COASTAL HAZARDS

Location

The City of Superior lies at the westernmost tip of Lake Superior, bordered by St. Louis Bay to the northwest, Superior Bay to the northeast, Allouez Bay to the southeast and the St. Louis River estuary in the southwest. The City is sheltered from Lake Superior by Minnesota and Wisconsin Points, natural sand bars spanning over nine (9) miles, separating Lake Superior from the bays and the City. The Superior Entry is a 500-foot open water channel between Wisconsin and Minnesota points used by recreational boating and shipping traffic accessing Superior Bay.

Hazard Profile

Coastal hazards affecting the City of Superior include high and low lake levels, storm surges, seiche events, wave run-up, wave set-up and coastal flooding as a result of one or more of the above. Several factors can contribute to coastal flood risk. Susceptibility is influenced by shore topography, landmasses, water depth and direction of event. The rivers and bays associated with the City are influenced by lake level fluctuations, storm surges and wave and seiche energy. The red clay soils and sandy shorelines are prone to erosion as direct and indirect effects of coastal water hazards.

Despite potentially high wave and seiche energies from Lake Superior, the City of Superior remains relatively sheltered from disturbance due to the natural barrier of Minnesota and Wisconsin points. Wave and seiche events affecting the City tend not to pose a significant threat to life and property contained within the harbor.

The City is a prime target for the natural phenomenon of “lake effect” snowstorms. Even during winter, water contained in large masses, such as Lake Superior, stays warmer than the air temperature. When cold air from northern storm fronts hit the warm lake air, it destabilizes and forms clouds, resulting in snowfall. This often occurs on the tail of a conventional snow event, thus areas prone to lake effect events receive higher snow amounts over longer periods of time than areas further away from the lake. Lake effect snowfall is dependent on the position of the storm tracks, the degree and variations in lake water temperatures, the extent of ice coverage and the prevailing wind direction and speed. Lake effect snowfall contributes between 30% and 50% of the annual winter snowfall on the eastern and southern shores of the Great Lakes. This coastal phenomenon is discussed further in the Winter Hazard section.

Extreme Lake Levels from Coastal Hazards

Extreme high water levels in Lake Superior may result from intense or prolonged seiche events, rain, or snowmelt. Extreme low lake levels may occur after prolonged winter

and/or summer drought. Water level changes may occur as short-term, seasonal, or long-term phenomena and are influenced by regional climate events, as well as events occurring at or near the City of Superior.

The average lake level for Lake Superior at the Duluth-Superior Harbor is 601.1 feet (USACE Data 2003, IGLD 85, measured at Father Point, Quebec, Canada). Lake levels are lowest in March (600.7 feet, IGLD 85), before the spring thaw and highest in August and September (601.7 feet IGLD 85), during the thunderstorm season. The National Flood Insurance Program study of 1977 reported the 100-year open coast flood elevation for Lake Superior at the City of Superior to be 603.4 feet.

Influences on water levels in Lake Superior include snowmelt, rain (direct and runoff), heat contributing to evaporation and control of water flow at the St. Mary's River, connecting Lake Superior to Lake Michigan. About 40% of water input into the lake is contributed by spring snowmelt. The locks at Sault Ste. Marie may be adjusted to control flow, holding water in at low lake levels, or letting water out at high lake levels. The activity of the locks, including control of flow, is coordinated with the International Joint Commission, a bi-national commission of members from Canada and the United States who govern the Great Lakes Seaways.

Historical Events

In 84 years of records, the highest lake level measured in the harbor was 603.4 feet (IGLD 85) in October 1985 and the lowest 599.5 feet (IGLD 85) in April 1926. Figure 5.1 shows lake levels at the City of Superior 1918-2010.

<u>High Lake Levels</u>

In 1968, heavy spring and summer rains raised the lake level at the Duluth-Superior Harbor 1.7 feet above normal. Grain elevators near the shores of Superior and St. Louis bays suffered damage to mechanical elevator components and grains stored in the elevators. Residents along Minnesota's Park Point complained of flooded docks and basements and heavy shoreline erosion. Land along Wisconsin Point suffered similar erosion.

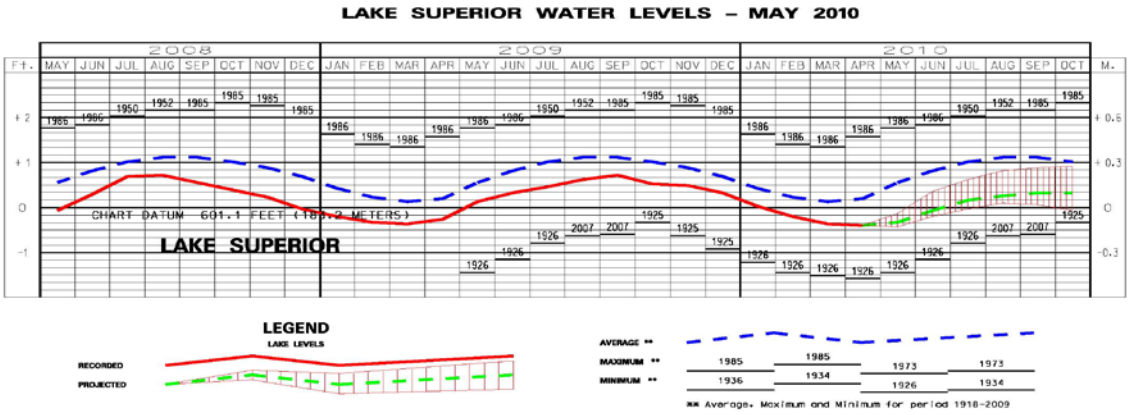
In 1996, heavy winter and summer precipitation along the south shore of Lake Superior contributed to lake levels rising to 602.95 feet, 1.85 feet above normal. Great Lakes shipping benefited from the high lake levels since they were able to carry 12-16 extra load-inches of cargo and still clear the harbor floor. Each load-inch of cargo adds an additional value to the load. Lakeshore property owners, however, anticipated fall storms would increase already high erosion rates.

<u>Low Lake Levels</u>

Low lake levels can significantly influence the Duluth-Superior Harbor Port and docking facilities along Superior Bay in the City of Superior. Low lake levels in 1999 and 2000 caused severe impacts to business, industry and private property throughout the Lake Superior Region. Low winter and summer precipitation, La Niña effects, and high temperatures year-round led to low water input into the lake and no ice cover to protect

the lake from evaporation during winter months. Summer heat accelerated evaporation rates, thus increasing overall evaporation rates year-round. It was estimated that Lake Superior lost 63 trillion gallons of water in 3 years, causing a 9-inch drop in lake level in 1999 and an 18-inch total drop by 2000.

Figure 5.1: Lake Levels for Lake Superior at the City of Superior 1918-2010 USACE-Detroit District.



Predictability & Probability

Based on research into local events, the probability of extreme lake levels affecting the City of Superior is low (1% or less).

Lake levels reaching 2.3-feet above normal (601.1 feet GLVD) is equivalent to the flood-stage level designated by the National Flood Insurance Program for a 100-year event. City documentation supports this correlation. The probability of extreme low lake levels, equivalent to a 1.2-foot drop in lake level below normal, may be expected every 100 years. Moderate high and low water levels in Lake Superior tend to follow a 30-year pattern.

Lake level predictions can be based on weather trends including temperature and precipitation data accompanied with the 30-day forecast.

Wet or dry spells persisting for as little as 5 weeks can result in significant lake level changes. High-level lake effects may be seen much sooner when wet events are moderate to severe.

The probability of a severe storm affecting the level of Lake Superior and impacting the City of Superior depends on wind direction and velocity. Storm impacts can vary drastically between the City of Superior and neighboring Duluth, Minnesota, which lies along the north shore of Lake Superior with nearly half of its eastern edge directly exposed to the lake.

Seiche Events from Coastal Hazards

Seiche events are caused by local variations in atmospheric pressure or by high, persistent winds, causing water to build up on the low pressure or windward shore. Water levels oscillate from shore to shore anywhere from hours to days after the source has subsided. The orientation of Lake Superior and the position of Superior at the westernmost tip influence the frequency and amplitude of seiche events affecting the City. This is due to the tendency of weather patterns and pressure systems to move west to east, coinciding with the orientation of the lake.

Winds in the City of Superior are predominantly northerly, southerly and westerly and blow at speeds between 10-40 miles per hour. These winds tend to push water up against the eastern shores of Lake Superior and the Keweenawan Peninsula. Superior receives the backlash of a seiche event as the wind or atmospheric event subsides and water levels oscillate until they return to a resting state.

The period and fluctuation of a seiche event depends on lake dimensions, water depth and shoreline contour. Seiche events with water level changes up to 0.5 ft are common and frequent in the Duluth-Superior Harbor area. Changes of 1-2 feet from normal water levels are considered significant. A range exceeding 2 feet above the normal lake level in the Duluth-Superior Harbor would be considered dramatic and could reach or exceed the flood levels set for the City of Superior by the National Flood Insurance Program (NFIP). Oscillation periods are approximately 30-45 minutes from high to low water. Some events may occur extremely quickly with a rise or fall of up to a foot in 3 to 15 minutes.

Seiche events may cause inundation of uplands and/or exposure of lowlands, damage to ships and docks, soil erosion and injury to swimmers and boaters. Though seldom significant in the City of Superior, bays tend to be the areas most affected by seiche events, since water can funnel in and build up against the shore on the incoming current. Engineers took seiche effects into consideration during development of the Duluth-Superior Harbor to prevent damage to grain elevator drainage operations and to determine safe shipping routes and dredging maintenance schedules throughout the harbor (Duluth News-Tribune 8-6-1939).

Historical Events

- A seiche event in July 1871 followed a severe thunderstorm and resulted in a two-foot increase in water level in St. Louis Bay. This event occurred during construction of the Duluth Ship Canal. Oscillations during this event ran in 30-minute intervals for several days.
- Another seiche event beginning at 6:00 a.m. July 11, 1935 and lasting until 8:00 p.m. July 12, 1935 was caused by an extremely sharp low-pressure system centered across Lake Superior. The maximum variation in water level from this event was 1.4 feet in Duluth-Superior and 3.5 feet in Ashland, Wisconsin. This event threatened swimmers in Chequamegon Bay and flooded U.S. Highway 13 with approximately 3 feet of water.

- An intense seiche event in August 1938 caused a 1-foot variation in lake level in about 1 hour. This event caused ships to collide with concrete buttresses, resulting in damage to both. The event also interrupted shipping operations, as ships had difficulties getting out of the harbor due to "strong currents sweeping in and out of the harbor" (Duluth News Tribune 8-22-1938). Events such as these have been reported infrequently and were often mistakenly reported as "tidal waves".

Predictability & Probability
Based on research into local events, the probability of seiche events causing lake levels to exceed the flood stage in the City of Superior is low (1% or less).

Extreme seiche events are difficult to predict. A 2.3-foot rise in lake level at the Duluth-Superior Harbor is comparable to the flood-stage level designated by the (NFIP) for a 100-year event. Local records support this prediction. Moderate seiche events with a rise or fall of 0.5-1 foot may occur annually.

Seiche events created by atmospheric pressure may be predicted when low pressure systems approach the lake from the west, following high pressure systems moving east. Seiche events caused by persistent winds may be predicted using the Zuiderzee formula (USACE, Vol. 1 October 1, 1938).

$$h = \frac{V^2 F}{800 D}$$

h= height of change in elevation in feet
V= wind velocity in miles per hour
F= Fetch in miles
D= Depth of water in feet

Wave Energy from Coastal Hazards

Waves are surges of water resulting from a combination of water depth, wind speed, wind direction, wind duration and offshore topography. Shallow waters tend to break waves before they build significant height and damage structures onshore. Waves generated in Lake Superior tend to break and disperse onto Wisconsin Point.

High northeasterly winds creating wave activity on exposed shorelines may develop rip currents, which are high-velocity, river-like, shallow water currents responsible for several deaths in the Great Lakes. Wave energy is a primary cause of erosion, especially on shores adjacent to Lake Superior, such as the far eastern end of Superior and the lakeside of Wisconsin Point.

Historical Events
There were no historical events found.

Predictability & Probability

Based on research into local events, the probability of wave energy causing lake levels to exceed the flood stage in the City of Superior is low (1% or less).

Wave energy can be predicted based on shore and offshore topography, water depth and weather forecasting of wind direction and velocity. Most wave energies are broken by Minnesota and Wisconsin Points, which shelter the City of Superior from the open lake. Typically, there is not enough distance or water depth for hazardous waves to generate within Superior or St. Louis bays. Based on this geography, there is little probability for hazardous wave action to affect the City of Superior, unless a wave was so immense that it crested beyond the sand bars of Minnesota or Wisconsin Points. No significant wave events affecting the City of Superior have been documented.

Erosion from Coastal Hazards

Coastal erosion is caused by day-to-day wave influence, high water levels associated with high precipitation, seiche events, or normal lake level fluctuations. These influences gradually undercut the bluffs and shorelines along the coast of Lake Superior. Nearly 80% of Wisconsin's erodible Great Lakes shoreline suffers from erosion and recession problems. The City of Superior is developed on these types of highly erodible sand and red clay soils, which pose the greatest threat to water quality within the Lake Superior watershed. The Wisconsin Coastal Management Program has identified erosion of coastal bluffs, banks and beaches as one of three primary types of natural hazards affecting Wisconsin's Great Lakes shores.

Coastal erosion has very significant impacts on property in the City of Superior. The clay soil upon which Superior is built has temperamental properties that make it vulnerable to slumping when large amounts of sediment moves downhill under gravity. Clay particles are small with a large surface area to volume ratio. Weathering, a phenomenon soil particles undergo as they age, is accelerated by factors including hydration, impact and frost. Weathering weakens soil structure, destabilizing the ground and increasing the tendency to slump. The effects of water on clay in Superior can be devastating. These soils are very stable when dry, but when wet have a shrink-swell property that contributes to the overall instability of the soil.

Coastal erosion and slumping may pose significant threats to properties along the Lake, bays, rivers, creeks and streams. Loss of property from slumping has been documented along the Nemadji River in the City of Superior and along the St. Louis River in the nearby Village of Oliver.

Erosion in developed harbor areas is less significant, due to the methods used to construct piers and docks. Most facilities were created from dredged sediments and are contained with sheet piling, concrete walls, riprap, or wood piling driven into the bay bottom. Propeller activity from boats causes the most erosion at these sites and annual maintenance is usually necessary in slips and channels.

Historical Events

Though possible erosion sites exist, there have been no references to major hazardous erosion occurring to coastally juxtaposed parcels within the City of Superior. City, county, and federal units of government own most of the coastal properties that may be affected by coastal erosion. These properties are generally undeveloped, including the critical areas on Wisconsin Point. Minnesota Point, governed by Duluth, Minnesota, is heavily populated with residential homes. Citizens frequently complain about coastal erosion of the sand substrates during high lake levels, storm surges, and seiche events.

Predictability & Probability

The University of Wisconsin-Superior has been working with Douglas County, the City of Superior, the Village of Oliver and other local and regional agencies in a cooperative effort to map and further study slumping and other erosion activity along the St. Louis, Nemadji, and Pokegama rivers and St. Louis and Superior bays. Though slow moving, the probability of coastal erosion is constant. Catastrophic events may be expected once every 100 years or less (<1% probability), though minor site-specific damage from coastal erosion is more probable (2-5%).

Ice from Coastal Hazards

Ice does not typically cover the whole of Lake Superior. The harbor, including Superior and St. Louis bays, typically forms near-complete ice sheets, especially on the bay side of Minnesota and Wisconsin points. Partial sheets may float between the north and south shores on the lake and bay sides of Minnesota and Wisconsin points. Ice sheets, from a few inches to several feet thick, form as early as mid-November and persist as late as early May.

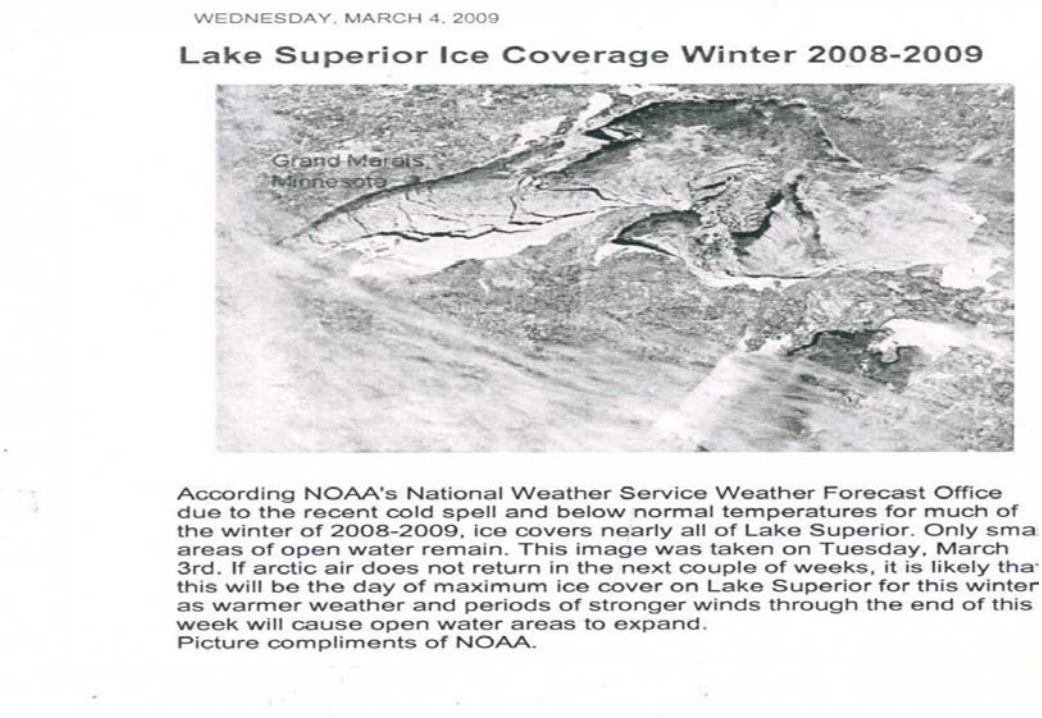
Ice in the harbor essentially ends the shipping season. Coast Guard cutters and icebreakers may break up ice to prolong the fall shipping season, or accelerate the start of the spring shipping season. Other ice-cutting operations are handled by private towing companies.

Ice push is a general term for the movement of sediment by the thrust of ice against land. Some common features include ice-push ridges and mounds, ice-gouge, ice pile-up, ride-up rubbling and bulldozing. This abrasion can cause severe erosion as the sharp ice scours the shoreline, with potential for severe damage during the winter, or in spring as the ice melts and the ground softens.

Figure 5.2 shows Lake Superior during the winter 2008-2009. Lake Superior was nearly covered by ice, which is rare. This caused the St. Lawrence Seaway to open on March 31, 2009, a full week later than in 2008 and 10 days later than in 2010. The Seaway opening as early as March 21, 2010 is an encouraging sign for the economy and the shipping

season. On March 6, 2014, NOAA recorded Lake Superior was nearly over 95% covered in ice. This was due to artic blasts and record snowfall from late 2013 to 2014.

Figure 5.2 Ice Cover on Lake Superior, 2009 and 2014



Lake Superior Ice Coverage Winter 2013-2014

March-2014

Source: NOAA

Historical Events
There were no historical events found.

Predictability & Probability
Ice cover in the harbor is expected annually. During exceptionally mild years, ice cover has been delayed during winter months by warm weather or it has been extended into spring months by prolonged or extreme cold throughout the winter and/or into spring. The probability of catastrophic ice events is low (<1% annually).

Wind from Coastal Hazards

Wind events are prevalent in the City of Superior. Winds most commonly (> 45 days per year) come from northwesterly directions at 10-20 miles per hour (mph). Other common (> 40 days per year) winds are northeasterly at 3-10 mph. Wind off Lake Superior can be most damaging, since air can flow for 200 miles without obstacles. Wind can come in straight-lines or downbursts during winter or summer. Windstorms can exceed 40 mph and have been recorded as high as 100 mph. Winds may come at any time of year, alone or accompanying rain or snow.

Historical Events
- During two storms in April and May 1953, 33-55 mph winds persisted for time periods ranging from 20 minutes to a full day preventing ore boats from docking and loading. During the April storm these winds caused ore boats to crash up against docks, causing damage to both the boats and docks.
- In November 1958, 35-75 mph winds gusted for 8 hours, downing power lines, poles, trees, branches, telephone poles and fencing. High waves halted shipping traffic in the Duluth-Superior Harbor.
- In May 1959, 45-93 mph winds gusted for 24 hours. Glass blew out of windows, tree limbs fell onto houses and streets and power lines, poles and telephone poles were blown down. Marine advisories were issued for Duluth-Superior Harbor shipping activity, forcing ships to anchor out in the lake as opposed to maneuvering through the entries and bay. Tugboats were not able to control the big ships against wind forces.
- In November 1960, 73 mph gusts lasted 24 hours, creating waves that washed out Quebec Pier. Driving sleet damaged power lines, causing power outages, damage to loose building trim and interruption to telephone service.

Predictability & Probability

Wind may be predicted with reasonable notice using meteorological techniques to determine likely intensity and duration. Based on the last 60 years of recorded wind events, there is a 5% probability of having a significant (>72mph) wind event in any given year.

Table 5.1 Wind Events in the City of Superior			
Date	**Velocity (average)**	**Gusts (mph max)**	**Duration (hours)**
March 13, 1943	45	45	72
October 10, 1949	95	102	0.5
April 25, 1953	35	48	12
May 1, 1953	33	55	24
May 4, 1955	30	82	12
November 17, 1958	35	75	8
May 11, 1959	45	93	24
November 28, 1960	73	73	24
July 30, 1973	55	55	12
September 11, 1978	30	49	36
June 21, 1986	74	74	12
March 23, 1991	40	40	24
July 21, 1996	53	53	12
June 22, 1999	50	50	12
July 23, 1999	52	52	12
August 14, 2000	50	50	12
August 8, 2001	50	50	12
July 19, 2003	55	55	12

Vulnerability Assessment

Assessing the vulnerability of the City of Superior to coastal hazards is impaired by the lack of data organized into floodplain analysis. Data compiled by the NFIP in 1977 has not been updated. The following vulnerability analysis was conducted using the most current and complete data available from the United States Army Corps of Engineers – Detroit District, National Oceanic and Atmospheric Administration, the National Flood Insurance Study of 1977, and data on record with Douglas County and the City of Superior.

Industries, docks, wharfs, grain elevators, railroad yards and other non-residential structures dominate the northern tip and northeastern edge of the City of Superior along St. Louis Bay. Billings Park and the Superior Municipal Forest lie at the edge of St. Louis Bay and include Pokegama, Kimball's and other smaller bays. Barker's Island Marina, the S.S. Meteor Maritime Museum, public parks and trails, Burlington Northern Ore Docks and Connor's Point Industrial Park are examples of developments adjacent to Superior Bay that may be vulnerable to coastal hazards.

Residential Properties

The Billings Park area, located on the western edge of the City of Superior north of St. Louis Bay, includes homes vulnerable to coastal erosion from long-term effects of coastal

water processes on shoreline bluffs. Similar damage has already been seen upstream along the St. Louis River in Oliver Township, where homes have been in danger of slipping into the river. Billings Park coastal homes are situated in bays, which offer some protection from erosion, but this simply prolongs the process, not prevents it.

Given an average erosion rate of one (1) foot per year in the Great Lakes (*Evaluation of Erosion Hazards, April 2000, Heinz Center for Science, Economics and the Environment*), the average home (situated 100 feet from a bluff or bank) could have approximately 100 years before the edge of the bluff or bank reached the front door. In Billings Park, however, hazards lie in the specific erosive processes acting on the bluffs. Since the bluffs are made up of more than 100 feet of unconsolidated clay till, they are prone to undercutting, where erosion from water activity occurs mainly at the base of the bluff. Undercutting weakens the structural capacity of the bluff and can cause major landslides. Storm surges, high lake levels and seiche events can whittle away at the base of the bluff faster than may seem apparent from the top of the bluff.

Commercial & Industrial

The shipping industry suffers the greatest risks from coastal hazards affecting the City of Superior and the Duluth-Superior Harbor. This includes risks from fluctuating lake levels, seiche events, erosion and wind. The Port handles 36.5 million metric tons of cargo, 90% of which is coal, iron ore and grain. The remainder includes wood products. Details of the history, economic structure and land use planning for Superior's Port are found in Superior's Port Plan, developed by the Arrowhead Regional Development Commission-Metropolitan Interstate Committee.

Man-made piers and docks in this area protect harbor properties from coastal erosion processes. Corrugated steel, concrete, and/or wood piling and retention structures and riprap retain the mostly man-made piers, docks and equipment that make up the Superior Port facilities. Most facilities were created from sand material dredged from the shipping channels when the harbor area was created in the late 1800s and early 1900s. Ship propellers greatly influence the wear and tear on these structures.

The slow breakdown of erosion control structures has led to problems for both ship and dock operations. Some facilities use routine dredging to maintain 30' depths at docks. Erosion control structures are made from wood or steel material and, over time, have degraded to the point that maintenance or replacement has become necessary at many facilities. Midwest Energy Company, located at the north end of the City at St. Louis Bay, has sediment retention structures made from steel. The company has recently invested millions of dollars in upgrading and repairing failing retention structures.

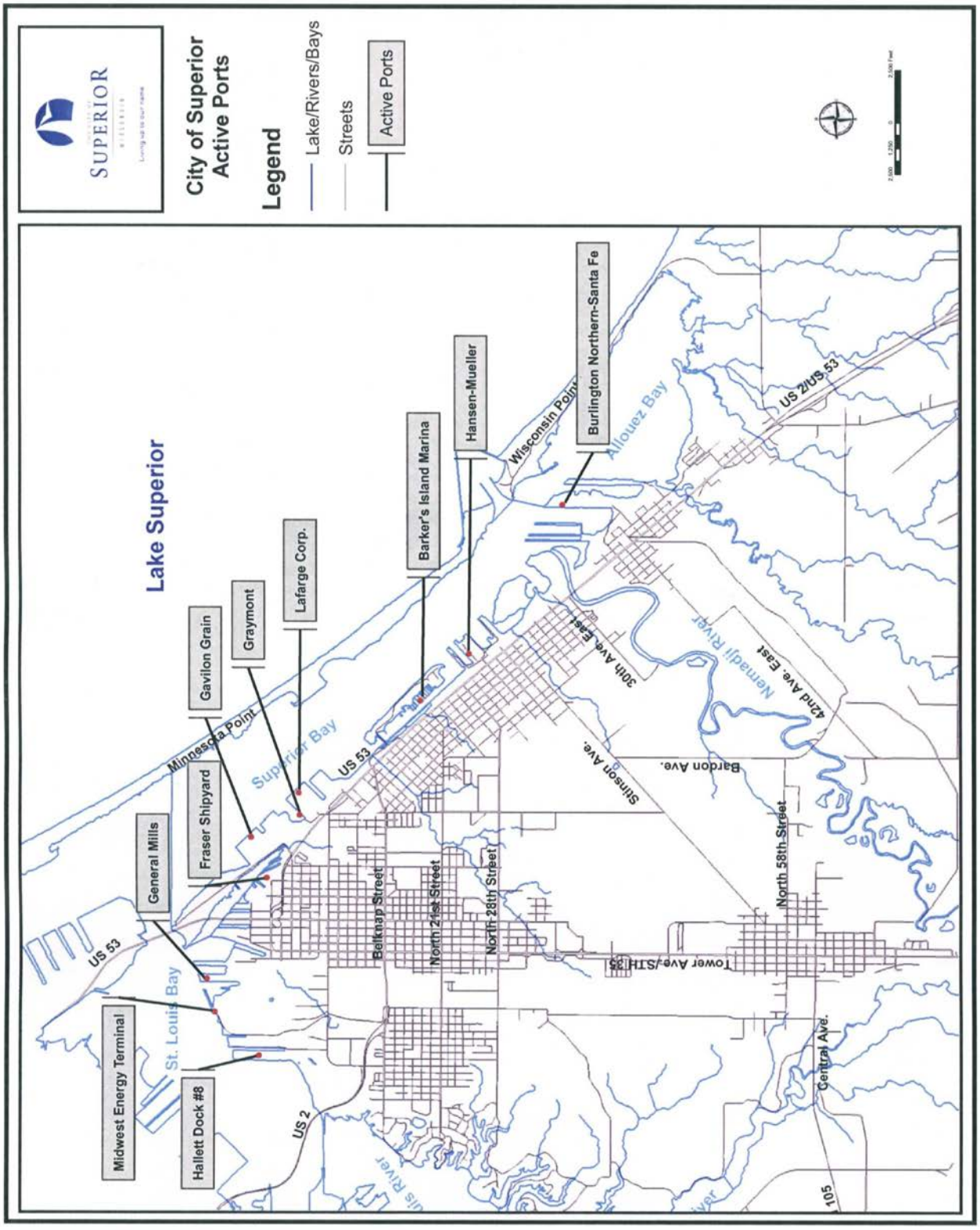
During years of low lake levels, many marinas throughout the Lake Superior region spent anywhere from $100,000 to more than $1 million on dredging operations in order to keep their docks operational. Commercial loading docks invested additional funding for maintaining or increasing the depth at their docks to accommodate ships during low lake level years. The Great Lakes shipping industry was forced to reduce loads by 15% or more, increasing the number of trips and associated fuel costs and then passing these

costs on to the receiver. The shipping season was prolonged, however, due to little or no ice cover during those winters. The dredging industry boomed during this time, working hard to keep shipping channels, ferry routes and marinas clear for use.

Table 5.2 City of Superior Active Cargo Dock Operators

Company	Cargo	# Employees
Hansen-Mueller	Grain	5
Lafarge Corporation	Cement	6
Hallett Dock Company	Various	14
General Mills	Grain	25
Gavilon Grain LLC	Grain	27
Graymont	Limestone	50
Cenex Harvest States	Grain	55
Midwest Resources Energy Company	Coal	71
Burlington Northern-Santa Fe	Taconite	80
Fraser Shipyards	Various	40-150

Map 5.1: City of Superior Locations of Active Ports



The Superior Entry is a natural break in the sand bars between Minnesota and Wisconsin points. The Army Corps of Engineers took over maintenance of the entry in 1878. In the early 1900's, an arrowhead shaped backwater was constructed of steel pile and rubble beyond the north and south concrete piers, already in place. The original piers left ships vulnerable to wind and waves. This backwater provides a still area for ships to safely pass through the Superior Entry.

Roughly 15% of the Port's shipping traffic uses the Superior Entry along with a number of recreational and sport boats which patronize Barker's Island Marina. Approximately 90-95% of ships using the Superior Entry are destined for the Burlington Northern-Santa Fe (BNSF) taconite loading docks. The remaining ships may be destined for the Fraser Shipyard or other docks along Superior Bay, including Quebec Pier, home of Hansen-Mueller, Graymont, Sivertson Fisheries and Lafarge Corp.

Ships may alternatively use the Duluth, Minnesota entry to access Superior's docks. Superior's docks, located along St. Louis Bay and the northern tip of the City (near Interstate 535), include Midwest Energy Resources, General Mills (Superior Annex) and Hallett Dock Co. #8. Docks in Howard Bay, which are accessible from St. Louis Bay, include Gavilon Grain LLC, Cenex-Harvest States, Fraser Shipyards and Superior-Lidgerwood-Mundy Corp.

Operations at the BNSF railroad and dock facility in the Allouez neighborhood of East Superior are vulnerable to high winds. Aerial conveyor belts that transport taconite from storage areas to the loading dock are elevated above the yards and over Highway 2 (East 2nd Street) and the neighborhood of Allouez, where several homes are located. These structures are monitored by remote sensors that measure wind speeds at the level of operation. When wind speeds reach 50 mph, operation automatically shuts down and an alarm sounds. When this occurs, the equipment, including stackers raised high in the air, are locked down and braced against the prevailing winds, thus protecting the equipment and other property around it.

Ships arriving and exiting the Duluth-Superior Harbor through either the Duluth Ship Canal or the Superior Entry must prepare for high wind conditions inside and outside the harbor. Many ships will anchor outside either entry to wait out a storm, rather than trying to maneuver through the narrow entries. Port facilities may also advise ships against attempting to load during high winds to prevent damage to docks and loading equipment. Ships may also choose to remain tied off to a dock until winds subside, rather than depart during a windstorm. These actions are generally determined by the ship's captain rather than by the Port facility.

While many of the docking facilities and Port equipment are located along the northern tip and northeastern facing edge of the City, these structures are placed and engineered with winds in mind. For example, the BNSF Allouez docks are aligned with the prevailing northeasterly winter winds.

The Barker's Island Marina is a private, pleasure craft facility with floating slips available for recreational vessels. Construction of the Harbor began in 1978 and was opened in 1980. Twenty years after its initial construction, a survey by the City found that the harbor had sustained its original depth and suffered minimal erosion. Even through periods of extremely low water, Barker's Island maintained an 8-foot clearance without clearance problems, has not closed portions of the facility due to low water, or needed to dredge this facility. Rock rip-rap buffers the shore from ice push. The location of the harbor behind Minnesota Point, shelters boats and the facility from wind, waves, changing lake levels and coastal storm surges. Thus, problems related to weather are very few and far between.

To avoid damage from winds, boats in dry storage are usually aligned with the northeasterly winds that are common during winter storms. The marina has withstood storms involving winds in excess of 70 mph with little to no damage to its facilities or moored vessels. In an isolated incident, one vessel in dry storage was knocked off its cradle during severe straight-line winds. During an isolated incident in 1997, severe winter gales pushed new ice against the dock facility, causing damage to the dock. Docks are pulled away from the shore during the winter to prevent damage from ice push.

Boaters using the marina can check with staff for weather information, though many vessels are equipped with on-board radios to get weather and Coast Guard information and advisories. Boaters may leave a float plan with the harbormaster.

Parks & Recreation

The City has extensive parks and recreation developments, including neighborhood parks, boat launch facilities, waterfront and riverfront trails, open space corridors and sports and athletic facilities. Many of these developments enhance public access to Lake Superior.

City parks and recreational facilities along coastal areas include the Superior Municipal Forest, an outdoor classroom located within the Superior Municipal Forest, Billings Park, Arrowhead Fishing Pier, Harbor View Park, Osaugie Trail, Rotary Pavilion, Hog Island Special Use Area, Loon's Foot Landing Public Boat Launch, and Wisconsin Point Open Space. Barker's Island includes the S.S. Meteor Museum, a play area, a fountain and pond, green space, a public boat launch, tennis courts and a designated swimming area. Details of these facilities can be found in the City of Superior Master Park Plan (January 2001).

Swimming

There are a few designated swimming areas controlled by the Superior Parks and Recreation Division of Public Works. Swimming is permitted at Wisconsin Point. Hazards may exist, however, as many incidents have occurred along the lakeside of Minnesota Point. Rip currents are known to occur along Minnesota Point and have caused drownings. Rip currents may also occur along Wisconsin Point, as high winds have created similar current effects that can complicate swimmers' efforts to get back to

shore. Rip currents have not been investigated for Wisconsin Point or other areas around Superior.

One area on the west side of Barker's Island is designated for swimming, while areas to the north, south, and east side are posted against any swimming activity. Several deaths and one critical injury have been recorded at the north end and east (channel) side of the island. These hazards may be attributed to the turbulent water conditions along the channel when ships are passing through or to unpredictable current conditions below the surface of the water. Exact causes for the hazards and drownings are unknown.

Wastewater Treatment Facility
The only critical facility located along the coastal areas of the City is the Municipal Wastewater Treatment Plant. There are two plants co-located along Superior Bay including the main plant and the combined sewer treatment plant #2 (CSTP #2). Rip-rap is used to control erosion around the CSTP basin between the main treatment plant and Superior Bay. The remainder of the plant is set at a distance far enough inland to protect the majority of the system from moderate coastal hazards, including high lake levels. Pipes carry treated water from the plant into Superior Bay.

Natural Resources
Lake and shoreline ecosystems do not tend to be damaged from high and low lake levels, due to their dynamic nature. Some actually thrive. Research on the fishing industry revealed little impact on fish populations, since fish move out to deeper water or stay put depending on the lake level. Fish spawning habitat may show a slight negative impact when spawning grounds near shore are unsuitable, but current research does not show impact for the short (<5 year) term. Many plant systems thrive on variable lake level situations as it provides opportunity for submerged and buried seeds of aquatic and emergent plants to become exposed, initiating germination. Low water levels can impact major resting and feeding areas as well as nesting areas for migrating ducks, geese, swans and other waterfowl.

Wisconsin Point
There are two buildings and additional outbuildings owned by United States Coast Guard and the United States Navy, as well as public roadways and the Annishinabe Native American burial site on Wisconsin Point that may be threatened by coastal processes.

Loss and Replacement Estimates

Areas exposed to Lake Superior along Wisconsin Point and the south shore of Lake Superior includes undeveloped, vacant properties owned by the United States Navy, City of Superior, Douglas County and the State of Wisconsin. Much of the land bordering St. Louis, Superior and Allouez bays is privately owned for either commercial or residential use. Although many improved residential lots border St. Louis and Superior bay, most of these parcels are not developed or otherwise improved. Erosion may be the greatest coastal threat to structures and property values. For tax-exempt properties, including city,

county, state, and federal land, a general value of $1,000 per acre was established by the City Assessor. This value applies to both improved and unimproved parcels.

Based on the low probability of any of the discussed coastal hazard events occurring in the City and the extent of damage experienced during previous events, the damage from a significant future event may result in a structural loss of approximately 10% of the current improvement value. Additionally, damages could result in approximately 5% or more loss of land value, due to erosion caused by coastal events. This potential damage would total approximately $6.4 million to structures and $1.2 million to land value.

Landslides in coastal areas, which have not yet occurred in the City, may pose larger potential losses, as homes may sustain a higher percent of damage and the property may have to be completely mitigated to prevent further loss. If the City were forced to mitigate 25% of coastal homes, the potential loss of structure and land would be approximately $8.5 million.

Map 5.2 shows the land classification of parcels within 50 feet of the coastline.

Map 5.2: City of Superior Coastal Areas & Parcel Land/Ownership Classification

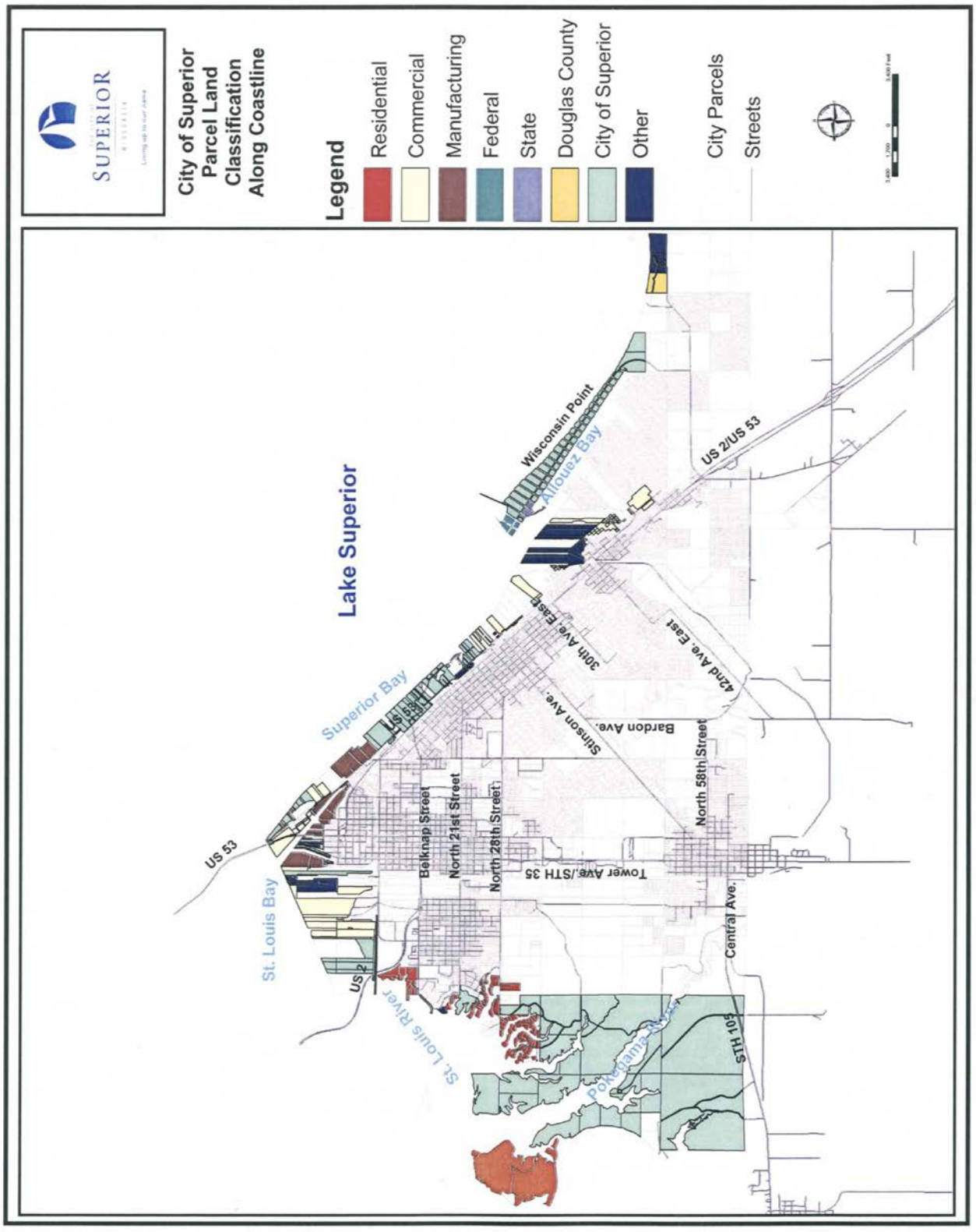


Table 5.3 City of Superior Value of Coastal Properties

Parcel Land Classification	Total Parcels	Acreage	Land Value	Improvement Value	Total Value
Residential	172	251	$14,139,800	$43,106,400	$57,246,200
Commercial	94	544	$37,704,500	$139,890,300	$177,594,800
Manufacturing	25	170	$88,600	$1,324,300	$1,412,900
Federal	4	20	n/a	n/a	n/a
State	10	15	n/a	n/a	n/a
County	38	426	n/a	n/a	n/a
City	143	2770	$3,384,000	n/a	n/a
Other	26	177	n/a	n/a	n/a

Source: City of Superior's GIS data of parcels located within 50 feet of coastline.

Commercial Property

There are 25 manufacturing parcels totaling 170 acres and 94 commercial parcels totaling 544 acres in coastal areas of the City. The Duluth-Superior Harbor reported a total economic impact for the two cities over $200 million and 2,000+ jobs in 2011. Most are located at the northern point of the City at or near the Duluth-Superior Harbor and include Great Lakes shipping docks, grain elevators, railroad transport operations and materials holding facilities. The economic impact of Barker's Island Inn and Marina totals almost $4 million annually, including an estimated $500,000 each in local expenditures and payroll and 80% +/- of its business comes from out-of-town visitors.

The slow breakdown of the erosion control structures at Port facilities can lead to problems for both ship and dock operations. Some operations use routine dredging to maintain 30' depths at docks. Costs for dredging in the Duluth-Superior Harbor are roughly $7.55 per cubic yard plus an additional $3.50 for use of the Army Corps of Engineers confined disposal facility.

Residential Property

The Heinz Center for Science, Economics, and the Environment estimates annual erosion losses for structures averaging over 500 feet on a Great Lakes coastal bluff in Wisconsin at $0.08 per $100 of structure value. This would mean $156 in damages every year for the average $195,000 home in Billings Park. The Heinz Center also compiled data showing that homes closer to vulnerable shorelines are worth less than homes further away from the shore.

The annual cost of erosion is the sum of the expected annual damage to structures plus the loss of land. Damage reimbursement by programs including the NFIP applies to structures only, not to land. Erosion is one of the few hazards that affect not only the structures built on land, but also the land itself.

A coastal edge of the Billings Park area, located along the western edge of the City above St. Louis Bay, is residentially populated with about 80 middle- to upper-class homes

valued between $89,000 and $600,000. Many homes are near the bluff overlooking the St. Louis River and have private docks and outbuildings. These homes are vulnerable to erosion from long-term effects of coastal water processes and heavy rain induced landslides. Similar damage has been seen upstream along the St. Louis River in Oliver Township.

These coastal homes are mostly situated in protected bays, which offer some shelter from erosive activity occurring in St. Louis Bay. This protection does not prevent erosion, but may prolong the process. Additional homes, valued between $100,000 and $300,000 are located just north of Billings Park Proper along the coast of St. Louis Bay. These, too, are situated on bluffs overlooking the bay and are vulnerable to the same erosive elements.

The southeastern end of Barker's Island has been parceled for private, residential development. Homes average approximately $374,500 and are situated approximately 30 to 75 feet from the sandy shore. Since 2010, an additional 3 acres of land at this location is under residential development.