with receding shorelines that consist of dunes can also use this approach. Great Lakes water levels can vary significantly over several decades. Coastal development faces its most significant risk during periods of high water (LaValle 2000). Where an erosion line cannot be easily identified using the point on the shoreline impacted by the highest recorded water level for the associated lake ensures property is appropriately setback from the coast during periods of high water. This recommendation seeks to maintain the economic prosperity, environmental health and social well-being of coastal communities by ensuring development does not encroach into areas where there is risk to public health or safety or of property damage.

2. Slope Stability Analyses should be based upon highest groundwater conditions (when the bluff is most likely to fail) and safety factors appropriate for the consequences of failure.

Issue: Much of Wisconsin's Great Lakes coastline consists of cohesive bluffs typically 50 to 200 feet high that are prone to landslides. Water is the most critical agent acting upon bluffs. Water entering the groundwater system adds weight to the bluff and most importantly reduces the internal soil strength. Portions of bluffs that are saturated with groundwater are less than half as stable as bluffs that are fully drained. (WCMP 1977) Bluffs often fail when groundwater in the bluff is at its highest level. In addition, the safety factor is a variable in the analysis. Bluffs with a safety factor of 1.0 are in a condition of "imminent collapse". Larger safety factors are needed for residential development and infrastructure.

Figure 33 shows a series of dotted lines along which sections of a glacial till bluff top can fail and slide. It is intended to show potential failure surfaces at any given point in time.

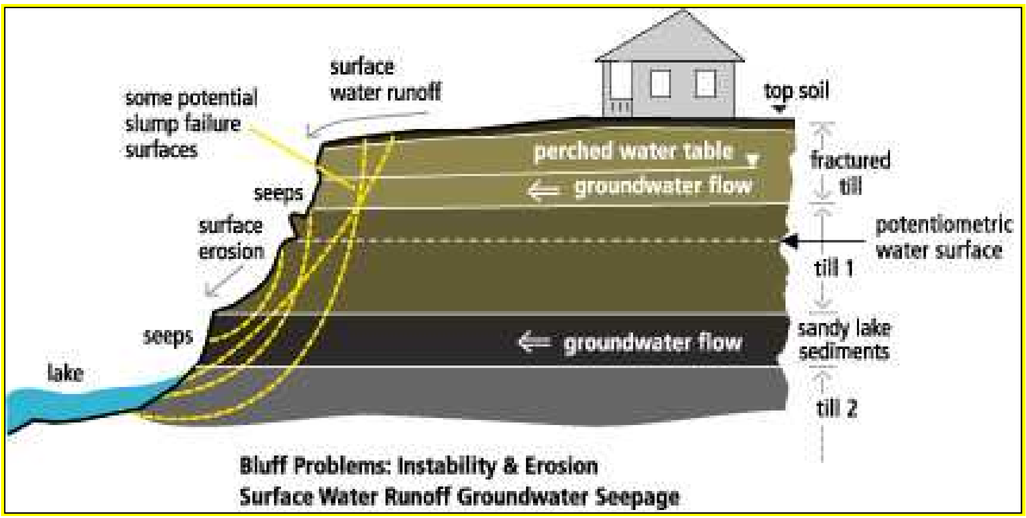


Figure 33 - Cross Section of a cohesive bluff

Recommendation*:* The stable slope angle used for siting new construction or protecting existing facilities should be determined by slope stability analyses that account for:

- the highest groundwater conditions that can occur at the site - *not* the elevation of the groundwater on the day of the analysis (a default of 3/4 of the bluff height should be used unless the site has a layer of lake sediments higher on the bluff face) and
- safety factors appropriate of the types of facilities planned for construction and the consequences of slope failures after development. A factor of safety of 1.5 is recommended for residential structures or infrastructure.

Rationale: Bluffs frequently fail when groundwater in the bluff is at its highest level. Any stability analysis conducted should demonstrate stability during worst-case conditions. Furthermore, if a safety factor of 1.0 is utilized the analysis would be based on a condition of "imminent collapse". Theoretically, a slope with a factor of safety of less than 1.0 will fail and one with a factor of safety of 1.0 or greater will not fail. However, because the modelling is not exact and natural variations exist for all of the parameters affecting slope stability, a factor of safety of 1.5 is commonly used to define a stable slope, or alternatively to define the "safe" set-back distance for permanent structures or valuable infrastructure from an unstable slope. (Ottawa, 2013)

3. Stormwater management and on-site waste disposal designs developed as part of coastal construction site design should direct stormwater and effluent away from the bluff and should not discharge to the groundwater within the unstable portion of the bluff top.

Issue: Features of coastal development likely to increase the instability of coastal slopes, including the siting of septic systems and stormwater control measures, need more specific regulation to reduce the likelihood of negative impacts. Changes to surface water drainage patterns in coastal areas can destabilize bluffs. Stormwater and wastewater discharges to groundwater increase risk of bluff slumping or failure. Stormwater and wastewater management practices near bluffs should include limitations on discharge to groundwater within the unstable area portion of the bluff top.

Recommendations:

a. Managing stormwater on private property should minimize alteration to normal surface water drainage patterns. Guidance materials should be developed and distributed to coastal landowners highlighting proper stormwater management principles for bluff top development.

- Stormwater should be directed away from the bluff. Existing stormwater drainage patterns to nearby ravines and gullies should be maintained where possible. Development should not be allowed to encroach upon these gullies and ravines so that the**se features** can continue to effectively convey stormwater to the coast.
- Stormwater management practices near bluffs should include limitations on discharge to groundwater within the unstable area portion of the bluff top.

Rationale: Directing stormwater away from bluffs helps maintain the stability of coastal slopes both on the property to be developed and that of others. Stormwater retention basins constructed inland from coastal slopes contribute to infiltration and increased groundwater discharge at the slopes. Low Impact Development (LID) is an approach to stormwater management that promotes stormwater infiltration within individual lots in a subdivision. LID practices such as rain barrels can be effectively utilized if properly modified for bluff tops. Enlarged storage capacity rain barrels (e.g. multi-barrel systems) with slow release can avoid negative impacts to slope stability following large storms. However, other LID practices such as rain gardens and porous pavement can increase groundwater flow toward the bluff face, making bluffs less stable. It is important that these systems be constructed as far from the bluff as possible.

b. On-site waste disposal systems, including mound systems, should be placed landward of the coastal buildings they serve so that the effluent from these systems does not contribute to bluff landslides. Coastal community setback ordinances should explicitly exclude the placement of on-site waste disposal systems in the setback area since the Wisconsin Uniform Plumbing Code does not address this issue.

Rationale: Homeowners prefer mounds systems not be visible from the street to enhance curb appeal and therefore often opt to construct the systems in the back yard. However, the back yards of houses that are setback from coastal bluffs are not safe locations for on-site waste disposal systems. The added weight of these systems increases the loads and stresses on nearby slopes. The liquids that infiltrate into underlying soils reduce the friction between soil particles, migrate to adjacent slopes and seep from the bluff face onto the beach and into the lake. This partially treated sewage not only reduces the strength of slopes contributing to slope failure but contains fecal matter that constitutes a health hazard to beach users and adds pollutants to the lake.

4. *Non-structural shore protection measures should be encouraged.*

The non-structural shore protection measures (i.e. bluff top stormwater and wastewater management, maintaining and enhancing vegetation on coastal slopes and beach nourishment) should be used to protect existing at-risk development. Structural measures should only be used to protect existing developments as a last resort.

Issue: The traditional response to coastal erosion has been to attempt to intervene in the natural process—building protective structures to divert wave action, stop erosion at one point and build up the beach at another, and so forth. Such endeavors to protect a shoreline, however, can have unintended adverse impacts on other locations and over the long term.

The permitting of new shore protection structures can be a contentious process as adjacent property owners and other interested parties claim harm to private and public properties. State governments and the U.S. Army Corps of Engineers have respective responsibilities for the public lakebeds upon which shore protection structures commonly encroach. The effectiveness and survival of shore protection structures are threatened by severe storm waves riding ashore on storm surges, by bluff/bank collapse, by freeze-thaw fracturing of armor stone, and by lakebed erosion. Most shore protection structures interfere with the natural erosion process that contributes material to beaches.

Some portions of typical shore protection structures intrude upon the public lakebed or are constructed below the Ordinary High Water Mark. As a result they often limit public lateral movement along the coast and reduce the amount of sand containing sediments that builds beaches. Downdraft shoreline can have reduced sand cover in the near shore area increasing the potential for lakebed erosion. Lakebed erosion, an unseen coastal hazard, can undermine shore protection structures—leading to a shortened structure life and the prospect of catastrophic collapse, triggering massive slope failure in some places and the loss of facilities on bluff top land. In response to the adverse impacts - Maine, North Carolina, South Carolina and Oregon prohibit hard armoring of their coasts.

Recommendation: Shore protection structures should be considered only as a last resort and then only to protect existing buildings, not undeveloped lots. If there are no feasible non-structural options, shore protection structure designs should include: a site investigation of slope stability and lakeshore erosion, a no adverse impacts (NAI) analysis for all new shore protection structure applications, a plan for ensuring adequate quality control of materials used in the designed structure, and adequate monitoring and maintenance plans.

Rationale: In the Great Lakes, the littoral transport system carries sand and other sediments along the coast by waves and currents. Shore protection structures interfere with natural erosion and littoral drift that contribute sand to protective beaches and can deprive the littoral transport system of sediments that replenish areas that are down current. When this happens, areas that are down current of the structures lose land because there are no sediments left to restore those removed by the longshore drift. In addition, installation of shore protection structures results in the loss of natural habitat for fish and other aquatic organisms. Beyond the adverse impacts, in coastal areas with limited sand, lakebed erosion can undermine shore protection structures making them a short-term high-maintenance solution.

The U.S. Army Corps of Engineers, in cooperation with the Great Lakes States, has developed a publication called *Living on the Coast* (USACE/Wisconsin Sea Grant 2003). This publication recognizes the impacts of lakebed erosion and provides guidance for coastal property owners:

- adapt to natural processes,
- restore natural shorelines, moderate erosion and
- use armoring only as a last resort and with caution to avoid possible unintended consequences to other properties and public interest values.

For existing structures that are threatened, the report highlights a number of non-structural options available to homeowners including:

- managing stormwater on the bluff top by directing rain gutter downspouts and storm water away from the bluff,
- locating rain gardens and on-site waste disposal systems as far from the bluff as possible,
- retaining and nourishing beaches,
- maintaining and enhancing vegetation on coastal slopes and
- relocating threatened buildings.

5. Coastal hazard information should be readily available to the public.

Issue:

Coastal erosion hazard risks are not commonly known to realtors, sellers and potential buyers. The average length of ownership of coastal property is less than 10 years. Great Lake water levels fluctuate on the order of decades. Coastal property transactions have long been a "let the buyer beware" proposition. When these buyers receive a permit to build, they assume that it verifies it is safe to build there. The Wisconsin Coastal Management Program

Recommendation:

Erosion hazard maps for Wisconsin's coastal counties and other site- and reach- specific erosion information should be readily available to the public. Recession rate data and/or erosion hazard area mapping should be generated where gaps exist.

Rationale:

Coastal erosion hazard assessments and associated erosion hazard maps have been developed for Lake Michigan. Erosion hazard assessments have also been completed for the Lake Superior coastline.

Communities need to be able to identify where the setback requirements apply. Buyers of coastal property should be properly informed of the hazard. While during our interviews community permitting staff felt that setbacks should be established at the time of permit issuance, they suggested that Coastal Erosion Hazard Area mapping be available for informational and planning purposes.

6. Coastal communities should re-examine and revise their setback ordinances, while coastal communities without construction setback regulations should adopt them.

Coastal construction setbacks reduce the risk of erosion and/or landslides to new or replacement buildings and other facilities during their expected useful lives as climate changes occur. A coastal construction setback ordinance should include or account for the following elements:

- ***a. A recession rate and setback component for receding bluffs.***
- ***b. A planning horizon that exceeds the useful life of buildings.***
- ***c. A stable slope setback component for coastal bluffs prone to landslides.***
- ***d. A setback for bluffs along coastal gullies and ravines.***
- ***e. An additional facility setback component to provide an erosion safety margin over the expected life of new buildings and to enable future relocation of those buildings if needed.***
- ***f. A special exception permit criteria that focus on the moveability of the structure, not the existing setback on adjacent property.***
- ***g. A no prudent alternative and no adverse impact analysis when structural shore protection is proposed.***

Issue: In the 1980s the WCMP funded the development of a model coastal ordinance for construction setback distances. The WCMP promoted the adoption of this ordinance by coastal counties, an effort that was very successful. Racine, Ozaukee, Sheboygan, Manitowoc, Kewaunee, Bayfield and Douglas Counties adopted coastal setback provisions.

The recommended coastal zone protection standards in the model ordinance identified at that time warrant consideration of some enhancements given both better understanding of coastal stabilities and a shift to larger-sized buildings and other developments.

Over the past three decades there have been significant increases in both the rate and magnitude of individual investments in Wisconsin's coastal development. Many modest homes and seasonal cabins have been replaced by large four season homes of the types frequently seen in upper middle class or wealthy urban neighborhoods. Modern coastal buildings tend to be bigger and involve substantially larger investments than those standing when the Wisconsin Coastal Setback Model Ordinance was developed. Most of these buildings are built for year-round use and have useful lives approaching 100 years.

Coastal buildings built too close to the Great Lakes' unstable bluffs are be threatened by landslides and may ultimately require relocation or demolition. Where relocation may be necessary, building standards should be considered that would limit the footprint and require a foundation design that facilitates relocation. As an example, construction of buildings on concrete slabs is not appropriate on unstable bluffs tops since buildings constructed on slabs are difficult to move.

Soil conditions on bluffs with a changing climate include the possibilities of more surface and groundwater flow accompanying more extreme and frequent precipitation events, warmer winters with more frequent thaws and consequent slope failures, and the drying out of cohesive slopes during prolonged drought. Coastal slope stability analyses should use criteria that include an assumed maximum groundwater elevation and worst case soil conditions to determine site stability under conditions in which a given slope is most likely to fail.

Recommended components and enhancements to model coastal setback ordinance:

a. A recession rate setback component to address the rate of shoreline recession prevalent for the community. Where rates of recession are unknown rates of 2 or 3 feet per year should be utilized. (Reference from which setback measured changed from OHWM to Erosion Reference Feature.)

Rationale: Recession is the landward movement of a feature, such as a bluff or dune crest. Shoreline recession affects significant portions of the Great Lakes coast. The rate of recession is affected primarily by cyclically changing lake levels, disruption of longshore transport of beach-building material, intense rainfall events and storm-generated waves. Rates of bluff and dune recession along the shores of the Great Lakes vary from near zero to tens of feet per year because of annual variability in wave climate and lake levels (National Research Council, 1990). High Great Lakes water levels in the 1950s, mid-1970s, 1980s caused widespread bluff recession, damaging millions of dollars' worth of coastal development. Setting structures an appropriate distance back helps ensure the structures are not at risk during the lifetime of the structure.

Referencing coastal construction setbacks from an Erosion Reference Feature ties the setback directly to the hazard (e.g. bluff crest or bluff toe). An Erosion Reference Feature is defined in the NFIP regulations (See below) and is the reference most Great Lakes coastal states with coastal setback regulations utilize
.

> 44 CFR 59.1 Definitions. Reference feature is the receding edge of a bluff or eroding frontal dune, or if such a feature is not present, the normal high-water line or the seaward line of permanent vegetation if a high-water line cannot be identified.

b. A planning horizon that exceeds the useful life of buildings. (Recommended planning horizon: Increased from 50 to 100 years. Minimum: 60 years.)

Rationale: When the model ordinance was developed a 50 year period was seemed like a reasonable minimum figure, since was felt at the time it approximates the useful life of a typical residence (Yanggen 1981). However, coastal development since has become increasingly upscale. In recent decades, the value of coastal property has substantially increased. (The structure in Figure 32 is an example of the types of structures constructed on the Great Lakes coast.) Many coastal buildings, including residential homes, have useful lives of 70 to 100 years and beyond (Anderson 1978). In addition, homes with very large footprints cannot be readily relocated.

The Upton-Jones amendment to the act authorized and funded FEMA to map and reduce risks in coastal erosion hazard areas. Should Congress authorize and fund FEMA to reinstitute this program which sunset in 1989, the mapping would be based on 60 year planning horizon.

c. A stable slope setback component for coastal bluffs prone to landslides. (Reference from which setback measured changed from OHWM to Erosion Reference Feature and some additional standards on how site-specific slope stability analyzes should be conducted have been added.)

The coastal model ordinance includes a component to address unstable slopes. Referencing coastal construction setbacks from an Erosion Reference Feature ties the setback directly to the hazard (e.g. bluff crest or bluff toe). In addition, language has been added on how to properly conduct slope stability analyzes.

Stable slope angles to be used as guidelines for siting new constructed facilities should be determined by slope stability analysis that includes:

- the highest groundwater conditions that can occur at the site (not the elevation of the groundwater on the day of the analysis) and
- safety factors appropriate of the types of facilities planned for construction and the consequences of slope failures after development.

Rationale: Rationale and more detail provided under recommendation 2.

d. A setback for bluffs along coastal gullies and ravines. (New Addition)

Rationale: Bluffs in coastal gullies and ravines along the coast will likely be made up of soils similar to those of the adjacent bluffs on the open coast. Gullies may have periodic high flow from runoff that removes slumped material at the base of slopes just as waves remove slumped material on coastal slopes. Actively eroding gullies can be as hazardous as actively eroding coastal slopes that face the lake.

e. An additional facility setback component of 100 feet to provide an erosion safety margin over the expected life of new buildings and to enable future relocation of those buildings if needed. (New addition)

Rationale: The recession setback methodology is intended to predict the location of the stable bluff edge at the end of the planning horizon. The end of the planning horizon should not be the time at which a permitted structure collapses because of slope failure. An additional setback is needed to ensure that buildings and other structures are adequately setback from the bluff edge at the end of the planning horizon. This additional setback is particularly important if the planning horizon is shorter than the expected life of the structure.

The additional 100 foot setback distance serves two purposes: 1) to provide a margin of safety in case the rate of recession and/or the landslide potential is greater than predicted and 2) to provide room for equipment for safely removing a building threatened by erosion or bluff slumping at the end of the planning cycle.

f. A Special exception permit criteria that focus on the ability of the structure to be relocated, not the existing setback on adjacent property. (New addition) – Building permits for setbacks less than the minimum should not be issued unless:

- the applicant has been warned about the increased risk of damage or loss from erosion by use of a reduced setback, and
- the building design and the lot space make future relocation of the building readily feasible.

***Rationale*:** Zoning law includes a special exception process particularly for when a community ordinance makes a pre-existing lot unbuildable. Wisconsin Shoreland Management regulations include a provision for a special exception process that permits proportionate reduction of setbacks where nearby structures are built at a lesser setback. This rule does not and should not apply to erosion hazard setback. To permit a lesser setback in these instances would be akin to allowing new development in the floodplain because there is already development there. Setbacks from unstable bluffs and a receding coastline are related to safety and catastrophic damages to property.

Special exceptions that allow reduced setbacks in coastal hazard areas should include conditions to address safety and prevent catastrophic loss of property. The most common approach is to limit the size and design of the structure. Requiring building standards that enable the building to be relocated when threatened by coastal recession is a prudent way to lessen future risk of damage and loss from erosion, and also allow reasonable use of the substandard lot.

g. A no prudent alternative and no adverse impact analysis when structural shore protection is proposed. (New addition).

Rationale: When owners of existing developments experience increased shoreline and bluff erosion that threatens property or buildings, long-standing common practice is to install riprap or other solid erosion control structures (e.g. sea walls, revetments, etc.). Existing Wisconsin and local government shoreland and coastal zone policies on shore protection structures do not take into account that such structural "solutions" can adversely affect nearby coastal property owners and the condition of the public lakebed and nearshore waters of the Great Lakes. These factors include:

1) Lakebed erosion in some nearshore locations that eventually undermines most types of shore protection structures, resulting in the need for frequent repair or shortening their useful lives.
2) Long-term negative impacts of some shore protection structures on beaches where the structures are located and on neighboring properties for some distance along the coast. This includes the negative impacts of building shore protection structures adequate to meet a broadening range of likely future lake levels and extreme storm conditions.
3) Negative impacts of shore protection structures on public access and recreation use and nearshore habitat for aquatic organisms.

The U.S. Army Corps of Engineers, in cooperation with the Great Lakes States, has developed a publication called *Living on the Coast* (USACE/Wisconsin Sea Grant 2003). This publication recognizes the impacts of lakebed erosion and provides guidance for coastal property owners:

- adapt to natural processes,
- restore natural shorelines, moderate erosion and
- use armoring only as a last resort and with caution to avoid possible unintended consequences to other properties and public interest values.

The principal message of *Living on the Coast* is to do everything possible to avoid placing buildings and other structures where flooding, storm waves and erosion are likely to damage them or shorten their useful lives. For existing structures that are threatened, there are a number of options other than shore protection available to homeowners including:

- managing stormwater on the bluff top by directing rain gutter downspouts and storm water away from the bluff,
- locating rain gardens and on-site waste disposal systems as far from the bluff as possible,
- retaining and nourishing beaches,
- maintaining and enhancing vegetation on coastal slopes and
- relocating threatened buildings.

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Attachment

COASTAL EROSION HAZARD MODEL ORDINANCE

Revised December 2015[1]

1.0 Findings of Fact and Statement of Purpose

1.1 Finding of Fact

The coastal erosion hazard areas of _______________ are subject to substantial erosion. These hazard areas have been identified on the basis of studies of shoreline recession, stable slope angles and other engineering and geological studies and principles. Improper land use within these areas causes erosion damages in the form of property losses, environmental degradation and impairment of public rights in navigable waters. These erosion damages are the result of: (1) structures placed in areas which will be undermined by erosion; (2) land use activities which accelerate erosion; and (3) improperly designed, installed and maintained protective measures which accelerate erosion on nearby properties and cause environmental damage.

1.2 Statement of Purpose

It is the purpose of these regulations to protect the public health, safety and general welfare and to reduce erosion damages by: (1) establishing a setback line designed to minimize losses over the projected lifetime of a structure; (2) restricting uses which are vulnerable to erosion damage; (3) regulating land disturbance, stormwater drainage and other activities which increase erosion; and (4) requiring that proposed protective measures are properly designed, installed and maintained.

2.0 Lands to Which Regulations Apply

(Option #1) These regulations shall apply to all lands which are within (500) feet of the shoreline of Lake _________________________.

(Option #2) These regulations shall apply to all lands within the Erosion Hazard Overlay District as shown on the Official Zoning Map.

3.0 General Provisions

3.1 Effect on Other Regulations

3.11 These provisions are intended to supplement and not to repeal other applicable regulations, however, where these provisions impose greater restrictions they shall control.

3.12 No lot shall hereafter be created, subdivided or otherwise established without sufficient depth to accommodate structures in compliance with these provisions.

3.2 Warning and Disclaimer of Liability

These provisions are considered the minimum reasonable requirements necessary for reducing erosion damages for a Option 1: 100 year period Option 2: 60 year period. These requirements are based upon engineering, geological and other scientific studies and principles. Faster rates of erosion may occur. Erosion rates may be increased by natural causes such as major storms or high lake levels or by manmade causes such as the construction of erosion control measures or land disturbing activities. These regulations do not guarantee nor warrant that development in compliance with its terms

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[1] This model ordinance was adapted from Yanggen (1981) – Revisions highlighted in yellow – Background and rationale available in the report titled Managing Coastal Hazard Risks on Wisconsin's Dynamic Great Lakes Shoreline – 2015.

will be free from all erosion damage. Reliance on these regulations shall not create liability on the part of the enacting government or any officer or employee thereof.

4.0 Definitions

4.1 A "Bluff" is that segment of the shoreline which is 10 feet or more in height and which has a rise of 10 feet or more vertical distance in less than 25 feet horizontal distance.

4.2 Bluff crest is the upper edge or margin of a shoreline bluff.

4.3 Bluff toe is the base of the bluff where it meets the beach.

4.4 Dunes and beaches are those erodible segments of the shoreline which are not bluffs.

4.5 Erosion Reference Feature is the receding edge of a bluff or eroding frontal dune, or if such a feature is not present, the highest recorded water level for the associated lake.

4.6 Shoreline protection devices mean breakwaters, groins, revetments, seawalls, bulkheads, riprap, bluff stabilization projects and similar measures.

5.0 Erosion Hazard Setback Lines –

Within the boundaries of the erosion hazard areas established by Section 2.0 the minimum erosion hazard setback shall be as follows:

5.1 Bluffs

5.1.1 A stable slope angle setback shall be established at a ratio of (2 ½ for Lake Michigan) (3 for Lake Superior) feet horizontal distance to every one foot vertical distance. The measurement shall be made from the toe of the bluff perpendicular to the shoreline. There shall be two such measurements made for every 100 feet of shoreline at points not less than 50 feet apart. The stable slope angle setback shall be a line connecting these two points or such line extended. In cases of an irregular shoreline or where the lots are not perpendicular to the shoreline, the Zoning Administrator may require that additional points of measurement be used to determine the stable slope angle setback.

5.1.2 An additional recession rate setback shall be measured from the stable slope angle setback. The recession rate for [Option 1: 100 year period Option 2: 60 year period] shall be calculated using the average annual recession rate indicated on the official zoning map. Where no recession rate information is available, the recession rate can be calculated by assuming a (2) (3) foot per year average annual recession rate.

5.1.3 An additional facility setback of 100 feet shall be provided.

5.2 Ravines

A stable slope angle setback shall be measured at a ratio consistent with Section 5.1.1 for all ravines 10 feet or deeper. The measurement shall be made from the center of the deepest part of the ravine.

5.3 Dunes and Beaches - A recession rate setback shall be measured from the Erosion Reference Feature. The [Option 1: 100 year period Option 2: 60 year period] year recession rate shall be calculated using the average annual recession rate indicated on the official zoning map. Where the recession rate is not known, the recession related setback shall be calculated by assuming a (2) (3) foot per year average annual recession rate.

5.4 Minimum setback - There shall be a minimum setback of 75 feet from the Erosion Reference Feature in all cases. In areas where the bluff height is greater than __ feet, the minimum setback shall be 75 or 100 feet from the top of the bluff.

[Commentary: In areas where deep slumps are likely, 100 feet would ensure that 2 slumps of 50 feet during the life of the structure would not damage the structure. Seventy-five feet would account for allow 2 slumps of 35+ feet and would be consistent with the standard 75 foot shoreland zoning setback. The difference would be that this setback would be from the bluff edge not the ordinary high water mark.]

5.5 The bluff crest, bluff toe and setback lines shall be determined by the zoning administrator on the basis of data submitted by a licensed surveyor or on the basis of field inspection.

5.6 The Zoning Agency may issue a conditional use permit allowing modification of the erosion hazard setback upon presentation by the applicant of acceptable engineering studies documenting (1) lower recession rates or (2) more stable slope conditions.

5.7 Engineering studies evaluating slope stability shall use the top of the lake sediments or ¾ the height of the bluff (whichever is greater) as the groundwater surface.

5.8 Engineering studies evaluating slope stability for the placement of permanent structures shall ensure that the long-term safety factor is greater than 1.5.

6.0 Regulation of Uses Within Erosion Hazard Setbacks

These provisions supplement the underlying zoning which remains in effect to the extent its provisions are more restrictive. The following uses are prohibited uses, permitted uses and conditional uses within the erosion hazard setbacks established.

6.1 Prohibited Uses

6.11 Residential, institutional, commercial, industrial, agricultural and public buildings designed for permanent use at the proposed location.

6.12 Septic tank systems and other on-site waste disposal facilities.

6.2 Permitted Uses

6.21 Open space uses

6.22 Storage of portable equipment, machinery or materials

6.23 Accessory buildings which can be easily and economically moved, such as storage sheds, dog kennels and animal housing units

6.24 Minor structures such as driveways, walkways, patios and fences

6.3 Conditional Uses

6.31 Building and structures which are readily removable in their entirety provided they are so located and constructed that they may be removed prior to erosion damage

6.32 Other uses similar to those permitted in 6.2 and 6.3 which are determined by the Zoning Agency to be compatible with the purpose and intent of these regulations. (See also Regulation of Shoreline Protection Devices and Land Disturbances.)

7.0 Regulation of Shoreline Protection Devices and Land Disturbances

7.1 The following shoreline protection activities are conditional uses:

7.11 All structures or deposits, which are shoreline protection devices, below the ordinary high watermark.

7.12 The placement of shoreland protection devices above the ordinary high watermark.

7.13 "Shoreline protection devices" means breakwaters, groins, revetments, seawalls, bulkheads, riprap, deposition of materials such as stone and concrete rubble, bluff stabilization projects and similar measures.

7.14 **T**he applicant must first establish that there is no feasible and prudent alternative to the need to construct the proposed shore protection structure, including the inability to relocate any building threatened because of coastal erosion on the applicant's lot of record.

7.15 ***.*** A long-term maintenance program must be included. The maintenance programs must include specifications for normal maintenance of degradable materials including repairs necessary to maintain the integrity of the shore protection structure. To assure compliance with the proposed maintenance programs, a bond or other financial security may be required.

7.16 The application for shoreline protection devices shall include a certification from a licensed professional that the proposed device will not adversely impact the stability and integrity of neighboring properties, building foundations, buried services and infrastructure.

7.2 The following land disturbing activities are conditional uses when conducted within 300 feet of the ordinary high watermark or the erosion hazard setback, whichever is a greater distance.

7.21 Alteration of more than (500) square feet of wetlands. For purposes of this regulation, "wetlands" are defined as "those areas where water is at, near or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation, and which have soils indicative of wet conditions". The provisions of NR 115 shall control where applicable.

7.22 Filling or grading on all slopes of 20 percent or more

7.23 Filling or grading of more than (1000) square feet on slopes of 12-20 percent

7.24 Filling or grading of more than (2000) square feet on slopes of 12 percent or less

7.25 Dredging, construction or other work on any artificial waterway, canal, ditch, lagoon or similar waterway

7.26 Removal of more than (500) square feet of vegetation. Where vegetation is removed, it shall be replaced, as far as practical, with other vegetation that is effective in retarding runoff, preventing erosion and preserving natural beauty.

8.0 Conditional Uses

8.1 In General

Conditional uses are uses which may create special problems and hazards if allowed as a matter of right. Whether such uses can be appropriately established depends upon the facts and circumstances of the particular situation. The conditions which may be attached to development permission can, in some instances, avoid adverse effects on adjoining property or the public welfare.

Conditional uses are allowable only upon approval by the Zoning Agency authorized to issue conditional use permits. The Zoning Agency may, after public notice and hearing, permit, deny or permit the use subject to attached conditions. In passing upon a conditional use the Zoning Agency shall specify the information to be supplied, evaluate the proposed use according to specified standards, and attach appropriate conditions to development permission.

8.2 Procedure

8.21 Any use listed as a conditional use shall be permitted only upon application to the Zoning Administrator and issuance of a Conditional Use Permit by the Zoning Agency.

8.22 Before passing upon an application for a Conditional Use Permit the Zoning Agency shall give notice and hold a public hearing in the manner specified by statute. (Sec. 59.97(6)-counties) (s. 62.23(7)(e)6-cities

8.23 The Zoning Agency shall, when appropriate, seek technical review assistance available from the Department of Natural Resources, County Soil and Water Conservation District, US Corps of Engineers, and other agencies having relevant expertise.

8.3 Information to Be Supplied

The Zoning Agency may require the applicant to furnish the following data which it finds is pertinent and necessary for its determination:

8.31 A plat of survey prepared by a registered land surveyor, or other maps drawn to scale showing the location and dimensions of: property boundaries, the ordinary high watermark, contours of the site, required and proposed yards and setbacks, existing and proposed vegetative cover and landscaping, existing and proposed buildings, structures, driveways, parking and loading areas and streets, existing and proposed areas for the storage of equipment, machinery and materials, areas of proposed grading, filling, dredging and vegetative removal, and **existing and proposed methods of controlling stormwater runoff and problem groundwater conditions.**

[Commentary: Surface water should be directed away from the bluff and prevented from running over the edge and down the face of a bluff. Rain gardens and on-site waste disposal systems should be located as far from the bluff as possible. Rain gutter downspouts should be directed away from the bluff.]

8.32 Plans of buildings and other structures, sewage disposal facilities, water supply facilities.

8.33 A description of the method of operation of industrial and commercial uses.

8.34 A report, prepared by a registered professional engineer, certifying that the site is or can be made suitable for the proposed development. The report shall consider, describe and analyze the following:

(1) past, current and future wave induced erosion based upon recession rates and wave energy calculations;

(2) geologic conditions including the soils and stratigraphy of the site and an analysis of the properties and stability of the materials present – for any slope stability analyses conducted the groundwater elevation shall be assumed to be at the height of the lake sediments or ¾ the height of the bluff (whichever is greater).

[Commentary: Bluffs frequently fail when groundwater in the bluff is at its highest level. Any stability analysis conducted should demonstrate stability during worst-case conditions. Any slope stability analysis should evaluate the site based upon when it is most likely to fail.]

(3) ground and surface water conditions and variations including changes that will be caused by the proposed development;

(4) plans and specifications for bluff and shoreline stabilization measures and plans and specifications for measures to protect against wave erosion, including the estimated life of such measures, their cost, the

maintenance required and the effect on nearby properties and the shoreline and lake environment;

(5) where a modification of the erosion hazard setback is proposed the minimum setback required to provide a reasonable degree of safety to the proposed use for at least a ______year period; Any stability analysis shall include a factor of safety of 1.5 or greater for permanent structures and infrastructure.

(6) methods to be used to control surface erosion and stormwater runoff during and after construction;

(7) the elevation of the 100 year flood, storm surges, wave height and wave runup where the site is subject to flooding.

8.35 Other pertinent data necessary to determine if the proposed use and location is consistent with the requirements of these regulations.

8.4 Standards Applicable to All Conditional Uses

In passing upon a condition use, the Zoning Agency shall evaluate the proposed use in terms of:

8.41 The erosion and flooding hazard

8.42 The need of the proposed use for a shoreland location

8.43 Compatibility with nearby land uses

8.45 Adequacy of proposed waste disposal and water supply systems

8.46 Location with respect to existing or proposed roads

8.46 The demand for public services engendered and the adequacy of existing services to meet the demand

8.47 Protection of the scenic beauty of the shoreland

8.48 Protection of public rights in navigable waters

8.5 Conditions Which May Be Attached to Conditional Uses

8.5.1 Upon Consideration of the factors listed above, the Zoning Agency may attach such conditions, in addition to those required elsewhere in this ordinance, that it deems necessary to further the purpose and intent of these regulations. Such conditions may include, without limitation because of specific enumeration: bluff and shoreline stabilization measures; measures to protect against wave attack; control of ground water seepage; revegetation and landscaping; control of surface water runoff; the continued and regular maintenance of the above listed measures; design and construction of structures to be moveable in accordance with accepted architectural or engineering standards; the removal and relocation of uses prior to erosion damage; type of construction; construction commencement and completion dates; performance standards and operational controls; dedication of land; sureties and performance bonds; deed restrictions; and other measures designed to ensure the satisfactory location and maintenance of uses in accord with the purpose and intent of these regulations.

8.5.2 When a conditional use is approved a record shall be made of the land use and structures permitted, and the conditions attached to such permission. Violation of conditions attached to a conditional use shall constitute violation of this ordinance. The Zoning Agency may, after notice and hearing and opportunity for corrective action, revoke the permit and seek a forfeiture or injunction order as provided in Section _____of this ordinance.

8.5.3 All legal existing uses which would be classified as conditional uses if they were to be established after the effective date of this ordinance or its amendment are hereby declared to be conforming conditional uses to the extent of the existing operation only. Any addition, alteration, extension, or other change in the existing operation shall be subject to the conditional use procedures as if such use were being

9.0 Nonconforming Uses

The lawful use of a building or premise existing at the effective date of this ordinance or its amendment may continue in the same manner and to the same extent subject to the following requirements:

9.1 Routine repairs and maintenance are permitted

9.2 No alterations, additions or expansions shall occur which increase the dimensional nonconformity within the erosion hazard setback unless a variance is obtained as provided in 8.0

9.3 The use of any vacant lot or parcel shown on a recorded subdivision plat, assessor's plat or a conveyance, recorded in the office of the Register of Deeds, which does not conform to the erosion hazard setback shall be permitted only upon the issuance of a variance by the Board of (Adjustment) (Appeals).

10.0 Variance

A variance from the erosion hazard setback may be granted by the Board of (Adjustment) (Appeals) based upon the following standards:

10.1 No variance shall be granted which would have the effect of allowing in any district a use not permitted in that district.

10.2 No variance shall be granted which would have the effect of allowing a use of land or property which would violate state laws or administrative rules.

10.3 A variance may be granted where strict enforcement of the terms of this ordinance results in unnecessary hardship and where a variance will not be contrary to the public interest, will allow the spirit of the ordinance to be observed, and substantial justice done.

10.4 Conditions shall be attached in writing to all approved variances where such conditions will achieve compliance with the standards of this ordinance. Such conditions may include:

10.41 The proposed use is located as far landward of the erosion hazard setback as is practical.

10.42 **Septic tank systems and other on-site waste disposal facilities are placed landward of the principal structure.**

10.43 **The proposed structure is designed, constructed and located so as to be moveable to a safe location prior to erosion damage and a deed restriction is recorded requiring removal.** Slab on grade construction is not permitted unless it can be demonstrated that the associated structure can be moved if necessary.

10.44 Those conditions which may be attached to conditional uses as specified by 8.5.

Reference: Yanggen, Doug A. (Jan 1981) Regulations to Reduce Coastal Erosion Losses. University of Wisconsin-Extension for the Wisconsin Coastal Management Program.