FINAL

Milwaukee County Coastal Resources Inventory

Prepared by

Milwaukee County, Environmental Services Unit

In Partnership with Wisconsin Coastal Management Program
and
GZA Environmental, Inc.

Milwaukee County Project 5741-19805

Coastal Resilience Grant No. 017.CR08

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INTRODUCTION

Milwaukee County has extensive property holdings along the Lake Michigan shoreline, primarily as part of the Milwaukee County Park System. The Milwaukee County Parks Department operates and maintains a variety of recreational assets and facilities related to the outstanding natural resources in its shoreline parks. Extreme weather has damaged Milwaukee County's coastal natural resources and associated recreational facilities. It is anticipated that damaging events will continue to occur in the future, with the possibility that the severity will be greater due to the effects of climate change.

In 2019, Milwaukee County received a grant from the Wisconsin Coastal Management Program's (WCMP) Coastal Resilience Grant Program to undertake a comprehensive study to identify and address the vulnerability of its coastal resources, facilities, assets, and infrastructure (herein referred to as coastal resources) to extreme weather. This report, which was funded in part by the grant, inventories Milwaukee County's coastal resources and summarizes their current value, condition, and vulnerability. The comprehensive study of its coastal resources is an important first step in an effort to improve Milwaukee County's preparedness for extreme weather.

The Coastal Resilience Grant is funded by the National Oceanic and Atmospheric Administration (NOAA) and is being administered by WCMP. WCMP has partnered with the University of Wisconsin Sea Grant Institute, the University of Wisconsin-Madison Department of Civil and Environmental Engineering, and the Southeastern Wisconsin Regional Planning Commission (SEWRPC) on this NOAA-funded project to enhance community capacity in southeastern Wisconsin to build resilience to coastal hazards. The grant provided financial resources and technical assistance to Milwaukee County and other grant recipients in southeastern Wisconsin to plan and prepare for hazards like shoreline recession, bluff failure, beach erosion, coastal flooding, and damage to waterfront infrastructure. As part of the grant application process, applicants did a self-assessment of their coastal hazards. An outcome from this self-assessment was the realization that Milwaukee County lacked a comprehensive asset inventory.

This report summarizes Milwaukee County's coastal resources and their vulnerability to weather driven damage, and it evaluates these resources from a resiliency perspective. The information generated by the study will provide valuable information for the development of Milwaukee County's capital improvements budget, making cost-effective use of scarce local funds. Documenting the extent to which the County's coastal resources are vulnerable to extreme weather will also help in the pursuit of construction grants, and potentially help stimulate greater investments in funding coastal protections by the state and federal governments.

BACKGROUND

Milwaukee County's eastern border spans 32 miles of Lake Michigan "Lake" coastline, approximately 9 miles of which is owned by Milwaukee County. The majority of the County-owned land is part of the Milwaukee County Park System. The Lake is a popular attraction, and Milwaukee County Park lands are maintained to accommodate a variety of recreational pursuits for the benefit of residents from the municipalities throughout the County. Natural and recreational features located on the lakefront include formal sand beaches, cobble shorelines, vegetated bluffs/environmental corridors, nature trails, picnic areas, open space recreational trails, boat launches, marinas, and waterfront parks. In addition, there are various types of infrastructure that support those activities such as paved walks, park roads, stormwater management features, and shore protection devices. Other County assets along the lakeshore that are not within the Park System include the War Memorial and Art Museum. This study is limited to County-owned assets and does not address facilities such as Summerfest Grounds or other non-County facilities.

Extreme weather has damaged Milwaukee County's coastal resources and is expected to continue to occur in the future, with the possibility that the severity will be greater due to the effects of climate change. These concerns were raised in our Coastal Resilience Grant Self-Assessment (August 2018) where coastal hazard issues were rated as follows:

Shoreline Recession & Bluff Failure	High
Coastal Flooding	Moderate
Shore Protection Damage	Moderate
Beach Loss	Moderate
Beach Impairment	High
Port, Harbor, & Marina Damage	Moderate
Port, Harbor, & Marina Navigation Impairment	Moderate

Extreme weather events of January 2020, in combination with the high Lake levels, resulted in extensive damage to shoreline assets. Damaged assets included docks/piers, boat ramps, breakwaters, revetments, beaches, stormwater control devices, and extensive bluff erosion. The estimated cost to repair these damages is in excess of $8 million.

Lake levels have a significant impact on wave-induced shoreline erosion and beach sand movement. In 2019, Lake Michigan water levels ascended to record highs. Projections by US Army Corps of Engineers forecast that new record highs will be set in 2020[1].

PREVIOUS STUDIES and RELATED WORK

Numerous studies, dating back more than 50 years, have assessed the condition and remediation of certain coastline assets, focused largely on bluff erosion. Some of the studies took into consideration how weather and lake water levels are affecting assets. The more notable reports include:

Wisconsin Shore Erosion Study, Wisconsin Coastal Management Program, 1977.
This report provided the baseline data for many subsequent studies. It includes bluff slope stability analyses for 168 sites.

A Lake Michigan Shoreline Erosion Management Plan for Northern Milwaukee County Wisconsin – Community Assistance Planning Report No. 155. SEWRPC. December 1988.
This study reviewed bluff and beach characteristics and near shore bathymetry for the northern half of Milwaukee County. It includes discussion of the mechanism influencing bluff erosion and beach erosion, includes detailed analysis of bluff stability for 36 stations, using both probabilistic and deterministic methods. Alternative control measures were included such a bluff toe protection, revetments, bulkheads, groins, breakwaters and slope stabilization. An implementation plan was provided with estimates of cost. Figure 1 provides a graphic illustration of the recommended plan.

South Shore Breakwater Planning- Interim Conceptual Design Report. Baird. February, 2003.
This design report consisted of options created for shore protection improvements along South Shore area based on wave elevations. The center section of the South Shore breakwater was rehabilitated close to Alternative 4. The shoreline revetment work is essentially what is represented as enlargement area 1 – concept 1 of the design report. The revetment areas to the south of Area 1 were not constructed.

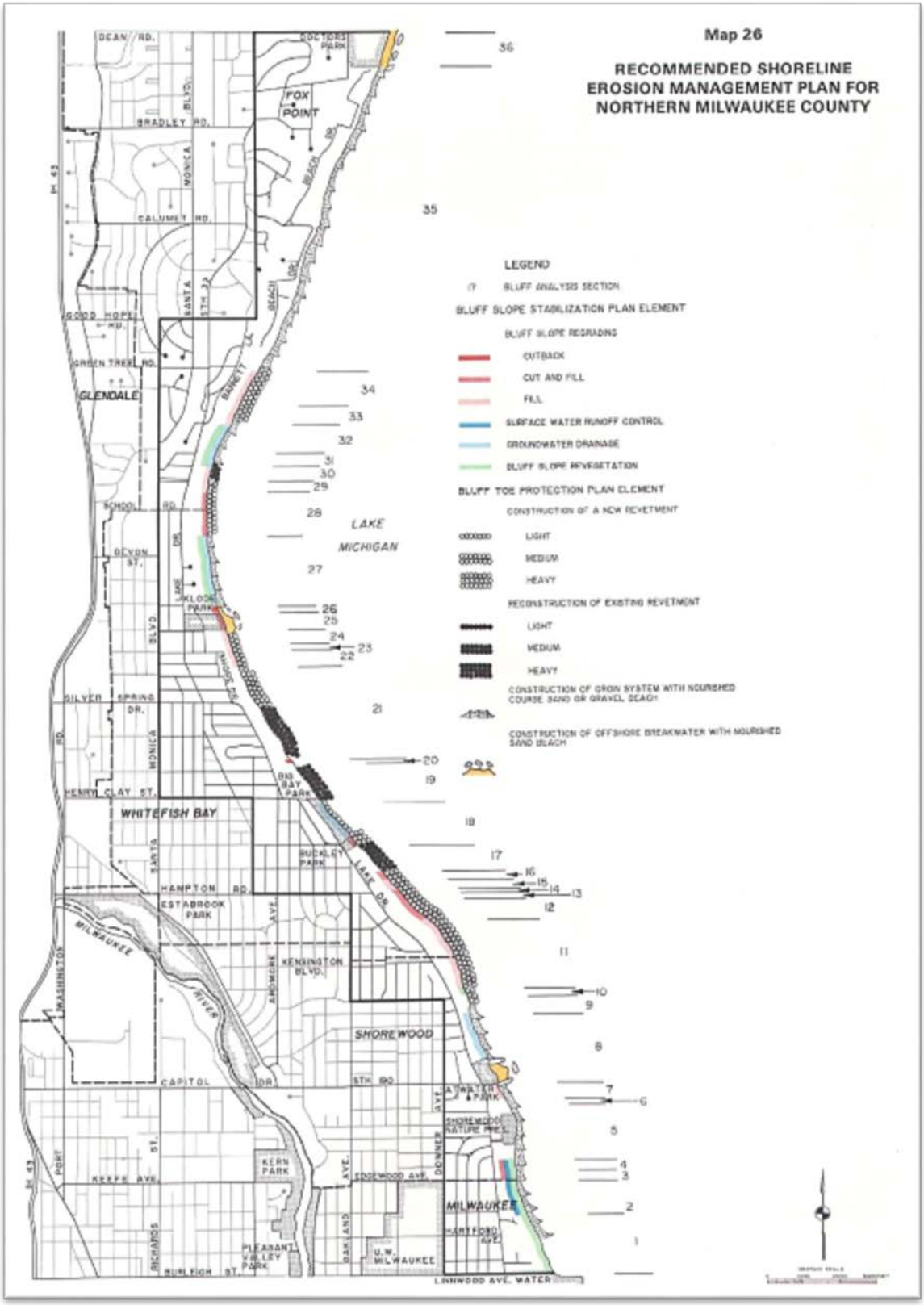

Figure 1. Recommended Shoreline Erosion Management Plan for Northern Milwaukee County.

A Lake Michigan Shoreline Erosion Management Plan for Milwaukee County Wisconsin – Community Assistance Planning Report No. 163. SEWRPC. October 1989.

This report provides a brief summary of the resources along the shoreline, historic land use activity, and erosion processes and goes into greater detail than previous studies on existing erosion problems for each municipality within the County. The report provides details and analysis on the following:

- Reviews conditions of major shore protection structures;
- Provides bluff stability analyses for 100 sections;
- Describes multiple alternatives for select areas such as offshore breakwater improvements;
- Considers potential damage to major structures under various Lake Michigan water levels and storm wave heights.

Lake Michigan Shoreline Recession and Bluff Stability in Southeastern Wisconsin: 1995. Technical Report No. 36. SEWRPC, December 1997.

This report updates the 1977 study, reviewing shoreline erosion conditions over the area extending from the Illinois border to the northern edge of Ozaukee County. The study area was divided into 17 sub-areas, or 'reaches'. According to the report, between 1963 and 1995 the average annual bluff recession rates ranged up to 10 feet per year with episodic rates as high as 100 feet (ft) per year during major storm events. The report describes the processes affecting erosion, such as climate (air temperature, precipitation, and wind), Lake Michigan water levels, bluff erosion, and beach erosion. The report also updated the slope stability analyses. Portions of the Milwaukee County bluffs were found to have safety factors less than 1, indicating unstable conditions. Map 95, taken from this study, is provided as Figure 2, provides a graphic illustration of slope stability for the five reaches of Milwaukee County.

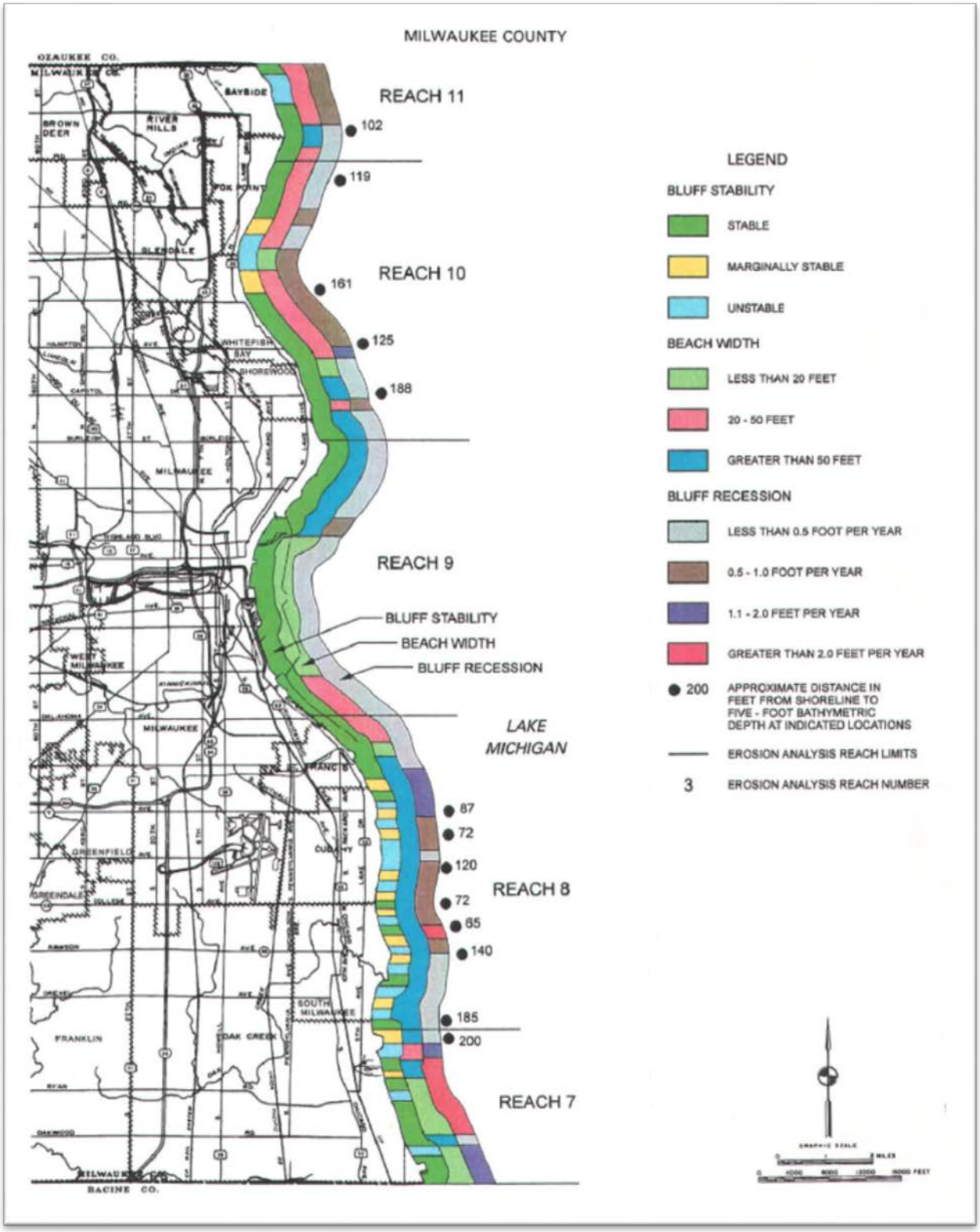

Figure 2. Summary of Lake Michigan Shoreline Erosion and Bluff Stability Analysis in South Eastern Wisconsin: 1995.

Shoreline Erosion Study for Warnimont Park in the City of Cudahy, STS Consultants, 2001.
This study, performed for Milwaukee County's Department of Public Works, included soil borings and geotechnical analysis of the former Warnimont Park gun club area, east of the golf clubhouse. The report reviewed past studies by SEWRPC, regional geology and groundwater, and the site-specific conditions. Slope stability analyses from the report concluded unstable conditions. Remedial alternatives for preventing bluff erosion were developed. Cost estimates to implement the alternative ranges from $3.4 million to $14 million.

Milwaukee County Wisconsin Pre-Disaster Mitigation Plan, Milwaukee County Emergency Management, June 2011.
This plan, which was prepared in conjunction with Wisconsin Emergency Management (WEM) and Maxim Technologies, identifies safety hazards resulting from extreme weather events, such as flooding, high winds and tornadoes, heat waves and extreme cold, earthquakes. Coastal erosion was also considered. The plan evaluated the vulnerability of properties, infrastructure and businesses from potential events and makes specific recommendations to reduce future impacts. Note that these assessments were done county-wide and not limited to public property. The assessment of coastal recession impacts concluded a potential cost of $1.2 billion. One of the specific recommendations related to the coastline was to stabilize the bluff slope east of the South Milwaukee Water Treatment plant.

Lake Park Bluff Stability and Plant Community Assessment, 2003. Memorandum Report No 156, SEWRPC, September 2004.
This report focuses on the 30-acre area in the eastern potions of Lake Park, providing a history of the park development, vegetation history, a review of bluff erosion processes, and an assessment of bluff stability. The report describes how bluff vegetation community benefits bluff stability.

Impacts of Coastal Structures on Coastal Bluffs on Wisconsin Coast, Nicholas Jordan, 2017.
In this masters' thesis report, Jordan researched how bluffs and beaches along the Lake Michigan coast are impacted by nearby coastal structures. The study focused on the bluffs and off-shore structures located east of Sheridan Park.

In addition to the above, there is ongoing work by Milwaukee County and others. Milwaukee County Parks Department is currently developing a Bluff Management Policy. This work, which is also funded in part though the Coastal Resiliency Grant Program, will create a formal policy for how County-owned lands near bluff areas should be managed to limit bluff erosion.

ASSET LISTING

To develop a list of coastline assets requires a definition of what area is included as "coastline". Since there is no standard definition or guide to use that clearly delineates what is coastline, this study reviewed guidelines created by SEWRPC and others, in addition to the criteria that are being developed for the Bluff Management Policy.

One approach for determining shoreline areas involves projecting out a 60-year continued recession rate. The most intense shoreline recession rate in Southeastern Wisconsin in the past 59 years was 225 feet (in Kenosha County), or 3.82 ft/yr, which extrapolates to 229 ft for 60 years.

A more conservative approach is to determine the stable bluff slope from toe to peak (determined to be a 22° slope for Lake Michigan bluffs in Wisconsin)[2] and then add a factor of safety of 100 feet from that point. The largest horizontal distance of bluff in Milwaukee County if it were to stabilize at a 22° slope would be 327 feet. This bluff is located in Whitefish Bay just southeast of Klode Park with a toe elevation at 584 ft, a crest elevation at 716 ft, and a current width of 285 horizontal feet. A stable slope crest at this location is 327 ft from the toe. When adding a 100 ft factor of safety, the maximum setback is 427 feet.

The area of interest for the inventory includes a 427 feet bluff set back distance from the 1913 historical coastline according to the 2013 Wisconsin Act 140. Wisconsin Coastal Management Program created a 2015 Milwaukee County shoreline. The coastal area for this project will consist of the 427ft landward from the 2015 shoreline and the 427ft the from the lakebed area, most of which is the same.

Additionally, all land and assets part of the original Lake Michigan lakebed are included in our assessment, even if it is further than 427 ft from the 2015 shoreline. Any asset in this "coastal area", even partially, was inventoried.

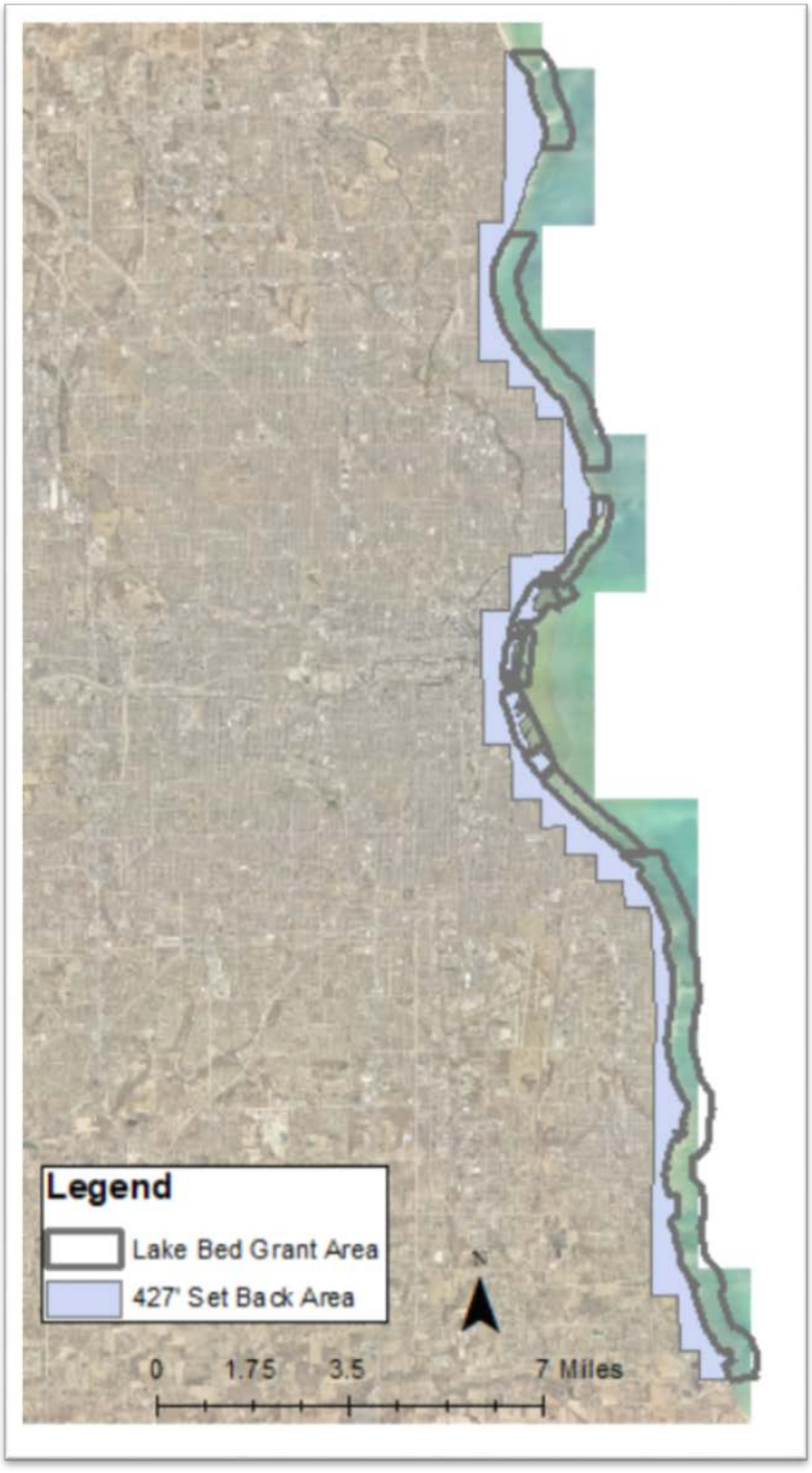

Figure 3. Coastal Inventory Area.

A complete list of the assets is provided in Appendix 1. Assets are arranged into 16 categories. The table includes the County Asset ID number.

CONDITION ASSESSMENT

Because of the large number of assets, the condition assessments are provided in summary fashion according to the major category. Each asset category has a different set of metrics to measure condition. In general, conditions were rated as unstable, fair or stable. The sites-specific asset assessments are provided in Appendix 1. Some assets' conditions were deemed unnecessary and updated constantly. These were given a rating of NA in Appendix 1. In Table 1 and 13 they are gray filled.

Utilities such as animal habitats, gas lines, electrical lines, sanitary sewer, sanitary structures, storm sewer, and storm structures were not included due to lack of mapped data and time constraints for this project. Aquatic features such as pools, wading pools, and fountains were not included as none existed in the coastal area.

The condition metrics are described below. Results are summarized in Table 1. If an asset type had no subassets, the cell was filled with gray.

Asset Type	SubAsset Type	Condition				
		Metric	Poor	Fair	Good	Weight
Athletic Courts	Volleyball Courts					
	Tennis Courts	PASER Scoring[3]	< 40	41-69	> 70	100%
	Track					
Athletic Fields	Soccer					
	Multi-Use					
	Archery					
Aquatic Features	Lagoon	BMP Maintenance Assessment [1]	1	2	3	100%
Beach	Cobble/Gravel	Soil type, nourishment needs, and amount of beach unusable [2]	D, F	C	A, B	100%
	Formal Sand	Soil type, nourishment needs, and amount of beach unusable [2]	D, F	C	A, B	100%
Bluffs		Slope steeper than 22 degrees[2]	> 6%	3 - 6%	< 3%	40%
		Vegetative Cover[4]	Mostly Bare Slope	Partly Vegetated	Thick Cover	25%
		Bluff Failure[4]	Deep seated slumps	Shallow slides, Creep	Mostly Vegetated	20%
		Bluff Modification[4]	Fill	Regraded	No modification	15%
Bridge	Pedestrian	National Bridge Inventory or NA	0-4	5-6	7-9	100%
	Vehicle	National Bridge Inventory or NA	0-4	5-6	7-9	100%
Buildings		VFA [3]	Poor	Fair	Good	100%
Golf Course	Tee	Vegetation Cover	Sparse	Thin Cover	Thick Cover	50%
	Fairway	Landscape	Rocky/Divots	Some Divots	Smooth	50%
	Bunker					
Marina Components	Grinder					
	Fuel Pump					
	Pier/Dock					
	Boat Launches	Cracking, spalling, area underwater [2]	D, F	C	A, B	100%
	Harbor Siltation					
Non-Paved Trails						
Open Vegetation Space						
Paved Areas	Oak Leaf Trail	PASER Scoring[3]	< 40	41-69	> 70	100%
	Palk Walk Ways	PASER Scoring[3]	< 40	41-69	> 70	100%
	Parking Lots	PASER Scoring[3]	< 40	41-69	> 70	100%
	Park Roads	PASER Scoring[3]	< 40	41-69	> 70	100%
Playgrounds						
Shore Protection Device	Bulkhead	Degradation [2]	D, F	C	A, B	100%
	Breakwater	Degradation of concrete, steel sheet piling [2]	D, F	C	A, B	100%
	Groins	Undermining, loss of material, and cracking [2]	D, F	C	A, B	100%
	Revetment / Rip Rap	Erosion, dislodging, and undermining [2]	D, F	C	A, B	100%
Storage Tanks						
Stormwater Management Feature	Rain Garden	BMP Assessment [1]	1	2	3	100%
	Infiltration Basin/Swale	BMP Assessment [1]	1	2	3	100%
	Permeable Pavers	BMP Assessment [1]	1	2	3	100%
	Subsurface Infiltration	BMP Assessment [1]	1	2	3	100%
	Sedimentation Chamber	BMP Assessment [1]	1	2	3	100%
	Regenerative Conveyance	BMP Assessment [1]	1	2	3	100%
	Dry Detention Basin	BMP Assessment [1]	1	2	3	100%

Table 1. Condition Metrics.

[1] See Appendix 1. BMPs (Best Management Practices)
[2] See Appendix 2.
[3] Building condition and cost software

Athletic Courts

Definition: Tennis courts with an asphalt finish, running tracks, or standalone sand volleyball courts. No basketball courts were within the defined coastal area.

Number of Assets: 1 volleyball court, 1 tennis court, 1 track

Condition Assessment: The most current condition rating for these assets was derived from Milwaukee County's Athletic Court Assessment using University of Wisconsin-Madison's "Pavement Asphalt Surface Evaluation and Rating" (PASER)[3]. Conditions are updated about every 3 years. Assets are rated as either "poor condition" (score of 0 – 40), "fair" condition (41-69), or "stable" condition (70 – 100). For the stand-alone volleyball and cinder trail acting as a running track the condition assessment metrics were deemed unnecessary, and so the condition state is acceptable. Maintenance on these areas are continuous.

Athletic Fields

Definition: Grassy fields for athletic events: soccer, multi-use, or archery

Number of Assets: 7

Condition Assessment: Metrics deemed unnecessary, however condition state is acceptable. Maintenance on these areas are continuous.

Aquatic Features

Definition: Inland features incorporating water: pools, wading pools, lagoons, and fountains. Only lagoons were within the coastal area.

Number of Assets: 2

Condition Assessment: See Stormwater Management Devices

Beaches

Definition: area landward of sand or sandy gravel forming at the shoreline

Number of Assets: 9

Condition Assessment: GZA created a condition assessment for beaches based on observable sand erosion, soil type, nourishment needs, and amount of beach unusable due to high lake levels, scoring them from A to F.

An example of beach change occurs at Bradford Beach; the northern portion has eroded. NOAA lake elevation predictions suggest the continuation of beach shrinkage, moving southward throughout the summer and fall of 2019.

Below is a Bradford Beach with 3D surface models in AutoCAD Civil 3D representing various years throughout the 2000s. In each year, modeled areas that had dry land the sand volumes had declined when lake levels were higher. This indicates that the lake is eroding sand volumes in areas that are yet to be fully submerged, not just taking up surface area due to elevation. The waves are eliminating and encroaching on land that is higher than the water elevation. An 18-inch drop off from top to bottom of this edge is cut away by wave action.

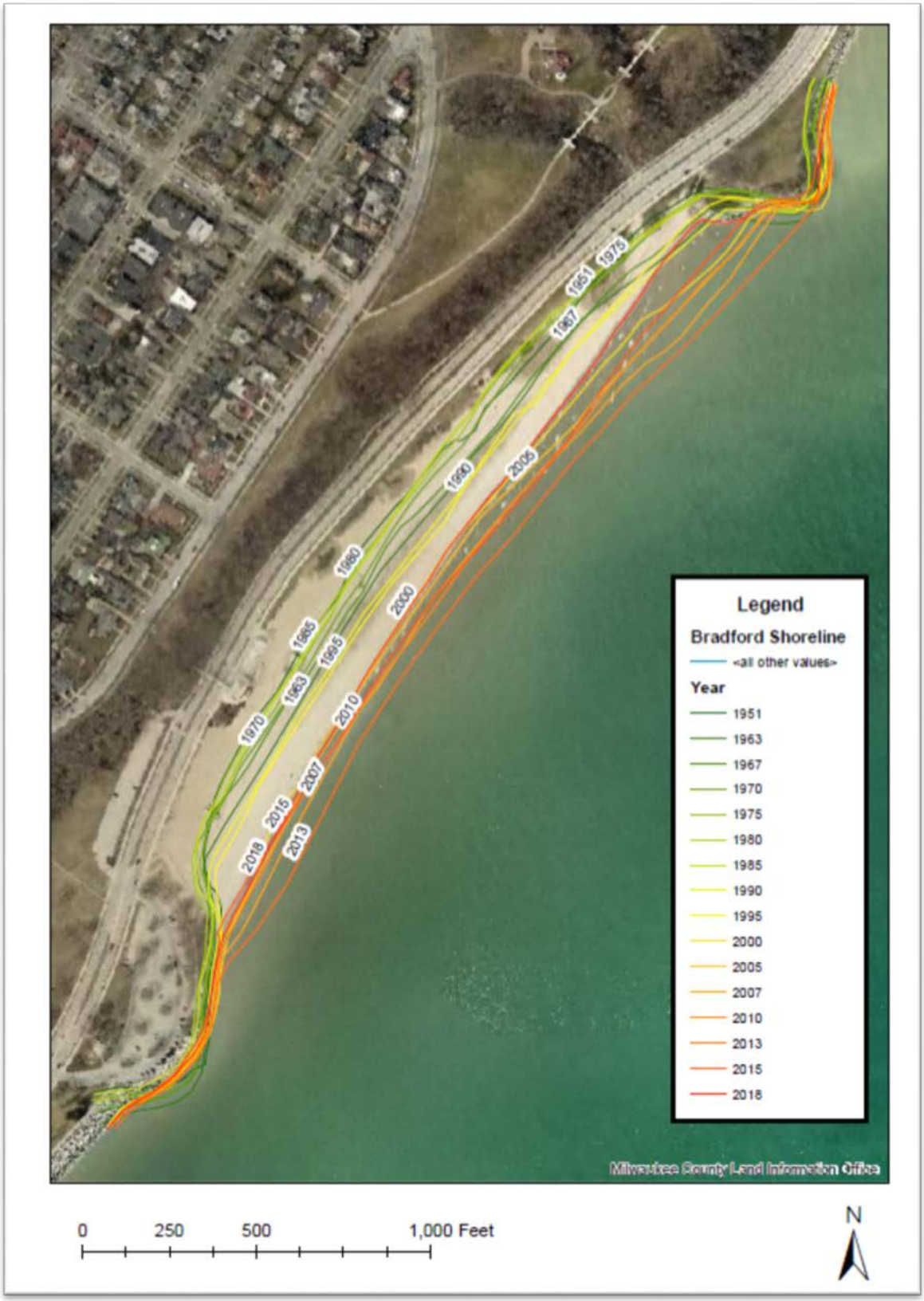

Figure 4. Bradford Beach Shoreline 1951 to 2018.

Bluffs

Definition: The bluff sections are the area between the bluff crest and toe. The bluff crest is the location where the relatively flatter upland meets the steeper bluff "face". The bluff toe is the location where the bluff face meets the beach or Lake. Note it was not economically feasible to advance boreholes for each bluff section in order to assess sediment classification or groundwater levels. The seepage lines are not constantly visible and could not be used as a source of groundwater levels. At the time of this report Milwaukee County is working with SEWPRC to expand the coastline that is classified as a bluff, namely in Lake Park and Juneau Park areas. Milwaukee County intends to include these bluffs in the additional studies.

Number of Assets: 45,506 lineal feet

Condition Assessment: Metrics consisted of Slope Compared to 22°[2], Vegetative Cover[4], bluff Modification[4], and Bluff Failure[4]. Each asset category has a different set of metrics to measure vulnerability. If the condition score is equal to or less than 1.67 the assets overall condition is "poor", between 1.67 and 2.33 is considered "fair," and greater than 2.33 is considered "good."

County Park	Bluff Length (ft)	Condition Score (mean)
Bay View Park	4,238	2.15
Bender Park	2,757	2.11
Big Bay Park	1,554	2.26
Doctors Park	2,184	2.44
Grant Park	8,410	2.15
Lake Park	7,374	2.55
Sheridan Park	9,681	2.13
South Shore Park	1,634	2.45
Warnimont Park	7,674	1.87
Grand Total	45,506	

Table 2. Milwaukee County Bluffs' Condition

Figure 5. Milwaukee County Bluffs

Addition information on the County's bluff assessment can be found in Appendix 3.

Bridges

Definition: a structure conveying a path or road across a ravine, river, or other obstacle

Number of Assets: 18 pedestrian, 2 vehicle.

Condition Assessment: Major bridges were inspected by Wisconsin Department of Transportation. The condition assessment was based on the National Bridge Inventory (NBI) includes a structural evaluation of deck, superstructure, substructure, and culvert on a 0-9 scale. If the average rating was 7, 8, or 9 it was considered "good", 5 or 6 was "fair" and 0, 1, 2, 3 or 4 is "poor." Non-major bridges were scored as NA.

Asset Type	Condition	Location
Bridge	NA	Grant Park (4)
Bridge	NA	Lake Park (7)
Bridge	NA	McKinley Park (1)
Bridge	Fair	Bradford Beach Pedestrian Bridge over Lincoln Memorial Drive
Bridge	Good	Brady Street Pedestrian Bridge over Lincoln Memorial Drive
Bridge	Good	Lake Park South Lions Pedestrian Bridge over Drainage Ravine
Bridge	Good	Lake Park North Lions Pedestrian Bridge over Drainage Ravine
Bridge	Fair	East Lafayette Place & North Summit Ave. Bridge over the Oak Leaf Trail
Bridge	Poor	Lake Park Drive Pedestrian Bridge over Ravine Road
Bridge	Fair	East Mason Street Bridge over Lincoln Memorial Drive

Table 3. Milwaukee County Bridges' Condition

Buildings

Definition: a structure with a roof and walls

Number of Assets: 50

Condition Assessment: County buildings conditions are stored in VFA (10.8.3.0 Build 3), a software from Accruent. VFA allows for the calculation of an industry standard facility condition index (FCI). The County has gathered the components or systems in its buildings (structural, architectural, and mechanical). These were assigned an estimated lifespan based on manufacturing. Condition assessments are used to more accurately update the building

lifespan. The sum of anticipated repairs and replacements needed in the current year and the next year is divided by the total replacement cost of the building to create the FCI. A 0.0 - 0.049 is “good”, 0.05 - 0.09 is “fair,” and a 0.1 and greater is considered “poor.” Some buildings have not yet been rated.

Assessment	Asset Number
Good	25
Fair	9
Poor	4
Not Assessed	12
Non County	7
Grand Total	**57**

Table 4. Milwaukee County Buildings’ Condition.

Golf Courses

Definition: areas designated to play golf

Number of Assets: 2 Tee, 1 Fairway, 1 bunker

Condition Assessment: Metrics included vegetation cover and overall landscape. All four golf course areas were rated good.

Marina Components

Definition: Includes docks/piers, boat launches, grinders, and fuel pumps.

Number of Assets: 20 floating piers, 2 permanent piers, 11 boat launches, 2 grinders, and 3 fuel pumps.

Condition Assessment: Metrics deemed unnecessary for piers, grinders, and grinders however condition state is acceptable. Maintenance on these areas are continuous. Conditions metrics for boat launches included cracking, spalling, and area underwater. Condition for siltation was not assessed. It is recommended for the next study to include soil testing for PCBs, heavy metals, and other hazardous chemicals.

Wave action causes material at the bottom of the harbors and surrounding areas to shift. In previous years sediment has built up to the point where boats could not enter Bender Harbor,

resulting in dredging. The condition assessment for harbor siltation would ideally include a bathymetric survey.

Non-Paved Trails

Definition: Unpaved areas or trails meant for walking or biking.

Number of Assets: 20 Trails, about 40 miles total.

Condition Assessment: Metrics deemed unnecessary, however condition state is acceptable. Maintenance on these areas are continuous.

Open Vegetated Space

Definition: Area of non-exceptional vegetation not used for athletics or golf

Number of Assets: 1,195 Acres

Condition Assessment: Metrics deemed unnecessary; however, condition state is acceptable. Maintenance on these areas are continuous.

Paved Areas

Definition: Paved areas including parking lots, roads, service yards, walkways

Condition Assessment: PASER Assessment[4]. A score of 0 - 40 is poor, 41 - 69 is fair, and 70 – 100 is stable.

Playgrounds

Definition: Play equipment areas

Condition Assessment: Metrics deemed unnecessary; however, condition state is acceptable. Maintenance on these areas are continuous.

Shore Protection Devices

Definition: structure protecting the shore area from waves either on land or in water: bulkhead, breakwater, groins, and revetments (riprap).

Condition Assessment: GZA created a condition assessment for shoreline protection devices, scoring them from A to F. Bulkheads were assessed on degradation. Breakwaters were assessed

on degradation of concrete, steel sheet piling. Groins were assessed on undermining erosion, loss of material, and cracking. Revetment was assessed on erosion, dislodging, and undermining of stone and concrete blocks.

Structures not assessed by GZA used condition scores from WCMP[4].

Storage Tanks

Definition: Either an aboveground or belowground containers to hold liquids for long term

Condition Assessment: U.S. Code, Title 42, Chapter 82, Subchapter IX., stipulates guidelines regarding Underground Storage Tank (UST) installation, monitoring, and maintenance procedures including leak detection systems. In addition, the EPA authorizes a state program, codified in ATCP 93. This ensures storage tanks are in "good" condition or repaired to the good condition.

Stormwater Management Features

Definition: Devices to capture stormwater (excluding storm sewers): rain gardens, infiltration basins/swales, permeable pavers, subsurface infiltration, sediment chamber, regenerative conveyance, and dry detention basins.

Milwaukee County annual implements Green Stormwater Infrastructure Performance assessment.

The Condition of the Stormwater BMPs (Best Management Practices) were determined by reviewing the two most recent BMP inspection reports. Site that were functioning properly were given a rating of 3. Sites that had some early signs of failure and needed minor maintenance items were given a rating of 2. Sites that were currently failing and needed more intensive maintenance were given a rating of 1. See Appendix 1 for more details.

VULNERABILITY ASSESSMENT

Asset categories have different sets of metrics to measure vulnerability. For example: athletic fields were based on distance from the shore, if asset is located in a flood plain, if it has shoreline protection, and if it was located on a bluff. Assets with multiple metrics have a score weight associated with it, for example "distance from the shoreline" may be worth 25%. The further the distance from the shoreline the less vulnerable the asset is to erosion. "Low" vulnerability is worth 3 points since low vulnerability is desirable, each "medium" is worth 2 points, and each "high" vulnerability is worth 1 point. Then the 3, 2, or 1 point is multiplied by each metric's weighing factor and added together. If the total score is less than 2.00, the assets overall vulnerability is "high" vulnerability, from 2.00 to 2.49 is considered "medium," and 2.5 or greater is considered "low." This evenly distributes assets into low, medium, and high scores.

Asset Type	Vulnerability						
	Metric	High	Medium	Low	Weight	Score	Weighted
Athletic Courts	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%	1	0.25
	In 100 Year flood plain (Elevation at 587.5ft)	Yes	-	No	25%	1	0.25
	Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%	3	0.75
	Located on a bluff?	Yes	-	No	25%	3	0.75
						Total	2

Table 5. Example Scoring.

In this example an athletic field that is < 100 ft from the shore, in the 100-year flood plain, has rated good shoreline protection, and isn't located on a bluff would be:

1 * 0.25 + 1 * 0.25 + 3 * 0.25 + 3 * 0.25 = 2, Medium Vulnerability

Milwaukee County did not seek to predict effects of storm surges, erosion, Lake Michigan levels, temperature or precipitation. However, we utilized past data that incorporates factors from weather changes such as: bluff changes in slope and volume, shoreline recession, and distance from the shoreline.

A summary of vulnerability assessment is provided as Table 6. The weight % relate to subassets. For Marina Components wave and lake level overtopping is the only metric for boat launches; sediment dredging is the only metric for harbor siltation. Distance from shore, flood plain, shoreline protection, and located on a bluff are the four metrics for grinders, fuel pumps, and docks/piers.

Asset Type	SubAsset Type	Vulnerability				
		Metric	High	Medium	Low	Weight
Athletic Courts	Volleyball Courts, Tennis Courts, Track	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year flood plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%
Athletic Fields	Soccer, Multi-Use, Archery	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year flood plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%
Aquatic Features	Lagoon	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year flood plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%
Beach	Cobble/Gravel, Formal Sand	Soil type and shoreline protection [4]	D, F	C	A, B	100%
Bluffs		Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Recession Sum (5 years)[4]	> 1 ft	0.5-1 ft	< 0.5ft	30%
		Change in Soil Volume[3]	>7,500 ft^3	0 – 7,500 ft^3	<0 ft^3	20%
Bridge	Pedestrian, Vehicle	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year Flood Plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%
Buildings		Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year Flood Plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%
Golf Course	Tee, Fairway, Bunker	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year Flood Plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%
Marina Components	Grinder, Fuel Pump, Pier/Dock	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year Flood Plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%
	Boat Launches	Wave and lake level overtopping [4]	D, F	C	A, B	100%
	Harbor Siltation	Sediment Dredging	>2,000CY	1,000-2,000CY	<1,000CY	100%
Non-Paved Trails		Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year Flood Plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%
Open Vegetation Space		Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year Flood Plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%
Paved Areas	Oak Leaf Trail, Palk Walk Ways, Parking Lots, Park Roads	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year Flood Plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%
Playgrounds		Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year Flood Plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%

Shore Protection Device	Bulkhead	Wave and lake level overtopping [4]	D, F	C	A, B	100%
	Breakwater	Wave and lake level overtopping [4]	D, F	C	A, B	100%
	Groins	Wave and lake level overtopping [4]	D, F	C	A, B	100%
	Revetment (including rip rap)	Wave and lake level overtopping [4]	D, F	C	A, B	100%
Storage Tanks		Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		Above or Underground	Underground	-	Aboveground	25%
		Material	Steel	-	Fiberglass / impressed current	25%
		Wall	Single	-	Double	25%
Stormwater Management Feature	Rain Garden , Infiltration Basin/Swale, Permeable Pavers, Subsurface Infiltration, Sedimentation Chamber, Regenerative Conveyance, Dry Detention Basin	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
		In 100 Year Flood Plain (Elevation at 587.5ft) [3]	Yes	-	No	25%
		Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		Located on a bluff?	Yes	-	No	25%

Table 6. Vulnerability Metrics.

3. Wave run up calculation based on no off-shore protection structures. See Appendix 2.

4. See Appendix 2.

Athletic Courts, Athletic Fields, Aquatic Features, Bridges, Buildings, Golf Courses, Marina Components (Grinders, Fuel Pumps, Piers), Non Paved Trail, Open Vegetation Space, Paved Areas, Playgrounds, Stormwater Management Features all have the same vulnerability criteria:

Metric	High	Medium	Low	Weight
Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
In 100 Year flood plain (Elevation at 587.5ft)	Yes	-	No	25%
Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
Located on a bluff?	Yes	-	No	25%

Table 7. Vulnerability Metrics for General Assets.

Beaches:

Vulnerability Assessment: GZA created a vulnerability assessment based on amount and quality of shoreline protection and soil type (sand, gravel), scoring them from A to F. Sand is more desirable than gravel, but sand can more easily erode. Future studies should measure dry beach loss over time.

Bluffs:

Vulnerability Assessment:

Metric	High	Medium	Low	Weight
Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
Recession Sum (5 years)[4]	> 1 ft	0.5-1 ft	< 0.5ft	30%
Change in Soil Volume	>7,500 ft^3	0 – 7,500 ft^3	<0 ft^3	20%

Table 8. Vulnerability Metrics for Bluffs.

Certain bluffs have a shoreline protection asset that protects them from waves crashing into the bluff. The protection rating or lack of a protection is used to determine 25% of the bluff's vulnerability for the report.

The bluffs' toe line (where the bluff meets Lake Michigan or levels out horizontally) and the crest line's (where the bluff peaks and meets land westward that is relatively flat) changes in a five-year period. These were tracked, measured, and added together to create the total amount the bluff on average is receding into Lake Michigan. See Figure 6 and 7.

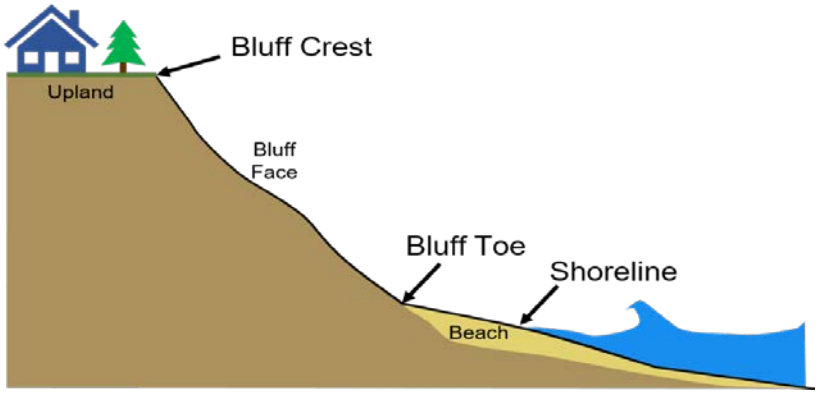

Figure. 6. Bluff Diagram[4]

The volume change compares the same bluff area between 2010 and 2015, using GIS's cut fill tool. This is summarized in Table 9. Bluff sites not only had sections with volume lost but also gained. These were summed in total volume lost and gain. The total volume change is the difference between gained and lost. The additional volume could only come from areas upland of the bluff crest, with the 2010 crest and underlying soil eroding down the face of the bluff by 2015 as shown in Figure 7. This suggests the upland area is similarly vulnerable to erosion as in the bluff face.

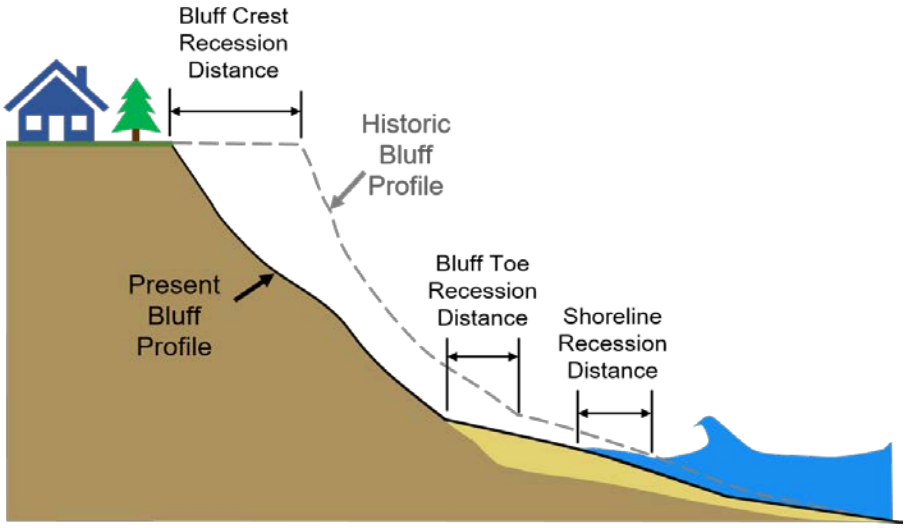

Figure 7. Bluff Changes[4]

For more calculation details see Appendix 3.

Marina Components (Boat Launches and Harbor Siltation):

Vulnerability Assessment: GZA created a vulnerability assessment for boat launches based on shoreline protection, scoring them from A to F.

Harbor siltation vulnerability is how likely the sediment will build up in the harbor, interfering with boat and other recreation use. Sediment buildup is estimated by the quantity of sediment each harbor has dredged over the last 20 years.

Metric	High	Medium	Low	Weight
Sediment Dredged	>2,000CY	1,000-2,000CY	<1,000CY	100%

Table 9. Vulnerability Metrics for Harbor Siltation.

Shoreline Protection Devices:

Vulnerability Assessment: GZA created a vulnerability assessment for shoreline protection based on, wave and lake level overtopping potential scoring them from A to F.

Storage Tanks:

Vulnerability Assessment:

Metric	High	Medium	Low	Weight
Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
In 100 Year Flood Plain	Yes		No	25%
Material	Steel		Fiberglass / impressed current	25%
Wall	Single		Double	25%

Table 10. Vulnerability Metrics for Bluffs for Storage Tanks

ASSET VALUATION

In this coastal area, of the Milwaukee County property, Milwaukee County identified 16 coastal asset categories. The valuation was most often evaluated on 2020 replacement cost. Bluff costs were preventative measures to postpone erosion. Shore protection devices are usually not replaced as a whole, therefore costs were replacement/repairs. Cost breakdowns for buildings can be found on VFA.

Asset Type	Sub Asset Type	Number of Assets	Value Type	Value Cost	Value Source	Sub Asset Valuation Total
Athletic Courts	Stand-alone volleyball courts	1	Replacement	$5,000/each	Capital Planning	$5,000
	Tennis Courts	1	Replacement	$115k/each	Capital Planning	$115,000
	Track	1	Replacement	$100k/each	Capital Planning	$100,000
Athletic Fields	Soccer	4	Replacement	$1,800/each	Capital Planning	$7,200
	Multi-Use	2	Replacement	$1,800/each	Capital Planning	$3,600
	Archery	1	Replacement	$1,800/each	Capital Planning	$1,800
Aquatic Features	Lagoon	2	Repair	$80/LF	Milwaukee County Lagoon Maintenance Projects	$592,954
Beach	Cobble/Gravel	3	Replacement	$0.24M / acre	2018 South Shore Cost Estimates	$3,997,505
	Formal Sand	6	Replacement	$0.24M / acre	2018 South Shore Cost Estimates	$8,676,735
Bluffs		45,505 LF	Preventative	$3,000/LF	Shoreline Erosion Study for Warnimont Park, 2001 with inflation	$1,486,059,488
Bridge	Pedestrian	18	Replacement	$45,000 - $2.5M	Capital Planning, MCDOT	$9,385,000
	Vehicle	2	Replacement	$2.5M-$27M	MCDOT	$29,500,000

Buildings		47	Replacement	$500-$34M	VFA. Architecture, mechanical, structural	$55,494,911
Golf Course	Tee	2	Replacement	$8/SF	Lohmann Quitno	$55,212
	Fairway	1	Replacement	$1/SF		$87,547
	Bunker	1	Replacement	$10/SF		$10,670
Marina Components	Grinder	2	Replacement	$90,000/each	South Shore Project Bids	$180,000
	Fuel Pump	3	Replacement	$20,000/each	Engineer's Estimate	$60,000
	Docks/Piers	20 floating	Replacement	$26,000/each	Pier Project Bid	$520,000
		2 permanent	Replacement	$28,000/each	Pier Project Bid	$56,000
	Boat Launches	11	Replacement	$12/SF	Capital Planning	$323,400
	Harbor Siltation	3	Dredging	$0-$660,000	Past 20 Year Dredging Cost	$732,000
Non-Paved Trails		20	Replacement	$6.75/LF	Capital Planning	$310,581
Open Vegetation Space		1195 Acres	Restoration	$6.3k/acre	Capital Planning	$7,527,551
Paved Areas	Oak Leaf Trail	14	Replacement	$70/LF	Capital Planning	$4,920,897
	Palk Walk Ways	65	Replacement	$70/LF	Capital Planning (assume 10ft width	$5,307,393
	Parking Lots	37	Replacement	$75/SF	Capital Planning includes storm sewer	$138,653,748
	Park Roads	19	Replacement	$280/LF	Capital Planning	$1,140,723,244

Playgrounds		9	Replacement	$180,000 - $400,000	Capital Planning	$1,405,000
Shore Protection Device	Bulkhead	2	Replacement/ Repair	$2,690/LF	South Shore Project Bids	$2,948,000
	Breakwater	8	Replacement/ Repair	$1,300/LF	South Shore Project Bids	$16,542,500
	Groins	25	Replacement/ Repair	$500/LF	GZA	$3,119,273
	Revetment / rip rap)	31	Replacement/ Repair	$115/LF	South Shore Project Bids	$6,765,922
Storage Tanks		7	Replacement	$17,000 - $120,000	BT Squared	$512,568
Stormwater Management Feature	Rain Garden	6	Replacement	$10.64/ SF	MMSD Green Infrastructure Calculations	$400,831
	Infiltration Basin/Swale	15	Replacement	$22.38/ SF	MMSD Green Infrastructure Calculations	$1,886,128
	Permeable Pavers	1	Replacement	$10/SF	City of Milwaukee GI Baseline Inventory	$102,614
	Subsurface Infiltration	1	Replacement	$10,000/ea	Bradford Beach Bids	$10,0000
	Sedimentation Chamber	1	Replacement	$10,000/ea	Bradford Beach Bids	$10,000
	Regenerative Conveyance	1	Replacement	$152,983/ each	RCS Bid	$152,983
	Dry Detention Basin	3	Replacement	$2.11/ SF	MMSD Green Infrastructure Calculations	$110,020

Table 11. Asset Valuations.

In addition to replacement values some of these assets create revue for the County by renting out buildings and rooms or and selling concessions. This also does not include social value.

The total asset valuation totals $2,927,425,276 with approximate 50% of the cost from bluff stabilization.

RESILIENCY RATING

The resiliency rating is based on the condition score multiplied by the vulnerability. The assets were then sorted into lower, medium, and high priority categories.

Some of the coastal area is comprised of landfilling projects for shoreline protection and land creation. One area of concern is landfill site, Manke Dump, in Warnimont Park. The landfill reportedly contains paints, lacquers, and foundry sands. The lack of data did not allow this to be factored into risk.

The total resiliency priority category rating for each asset is based on:

(A) Condition Value x (B) Vulnerability Value = Resiliency Rating

Where (A) and (B) are the weighting factors with high and poor scoring a 1, medium or fair scoring a 2, and low and good scoring a 3. NA conditions were considered a 3 for resiliency calculations.

Assets were grouped into three levels of priority, based on risk score:

- High Priority: Risk score below 4.5
- Medium Priority: Risk score between 4.5 and 6.74
- Lower Priority: Risk score 6.75 and above.

The top 40 high priority assets are listed below in Table 12. A score of 1 is the most potential risk. The full list of assets ordered by priority is in Appendix IV.

	Type	Location	Condition	Vulnerability	Risk Score	2020 Cost
1	Beach	Big Bay	1	1	1	$1,121,285
2	Groin	Warnimont Park	1	1	1	$454,883
3	Groin	Warnimont Park	1	1	1	$343,651
4	Rip Rap	McKinley Marina	1	1	1	$175,375
5	Parking Lot	Bradford Beach	1	1.25	1.25	$6,185,435
6	Breakwater	South Shore Park	1	1.5	1.5	$2,990,000
7-18	Groin	Sheridan Park	1	1.5	1.5	$55,000
19	Rip Rap	War Memorial and Art Center	1	1.5	1.5	$83,000
20	Rip Rap	War Memorial and Art Center	1	1.5	1.5	$83,700
21	Infiltration Basin	Bradford Beach Outfall 5	1	1.75	1.75	$192,448
22	Infiltration Basin	Bradford Beach Outfall 6	1	1.75	1.75	$209,727
23	Parking Lot	McKinley Park	1	1.75	1.75	$9,885,463
24	Road	Grant Park	1	1.75	1.75	$115,817,282
25	Beach	Doctor's Park	2	1	2	$1,388,520
26	Beach	South Shore	2	1	2	$413,250
27	Beach	Grant Park	2	1	2	$1,446,375
28	Beach	Sheridan	2	1	2	$1,487,700
29	Park Walk	Lake Park	1	2	2	$26,443
30	Parking Lot	McKinley Park	1	2	2	$31,382,932
31	Parking Lot	McKinley Park	1	2	2	$3,097,317
32	Parking Lot	McKinley Park	1	2	2	$2,291,099
33	Parking Lot	McKinley Park	1	2	2	$5,247,099
34	Parking Lot	War Memorial and Art Center	1	2	2	$2,276,142
35	Road	Grant Park	1	2	2	$11,607,632
36	Road	Cupertino Park	1	2	2	$5,617,185
37	Road	Grant Park	1	2	2	$4,007,372
38	Bluff	Warnimont Park	1.56	1.40	2.19	$240,719,868.66

Table 12. Highest Priority Rated Assets

GIS SUMMARY

GIS data and analysis were used to identify Milwaukee County assets within the coastal zone along with each assets' vulnerability and resiliency. The Milwaukee County GIS and Land Information Office (MCLIO) compiled a file geodatabase with all GIS data used in the project and the analytic results. The database includes all the mapped county owned assets located within the defined coastal zone. The assets list the assessed condition, vulnerability, and resiliency ratings in the feature's attribute data. It also includes the supporting GIS data used to complete the analysis, for example, shoreline protection polygons and their ratings from GZA, coastal bluff crest and toe lines, bluff recession data, and shoreline lines. The County site bluff data is also provided.

The GIS file geodatabase is available for download for public use here: https://gis-mclio.opendata.arcgis.com/datasets/bce9201dd312445b9b4567ee14d8032a

An interactive web map was also created to easily review and interact with the data in a user-friendly format. The map highlights which areas of the bluffs are at risk, the assets ratings, and supporting data that can be used to gain understanding of the coastal area, for example, DEM raster data, geotagged photos of the features from GZA, and aerial photography.

The web map is found here: http://mclio.maps.arcgis.com/apps/webappviewer/index.html?id=370390c8ee524135b51c5f849865901d

SUMMARY

Extreme weather has damaged Milwaukee County's coastal resources and is expected to continue to occur in the future, with the possibility that the severity will be greater because of climate change. Milwaukee County has about nine miles of coast on Lake Michigan, which is also nine of beaches, bluffs, and other assets that are continually degraded from storms and erosion. The County needs these assets to uphold recreation and create revenue, but a single storm in January 2020 caused approximated $8 million of damages to County-owned coastal assets.

Bluff and shoreline studies on Wisconsin's Lake Michigan have been occurring since 1977. These studies helped create condition and vulnerability metrics to coastal assets for this report. Milwaukee County found, added, and updated coastal assets, including ownership information.

Approximately 13% of assets fell into the poor condition and 22% assets were deemed highly vulnerable. The assets with the highest risk were the beaches, groins, and parking lots. Different infiltration basins, revetment, and parking lots by McKinley Marina all appeared in the top 40 most at risk.

The total asset valuation totals $2,927,425,276 with approximately 50% of the cost from bluff stabilization.

REFERENCES

1. Great Lakes Water Level Outlook- April 2020 Edition - Updated June 2020 https://www.lre.usace.army.mil/Missions/Great-Lakes-Information/Great-Lakes-Water-Levels/Water-Level-Forecast/Monthly-Bulletin-of-Great-Lakes-Water-Levels/

2. Policy Suggestions for Construction along Lake Michigan bluffs and Ravines within Milwaukee County. Memorandum. Himalayan Consultants, LLC. February 28, 2019.

3. University of Wisconsin-Madison's Transportation Information Center "Pavement Asphalt Surface Evaluation and Rating" (PASER). Posted December 4, 2019. Revised 2013.

4. Wisconsin Shoreline Inventory and Oblique Photo Viewer. The University of Wisconsin Sea Grant Institute. WisconsinView. Caitlin Wolters. Dr. David Mickelson, Geo-Professional Consultants, LLC. Association of State Floodplain Managers, Inc. http://floodatlas.org/asfpm/oblique_viewer/about.html

5. Coastal County Data for Download. Milwaukee County Land and Information Office. September 2020. https://gis-mclio.opendata.arcgis.com/datasets/bce9201dd312445b9b4567ee14d8032a

Asset Type	SubAsset Type	Number of Assets	Value Type	Value Cost	Value Source	Condition					Vulnerability				
						Metric	Poor	Fair	Good	Weight	Metric	High	Medium	Low	Weight
Athletic Courts	Volleyball Courts	1	Replacement	$5,000/each	Capital Planning						Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
	Tennis Courts	1	Replacement	$115k/each	Capital Planning	PASER Scoring	< 40	41-69	> 70	100%	In 100 Year flood plain (Elevation at 587.5ft)	Yes	-	No	25%
	Track	1	Replacement	$100k/each	Capital Planning						Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
											Located on a bluff?	Yes	-	No	25%
Athletic Fields	Soccer	4	Replacement	$1,800/each	Capital Planning						Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
	Multi-Use	2	Replacement	$1,800/each							In 100 Year flood plain (Elevation at 587.5ft)	Yes	-	No	25%
	Archery	1	Replacement	$1,800/each							Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
											Located on a bluff?	Yes	-	No	25%
Aquatic Features	Lagoon	2	Repair	$80/LF	Milwaukee County Lagoon Maintenance Projects	BMP Maintenance Assessment	1	2	3	100%	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
											In 100 Year flood plain (Elevation at 587.5ft)	Yes	-	No	25%
											Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
											Located on a bluff?	Yes	-	No	25%
Beach	Cobble/Gravel	3	Replacement	$0.24M / acre	2018 South Shore Cost Estimates	Soil type, nourishment needs, and amount of beach unusable	D, F	C	A, B	100%	Soil type and shoreline protection	D, F	C	A, B	100%

	Formal Sand	6	Replacement	$0.24M / acre	2018 South Shore Cost Estimates	Soil type, nourishment needs, and amount of beach unusable	D, F	C	A, B	100%	Soil type and shoreline protection	D, F	C	A, B	100%
Bluffs		45,505 LF	Preventative	$3,000/linear foot	Shoreline Erosion Study for Warnimont Park, 2001 with inflation	Slope steeper than 22° [2]	> 6%	3 - 6%	< 3%	40%	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
						Vegetative Cover[4]	Mostly Bare Slope	Partly Vegetated	Thick Cover	25%	Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
						Bluff Failure[4]	Deep seated slumps	Shallow slides, Creep	Mostly Vegetated	20%	Recession Sum (5 years)	> 1 ft	0.5-1 ft	< 0.5ft	30%
						Bluff Modification[4]	Fill	Regraded	No modification	15%	Change in Soil Volume	>7,500 ft^3	0-7,500 ft^3	<0 ft^3	20%
Bridge	Pedestrian	18	Replacement	$45,000 - $2.5M	Capital Planning, MCDOT	National Bridge Inventory	0-4	5-6 or NA	7-9 or NA	100%	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
	Vehicle	2	Replacement	$2.5M-$27M	MCDOT						In 100 Year Flood Plain (Elevation at 587.5ft)	Yes	-	No	25%
											Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
											Located on a bluff?	Yes	-	No	25%
Buildings		50	Replacement	$500-$34M	VFA. Architecture, mechanical, structural	VFA	Poor	Fair	Good	100%	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
											In 100 Year Flood Plain (Elevation at 587.5ft)	Yes	-	No	25%
											Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
											Located on a bluff?	Yes	-	No	25%
Golf Course	Tee	2	Replacement	$8/SF	Lohmann Quitno	Vegetation Cover	Sparse	Thin Cover	Thick Cover	50%	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
	Fairway	1	Replacement	$1/SF		Landscape	Rocky/Divots	Some Divots	Smooth	50%	In 100 Year Flood Plain (Elevation at 587.5ft)	Yes	-	No	25%
	Bunker	1	Replacement	$10/SF							Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
											Located on a bluff?	Yes	-	No	25%

Marina Components	Grinder	2	Replacement	$90,000/each	South Shore Project Bids						Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
	Fuel Pump	3	Replacement	$20,000/each	Engineer's Estimate						In 100 Year Flood Plain (Elevation at 587.5ft)	Yes	-	No	25%
	Pier/Dock	20 floating	Replacement	$26k/each	Dock Project Bid						Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
		2 permanent	Replacement	$28k/each	Dock Project Bid						Located on a bluff?	Yes	-	No	25%
	Boat Launches	11	Replacement	$12/SF	Capital Planning	Cracking, spalling, area underwater	D, F	C	A, B	100%	Wave and lake level overtopping	D, F	C	A, B	100%
	Harbor Siltation	3	Dredging	$0- $660,000	Previous Dredging Costs						Sediment Dredging	>2,000CY	1000-2000CY	<1,000CY	100%
Non-Paved Trails		20	Replacement	$6.75/LF	Capital Planning						Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
											In 100 Year Flood Plain (Elevation at 587.5ft)	Yes	-	No	25%
											Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
											Located on a bluff?	Yes	-	No	25%
Open Vegetation Space		1195 Acres	Restoration	$6.3k/acre	Capital Planning						Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
											In 100 Year Flood Plain (Elevation at 587.5ft)	Yes	-	No	25%
											Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
											Located on a bluff?	Yes	-	No	25%
Paved Areas	OLT	14	Replacement	$70/LF	Capital Planning	PASER Scoring	< 40	41-69	> 70	100%	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
	Palk Walk Ways	65	Replacement	$70/LF	Capital Planning	PASER Scoring	< 40	41-69	> 70	100%	In 100 Year Flood Plain (Elevation at 587.5ft)	Yes	-	No	25%
	Parking Lots	37	Replacement	$75/SF	Capital Planning	PASER Scoring	< 40	41-69	> 70	100%	Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%

					includes storm sewer										
	Park Roads	19	Replacement	$280/LF	Capital Planning	PASER Scoring	< 40	41-69	> 70	100%	Located on a bluff?	Yes	-	No	25%
Playgrounds		9	Replacement	$180k-400k	Capital Planning						Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
											In 100 Year Flood Plain (Elevation at 587.5ft)	Yes	-	No	25%
											Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
											Located on a bluff?	Yes	-	No	25%
Shore Protection Device	Bulkhead	2	Replacement/Repair	$2,680/LF	South Shore Project Bids	Degradation	D, F	C	A, B	100%	Wave and lake level overtopping	D, F	C	A, B	100%
	Breakwater	8	Replacement/Repair	$1,300/LF	South Shore Project Bids	Degradation of concrete, steel sheet piling.	D, F	C	A, B	100%	Wave and lake level overtopping	D, F	C	A, B	100%
	Groins	25	Replacement/Repair	$500	GZA	Undermining, loss of material, and cracking	D, F	C	A, B	100%	Wave and lake level overtopping	D, F	C	A, B	100%
	Revetment (including rip rap)	31	Replacement/Repair	$115/LF	South Shore Project Bids	Erosion, dislodging, and undermining	D, F	C	A, B	100%	Wave and lake level overtopping	D, F	C	A, B	100%
Storage Tanks		7	Replacement	$17,000 - $120,000	BT Squared						Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
											Above or Underground	Underground	-	Aboveground	25%
											Material	Steel	-	Fiberglass / impressed current	25%
											Wall	Single	-	Double	25%
Stormwater Management Feature	Rain Garden	6	Replacement	$10.64/ SF	MMSD Green Infrastructure Calculations	BMP Assessment	1	2	3	100%	Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
	Infiltration Basin/Swale	15	Replacement	$22.38/ SF	MMSD Green Infrastructure Calculations	BMP Assessment	1	2	3	100%	In 100 Year Flood Plain (Elevation at 587.5ft)	Yes	-	No	25%
	Permeable Pavers	1	Replacement	$10.00/SF	City of Milwaukee GI	BMP Assessment	1	2	3	100%	Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%

					Baseline Inventory										
	Subsurface Infiltration	1	Replacement	$10,000/each	Bradford Beach Bids	BMP Assessment	1	2	3	100%	Located on a bluff?	Yes	-	No	25%
	Sedimentation Chamber	1	Replacement	$10,000/each	Bradford Beach Bids	BMP Assessment	1	2	3	100%					
	Regenerative Conveyance	1	Replacement	$152,983	RCS Bid	BMP Assessment	1	2	3	100%					
	Dry Detention Basin	3	Replacement	$2.11/ SF	MMSD Green Infrastructure Calculations	BMP Assessment	1	2	3	100%					

Table 14. Asset Overview

APPENDIX I – ASSET LIST

See attachment.

APPENDIX II – GZA REPORT

See attachment.

APPENDIX III - BLUFF CALCULATIONS

Milwaukee County used the 2015 crestline[4] and toeline[4] to create a bluff polygons per county owned property along the shoreline. The polygons cover the bluff area within the site.

Source Data:

-Bluff Crest 2015[4]

-Bluff Toe 2015[4]

-Bluff Crest Recession 1995-2015[4]. Each data point represents an average of recession measurements along a 10 meter section of coast and does not represent any specific property or municipal boundaries.

-Bluff Toe Recession[4] 1995-2015. Each data point represents an average of recession measurements along a 10 meter section of coast and does not represent any specific property or municipal boundaries.

-Bluff recession[4] distances were measured from historical aerial photos in Geographic Information System (GIS) software for 1995-2015. Using GIS software, photos from each year are georeferenced to position them accurately in space and orthorectified to remove vertical distortions caused by the camera lens. Positive rates mean a landward movement (i.e. recession or erosion) and negative rates mean a lakeward movement (i.e. accretion). The recession distances were transected to show where the recession was measure when looking at the bluff.

-Backshore 2008[4]. In spring 2007, oblique digital photos were taken along Wisconsin's Lake Superior shoreline and the Lake Michigan shoreline south of the Sturgeon Bay Canal. The 2007 and 2008 photographs were geo-located using software called GPS-Photo Link (Geospatial Experts). The shoreline classification for the most part these were done mile by mile, with all six classifications being completed for a single reach before moving down the shoreline. In some cases, where it was clear that there was no change in classification over several miles, then the reach classification took place over several mile stretches. Generally Bing Maps or Google Earth was used as a supplement.

While the data was digitized for research purposed and may not reflect current conditions, it lent itself to the County's inventory with the following information for each bluff section:
Type: no bluff, low bank, or bluff
Vegetation: null, mostly bare slope, partly vegetated, mostly vegetated
Bluff condition: no bluff, unstable/failing, moderately unstable, or moderately stable
Bluff modification: null, regraded, fill, no modification, or no bluff
Bluff failure classification: null, no obvious failures, creep, shallow slides, slumps, no bluff

-Wi_shoreline_ln[4]: Line of Wisconsin's Lake Michigan shoreline, the location where the beach meets the water

-Beach class[4]: Identified shoreline as armored or unarmored, the type of protection, and the type of beach i.e. sand/ gravel, coarse, or gravel/cobble.

Using Linear Referencing Routes to determine Bluff Condition, Vulnerability, and Resiliency ratings.

Creating Routes:

a. Consider every county site with a bluff is considered its own route. Linear referencing allows us to evaluate the changing attributes of a bluff, i.e. the bluff's characteristics are not defined by the county boundaries. The variance in the bluff attributes including problem areas are lost when the rating is averaged problem with averaging the rating across the entire county site, is we lose the problem areas.
b. The route lines are defined by the Wisconsin Shoreline[4].The route base lines are the intersection of the county site boundaries and the shoreline line.
c. The linear referencing tool was rerun with the base routes and each of the condition and vulnerability ratings. This created the Bluff_ConditionRatings[5], Bluff_VulnearbilityRating[5], and Bluf_TotalRisk[5] line work. Each segment represents a unique combination of a condition, vulnerability, and resiliency rating.

Vulnerability Rating

Metric	High	Medium	Low	Weight
Distance from Shore	<100 ft	100-350 ft	>350 ft	25%
Shoreline Protection	Rated Poor or None	Rated Fair	Rated Good	25%
Recession Sum	> 2 feet	1-2 feet	< 1 feet	30%
Change in Soil Volume	>7,500 ft^3	0 – 7,500 ft^3	<0 ft^3	20%

1. Distance from the shoreline
    1. Used the intersection tool with the 2015 bluff toe line data and the bluff rating grid. This resulted in 50ft line segments of bluff toe lines. The bluff rating grid was used every time the data was averaged across the 50 ft zones.
    2. Used the Generate Near tool to calculate the distance between the bluff toe line segments and the shoreline.
    3. Set high-low rating based on low<100ft, medium=100-350ft, high>350ft
    4. Used the dissolve tool to merge the segments based on their rating, e.g. all contiguous segments of low distance rating are represented with one segment.
2. Shoreline Protection
    1. Used the different shoreline protection devices with transect lines as a guide to create a polygon area that described the area they are protecting, ShorelineProtectionZone[5] polygons. The zones assume that protection from the protection structures runs perpendicularly to the shore and covers the full coastal area.
    2. Used the Intersect tool to determine which segments of the route were protected by the shoreline protection devices.
    3. The ratings are based on the device's poor, fair, and good condition ratings. If the bluff segment does not have a shoreline protection device, the segment was assigned a poor rating.
2. Determining recession sum
    a. Used the recession point data[4]

b. Calculated Recession Sum for each point that had bluff toe and bluff crest recession data– took the average of the toe and crest recession rates for the short term 1995 to 2015 time frame and then multiplied by 20 for the distance.

c. Spatially joined the recession point data to the bluff rating grid. Calculated the average recession distance of the point data within the 50ft zone.
d. Gave rating based on distance - >1ft=high, 0.5-1ft=medium, <0.5ft=low
e. The recession point data does not cover some of the bluff in Lake Park. The bluff segments in this area were given a low recession rating.

3. Change in Soil Volume
    a. Clipped the 2010 and 2015 5ft DEM raster data with the bluff polygons. Used the raster cut fill analysis tool to determine the change in volume between the 5 years over this area.
    b. Used ESRI's Spatial Analyst Cut Fill operation to determine the volume change across the two time periods
    c. The cut fill operation determines the regions where material was removed (positive volume value) and where material was added (negative volume value). The results in the cut fill raster table include the number of cells in the change region, the total area, and the total volume change.
    d. To determine the volume change of bluff area in a single site and to set the data up for the bluff rating routes, the volume change was calculated by cell. To do this, an equal volume change is assumed across the full area and each cell 5ft x 5ft cell in the region is assigned the average volume change per cell (volume change divided by cell count).
    e. To easily view and work with the data, the raster data was converted to polygons (Bluff_VolumeChange). Refer to this feature class to identify areas of erosion (positive volume change). The Bluff_VolumeChange feature class also includes the volume by cell average.
    f. Converted the polygon to raster with the calculated volume change per cell as the pixel value.
    g. Used Zonal Statistics to sum the change per cell in each 50ft zone and bluff area respectively to calculate the total volume change (displayed in the "gridcode" field).

    h. Rated the change based on the ratings: high > 7,500ft^3, medium = 0-7,500ft^3, low < 0ft^3

The vulnerability was calculated with the linear referencing tool with the bluff lines by county site and then create routes with the four vulnerability variables. Each segment represented a unique combination of the four rating variables and county site, so the vulnerability score could be calculated by segment with the scoring matrix. The resulting bluff vulnerability ratings are available for review in the Bluff_VulnerabilityRating[5] feature class. The vulnerability rating was also calculated by county site. The bluff vulnerability by site is the average of the vulnerability ratings by length.

Calculating Condition

Metric	Unstable=1	Fair=2	Stable=3	Weight
Slope compared to 22°	>6%	3-6%	<3%	40%

Vegetative Cover	Sparse/ "Mostly bare slope"	Thin Cover/ "Partly Vegetated"	Thick Cover/ "Mostly Vegetated"	25%
Bluff Failure	Deep seated slums	Shallow Sides, Creep	No Obvious	20%
Bluff Modification	Fill	Regraded	No Modification	15%

1. Calculating Slope
    a. Clipped the countywide dataset of 5ft Slope Degree raster data that was derived from 2015 Lidar data to match the bluff polygon boundaries.
    b. Used the raster calculator to calculate the slope degree percentage difference from 22°.
    c. Used the Zonal statistics tool with the bluff rating grid and slope percentage raster data to determine the average percentage difference in the 50ft chunks.
2. Vegetative Cover, Bluff Failure, and Bluff Modification
    a. The vegetative cover, bluff failure, and bluff modification classifications in the Backshore 2008[4] line data were used. The Backshore linework spatially aligns with the base bluff route data, so it could be used directly with the linear referencing tool and did not need to be applied to the 50ft zones.

The condition was calculated with the linear referencing tool with the bluff lines by county site and then routes were created with the four condition variables. Each segment represented a unique combination of the four rating variables and county site. The condition score was then calculated by segment with the scoring matrix, so the condition score could be calculated by segment. The resulting bluff vulnerability ratings are available for review in the Bluff_ConditionRatings[5] feature class. The condition rating was also calculated by county site. The bluff condition by site is the average of the vulnerability ratings by length.

Calculating Resiliency

The resiliency rating was calculated by multiplying the condition and vulnerability scores. The intersect tool was used to combine the bluff condition and vulnerability ratings. Each line segment represents a unique combination of county site, condition rating, and vulnerability rating. The two ratings were multiplied per segment. The bluff resiliency by site is the average of the total risk ratings by length. The bluff resiliency scores are available for review in Bluffs_TotalRisk[5].

Calculating Bluff Cost

1. Used the intersect tool with the county site boundaries and bluff toe lines. The resulting line segments represented the bluff toe length by county site.
2. Multiplied the toe length in feet per county site by $3,000 to calculate the replacement cost of the bluffs per site.

All analysis was completed in ESRI ArcGIS Pro 2.5 software.

APPENDIX IV – ASSET LIST BY RISK

See attachment.