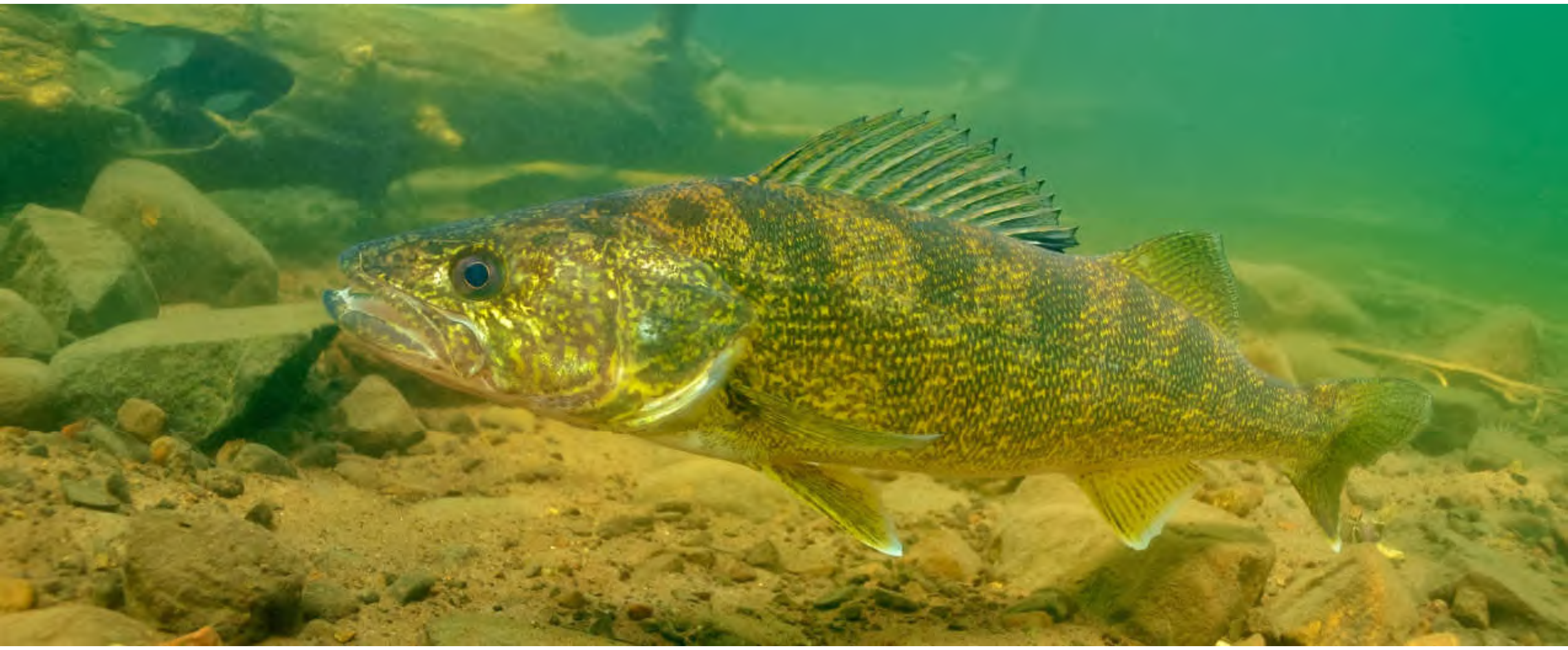

Saginaw Bay Reef Feasibility Study

February 2022
ECT No. 200654

Prepared for:
National Fish and Wildlife Foundation

On Behalf of:
Michigan Department of Natural Resources

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February 15, 2022
Date

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°F	degree Fahrenheit
µg/m3	microgram per cubic meter
µg/kg	microgram per kilogram
µS/cm	microsiemens per centimeter
ACOE	U.S. Army Corps of Engineers
BOD	Biological oxygen demand
BUI	Beneficial Use Impairment
CDF	Confined Disposal Facility
DO	Dissolved oxygen
ECT	Environmental Consulting & Technology, Inc.
EGLE	Michigan Department of Environment, Great Lakes and Energy
EPA	U.S. Environmental Protection Agency
Ft	Foot
GSD	Geological Services Division
GSS	Geological Services Section
mg/L	milligram per liter
MDNR	Michigan Department of Natural Resources
ORP	Oxidation reduction potential
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated byphenyl
pg/g	picogram per gram
RRD	Remediation and Redevelopment Division
SWAN	Simulating Waves Nearshore (Computer Model)
TEF	Toxic Equivalency Factor
TEQ	Toxic Equivalency
WRD	Water Resource Division

1.0 Executive Summary

1.1 Introduction

The primary objective of the Saginaw Bay Reef Feasibility Study was to determine if creation of a near-shore reef system near the mouth of the Kawkawlin River outlet in Saginaw Bay is feasible to help relieve flooding, sedimentation, and erosion for the shoreline communities. In addition, project partners were hopeful to better understand sedimentation patterns and potential reef improvements for fisheries and avian habitat improvement areas in Saginaw Bay near the mouth of the Kawkawlin River.

This report documents the need for this study, data collection and analysis results, and conclusions/findings agreed upon by project partners outlining the proposed way forward. The study included several key aspects to best understand the feasibility of a potential reef system in Saginaw Bay.

1.2 Background

Bangor Township, Michigan is coastal community located on Saginaw Bay that has been perpetually plagued with excessive flooding, sedimentation, and loss of aquatic habitat. The community is built around the Kawkawlin River, which outlets into Saginaw Bay. Due to excessive sedimentation and wind/wave backwater flooding, the river is extremely flashy and floods regularly during storm events. This flooding in the upland agricultural fields has created a perpetual loss of property and land for the community and contributed to the loss of critical reef habitat within the inner Saginaw Bay to support the fisheries. This study takes an innovative approach to creating a multi-functioning reef and changing thinking on how we can best protect coastal communities for years to come. The long-term project goals are to:

- Reduce sediment accumulation in the Kawkawlin River flood control channel by reducing wave action in the channel's vicinity,
- Reduce the occurrence of coastal flooding by creating reefs and restoring wetlands in a way that works with the natural water and sediment flows,
- Restore critical reef habitat for aquatic and avian wildlife.

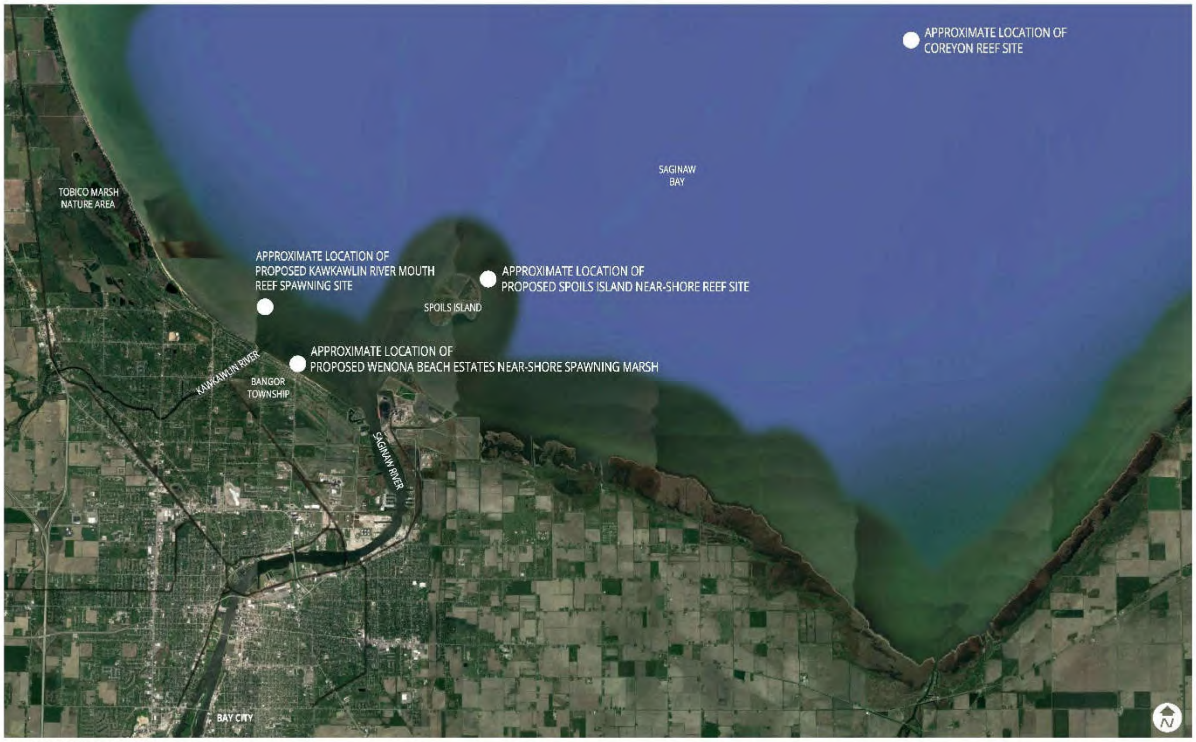


Figure 1-1. Site Vicinity Map – General Location of Proposed Reef System and Vicinity to Existing Coreyon Reef Restoration Location

Historically, inner Saginaw Bay contained reef habitat that provided important spawning habitat for many native species, including Walleye and Lake Whitefish. This was supported by reproduction in the watershed's rivers and on offshore reefs until the habitat degradation due to increased sedimentation from upland agriculture. The fish habitat health of the Bay continued to decline leading to the entire bay being listed as an Area of Concern due to loss of habitat and fish populations. Over the past 40 years, stakeholders have worked to begin restoring the lost habitat and fisheries populations through works of improvement around the bay. Stakeholders in the Bay area have performed data collection efforts to study Saginaw Bay in determining the best location for two reefs set for restoration; one near-shore and one off-shore. The off-shore Coreyon Reef project construction was completed in fall of 2019 by partners including the State of Michigan and local stakeholders (Figure 1-1). The goal of this proposed study is to help identify the feasibility of the near-shore reef location best suited to habitat conditions, as well as to best achieve additional coastal flood mitigation and shoreline protection goals.

1.3 Data Collection and Analysis

Data collection needs were identified by the project team to support outcomes for the feasibility study. Effort included bathymetric mapping, sediment sampling and porewater sampling. The project team findings and data collection summary includes:

- Over 10 square miles of bathymetric data – produced mapping and hardness data to inform proposed reef locations given water depth and slope.
- 50 sediment samples – data provided sediment/water depth and composition, and laboratory analysis of any potential contaminants present given the historical issues within the near-shore regions of the Bay from industrial sources.
- 39 porewater samples – laboratory analysis of porewater samples indicated the most suitable reef locations given measurable biological oxygen demand (BOD) concentrations.

All above data collection efforts and analysis helped inform and support this study and its proposed conclusions.

1.4 Hydrodynamic and Coastal Modeling

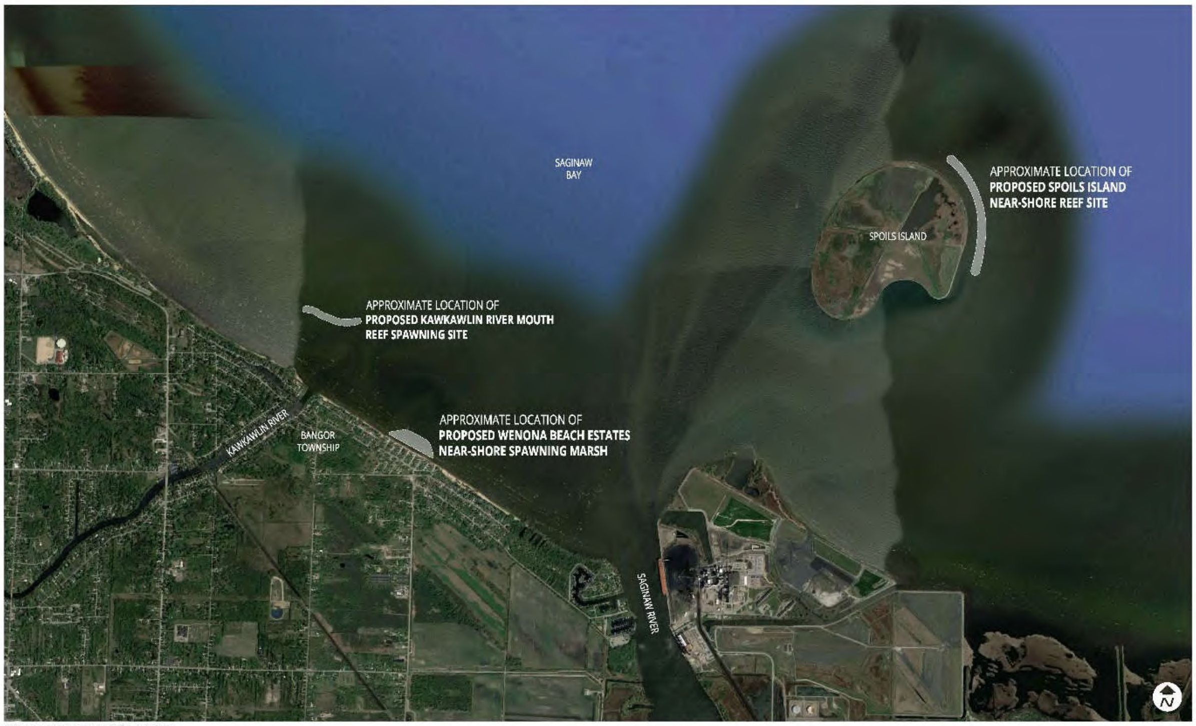
Modeling efforts were necessary to evaluate potential sediment resuspension and estimate coastal sediment transport to fully evaluate proposed reef locations. The wind-wave model identified highest sediment resuspension areas for consideration to ensure excess sedimentation would not degrade a proposed reef over time. Sediment transport modeling indicated that long-shore sediment could be reduced, while littoral transport is still a contributor and should be monitored by local stakeholders.

1.5 Recommendations and Conclusions

Findings of this feasibility study support final design of a 3-reef system located as shown in Figure 1-2. A summary of the three proposed reefs and benefits of each are as follows:

1. Proposed Kawkawlin River Mouth Reef Spawning Site
    a. Reduction in backwater wind/wave flood occurrence for coastal properties
    b. Near-shore rock reef restoration for improved fish spawning habitat
    c. Reduction in long-shore sediment accumulation at the mouth of the Kawkawlin River
    d. Reduced shoreline erosion caused by flood and receding waters
2. Proposed Spoils Island Near-shore Reef Site
    a. Rock reef restoration for improved fish spawning habitat
    b. Improved off-shore avian habitat conditions

3. Proposed Wenona Beach Estates Near-shore Spawning Marsh
    a. Reduction in coastal flooding of near-shore properties
    b. Near-shore marsh restoration for fish spawning habitat
    c. Reduced shoreline erosion caused by flood and receding waters



SITE LOCATION MAP
NOT TO SCALE

Figure 1-2. Site Location Map of Proposed 3-Reef System in Saginaw Bay

While originally envisioned as a single near-shore reef study, project partners expanded the scope of this study to include a reef systems approach with the goal of maximizing project outcomes. This 3-reef system restoration project will serve as a demonstration project that will help to inform future reef restoration efforts throughout the Great Lakes, including continued restoration in the Bay. The hope will be to continue studying these fish spawning habitat structures closely into the future with additional funding opportunities post-construction.

The project team recognizes several final design and post-implementation considerations include:

- Long-term reef maintenance - ensure sustainability and future habitat quality.
- Fish population and sedimentation monitoring – better understand success of the different habitat implementation types and any possible connection to sedimentation issues.
- Wet weather data and flooding instances analysis – identify correlation to enhanced coastal resiliency.

The above information will help better understand long-term project success and further inform future efforts. Understanding Saginaw Bay's historical sedimentation and contaminant loading concerns, the fisheries are anticipated to continue improving with implementation of this important project.

2.0 Background

Saginaw Bay is a large embayment of Lake Huron with a surface area of 2,960 square kilometers extending from the mouth of the Saginaw River to an imaginary line extending from Au Sable Point on the western shore to Point Aux Barques on the eastern shore. The entire bay was listed as an Area of Concern in 1987 under the Great Lakes Binational Water Quality Agreement due to Beneficial Use Impairments (BUIs), including “Degradation or Loss of Fish and Wildlife Habitat” and “Degradation or Loss of Fish and Wildlife Populations”. Eutrophication and sedimentation had severely degraded aquatic habitat in the bay, especially spawning reef habitat. The *Saginaw River/Bay Area of Concern Habitat Restoration Plan* identified two primary reasons for the fish and wildlife habitat and population BUIs: 1) Decline in populations of key recreational and commercial fisheries due to low dissolved oxygen from nutrient enrichment in the Saginaw Bay and 2) Loss and degradation of fish spawning areas in the bay and tributaries from sedimentation and decreased access to spawning areas when tributaries were dammed. Saginaw Bay once contained honeycombed rock reefs throughout the inner bay. These reefs were valuable spawning and nursery areas of important recreational and commercial fisheries, including walleye. Drainage and agriculture in the watershed caused vast amounts of sediment and nutrients to be washed into the bay, covering rock reefs and causing eutrophic conditions. Resulting habitat degradation led to the collapse of the walleye fishery in the 1940s and other fish stocks.

Led by the Saginaw River/Bay Public Advisory Council, known as the Partnership for the Saginaw Bay Watershed (the Partnership), significant efforts have been made in the last three decades to address water quality and habitat degradation in Saginaw Bay. For example, the 2002 Remedial Action Plan Update (PSC, 2002) states that between 1988 and 2002, two-thirds of the original 101 recommendations from the 1998 Remedial Action Plan have been at least partially completed. More than $170 million had been expended over a ten-year period to accomplish that progress. In addition, municipalities in the watershed had expended $700 million between 1972 and 2002 to address infrastructure upgrades and water quality. Efforts as of 2002 had achieved an estimated 80 to 90 percent reduction in phosphorous loads to Saginaw Bay. Similar efforts to delist Beneficial Use Impairments in the Area of Concern have continued to this date, paving the way for restoration of fish and wildlife habitat and populations.

In 2004, the Michigan Department of Natural Resources (MDNR) Fisheries Division published a Fisheries Special Report addressing options for completing the recovery of walleye in Saginaw Bay (Fielder and Baker, 2004). In that report, MDNR published the following findings:

> "The walleye population of Saginaw Bay is not fully recovered or is at least not functioning at the full capacity of the adult habitat and prey base."
>
> And,
>
> "The current situation (walleye population existing below carrying capacity; heavily dependent on stocking; and an ecologically unbalanced bay ecosystem) is unacceptable and further management initiatives are required to reach full recovery."

The 2004 MDNR recovery plan identified several reasons why the walleye population had not yet reached carrying capacity or full recovery in Saginaw Bay despites huge improvements since the 1944 population crash, noting that, in general, walleye recovery is recruitment limited. That is, natural reproduction was deemed insufficient to meet walleye recovery goals. MDNR further noted that limitations in recruitment were driven by habitat. While the vast majority of walleye reproduction occurs in tributary rivers, several fish passage barriers in the watershed limit access to suitable spawning habitat in the major tributaries. Saginaw Bay historically had extensive rock reef habitat that once contributed to walleye recruitment in the Bay. MDNR noted that historic reef habitat has been buried by sediment or degraded to the point that reef spawning it no longer contributes significantly to walleye recruitment. To address the recruitment issues in Saginaw Bay, MDNR identified several objectives including the following:

- "To increase abundance of walleyes in Saginaw Bay to the carrying capacity of the adult habitat."
- "To achieve a balance in predator/prey ratios in Saginaw Bay with walleye functioning as the principle predator."
- "For the above walleye population to be self-sustaining."

The last objective is important and extremely pertinent to this Feasibility Study. From a fisheries sustainability perspective, it is critically important that habitat is improved to the extent it can support self-sustaining populations without supplemental stocking. Only habitat improvements will ensure that walleye and other Great Lakes fish populations of Saginaw Bay will be resilient enough to sustain themselves through changes in climate and other external pressures and help society maintain healthy stocks that allow commercial and recreational harvest without jeopardizing fish stocks.

Unfortunately, much of the historic reef spawning habitat of Saginaw Bay may not be recoverable. Reef reclamation may be possible, but no technologies have been developed yet to cost-effectively reclaim reef habitat at large scales. MDNR notes that, while recovery of the original reef habitat may not be possible, increases of reef spawning habitat in the Bay could add an element of diversity to walleye recruitment that is important to making the population more resilient and, therefore, self-sustaining. In addition, MDNR noted that construction of reef habitat (in addition to the potential for reclamation) may be able to restore at least some of the reef spawning potential of Saginaw Bay, noting that there is a precedent for reef construction in the Great Lakes and inland lakes of Michigan. Several case studies are now available in the State of Michigan to support further efforts to design and construct reef habitat that is successfully used by target fish species for spawning. Such case studies include Saginaw Bay and the recent construction of 2 acres of reef on the historic Coreyon Reef. The Coreyon Reef project (Saginaw Bay Reef | Michigan Sea Grant) was designed using information obtained from other reef case studies throughout the Great Lakes. Construction was completed in 2019 following multiple years of study by MDNR in partnership with other organizations and Purdue University. Post-construction monitoring and evaluations are just being concluded; findings should be published some time in 2022.

2.1 Kawkawlin River Recreational Boating Channel

Recreational boating in the lower Kawkawlin River is popular and the lower Kawkawlin River provides access to Saginaw Bay for recreational vessels for both residents along the river and for the public using public and fee-based launches along the river. A recreational boating channel was constructed to facilitate recreational boat access to Saginaw Bay. The channel is maintained by Bangor Township with assistance from the Kawkawlin River Watershed Association. However, sedimentation of the channel impacts its usefulness and increases maintenance costs. Though the majority of sediment comes from the Kawkawlin River watershed, part of the sediment that fills the channel comes from long-shore current transport along the shoreline of Saginaw Bay. Creating sustainable communities and recreation along the Great Lakes shorelines will require addressing impacts to recreational facilities like the recreational boating channel and reducing the cost of maintaining them. Several efforts are under way throughout the watershed to reduce sediment loading from the watershed. This feasibility study investigates the potential of creating a near-shore walleye spawning reef that can also reduce long-shore current transport of sediment into the recreational boating channel.

2.2 Spoils Island

Spoils Island is a man-made "island" constructed by the U.S. Army Corps of Engineers (ACOE). It is a prominent feature of the bay located 1.5 miles northeast off the Saginaw River mouth and lying along the east edge of the Saginaw River shipping channel. It is a Confined Disposal Facility (CDF) that has been used by the ACOE for the disposal of shipping channel dredge spoils. While not technically a true island or natural feature of the bay, it has become known locally as Spoil Island and is a permanent feature of the Bay. Its construction essentially forms an offshore island with a shoreline comprised primarily of riprap and surrounding shallow water areas. Though artificial, the shoreline presents the potential opportunity to construct a near-shore walleye spawning reef in shallow water off its shores where conflict with recreational boating should be minimal. The area around Spoil Island was studied to determine if suitable conditions were present for adding near-shore fish spawning reef habitat.

2.3 Wenona Beach Estates

Wenona Beach Estates is a small residential neighborhood located along the southwest shoreline of Saginaw Bay and southeast of the Kawkawlin River mouth. This Great Lakes shoreline neighborhood exemplifies many of the residential communities along the shorelines of the Great Lakes that are threatened by flooding and shoreline erosion, especially in the face of climate changes and high Great Lakes water levels. More importantly, it presents a case where existing coastal wetlands provide shoreline protection while further loss of coastal wetlands could exacerbate threats to the shoreline community. Making such Great Lakes shoreline communities more resilient in the face of climate changes is important for their long-term viability and prosperity. At the same time coastal wetlands provide protection to shorelines, those wetlands also provide important fish spawning and nursery habitat and wildlife habitat. Therefore, restoring and protecting the remaining coastal wetlands off the shoreline at Wenona Beach Estates will make that Great Lakes shoreline community more resilient and provide critically important fish and wildlife habitat. This feasibility study looked at potential loss of the remaining coastal wetlands and potential outcomes of restoring and protecting them. Like spawning reefs provide spawning habitat for some native Great Lakes fish species, spawning marshes provide spawning habitat for other native Great lakes fish species such as Yellow Perch and Northern Pike.

3.0 Data Collection and Analysis

Bathymetric mapping, sediment sampling, and porewater sampling were conducted to support this feasibility study as described in the following sections. EGLE Bathymetric Investigation memorandum methods, procedures, and results/data are presented in Appendix B.

3.1 Bathymetric Data

Bathymetric mapping was conducted by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) Geological Services Section (GSS) of the Remediation and Redevelopment Division (RRD) using boat-mounted GPS and single-point and multi-beam sonar equipment. The bathymetric data were used to update an existing wind-wave model (Section 4.1) and to support the study of potential reef sites. In addition, the sounding data were used to infer relative sediment hardness, which also used to study potential reef sites as discussed in Section 4.0.

3.2 Sediment Quality Data

Sediment samples were collected by EGLE-GSS to analyze sediment quality in the study area. Ten sediment samples were collected for particle size analysis and 50 sediment samples (47 sample locations plus three duplicate samples) were collected for laboratory analysis of parameters presented in the EGLE Water Resources Division Policy and Procedure WRD-048, Sediment Testing for Dredging Projects, dated April 13, 2018 (WRD-048). Barium and silver were also included for metals analysis. A discussion of the results is presented below. Sediment sample locations are depicted on Figure 3 and Figure 4 of Appendix B. Data show that sediments in the vicinity of the proposed project locations is sufficiently high quality and the sites would be suitable habitat in this regard.

Sediment particle size analysis on the ten samples shows that the sediments sampled were consistently comprised of sand-size particles. The sand fraction ranged from 39 to 96 percent sand-size particles. However, all but two of the seven samples were greater than 76 percent sand. Correspondingly, the fine fraction was typically low, ranging from 0.1 to 57.5 percent, but five the seven samples ranged from 0.1 to 20.5 percent fines. Samples A181 and A242 contained the highest percent fines. Sample A181 was collected northeast of the Kawkawlin River mouth. Sample A242 was collected southeast of Spoils Island.

All 50 sediment samples reported concentrations of metals either above the laboratory reporting limit or below the laboratory reporting limit but greater than or equal to the method detection limit. The metals that were reported below the laboratory reporting limit but greater than or equal to the method detection limit had a data qualifier that noted the concentration is an approximate value. All of the detected/approximated concentrations of metals were reported below the Aquatic Life and Wildlife Screening Guidelines from Table 2 of WRD-048. It should be noted that there are no Aquatic Life and Wildlife Screening Guidelines for barium or silver.

Four sediment samples, A133, A292, A2101, and A2112, reported concentrations of the polychlorinated biphenyl (PCB) Aroclor-1248 either above the laboratory reporting limit or below the laboratory reporting limit but greater than or equal to the method detection limit. The samples that were reported below the laboratory reporting limit but greater than or equal to the method detection limit had a data qualifier that noted the concentration is an approximate value. All remaining PCB parameters were reported non-detect (not detected at the reporting limit). The detected/approximated concentrations of Aroclor-1248 were reported below the Aquatic Life and Wildlife Screening Guidelines from Table 2 of WRD-048.

Concentrations of one or more polycyclic aromatic hydrocarbons (PAHs) were reported for 25 sediment samples (24 sample locations plus one duplicate sample). Each PAH parameter that was detected from the 25 samples contained a data qualifier that noted the result is less than the laboratory reporting limit but greater than or equal to the method detection limit and the concentration is an approximate value. All remaining PAH parameters were reported non-detect. The detected/approximated concentrations of PAHs were reported below the Aquatic Life and Wildlife Screening Guidelines from Table 2 of WRD-048.

All 50 sediment samples reported concentrations of one or more dioxins and furans either above the laboratory reporting limit or below the laboratory reporting limit but greater than or equal to the method detection limit. The parameters that were reported below the laboratory reporting limit but greater than or equal to the method detection limit had a data qualifier that noted the concentration is an approximate value. Additional data qualifiers included the compound being found in the blank and the sample; and the reported result is the estimated maximum possible concentration of the analyte, quantitated using the theoretical ion ration. The measure ion ratio does not meet qualitive identification criteria and indicates possible interference.

All 50 sediment samples reported the concentration of 2,3,7,8-TCDD Toxic Equivalency (TEQ) above the Aquatic Life and Wildlife Screening Guideline (0.00012 µg/kg or 0.12 pg/g) from Table 2 of WRD-048. Per the references in WRD-048, each of the reported concentrations of dioxins and furans is multiplied by the corresponding Toxic Equivalency Factor (TEF) of 2,3,7,8-TCDD and the values are added together for comparison to the Aquatic Life and Wildlife Screening Guideline. The TEQ values for 2,3,7,8-TCDD are included on Table 1 in Appendix B. The sediment sample locations that were reported above the Aquatic Life and Wildlife Screening Guideline are illustrated on the Figure 3 and Figure 4 in Appendix B.

All 50 sediment samples reported concentrations of phosphorus above the laboratory reporting limit. In addition to phosphorus, 31 sediment samples plus one duplicate sample were analyzed for phosphorus as phosphate and pentoxide. All of the samples reported concentrations of phosphorus as phosphate and pentoxide above the laboratory reporting limit. It should be noted that no Aquatic Life and Wildlife Screening Guidelines are presented for phosphorus on Table 2 of WRD-048.

3.3 Porewater Quality Data

Personnel from EGLE-GSS collected 39 porewater samples from the sediment core sample locations. The remaining eight sediment core sample locations did not produce sufficient quantities of porewater to facilitate sample collection. A water quality meter was utilized to ensure the porewater screen was isolated from the surface water by measuring water quality parameters of the water surface before sampling and during porewater purging. The monitored water quality parameters included temperature, dissolved oxygen (DO), conductivity, pH, and oxidation reduction potential (ORP). Ranges of the water quality parameters are presented below:

	Surface Water	Porewater
• Temperature (°C):	21.8 – 27.4	21.1 – 27.9
• DO (%):	51.7 – 135.5	0 – 82.7
• DO (mg/L):	4.39 – 10.81	0 – 6.9
• Conductivity (µS/cm):	0.276 – 0.6	0.393 – 1.87
• pH:	7.94 – 9.71	6.7 – 8.89
• ORP (mV):	-144.9 – 95.6	-184.4 – 159.8

EGLE-GSS staff collected samples for laboratory analysis of biological oxygen demand (BOD) from 39 of the sediment core locations. Detectable concentrations of BOD were reported from samples A212 (4.4 mg/L), A2102 (3.4 mg/L), A281 (15 mg/L), and A241 (2.3 mg/L). No other samples were reported with detectable/reportable concentrations. Data qualifiers for the samples that reported concentrations of BOD included the sample was prepped or analyzed beyond the specified holding time and the result was detected in the unseeded control blank.

4.0 Hydrodynamic and Coastal Modeling

An existing wind-wave model for Saginaw Bay was used to evaluate potential sediment resuspension at multiple water levels and wind directions. Sediment resuspension is an important consideration in reef siting because it is a relative measure of how susceptible a constructed reef is to sediment impacts. Excess sediment accumulation can smother fish eggs and fill the interstitial spaces of rock. High sediment resuspension rates ensure egg oxygenation and sediment cleansing during wind events. In addition, CSHORE was applied to estimate coastal sediment transport. Long-shore sediment transport may be contributing to filling and blockage of the Kawkawlin River recreational boating channel. Siting of a reef near the mouth has the potential to reduce long-shore sediment transport and channel filling. Model modifications, application, and results are presented in the following sections. Maps and Figures displaying modeling results are provided in Appendix A.

4.1 Wind-Wave Modeling

An existing wind-wave model was refined and updated for evaluating reef siting. This model is based on the SWAN (Simulating Waves Nearshore) model code (Booij et. al., 1999). SWAN is a spectrally-averaged wave model which is best suited for describing wave conditions at intermediate depth conditions, especially those deeper than the surf zone. It was originally developed for Saginaw Bay at a two-kilometer scale and was downscaled to a 150-meter scale to support this feasibility study. Bathymetric data collected within the study area as part of the project were merged with the existing regional dataset and used as an input to the model. These data were along a regular grid at a 600-foot spacing and covered the entire region where reef siting was being considered.

Four water level conditions were simulated – low, moderate, high, and extreme high: 577.1, 579.1 (median lake level), 581, and 584 (IGLD85). Wave inputs from those water levels were the maximum from the USACE Wave Information Study record (1979-2014): 3.6-foot waves out of the northeast generated from a sustained 34-mph wind. Eight wave directional conditions were simulated at regular 45-degree intervals (360 degrees). The directional tests were all done at the median lake level (579.1 feet IGLD85).

Figure 1 (Appendix A) illustrates predicted wave heights during high winds (> 30 miles per hour) from each of eight simulated wind directions and for median lake level conditions (579.1 feet, IGLD85).

Figure 2 (Appendix A) shows sediment resuspension potential predicted by lakebed shear stresses and integrates the predictions from the eight simulated wind directions (Figure 1). Figure 2 presents a qualitative representation of long-term resuspension potential during coastal storms. Lakebed shear stresses associated with each of the eight wind directions were weighted according to their frequency of occurrence to produce Figure 2. These model results were used to evaluate reef siting as discussed below. Figure 3 (Appendix A) presents maximum resuspension potential among all eight simulated wind directions.

4.1.1 Kawkawlin River Mouth Near-shore Reef Site

The ability of a near-shore reef placed near the mouth of the Kawkawlin River to effectively reduce sedimentation in the recreational boating channel depends in large part on is the degree to which long-shore transport contributes to the sedimentation. Long-shore transport can be reduced by a near-shore reef, while other sediment sources, such as watershed sources, cannot be reduced by a reef. To evaluate that factor, LimnoTech conducted coastal sediment transport modeling to estimate the littoral sediment transport. Modeling assumed that the nearshore area updrift of the Kawkawlin River is comprised of 100% fine sand (100 microns). This assumption would tend to push the computed littoral transport rate higher than if the shoreline was assumed to contain a mix of other sediment types.

LimnoTech calculated long-shore transport potential in two ways that are commonly used to inform design of coastal structures. Method 1 used the CSHORE model, a commonly applied one-dimensional coastal wave and sediment transport model used to predict sediment transport in the surf zone (Kobayashi, 2009). Method 2 used an energy flux calculation method described in the USACE Coastal Engineering Manual (USACOE, 2020). Results from both methods were comparable, both in terms of total sand movement to the Kawkawlin River mouth per year, and the wave angles which drive more of the transport than other directions (Appendix A, Figure 3). Most of the long-shore transport occurs when winds are at 10 to 40 degrees relative to shore, the peak correlating to a wind direction of approximately 45 degrees relative to the shoreline. It was estimated that littoral transport of sand can only account for 10 to 25% of sediment accretion at the mouth of the Kawkawlin River, roughly an estimated 400 cubic yards/year over a 36-year simulation of wave-driven sediment transport (1979-2014).

LimnoTech estimated the Kawkawlin River watershed sediment delivery using the U.S. Geological Survey's SPARROW model (a web-based tool which has been calibrated in other Michigan watersheds). Application of SPARROW resulted in an estimated sediment yield of 43.1 MT/km^2/year for the Kawkawlin River watershed. The watershed area is approximately 225 square miles. Assuming a sediment dry bulk density of 1,500 kg/m3, SPARROW estimated 21,000 cubic yards/year of sediment delivery to Saginaw Bay at the mouth of the Kawkawlin River from watershed sources.

Estimates of littoral sediment movement (400 cubic yards/year) are too small to explain rates of sediment accumulation in the channel (~4,000 cubic yards/year). However, estimates of sediment delivery from the watershed (20,000 cubic yards/year) are large enough to explain rates of sediment accumulation in the channel. Furthermore, sediment characterization data in the Kawkawlin River navigation channel show a variety of sediment types, but the most relevant data indicate that the sediment accretion is comprised mostly of silts and clays. This was a sediment core[1] taken in 2014 prior to dredging from an area known to have accumulated large quantities of sediment. A sample from this core was comprised of 67% silt/clay. The silts and clays that predominate in sediment samples taken from the channel most likely originate within the Kawkawlin River watershed.

Despite this finding, the analysis conducted shows that long-shore transport in the Bay along the adjacent shoreline likely contributes some sediment to the recreational boating channel. Anecdotal reports suggest that small sediment "wedges" may form in the channel, blocking smaller portions of the channel while the remainder of the channel is still open. Such small blockages could be due to concentrated near-shore sand transport rather than watershed sources. Regardless, reducing sedimentation in the channel will help Bangor Township reach its sustainability goals for the recreational channel and reduce long-term maintenance costs. Therefore, a near-shore reef at the mouth of the Kawkawlin River was evaluated for its potential of reducing near-shore sand transport into the channel.

Analyses using CSHORE show that a linear reef located north of the boating channel and running parallel to the shoreline in approximately 6-10 feet of water (at Low Water Datum) could create a

[1] Technical letter from Tim Hebert (Environmental Consulting & Technology, Inc.) to Russell Beaudien (Spicer Group, Inc.) dated October 2, 2014 providing sediment sampling results: "Kawkawlin River Dredge Project – Sediment Sampling Results, Bangor Township, Bay County, Michigan", October 2, 2014."

reduced wave height and energy envelope, thereby reducing long-shore sediment transport from north to south, toward the boating channel (Appendix A, Figure 5). A reef of approximately 1,600 feet as shown in Figure 5 could substantially reduce channel sedimentation without impacting adjacent shoreline properties. The wind-wave model shows that maximum relative sediment resuspension potential in the area of the river mouth reef is moderately high at the median lake level (Appendix A, Figure 2) and over the long-term (Figure 3). Sediment resuspension should be high enough near the mouth of the Kawkawlin River to keep a reef clean of sediment, especially the presence of a reef will increase wave energy on the reef surface.

4.1.2 Spoils Island Near-shore Reef Site

The wind-wave model was used to assess sediment resuspension in the study area to support reef siting. Based on the modeling of a combination of wind directions and water elevations, wave modeling shows that the maximum relative sediment resuspension potential occurs along the north and northeast side of the island (Appendix A, Figure 6) at the median lake level (579.1 feet IGLD85). The wind-wave model does show higher sediment resuspension potential along the east and southeast side of the island under some conditions (Appendix A, Figures 2 and 6), but the proximity of the shipping channel to the east side of the island does not present good conditions for siting a reef. Relative sediment hardness mapped using the bathymetric sounding equipment (see Section 2.1) also suggests that wind-wave energy creates a harder bottom along the north and northeast side of the island (Appendix A, Figure 7). The south and southeast shorelines have much lower relative sediment resuspension potential and softer bottom materials, suggesting reef siting along the south or southeast shoreline of the island would be less desirable due to potential sediment impacts. Furthermore, water depths south and southeast of the island may be too shallow to construct a reef with enough bottom relief to be attractive to fish while maintaining adequate water depth over the reef. In fact, a reef constructed with sufficient bottom relief in shallow water south and southeast of the island could be partially exposed at low water elevations. Siting a walleye spawning reef in 8-12 feet of water at low water datum along the northeast shoreline of the island would likely be more attractive to fish and less susceptible to sediment accumulation (Appendix A, Figure 8).

4.1.3 Wenona Beach Estates Near-shore Spawning Marsh

In addition to the reef sites evaluated above, the feasibility of a potential near-shore spawning marsh was also evaluated. Wenona Beach Estates is a small residential neighborhood located southeast of the Kawkawlin River mouth. The area is susceptible to flooding due to low-lying topography and water level surges caused by sustained northeast winds (Appendix A, Figure 9). Figure 9 illustrates the elevation of the land surface using color shading around and at Wenona Beach Estates. To further illustrate flood susceptibility. Figure 9 shows that the ground over much of Wenona Beach Estates is at or lower than an elevation of 584 feet, an elevation that is inundated during some surge conditions. Saginaw Bay reached an elevation of 574 feet (IGLD85) in September 2021 and the Federal Emergency Management Agency (FEMA) 100-year flood elevation is 585 feet (IGLD85).

Among the many important ecological and cultural benefits of Great Lakes coastal marshes, they can reduce shoreline flooding and erosion (SAI, 2005)[2]. Coastal marshes are important to the sustainability of Great Lakes shoreline communities like those along the southern shores of Saginaw Bay. Significant wetland losses have occurred along the shorelines of Saginaw Bay since European settlement due to agricultural conversion and shoreline development. Estimates suggest that approximately 700,000 acres of wetlands once existed along the shorelines of Saginaw Bay, including nearly 37,000 acres of emergent vegetation (PSC, 2008). Aerial photographs show coastal marsh along the Wenona Beach area (Appendix A, Figure 10). Aerial photographs also suggest that the marsh is eroding or substantially reduced in area during Great Lakes high-water levels. Restoring and stabilizing a coastal marsh at this location could help protect the shoreline by reducing the severity of flooding and reducing shoreline erosion (Figure 11).

To evaluate the potential erosion or loss of the coastal marsh at Wenona Beach, LimnoTech applied the CSHORE model to compare wave height predictions and coastal flooding for three morphological conditions: existing conditions, a condition that represents an eroded wetland (i.e. a condition that may occur in the future without wetland restoration and protection), and a hypothetical design condition (i.e., a restored and protected wetland condition). Modeling shows that the benefit of such a coastal marsh restoration at this location would be to avoid increased future inundation that may occur if the marsh continued to erode and subsequent increase in flood severity (Appendix A, Figure 12).

[2] https://www.epa.gov/great-lakes-monitoring/why-monitoring-great-lakes-coastal-wetlands-important

The top panel of Figure 12 illustrates the assumed shoreline morphological (i.e., elevation) profiles along a transect perpendicular to the shoreline at Wenona Beach Estates. The middle panel illustrates model-calculated wave height. Station zero on the x-axis is toward Saginaw Bay to the northeast. Station 10+00 is landward at the shoreline. Compared to the existing condition (black line, top panel), erosion would cause the shoreline to recede landward and become a steeper transition (red line, top panel). Restoring a marsh would create a longer, flatter transition (green line, top panel) between the open waters of Saginaw Bay and the shoreline. The middle panel shows resulting wave heights under those three scenarios, corresponding to the x-axis stations in the top panel. Note at approximately station 7+70 estimated wave height under existing conditions (black line) is less than one foot. However, under the eroded conditions (red line), wave height is estimated at nearly two feet. Estimated wave height under a restored marsh scenario (green line) is similar to existing conditions at station 7+70. However, note that estimated wave heights under the restored marsh condition are lower than existing out to approximately station 2+30. Lower wave heights and less wave run-up will could reduce flooding by 25% compared to existing conditions; more importantly, the restored marsh scenario could prevent a 266% increase in flooding caused by further marsh and shoreline erosion at Wenona Beach Estates (Figure 12, bottom panel).

5.0 Recommendations and Conclusions

Based on the data collection, modeling, and evaluations performed and discussed above, the following recommendations are made for further consideration in final design.

5.1 Kawkawlin River Mouth Spawning Reef Site

This study showed that the potential for a spawning reef located near the mouth of the Kawkawlin River is feasible. Long-term sediment resuspension potential is moderately high (Appendix A, Figure 3), which would help to limit the degree of sedimentation at the reef. In addition, a reef sited as shown in Figure 5 (Appendix A) could reduce long-shore transport of sand into the Kawkawlin River recreational boating channel. Though long-shore transport was shown to only contribute 10 to 25 percent of the sediment accumulation in the channel, reducing that source would contribute to long-term coastal resiliency by keeping the flood control clear more often and by reducing long-term dredging costs.

A spawning reef sited near the mouth of the Kawkawlin River as shown in Figure 4 would have to be designed to avoid potential navigational conflicts. It is possible the structure would require navigational hazard aids to prevent boating collisions and damage. The recreational boating channel is already marked with navigational aids seasonally. Therefore, if boats remain in the channel until clear of the reef, boating conflicts could be avoided. It will be important to make sure the channel is marked until boats safely clear the reef.

Design of the reef as a near-shore walleye spawning reef requires correct placement relative to water depths and bottom relief. Bottom relief is important to fish attraction and includes the height of the reef above the existing lakebed and slope of the reef face. Design of the reef as a walleye or general fish spawning structure may be contrary to building a reef that is fully effective at reducing long-shore transport of sand into the channel. While the two goals can be balanced to achieve the best results, priority could be given to walleye or other native fish spawning.

5.2 Spoils Island

Spoils Island offers a unique opportunity to site a near-shore walleye spawning reef, despite the artificial nature of its shoreline. Recreational boating is less prevalent along its shoreline, so navigational conflicts would be minimal compared to other near-shore areas along the Bay shoreline. Wind-wave modeling, bathymetric mapping, and bottom relative hardness mapping showed that the sediment resuspension potential along east and north sides of the island should be sufficient to support a reef. Siting a reef along the west side of the island is not recommended due to the proximity of the navigation channel. Also, positioning a reef along the south side of the island is also not recommended due to the potential for sedimentation and sediment PCB contamination. Similarly, the southeast side of the island is not recommended for a reef site either due to sedimentation potential and shallow water depths. However, a near-shore reef is recommended along the north and northeast side of the island as shown in Figure 8 (Appendix A). Relative substrate hardness is greatest in this area, sediment resuspension potential is high, and water depth is great enough to support a reef with sufficient bottom relief to attract fish while maintaining adequate water depth over the reef to reduce potential recreational boat navigation concerns.

5.3 Wenona Beach Estates

Like many coastal communities around the Great Lakes, Wenona Beach Estates is threatened by flooding and shoreline erosion associated with fluctuating Great Lakes water levels and storm events. This feasibility study showed that further erosion and loss of the coastal marsh at Wenona Beach Estates would result in a significant increase in flood risk. More importantly, restoring and protecting the marsh would not only avoid further loss, but could reduce the flood risk compared to existing conditions by up to 25%.

Reducing flood risk and shoreline erosion, however, would not be the only benefits derived from restoring and protecting the coastal marsh. The project could serve as a pilot project for restoring other coastal marshes around the Saginaw Bay shoreline. Coastal marsh restoration at this location, if properly designed, could also increase fish spawning and nursery habitat for species such as Northern Pike (Esox lucius) and Yellow Perch (Perca flavescens).

Restoring and expanding the coastal marsh at Wenona Beach Estates will involve future outreach meetings to solicit residents and public feedback on this design concept. The project team is hopeful to create a balanced wetland design that functions well for the ecosystem while enabling people's continued enjoyment of the bay.

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