Characterization of Kalamazoo Lake and Harbor Hydrology to Support Recreational Boating

Final Report
December 2022

MDNR Michigan Waterways Grant Program
Allegan County Contract # 11046

Contract Period of Performance: March 2020 to December 2022

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Introduction, Program Goal, Key Project Elements and Financial Summary

This report summarizes the results of a MDNR Michigan Waterways Grant entitled "Characterization of Kalamazoo Lake and Harbor Hydrology to Support Recreational Boating". The overall goal of the program was to collect a set of hydrologic, geochemical and biological observations of the greater Kalamazoo Lake and harbor areas to be used to make informed science based decisions for maintaining Kalamazoo Lake as a viable harbor and recreational area.

Six key project elements were identified to realize the updated characterization of this important part of the Kalamazoo watershed. They included:

1) New bathymetric surveys of Kalamazoo Lake and the adjoining river channels,
2) Sediment coring and analysis of the cores for contamination as well as grain size for sediment redistribution modeling,
3) Monitoring water quality and nuisance aquatic vegetation with remote sensing,
4) Mapping water flow (surface currents) in Kalamazoo lake,
5) Generating 3-D circulation and sediment fate and transport models for the greater harbor area, and
6) Outreach to stakeholders through a website and smart phone application.

Each program element was addressed to varying degrees of completion due to the funding limitations as described below. The bathymetric surveys, sediment coring and analysis, and monitoring of water quality and nuisance vegetation were completed, while the mapping of the surface currents in Lake Kalamazoo, and generation of a 3-D circulation model with fate and transport of sediments was only partially completed. The web site (www.kalamazoolakeharbor.org), which is smart phone compatible, is operational and will continue to be hosted beyond the performance period of the contract.

The project award was funded for $160K, however due to required cost share of 100%, the activity was only funded to an amount of ~$70K. To fund the required cost share, $5K contributions from the cities of Douglas, Saugatuck, Saugatuck Township, Saugatuck Chamber of Commerce and Allegan County were solicited. MTRI also contributed $10K in cost share as well, resulting in a total cost share of $35K. A major expenditure for the program was the collection and analysis of the sediment cores addressing legacy PCBs contamination in Kalamazoo Lake and the adjoining river channel. The State of Michigan under the auspices of EGLE collected 39 cores in the summer of 2019. EGLE assumed the cost of collecting the samples and delivering them to ALS Environmental for PCBs, heavy metal, and grain size analysis. The $70K grant paid the $19K for the ALS analysis resulting in $51K remaining to perform the program elements summarized above.

The period of performance was from March 2020 to December 2022. However it should be noted that the program was put on hold by the state from April 2020 to September 2020 due to Covid-19 funding concerns.

Program Summary and Highlights

All the major findings as well as the field data collected as part of the harbor characterization can be found on the MTRI maintained website (www.kalamazoolakeharbor.org). The website will serve as the repository of the information generated during this characterization as well as being a conduit for information sharing with the stakeholders. The collected field data includes the sediment cores, bathymetric (depth) data, some limited surface currents obtained by near-surface drogues, water quality (Chlorophyll, algal types, secchi disk (water clarity), water temperature, water light attenuation used to generate photic zone), and drone based video of the harbor including the areas of nuisance aquatic vegetation such as *Eurasian watermilfoil*, The project also utilized observations of potential water column contamination sampled at the Blue Star Bridge by EGLE, Lake Michigan water level data from the Holland NOAA Station, and wind and wave forecasts supplied by NOAA.

The program highlights can be summarized as follows:

1) **Bathymetry Update-** The bathymetry of the greater Kalamazoo Lake including Douglas and the adjoining river channels was resurveyed. These data have been used to generate a new updated depth map of the area that has been made available to the recreational boaters via the website. Additionally the data was used to generate Lake Bottom roughness and rugosity maps which are useful when assessing sediment transport. The new updated bathymetry was also used to compare to previously collected depth information to create historical sediment deposition values for the various portions of the harbor area. Finally the new digital bathymetry through GIS technology can be used to generate hypothetical depth maps of the harbor based on changing water levels. For example, a map was generated with a hypothetical four foot decrease in water level, and showed that a significant portion of the harbor would be unusable by vessels with four foot drafts.
2) **Contaminant Analysis-** An important part of the harbor characterization was the assessment of Lake Bottom sediment contamination with legacy PCBs. Additionally the water column was evaluated in respect to any PCB contamination using the EGLE long term surface water sampling data at the Blue Star Bridge. Thirty-nine cores were collected by EGLE personnel and analyzed by ALS Environmental for PCBs, heavy metals and grain size. The 39 cores resulted in 184 individual assays representing surface sediment down to a maximum of nearly 5 ft.in depth. The surface (0-2 inches) showed no PCB detected with the exception of one site near the new Douglas Marina. It should be noted that the detected concentrations were well below the regulatory limit of 1 ppm. Only two sites had PCB concentrations above 1 ppm in the top foot of sediment (both in the 6-12" assay). **Bottom Line: There is no or very little risk of PCB exposure from lake sediments in our harbor**. The water samples collected from 1999 to the present were also examined to ascertain if the EPA Maximum Contamination level (MCL) for PCBs in drinking water of 500ppt was exceeded. This assessment, also included in the website indicated none of the samples since 1999 have exceeded the EPA MCL. **Bottom line: Since 2014 no PCBs**

detected in Lake Kalamazoo river water. The water in our harbor is safe to recreate in!

3) **Outreach and Information Sharing-** One important aspect of the harbor characterization was to support recreational boating. To address this part of the grant requirement we generated the new bathymetry map, generated a section of the website that indicates the location of fuel, marinas, restaurants, motels with docks, public docks and launches, and parks. The high resolution drone data that shows infrastructure as well as the "weeded" areas is also useful to the boating community. In addition to serving the recreational boating community, the website also addresses other issues of importance to the greater stakeholder community, namely high water, river water flowing down to Oval Beach, and the contamination issue previously discussed. To address high water levels and the intermittent flooding that occurred prior to this year, the USACE water depth information for Lake Michigan was translated into understandable summary information used to predict water levels in the harbor area for a few months out to a year in the future. These data shared on the website were used by the local community to better manage the shoreline. In respect to Oval Beach, hydrodynamic scientists from Michigan Tech put together a model that on a daily basis predicted where the "brown sediment rich river water" would flow when it reached Lake Michigan. The model which utilizes river and wave, wind and current information on Lake Michigan successfully predicted when Oval Beach was adversely affected by brown river water. The projects highlights and conclusions have been briefed in person to the Kalamazoo harbor Advisory, the local municipalities, the Kalamazoo River Watershed Council. MTRI will continue to present the findings upon request beyond the performance period of the contract.
4) **Water Quality Monitoring-** The water quality of the harbor areas was sampled multiple times during the project (Oct 2020, July 2021, September 2021), and included measurement of Chlorophyll-a (Chl), algal groups, water temperature, water depth, and water clarity (using a Secchi disk). Using the Secchi disk depth, the 10% photo depth light level was able to be calculated, which is an important value when addressing nuisance benthic algae. Extensive details of the sampling are included on the website. The Chl values were approximately 25 mg/L in the summer indicating a eutrophic environment while in the fall the values dropped by a factor of three. Water visibility, which is related to Chl concentration, was 3-6 feet in the fall and 1-3 feet in the summer, again typical river values. **The dominant algal type was diatoms with no Harmful Algal Blooms (HABs) observed.**

Kalamazoo Lake Sediment Contamination

Introduction

The United States Environmental Protection Agency (EPA) designated the Kalamazoo River as an Area of Concern (AOC) under the Great Lakes Water Quality Agreement (1987). The Kalamazoo River has also been named a Superfund site (Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund site). These designations were the result of historic polychlorinated biphenyl (PCB) contamination, largely from paper mills operating along the river from the 1950s to the 1970s. The AOC/Superfund site extends along 80 miles of the Kalamazoo River from Morrow Dam in Kalamazoo County to where the river outflows into Lake Michigan. Kalamazoo Lake in Allegan County is the last inland body of water along the Kalamazoo River before it flows out to Lake Michigan.

Michigan's Department of Environment, Great Lakes, and Energy (EGLE) lists sediment chemistry monitoring as an important component of the comprehensive Great Lakes water quality monitoring strategy. They list numerous purposes for monitoring sediment chemistry, including to identify priority remediation locations, to assess the effectiveness of past remediation efforts, to determine if contamination levels are changing over time, and to identify if new contamination is occurring. Since being declared part of the Superfund site, Kalamazoo Lake sediments have been sampled and tested for levels of PCB contamination numerous times. An extensive sampling effort took place in 2000, led by the potentially responsible parties (PRPs), which comprehensively examined the contamination both across the region and at discrete vertical gradients. Additional sampling events in 2012 and 2013 were related to dredging projects, and included sampling a selection of sites in the proposed dredging path and analyzing sediment PCBs over the entire extraction depth (6-10 feet).

Included in the statement of work for this grant was a comprehensive re-sampling of PCB sediment contamination in the Kalamazoo Lake and Harbor region, similar to the effort undertaken in 2000. This section of the report will summarize the results of the 2019 sampling effort, including whether any surface sediments currently contain PCBs at a level of concern, how contamination levels have changed from 2000 to the present, and how PCB contamination has been redistributed in the vertical soil profile.

Data Collection

The 2019 sediment sampling effort included sediment cores from 39 sites. To facilitate comparisons to historic retrievals, sampling points were selected to overlap past sampling sites, primarily those from the 2000 effort. Site locations were in Kalamazoo Lake, the adjoining river channels, and two sites in Lake Michigan (Figure 1).

***Figure 1**: Locations of sediment sampling sites for 2019 effort.*

From July 15-19, 2019, sediment cores were collected and processed by staff from EGLE's Remediation and Redevelopment Division's (RRD) Geological Services Section (GSS). At 28 sites, cores were collected using a VibeCore-D sediment sampler (Specialty Devices, Inc., Plano, TX). This system vibrates a 6-foot long, 3-inch diameter polycarbonate core tube into the sediment in order to extract a sample. Where the sampling locations were too shallow or the bottom was too hard to operate the VibeCore-D system (11 sites in total), a gas-powered post pounder was used to advance an 8-foot long, 2-inch diameter polycarbonate tube into the sediment to obtain the core. At all 39 sites, the cores were advanced until refusal, and recovered using a lifting bail attached to the GSS survey vessel winch.

After collection, cores were capped and taken to shore. On shore, the samples were frozen and sliced into pre-defined depth intervals (0-2", 2-6", 6-12", and every 12" to maximum depth). Slices were photographed, logged following the Unified Soil Classification System, and placed into sampling jars. In total, 184 slices were collected from the 39 sites. These samples were then sent to ALS Environmental (Holland, MI) for analysis. Moisture (using EPA method SW3550C) and PCB contamination (Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, 1268; SW8082) were analyzed for each of the samples. Total PCBs were calculated as the sum of the analyzed Aroclors. A composite of the 0-2" and 2-6" samples was used for further analyses, including moisture, mercury (SW7471B), metals (arsenic, barium, cadmium, chromium, copper, lead, selenium, silver, zinc; SW6020A), and particle size analysis (D422).

Prior sediment sampling efforts for which we have data took place in 2000, 2012, and 2013. The 2000 effort took place between March 9 and March 29, 2000 and resulted in a total of 294 samples from 59 sites (Figure 2a). Total PCB concentration is available for each depth sample. The 2012 effort included 8 sites sampled on April 13, 2012 (approximate sample locations in Figure 2b). Sediment from each site was tested for PCBs as a composite to the proposed dredging depth. Another sampling effort took place in December 2012 and April

2013 including 16 sites (approximate sample locations in Figure 2c). Sediment from each site was composited to the proposed dredging depth (6 or 10 feet depending on sample location) and tested for PCBs (only Aroclor 1242), moisture, metals, and semivolatile organic compounds.

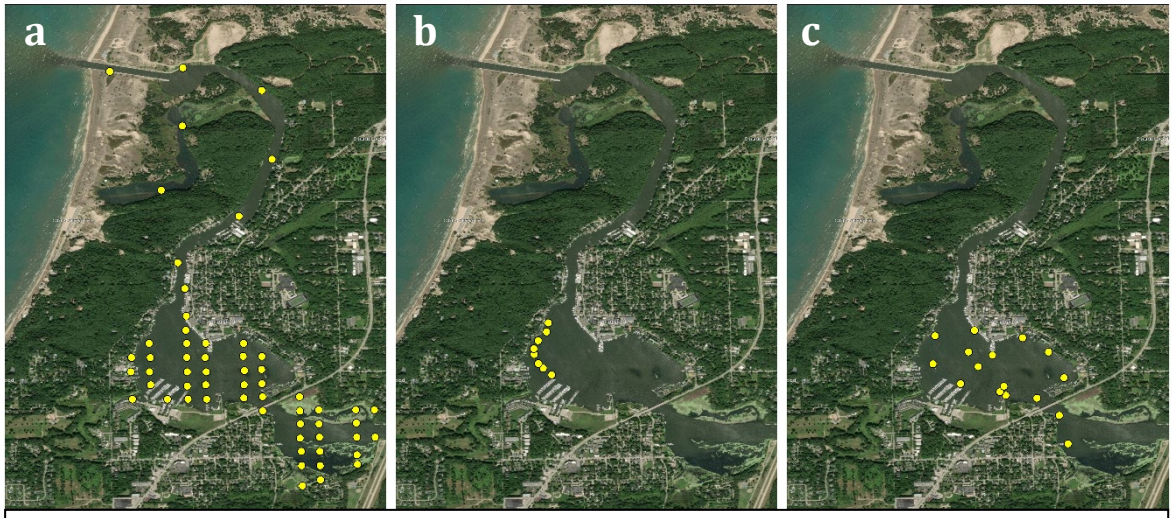

***Figure 2**: Locations of sampling sites for prior sediment PCB sampling events. a) 2000; b) 2012; c) 2012-2013.*

To compare across sampling efforts, all PCB contamination values were converted to units of parts per million (ppm). Soils with PCB concentrations exceeding 1 ppm are regulated for disposal under the Toxic Substances Control Act (TSCA).

Results and Conclusions

Out of all the sites sampled in 2019, only one (SS-15, located near Wade's Bayou Memorial Park in Douglas, MI) had detectable PCB concentrations in the top 2 inches of soil and that concentration (0.160 ppm) was well below the regulatory limit of 1 ppm. None of the sampled sites revealed concentrations above 1 ppm in the top 6 inches of sediment. In total, only five sites (seven samples) had PCB concentrations exceeding the regulatory limit: KL-38 from 12-24" (2.1 ppm); KL-54 from 24-34" (3.96 ppm); KL-61 from 12-24" (1.2 ppm), 24-36" (1.3 ppm), and 36-48" (3.2 ppm); KL-75 from 6-12" (1.2 ppm); and SS-15 from 6-12" (1.3 ppm). The locations of all 2019 sampling sites with detectable concentrations can be seen in Figure 3a, and the sites where concentrations exceeded regulatory limits can be seen in Figure 3b.

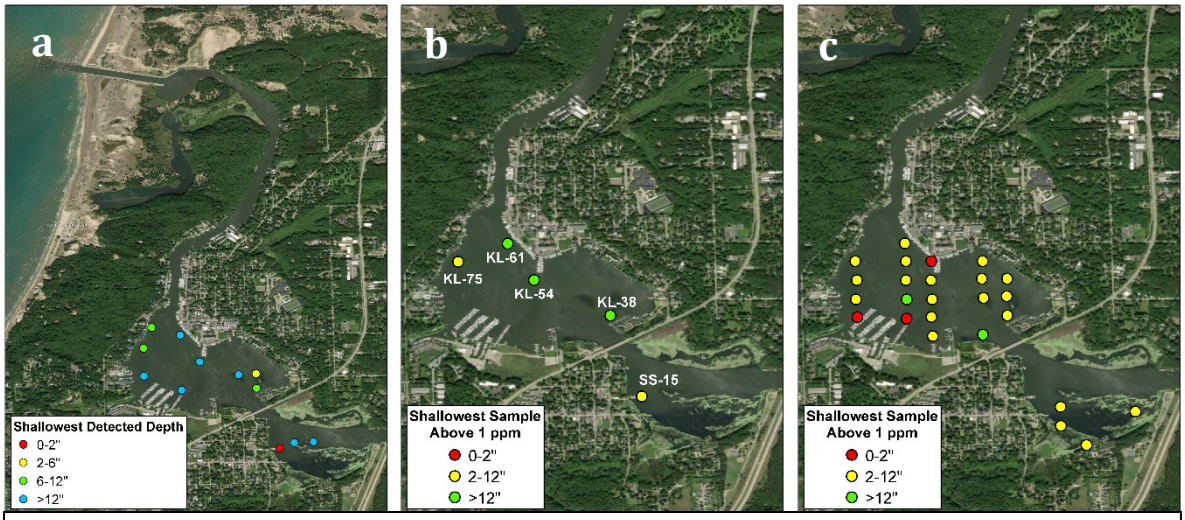

***Figure 3**: Locations of sediment sampling sites with detected PCBs. Panel a shows all 2019 sampling stations where PCBs were detected, colored by the shallowed depth of detection; Panels b and c show the 2019 and 2000 sampling stations, respectively, where at least one sample had PCB concentrations exceeding the 1 ppm regulatory limit. Marker color indicates the shallowest depth in which a sample exceeded the limit.*

The locations of all sites from the 2000 sampling effort where concentrations exceeded regulatory limits can be seen in Figure 3c. The sampling effort in 2000 revealed far more stations with samples exceeding the regulatory limit (25) than were observed in 2019 (5). Further, at the sites that were sampled in both years, the elevated concentrations were closer to the surface. Figure 4 shows the vertical profiles for the five 2019 sampling sites where PCB contamination exceeded the regulatory limit of 1 ppm. Of these, four were also sampled in 2000 and those profiles are also shown in Figure 4. These plots show that not only were the PCB concentrations generally higher in 2000, but the elevated concentrations have shifted deeper in the profile as new sediment from upstream is deposited on top of the contaminated sediments. Site KL-75 is the exception, with no deep PCB contamination layer in 2019. This site is located along the dredged path from Lake Michigan to Tower Marina, so the deeper contaminants observed in 2000 may have been removed in the dredging process.

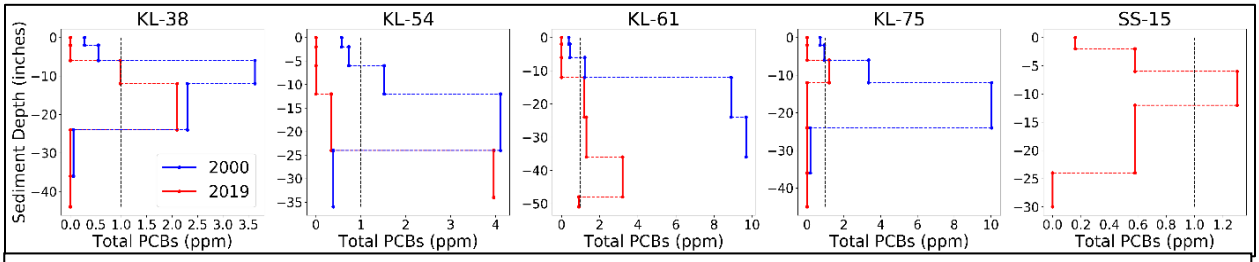

***Figure 4**: PCB contamination profiles for the sampling sites where PCB samples from 2019 exceeded the regulatory limit of 1 ppm: KL-38, KL-54, KL-61, KL-75, and SS-15. Profiles from 2019 are shown in red, and where possible, profiles from 2000 are in blue.*

In summary, PCB concentrations in the sediments of the Kalamazoo Lake region appear to have improved over the last 20 years. None of the sampling stations visited in 2019 had concentrations exceeding regulatory limits in the top six inches where they are most likely to be re-suspended into the water, and only five had elevated concentrations anywhere in the sampled profile. Where the 2019 sediment samples did contain elevated PCB concentrations, they had been shifted deeper since the 2000 sampling effort, reducing the likelihood of human exposure.

Sediment contamination results have been shared with EGLE and are available upon request from MTRI (shuchman@mtu.edu; krbosse@mtu.edu).

Kalamazoo Lake Bathymetry

Introduction

Another key aspect of the grant was to collect updated bathymetry in order to ensure safe access to the lake for recreational boaters. Updated depth maps for Kalamazoo Lake and the adjoining river channels are necessary for sailboats and motor yachts in order to determine the navigable areas based on keel depth. Recent bathymetric maps for Kalamazoo Lake were generated in 2006, 2013, and 2018, however some of these maps did not include several key regions including the river channels up- and downstream of Kalamazoo Lake.

These maps are also useful for creating "so what" scenarios such as a decrease in water depth based on climate modeling done by NOAA and the United States Army Corps of Engineers (USACE). This allows for the assessment of navigable waters under different depth level scenarios. For example, up-to-date bathymetric maps allow for the assessment of navigability changes as a result of Lake Michigan water depths decreasing by over two feet between August 2020 and September 2022.

Data Collection and Results

A small team of MTRI scientists visited the Saugatuck area in October 2020 in order to collect updated bathymetry of Kalamazoo Lake and the surrounding waters. Transects were conducted of all navigable waters between the I-196 overpass and Lake Michigan. Select regions were not able to be measured on that visit due to high levels of *Eurasian watermilfoil* (EWM) or other emergent vegetation preventing passage of our vessel or otherwise impacting the bathymetric measurements. After the EWM was chemically treated in summer 2021, the sampling team returned to complete the survey in September 2021.

The data collections resulted in over 30,000 discrete depth measurements. These data were combined in ArcGIS Pro and were used to make interpolated bathymetry maps for Kalamazoo Lake and the adjoining river channels. Using the ReefMaster software package, the lake bottom roughness and rugosity were derived using the ReefMaster software package. These data were also interpolated to generate lake-wide maps.

Figure 5 shows one of the maps created as part of this project. It includes the interpolated bathymetry and 1 foot contour lines for Kalamazoo Lake and the river channel adjoining Douglas. The final maps are all available to view in a mobile-friendly digital webmap on the website. The individual measurements (in shapefile format) or formatted maps (in PDF format) are available upon request from MTRI (shuchman@mtu.edu; krbosse@mtu.edu).

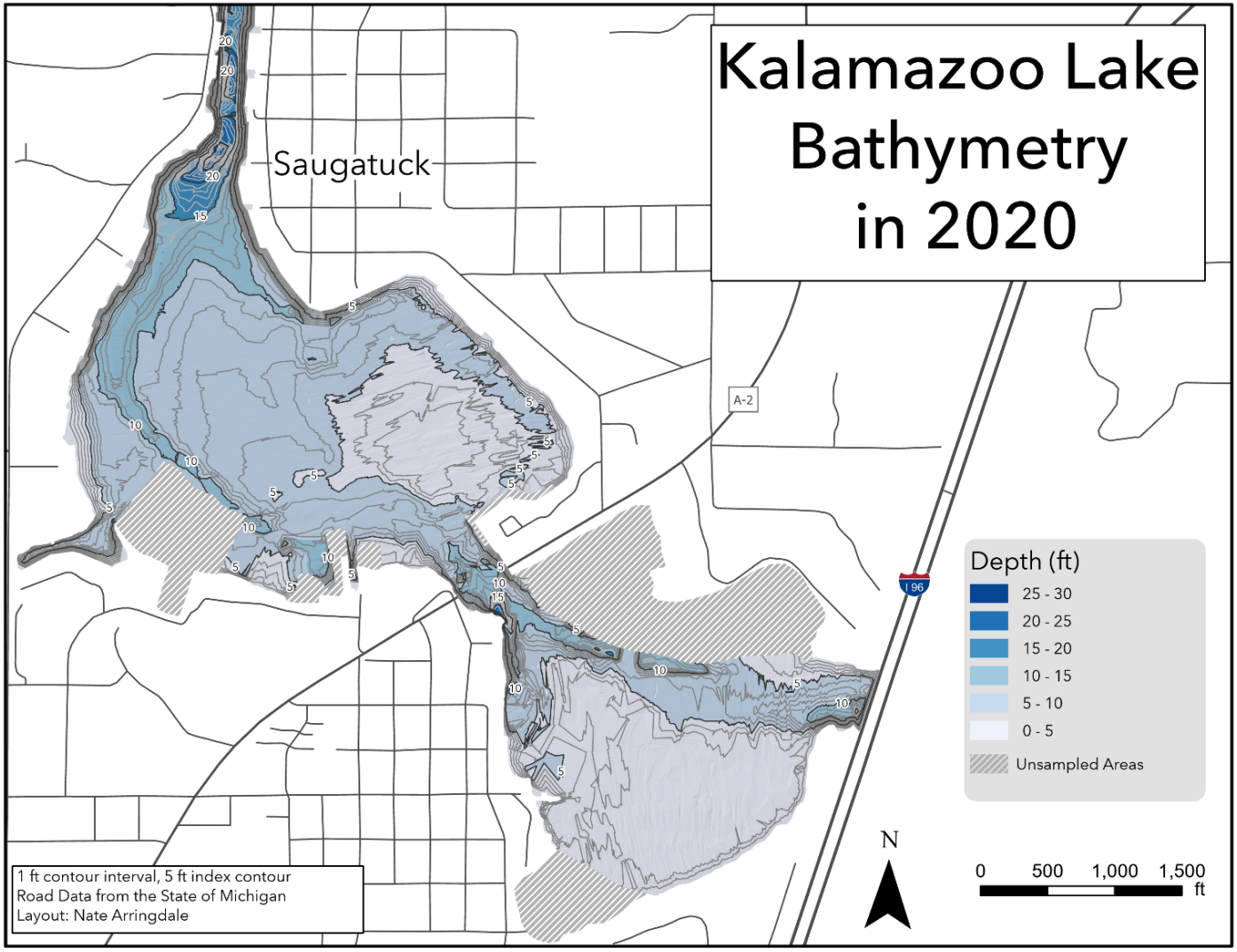

Figure 5: *Updated bathymetric map for Kalamazoo Lake and the Kalamazoo River channel near Saugatuck and Douglas, MI. 1 ft contours are displayed, with bold lines at each 5 ft interval. Areas marked with slashed lines were not sampled due to dock presence or persistent EWM presence.*

Kalamazoo Lake Harbor Website

MTRI developed a website to facilitate the sharing of data collected as part of this grant and other information relevant to recreational users of the Kalamazoo Lake and Harbor region. This site is mobile-friendly and can be found at the following URL: https://www.kalamazoolakeharbor.org/. Included on the website are historical and updated bathymetry, PCB contamination analysis, drone photography, and regularly-updated water level information. While the project work has come to an end, the website will be hosted at MTRI beyond the program end date. Detailed descriptions of each website page are below.

Lake Bottom Mapping

http://www.kalamazoolakeharbor.org/webmap.html

This page is where we have shared the maps that were generated as part of this project. The page is mobile-friendly and allows users to navigate to different parts of the lake and zoom in and out. The available maps on the page include:

- **2020 and 2018 Bathymetry Maps**: While the 2020 map is more recent and covers a broader spatial area, the 2018 map may be more currently relevant since the 2020 sampling took place during a period of historically high water levels which have since receded.
- **2018 Bathymetry Map with Hypothetical 4 Ft Water Loss**: This map was derived from the 2018 bathymetry map, and represents what the lake depth might look like if the water level were to drop 4 ft (i.e., depths similar to the historic lows observed in 2013). The results indicate that much of the lake would be shallower than 4 feet aside from the dredged channels.
- **2020 and 2018 Roughness and Hardness (Rugosity) Maps**: These maps show how the lake bottom texture changes across space. The data is necessary for sediment transport modeling and may also be useful for recreational users deciding where to fish. The mapped values are relative within each dataset, so the shift in values between years is less relevant than the change in spatial patterns.
- **2006-2018 Sedimentation:** This map shows the approximate amount of water level change due to sediment deposition between 2006 and 2018 depth samplings. The eastern basin of Kalamazoo Lake has experienced the largest amount of sediment deposition, and therefore, water level decrease.

Recreational Boater Information

http://www.kalamazoolakeharbor.org/webmap2.html

This page also contains a mobile-friendly webmap, providing users with a selection of water- and land-accessible destinations in the Kalamazoo Lake region. This includes marinas, restaurants, parks, and other docking locations. In addition to the locations of the sites, the map also includes business websites and phone numbers as applicable, and information about whether fuel can be purchased there.

Sediment Contamination

http://www.kalamazoolakeharbor.org/sediment-contamination.html

The primary purpose of this page is to disseminate the results of the sediment contamination analysis already discussed in the Kalamazoo Lake Sediment Contamination section above.

In addition to the analysis of current and historical sediment PCBs, the page showcases a brief analysis of surface water PCB contamination. This analysis is based on data collected by State of Michigan personnel at the Blue Star Bridge from 1999 to 2018 for the purpose of monitoring PCBs in the harbor water column. This analysis showed that the measured concentrations have generally declined from their peak in the early 2000s through 2018 (aside from a potentially anomalous sample in 2016). Recent data indicate a small concentration increase in 2021, which we postulate may be related to recent dam activities upstream. We also note that despite the increased concentrations earlier in the data record, all measurements are well below the EPA's 500 PPT maximum contamination level.

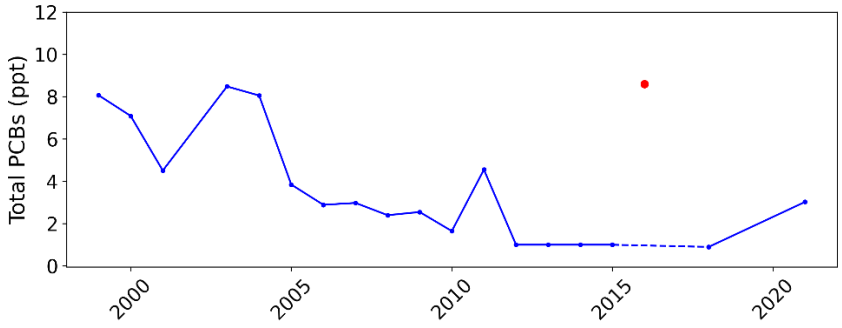

***Figure 6**: Mean annual PCB contamination in Kalamazoo Lake surface waters. The elevated 2016 concentration is colored red because despite its high value, the EGLE data indicated that no PCBs were detected.*

The sediment and surface water analysis resulted in the conclusion that PCB contamination has improved over the last 20 years and is not a significant concern in either the sediments or surface waters of Kalamazoo Lake.

Water Quality Sampling

http://www.kalamazoolakeharbor.org/water-quality.html

Kalamazoo Lake water quality was sampled multiple times by MTRI scientists during the project performance period (in October 2020 and September 2021 along with the bathymetric sampling, and again in July 2021). These measurements were used to assess water clarity and algal composition and concentrations, important parameters in determining the overall health of the water system. In all three sets of measurements, vertical profiles of algal composition/concentration were obtained using MTRI's FluoroProbe instrument and water clarity was estimated using a Secchi disk.

This page of the website provides the results of each individual sampling visit and includes context about what the results mean in terms of water quality. For instance, our sampling showed increased chlorophyll concentrations and decreased water clarity in the two summer 2021 sampling events relative to the results observed in fall 2020. However, these results are fairly typical of the normal seasonal cycle and not indicative of a negative shift in water quality. Additionally, our water column sampling indicated that the dominant algal groups present were diatoms and green algae, with very little presence of cyanobacteria or HABs.

High Water Issues

http://www.kalamazoolakeharbor.org/water-level.html

Starting in Spring and Summer 2019, Saugatuck and Douglas experienced several high-water events resulting in flooding. A major flooding event around Thanksgiving 2019 led MTRI to create a brief report detailing the reasons behind the flooding events and letting the community know the future outlook. Having received positive feedback from that initial report, the MTRI team generated updated reports regularly over the next several years. This became particularly important as Lake Michigan water levels reached record highs in Summer 2020.

This page on the website was created to host the latest version of the report, and as an access point for the prior reports. Currently available on the page are reports from December 2019, July 2020, January 2021, April 2021, August 2021, November 2021, May 2022, and September 2022.

These reports utilize historic water level data and forecasts from the United States Army Corps of Engineers (USACE), based on the fundamental point that Lake Michigan and Kalamazoo Lake are hydrostatically connected and therefore the water levels are linked. Each new report provides an update on the current state of the Lake Michigan (and therefore Kalamazoo Lake) water levels relative to the historic average and to the recent historic high levels. Readers are reminded of how to access current water level measurements with information on the threshold level that will result in flooding based on the height of the seawalls along Kalamazoo Lake. Finally, each report ends with a summary of the USACE projection on future lake levels, giving readers an understanding of what to expect in the coming 6-12 months (see Figure 7 for an example forecast).

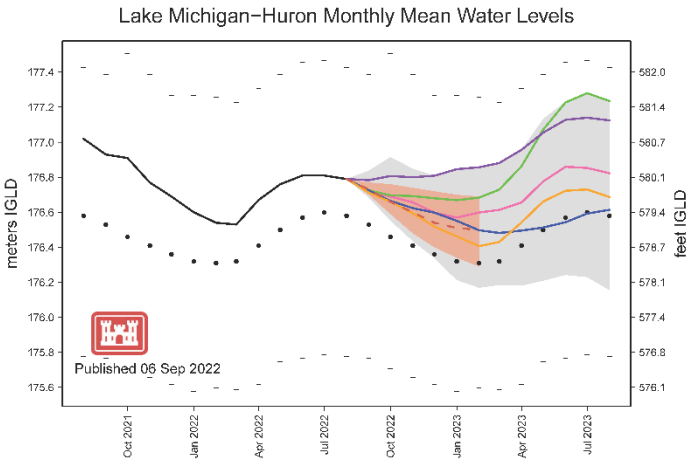

***Figure** 7: Example water level projection for Lake Michigan which displays the most likely water level scenario for the next 6-12 months.*

With permission from the publisher, we have also shared an October 2020 article in the Physics Today magazine that highlights the increased water levels in 2020. The article provides historical context for the water levels, scientific explanations for why the water levels were rising, and the impacts of the water levels on homeowners. A link to this article and downloadable PDF is provided at the top of the *High Water Issues* page.

Water Flow Modeling

http://www.kalamazoolakeharbor.org/water-flow.html

Discharge from the Kalamazoo River into Lake Michigan contains chlorophyll, dissolved organic carbon (DOC), and inorganic suspended sediments. Together, these constituents determine the color of the water. Elevated DOC concentrations are a result of decaying materials like leaves, and typically leave a brown tint to water. Depending on the wind and wave conditions on Lake Michigan, the water flowing out of the Saugatuck harbor entrance can flow to the north, west out from shore, or south. When the river water flows south, the "brown" water can end up at Oval Beach, the popular tourist attraction run by the city of Saugatuck. The common misconception that the brown river water is polluted can adversely affect the enjoyment of Oval Beach users.

Professor Pengfei Xue and his team at Michigan Tech University created a hydrodynamic particle tracking model that simulates where the Kalamazoo River discharge will flow based on wind and wave conditions. The model utilizes information from a buoy off Port Sheldon (approximately 25 km north of the harbor entrance), a Lake Michigan surface current forecast provided by NOAA/GLERL and river flow data from a USGS stream gauge to produce the results.

When the model was active, this page would provide a daily forecast for the Kalamazoo River discharge direction on an hourly basis. The video would show the direction and intensity of the wind and currents, along with a map showing the projected location of the discharge waters. Website users could use this page to determine if discharge waters would be impacting the Lake Michigan waters near Oval Beach and consequently, if the waters might be a darker color.

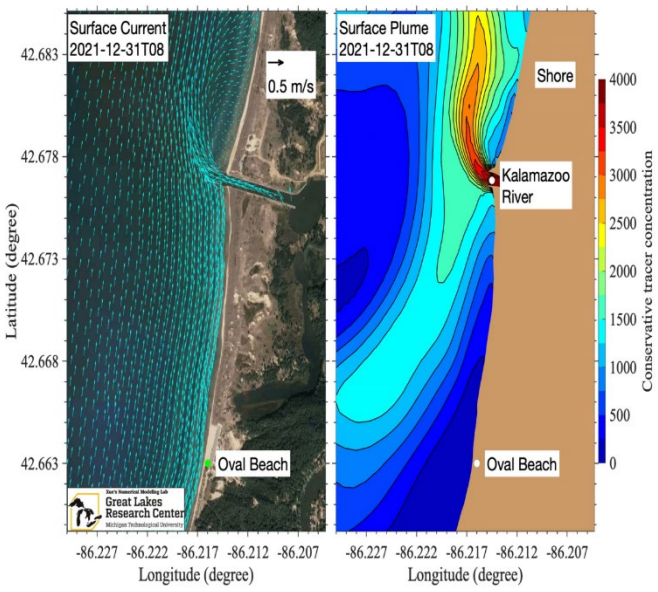

***Figure 8**: Example output from the particle tracking model as displayed on the website. The left panel shows the forecasted wind and the right panel shows where the Kalamazoo River plume is forecasted to travel.*

The model is no longer active, but the page still contains an example forecast video and a video showing the modeled flow hourly from May through August 2020.

HAB Identification

http://www.kalamazoolakeharbor.org/hab_id.html

In response to concern from residents related to the high prevalence of EWM in Kalamazoo Lake, a page was added to the website in order to help boaters with the identification of harmful algal blooms. The page consists of the slides from a presentation put together by EGLE and the Michigan Department of Health and Human Services. These slides contain useful pictures that should help boaters be able to distinguish a toxic harmful algal bloom from more innocuous conditions like EWM and duckweed.

Drone Footage

http://www.kalamazoolakeharbor.org/dronefootage.html

On two separate dates in 2020 and 2021, an FAA-certified MTRI scientist collected drone footage around the Kalamazoo Lake region, including Kalamazoo Lake and the adjoining river channels. This page includes 7 high resolution videos resulting from these drone flights. Of note, these videos show the high concentrations of emergent vegetation in 2020, and the improvement observed post-treatment in 2021.

***Figure 9**: Still photo extracted from a drone video taken on July 8, 2020 over Kalamazoo Lake. The photo shows the large patches of Eurasian watermilfoil growing in the eastern basin of Kalamazoo Lake between the East Shore Harbor Condominiums and Sergeant Marina.*