Great Lakes Coastal Resilience in a Changing Climate

Adam Bechle
Coastal Engineering Outreach Specialist
Wisconsin Sea Grant
bechle@aqua.wisc.edu

WICCI
WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

Sea Grant
University of Wisconsin


[Jeff DuMez]


[Capt. Dennis Carr, Wisconsin Civil Air Patrol]


[Wisconsin Sea Grant/Gene Clark]

Wisconsin Sea Grant

Wisconsin Sea Grant promotes the sustainable use of Great Lakes resources through research, education and outreach

Sea Grant
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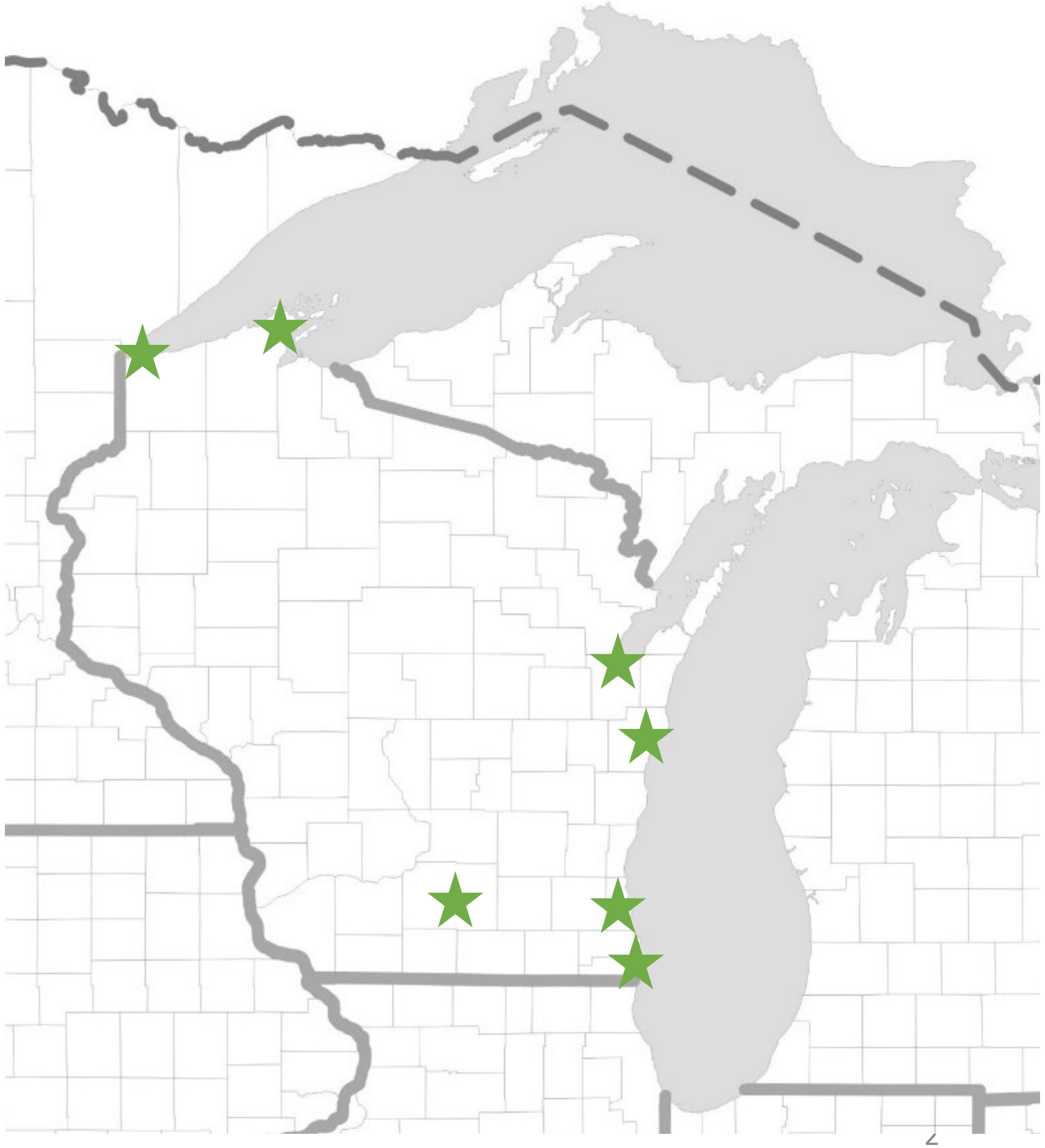


[www.amaps.com]

Wisconsin Initiative on Climate Change Impacts

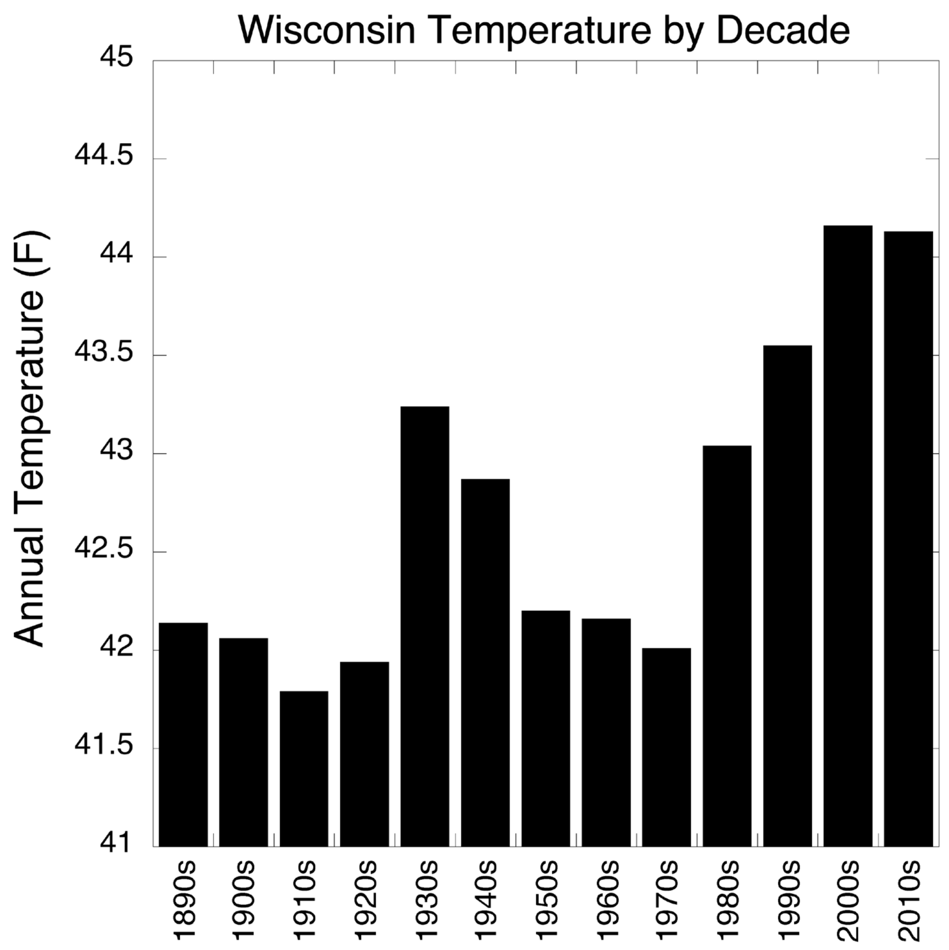
Nelson Institute for Environmental Studies | Wisconsin Department of Natural Resources

WISCONSIN
DEPT. OF NATURAL RESOURCES

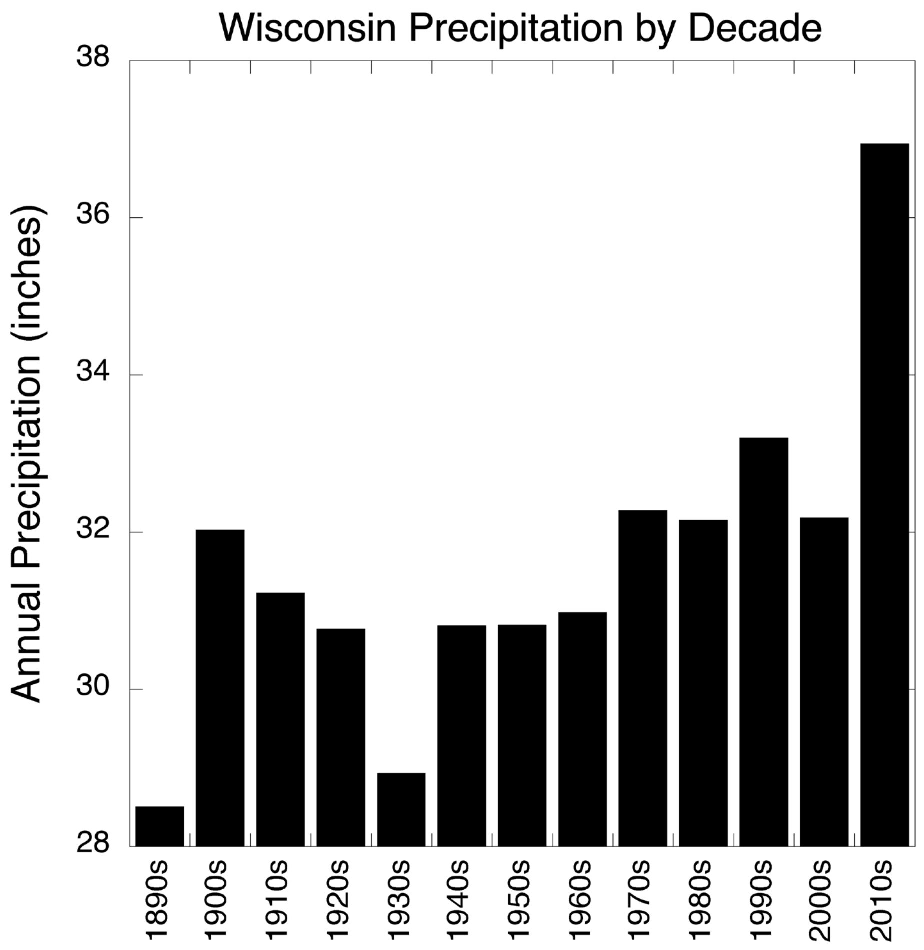
WICCI's mission: Generate and share information that can foster solutions to climate change in Wisconsin (and beyond).

wicci.wisc.edu

Warmer and Wetter



2000s and 2010s = warmest decades



2010s the wettest decade by far

WICCI Working Groups

Air

Climate

Geospatial

Water

Fisheries

Great Lakes

Water Resources

Coastal Resilience

Land

Agriculture

Forestry

Plants and Natural Communities

Wildlife

People

Community Sustainability

Human Health

Tourism

Infrastructure

132

Scientists & Practitioners

45

National and State Agencies, Organizations & Universities

WICCI Coastal Resilience Working Group

Co-Chairs

Adam Bechle
Wisconsin Sea Grant

David A. Hart
Wisconsin Sea Grant

Workgroup Members

Kate Angel
Adam Arend
Gene Clark
Faith Fitzpatrick

Michelle Hase
Jim Killian
Al Lulloff
Dave Mickelson
Lydia Salus

Andrew Struck
Sara Szabo
Crystal von Holdt
Chin Wu

historically disadvantaged communities live. The data will be geographically specific to areas across the state and will help guide investment in Wisconsin's infrastructure. This work will help stormwater engineers and planners better evaluate risks and reduce damage to roadways and other infrastructure.

Embedded carbon

Carbon dioxide, a greenhouse gas, is released during the process of creating the most common construction materials like concrete and steel. The emissions from the production of these materials represents a significant source of greenhouse gases. While agencies and the construction industry are aware of the issue and starting to address it, they would benefit from consistent standards to be able to compare construction bids as part of reducing greenhouse gas emissions.

Infrastructure sustainability programs that encourage the use of sustainable materials, recycling, better planning, and more efficient construction practices can reduce carbon emissions from construction materials. These programs can also benefit the regional economy by encouraging locally sourced materials and spur technical and business innovations.

Solutions

Support efforts to plan and design infrastructure projects that specifically consider vulnerability and risk associated with future climate conditions

Provide additional funding for infrastructure replacement or repair to proactively make infrastructure more resilient to future changes.

Provide a standardized method to evaluate and report embodied carbon emissions from the most commonly used construction materials in Wisconsin

Learn more

The **Infrastructure Working Group** considered these issues, impacts, and solutions and are working closely with infrastructure engineers and scientists to find practical solutions that will work for the transportation industry.

COASTAL RESILIENCE

Wisconsin's Lake Michigan and Lake Superior coasts have been impacted by extreme and rapid fluctuations in lake levels in the past decade. Along Lake Michigan, near record high water levels in 2020 followed record low water levels in 2013. In the past decade, fluctuations in Great Lakes water levels have been rapid. For example, the monthly average water levels on Lake Michigan rose 1.7 feet in six months from the record low level in January 2013 to July 2013; 1.7 feet in four months from March to July 2014; 1.7 feet in five months from February to July 2017; and 1.8 feet in five months from February to July 2019.

Both high and low water level extremes are anticipated under a changing climate along the Great Lakes coastline. This could include potentially higher highs, lower lows, and more rapid fluctuations than seen in the historical record. High variability in water levels combined with bigger waves and storm surge could increase erosion and decrease the stability of coastal bluffs.

These climate changes will impact coastal-dependent industries and people who live in the coastal area. At low water levels, concerns include insufficient water depths for navigation in ports, harbors, and marinas and increased scour around coastal structures. At high water levels, concerns include increased erosion, flooding, bluff failure, and infrastructure damage from high water levels combined with storm surges. Also, as water temperatures increase, coastal beaches and drinking water intakes are more likely to be impacted by potentially toxic blue-green algal blooms.

Increasing wave energy

Wave energy reaching Great Lakes coasts is expected to increase in the future, in part due to anticipated decreases in ice cover extent and duration. A reduction of ice cover will expose the coast to waves for a greater portion of the winter, the season when coastal storm intensity is greatest and large wave events are most frequent. Great Lakes wave energy has also been observed to increase during the summer months, associated with an increased frequency of extreme wind speed events.

Greater wave energy reaching the coast will lead to increased erosion and flooding of the shoreline. During times of higher water levels, these large waves will be able to reach further inland and cause greater coastline erosion and flooding.

During times of lower water levels, greater wave energy will increase erosion of the lakebed, a process known as downcutting. With the lakebed steepened by erosion, waves travel towards the coast in deeper water and are able to reach the coast at a greater height.

Nature-based solutions like this constructed wetland with native plantings can make coastal areas more resilient. Sam Myers Park, Racine, Wis. Photo credit: Adam Bechle

"We have two sections of Beach Drive within 20-30 feet of the shoreline and a sanitary sewer main that is literally in the lake… In October and November of 2019 and January of 2020, storms threw debris, driftwood, and concrete rubble, up and onto the road a distance of fifty or sixty feet. It was really something else. We documented, in the six weeks between mid-October and early December of 2019, that we lost upwards of seven feet of shoreline just in that six-week period."

–Scott Brandmeier, Director, Public Works Department, Fox Point, Wis.
Read the full interview

"Bluff erosion is an issue we've been seeing both on our coastal park properties and private land and residences. I've been with the county a little over twenty years now and I can say that these last few years we've seen the most change in our coastal park properties because of erosion. We've also seen pretty severe erosion at some private properties we deal with on a planning level. Some of those houses have had to be evacuated because of the rapid loss of the bluff."

–Andrew Struck, Director, Parks and Planning Department, Ozaukee Co., Wis.
Read the full interview

Increasing precipitation

Trends of increasing precipitation totals and heavy rainfall event frequency are expected to continue under a changing climate. Increased heavy rainfall will lead to more frequent flooding in rivers and stormwater infrastructure that drain to the Great Lakes, especially during periods of higher water levels, which can limit the ability for outlets to drain into the lake.

An increase in rainfall total and frequency of extreme events will likely reduce the stability of coastal bluffs and cause more bluff slumping. Surface water runoff down the bluff face erodes surface soils and can carve gullies into the bluff face where flow concentrates. Water that infiltrates into the bluff's groundwater table lubricates soil particles and reduces the stability of the bluff slope, increasing the likelihood of collapse. In times of drought, the dryness can create deep fissures in shoreline bluffs. These fissures allow surface water access to deeper parts of the bluff. Thus, heavy rainfall amidst drought conditions can lead to major slope failure.

In the long term, to stabilize Great Lakes coastal bluffs, improved coastal-specific stormwater and groundwater management practices are needed for near coastal bluff areas.

Vulnerability assessments

Vulnerability assessments identify critical infrastructure and help to protect homes, ports, harbors, and marinas. Since periods of high and low water levels typically fluctuate on the scale of decades, it can be easy to forget the threat of either extreme. Documenting vulnerabilities to both high and low water levels and incorporating hazard mitigation strategies into long-term plans can help communities keep building resilience to these impacts.

A recent project to address coastal resilience, the Southeastern Wisconsin Coastal Resilience project, made communities more aware of their vulnerabilities and sparked specific projects to strengthen their resilience to coastal hazards during both low- and high-water periods.

Vulnerability assessments to identify critical infrastructure can help communities adapt to periods of high and low water levels along the Great Lakes. High water levels overtop a seawall and inundate a sidewalk in Manitowoc, Wis.
Photo credit: Adam Bechle, Wisconsin Sea Grant

Managed retreat

Relocation of homes and communities in response to erosion and flooding is becoming increasingly common in coastal areas around the United States. Relocation of buildings away from high-risk coastal areas is often considered part of a larger planning strategy referred to as a "managed retreat." This strategy focuses on purchasing, relocating or demolishing homes that are in imminent danger from coastal erosion processes rather than constructing control structures.

Outreach and education are often needed to help make the case for managed retreat programs. While the cost of relocation can be a significant portion of the value of a home, relocation can oftentimes be the cheapest and most effective strategy to deal with coastal erosion compared to attempts to halt erosion.

The voluntary acquisition and conversion to open space of at-risk coastal property may improve public access to Wisconsin's Great Lakes coasts for residents without the financial means to own coastal property.

Dredging

The need to dredge to maintain critical channel depths in Wisconsin's Great Lakes harbors may increase under a changing climate, as periods of low Great Lakes water levels are likely in the future, potentially reaching lower lows due to increased periods of drought and/or increased evaporation from warmer temperatures and reduced ice cover. Much of the material dredged to maintain channels may be relatively uncontaminated. Instead of putting the dredge material into rapidly filling and costly confined disposal facilities, alternative uses for dredged material could provide significant cost savings as well as sustainable environmental benefits. The material could be used in civil engineering projects.

Nature-based shorelines

Wisconsin's Coastal Management and Sea Grant Programs have resources that can help communities manage beaches given the extremes in Great Lakes water levels. Sam Meyers Park on the City of Racine's waterfront was restored and is an example of nature-based shoreline restoration work. The extensive restoration turned a beach with poor water quality and invasive species into a vibrant wetland dune ecosystem with a swimming area that has good water quality. Restoration of the park has created an additional high quality public access point to Wisconsin's Great Lakes coasts for residents without the financial means to own coastal property.

Nature-based solutions can protect shorelines and, once established, be more appealing and beneficial for wildlife. Rock sill and marsh vegetation plugs installed to protect the Wisconsin Point shoreline in Allouez Bay, Superior, Wis.
Photo credit: Adam Bechle

Wisconsin Point is a large freshwater sandbar on the eastern boundary of the City of Superior in Douglas County, Wisconsin. Changing water levels and uncommon wind directions in Lake Superior led to erosion along the one road going down the center of the peninsula, cutting up close to and compromising the road. The City of Superior parks director pushed for a non-traditional approach to address the erosion and rebuild the road. The

Adapting to a Changing Great Lakes Coast

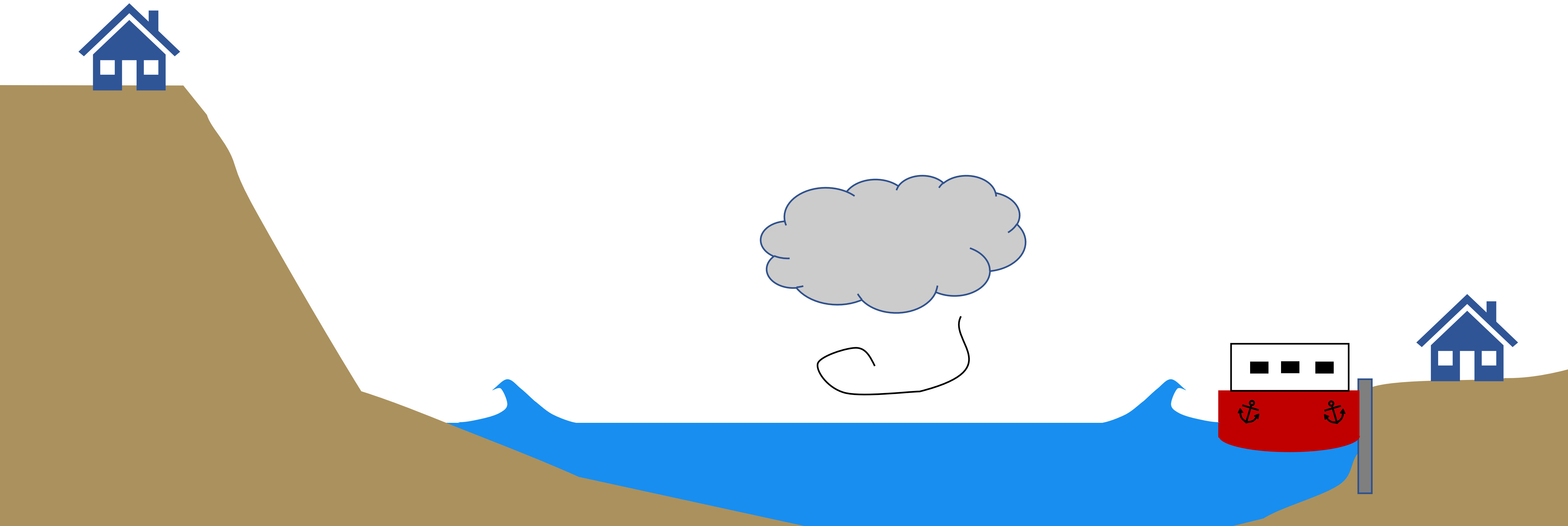
- How is climate change affecting Great Lakes coasts?

- What are the impacts to coastal communities?

- What strategies can be used to adapt?

Great Lakes Coastal Climate Stressors

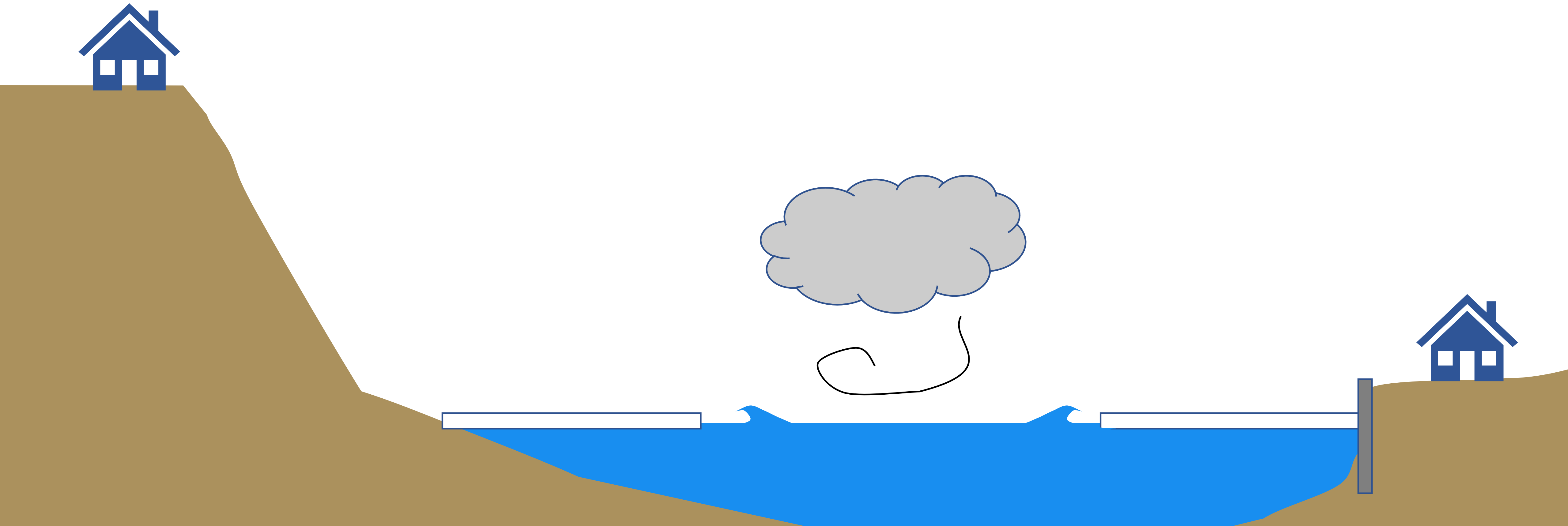
Wave Energy



Great Lakes Coastal Climate Stressors

Wave Energy

Ice Cover

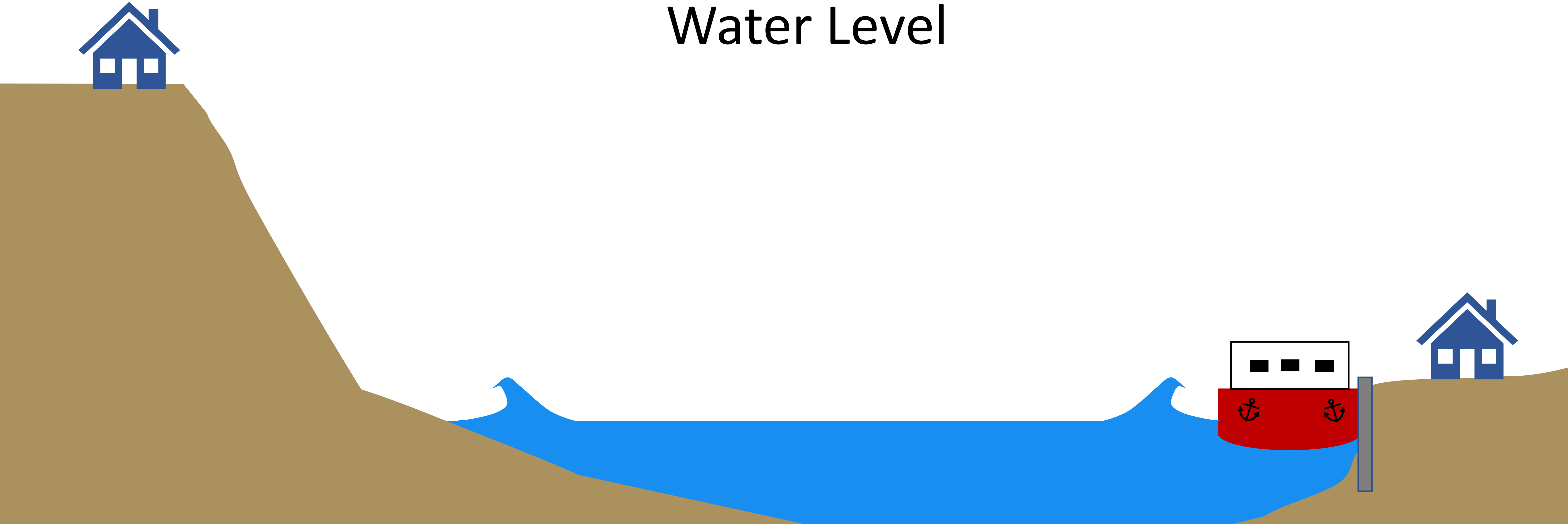


Great Lakes Coastal Climate Stressors

Wave Energy

Ice Cover

Water Level

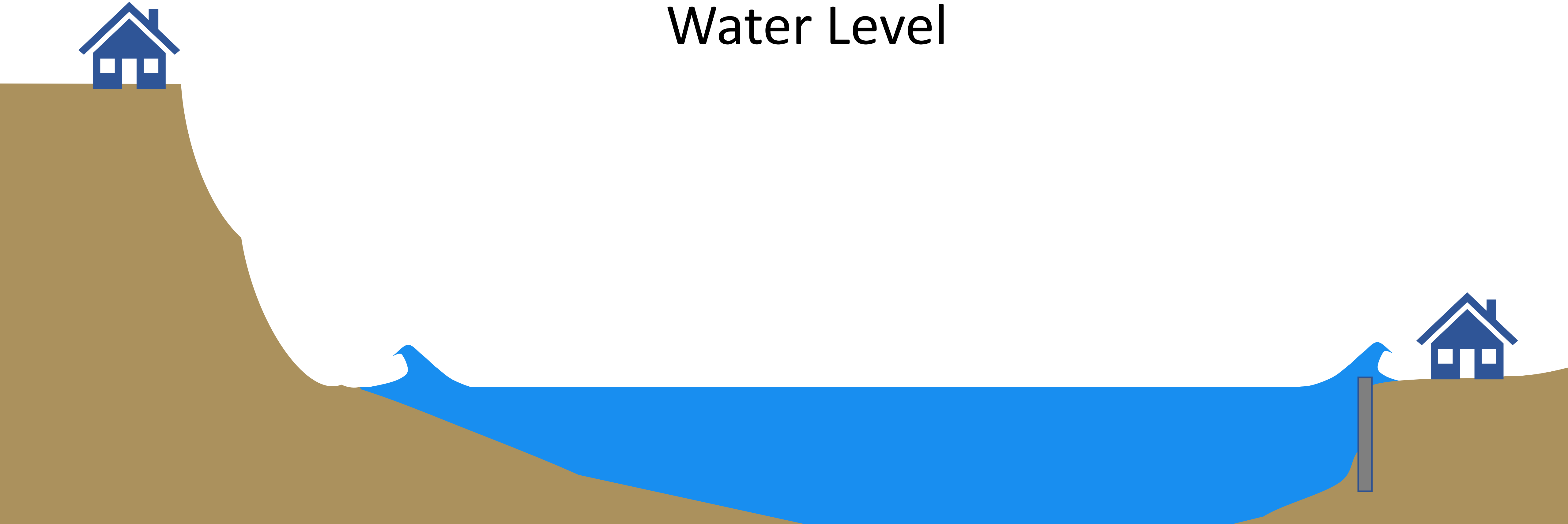


Great Lakes Coastal Climate Stressors

Wave Energy

Ice Cover

Water Level

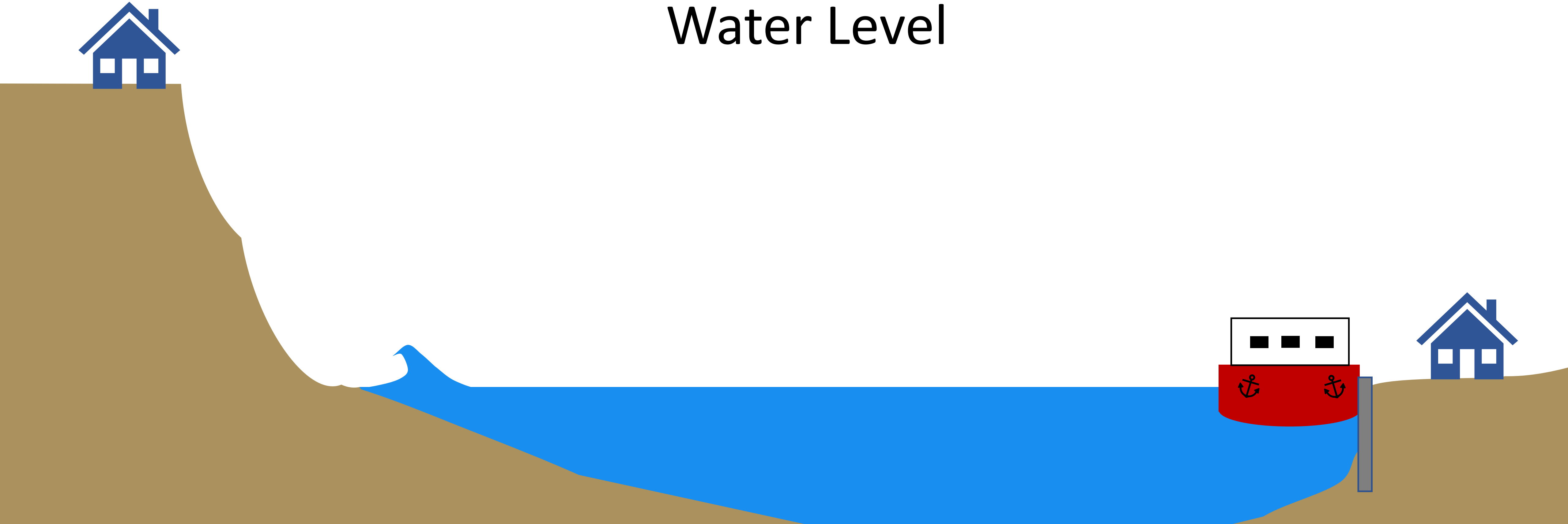


Great Lakes Coastal Climate Stressors

Wave Energy

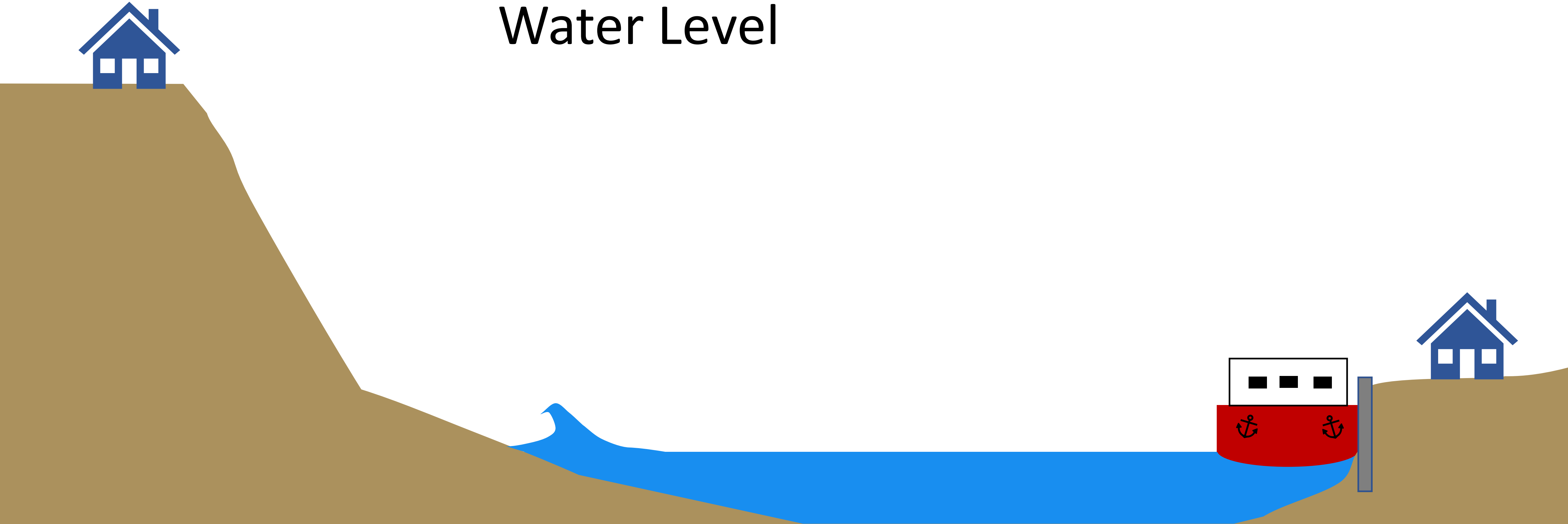
Ice Cover

Water Level

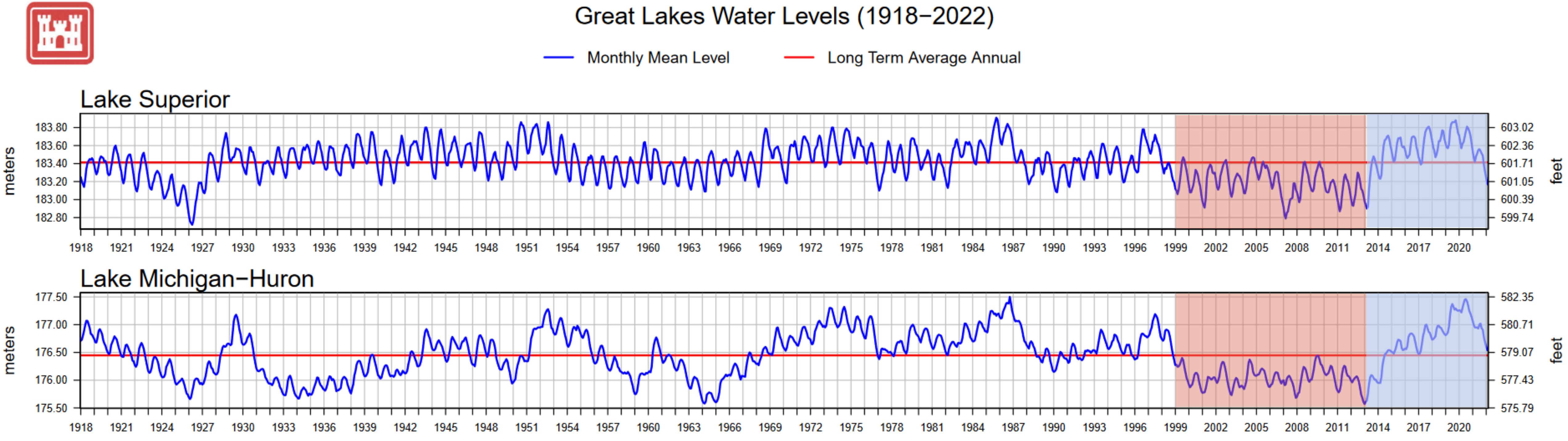


Great Lakes Coastal Climate Stressors

	Trend	Future
Wave Energy		
Ice Cover		
Water Level		

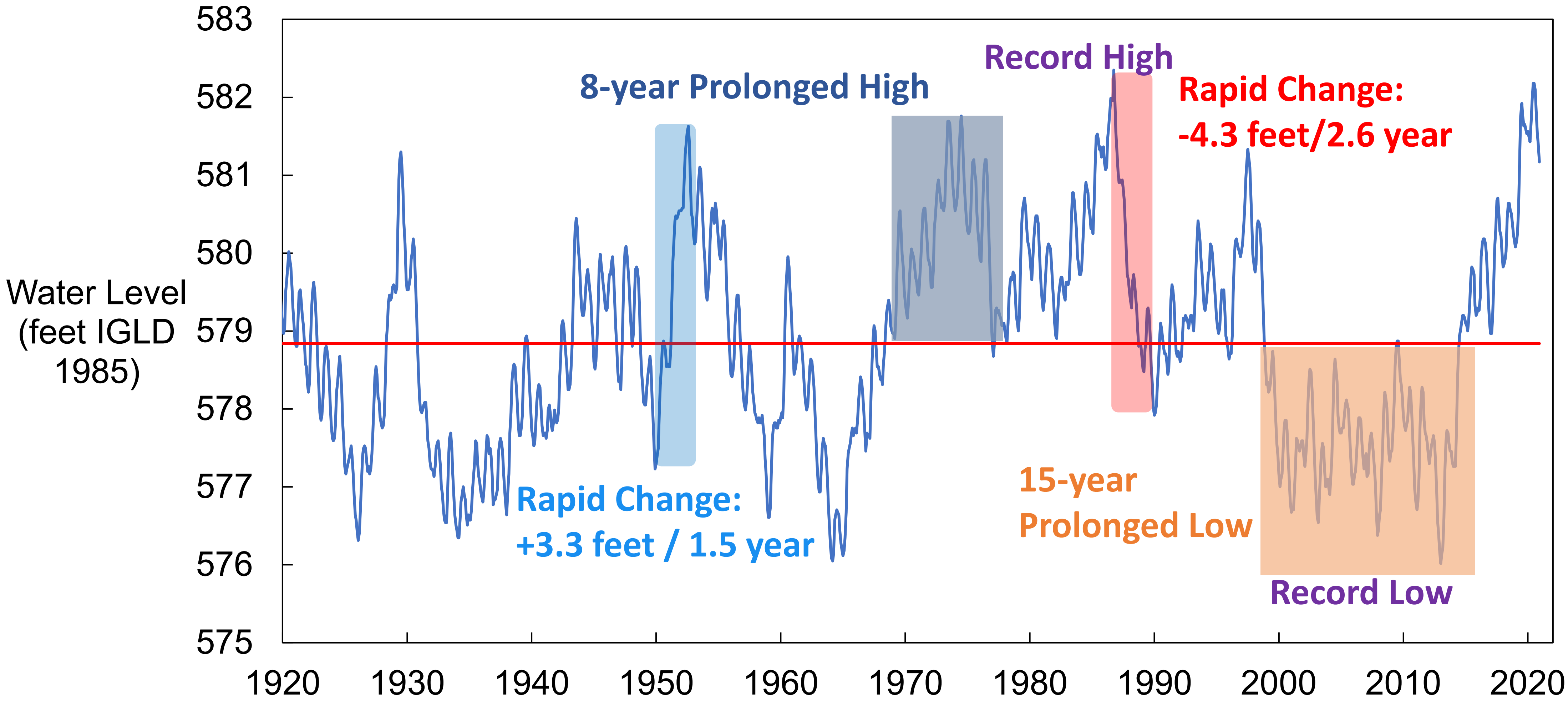


Historic Water Levels



[https://lre-wm.usace.army.mil/ForecastData/GLBasinConditions/LTA-GLWL-Graph.pdf]

Lake-Michigan Huron Water Levels



Average Seasonal Fluctuation: 1 foot

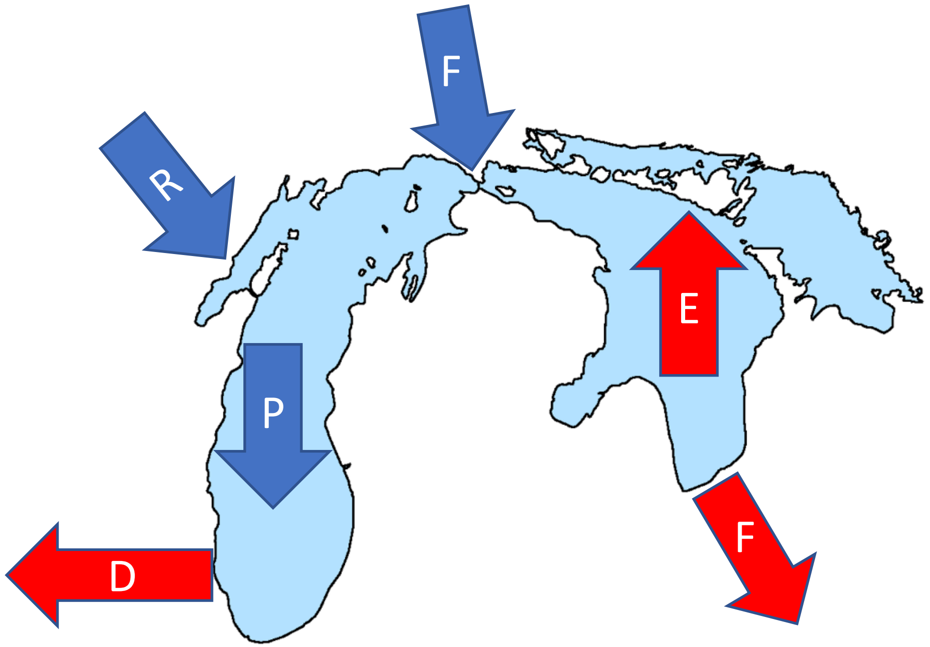
Historic Range: 6.4 feet

Great Lakes Water Budget

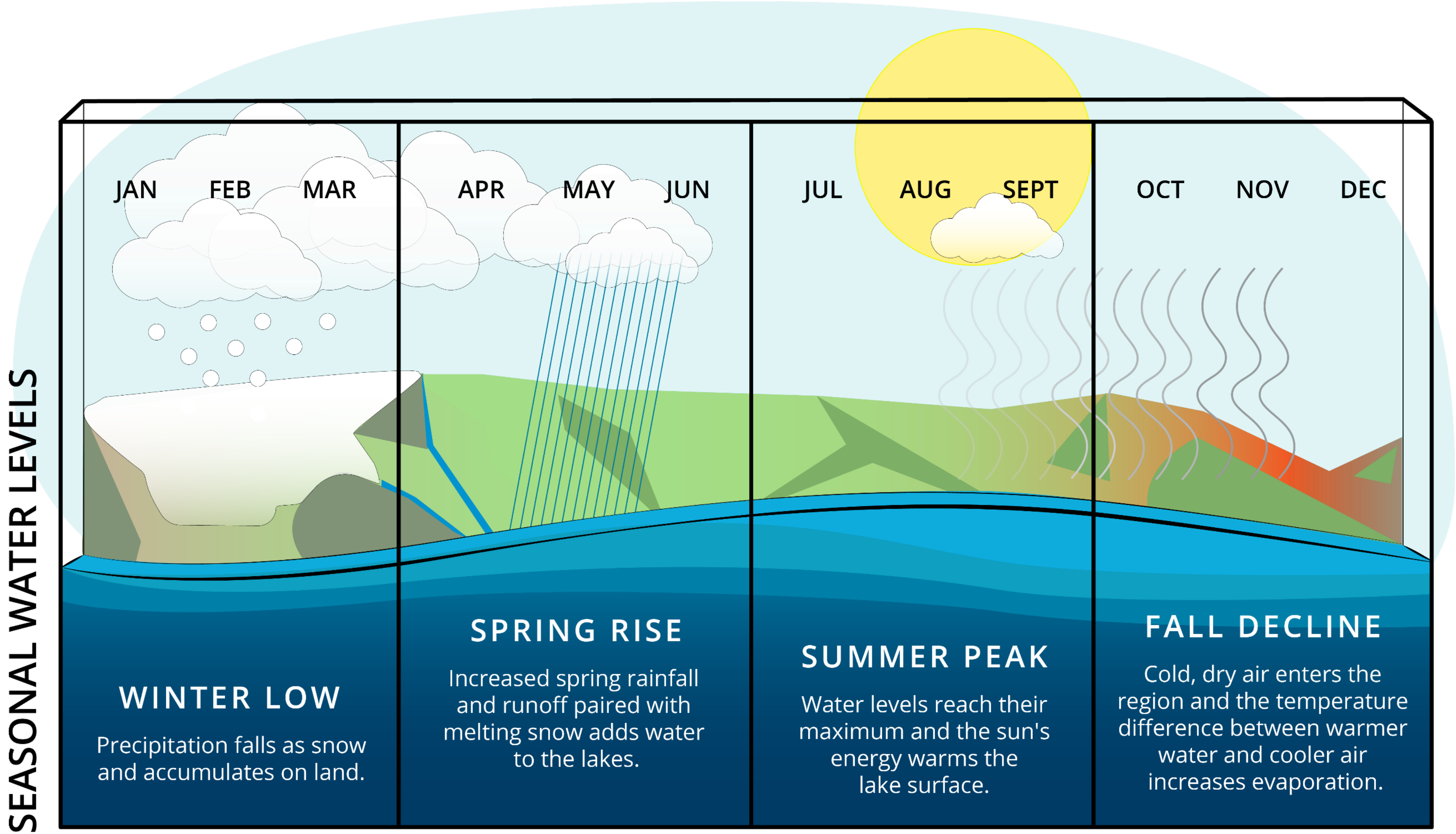
- **Precipitation** onto a lake surface
- **Runoff** into a lake
- **Evaporation** from lake surface
- **Flow** through connecting channels
- **Diversions** into/out of lake system

Net Basin Supply (NBS)

NBS = P + R - E



Seasonal NBS Components



[NOAA]

The Road to Record High Water Levels

Geophysical Research Letters

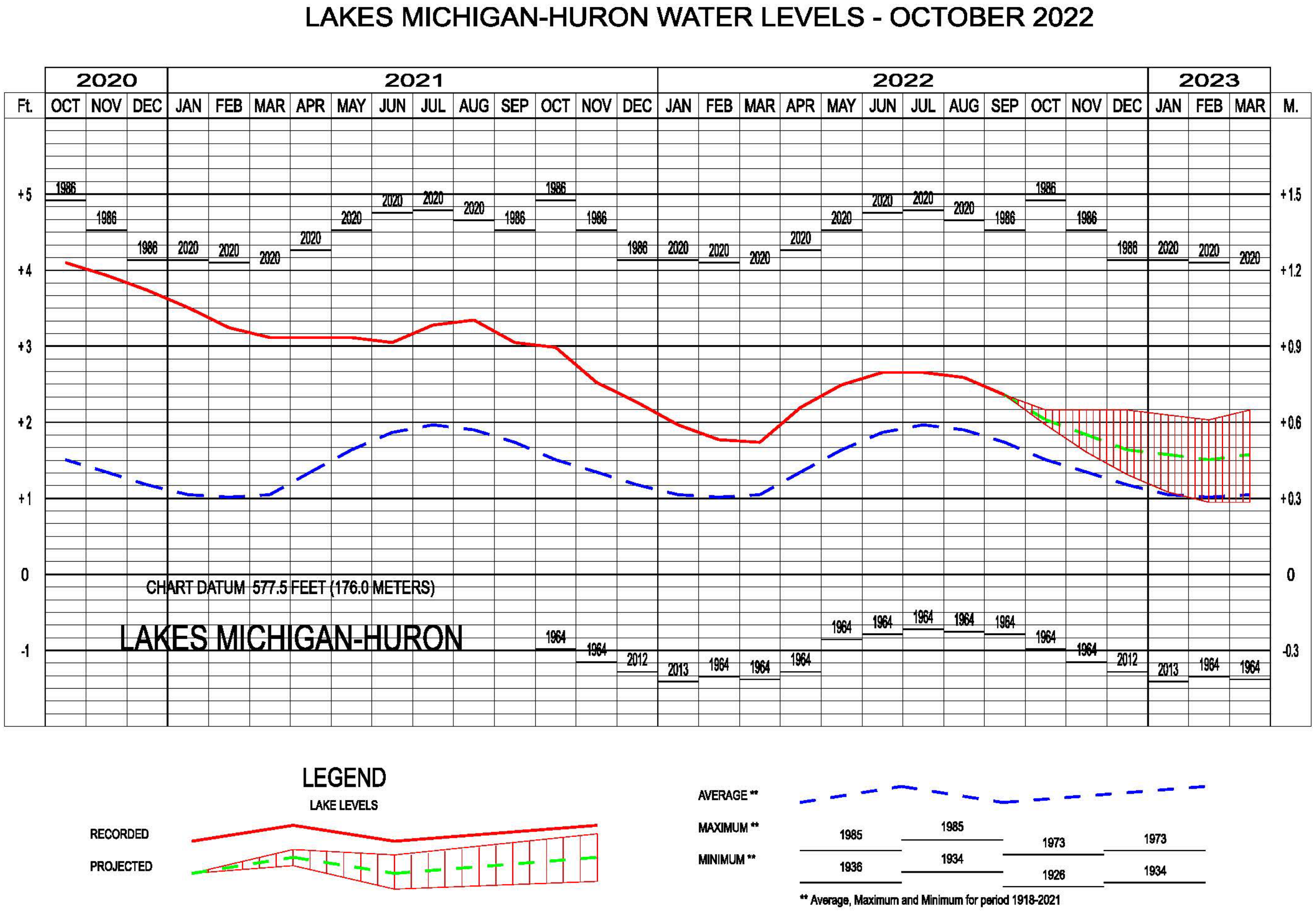
Research Letter

A Tug-of-War Within the Hydrologic Cycle of a Continental Freshwater Basin

A. D. Gronewold, H. X. Do, Y. Mei, C. A. Stow

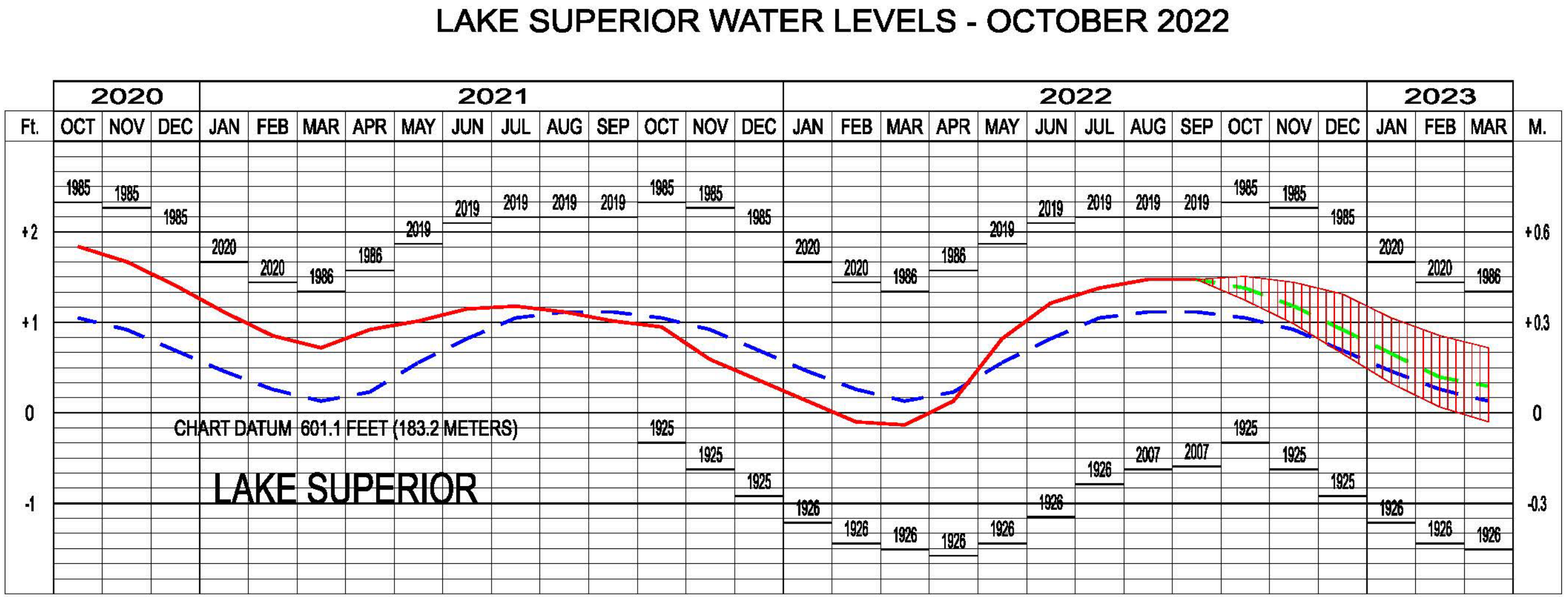
First published: 04 January 2021 | https://doi.org/10.1029/2020GL090374

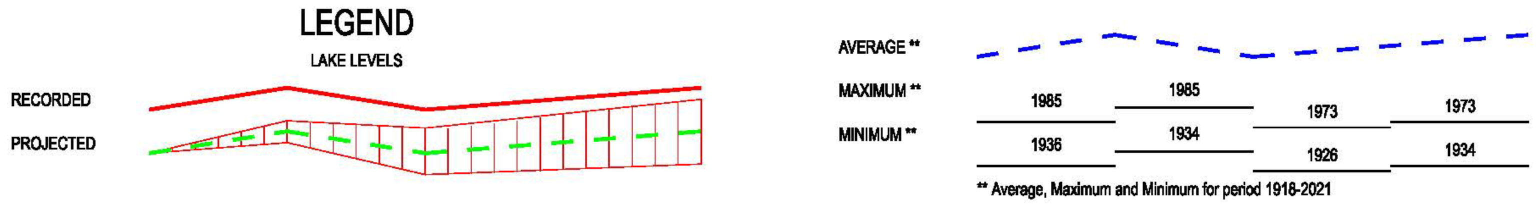
Monthly Bulletin of Great Lakes Water Levels



https://www.lre.usace.army.mil/Missions/Great-Lakes-Information/Great-Lakes-Water-Levels/Water-Level-Forecast/

Monthly Bulletin of Great Lakes Water Levels





https://www.lre.usace.army.mil/Missions/Great-Lakes-Information/Great-Lakes-Water-Levels/Water-Level-Forecast/

Great Lakes Coastal Climate Stressors

	Trend	Future
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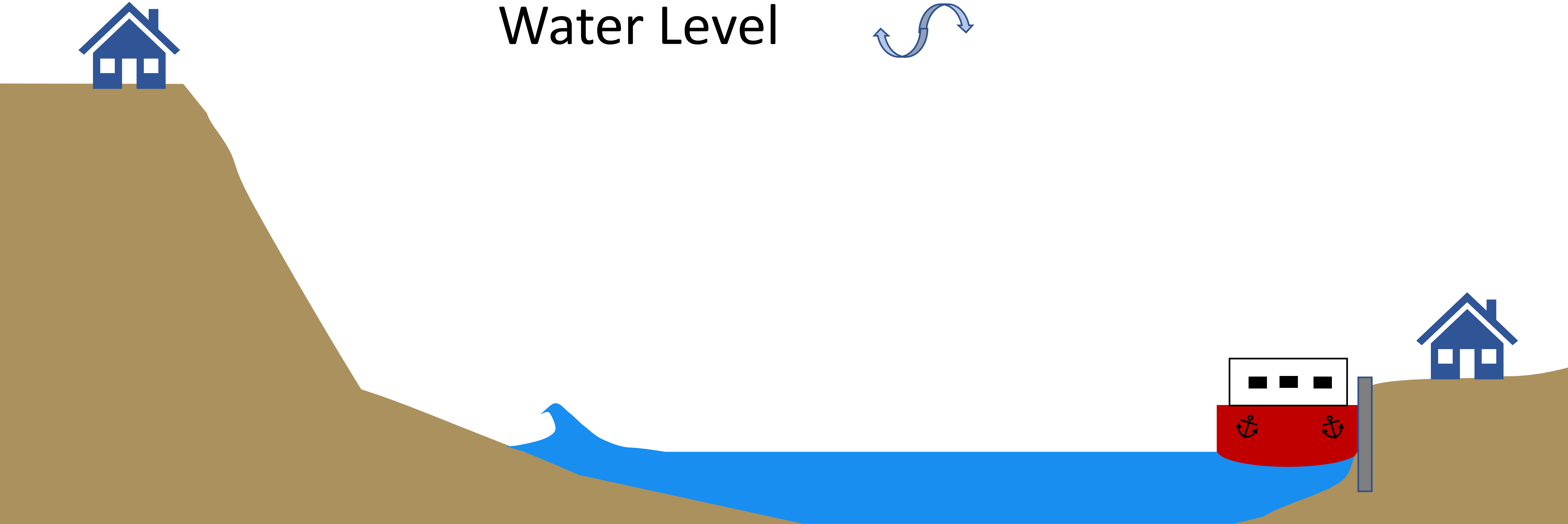
Water Level		



Water Levels in a Changing Climate

- **Precipitation** onto a lake surface
- **Runoff** into a lake
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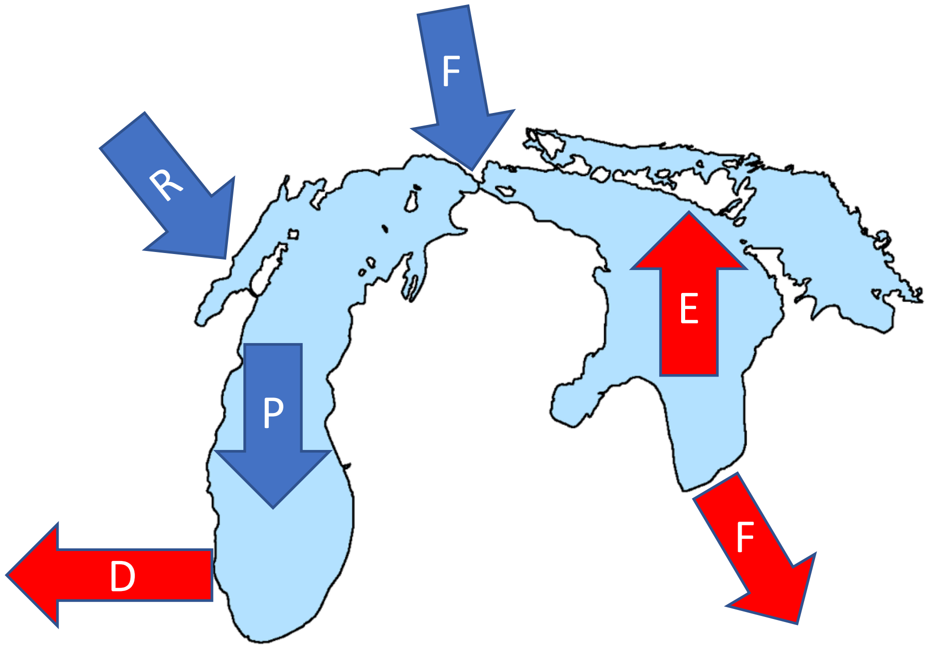
Net Basin Supply (NBS)

? NBS = P + R - E



Projected Water Levels

- **Precipitation** onto a lake surface
- **Runoff** into a lake
- **Evaporation** from lake surface

Net Basin Supply (NBS)

? NBS = P + R - E

2011 WICCI Report

NBS = P + R - E

Croley et al., 1990

Hartman, 1990

Hayhoe et al., 2010

Angel and Kunkel, 2010

2021 WICCI Report

NBS = P + R - E

MacKay and Seglenicks, 2013

Music et al., 2015

Notaro et al., 2015

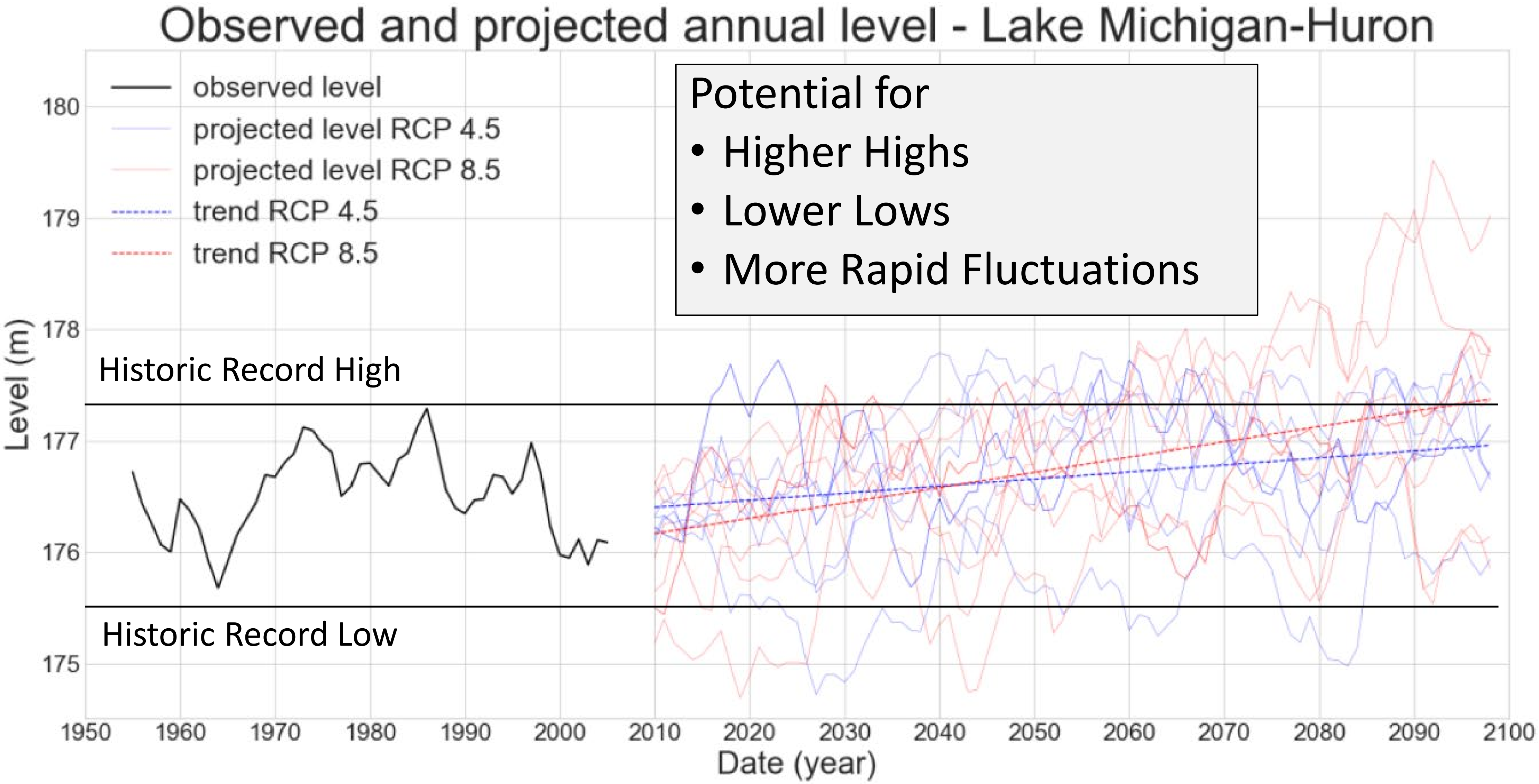
Mailhot et al., 2019

VanDeWeghe et al. 2022

Seglenicks et al. 2022

Kayastha et al. 2022

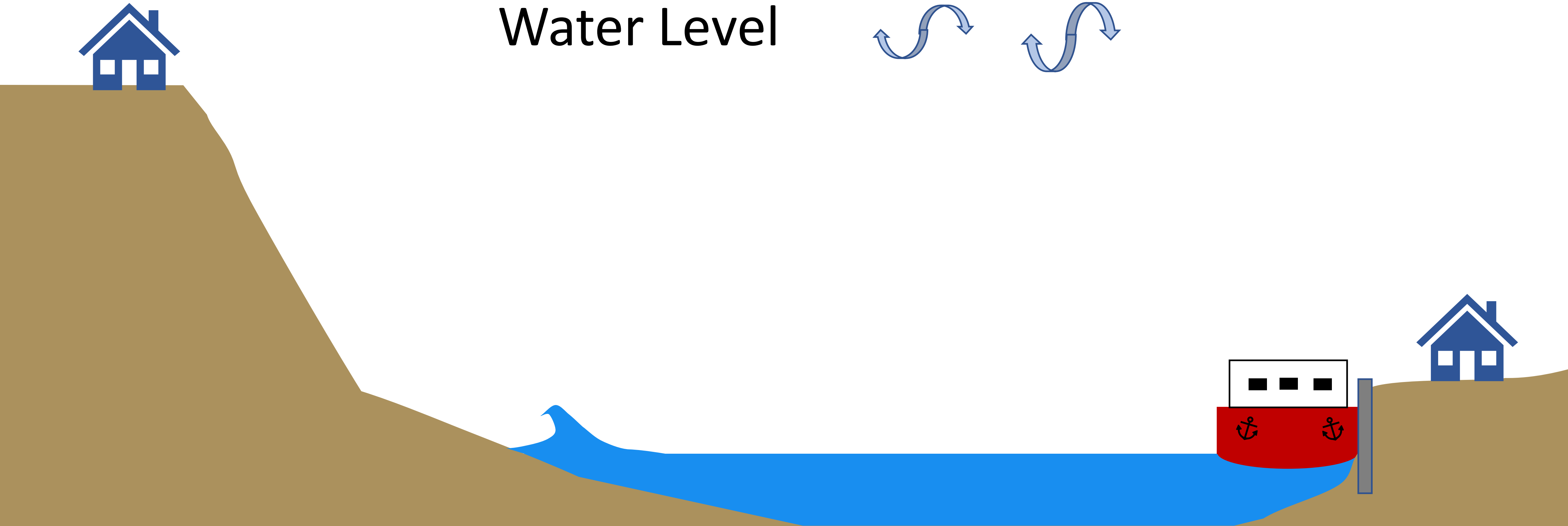
Projected Water Levels



[ECCC; Seglenicks et al. 2022]

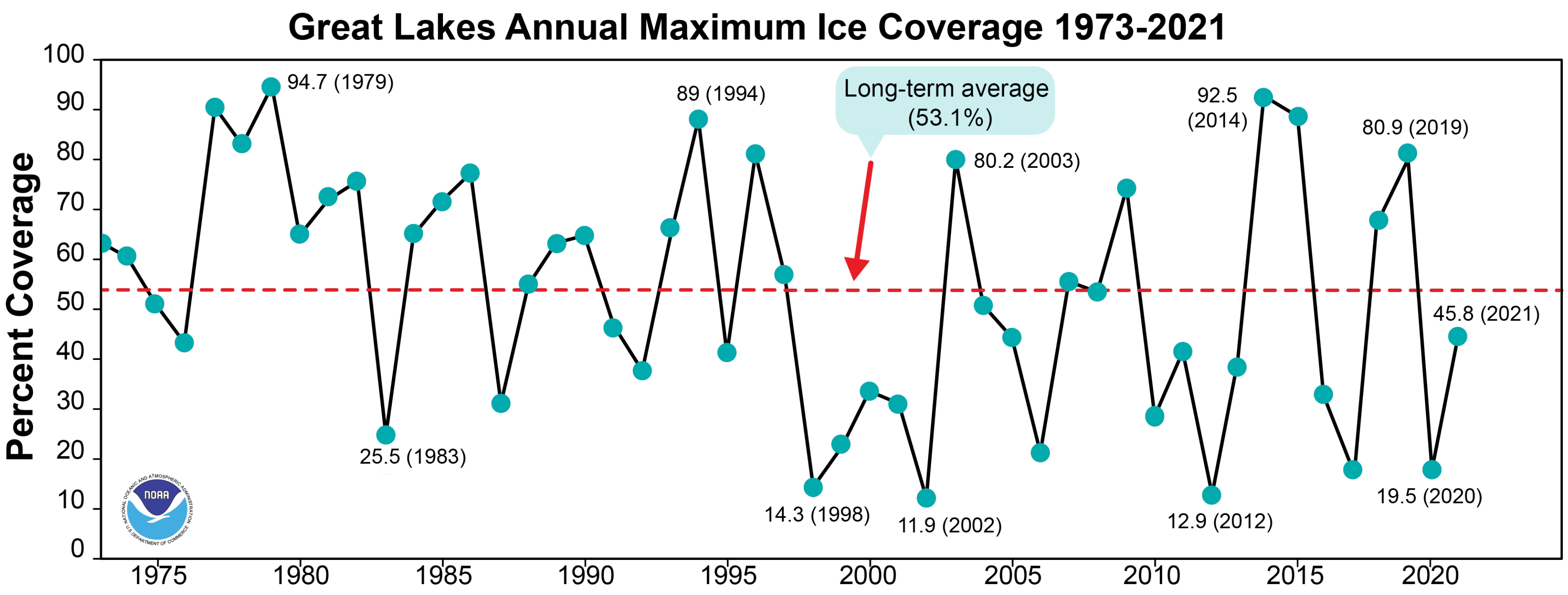
Great Lakes Coastal Climate Stressors

	Trend	Future
Wave Energy		
Ice Cover		
Water Level		



Declining Ice Cover

[MODIS Satellite Image]

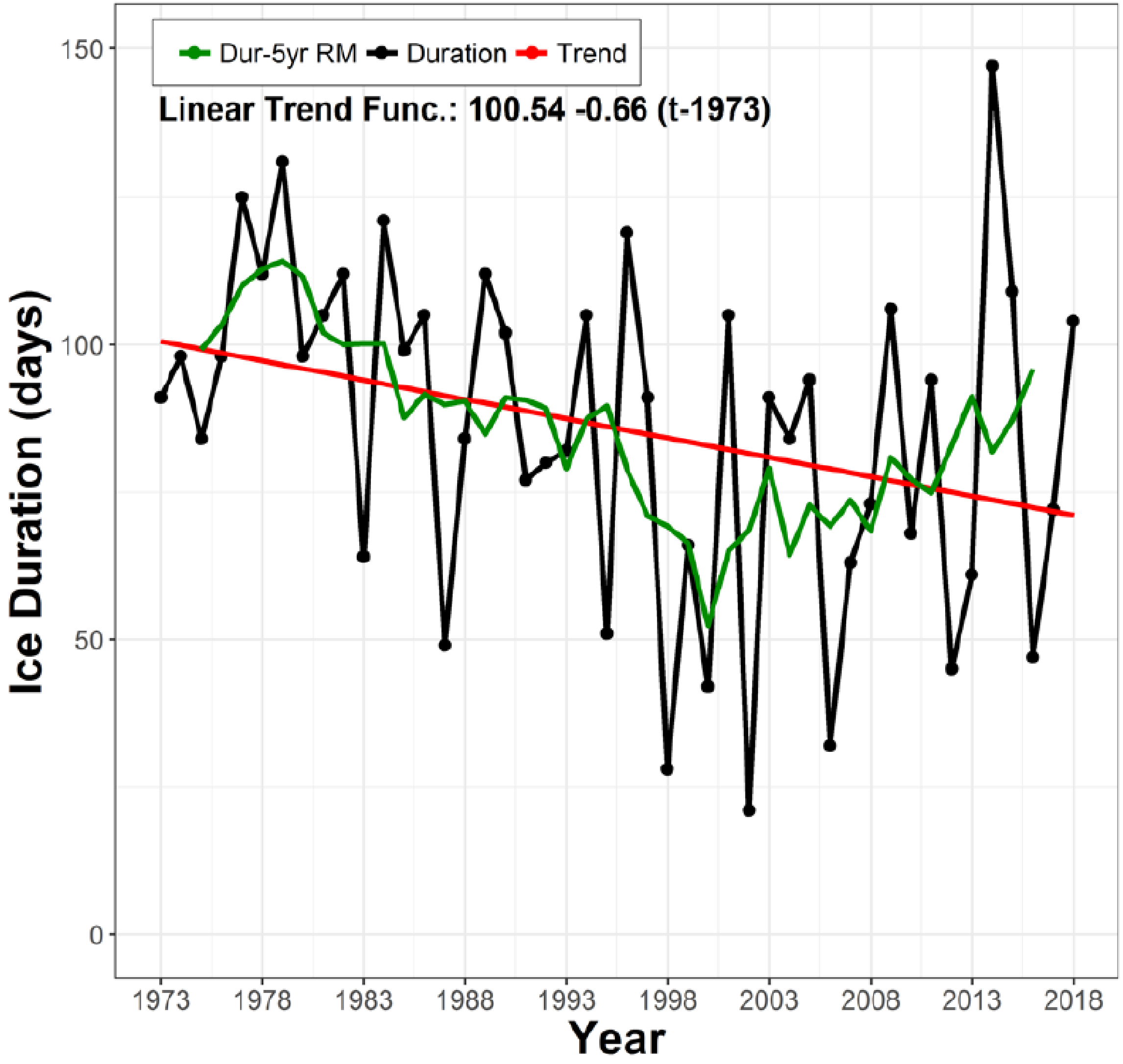


[Wang et al., 2020]

Declining Ice Duration

[MODIS Satellite Image]

All Great Lakes



[Wang et al., 2020]

Great Lakes Coastal Climate Stressors

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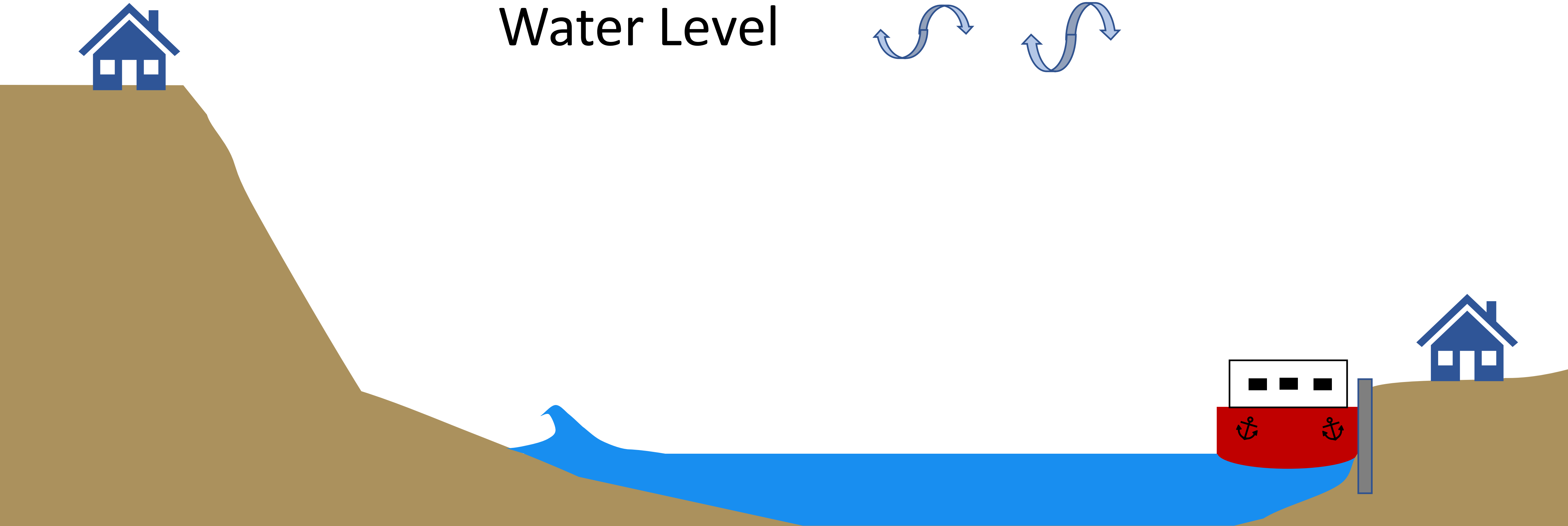
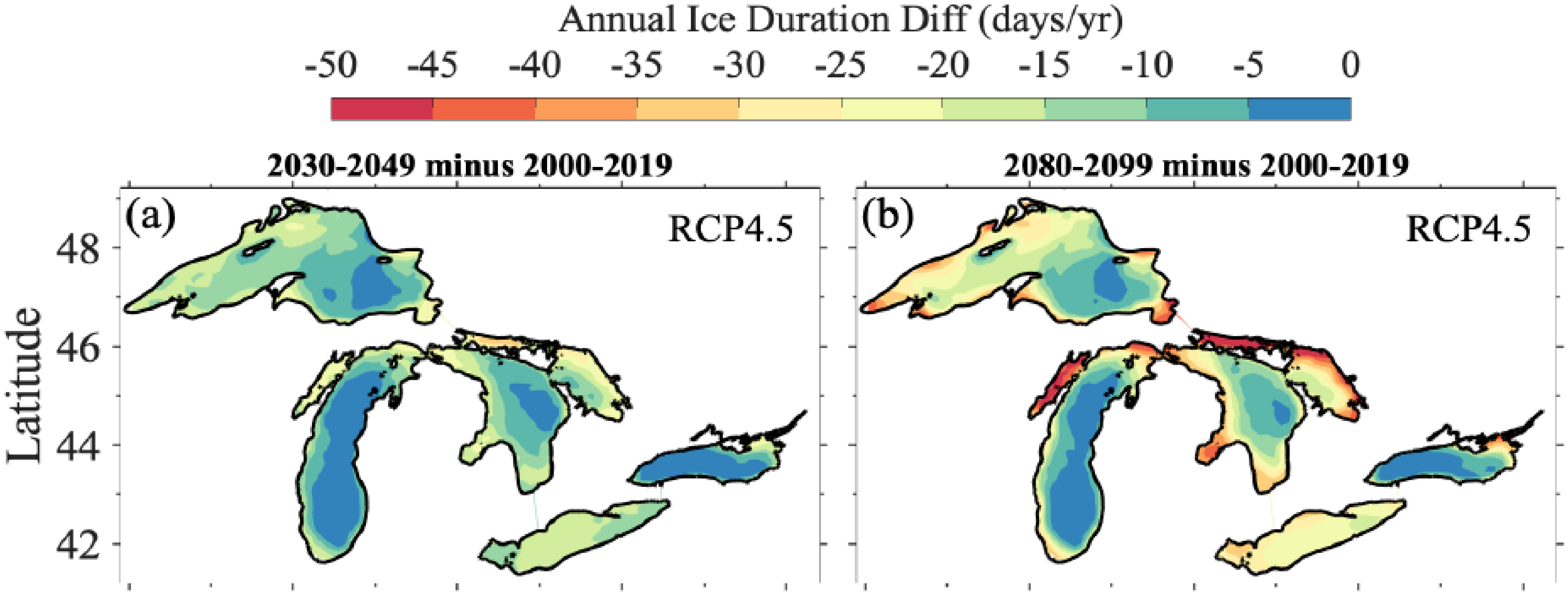


Ice Duration Projected Changes



[Xue et al. 2022]

Great Lakes Coastal Climate Stressors

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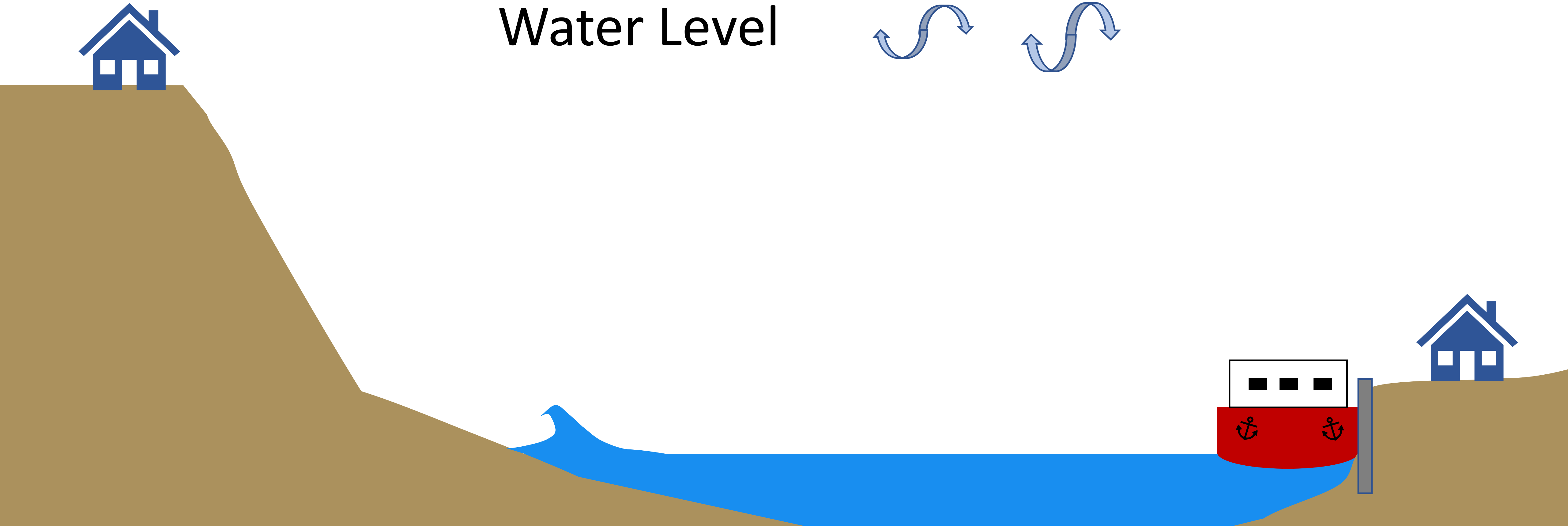
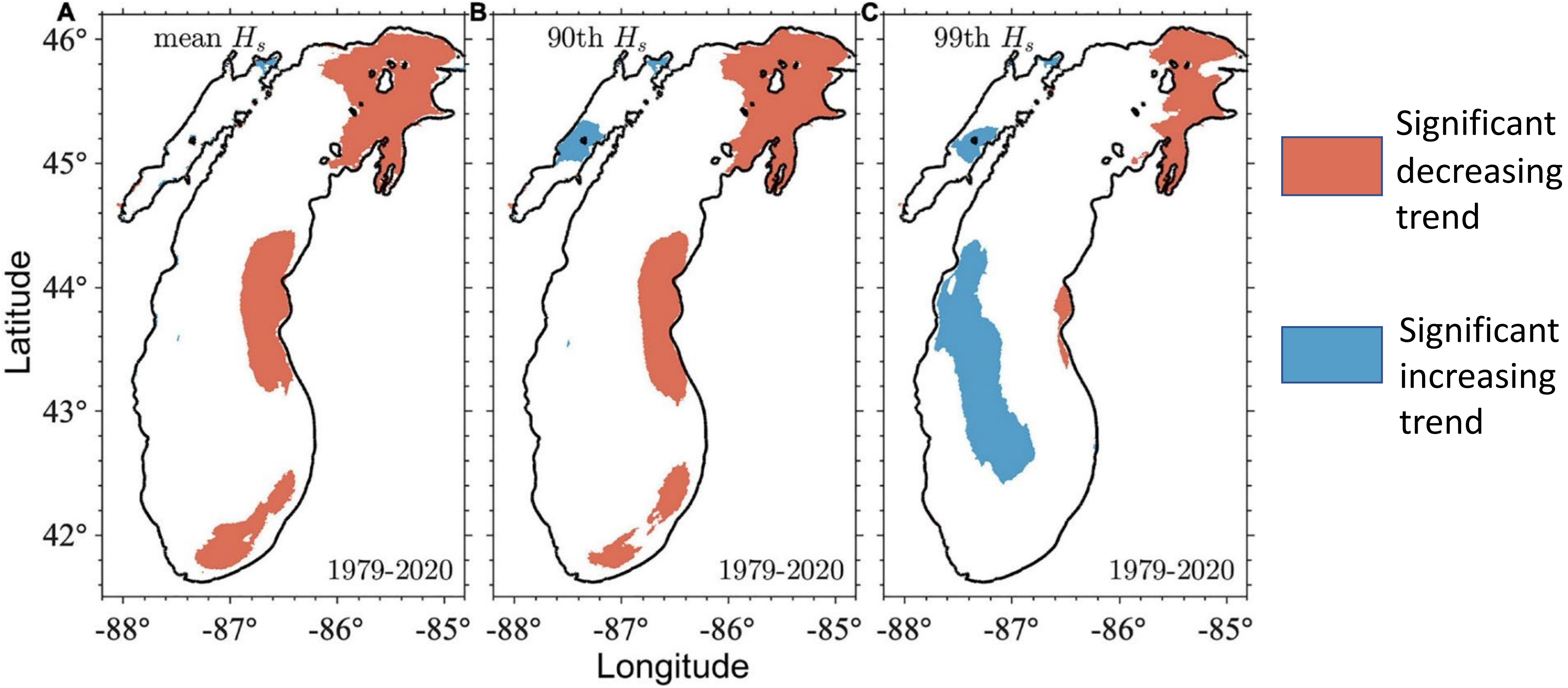


Wave Energy Trends

1979-2020



[Huang et al. 2021]

Great Lakes Coastal Climate Stressors

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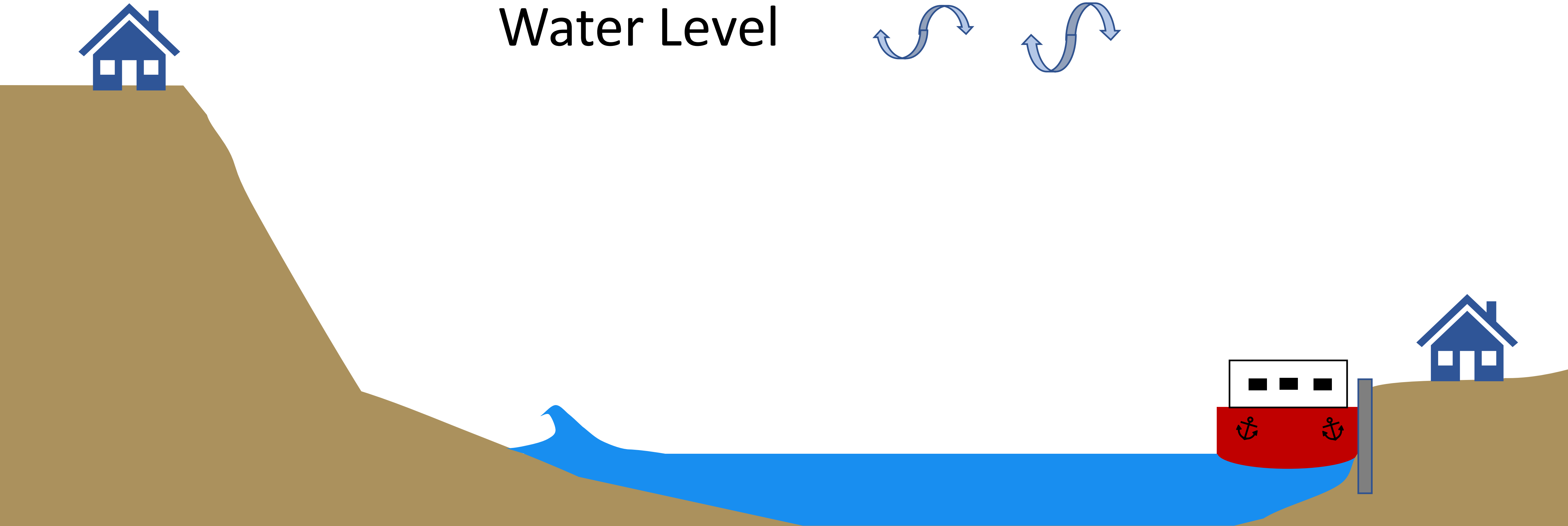
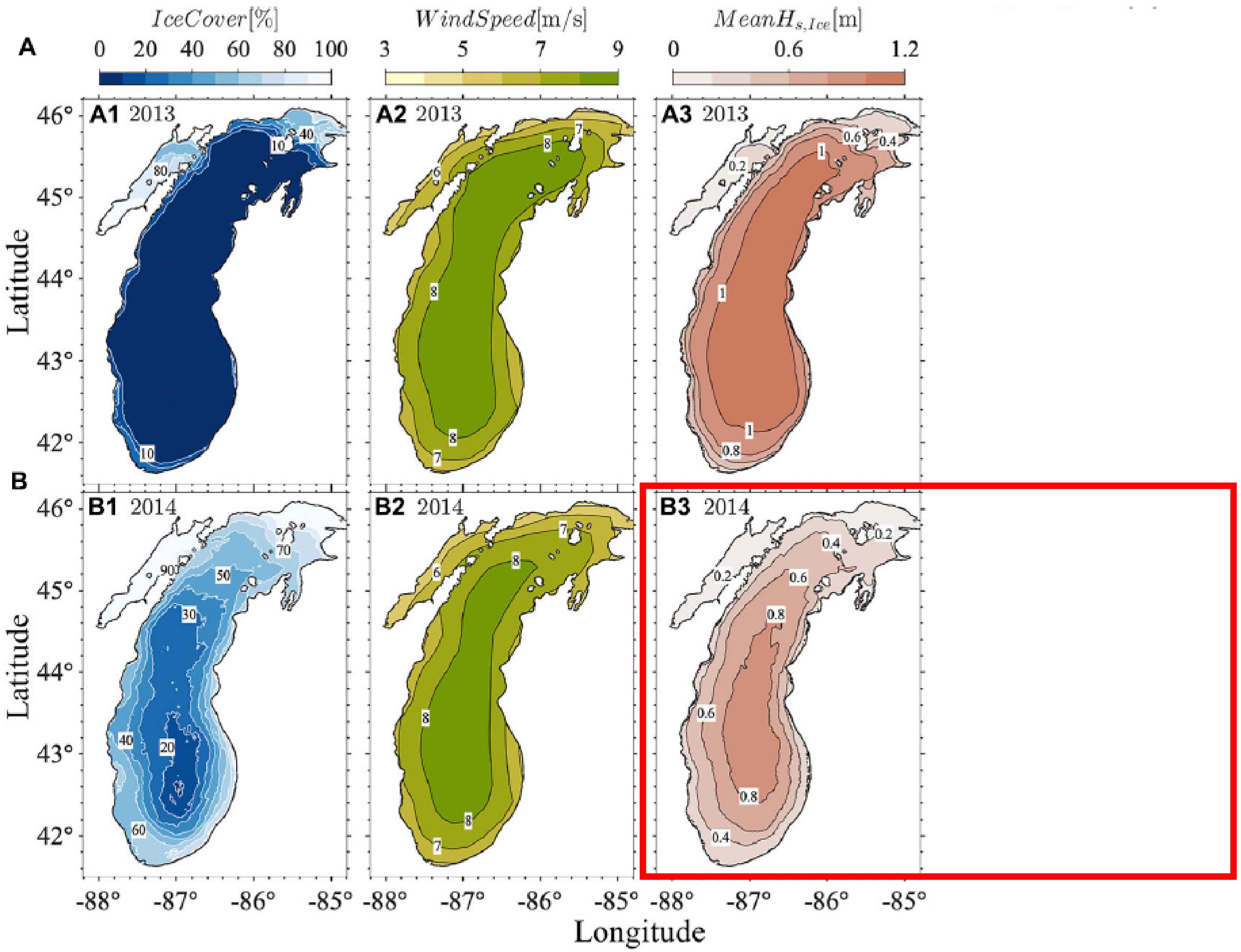


Anticipated Wave Energy Trend

Low Ice
2013

High Ice
2014



Huang et al. (2021)

No Ice
2013

No Ice
2014

50% increase
in Mean H_s

Anticipated Wave Energy Trend

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE

10.1002/2014JC010278

Wave climatology in the Apostle Islands, Lake Superior

Joshua D. Anderson[1], Chin H. Wu[1], and David J. Schwab[2]

[1]Department of Civil and Environmental Engineering, University of Wisconsin-Madison, Madison, Wisconsin, USA, [2]U-M Water Center, University of Michigan, Ann Arbor, Michigan, USA

Key Points:

- Wave climate of the Apostle Islands in Lake Superior for 35 year was hindcast

“Loss of ice cover is the dominant mechanism for an increasing wave climate in the Apostle Islands”

Great Lakes Coastal Climate Stressors

	Trend	Future
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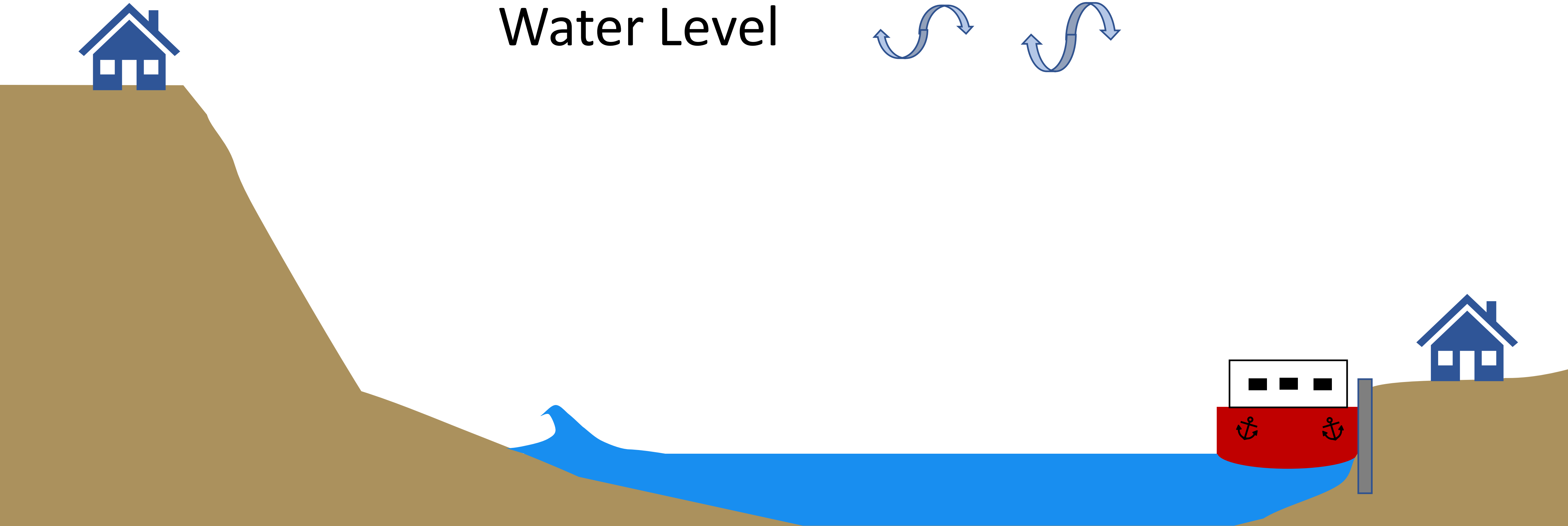
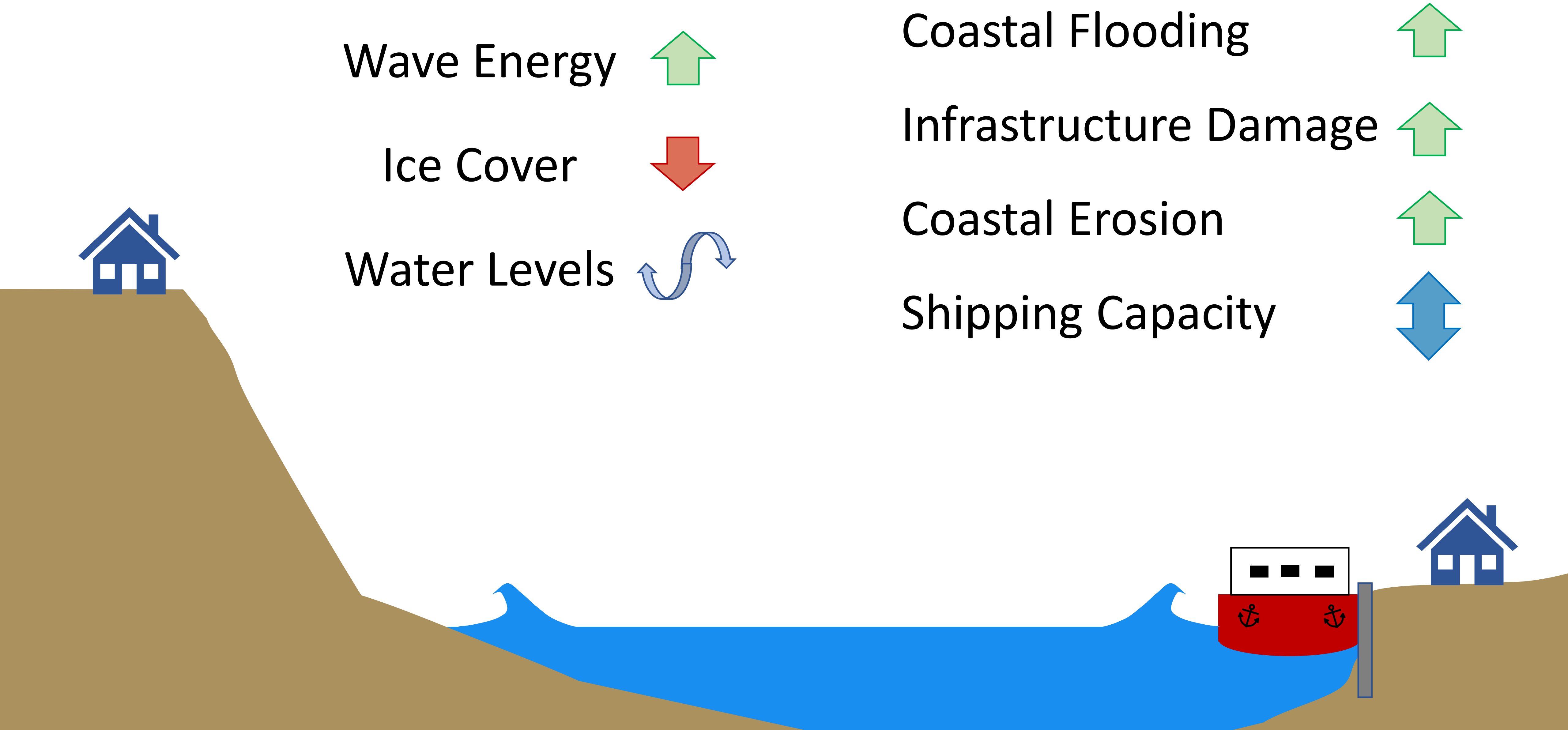
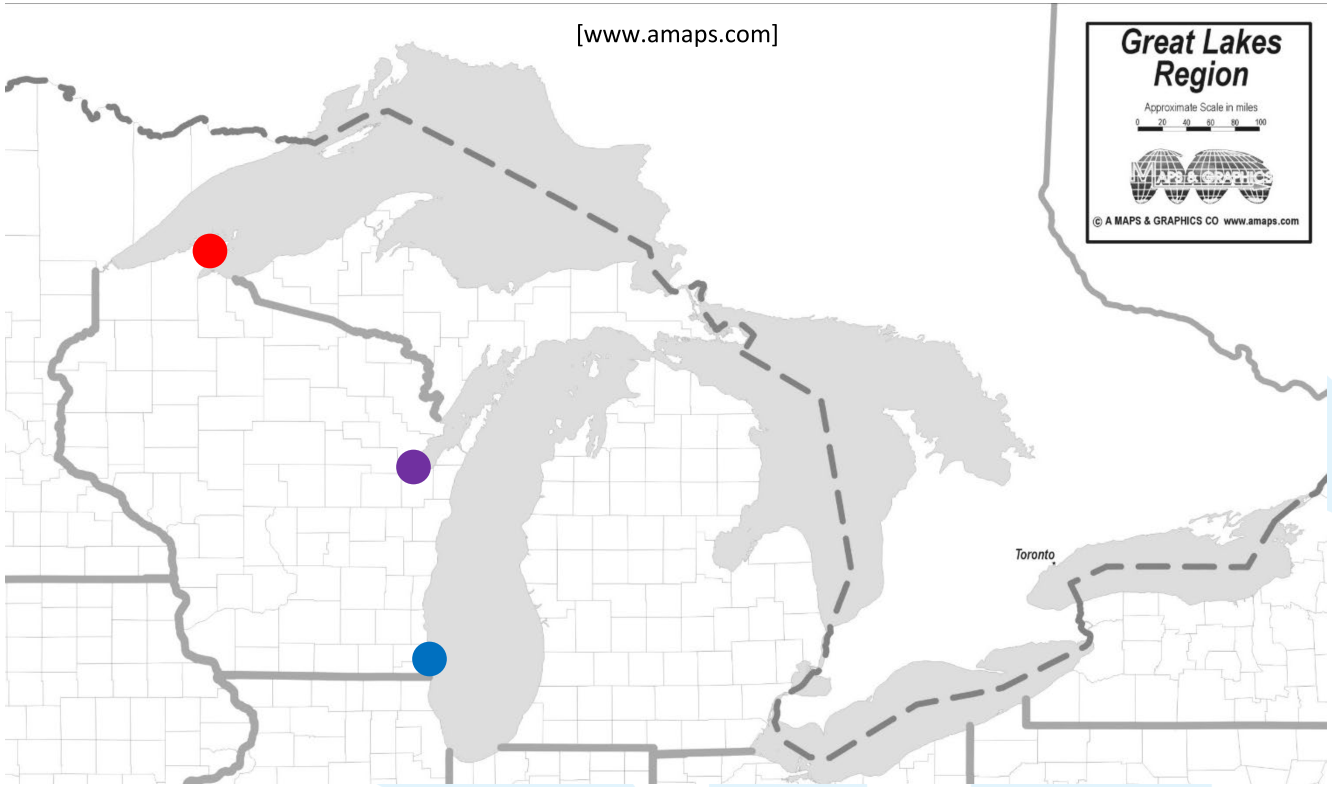
Water Level		



Great Lakes Coastal Climate Change Impacts



[www.amaps.com]

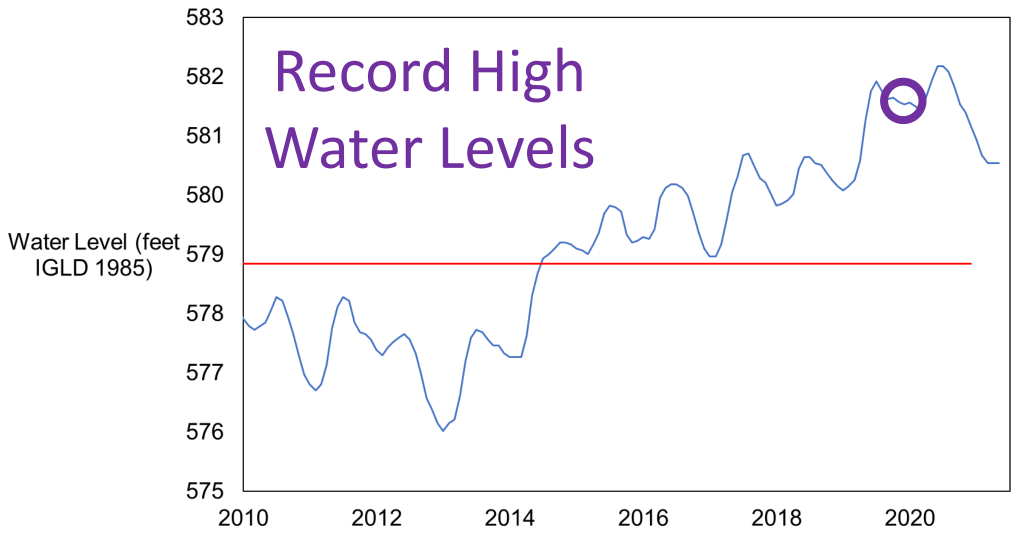


[Wisconsin Sea Grant/Gene Clark]

[Jeff DuMez]

[Wisconsin Shoreline Inventory and Oblique Photo Viewer]

January 11th 2020 Southeastern Wisconsin Coastal Storm



[Michael Sears – Milwaukee Journal Sentinel]

[Stephanie Jones – Racine Journal Times]

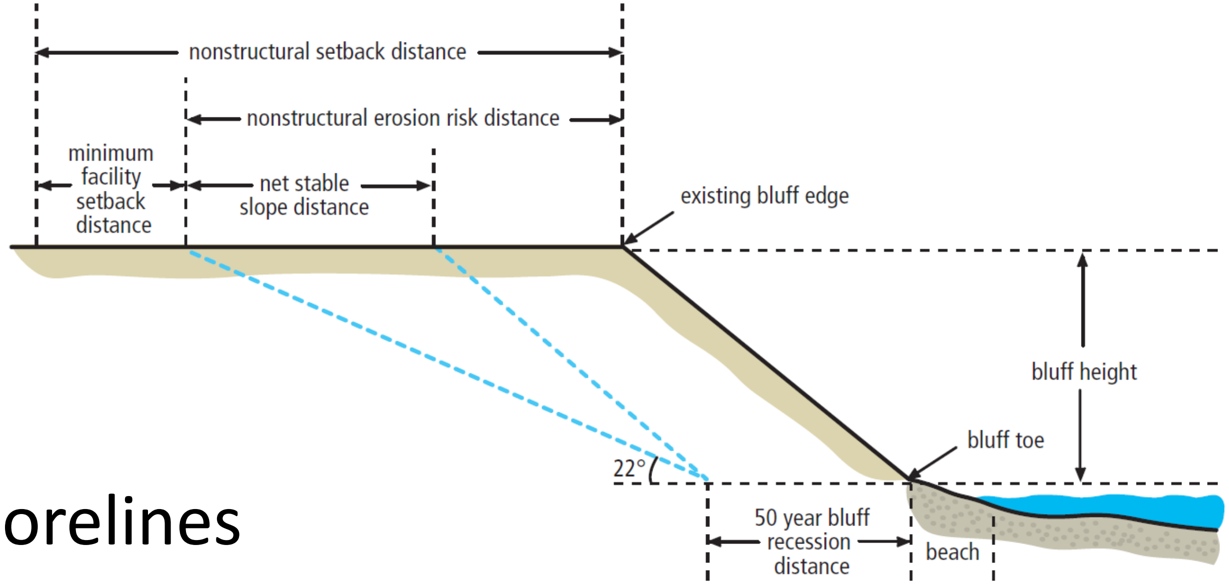
$30 Million Presidential Disaster Declaration

Adapting to a Changing Great Lakes Coast

- How is climate change affecting Great Lakes coasts?
- What are the impacts to coastal communities?
- What strategies can be used to adapt?

Adaptation Strategies

- Consider function at all lake levels
- Assess vulnerability of critical assets
- Coordinate actions along the coast
- Locate homes away from eroding shorelines

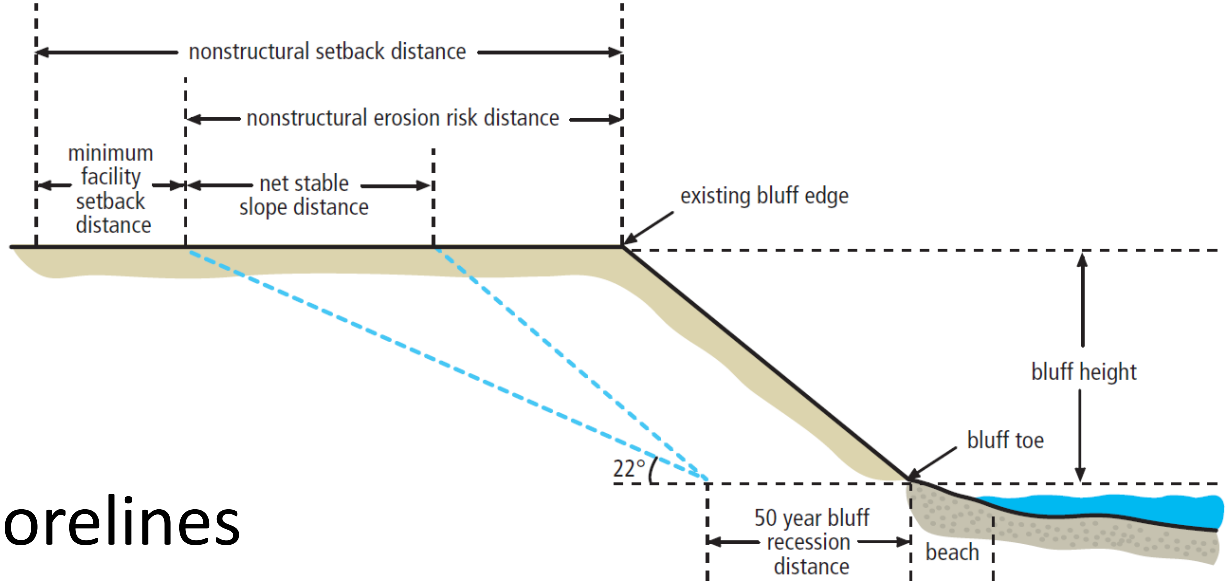


CHAOS
COASTAL HAZARDS OF SUPERIOR

COLLABORATIVE ACTION FOR LAKE MICHIGAN COASTAL RESILIENCE
CALM

Adaptation Strategies

- Consider function at all lake levels
- Assess vulnerability of critical assets
- Coordinate actions along the coast
- Locate homes away from eroding shorelines
- Work with natural processes to protect the coast



Barry Kreiner, City of Marysville, Mich.

Michigan Department of Environment, Great Lakes and Energy

Learn More About Adaptation Strategies

https://publications.aqua.wisc.edu/product/adapting-to-a-changing-coast-for-property-owners/

https://publications.aqua.wisc.edu/product/adapting-to-changing-coast-for-local-officials/

Learn More About Adaptation Strategies

https://wicci.wisc.edu/coastal-resilience-working-group/

Wisconsin Initiative on Climate Change Impacts

Nelson Institute for Environmental Studies | Wisconsin Department of Natural Resources

Coastal Resilience Working Group

WICCI's Coastal Resilience Working Group uses innovative methods and technologies to describe and predict the effects that the changing climate will have on the communities and property owners of Wisconsin's coastlines.

Thank You

wicci.wisc.edu

Adam Bechle
Coastal Engineering Outreach Specialist
Wisconsin Sea Grant
bechle@aqua.wisc.edu

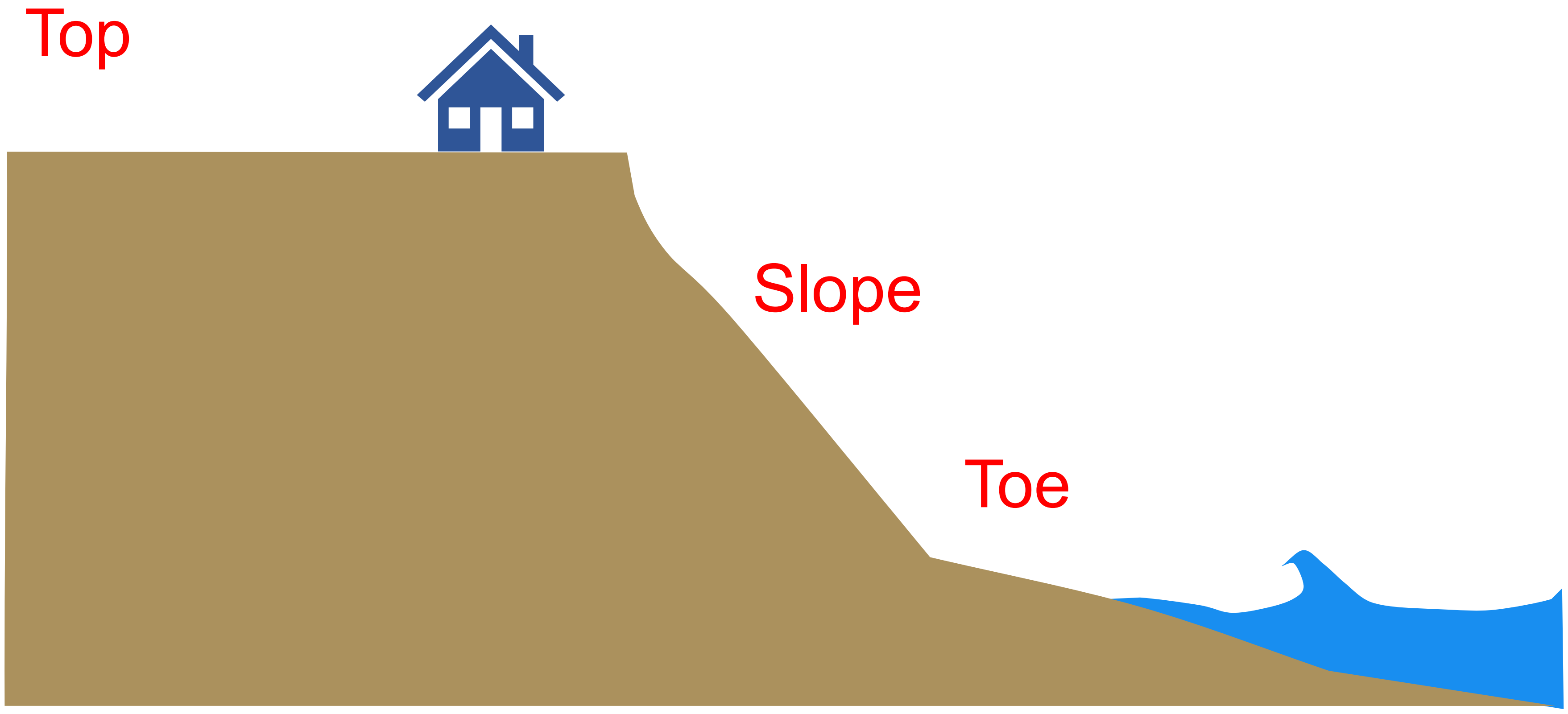
[USACE]

[Dave Mickelson]

[Capt. Dennis Carr, Wisconsin Civil Air Patrol]

Protecting coastal investments

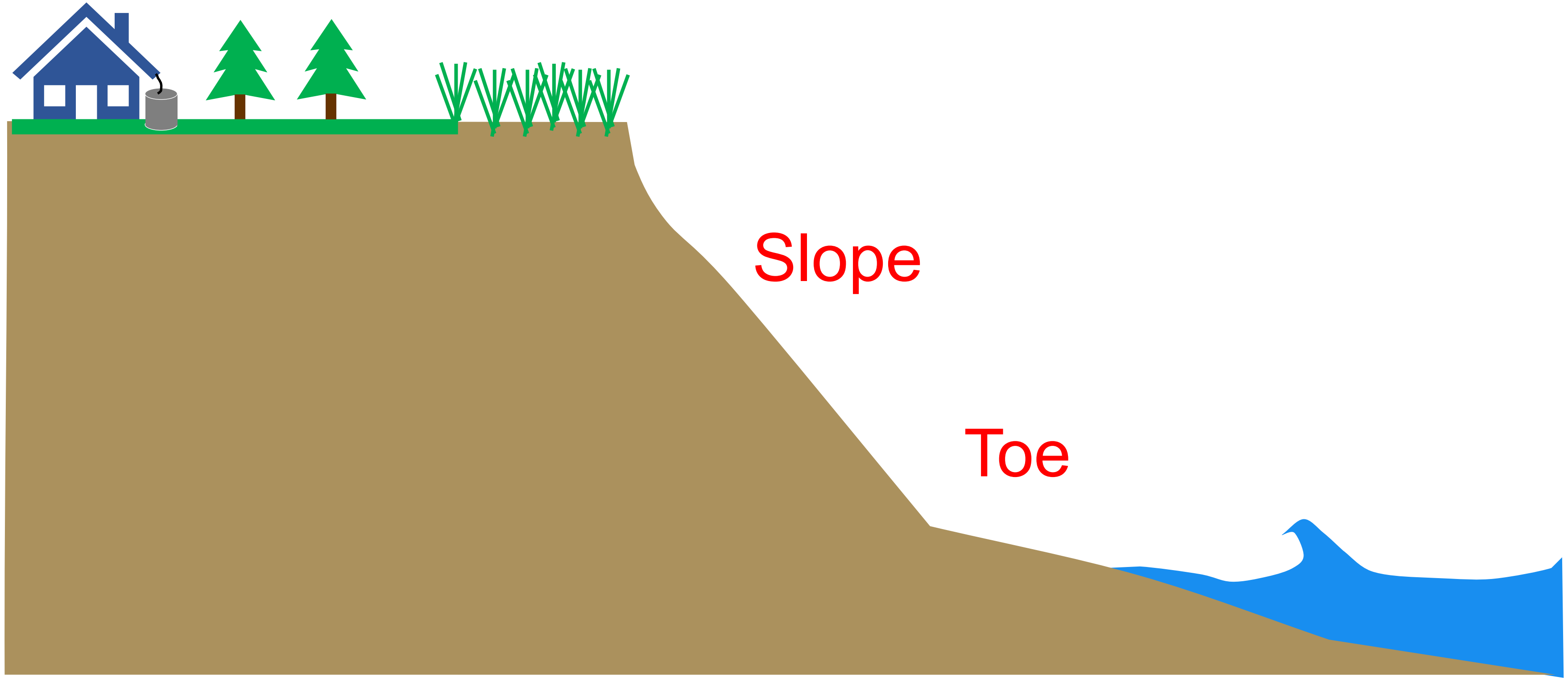
A top-down approach



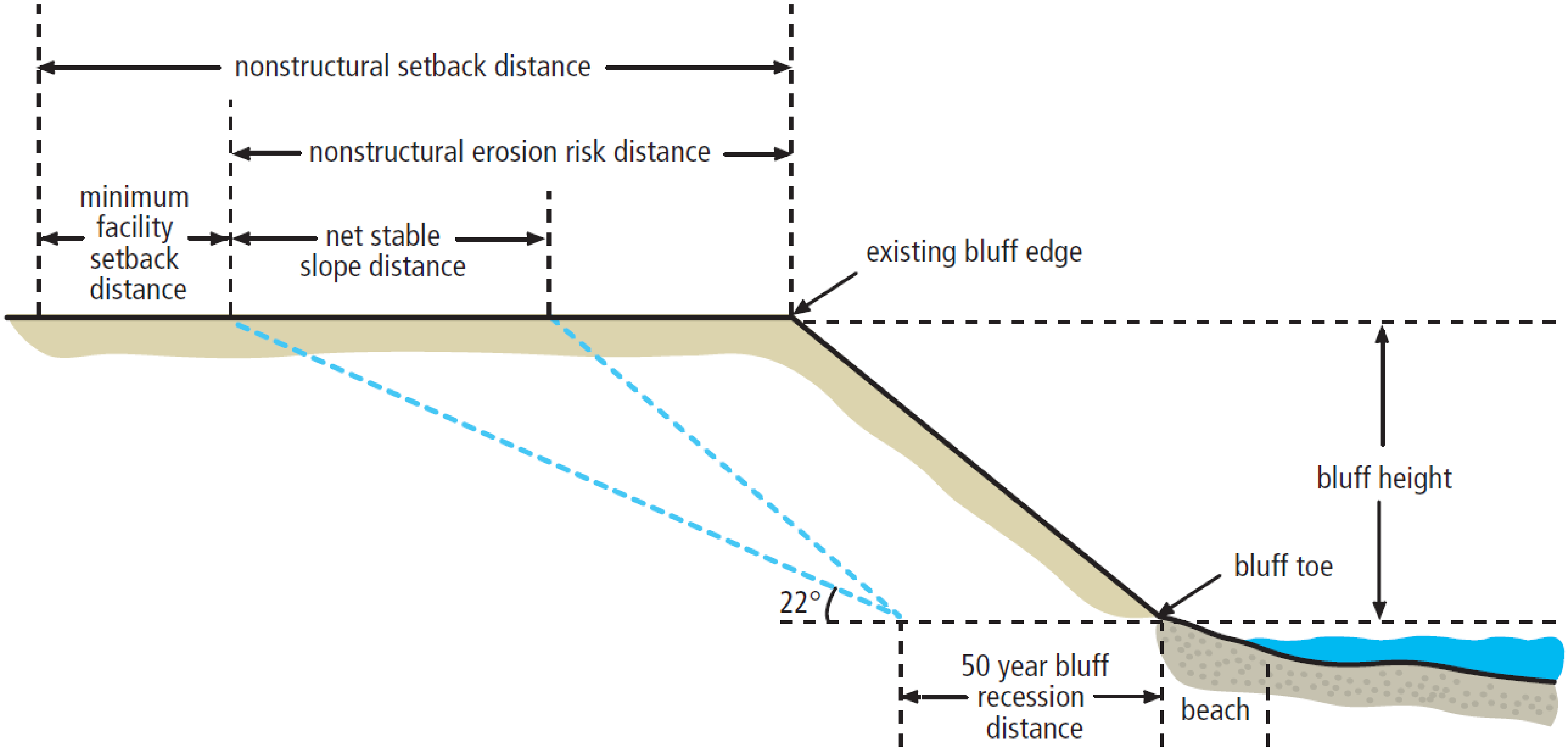
Protecting coastal investments

A top-down approach

Top: Manage Land Use,
Water & Vegetation



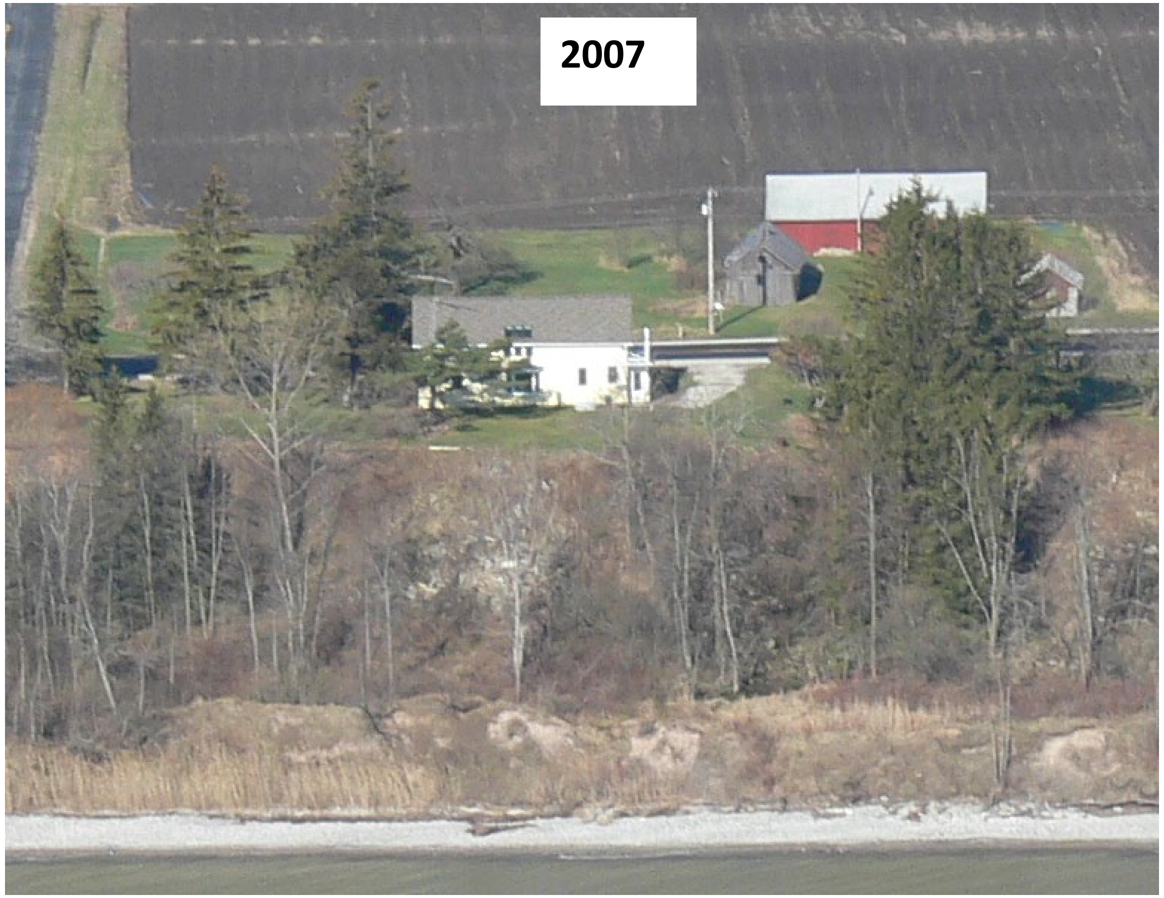
Building Setbacks in Local Ordinances



[Wisconsin Sea Grant: Protecting Coastal Investments]

Building Relocation

Sheboygan County



[All photos from Wisconsin Shoreline Inventory and Oblique Photo Viewer]

Asset Relocation

Bay View Park

[Capt. Dennis Carr, WI Civil Air Patrol]

Asset Relocation

Bay View Park - 2005

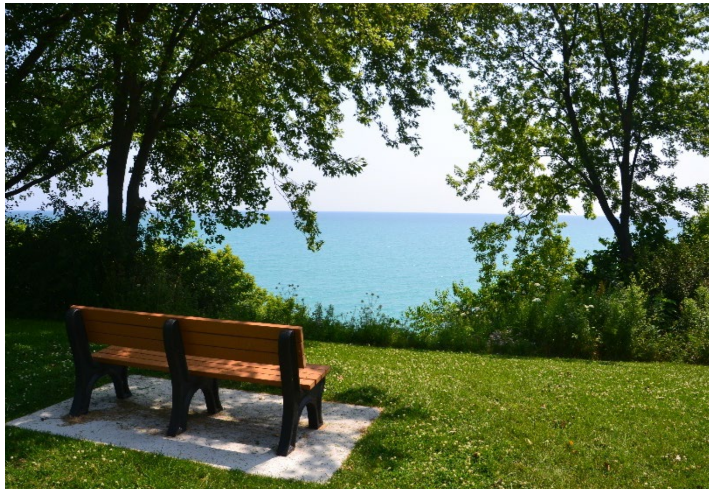
[Milwaukee County Land Information Interactive Map]

Maintain and Enhance Vegetation

Deep Rooted & Native

[Adam Bechle]

Frame Views



[Adam Bechle]

“No Mow” Buffer

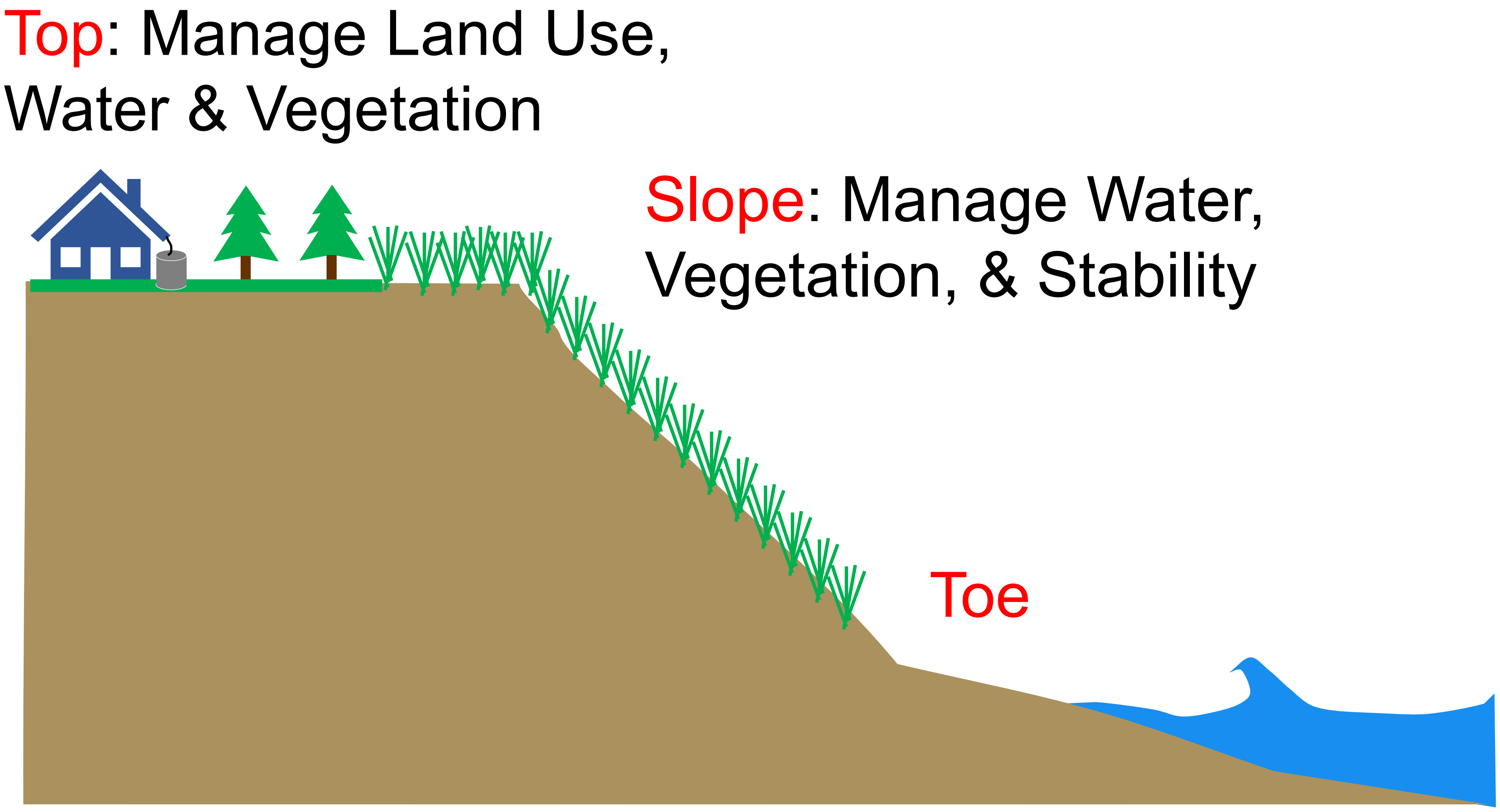
[Adam Bechle]

Prune Trees

[Adam Bechle]

Protecting coastal investments

A top-down approach



Maintain and Enhance Deep Rooted Vegetation

Bender Park

[Adam Bechle]

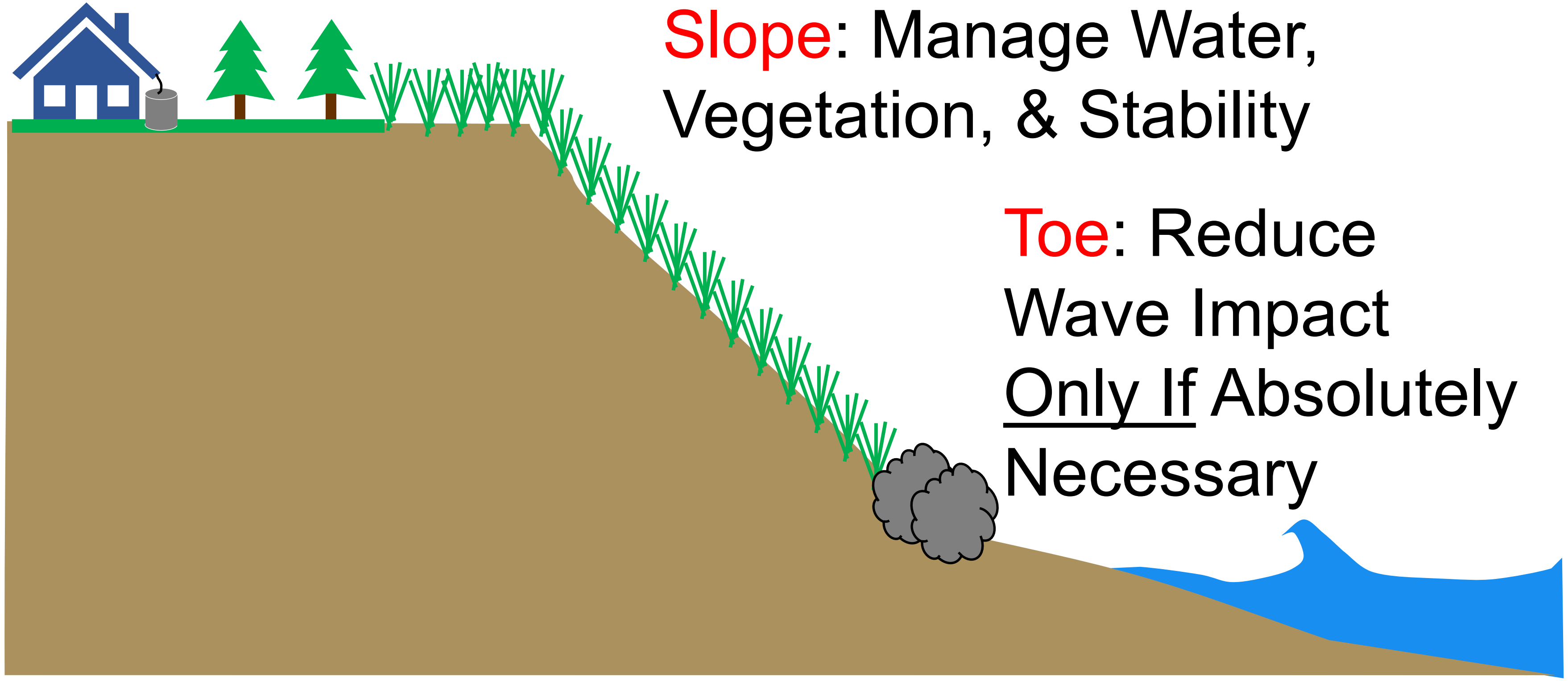
Protecting coastal investments

A top-down approach

Top: Manage Land Use, Water & Vegetation

Slope: Manage Water, Vegetation, & Stability

Toe: Reduce Wave Impact <u>Only If</u> Absolutely Necessary



Green-to-Gray Spectrum of Shore Protection

U.S. Army Corps of Engineers

Systems Approach to Geomorphic Engineering

Nature-Based Shorelines
Living Shorelines
Coastal Green Infrastructure
Natural and Nature-Based Features (NNBF)
Engineering With Nature (USACE)

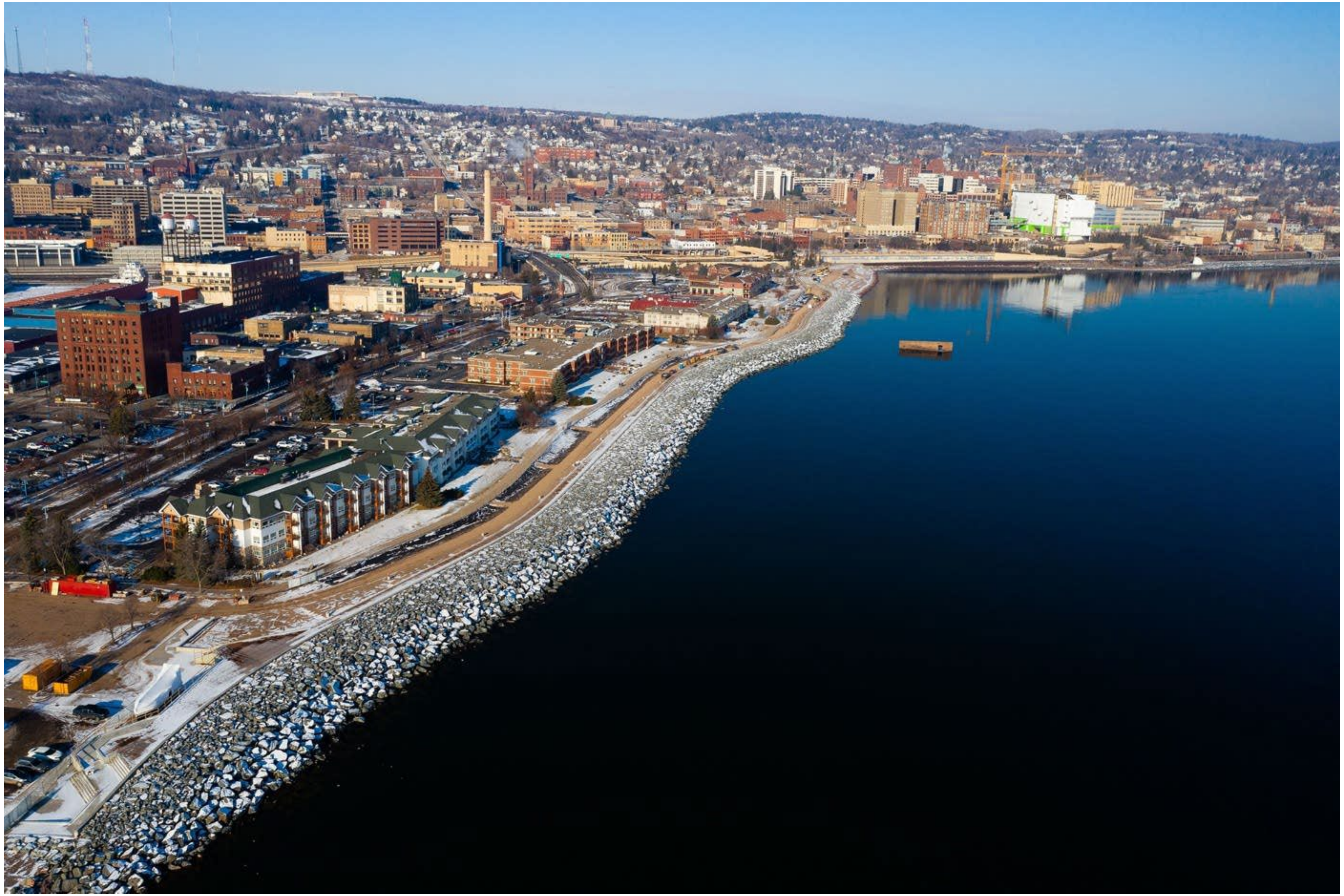
Coastal Structures
Hard Armoring
Gray Infrastructure

http://sagecoast.org/info/information.html

Armoring in Duluth

[KUMD; http://www.kumd.org/post/it-just-me-or-are-there-lot-more-damaging-storms]

Armoring in Duluth



[Derek Montgomery for MPR News; Duluth rebuilds Lakewalk to — hopefully — withstand future storms | MPR News]

Nature-Based Shoreline - Samuel Myers Park, Racine

Capt. Dennis Carr

Nature-Based Shoreline - Samuel Myers Park, Racine

[[Racine Department of Public Health]

Learn More

https://publications.aqua.wisc.edu/product/adapting-to-a-changing-coast-for-property-owners/

Learn More


A PROPERTY OWNER'S GUIDE TO
Protecting Your Bluff
UNIVERSITY OF WISCONSIN SEA GRANT INSTITUTE


Nature-Based Shoreline
OPTIONS FOR THE GREAT LAKES COASTS
UNIVERSITY OF WISCONSIN SEA GRANT INSTITUTE

https://wicci.wisc.edu/coastal-resilience-working-group/

Summary of Issues and Impacts

Wisconsin's Great Lakes coast is composed of bluffs, dunes, beaches and waterfront infrastructure. These interconnected coastal features serve as the interface between high-value upland areas and the economic, recreational and cultural assets of the Great Lakes. Processes like fluctuating lake water levels, waves, erosion, sediment transport and slope failure can combine to damage coastal properties and impair the function of waterfront facilities. Climate change threatens to exacerbate the coastal hazards facing Wisconsin's coastal communities.

Climate Issues Affecting Coastal Resilience

Fluctuating Lake Levels

Both high and low water level extremes are anticipated to continue under a changing climate. This could include potentially higher highs and lower lows than seen in the historical record. This is because both precipitation and evaporation are anticipated to increase under a changing climate, leading to a tug-of-war in water supply into and out of the lakes that may have more extremes than in the past.

Declining Ice Cover

The observed trend of declines in the extent and duration of ice cover on the Great Lakes are expected to continue in a future warmer climate. Reduced ice cover exposes the coast to greater wave energy.

Increasing Wave Energy

Wave energy reaching Great Lakes coasts is expected to increase in the future in part due to anticipated decreases in ice cover extent and duration. A reduction of ice cover will expose the coast to waves for a greater portion of the winter, the season when coastal storm intensity is greatest and large wave events are most frequent. Great Lakes wave energy has also been observed to increase during the summer months, associated with an increased frequency of extreme wind speed events.

https://wicci.wisc.edu/coastal-resilience-working-group/

Stories

Bluff erosion in Ozaukee County

Record-high Lake Superior water levels causing erosion on Wisconsin Point in

Village of Fox Point Beach Drive protection

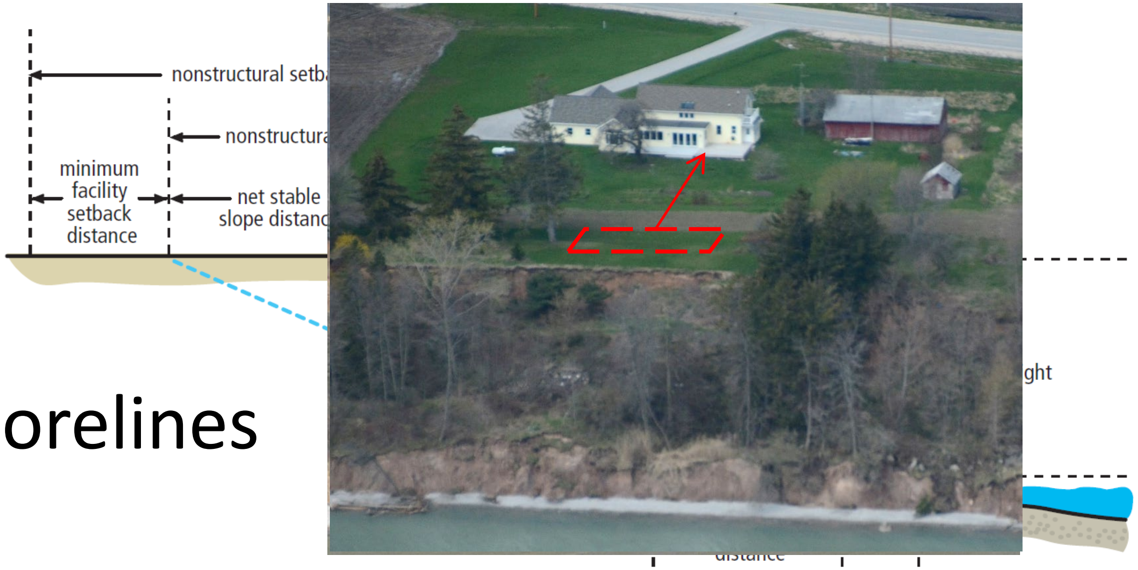
Resources

Expand all | Collapse all

+ Understanding Great Lakes Coastal Hazard Issues
+ Adaptation Options
+ Maps and Data
+ Planning and Policy Options
+ Wisconsin Coastal Resilience Hubs and Networks
+ Other Great Lakes-Wide Climate Change Assessments
+ Working Group Documents

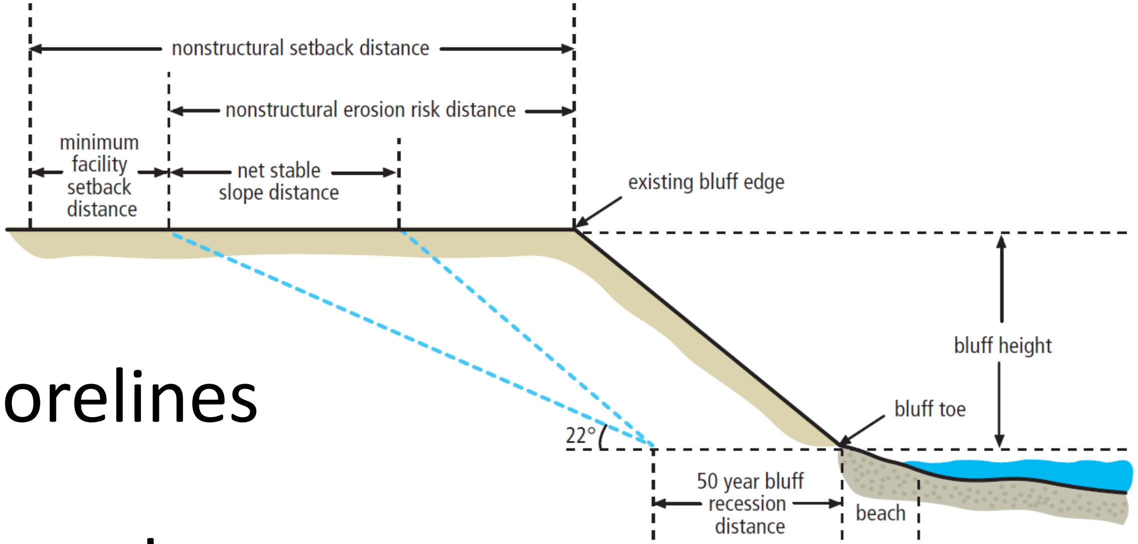
Adaptation Strategies

- Consider function at all lake levels
- Coordinate actions along the coast
- Locate homes away from eroding shorelines



Adaptation Strategies

- Consider function at all lake levels
- Coordinate actions along the coast
- Locate homes away from eroding shorelines
- Work with natural processes to protect the coast



Barry Kreiner, City of Marysville, Mich.


Michigan Department of Environment, Great Lakes and Energy

Learn More About Adaptation Strategies

https://publications.aqua.wisc.edu/product/adapting-to-a-changing-coast-for-property-owners/

https://publications.aqua.wisc.edu/product/adapting-to-changing-coast-for-local-officials/

Learn More About Adaptation Strategies

ADOPTING A LONG-LOT FORMAT FOR NEW SUBDIVISIONS

Who?
Municipal government

Purpose?
Ease relocation of structures away from eroding bluffs

Challenges?
Difficult to implement in areas that are already developed

Scope?
Local

New Legislation?
Yes

Relocating homes away from a rapidly eroding or unstable bluff top can often be much more effective and less expensive than re-grading the bluff or adding a revetment to stabilize the bluff toe. However, relocating a home requires lot space. One approach that would make this strategy easier to implement would be to use a long-lot format for new subdivisions in which the parcels are laid out in long strips perpendicular to the coast, providing room for a home to move back in the event that it becomes necessary to do so.

BENEFITS	CHALLENGES
Eases relocation of at-risk structure by providing property buffer away from coastline	Difficult to implement in already developed areas
Protects coastal ecosystem and sediment budget of lake by focusing on retreat rather than shore armoring	

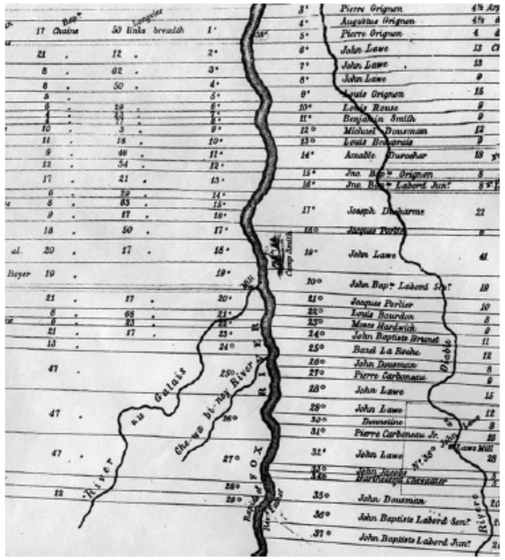
Resources

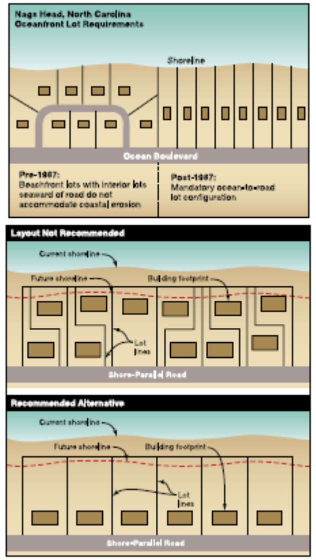
The long-lot format was first put to use in Quebec, when tenant farmers were granted parcels of land in exchange for rental payments in the form of goods and natural resources. As many of the settlers of the time were more interested in the fur trade than in farming, maximizing river-front access drove the development of narrow strips of land called long lots or ribbon farms. This practice was carried forward throughout North America, wherever the French settled. This article from the University of Wisconsin-Green Bay discusses the use of the long-lot system in Wisconsin.
uwgb.edu/wisfrench/library/maps/jung/frmaps.htm

The Federal Emergency Management Agency (FEMA) Coastal Construction Manual has some excellent discussions of recommended zoning and subdividing practices for shoreline properties in chapter four. The recommendations for shoreline properties include laying out lots in narrow strips perpendicular to the shoreline, with each lot having room for a house to retreat and access to a road. Here, FEMA is essentially recommending the use of a long-lot format for coastal properties.
www.fema.gov/media-library/assets/documents/3293

Related Options

Creation of an Aid Fund for Coastal Properties
Revolving Loan Fund
Purchase of At-Risk Properties
Purchase or Transfer of Development Rights
Require Proof that Retreat Is Not an Option Before Permitting Shore Structure





Adopting a long-lot format for new subdivisions images: The idea of laying out lots in narrow strips along the water is as old as European settlement in North America. French settlers used exactly that approach along the Fox River when they settled near Green Bay, Wis. (left). While they were interested in trade and having ready access to a transportation route, this approach is also useful for building resiliency on coastal properties.

The FEMA "Coastal Construction Manual" provides a clear recommendation that new subdivisions should have room for relocation and have common access to a road should evacuation become necessary (bottom right). This idea became law in North Carolina in 1987. A diagram of two subdivisions shows that after 1987 the distribution of lots followed what could be called a long-lot format (top right). Using this approach for new subdivisions along the Lake Michigan coast in Wisconsin could be an effective tool to improve resiliency.

https://publications.aqua.wisc.edu/product/adapting-to-changing-coast-for-local-officials/

https://wicci.wisc.edu/coastal-resilience-working-group/

Wisconsin Initiative on Climate Change Impacts

Nelson Institute for Environmental Studies | Wisconsin Department of Natural Resources

Coastal Resilience Working Group

WICCI's Coastal Resilience Working Group uses innovative methods and technologies to describe and predict the effects that the changing climate will have on the communities and property owners of Wisconsin's coastlines.

Thank You

wicci.wisc.edu

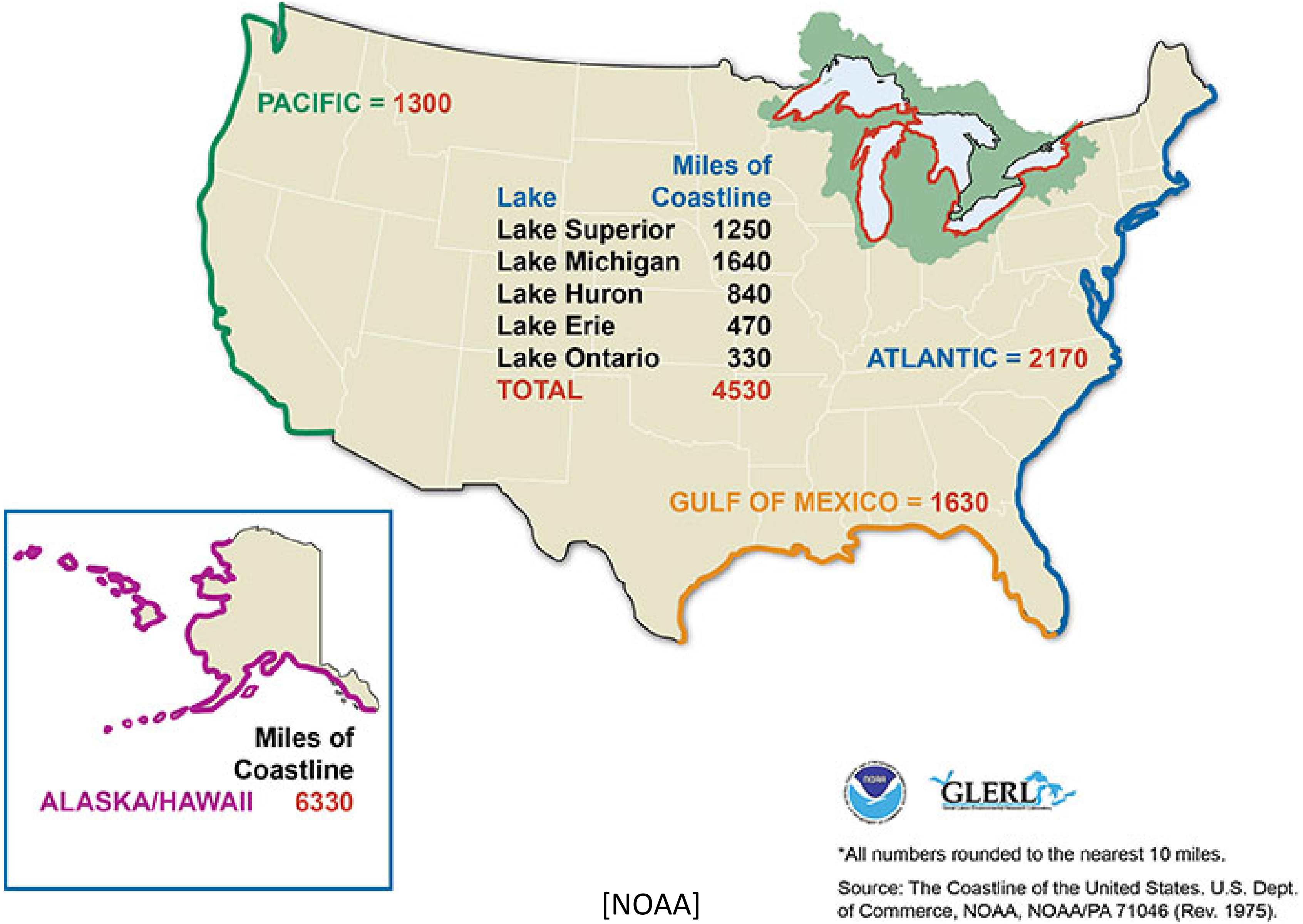
Adam Bechle
Coastal Engineering Outreach Specialist
Wisconsin Sea Grant
bechle@aqua.wisc.edu

[USACE]

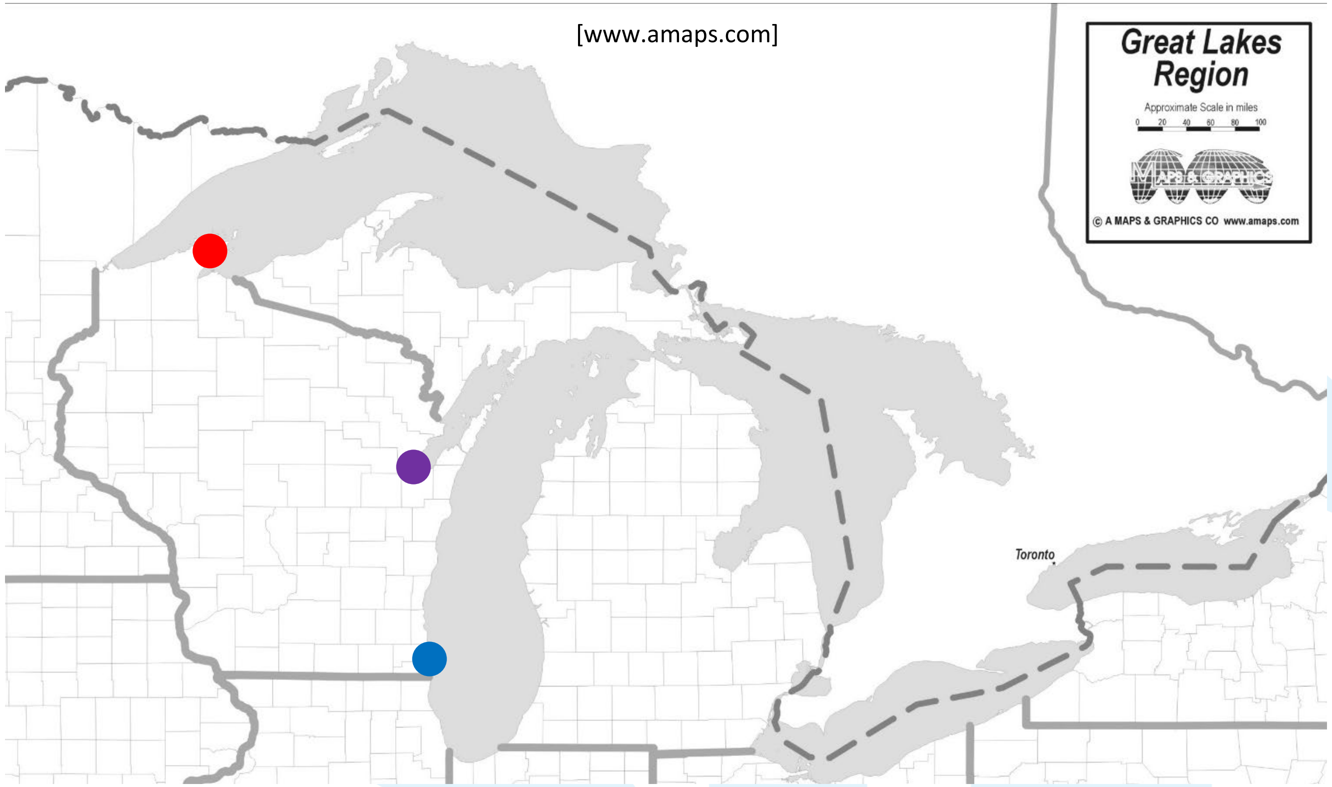
[Dave Mickelson]

[Capt. Dennis Carr, Wisconsin Civil Air Patrol]

Wisconsin’s 1000 Miles of Great Lakes Coast



[NOAA]



[www.amaps.com]

[Wisconsin Sea Grant/Gene Clark]

[Jeff DuMez]

[Wisconsin Shoreline Inventory and Oblique Photo Viewer]

Coastal Flooding

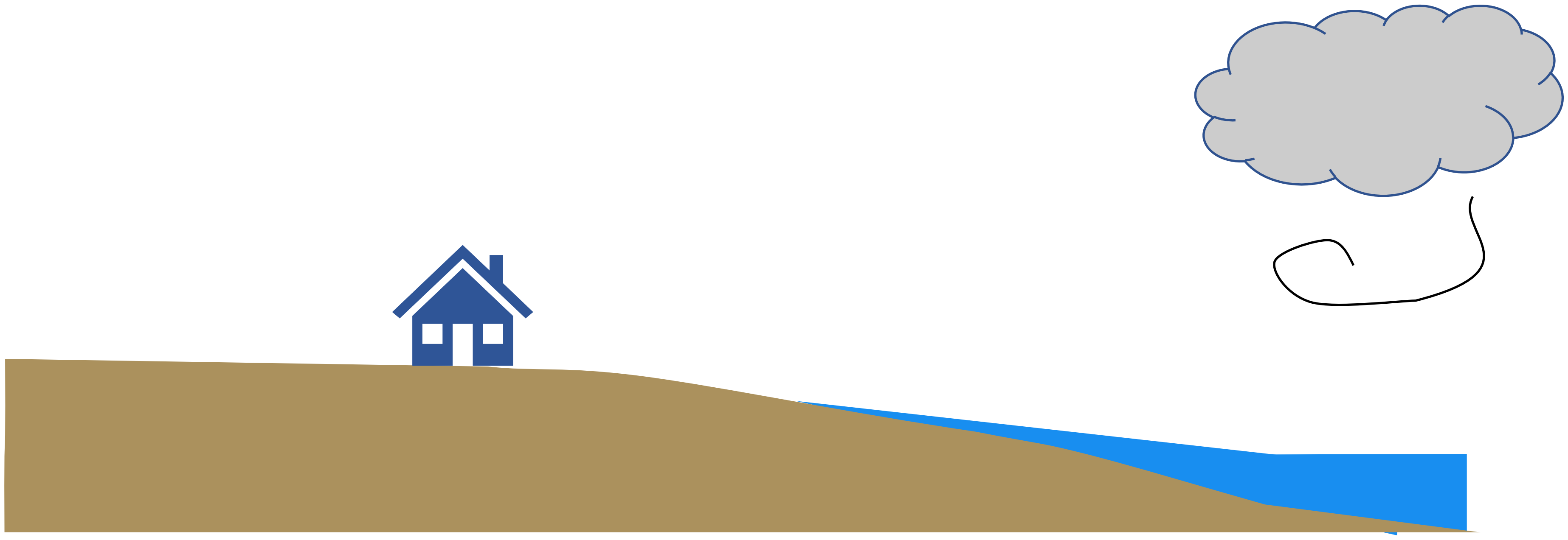
Average Water Levels

Coastal Flooding

Average Water Levels

+

Storm Surge



Coastal Flooding

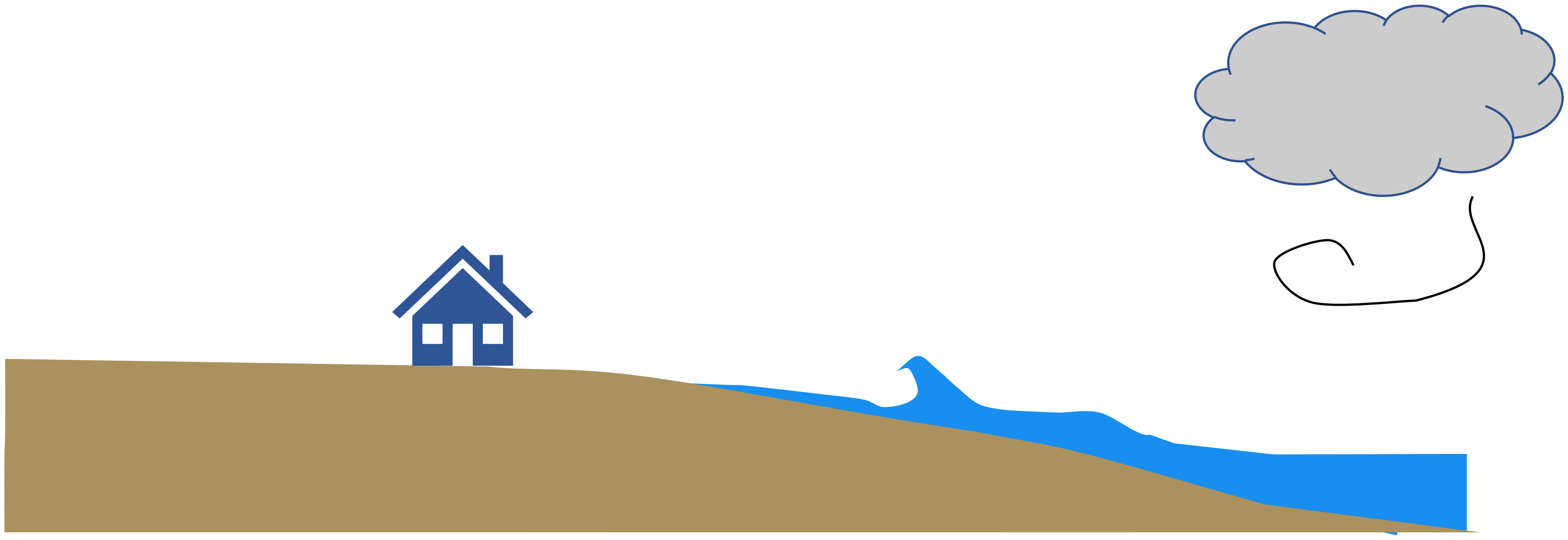
Average Water Levels

+

Storm Surge

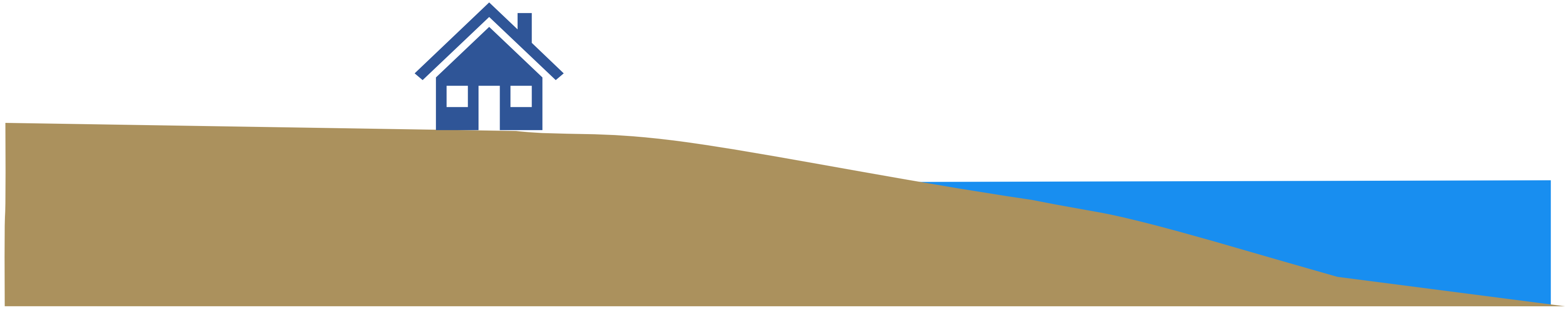
+

Wave Runup



Coastal Flooding

High Water Levels

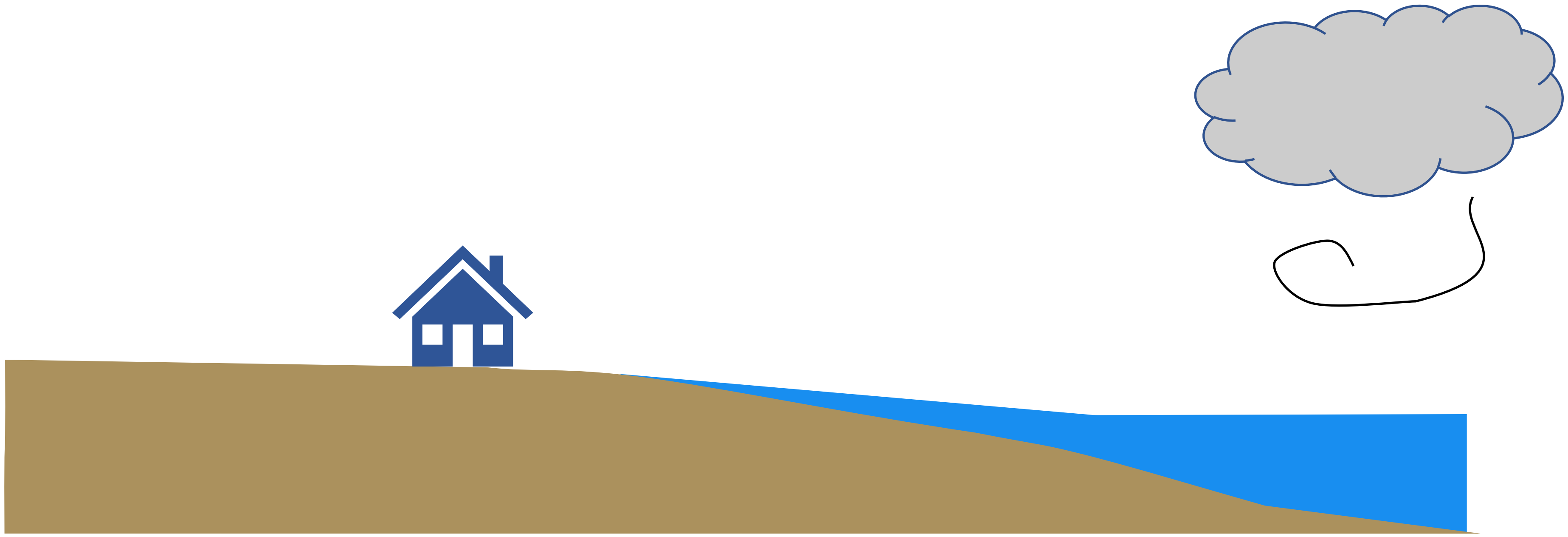


Coastal Flooding

High Water Levels

\+

Storm Surge



Coastal Flooding

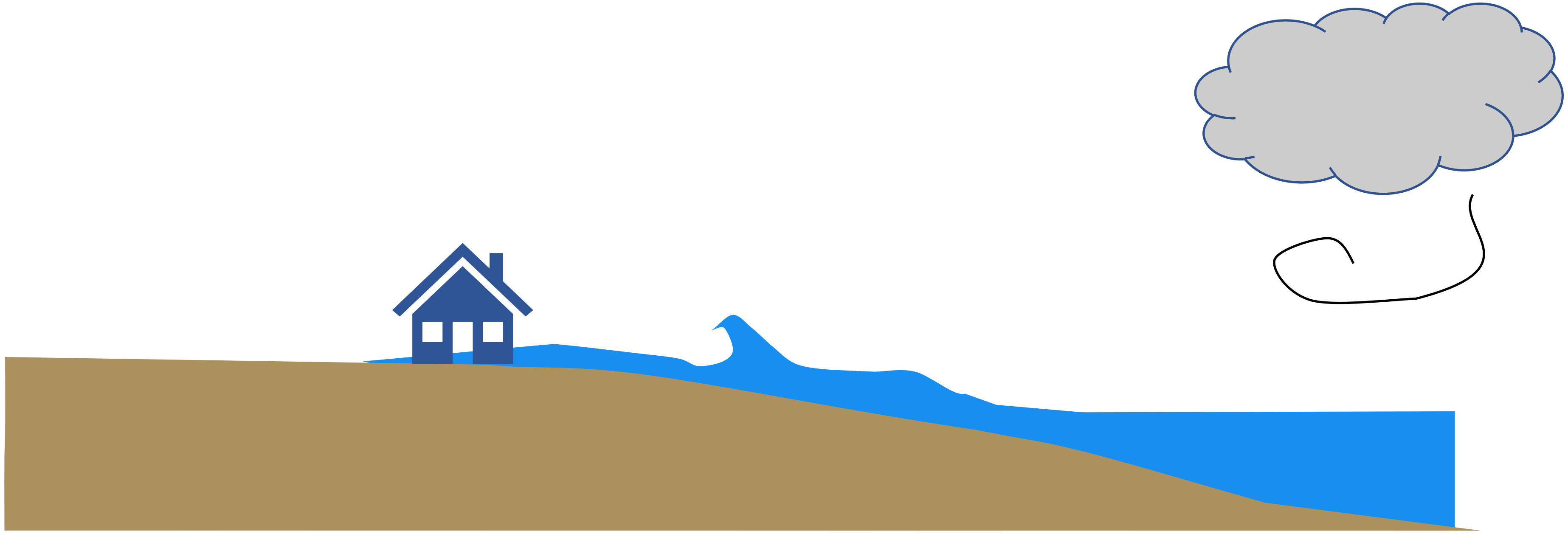
High Water Levels

\+

Storm Surge

\+

Wave Runup



Green Bay Coastal Flooding 2019-2020

[Julia Noordyk]

[Jeff DuMez – Brown County]

April 8, 1973

GREEN BAY PRESS-GAZETTE

VOLUME LVIII, No. 283 — 48 PAGES — GREEN BAY, WISCONSIN, TUESDAY, APRIL 10, 1973 — 15 CENTS

Floods Force 800 From Homes

Never Been So Bad, Flood Victims Say

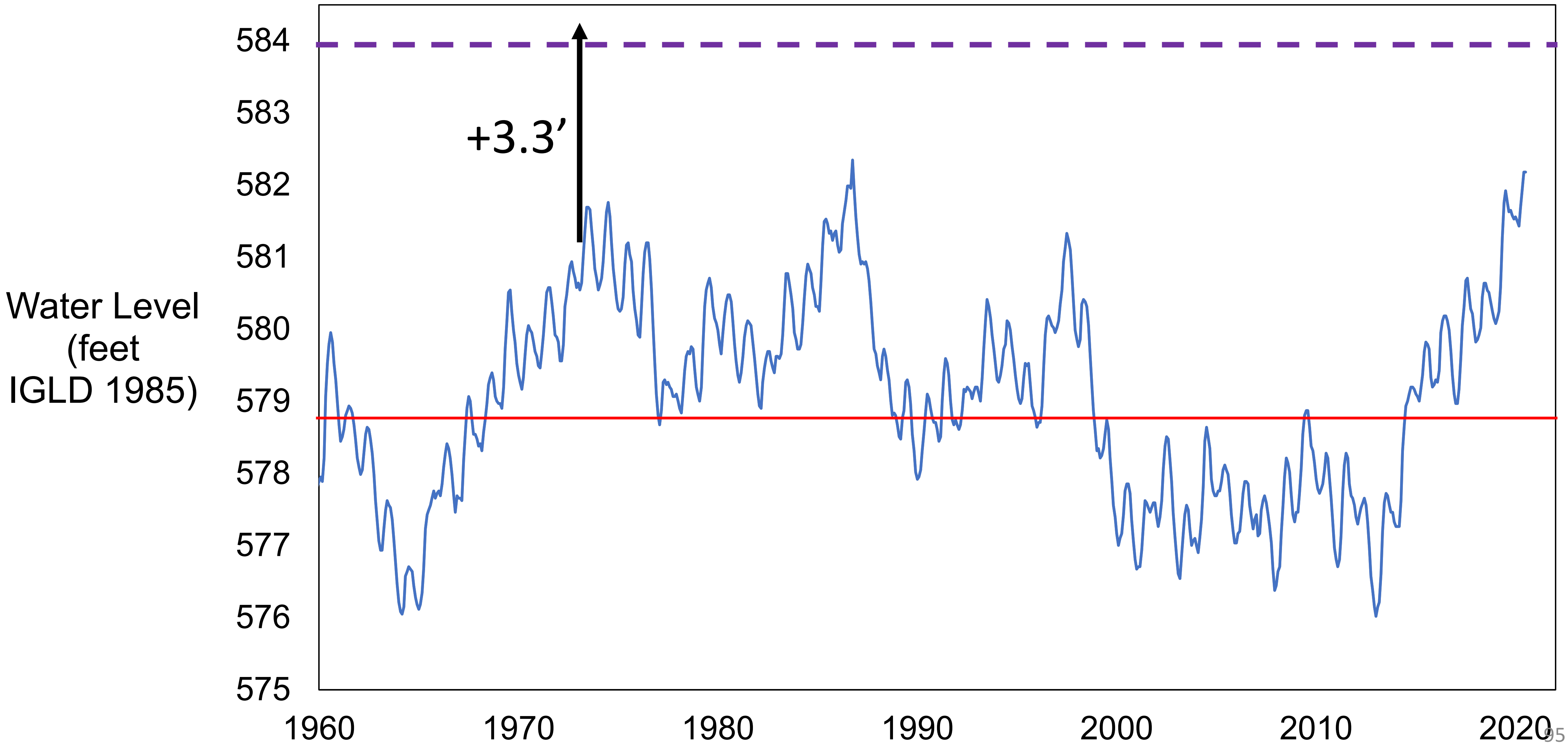
$2 Million Damage at MSD

Rescue Crews Resort to Waders

[Green Bay Press-Gazette]

[Green Bay Press-Gazette]

April 8, 1973


Water Level (feet IGLD 1985)
584
583
582
581
580
579
578
577
576
575
+3.3’
1960
1970
1980
1990
2000
2010
2020

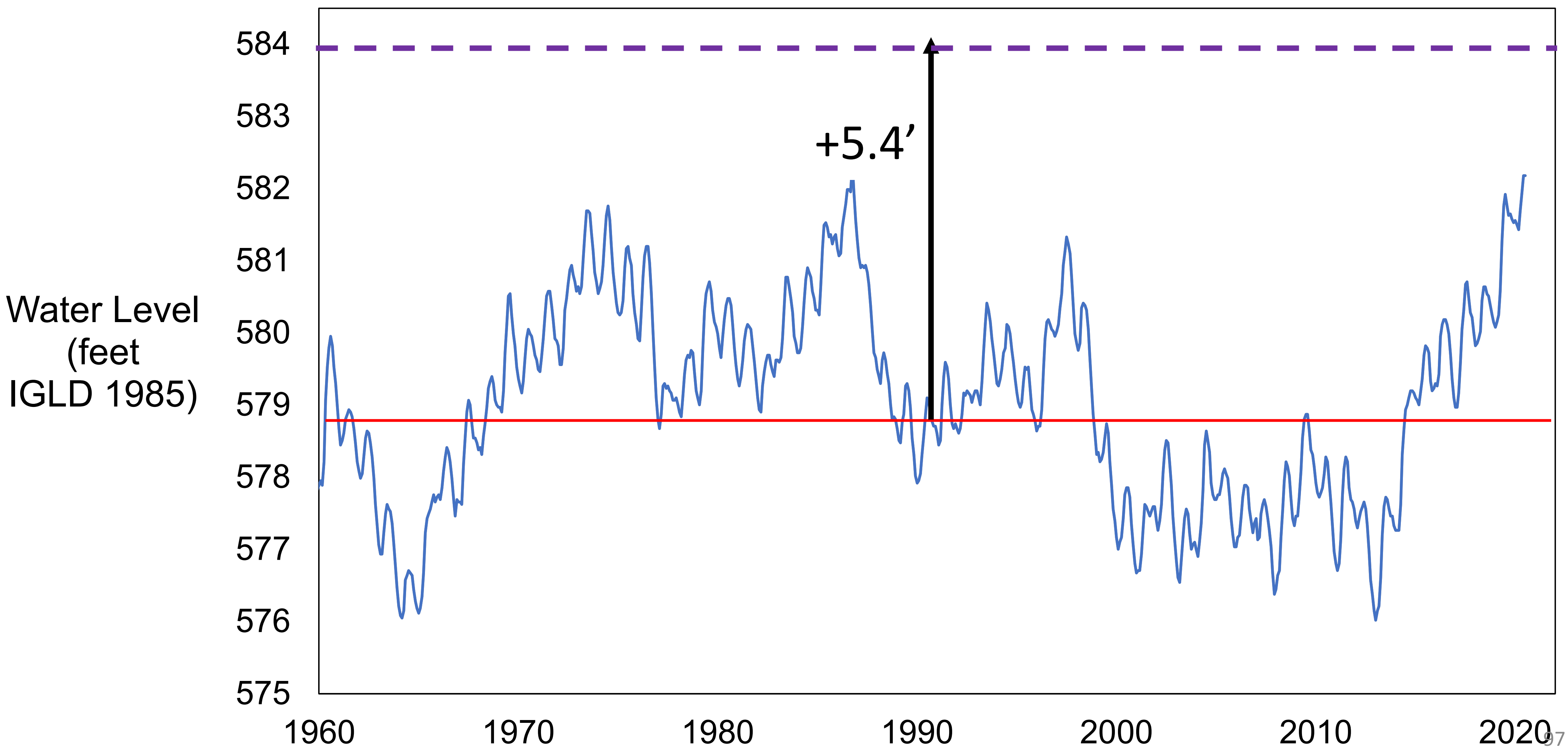
May 12, 1973

Dike Work Started — Heavy equipment was brought in this week to move sand and clay for the state of the $1 million east shore dike. The Boulanger Construction Co. of Casco is building the dike which will run from near the mouth of the Fox River to Mahon Avenue. It is hoped the dike will prevent flooding, such as that which occurred last month which caused widespread damage to homes and businesses on the Northeast Side.

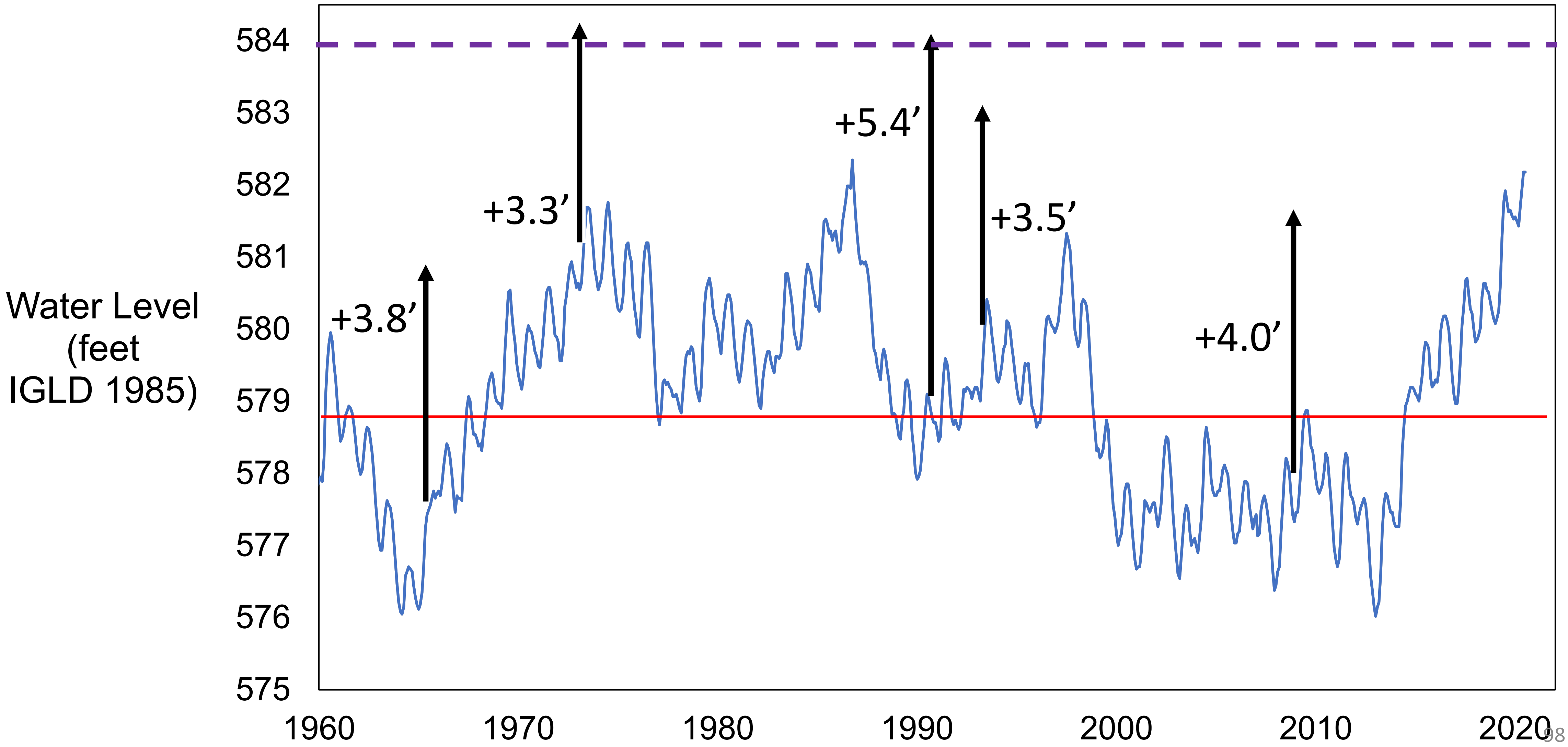
(Press-Gazette Photo)

[Green Bay Press-Gazette]

December 3, 1990



Timing of Water Levels + Storm Surge



December 1, 2019

+2.4 foot storm surge

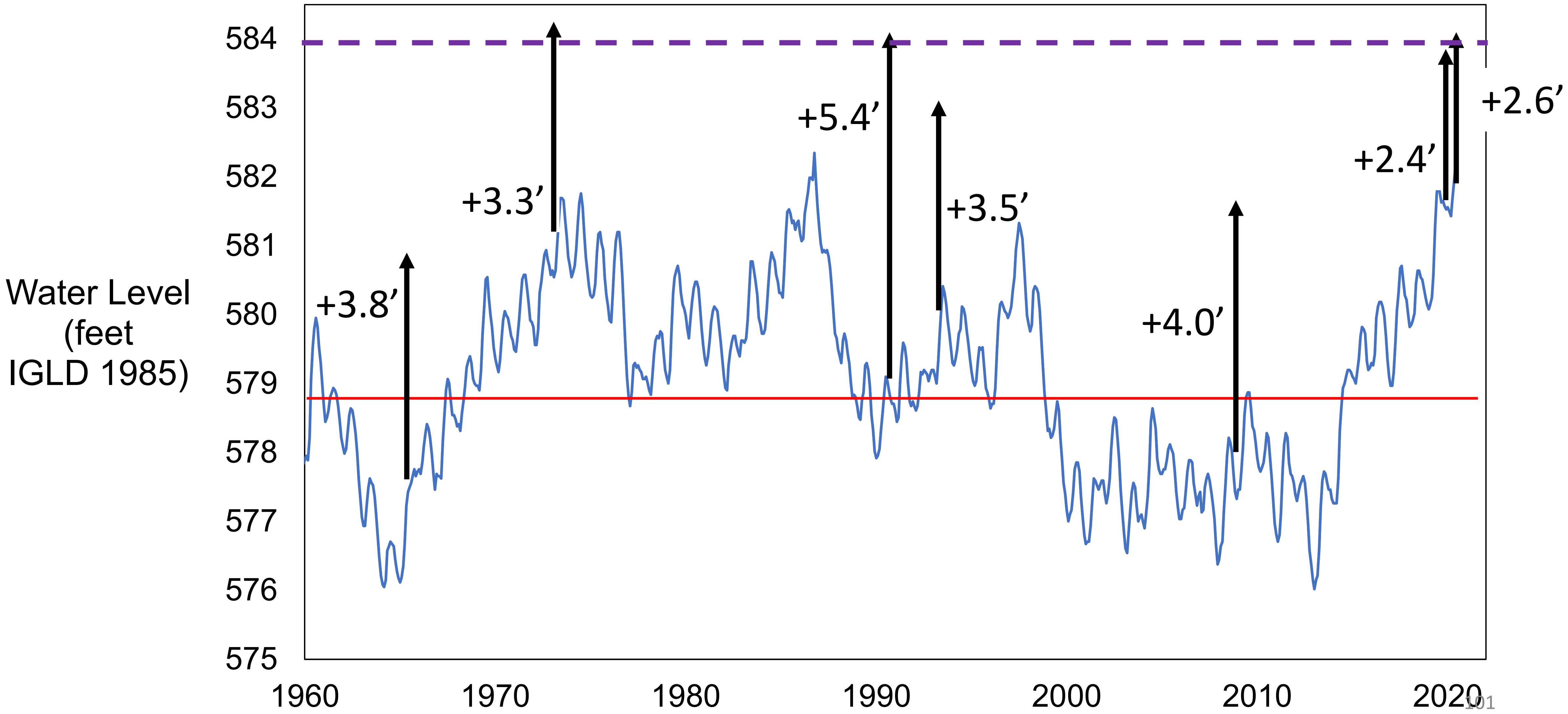
[Julia Noordyk]

April 28, 2020

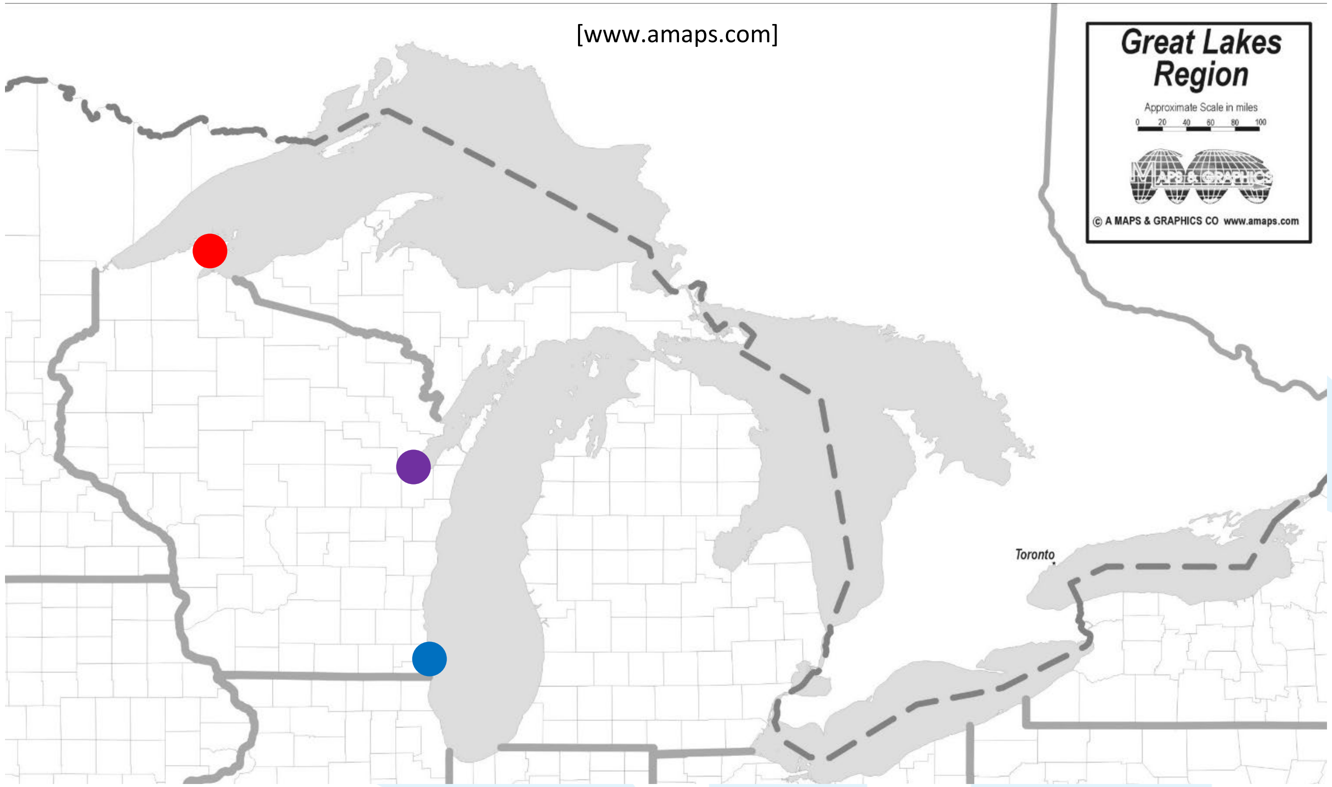
+2.6 foot storm surge

[Jeff DuMez, Brown County]

Timing of Water Levels + Storm Surge



[www.amaps.com]

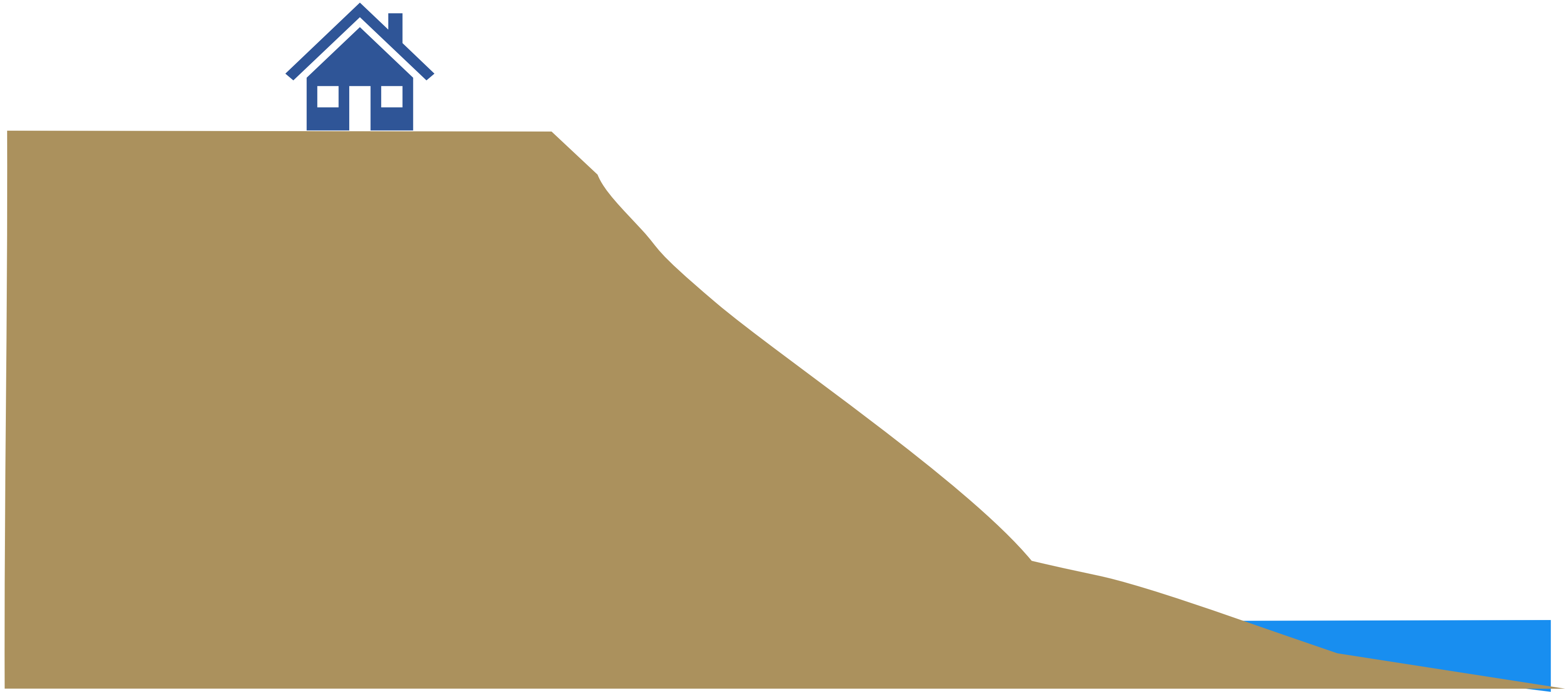


[Wisconsin Sea Grant/Gene Clark]

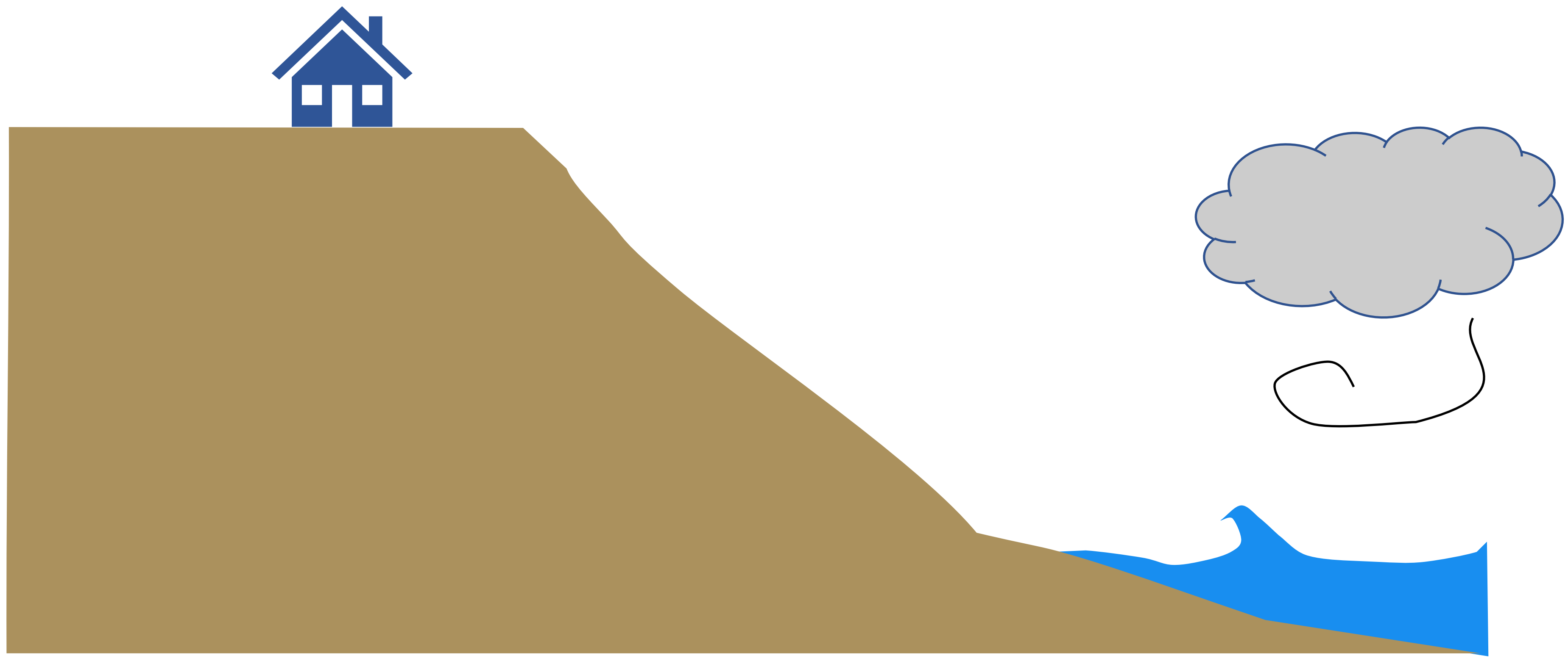
[Jeff DuMez]

[Wisconsin Shoreline Inventory and Oblique Photo Viewer]

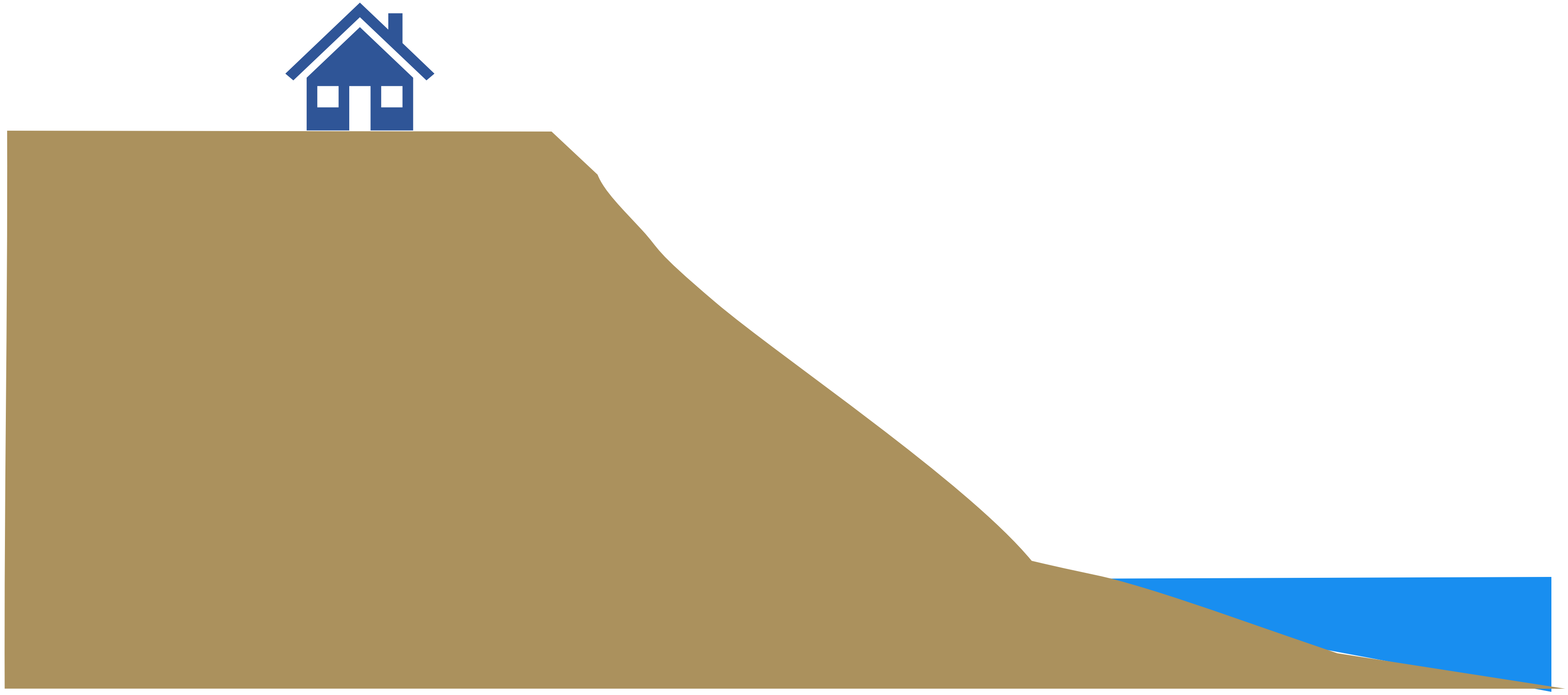
Water Level Impacts on Coastal Bluffs



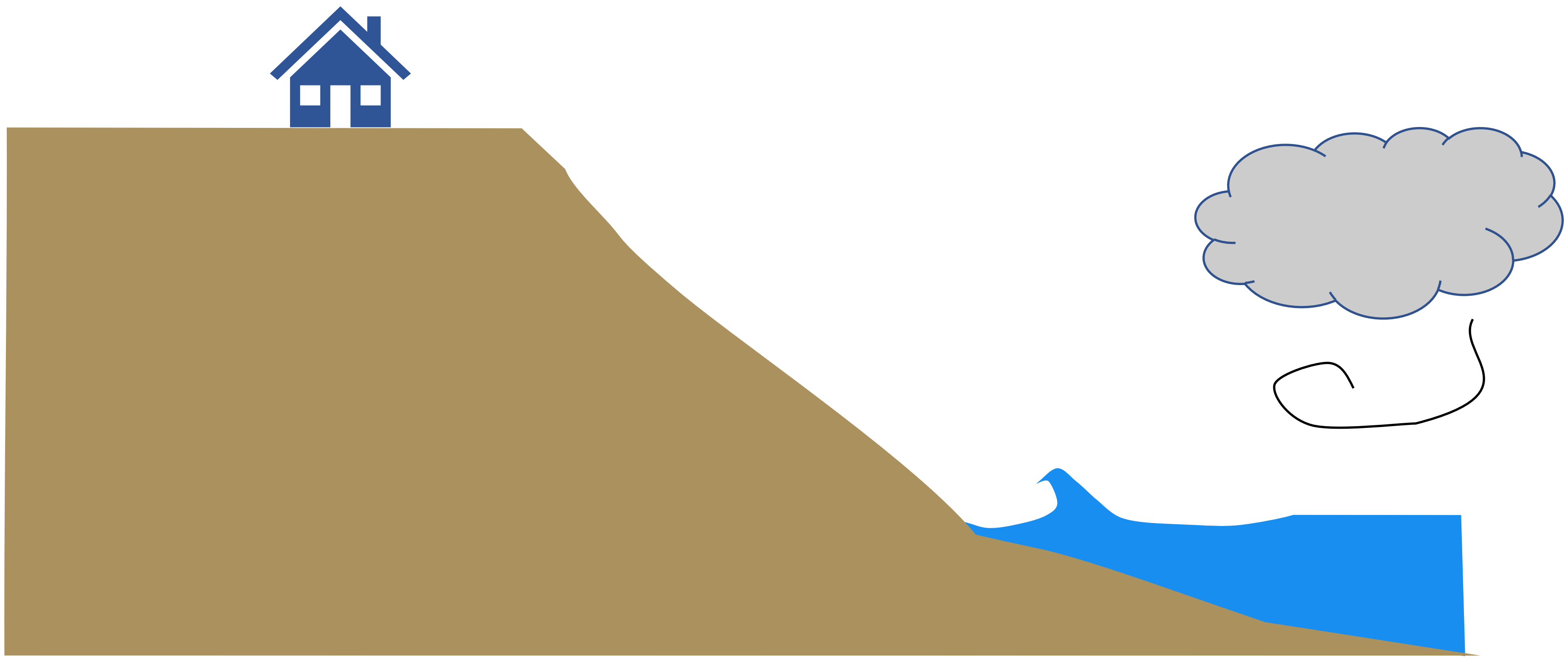
Water Level Impacts on Coastal Bluffs



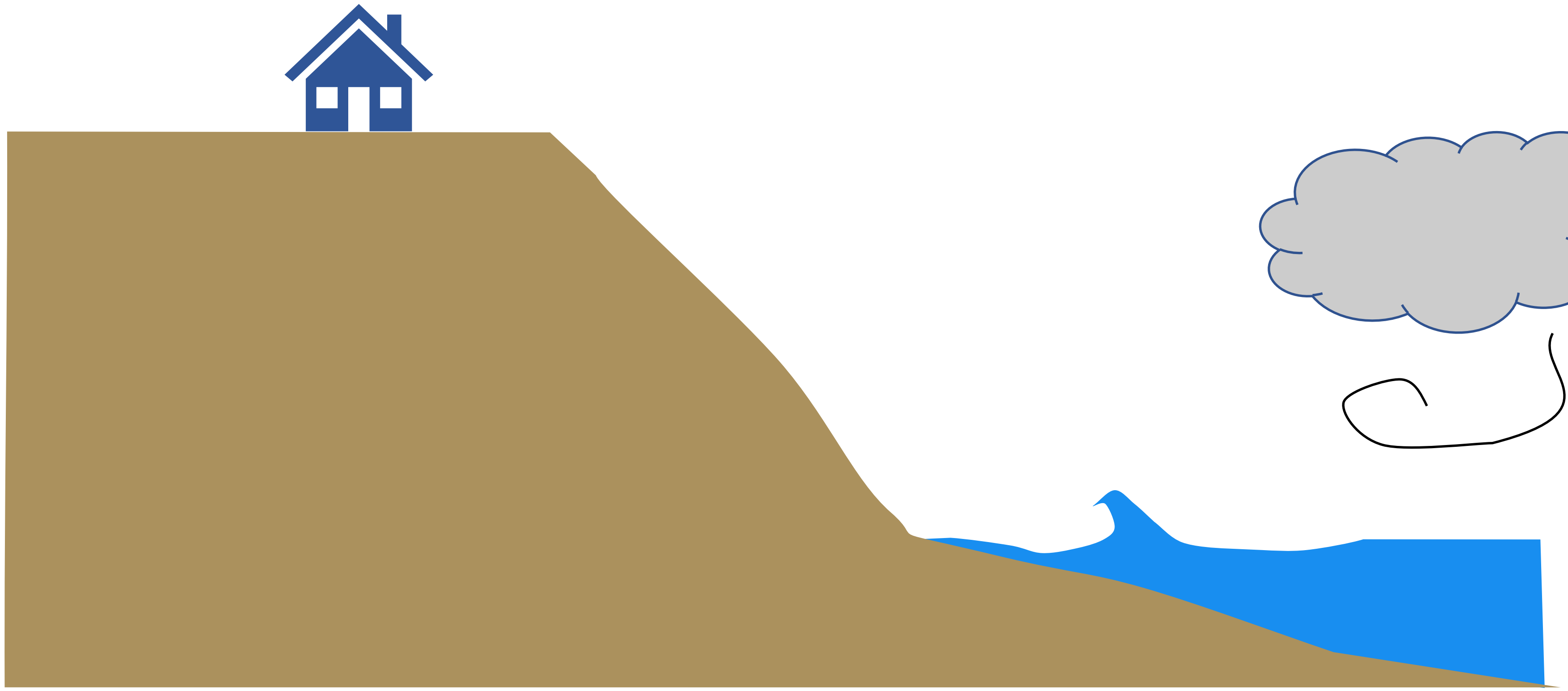
Water Level Impacts on Coastal Bluffs



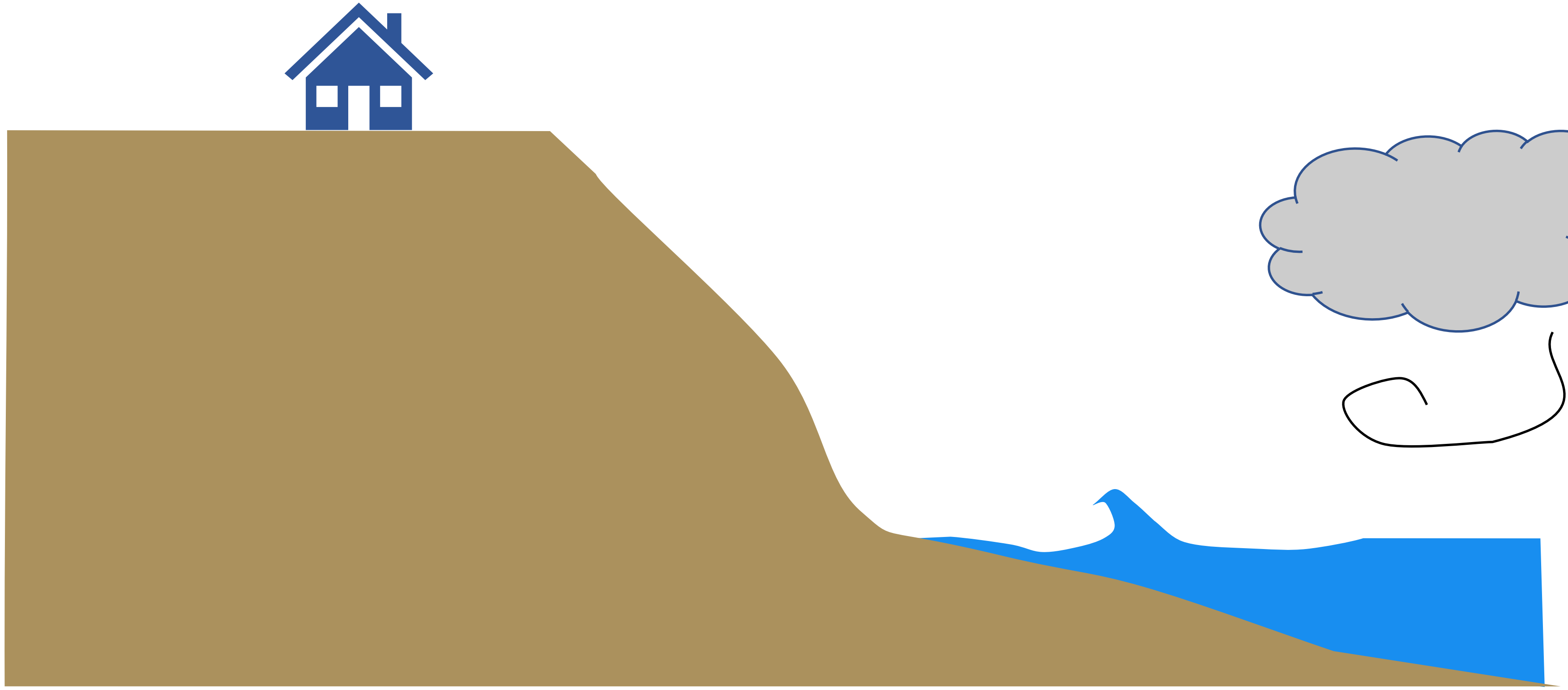
Water Level Impacts on Coastal Bluffs



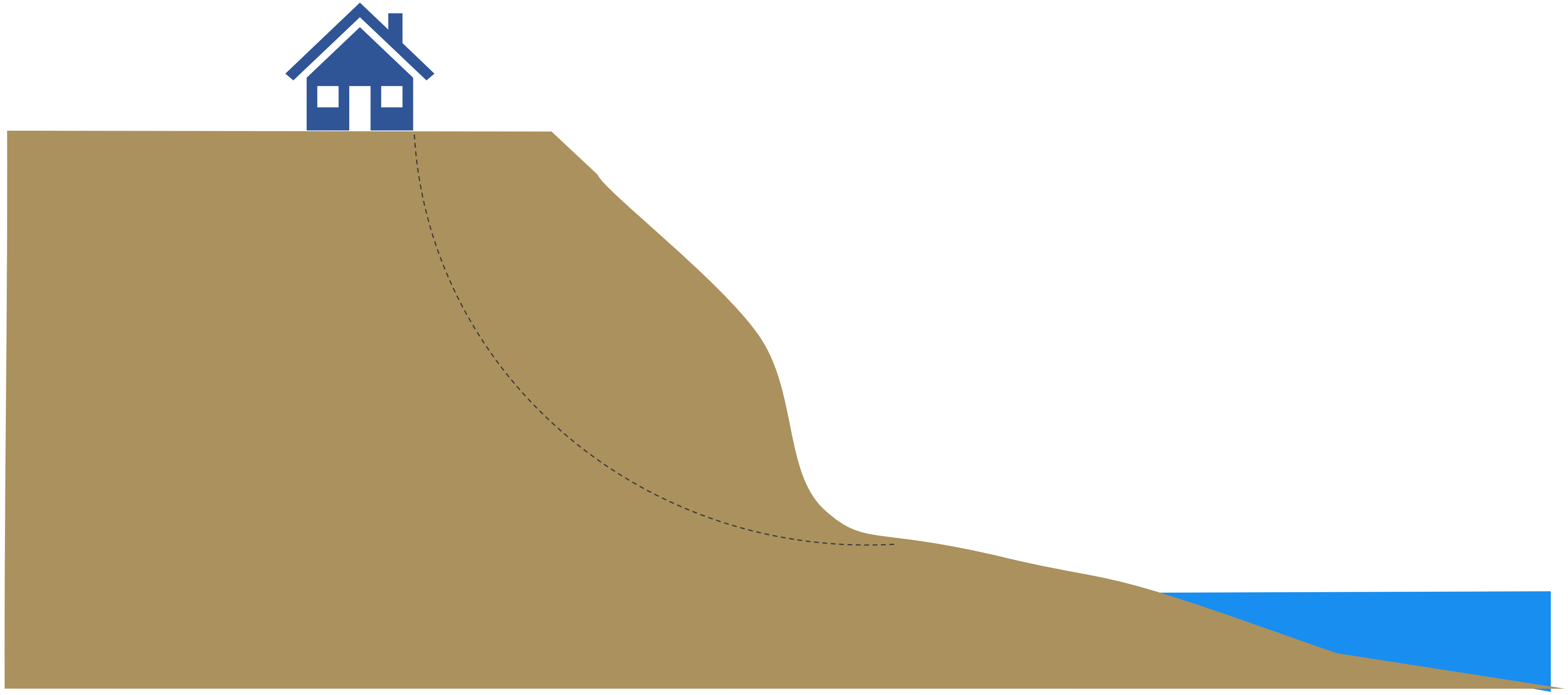
Water Level Impacts on Coastal Bluffs



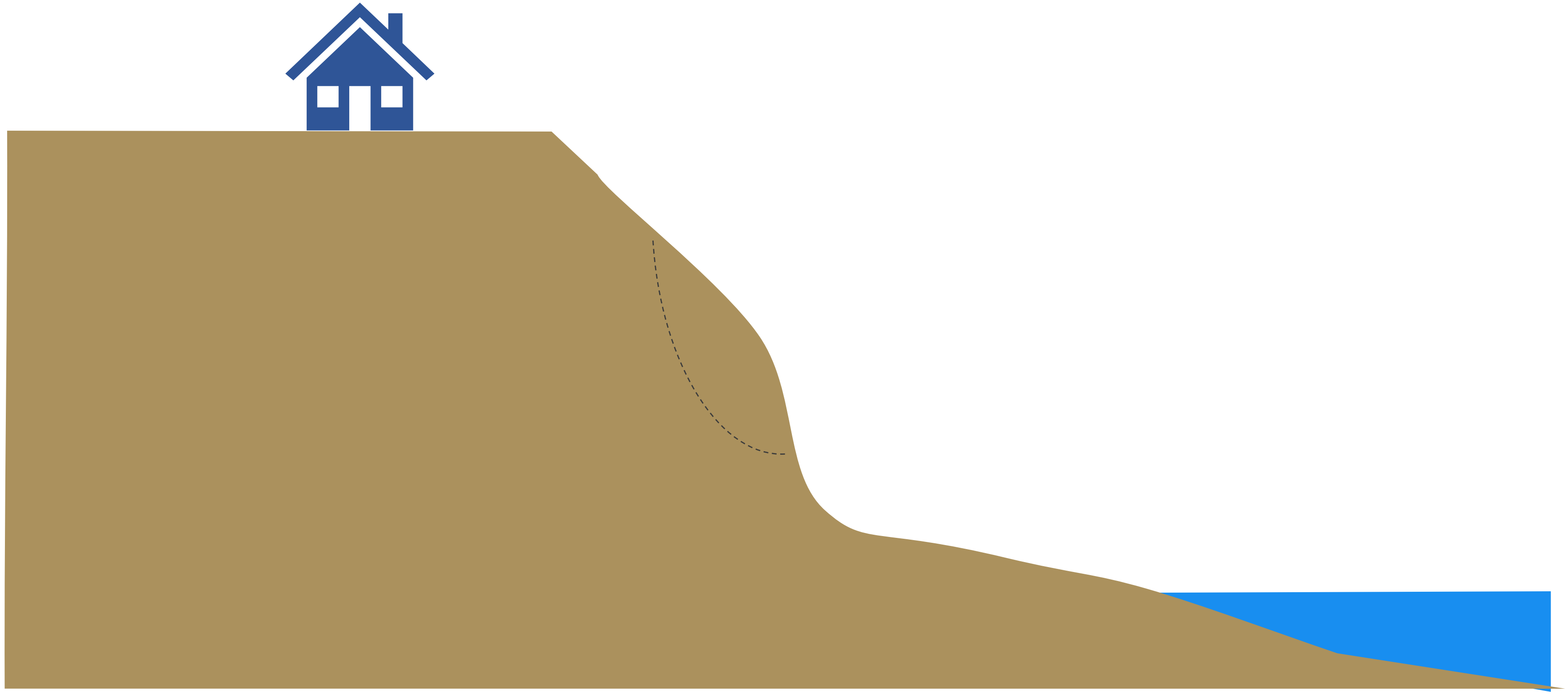
Water Level Impacts on Coastal Bluffs



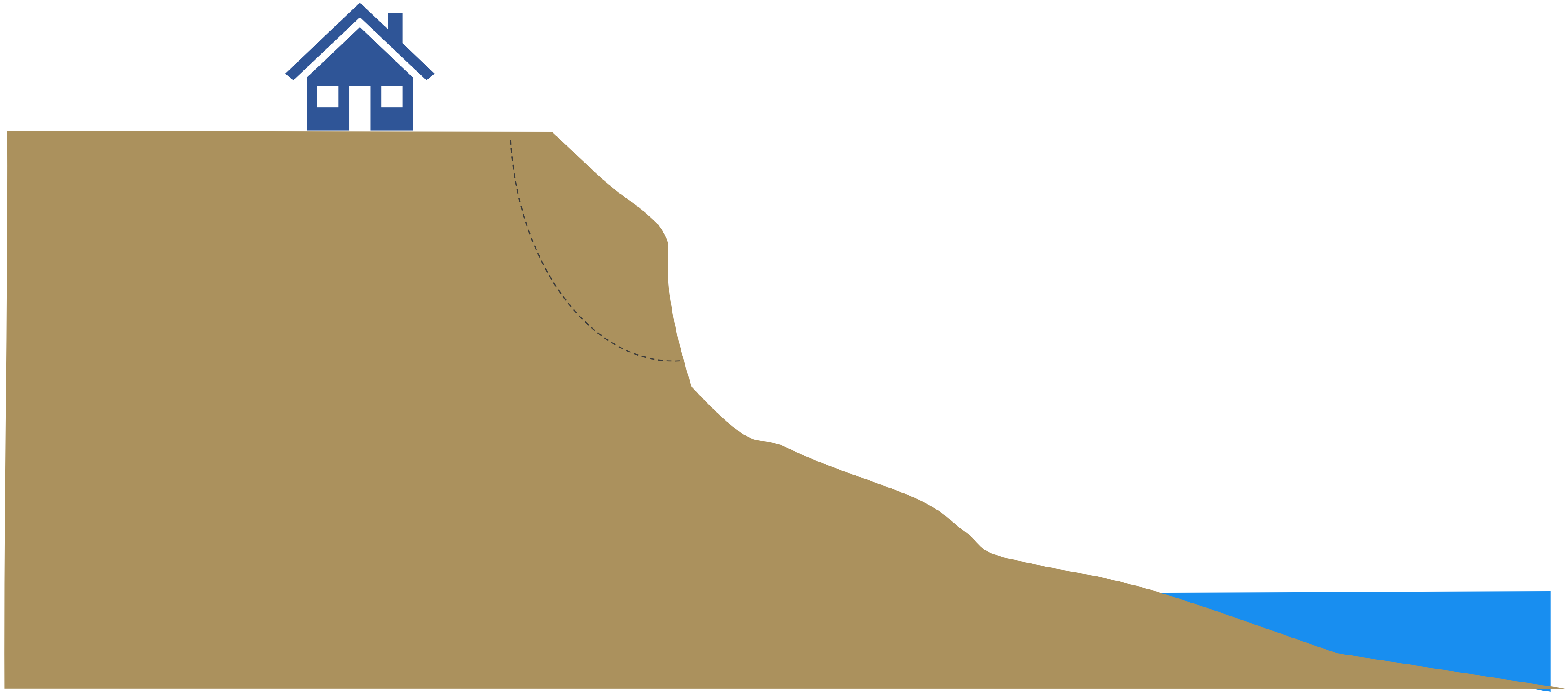
Water Level Impacts on Coastal Bluffs



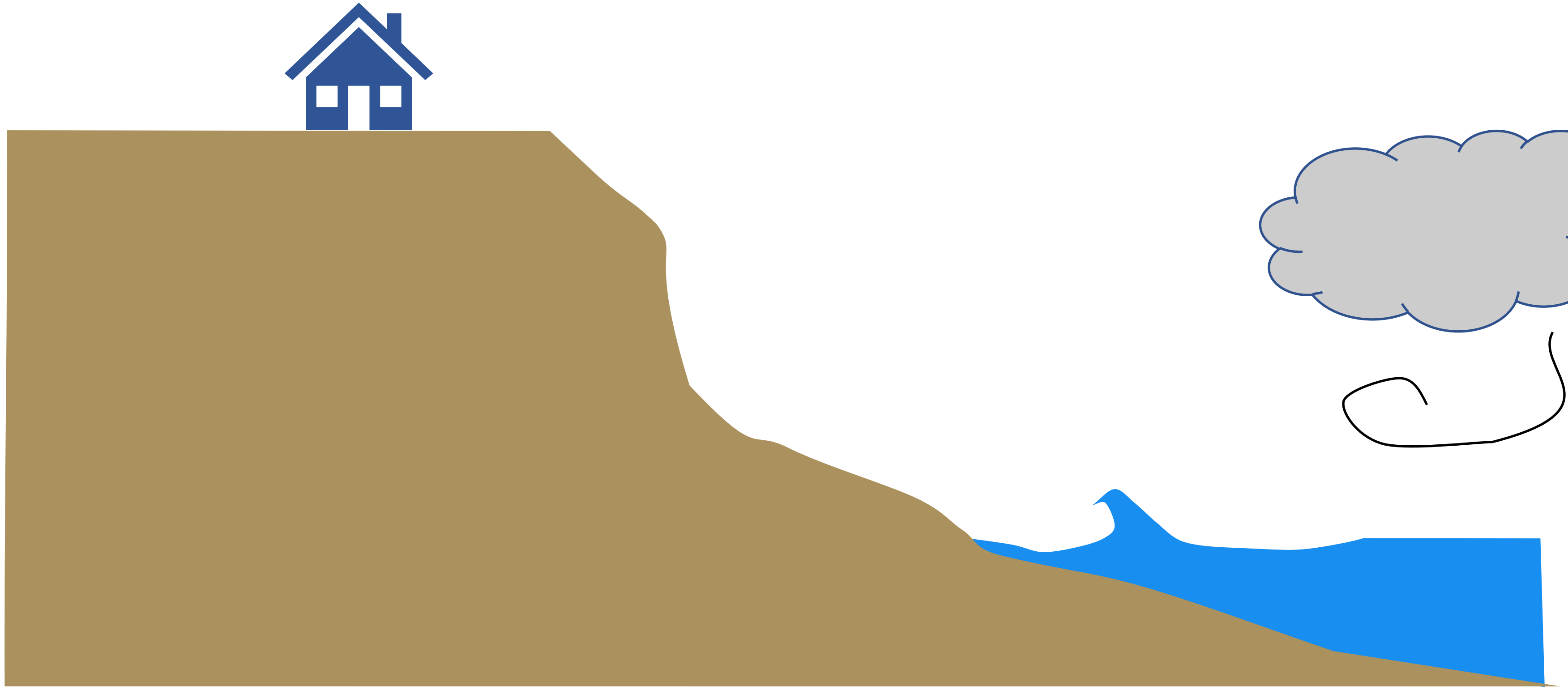
Water Level Impacts on Coastal Bluffs



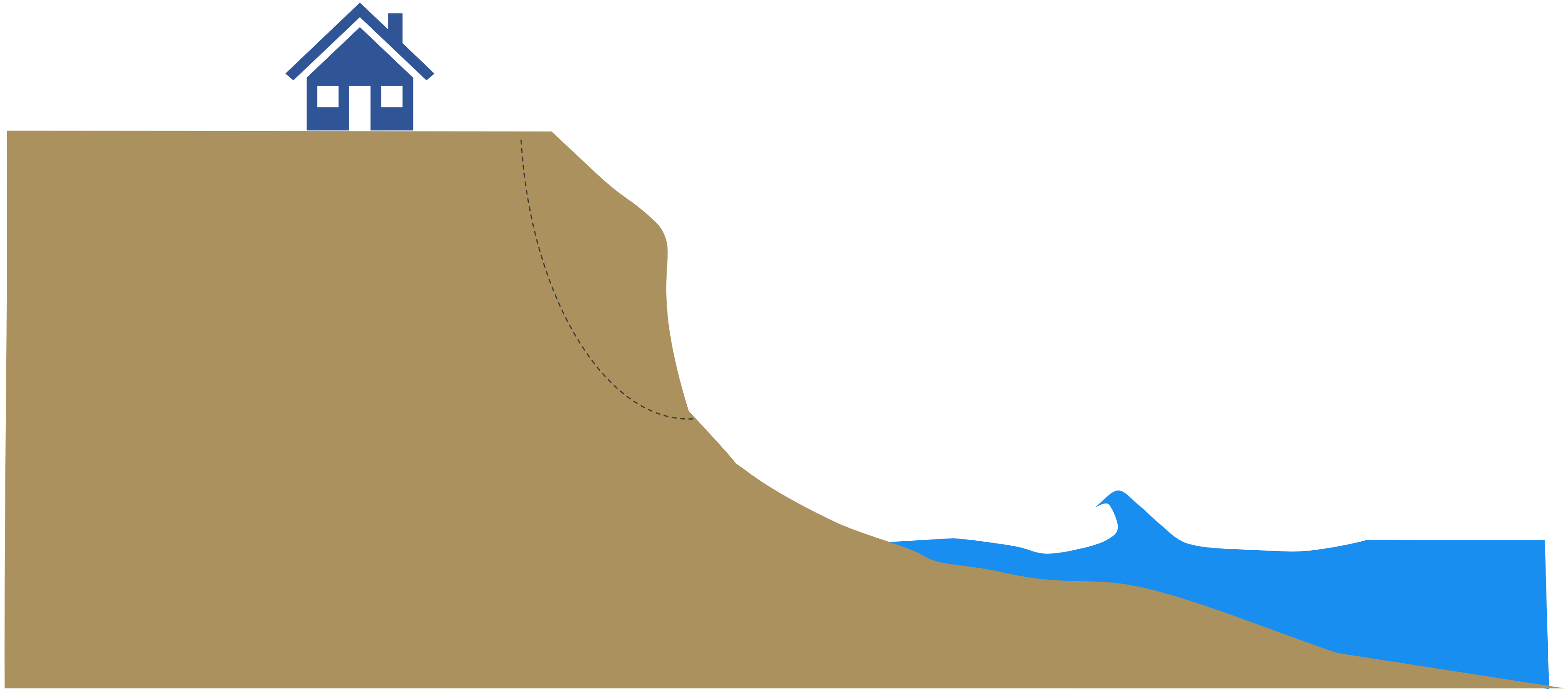
Water Level Impacts on Coastal Bluffs



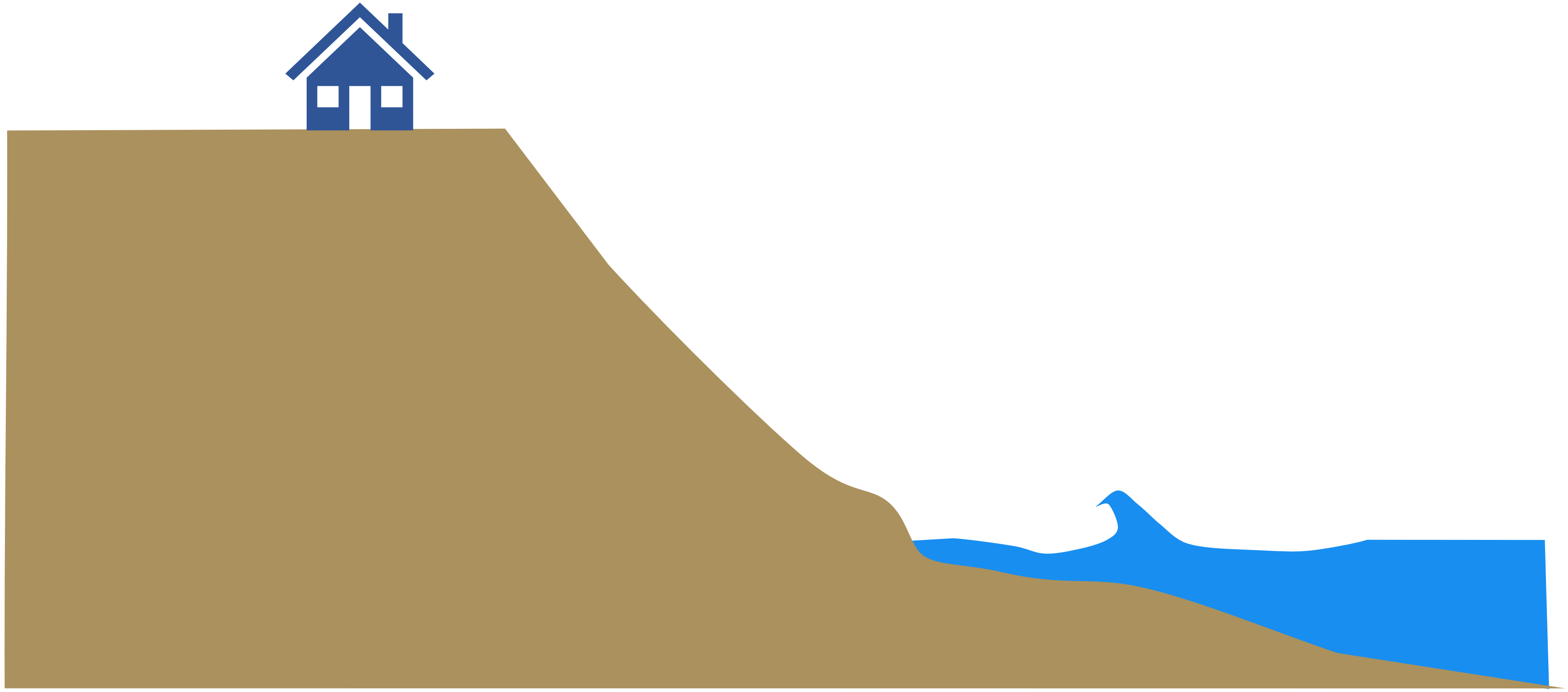
Water Level Impacts on Coastal Bluffs



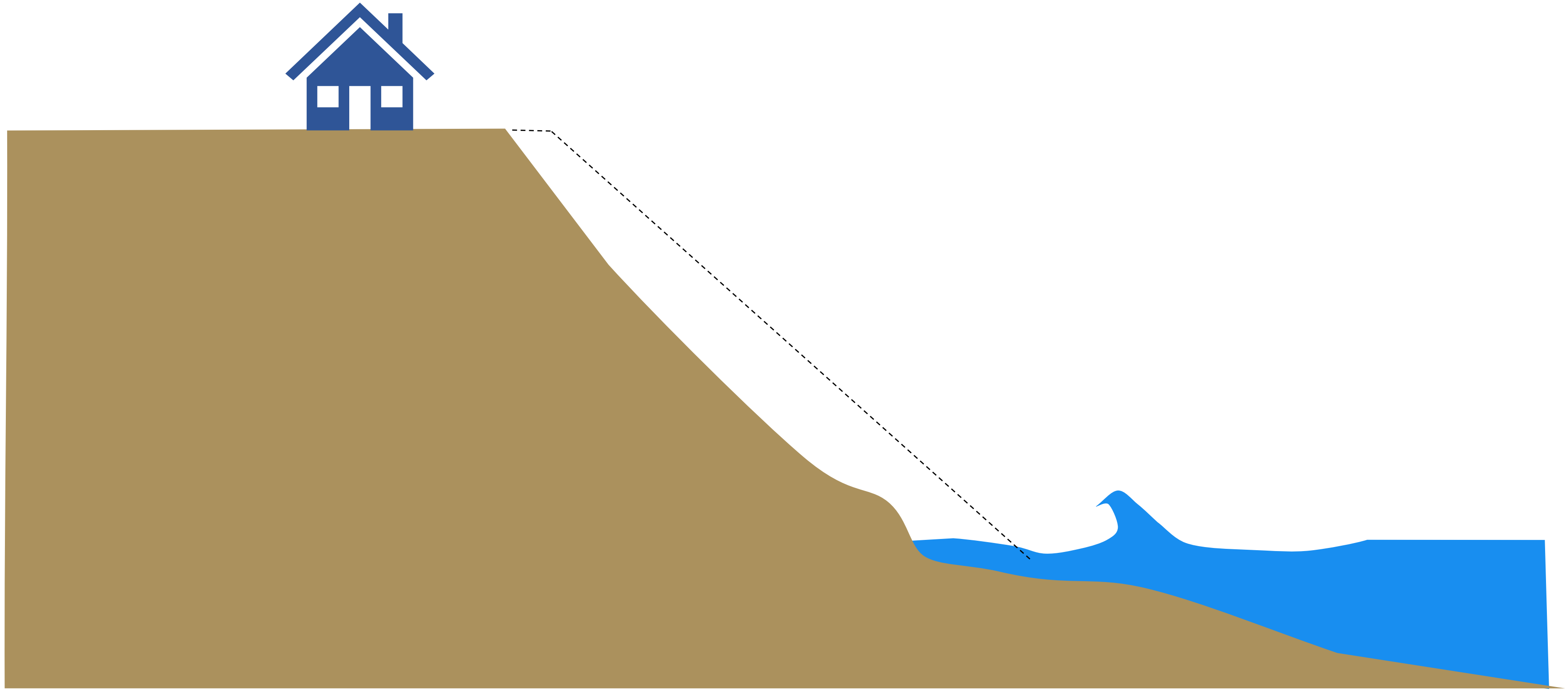
Water Level Impacts on Coastal Bluffs



Water Level Impacts on Coastal Bluffs



Water Level Impacts on Coastal Bluffs



Water Level Impacts on Coastal Bluffs

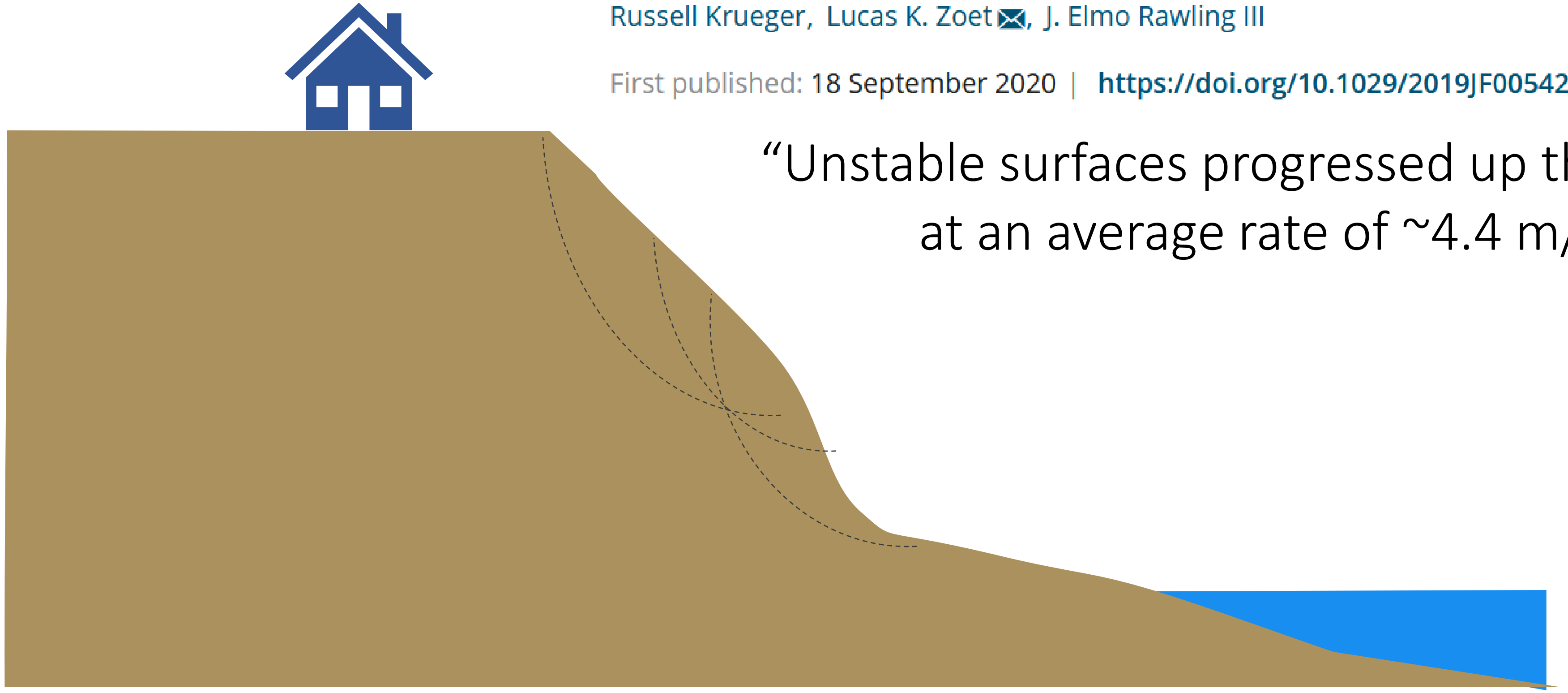
JGR Earth Surface

Research Article

Coastal Bluff Evolution in Response to a Rapid Rise in Surface Water Level

Russell Krueger, Lucas K. Zoet, J. Elmo Rawling III

First published: 18 September 2020 | https://doi.org/10.1029/2019JF005428



"Unstable surfaces progressed up the bluff faces at an average rate of ~4.4 m/year"

Bluff Height Impact on Recession Response

[Wisconsin Shoreline Inventory and Oblique Photo Viewer]

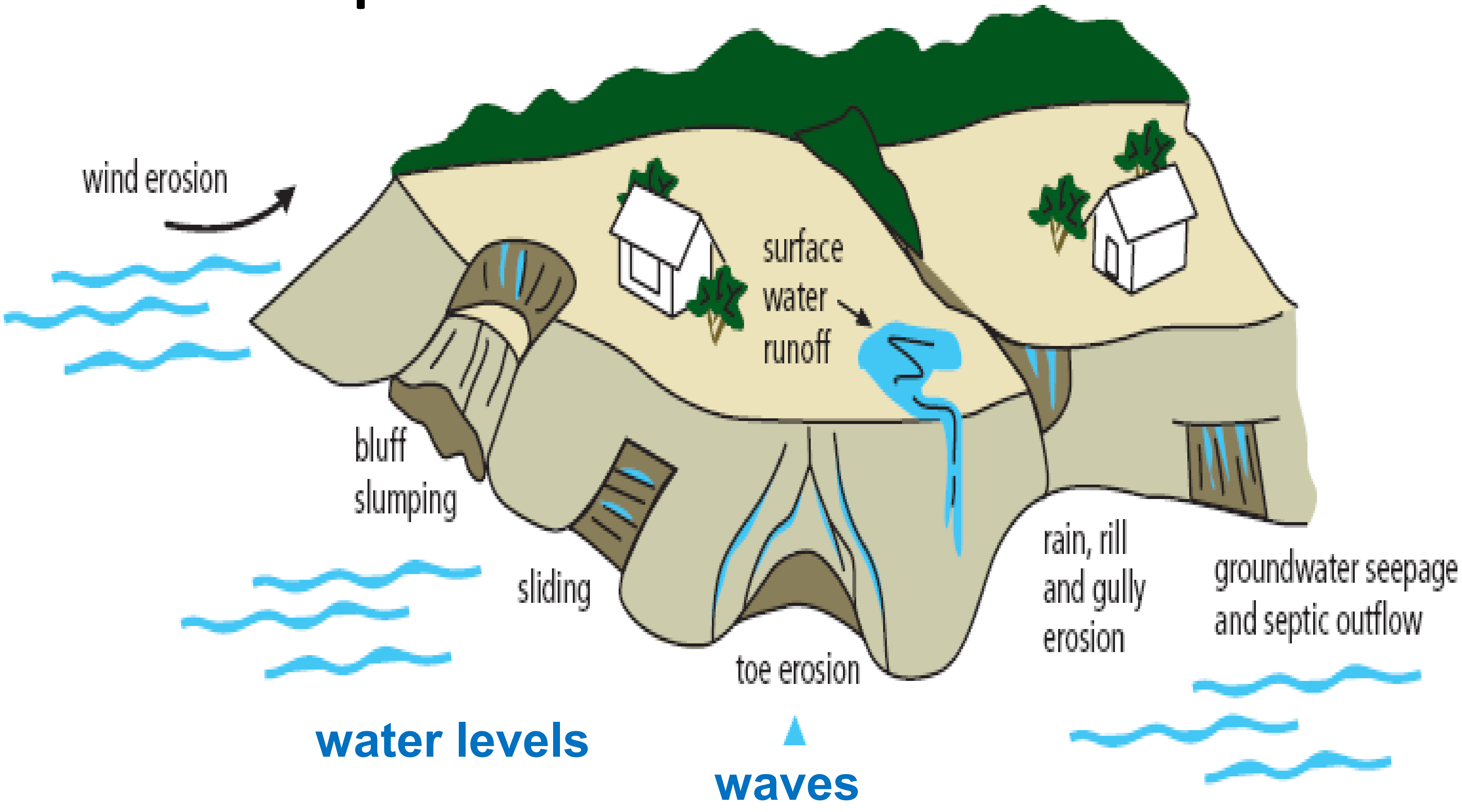
Bluff Height Impact on Recession Response

[Wisconsin Shoreline Inventory and Oblique Photo Viewer]

[Wisconsin Shoreline Inventory and Oblique Photo Viewer]

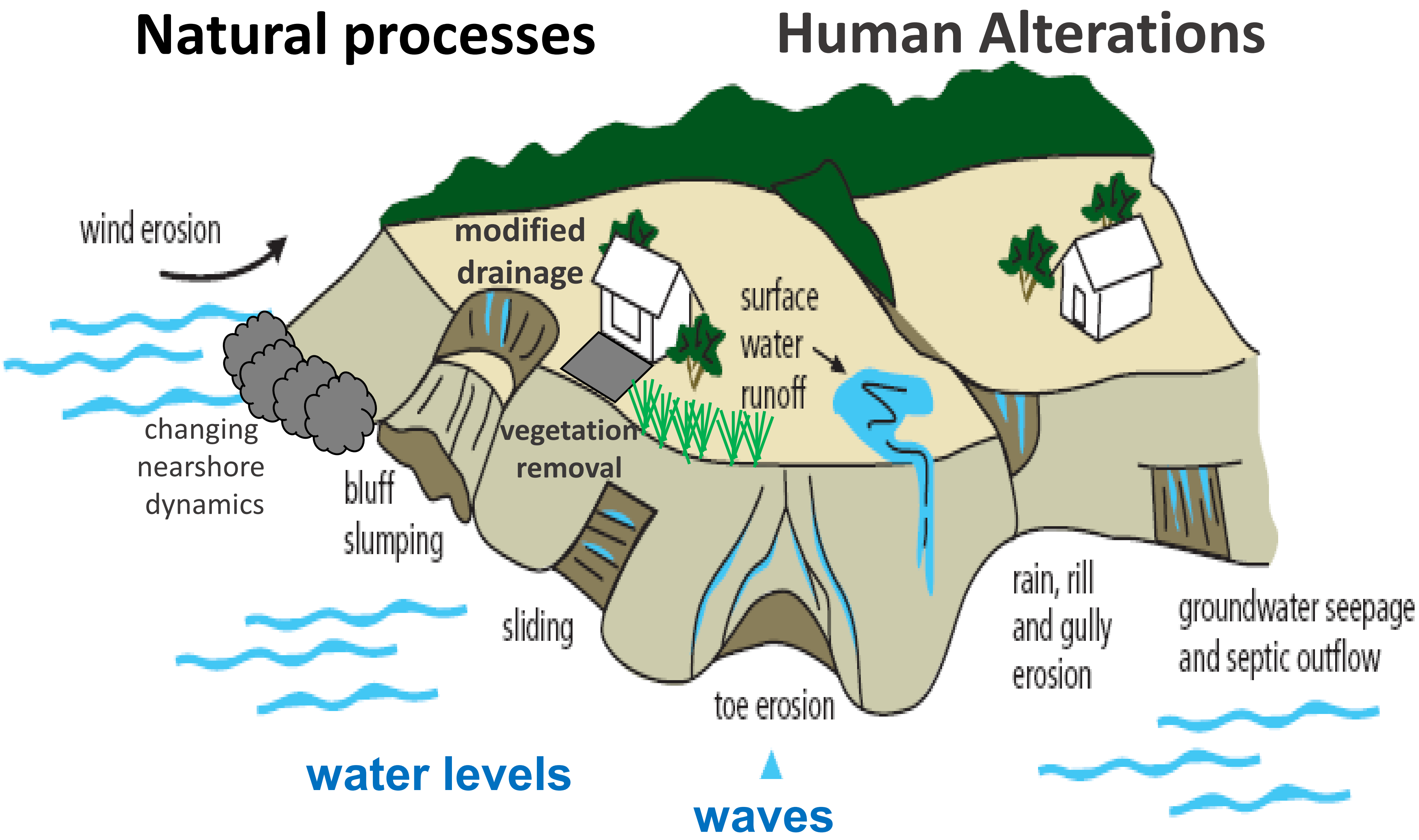
Factors of Shoreline and Bluff Recession

Natural processes



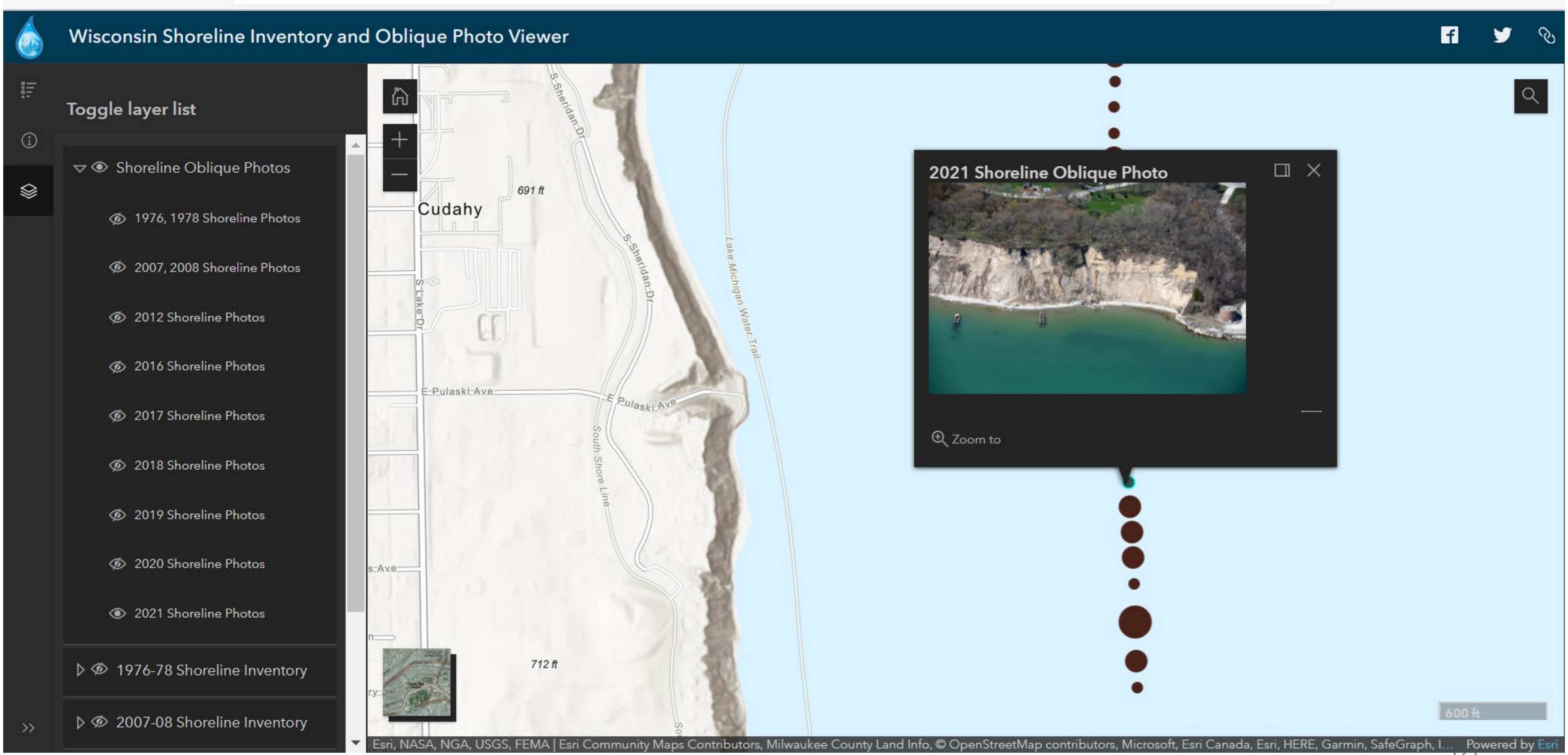
[USACE/Wisconsin Sea Grant: Living on the Coast]

Factors of Shoreline and Bluff Recession



[USACE/Wisconsin Sea Grant: Living on the Coast]

Track Changes at no.floods.org/wcmp



no.floods.org/wcmp

Nature-Based Shorelines use or mimic natural features to stabilize the coast

Great Lakes Nature-Based Shorelines

ASC Publications
University of Wisconsin Sea Grant Institute & Water Resources Institute

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- Coastal Engineering
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- Program Information

Nature-Based Shoreline Options for the Great Lakes Coasts

Free Download

Category: Coastal Engineering

DESCRIPTION

This guide describes different types of nature-based shoreline techniques and case studies suitable for the Great Lakes. Includes a glossary of coastal terminology. 52 pages.

https://publications.aqua.wisc.edu/product/nature-based-shoreline-options-for-the-great-lakes-coasts/

Green-to-Gray Spectrum of Shore Protection

U.S. Army Corps of Engineers

Systems Approach to Geomorphic Engineering

Nature-Based Shorelines
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Natural and Nature-Based Features (NNBF)
Engineering With Nature (USACE)

Coastal Structures
Hard Armoring
Gray Infrastructure

http://sagecoast.org/info/information.html

Benefits of Nature-Based Shorelines

Barry Kreiner, City of Marysville, Mich.

Michigan Department of Environment, Great Lakes and Energy

- Habitat creation or improvement
- Water quality improvements
- Can use hybrid approaches
- Aesthetic enhancements
- Public access may be easier
- Costs may be lower

Challenges in the Great Lakes

Adam Bechle

- High wave energy
- Ice impacts
- Water level fluctuations

Adam Bechle

- Short growing season
- Maintenance needs
- Emerging practices

NBS Techniques Summary

Vegetation

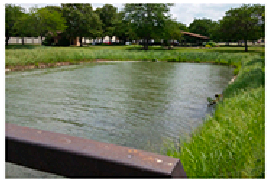
Native vegetation planted on the shore to reinforce sediments with its roots, dissipate wave energy and slow erosive runoff and wind.

Nourishment

The placement of clean sediment, often sand, on beaches, dunes or in nearshore waters to replace lost sand or build dunes.

Slope Stabilization

Regrading or reinforcing an eroding or failing bluff, bank or dune to a stable slope to allow vegetation to establish.



Edging

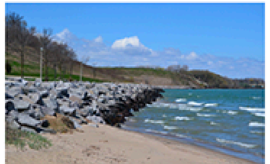
The placement of coir logs, wood or stones at the toe, or base, of the shoreline to prevent erosion and allow vegetation to establish.

Sill

A low-profile structure located in the water just off the shoreline to dissipate wave energy and create an area of protected natural marsh.

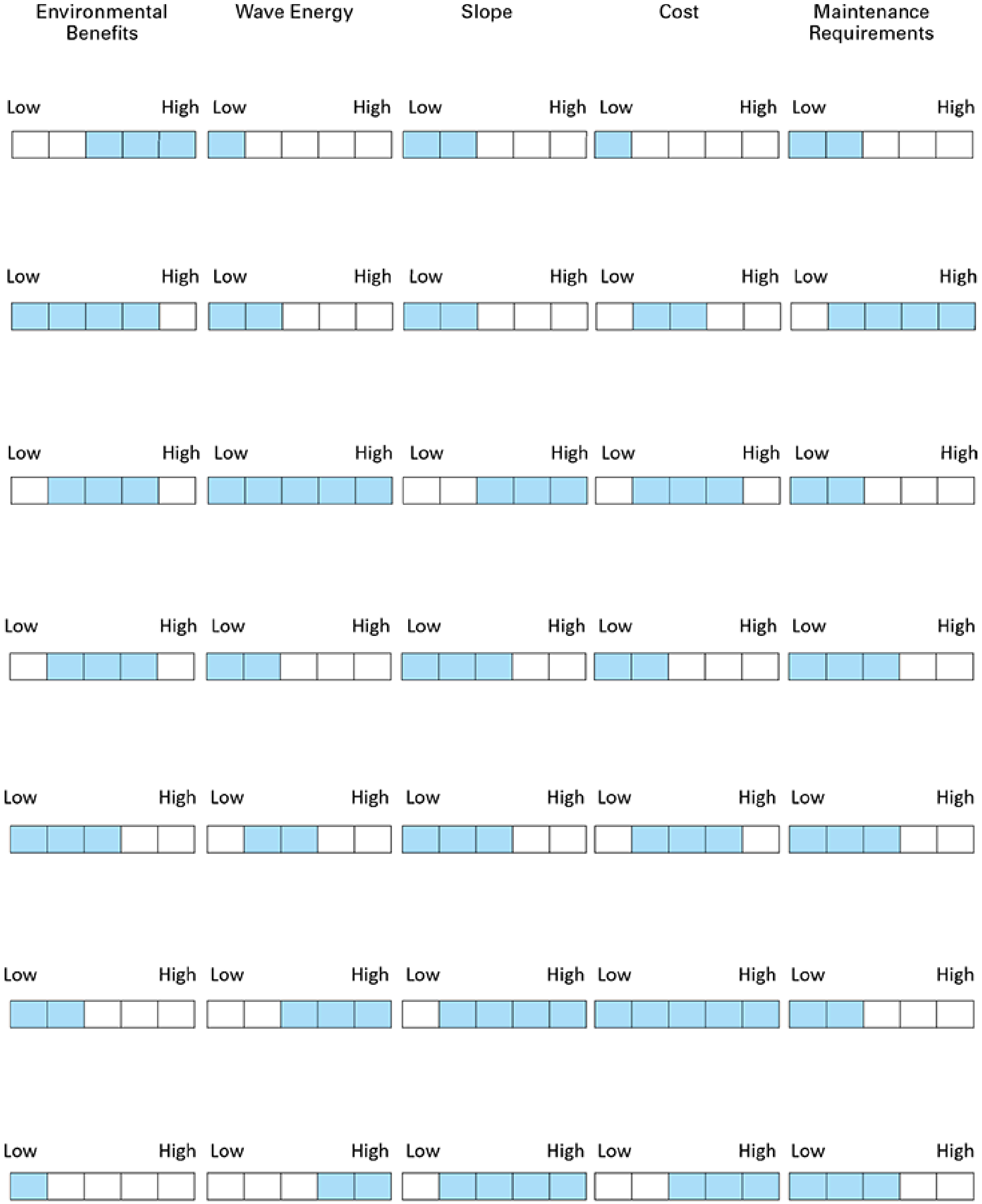
Ecologically Enhanced Hard Armoring

Vegetation, textured surfaces or other features added to conventional hard armoring structures to provide habitat and other benefits.



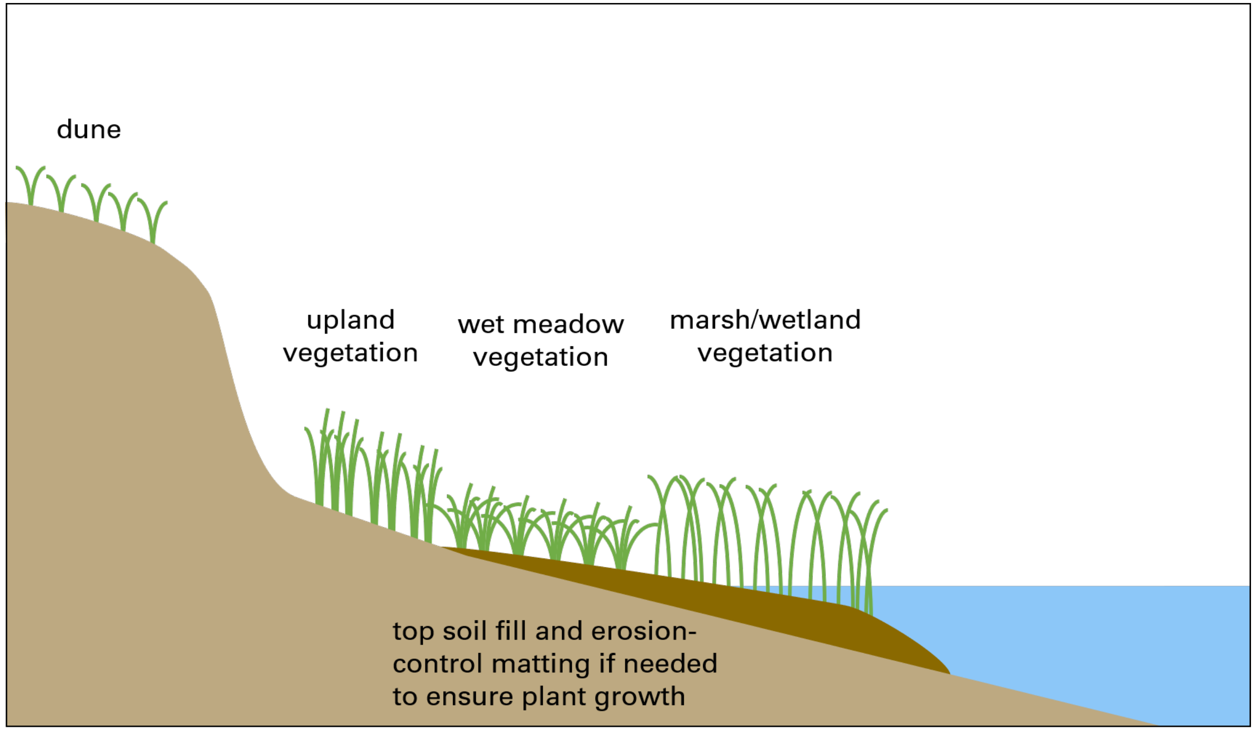
Hard Armoring

Rock, concrete or steel structures placed along the shoreline to slow erosion such as revetments, seawalls, groins and breakwaters.



Vegetation

Native vegetation planted on the shore to reinforce sediments with its roots, dissipate wave energy and slow erosive runoff and wind.



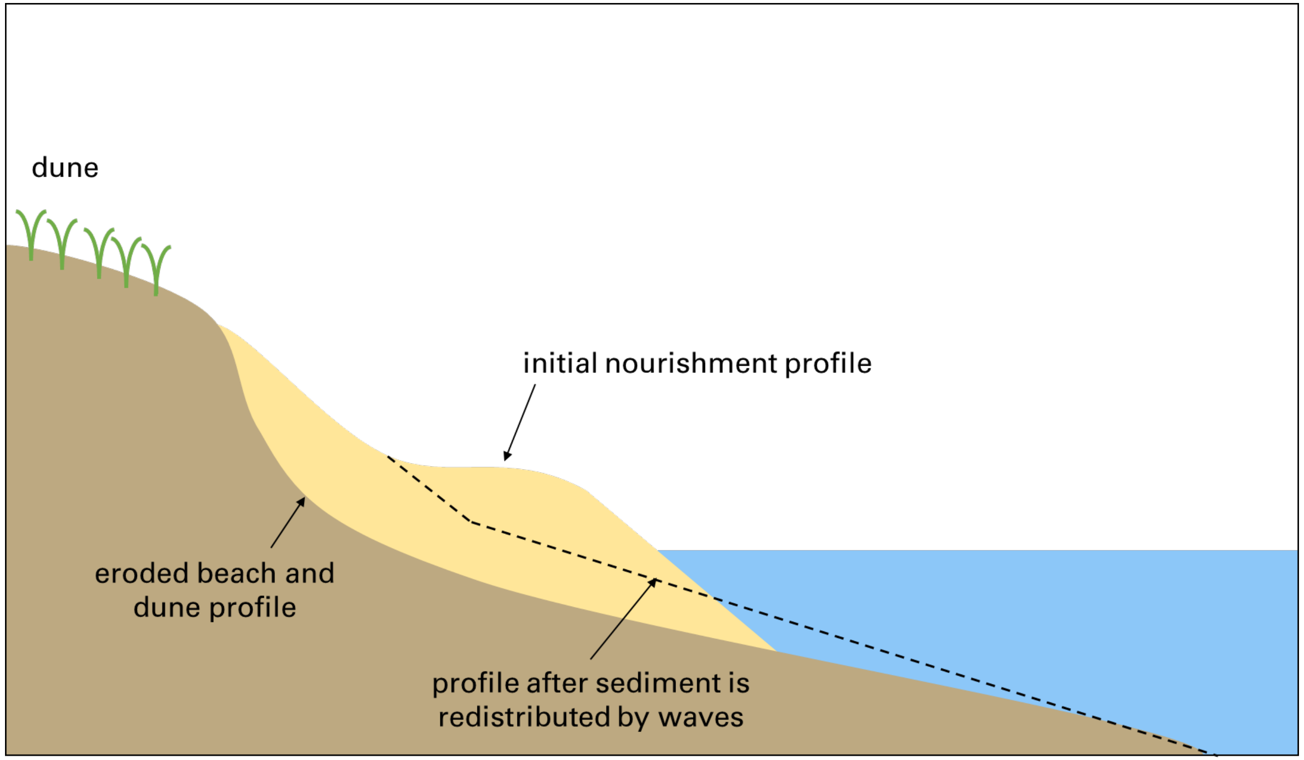
<u>Case Study</u>

Bradford Beach
Milwaukee, WI

Stevan Keith, Milwaukee County

Nourishment

The placement of clean sediment, often sand, on beaches, dunes or in nearshore waters to replace lost sand or build dunes.



<u>Case Study</u>

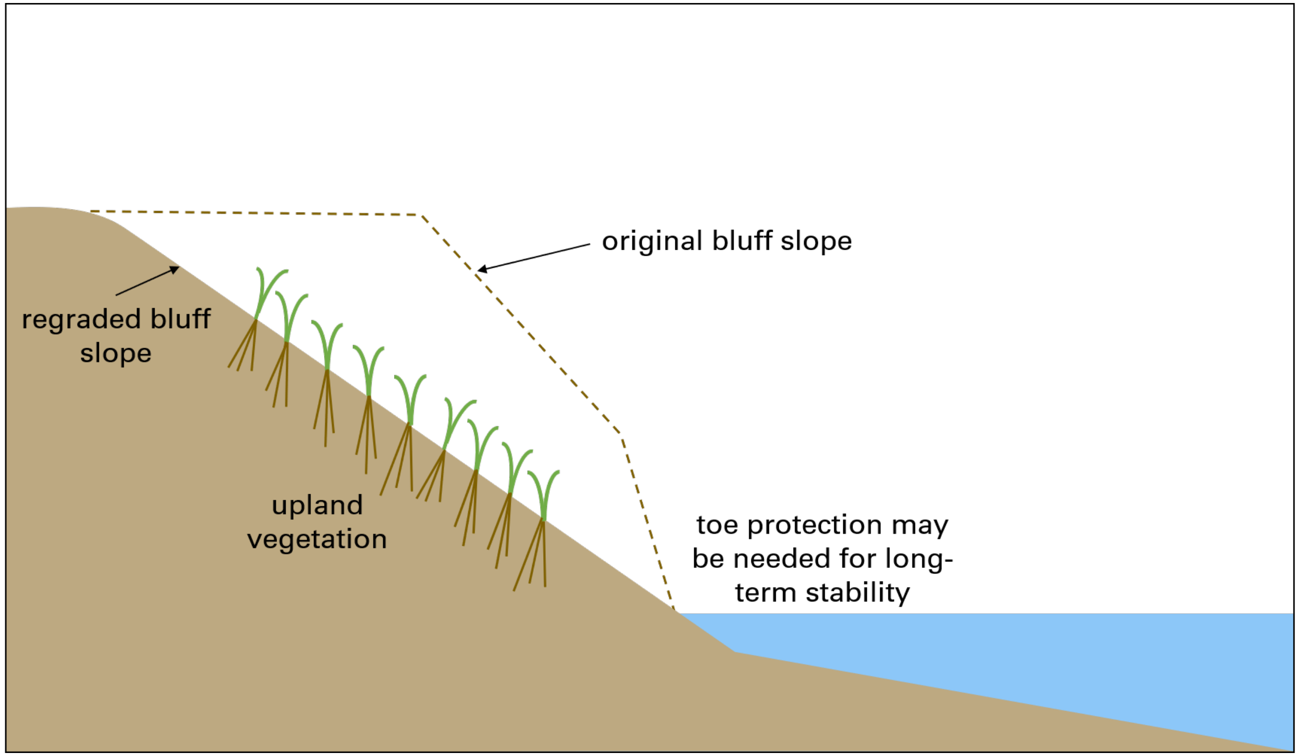
Blue Harbor Beach

Sheboygan, WI

Capt. Dennis Carr, Wisconsing Wing – Civil Air Patrol

Slope Stabilization

Regrading or reinforcing an eroding or failing bluff, bank or dune to a stable slope to allow vegetation to establish.



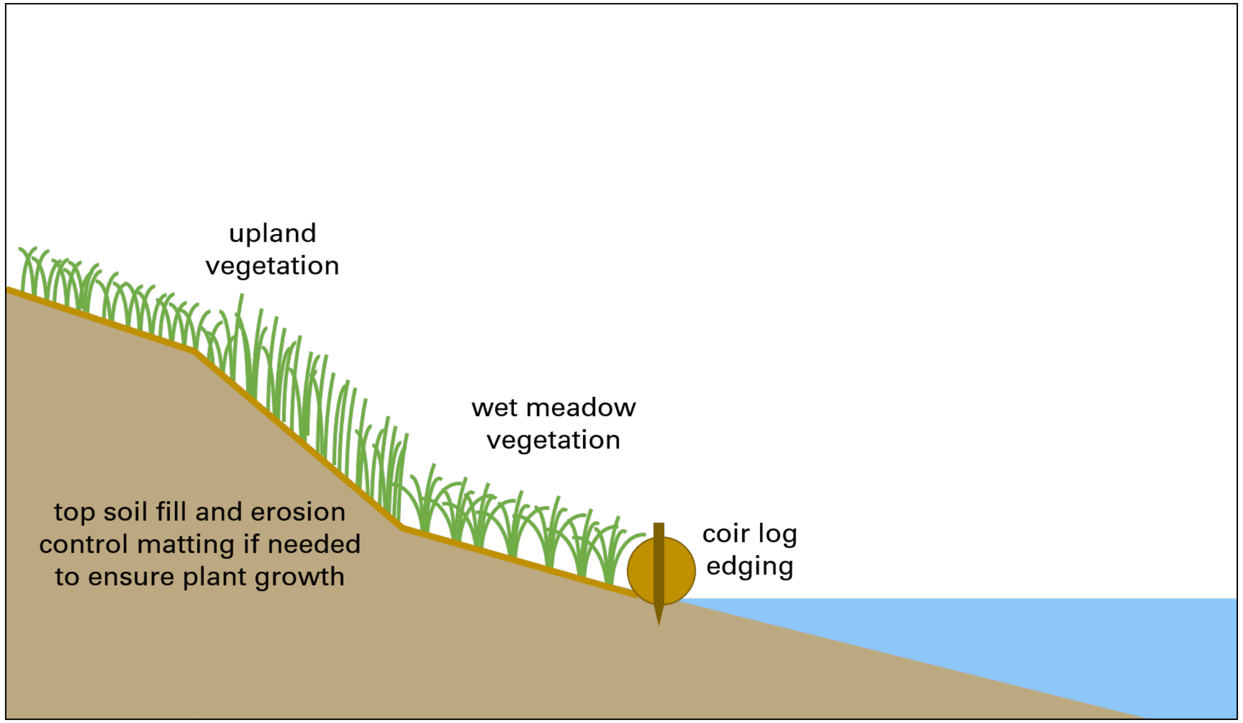
Case Study

Former University of Wisconsin-Milwaukee Chancellor Residence Shorewood, WI

Marek Landscaping

Edging

The placement of coir logs, wood or stones at the toe, or base, of the shoreline to prevent erosion and allow vegetation to establish.



<u>Case Study</u>

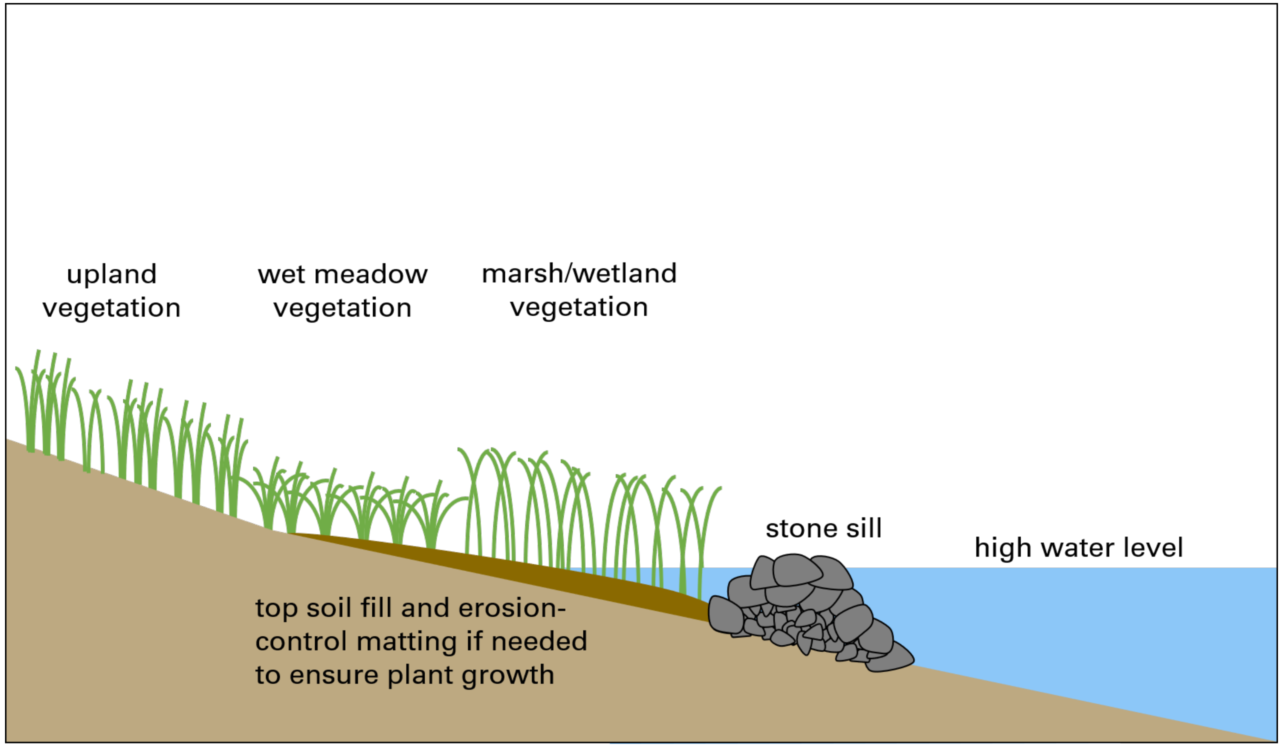
Shoreline Park

Sandusky, Ohio

Erie Soil and Water Conservation District

Sill

A low-profile structure located in the water just off the shoreline to dissipate wave energy and create an area of protected natural marsh.



Case Study

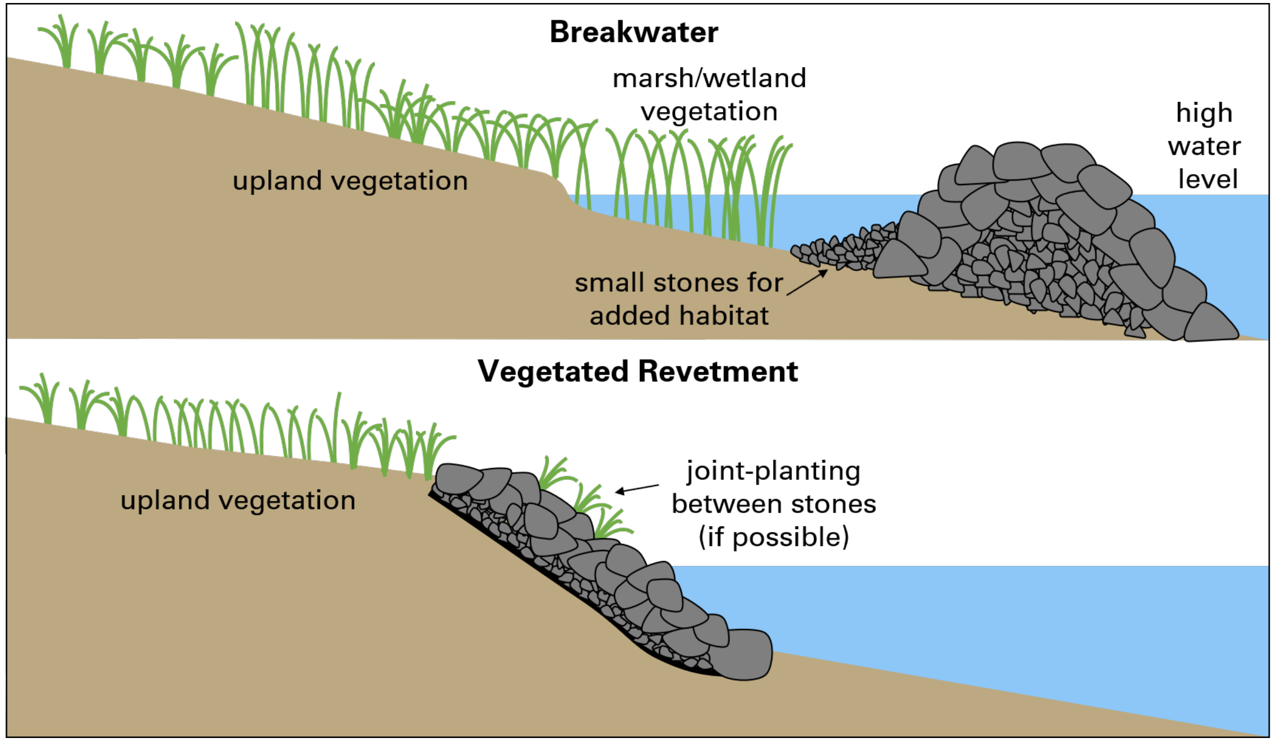
Marysville Living Shoreline

Marysville, Michigan

Michigan Department of Environment, Great Lakes, and Energy

Ecologically Enhanced Hard Armoring

Vegetation, textured surfaces or other features added to conventional hard armoring structures to provide habitat and other benefits.



<u>Case Study</u>

Samuel Myers Park

Racine, Wisconsin

Capt. Dennis Carr