Wisconsin Science & Technology Advisory

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Re: Policy options to mitigate shoreline erosion along Lake Michigan in Wisconsin
Date: March 3, 2021

EXECUTIVE SUMMARY

Shoreline erosion along Lake Michigan has been identified as a high priority hazard[1] by the Wisconsin Department of Administration's Wisconsin Coastal Management Program (WCMP), which seeks to coordinate coastal management efforts through research, monitoring and grant funding. Many past and ongoing local and regional efforts have attempted to address coastal erosion, but despite their successes, there is still an ongoing need to address this enduring issue. Long-term coastal resilience will require a coordinated approach that utilizes various strategies. This memo focuses on options that property owners and municipalities can use to address erosion. We propose several options that could be part of a coordinated strategy, including supporting the WCMP and further erosion control research, relocation or removal of structures, managing stormwater and groundwater, implementation of green infrastructure and natural solutions, beach nourishment, and utilization of hard infrastructure as a last resort.

INTRODUCTION

The Great Lakes present unique challenges for coastal property owners and municipalities, including navigating changing water levels and mitigating the impacts of various coastal processes. Although water levels fluctuate naturally over time, climatic changes such as periods of prolonged drought, increased precipitation, and more storm events have exacerbated fluctuations. For example, Lake Michigan reached record low water levels in January 2013. Over the following several years, water levels increased rapidly, rising 2.9 feet by July 2014 and another 1.8 feet by July 2017.[2] In 2020, 8 of 12 months rose above the highest water levels recorded in over 100 years.[3-4] The high lake levels allow high-energy waves to reach higher elevations on the shoreline, resulting in erosion that has impacted Lake Michigan's coastal communities.

A majority of Great Lakes shoreline erosion occurs due to wave action,[5] although storms, winter ice formation, wind, surface water erosion (e.g., stormwater or irrigation runoff) and groundwater seeps and springs also contribute. Erosion occurs when wave energy degrades a beach, bluff, dune, or structure in a way that is not naturally reparable,[5] for example, by changing the ratio of sand coming into and out of a beach or removing material from a bluff face causing collapse. Several factors influence erosion rates including the marine environment (e.g., wave action, water levels), weather and climate, geology, and human interactions (e.g., implementation of structures, dredging).[5] Erosion processes are episodic, occurring over years to decades. Failures can happen quickly, necessitating short-term action. However, the stability of shorelines should be viewed over the longer-term.[5]

Nearly one-half of Wisconsin's Great Lakes shoreline is vulnerable to coastal erosion. The 1979 National Shoreline Study[6] identified 290 miles of Wisconsin's 620 mile mainland shoreline as having significant erosion potential, which has only worsened with climate change-driven lake fluctuations. Of special concern are densely populated shoreline counties in areas subject to significant erosion such as

Milwaukee, Racine, Kenosha, Ozaukee, and Sheboygan. Two storm events in October 2019 resulted in 10-20 feet of beach recession each in 12-hour periods along the western Lake Michigan shoreline, flooding roads, parks and river channels.[7] Such losses impact the lives and investments of affected property owners and can lead to changes in land use due to hazardous conditions that negatively impact communities and their tax base.

Shoreline property is held under a mix of private and state/county/tribal/municipal government ownership, creating a complicated environment requiring both public and private implementation of solutions. Erosion mitigation efforts on individual properties can often have unintended consequences on neighboring shorelines. As individual property owners on unstable shorelines are forced to take immediate action to protect their property, the default solution is often the application of hard armoring infrastructure that can worsen erosion on adjacent properties. This potentially seeds further damage and conflict (e.g., the case of Concordia University, which carried out a $12 million shoreline stabilization project that resulted in litigation over alleged increased erosion and damage to neighboring properties).[8] The Wisconsin Department of Natural Resources offers emergency permitting for temporary erosion control and will work with property owners on best approaches towards permanent solutions,[9] but it is clear that coordinated management is needed to tackle this coastal hazard.

The WCMP administers federal funds towards coastal projects and works to coordinate management of Wisconsin shorelines, along with partner institutions like the University of Wisconsin System, Wisconsin Department of Natural Resources, and other regional and federal agencies. The National Oceanic and Atmospheric Administration (NOAA) has praised the WCMP and partners for the effectiveness of their grant projects, such as the Southeastern Wisconsin Coastal Resilience Project.[10] This multi-year initiative provides resources and assistance to southeastern Wisconsin communities in Ozaukee, Milwaukee, Racine, and Kenosha Counties to plan and prepare for hazards like shoreline recession and bluff failure, beach erosion, coastal flooding, and damage to waterfront infrastructure. In their 2021-2025 Needs Assessment Report, the WCMP identified shoreline erosion as a high priority hazard requiring further research, monitoring, community outreach, and inter-agency cooperation.[1]

POLICY OPTIONS

Due to the complexity of shoreline erosion hazards, potential policy solutions will likely necessitate multiple mitigation tactics. The Lake Michigan shoreline encompasses varying geologies and a mixture of private and public land, with no one-size-fits-all solution. Expert opinion suggests a “top-down” approach in which mitigation efforts aim to control human-driven erosion sources before lake-driven sources, maximizing efficiency and minimizing unintended consequences.[11-12] Below, we outline possible policy options (in “top-down” approach order) by the following categories:

- The support of on-going monitoring and organizing efforts of the Wisconsin Coastal Management Program, Department of Natural Resources, and others
- Relocation of impacted structures
- Management of stormwater and groundwater
- Implementation of “Green” or “Soft” protective infrastructure (revegetation, sills)
- Nourishment of existing beaches
- Implementation of “Grey” or “Hard” protective infrastructure (revetments, seawall, bulkhead, breakwater)

Continued Support of Erosion Monitoring and Mitigation Projects

Shoreline and coastal bluff erosion are dynamic processes requiring extensive research and monitoring to ensure planning and policy efforts adequately address hazards to people, property, and lake ecosystems. With funding from NOAA’s Section 309 of the Coastal Zone Enhancement Program, the WCMP works with the Coastal Hazards Working group to monitor shoreline and bluff erosion, provide technical assistance to communities and property owners, and fund projects addressing erosion issues. Previous

monitoring and organizing efforts have resulted in major accomplishments such as a comprehensive, longitudinal GIS database and map of the shoreline, or multi-year community initiatives like the Southeastern Wisconsin Coastal Resilience Project.

Option 1: support and expand the erosion-related work of the Wisconsin Coastal Management Program, Wisconsin Sea Grant, and UW-Madison Coastal Sustainability Lab

Support the mission of the WCMP at the legislative level. Emphasize multi-year projects like the Southeast Wisconsin Coastal Resilience Grant Program, which address coastal erosion at the municipality-scale through a combination of regulation, planning, and mitigation measures.[13] Consider supplementing the federal Section 309-funded $375,000 5-year erosion budget with state funds to expand erosion monitoring and mitigation projects. The WCMP lays out a budget for all erosion-related efforts of $375,000 over five years from 309 funds in their 2021-2025 Needs Assessment Report,[1] without additional funding sources. However, the NOAA Final Evaluation Findings report from the previous funding cycle recommends that the WCMP continue to look for other external funding sources—state or federal—to diversify funding and meet growing demand for coastal grant resources.[10]

Advantages:

- Findings will provide scientific grounding to improve future policy and hazard planning.
- Extant federal funding through Section 309 of the Coastal Zone Management Act, funding of certain partner institutions, and possibly the Federal Emergency Management Administration cover much of the current WCMP projects.

Disadvantages:

- Research and monitoring take time and do not address current properties immediately threatened by shoreline erosion.
- Matching grants would require financial and labor resources beyond current federal funding support.
- Findings of research and monitoring may benefit and/or involve property owners, however direct implementation at the property level may not be immediate.

Relocation of Threatened Buildings

Moving structures landward from shorelines either on the existing property or to a new property can be a long-term and cost-effective solution for properties impacted by coastal erosion. Relocation has already been used by property owners independently in Wisconsin and Michigan.[14-15] This strategy increases a structure's longevity and works particularly well in areas with complicated shoreline stability or erosion that is more challenging to manage.[16] Relocation also preserves the health of both the Great Lakes and neighboring properties.

Option 2: subsidize the cost of relocation of threatened buildings

While relocation has seen a recent uptick in interest from property owners, the upfront costs serve as a barrier resulting in property owners losing buildings to erosion.[14] In 2011, a house in Sheboygan county was moved back from rapidly dropping bluffs for a total of $90,000. This included costs for a new septic system, foundation, plumbing and wiring as well as permits and taking down power lines.[15] A one-time subsidization of the relocation costs would serve as a longer term solution to the threat of coastal erosion to buildings.

Advantages:

- This strategy is reliable and effective.[16]
- The upfront costs can be lower than shore protection or bluff stabilization, and there are no long-term maintenance costs.[17]
- This strategy preserves both sediment input to lakes and shoreline ecosystems.[17]

- Negative impacts to neighboring properties caused by some infrastructure solutions are avoided.[18]
- In some cases, this solution may increase the value of a structure.[16]

Disadvantages:

- Cost varies greatly depending on the details of the structure, and it is possible for the cost of relocation to exceed the value of the structure.[18] While relocation cost is feasible for some property owners, it may be cost-prohibitive for others.
- Not all properties have the space required for relocation and require the purchase of a different lot.[17]
- This solution does nothing to stop the eventual erosion of the shoreline.[17]
- There is a potential negative impact to neighboring property values if this structure is moved to a different lot.[17]
- Property owners may not want their buildings moved.

Stormwater and Groundwater Management

Although stormwater and groundwater are often not the sole sources of bluff and dune erosion, managing them can reduce erosion. Human development can increase stormwater runoff and groundwater loads near shorelines, quickening erosion rates. Increased impervious surfaces and decreased vegetation can increase stormwater runoff, accelerating natural processes. Private septic systems can also contribute to increased groundwater in coastal areas, accelerating these processes. While scientists are uncertain as to the timing and magnitude of lake levels fluctuations in the future,[3] historical trends and climate predictions suggest that rainfall amounts and intensity will continue to increase in Wisconsin, making management of stormwater and rising groundwater levels imperative. Increased stormwater and groundwater from development are a vital consideration for new development projects, but they are also important to consider in existing developed areas, particularly since mitigating their impacts can be less costly than other measures.

Option 3: stormwater planning and regulation

Require property owners to direct stormwater (e.g., via the use of ditches, roof gutters, rain barrels, drainage swales, etc.) away from the coast. For example, the WDNR's Model Post Construction Stormwater Management Zoning Ordinance, sets standards for stormwater management following development or re-development.[19] The state could also adopt a flow duration standard, used in other areas of the United States, to supplement the existing Chapter NR 151 of the Wisconsin Administrative Code peak discharge standard, which would require that post-development flow duration of discharge be kept at pre-development levels.[19]

Advantages:

- This strategy is low-cost relative to other options, because it relies on regulation for implementation and because coastal stormwater and groundwater management projects tend to be more cost-effective than commonly used artificial structural methods.
- Regulations would require municipal-level action, and thus are not feasible for property-owners to implement.
- Whether enacted at the neighborhood (coastal management area), municipality, or state-level, this strategy is relatively large-scale, affecting many properties simultaneously rather than a more piecemeal property-level strategy.
- Erosion from stormwater and groundwater is much easier to mitigate than other forms of erosion (e.g., wave erosion).
- Managing stormwater effectively provides additional benefits to municipalities, such as improving water quality, groundwater recharge, and reducing flooding.

Disadvantages:

- Most planning and zoning regulations address new property development or re-development rather than existing developments.
- Stormwater planning does not address wave erosion. While it may mitigate bluff face (or slope) erosion, toe erosion (at the base where the bluff and water meet) may continue.
- Regulation requires enforcement; municipalities and property owners may be resistant to additional regulation.
- Does not provide money for project implementation.

Option 4: property-level stormwater and groundwater management

To manage stormwater and groundwater while protecting bluffs from shoreline erosion, a number of property-level mitigation measures could be taken. To address stormwater issues, homeowners could be encouraged to install drainage systems to direct stormwater away from the coast or green infrastructure to capture excess water through rain barrels, bioswales, and green roofs. Infiltration systems, such as rain gardens, however, should be located as far from the bluff edge as possible because they may cause oversaturation of the soils and increase bluff loading (additional weight that can contribute to collapse). To address groundwater issues, homeowners could be required to construct septic systems on the landward side of bluffs (i.e., as far from bluffs as possible). Installation of bluff dewatering systems to drain excess groundwater from bluffs is another option in heavily saturated areas. To address all forms of erosion, property owners could be encouraged to increase vegetation on their property, bluff or dunes. Homeowners could also be discouraged from mowing near bluffs, allowing natural vegetation to protect the shoreline.[20]

Advantages:

- More cost efficient (lower up-front and long-term maintenance costs) for individual property owners than commonly used artificial structural methods (e.g., retaining walls).
- Most stormwater management strategies are feasible for property owners to implement.
- Erosion from stormwater and groundwater is much easier to control than other forms of erosion (e.g., wave erosion).
- Managing stormwater and groundwater provides additional benefits, such as improving water quality, groundwater recharge, and reducing flooding.
- Addresses one of the main impacts of development on coastal properties.

Disadvantages:

- Does not address wave erosion. While management can mitigate bluff face (slope) erosion, it will not address erosion at the toe of the bluff.
- Depending on implementation, it is a piecemeal approach to shoreline erosion and would be dependent on property-level compliance or initiative.
- Permitting may be necessary and potentially complicated by lack of regulatory familiarity with green infrastructure.

Natural or "Green" Solutions

So-called "green" solutions approach erosion with environmentally friendly or low-impact applications of vegetation, rocks, or submerged reef-like structures (e.g., sills, see option 6). Revegetation with native shoreline plants and trees strengthens the shoreline's structural integrity as the deep roots of these plants bind the earth together, while their foliage and branches reduce erosion caused by rainfall and winds.[21] Submerged sills can reduce wave power while providing habitat for fish and other aquatic wildlife. Unfortunately, these techniques are not always considered before implementing "hard structures" due to

homeowner and contractor unfamiliarity, and can be discouraged or even prohibited by outdated, poorly worded, or ambiguous codes and ordinances.[22]

Option 5: promote green or revegetative strategies on eroded private property
Remove permitting hurdles for green infrastructure, educate, and incentivize* property owners to determine what green or revegetative strategies work best for their property and how to best implement them. Resources from institutions such as the Sea Grant[23-24] and the US Department of Agriculture[25] describe different revegetation strategies and help property owners assess their shoreline. This type of strategy has been experimented with in Accomack County, Virginia, where the RAFT Initiative distributes green infrastructure educational materials to homeowners, works to train contractors, acts as a permitting resource, and provides monetary reimbursements for green shoreline improvements.[26] (**Wisconsin State Statute 59.692 sec. 1f establishes that vegetative buffers along shorelines cannot be made mandatory on previously developed land*).

Advantages:
- Prevention of erosion while complementing natural shoreline dynamics and movement; increased resilience and absorption of wave energy, storm surge and floodwaters; and an adaptive tool in preparation for rising lake levels.[27]
- More feasible and cost efficient to implement (lower up-front and long-term maintenance costs) for individual property owners compared to commonly used artificial infrastructure methods. Living shoreline costs range from $50 – $150 per linear foot.[a] By comparison, the same analysis found bulkheads range in cost from $80 – $1200 per linear foot.[28]
- Some revegetation methods can be carried out by the property owners without specialized tools or knowledge.
- Natural infrastructure such as dunes can be rebuilt using simple biomimicry techniques, such as matrices of wooden planks that catch sand blown in by the wind and protect local vegetation.[29]
- Benefits local wildlife with better habitat.

Disadvantages:
- Many vegetation strategies work only on shallow to moderate slopes and fail where there is strong wave action.
- Some aggressive revegetation strategies require a contractor to implement safely, and many contractors may be unfamiliar with best practices.
- Permitting may be necessary and potentially complicated by lack of regulatory familiarity with green infrastructure.[22]
- Some property owners may dislike the idea of extensive vegetation potentially interfering with lake views or water access.
- Difficult to implement in urban environments where land is limited.
- Not all techniques have the same level of performance. Less practiced techniques may require more monitoring.

Option 6: facilitate installation of submerged sill systems in near and offshore environments
Submerged sills are underwater structures that reduce waves coming onto shore by "tripping" them similar to natural features like reefs and sandbars. Submerged sills can be built, natural, or a combination (green-grey infrastructure). The ability to calm waves is influenced by water level. In Lake Michigan, where water levels can vary greatly, multiple layers of sills at different elevations can be used to account for these changes. A project at the Kenosha dunes is proposing a system of submerged sills to reduce erosion and improve coastal and marine habitats.[30] As a prototype, the estimated cost of the Kenosha

[a] Costs for policy options referenced in this memo are high-level estimates from a personal communication with a local engineer that works on coastal projects and represent approximate costs.

dunes project is approximately $7-11 million for 0.5 km (0.33 mi) of shoreline, although future projects may be less expensive as construction techniques are developed and standardized. Facilitating the implementation of infrastructure off of the shoreline can better facilitate the movement of sediment crucial to a resilient coast as well as stabilize the immediate area.

Advantages:

- Sills can protect the shoreline from incoming waves and stabilize the nearby environment from wave erosion; this infrastructure is scalable to multiple properties and larger distances of shoreline.
- Risk to neighboring properties is mitigated by minimizing the disturbance to local sediment transport.
- Submerged sills are capable of withstanding the strong Lake Michigan wave environment.
- Local ecosystem habitats can be encouraged and incorporated into the design of submerged sills.
- Sills will build the nearshore sediment environment and facilitate sediment transport by providing a space for sediment to accumulate between the structure and the shoreline as well as a channel for sediment to travel in the nearshore environment (supporting healthy beaches).

Disadvantages:

- Submerged sills are an emerging practice and less well understood.
- The initial economic investment to implement sills is relatively high. While this may be feasible for some property owners, the cost may be prohibitive unless approached in groups and with institutional support (e.g., a group of neighbors partnering with state resources).
- Design for sill implementation is site-specific.

Beach Nourishment

Beach nourishment refers to the practice of adding sediment, usually sand, onto or adjacent to an eroding beach. Sediment can be moved to the beach by dredging from an offshore location or by moving sediment by truck from inland.[31] Waves break on the flat beaches causing them to lose energy, reducing offshore wave height by up to 40 percent.[32] Sediment from a nourished beach will naturally move offshore by waves and currents, creating sandbars that cause the waves to break further from the shoreline.[33-34] Structures placed to prevent the erosion of bluff cliffs may cause beaches to erode, as bluff erosion is a source of sediment for low-lying beaches.[35] Additionally, human-made structures like jetties can trap sediment and further cause erosion on beaches.[31] Beach nourishment has been implemented in many coastal areas in the United States, including in Solana beach in San Diego, CA where the project aims to protect eroding beaches and cliff-like bluffs with a blanket of sand for the waves to crash on before reaching the bluffs.[36] This method adds sediment to the beaches which could be redistributed naturally to adjacent areas via longshore drift, a process by which waves and tides carry sediment along the shore.[37] This can positively impact beaches that were not directly nourished, as well as reduce cliff erosion.

Option 7: establish a local planning group in Wisconsin that can coordinate beach nourishment projects using clean dredged materials

Material is dredged from waterways to maintain channel depths for commercial and recreational boat passage.[38] In the Great Lakes alone, 3-5 million cubic yards of material is dredged per year, half of which is not contaminated and does not need to be placed in a confined disposal facility (CDF).[38] Approximately 973,000 cubic yards of dredged material from Lake Michigan goes into CDFs annually.[39] High-level estimates of dredging cost are $30-50 per cubic yard with an additional ~$50 per cubic yard for industrial material and ~$100 per cubic yard of contaminated material. Non-contaminated dredged material can be used for beach nourishment projects. Communities can establish what is known as a *local beneficial use planning group,* which can plan and coordinate information about dredging projects, the expected volume of dredged material, the timing of projects, and where clean dredged material can be put to use.[27] The EPA has guidance for the development of local planning groups.[40] Local planning groups generally

consist of several committees including executive, management and policy review committees. Galveston Bay in Texas has a local beneficial use planning group made up of federal, state, and local agencies that have assisted in obtaining USACE approval for using dredged materials for various projects for over 50 years.[27]

Advantages:

- CDFs are filling up rapidly and building new CDFs can take years. Repurposing the non-contaminated material for beach nourishment projects can reduce this burden.[38]
- Sand is in short supply and this is an inexpensive way to get sand for eroded beaches that would otherwise go to waste.[38]

Disadvantages:

- This method is limited to nourishing beaches with similar sediment as the dredged materials. If the dredged material is smaller than the natural material, erosion may happen faster, and larger materials may erode slower.[41] Dredging from near offshore locations from the eroded beach may yield similar material, but dredged material from other locations could be different.
- This option would require interagency collaboration and permitting at the municipal, state, and potentially federal levels and is not feasible for property owners alone to create.

Option 8: obtain federal government assistance from the US Army Corps of Engineers to initiate a beach nourishment project

The US Army Corps of Engineers was authorized by Congress to play a role in shoreline protection in the 1930s.[42] The Corps provides shoreline protection under the Flood and Coastal Storm Damage Reduction program and has been involved with many beach nourishment projects along the Atlantic coast and several in the Great Lakes region.[43-45] The beach must be accessible to the public and the cost is shared between the community and federal government.[42] An approximate estimate for sand to nourish a beach is ~$20-40 per ton (high-level estimate).The USACE has carried out a beach nourishment project on Lake Michigan in Two Rivers, WI, where sand build-up between two piers was becoming a navigational hazard.[44] The sand was dredged and pumped onto the beach.

Advantages:

- There is a precedent for the US Army Corps of Engineers to be involved in beach nourishment projects in the Great Lakes and they have experience and expertise in complex coastal processes.[42]
- This technique widens the area of the beach and restores the natural look to eroded beaches, especially when the sediment closely resembles the native sediment, making beach nourishment projects aesthetically pleasing.[37] This can encourage tourism and provide a recreation area for residents.
- Beach nourishment projects can complement and protect hard infrastructure behind the beach.[32]

Disadvantages:

- Not all requests for a beach nourishment project will be built. The request will be evaluated with environmental analysis, public hearings, and reviews by state and federal agencies.[42] The beach must be of major public interest and Congressional approval is required.
- Federal aid will not cover the whole cost of the project and the community will be responsible for some of the cost.[42]
- This method generally is an ongoing process and requires repeated applications of sand, although this burden can be lessened using dunes or plants in the sand.[41] This could make beach nourishment projects expensive over time.

- The environmental and ecological impacts of beach nourishment are not well understood, but there is evidence to suggest that nourishment can bury and degrade beach habitats and reduce the density of invertebrates that serve as prey for birds and fish.[46-47]

Hard coastal structures

Hard coastal structures, sometimes referred to as grey infrastructure, are built features intended to protect the shoreline from coastal hazards such as waves. Around Lake Michigan, traditional shoreline protection strategies typically consist of armoring the coast with heavy stones, concrete, or other hard structures.[48] This traditional practice resists incoming waves, protecting the armored coastline from erosion. However, increasing evidence indicates these traditional methodologies have cumulative, direct and indirect impacts to the coastal environment, including, but not limited to, increased erosion at the edges of built structures.[49-50] Municipalities could help individual property owners implement hard infrastructure, such as through grant programs, however other evidence-backed options are preferable and hard infrastructure should be a last resort.

Option 9: help property owners install onshore parallel structures (e.g., revetment, seawall, bulkhead)

There are many types of shore-parallel structures, which, as the name suggests, are located parallel to the shoreline. Beaches are a kind of natural shore parallel infrastructure with a gradually sloping surface that allows waves to break and lose energy. However, sand is highly mobile and large amounts are needed to adequately diffuse waves.[5] Hard structures can help block direct interaction between high-energy waves and the shore. These techniques reflect much of the incoming waves, which increases wave energy in front of the structures, causing more intense offshore wave environments.[51] Hard shore-parallel structures also interrupt sediment movement both parallel to the shoreline and perpendicular; sediment is impeded from moving from the land to the water and vice-versa. One consequence of this is sediment saturated and sediment starved areas are created along the coast. A small seawall has a high-level estimated cost of $3,000-5,000 per linear foot; revetment and breakwater cost can vary dramatically depending on the location.

Advantages:

- Shore-parallel structures can help control erosion at the site of interest by blocking waves from directly interacting with the shoreline.
- These structures may serve to stabilize bluffs and dunes.
- Depending on size and cost, it is feasible for property owners to implement these strategies.

Disadvantages:

- Rapid erosion can occur at the flanks of these structures.
- Shore-parallel structures may prevent movement of sand, resulting in beaches disappearing in front of the structure.[5]
- Greater reflection of waves near the structure may change the coastal hydrodynamics, resulting in stronger wave action and changes in flow direction.
- The structure may trap sediment from bluffs, resulting in changes to the sediment budget, particularly for downdrift areas which may experience beach starvation.[5, 52]

Option 10: consider installation of perpendicular structures (e.g., groins, docks)

Perpendicular structures trap sediment and provide a calm area on the downdrift side of the structure. A groin structure extends perpendicular to a beach, stopping just short of the normal wave breaking line, allowing some sediment to travel downdrift.[5] Groins often serve to block sand movement and retain beach in a certain area. Alternatively, jetties or docks extend past the wave breaking areas, allowing no downdrift movement. These structures are often used to direct river output, protect a harbor, or serve as a navigational aid.[5]

Advantages:

- Perpendicular structures block waves, calming waters behind the structure and build beaches by blocking sediments from upstream.
- Beaches can help buffer erosion farther inland and provide recreation for communities to enjoy.

Disadvantages:

- Where the current predominately flows from, sediment will accumulate (up current deposition) and where the current flows to sediment will erode (down current recession).
- Structures block lateral sediment transport downstream, which may alter the shoreline and lessen sediment supply in those areas.
- Shore perpendicular structures can affect the local hydrodynamic environment, changing waves and currents sometimes to hazardous extents (e.g., rip currents and whirlpools).
- Perpendicular structures may be less feasible for individual property owners to implement and require municipal or community buy-in.

SUMMARY

The unique shoreline erosion challenges along Lake Michigan's shoreline will require policy solutions that use multiple mitigation tactics. Varying geologies and land use likely necessitate municipalities and property owners to work together, with no one-size-fits-all solution. A "top-down" approach, where mitigation efforts aim to control human-driven erosion sources before lake-driven sources, may maximize efficiency and minimize unintended consequences.

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