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CONTENTS

EDITOR'S NOTE

This revised issue of the Journal of Dredging consists of two manuscripts from researchers at the US Army Engineer Research and Development Center. In the first manuscript, ERDC researchers synthesize historical sediment quality data from Federal Channels in the Great Lakes. The results show significant reductions in dredged sediment contaminant concentrations over the decades. These contaminant reductions highlight important environmental improvement achieved through the diligent efforts of many to maintain critical infrastructure using environmentally sound construction practices. This information should allow channels historically labeled as "contaminated" and requiring special dredging consideration to be managed in more traditional manners. The most important result, from my perspective, is the increased opportunities to use these sediments beneficially. Historically, dredged sediments from these channels have been deemed "unsuitable" and placed in confined placement areas to isolate them from the environment. This manuscript shows there is potential to use sediments from these channels beneficially, possibly even returning them to the aquatic environment. I hope that studies of other ports and harbors will follow; I expect they will show similar results. The ramifications on our progress toward sustainable management of dredged sediments could be significant.

The second manuscript evaluates the need for aquatic habitat restoration at former sediment remediation sites. Contaminated sediments have been removed from these sites or isolated from the environment, but the resultant aquatic habitat has not been fully restored. This is a unique beneficial use of dredged sediments that could have significant potential.

Note that this is an updated version of this edition of the WEDA Journal of Dredging. It was first published in September 2025 with only the first manuscript.

Don Hayes
Editor, WEDA Journal of Dredging
November 2025

ENVIRONMENTAL IMPROVEMENTS IN SEDIMENT QUALITY DUE TO NAVIGATIONAL MAINTENANCE DREDGING AT GREAT LAKES INDUSTRIAL HARBORS

Jennifer Miller[1], Scott Pickard[2], Karen Keil[1], Richard Saichek[3], Rachel Hopp[4], Jillian Tomczak[4], Jason Miller[4], and Marissa Kneer[4]

ABSTRACT

Federal navigational dredging occurs on a regular basis at industrial harbors. The U.S. Army Corps of Engineers (USACE) samples sediment prior to dredging to determine appropriate sediment management and for Clean Water Act compliance. The sediment data generated for Great Lakes federal harbor navigational maintenance is archived at the three USACE District offices: Buffalo, Chicago and Detroit. Repeated sampling since the 1970s has produced a storehouse of data which is unpublished and has not previously been systematically analyzed for trends. Years of sediment data for Great Lakes commercial harbors were analyzed for contaminant trends. This paper presents a brief overview of Polychlorinated Biphenyl (PCB) concentrations in sediments over time at select industrial harbors within the Great Lakes. There appears to be an association between navigational maintenance dredging and decreases in PCB concentrations over time; today, sediment in regularly maintained Great Lakes federal channels is often less contaminated than background lake conditions. This finding is in direct contrast to the common perception that Great Lakes sediment is polluted and unsuitable for any beneficial use and, assuming sources are controlled, directly supports the notion that over time dredging promotes a cleaner environment by removing contaminated sediments.

Keywords: Great Lakes; sediment; maintenance dredging; PCBs; beneficial use

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) has been maintaining federal navigation harbors and channels by dredging for more than 200 years (USACE 2025a). For much of that time, management of the dredged sediment was an afterthought; sediment disposal was unregulated and untracked, with it being managed in the lowest cost and easiest manner possible, often by

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sidecasting or placement in deeper water. USACE officially began placing sediment in confined disposal facilities (CDFs) with the promulgation of the Rivers and Harbors Act of 1970; Public Law 91-611, Section 123(a) states "The Secretary of the Army, acting through the Chief of Engineers, is authorized to construct, operate, and maintain…contained spoil disposal facilities of sufficient capacity for a period not to exceed ten years…." At this time, it was well known that numerous lakes and rivers within the U.S. were polluted; the 1969 burning of the Cuyahoga River dramatized the condition of the nation's waters (Rotman 2010). Not only were waters impacted by pollution, but the sediment in lakes and rivers became the repository for debris, solids and insoluble materials dumped into the water. The confinement of navigational maintenance-dredged sediment (referred to as dredged spoil at the time) was seen as a practical method for managing polluted sediment. The original time period for operation of the facilities was extended (see Section 148 of WRDA 1976, Section 24 of WRDA 1988, and US Code Title 33, Section 419a). Eventually a total of 46 CDFs were constructed in the Great Lakes; 22 of the 46 original facilities are still in operation in some fashion.

USACE maintains 141 federal projects (harbors and channels) within the Great Lakes Navigation System by dredging 3 to 5 million cubic yards of sediment annually (USACE 2024a). Dredged sediment is currently placed in the nearshore littoral zone (including beach nourishment) if it is primarily coarse-grained in nature. If the dredged sediment is primarily fine-grain in nature, it is placed in deeper open waters outside the littoral zone, unconfined at upland sites, or in a CDF. Since 1990, the Great Lakes Navigation Team has tracked placement of sediment in these four categories (USACE 2024b). From 1990 to 2023, 46% of the maintenance-dredged sediment was placed in CDFs. Figure 1 shows the placement volumes over time. There is no clear trend in sediment management over time besides a general reduction in open water placement in the most recent years (driven by changes to Lake Erie sediment management). CDFs are still widely used for sediment management in the Great Lakes.

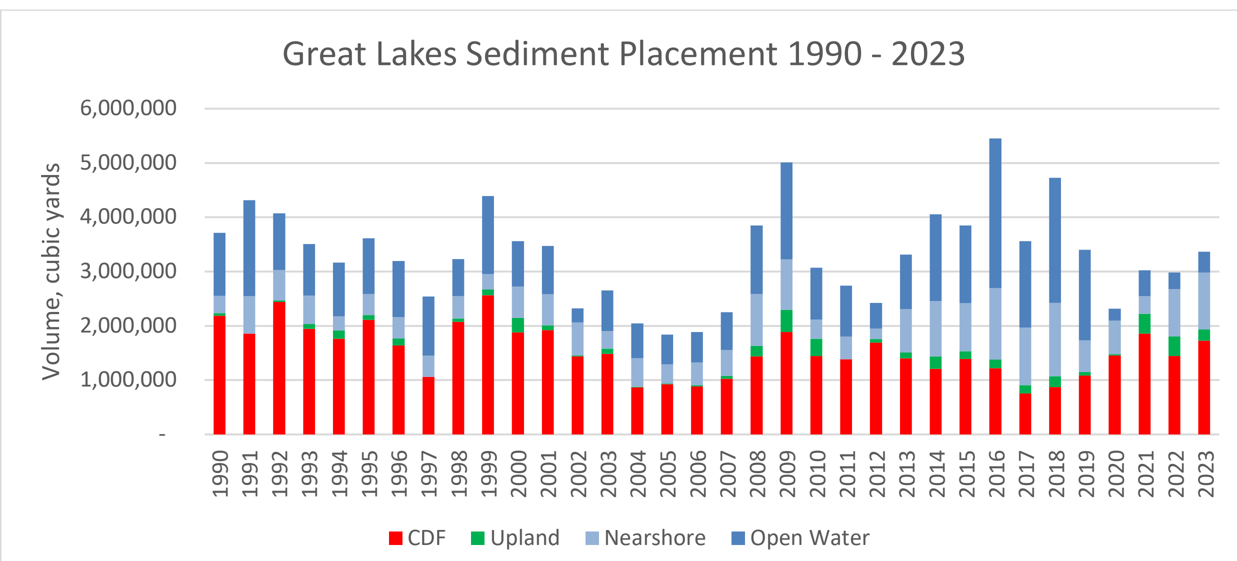

Figure 1. Sediment management in the Great Lakes

Although the confinement of dredged material has been routinely practiced in the Great Lakes since the 1970's, that approach is no longer favored. Section 117(c)(2)(B) of the Water Resources Development Act (WRDA) of 2024 directs USACE to beneficially use 70% of the navigational maintenance-dredged sediment. Beneficial use can include a range of "productive and positive uses of dredged material," from in-water uses within the aquatic ecosystem (e.g., beach nourishment, habitat restoration or creation) to upland uses (e.g., clean fill, agricultural land application) (USACE 2025b). Using 70% of the dredged sediment beneficially in the Great Lakes will be a challenge, given that historically USACE has beneficially used less than 30% (USACE 2024b).

One specific aspect of this challenge is a persistent and, based on experience of the authors, widespread belief that dredged sediment in the Great Lakes is categorically polluted, presents a risk to humans and the environment, and is unsuitable for any productive or positive use. Bias against sediment is represented through the common use of derogatory terms such as "spoil," "muck," "sludge" and "toxic waste" to describe the sediment and "dumping" to describe the dredging and dredged sediment management operation. The long public memory of the deplorable discharges and water quality issues before the 1972 Clean Water Act appear to be firmly associated with sediment. Again, based on the experience of the authors, skepticism encompassing dredged sediment tends to pervade regulatory agencies and the public, limiting innovation and new sediment management approaches, and often preventing all but the most coarse-grained dredged sediment (i.e., sand, gravel and cobble) from being beneficially used in the aquatic ecosystem. This perception appears inconsistent with decades of data and documentation indicating that sediment quality in most federal navigation projects within the Great Lakes, especially within industrial harbors, has remarkably improved through systematic maintenance dredging.

Passage of the Clean Water Act has greatly changed how the U.S. approaches water quality and pollution control. Rivers no longer start on fire and the unrestricted discharge of wastes is no longer allowed. Fish kills and beach closures due to pollution are greatly reduced. Efforts by USEPA and others to remediate sediment in Great Lakes rivers and harbors have been on-going since the 1980's. As sediment at federally maintained commercial harbors has been systematically dredged and polluted sediment has been confined over the last 50+ years, the sediment quality in these federal channels has remarkably improved. This paper focuses on trends observed at selected navigational harbors.

APPROACH AND METHODS

USACE routinely tests sediment physical and chemical quality prior to dredging harbors and channels. There are two guidance documents which are followed: the Inland Testing Manual (USEPA/USACE 1998a) and the regional derivative Great Lakes Testing Manual (USEPA/USACE 1998b). These documents outline a tiered approach to sediment characterization. For harbors which are frequently dredged, this approach results in sediment evaluations being conducted about every 2 to 10 years (depending on dredging needs, funding, and other factors). Data are used to evaluate the quality of the sediment to be dredged and to determine appropriate placement sites, as well as to support National Environmental Policy Act and Clean Water Act documentation and regulation.

The sediment data generated for Great Lakes federal harbor navigational maintenance is archived at the three USACE District offices: Buffalo, Chicago and Detroit. Repeated sampling since the 1970s has produced a storehouse of data which is unpublished and has not previously been systematically analyzed for trends. Sediment chemical data for metals, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) are available for a number of frequently maintained harbors and channels. This paper focuses on PCB concentrations in sediments at several harbors. PCBs were selected as a focus for this paper due to the availability of data (by comparison, PAH data are less available since PAHs were not typically measured in the 1980's and 1990's); due to the ecological interest (PCBs are still an issue in Great Lakes fish and are therefore of public notice); and due to the general lack of current sources (which allows conclusions to be made as to the fate of the legacy pollutants.)

Data used for this study were selected based on several criteria:

a. Consistency of availability of data over many years, ideally starting in the 1970s and continuing until present.
b. A high proportion of detectable concentrations of the parameter of interest, in this case PCBs.
c. Adequate documentation such as methods and detection limits (DLs) to allow for sufficient data review.

Sediment data on many harbors in the Great Lakes do not meet these criteria. For example, shallow draft harbors used primarily for recreation are often maintenance-dredged with a frequency of less than once every 10 years; these harbors have a corresponding lack of sediment data since the sampling frequency is usually tied to the dredging frequency. Many of these harbors are located in more rural areas and did not have the degree of sediment impairment present in commercial harbors situated within industrial areas, referred to henceforth as "industrial harbors." Even when sampled and tested, the sediment chemical data at the rural recreational harbors are largely unremarkable due to the large number of results below DLs, or very low concentrations. Consequently, the harbor sediments assessed in this paper are biased toward larger industrial harbors that are maintenance-dredged on a more frequent basis. The harbors discussed in this paper are shown in Figure 2.

Data quality was reviewed for this analysis. In general, results which were below method analytical detection limits ("non-detectable") are reported as the DL and were included in this analysis and valued at the DL. This allows the statistical analysis of censored datasets, which is a frequent limitation for environmental data. It is noted that the use of DLs for non-detectable data has the result of biasing reported concentrations high. For discrete channel areas, the available total PCB concentration data points for a sampling event (year) were averaged, with the measure of variability through error bars being represented as ± one standard deviation. These data were plotted to decipher concentration trends over time.

PCBs were analyzed by congeners (up to 209 individual compounds) or by Aroclors (commercial mixtures of PCBs exhibiting a "fingerprint"). The total PCB concentrations discussed here represent calculated totals based on measured congener concentrations or the sum of Aroclor mixtures as long as overlapping Aroclors were not reported (e.g. 1016 with 1254). In general, this

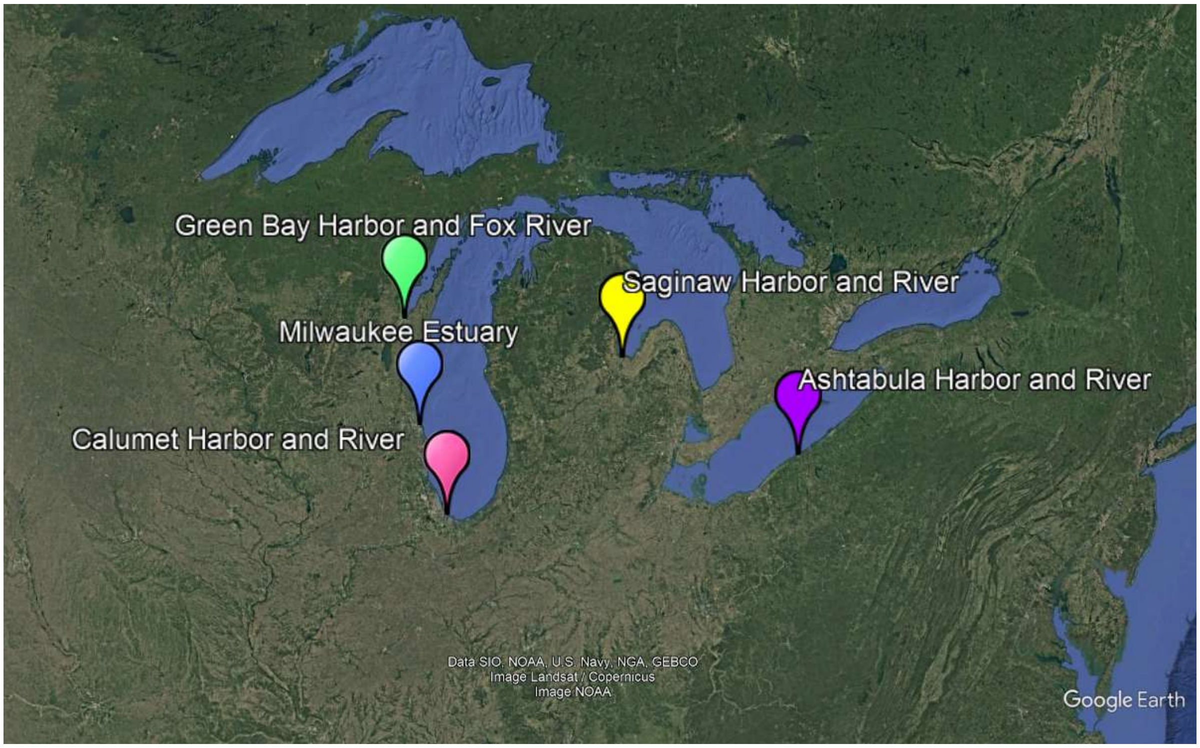

Figure 2. Great Lakes Harbors Discussed in this Study

was not an issue; most harbor data only detect a single Aroclor. Due to the uncertainty of PCB concentrations calculated through Aroclor data (Bernhard and Petron 2001), the total concentrations should be taken with some caution, but the trends are considered valid since the data for each harbor were generated following a consistent approach.

RESULTS AND DISCUSSION

Periodic dredging in Great Lakes harbors since the 1970s has removed large volumes of contaminated sediment from the commercial harbors discussed in this paper. These sediments were largely confined in CDFs, thus removing the contaminants from the environment and isolating them. PCBs are a prime example of the (unintentional) environmental benefits from this practice. PCBs were commercially manufactured starting in 1929, and were in use until production was banned in 1979 under the Toxic Substances Control Act (USEPA 2025). Although banned from sale, PCBs may still enter the environment from waste sites or improperly handled waste. (USEPA 2025) These compounds do not readily degrade in the environment and are useful to indicate historical pollution.

An overall reduction in the concentration of PCBs (in all media) in the Great Lakes is to be expected. The Clean Water Act has been effective at reducing or eliminating discharges of the compound. Sediment remediation by the USEPA under programs including Superfund and the Great Lakes National Program Office Legacy Act have targeted removal of contaminated sediment. However, these efforts do not address all of the contaminated sediment that represents the legacy of past discharges. The systematic maintenance dredging by USACE has also helped to reduce the total pollution load in the Great Lakes, as shown below.

Sampling and Dredging History at Select Great Lakes Harbors

In general, USACE samples one to five years prior to navigational maintenance dredging. The purpose of the sampling is to inform the dredged sediment management and ensure that the sediment is placed at an appropriate site, typically through Clean Water Act regulation. Occasionally, sediment is sampled during dredging, as it is placed in a CDF (such as for Calumet River channel dredging). There is a general correlation between sampling and dredging. The sediments sampled are typically removed from the navigation channel prior to the next sampling event. Note that shoaling in a navigation channel is typically localized and sediment sampling occurs where there is shoaling that will ultimately be dredged. A given Federal harbor or channel may not be fully shoaled, and dredging may not remove all shoaled sediment dependent on funding. Nevertheless, in general, the expectation is that a shoaled area is identified, sampled, and then dredged at a frequency of approximately every 1-5 years. The data were divided based on maintenance sections for each harbor. The river channels may be sampled and dredged separately from those in the harbors; discrete channel areas (such as the individual river channels at Milwaukee Estuary) may also be sampled and dredged separately. Reference sites, which are located outside the Federal channel and are not dredged or used for sediment placement, may be sampled as well. These locations are considered representative of the background conditions, often in the offshore lake basin. A limited number of reference site data points are available outside the federal channels.

Table 1 gives a summary of sampling and dredging years for five Great Lakes federal navigation projects. These projects are regularly maintained, such that USACE has documentation of sampling results and dredging activities over many years. While there is not always a one-to-one relationship between sampling and dredging activities, the two are inherently related. This provides confidence that changes in sediment quality over time are related to dredging activities and that the PCB concentrations measured in sediment in the federal channel did not dissipate solely from other factors such as environmental regulation.

PCB Concentrations in Select Federal Harbors and Channels

The average total PCB concentration in federal harbor and channel sediments was plotted over time across sampling years. The data represent discrete sections of these federal projects in many cases. For example, Milwaukee Estuary includes the harbor, and channels in Milwaukee River, Menominee River, Kinnickinnic River and Burnham Canal. Each portion of the estuary was maintained at different frequencies, although the larger area was typically sampled all at one time. The data for the different channel areas were separated and averaged for each channel area and sampling event.

Figures 3 through 7 show average total PCB concentration trends in the federal channel over time for Milwaukee Estuary, Calumet River, Fox River, Saginaw River and Ashtabula Harbor. The general trend in all cases is the same. Total PCB concentrations are higher in the 1970's through

Table 1. Summary of Sediment Sampling and Dredging Years

Project area	Sampling Years	Dredging Years[1]
Calumet River channel	1984, 1985, 1989, 1994, 1999, 2000, 2001, 2002, 2003, 2008, 2009, 2013, 2014, 2017	1984, 1985, 1989, 1994, 2000, 2001, 2003, 2012, 2013, 2015, 2017
Milwaukee Estuary - Milwaukee (Outer) Harbor - Milwaukee River channel - Menominee River channel -Kinnickinnic River channel - Burnham Canal	1984, 1987, 1990, 2002, 2011, 2023[2]	1986 (Menominee, Burnham) 1990 (Kinnickinnic, Milwaukee River and harbor) 1993 (Kinnickinnic, Milwaukee, Menominee rivers) 1995 (Kinnickinnic) 1999 (Milwaukee river) 2001 (harbor) 2007 (Kinnickinnic and Milwaukee rivers) 2008 (unclear locations) 2011 (unclear locations) 2015 (harbor) 2018 (entire federal channel) 2023 (harbor)
Fox River channel	1977, 1980, 1982, 1984, 1989, 1994, 1999, 2010	1978, 1982, 1984, 1985, 1987, 1989, 1990, 1991, 1993, 1994, 1995, 1996, 1997, 1998, 2001, 2002, 2003, 2005
Saginaw River channel	1977, 1980, 1983, 1988, 1994, 2004, 2011, 2021	(prior to 1982, unspecified dredging locations) 1982, 1984, 1988, 1991, 1992, 1993, 1995, 2006, 2008, 2009, 2011, 2012, 2013, 2014, 2015, 2016, 2018, 2024
Ashtabula Lower River Channel Ashtabula Outer Harbor Channel	1984, 1988, 1992, 1993, 2000, 2005, 2007, 2009, 2015, 2021	1978, 1979, 1980, 1981, 1983, 1987, 1989, 1990, 1993, 1994, 2001, 2003, 2007, 2009, 2011, 2013, 2014, 2015, 2017, 2018, 2019, 2022, 2023

[1] Dredging records are based on available information, which is not always complete as to location and quantity. The years listed represent the best judgement.
[2] Only Milwaukee Harbor was sampled all years.

1990's and highly variable. Following 1990 through 2000, the PCB concentrations are low and often non-detectable (<0.004 to <0.16 mg/kg), with lower variability.

Looking more specifically at the Milwaukee Estuary, it can be seen that all portions of the estuary had measurable (>1 mg/kg) concentrations of total PCBs prior to 1990, but between 1990 and 2000, concentrations dramatically decreased in most portions of the Federal project. This correlates well with multiple dredging events between 1990 and 2001. Total PCB concentrations in the Kinnickinnic River sediments did not decrease as rapidly, which may be due to other sources or less dredging. Recent sampling in the harbor shows very low sediment total PCB concentrations – an average of 0.08±0.03 mg/kg. This compares favorably to the overall Lake Michigan sediment

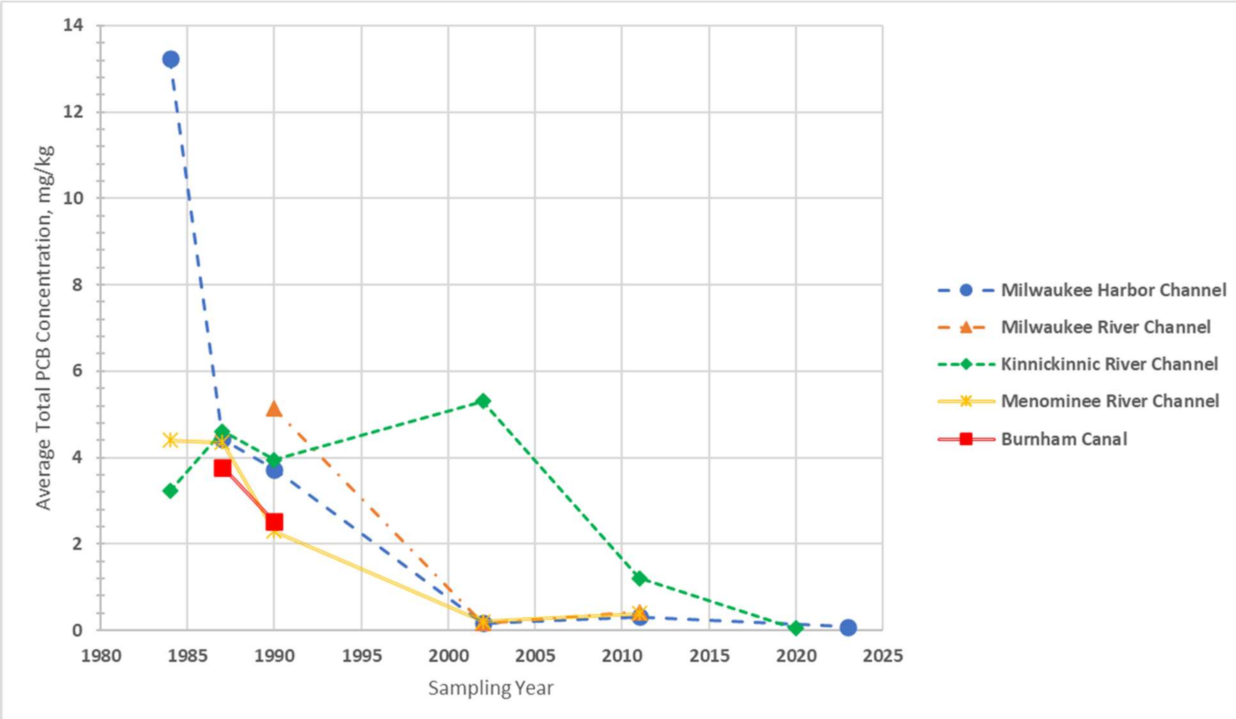

Figure 3. Milwaukee Estuary Channels, Wisconsin Sediment PCB Trends over Time

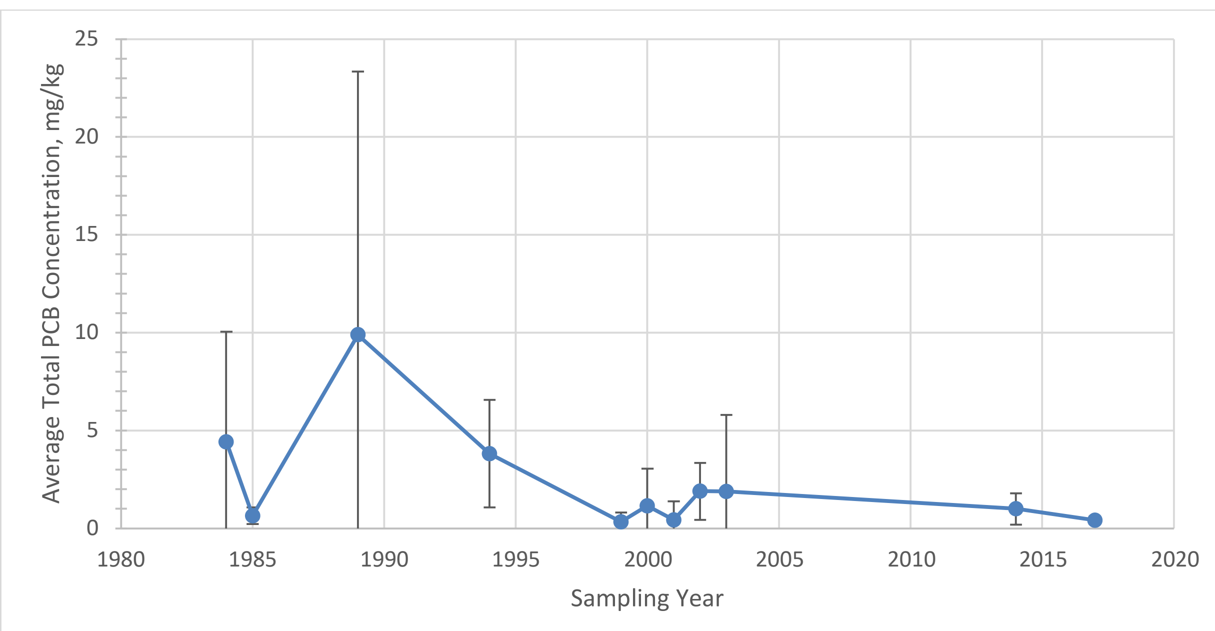

Figure 4. Calumet River Channel, Illinois Sediment PCB Trend Over Time

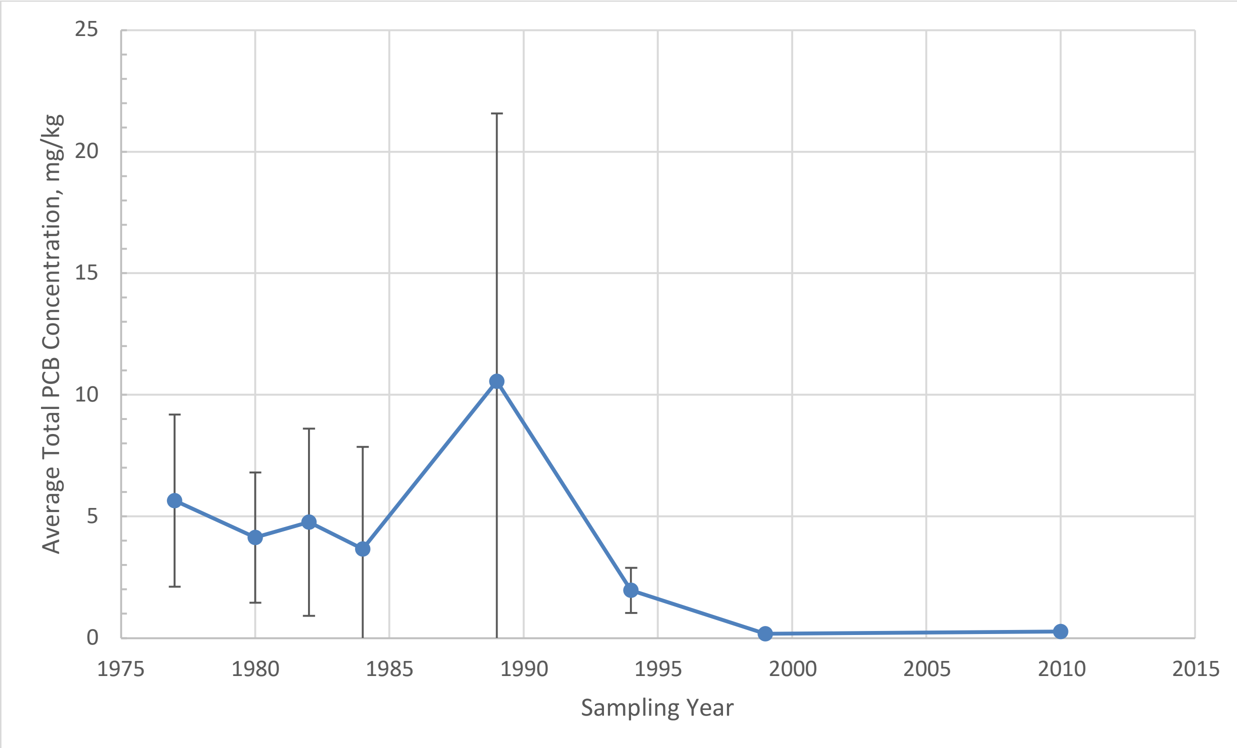

Figure 5. Fox River Channel, Wisconsin Sediment PCB Trend Over Time

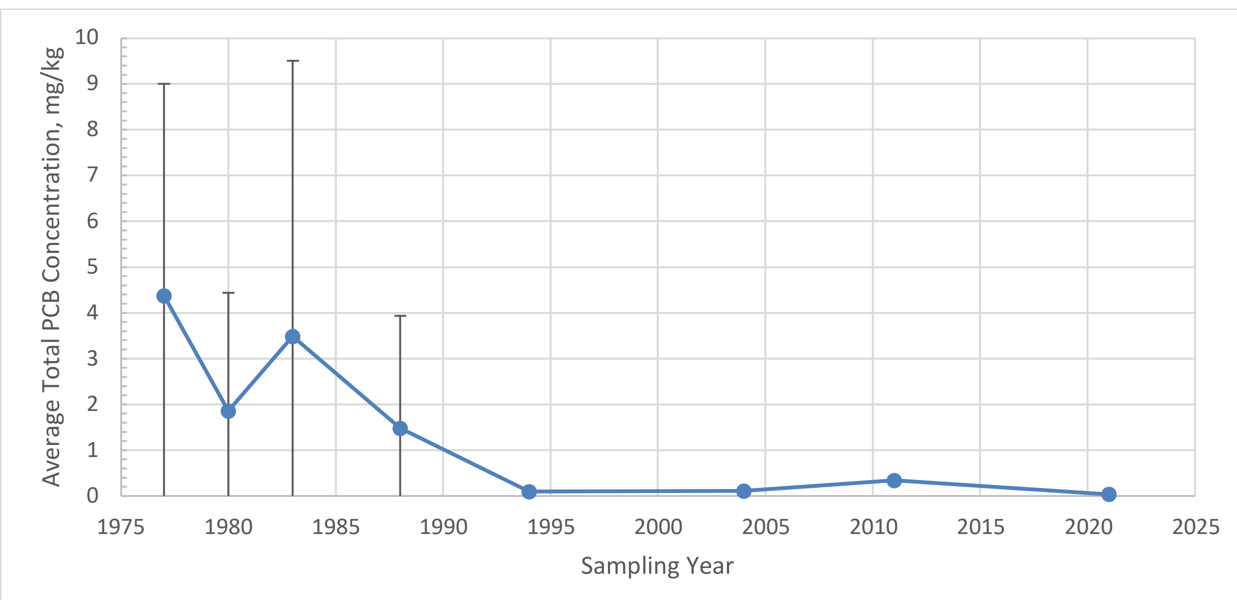

Figure 6. Saginaw River, Michigan Sediment PCB Trends Over Time

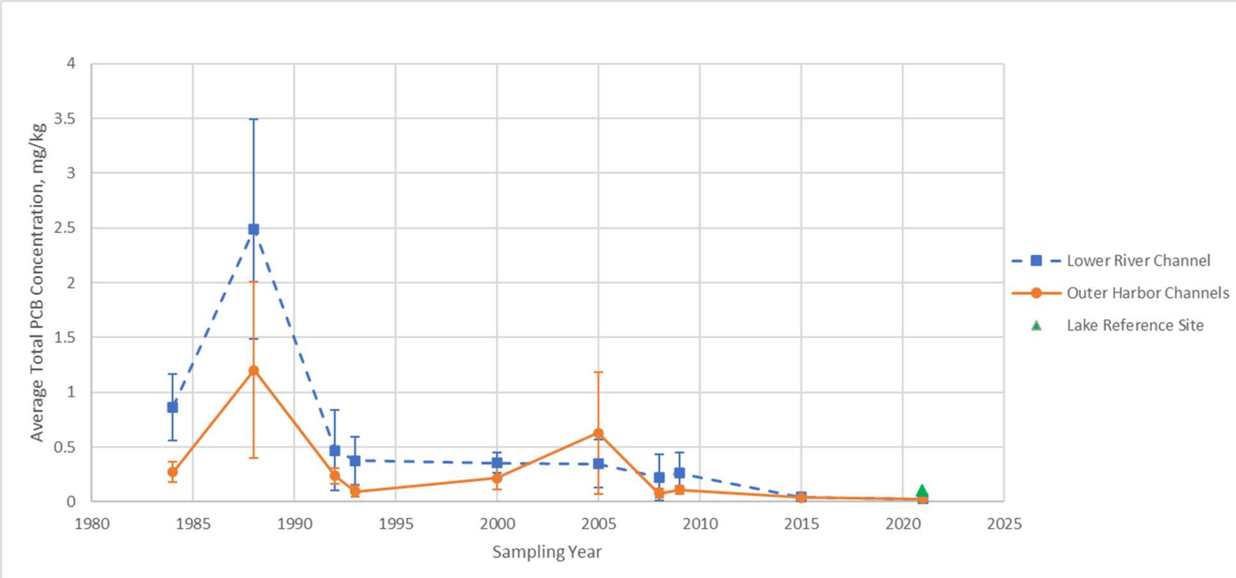

Figure 7. Ashtabula River and Harbor Channels, Ohio Sediment PCB Trends Over Time

background concentration, estimated in 2017 to be 0.0515 mg/kg (Guo et al. 2017). Milwaukee estuary is an Area of Concern under the Great Lakes Water Quality Agreement (International Joint Commission 1987), and although sampling in the federal channel shows low concentrations of PCBs in sediment, the areas outside the maintained channel still contain elevated PCB concentrations (concentrations measured during various studies found PCB concentrations varying from <0.01 to 188 mg/kg) (CH2M 2016; CH2M 2019; Jacobs 2024). This reinforces that the routine maintenance dredging has removed historically contaminated sediments, but to truly address the entire problem of PCB-related toxicity, areas adjacent to the federal channel must also be addressed.

The Calumet and Fox River channels follow similar trends (Figures 4, 5). Prior to 1995, both channels had measurable, and highly variable, concentrations of PCBs in sediment. After 1995, PCB concentrations are low and often non-detectable with lower variation. Both of these river channels are very long; dredging removes sediment from shoaled areas which are located sporadically along the river. The entire channel is not dredged at a given time. This approach means that it takes time to remove localized pockets of contaminated sediment, but the effect is still observed over time. Average concentrations in sediment along the river channel are lower after 1995, and there is also less variability in measured concentrations (as indicated by the smaller standard deviation). The channel sediments are consistently less contaminated after decades of sediment removal and confinement. Even though the sediment total PCB concentrations in the Calumet River channel are well below historic levels at 0.42±0.20 mg/kg, they are likely insufficiently low for beneficial use. Fox River channel sediments had lower concentrations (0.26±0.10 mg/kg, 2010) which appear reflective of remediation activities starting in 2004 (Wisconsin Department of Natural Resources [WDNR] 2025).

The Saginaw River federal channel sediments also show a dramatic decrease in sediment PCB concentrations. Historically, in the 1970s and 1980s, PCBs were routinely measured in concentrations greater than 10 mg/kg. As with the Calumet and Fox Rivers channels, the Saginaw River channel is miles long and is not dredged in entirety during any given year. Over the course of a number of years, the entire river has been addressed with sediment PCB concentrations declining dramatically by 1995. Starting in 1995, only one individual sediment sample had a detectable PCB concentration; all other sample results were non-detectable. Note that the "average" concentrations presented in Figure 6 represent the DLs for the 1994, 2004 and 2021 sampling events (0.1, 0.11 and 0.04 mg/kg, respectively); the 2011 event had one sample with a concentration of 0.81 mg/kg. For comparison, Gewurz et al. (2008) report a mean total PCB Lake Huron sediment concentration of 0.0227 mg/kg. The Saginaw River sediments in the federal channel show similar total PCB concentrations to the lake background.

Ashtabula Harbor channel sediment total PCB concentrations are shown in Figure 7. The Lower River Channel and Outer Harbor Channels are discrete channel areas within the harbor. In both of these areas, sediment concentrations have decreased in a similar fashion over time. The Lower River Channel sediment initially had higher PCB concentrations, but after 2005 concentrations have steadily decreased with measurements being very low or non-detectable. The Outer Harbor channel sediments exhibited a similar trend except for in 2005 where a single sample (1.5 mg/kg) skewed the average high. A lake reference site, used to represent background conditions within the lake and outside the dredging area, was also sampled in 2021. The average sediment total PCB concentration of 0.097±10 mg/kg at this site exceeded those in the Lower River Channel and Outer Harbor Channel sediments (0.026±10 and 0.027±23 mg/kg, respectively). The discrete lake site concentration was consistent with the average Lake Erie total PCB concentration of 0.0965 mg/kg reported by Marvin et al. (2002) and the 0.06 to 0.12 mg/kg concentration range for central Lake Erie basin bottom sediments projected by Li et al. (2018). These data illustrate the beneficial impact routine navigation dredging has had on sediment concentrations in the federal channel. This sediment dredged from Ashtabula Harbor Federal channels is currently being used for wetlands creation and would be appropriate for a variety of other in-water water beneficial uses as well.

The decreasing trends in total PCB concentrations in federally maintained navigation channels is common across the Great Lakes. Figure 8 shows the results from the five industrial channels discussed above plotted in tandem. Although two channels (Kinnickinnic River and Calumet River) still have sediment PCB concentrations that would preclude beneficial use, the decreasing trends are evident in all channels.

SUMMARY AND CONCLUSIONS

Historical PCB data on sediments in five Great Lakes federally maintained industrial harbors were plotted over time. Total PCB concentrations were averaged from samples collected across the federal channel or in discrete areas thereof. The plots show a consistent pattern. Prior to 1990, all harbors had elevated (>1 mg/kg) total PCB concentrations, such that the sediment required confinement or management by other appropriate means. The years between 1990 and 2000 represent a transition period after which the federal channel sediment transitions to low or non-detectable concentrations of PCBs. There appears to be an association between routine maintenance dredging in these channels and the observed overall reduction in federal channel sediment PCB concentrations over time.

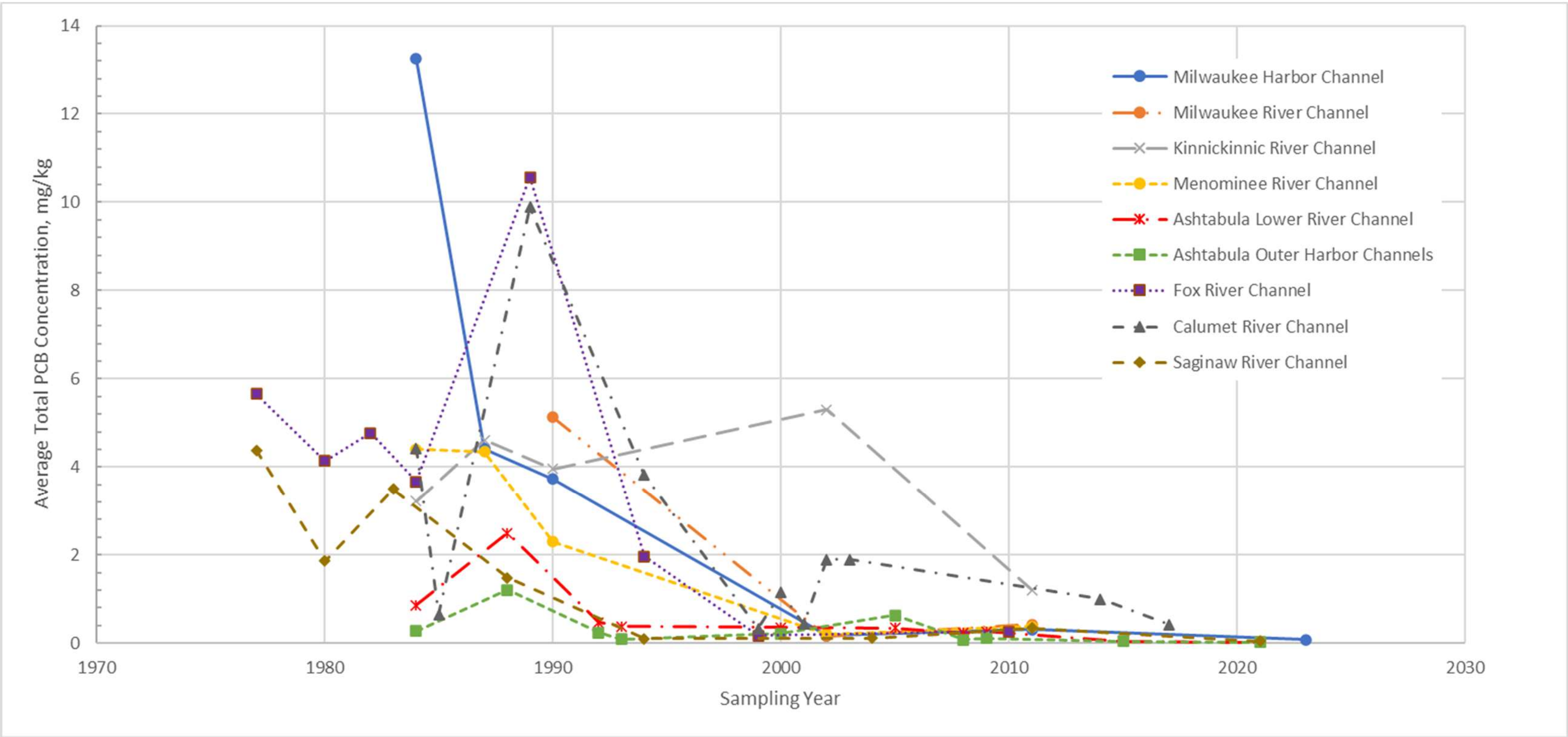

Figure 8. Summary of Average Total PCB Sediment Concentrations over time, in select Great Lakes Federal Navigation Channels

Although not a statistical analysis, anecdotally it is clear that regular dredging can be associated with the decrease of persistent historical contaminants within the federal channel. Dredging is not often credited with environmental improvement, however in the case of regularly maintained federal channels there appears to be a consistent trend showing that maintenance dredging reduces sediment PCB concentrations over time, at times to below general background levels. The result is that channel sediment is now likely suitable for beneficial use due to the low anthropogenic contaminant concentrations evidenced through the PCB data assessed in this paper. Future USACE dredged material management planning will need to include beneficial use as a viable sediment placement alternative at commercial harbors. More than 50 years of repeated maintenance dredging has markedly improved the quality of sediments in federal channels. It's time to change our approach to beneficial use of Great Lakes sediment.

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IDENTIFICATION OF BENEFICIAL USE OF SEDIMENT AND HABITAT RESTORATION NEEDS AT CONTAMINATED GREAT LAKES COASTAL AREAS

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ABSTRACT

Effectively planning sediment beneficial use (BU) projects can benefit from a systematic approach to identify potential project sites where sediment BU can be applied. One category of BU opportunities is represented by former remediation sites, where sediment contaminants have been removed or isolated, but where the resultant aquatic habitat has not been fully restored. Pairing sediment BU with habitat restoration at formerly contaminated sediment sites offers many potential benefits, including increased sediment BU applications and restoration of degraded habitat and related co-benefits. A tiered screening approach for prioritizing habitat uplift opportunities is presented. Focusing on the US Great Lakes, aquatic remediation sites were identified from publicly available information and subsequently screened based on proximity to a federal channel; proximity to BU sources; the range of benefits provided; support by stakeholders; and project implementability. The 53 project sites initially identified were effectively screened, resulting in a focused list of projects more likely to be successfully implemented. One high-ranking project will be advanced towards implementation, which will be discussed in a subsequent paper. While this paper focuses on habitat restoration at Great Lakes aquatic remediation sites, the approach is universally applicable.

Keywords: Habitat uplift, dredging, dredged material, nature-based solution, ecosystem restoration, remediation

INTRODUCTION

For more than 200 years, the US Army Corps of Engineers (USACE) has been maintaining US navigable waterways by dredging (USACE 2024a). For much of that time, dredged sediment was

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viewed as a nuisance, and a waste to be disposed of or discarded without value. USACE annually dredges between 150 million to 350 million cubic yards (115 million to 270 million cubic meters) of sediment (USACE 2024b). Of that volume, historically less than 40% of dredged material has been used beneficially (Searcy Bell et al. 2021; PIANC 2023).

Changes to the national approach for sediment management are underway by USACE. Section 125(a)(1) of the Water Resources Development Act of 2020 (33 U.S.C. 2326g) directs USACE to maximize beneficial use (BU) of dredged material. In January 2023, USACE released a *Sediment Beneficial Use of Dredged Material Command Philosophy Notice* (Spellmon 2023), establishing a goal to increase sediment BU to 70% by 2030 ("70/30 Goal") and subsequently codified in WRDA 2024 Section 117(c)(2)(B). Perhaps the most significant opportunity to achieve the 70/30 Goal is to apply broad implementation of nature-based solutions (NbS; Bridges et al. 2021), natural infrastructure (Benedict and McMahon 2006), and USACE Engineering With Nature® (EWN®) projects and to employ BU alternatives developed from a "Working with Nature" (PIANC 2018) perspective. Annual navigational dredging by USACE provides large quantities of clean material appropriate for nature-based projects (Searcy Bell et al. 2021; PIANC 2023). USACE is pursuing additional BU opportunities to meet the 70/30 Goal, including BU opportunities working with contaminated sediment.

Aquatic sites impacted by chemical contamination and subsequently remediated often require additional rehabilitation to restore ecological functions (Rohr et al. 2016). Sediment remediation, whether in marine or fresh water environments, typically results in a sediment surface that no longer poses adverse risks to human health or the environment, whether though dredging and backfilling, capping, or in-situ stabilization and cover (National Research Council 1997; US Environmental Protection Agency, USEPA 1994). Remediated areas are generally not designed to support habitat functions; in fact, active remediation can result in damaged ecosystems (Burger 2007), such as through solidification and stabilization that results in a hardened bottom (USEPA 2021d), capping methods that include armoring or other anchoring materials (USEPA 2021a; 2021b), or dredging that can alter water depths, thus hindering natural ecosystem functions (USEPA 2021c).

Clean dredged material can be used beneficially as the basis to restore aquatic habitats (Foran et al. 2018; Laboyrie et al. 2018; McQueen et al. 2024; Suedel et al. 2021) after remediation (Piercy, Welp, and Mohan 2023). The term "habitat uplift" can be used to describe this approach as it refers to restoring, enhancing, or establishing conditions that improve and sustain habitat functionality that is greater than the present condition, as quantified by biodiversity, ecosystem services, or other suitable metrics. In this case, material dredged from a federal navigation channel may be used as a basis to achieve this uplift by serving as a physical foundation to support a highly functional ecosystem (Piercy, Welp, and Mohan 2023).

Both sediment BU and ecological restoration of remediation sites can be linked and approached in a systematic manner to maximize opportunities to uplift aquatic habitats, consistent with the planning approach used by USACE (Orth and Yoe 1997). This paper presents one such systematic approach to identify habitat restoration needs and opportunities at formerly contaminated sediment sites where sediment remediation is planned or complete, and to identify opportunities to leverage BU using navigation-dredged sediment to create or restore habitat. The focus of this paper is on sites in the Great Lakes where multiple sites with previous remediation activities offer opportunities for habitat uplift. While focused on the Great Lakes, the approach described herein is widely applicable.

This paper presents a systematic screening process to identify candidate sites for habitat restoration and uplift using dredged sediment (i.e., leveraging BU). The paper presents an initial list of sites that underwent the screening process. At down-selected sites, the authors will engage site owners and stakeholders to optimize habitat alternatives that will be incorporated into designs for "shovel-ready" implementation. By using this systematic approach to document potential project sites that are not currently down-selected, pertinent information is retained as a basis for future implementation. This research directly integrates ecosystem restoration with the need to increase BU across the US.

APPROACH AND METHODS

Developing a List of Sites

The analysis of available restoration sites commenced with an initial search that generated a broad list of possible project sites based on publicly available sources from state and federal regulatory programs such as Superfund and the Great Lakes Legacy Act, which provide information on remedial action sites and their remediation status. Sites were limited to those within the Great Lakes and its tributaries. Focus was on waterways (rivers, lakes, and coastal areas) with identified sediment contamination issues that have been or are planned to be remediated. Sources of information on potential project sites include USEPA websites such as Enviromapper (USEPA 2024a) and similar state remedial action databases, program specific search sites such as Superfund (USEPA 2024c), and other agency programs such as the Great Lakes National Program Office Areas of Concern (USEPA GLNPO; USEPA 2024b). These sources were used to generate a list of remediation sites that spanned a broad Great Lakes footprint.

Screening Criteria

Potential project sites were prioritized using a tiered framework with five screening criteria to systematically narrow down the initial list (Figure 1). Project information was compiled in a spreadsheet matrix to organize and logically progress projects from discovering "deal-breaker" information about a site into practical matters affecting the likelihood of successfully implementing a restoration project. Ultimately, a broad list of projects was screened into a shorter list of sites to focus efforts to a final down-selected site.

Within each tier, criteria were assigned numerical values to compare and rank projects. Certain tiers contain multiple sub-criteria to further screen projects. This approach is designed not for statistical evaluation, but to screen projects and identify those worthy of further evaluation. Scores range from zero to three, with three indicating the highest alignment with the criteria. A score of zero signifies non-compliance with a criterion, while higher scores reflect increasing levels of compliance and alignment with the evaluation parameters. A project that scored zero in any criterion was removed from the active list; all other projects were retained for further evaluation.

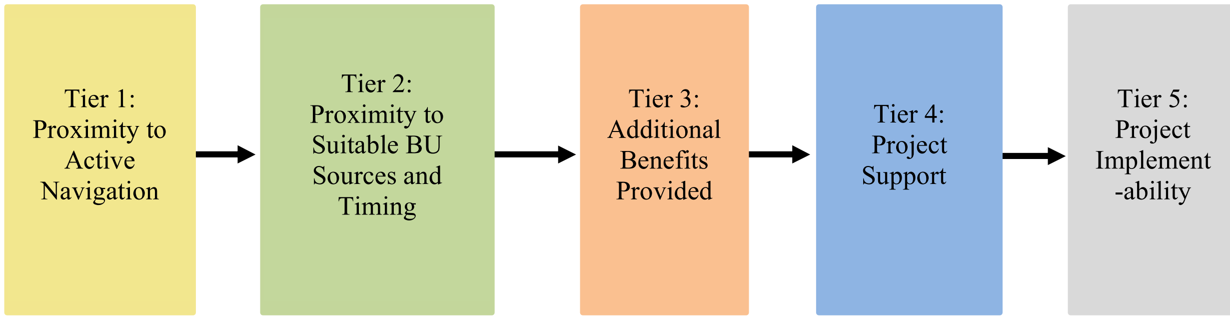

Figure 1. Screening Criteria Tiered Approach.

Tier 1: Proximity to Active Navigation

This matrix was designed to be a living tool, to be updated as additional information becomes available, with a site's overall score changing accordingly. Such an approach focused on projects that meet key criteria in the near term, thus increasing the likelihood for identifying potential project sites. A lower score does not necessarily mean that a candidate site is not well suited for habitat uplift; for example, a lower score may simply suggest that timing is not ideal for the site in question.

The screening began with an evaluation of site locations. Sites within active shipping areas or authorized channels were screened out, because habitat development is not consistent with ship navigation. The second tier focused on the potential availability of sediment for BU and the status of the project site. Tier 3 focused on the potential benefits from habitat restoration. Tier 4 addressed project support from stakeholders, while Tier 5 is about project implementability considerations. The following sections describe each tier in greater detail.

The first tier examines project location in the context of the potential for future disturbance, especially from commercial or recreational vessel traffic. The goal of habitat uplift is to restore habitat long-term, so if a site is within the federal navigation system or is otherwise actively used for waterway navigation, it could be impacted by future dredging or vessel traffic. Therefore, sites within a federal navigation channel or an active dock/slip were deemed unacceptable for habitat restoration and were screened from further consideration.

Tier 1 is a pass/fail criterion (i.e., scored one for pass or zero for fail) due to USACE restrictions against conducting projects in active federal navigation channels. If a Tier 1 criterion receives a score of 0, the project is dropped due to non-compliance. Tier 1 is the only category that can disqualify a project from further consideration.

Tier 2: Proximity to Suitable BU Sources and Timing

The second tier is concerned with the potential for a habitat uplift project to connect with an available and suitable source of dredged material, as well as with favorable timing relative to the site's remediation status. Tier 2 has three sub-criteria to evaluate: BU source location; BU source quality, quantity, and availability; and alignment of dredging and site remediation schedules.

The likelihood of a BU project being implemented successfully improves when dredged material is kept within the local watershed (Parson and Swafford 2012). This has ecological benefits, and perhaps more importantly is cost effective. Material costs including transportation costs often limit BU applications (Williams et al. 2020). Therefore, if a navigation dredging source cannot be identified within a site's local watershed, it is scored zero and screened as potentially infeasible. If a dredged material source is identified, the site is then ranked based on its distance to that source. A source located less than three miles (4.8 km) away receives the highest score of three, a source greater than three miles (4.8 km) but less than nine miles (14.5 km) away receives two points, and a source located over ten miles (16.1 km) distant is given a score of one.

Once a potential sediment source is identified, the next step is to evaluate whether it has the quantity and quality necessary to support habitat uplift. Considerations such as BU site footprint and depth can be compared to dredging volumes typical for the identified federal navigation maintenance area, or available stockpile volume. Environmental suitability of dredged sediment also should be evaluated based on the habitat type targeted for restoration (Keil et al. 2022). For our study, wetlands were the target habitat designated for uplift; therefore, source sediments must have characteristics to support wetland plant growth (National Research Council 1995; Van Riel et al. 2022). Aquatic, nearshore, or upland habitat uplift projects may evaluate these parameters differently.

Finally, the sediment source is evaluated relative to its availability. For example, a source of dredged material that is not dredged regularly or is not scheduled to be dredged for an extended period may not be available for near-term BU opportunities. For this sub-criterion, projects with BU sources that lack quantity, quality, or availability of dredged material are screened with a score of zero. Sources with both suitable quality and quantity are ranked with a score of two, and sources only with suitable quality *or* quantity are ranked lower with a score of one.

In addition to aligning a potential project to a nearby and suitable BU source, favorable alignment with overall site remediation is essential when prioritizing habitat uplift opportunities. Navigation maintenance dredging tends to occur on comparatively short schedules compared with remediation and restoration projects, which often have longer planning horizons. In Tier 2, projects in the planning phase or with stalled remediation efforts were screened with a score of zero as having too long or non-existent start times for habitat uplift. Projects with remedial action complete or in progress scored highest with a score of two, and projects in the remedial investigation or remedial design phase scored lower with a score of one. The remediation phase will change over time and so should be re-evaluated in the future; some projects screened in an initial evaluation could become viable in the future and projects with remediation in progress could stall and become less viable. Projects that passed Tier 2 sub-criteria were advanced to Tier 3.

Tier 3: Additional Benefits Provided

The third tier evaluates the benefits of a potential habitat uplift project. At this stage, because the central goal of this study is to achieve meaningful habitat uplift, projects were scored zero and screened from further consideration if there is little potential for additional habitat improvement. For example, if fully functioning wetland habitat already exists at a site, the opportunity to positively change that habitat by adding sediment is diminished. Creating habitat using dredged material is valued for its ability to improve fish and wildlife habitat, the site's aesthetics, and recreational opportunities, all of which can contribute to community health and resilience. Keil et al. (2022) provides examples of sites in Great Lakes Area of Concern where sediment BU has improved degraded waterway habitat to support removal of BU impairments.

Recognizing the potential to achieve multiple environmental and societal benefits, Tier 3 focuses on the additional benefit potential of a habitat uplift effort. It prioritizes projects that provide social and cultural benefits which can promote the wellbeing of vulnerable populations disproportionately impacted by pollution. The evaluation also considers whether the site has recognized Tribal nations benefits based on location and Tribal engagements.

Projects that support identifiable social and cultural benefits (score of two) consistent with EWN® principles are ranked above projects that may not provide these additional types of human enrichments. For the Great Lakes region, proximity to Tribal nations communities and treaty land areas are indicators considered for cultural benefit, but these may be defined differently for other areas of the US. Tribal and treaty areas can be determined from existing national websites (e.g., Federal and Indian Lands and Land Cessions Viewer, U.S. Forest Service 2025). National programs or state historical preservation offices provide maps or other information on the presence of cultural resources near the project (NOAA 2025). The presence of national, state or local parks may serve as an indication of the presence or lack of availability of greenspace or other social resources. Other national websites (U.S. Census Bureau 2025) may provide useful demographic information on a project area. A site is not penalized for lacking identified social or cultural benefits, rather, sites with these attributes get "bonus" points. A project only receives a score of zero and is screened from further consideration in Tier 3 if it is viewed as having little to no potential to provide habitat improvement.

Tier 4: Project Support

Tier 4 provides an opportunity to evaluate project support from stakeholders, including Tribal nations. Outreach is crucial to ground truthing project information and is a logical next step to continue the screening process. Strong stakeholder project support, at the time of implementation as well as for future monitoring and maintenance, can greatly facilitate project success. For example, many potential habitat uplift sites are located at former industrial sites, and property owners may have industrial/commercial land use goals (including under water areas) that are not compatible with habitat uplift.

In Tier 4, the scoring system evaluates stakeholder support for habitat uplift at the project site. Stakeholders for sites that score highest under Tiers 1 to 3 are contacted to gauge their willingness to support the project. Sites with little or no known support receive a score of zero and do not advance to Tier 5. A score of three indicates the highest alignment with supportive stakeholders. Projects with scores ranging from one to three demonstrate varying levels of stakeholder support and are progressed to Tier 5. As with other tiers, Tier 4 can be revisited in the future, as stakeholders and stakeholder interests may change with time.

Tier 5: Project Implementability

The fifth and final tier focuses on project implementability. A habitat restoration project that successfully leverages BU should include an initial evaluation of potential funding, cost, ease of permitting, logistical details such as site access and hydrodynamics, and implementation timeline. Tier 5 is therefore split into five sub-criteria to evaluate each of these considerations. The Tier 5 screening criteria should be collaboratively evaluated with stakeholders who are most familiar with these details, to identify and deprioritize habitat restoration projects with notable implementation impediments that lower the likelihood of success.

In scoring the sub-criteria, higher rankings were applied to 1) projects that appear to have straightforward implementation processes as defined by lower relative cost and available funding, 2) projects that did not have notable permitting challenges, and 3) and projects that are relatively easily accessed and have short implementation timelines. Implementation timelines of zero to two years are considered short-term, while timelines of six or more years are regarded as long-term. All projects reaching Tier 5 are retained for further consideration, as there are no pass/fail criteria; instead, site scores are further refined in this final tier to aid the identification of projects that achieve the highest scores and thus warrant further selection evaluation.

RESULTS AND DISCUSSION

The five-tier screening approach developed and applied in this study yielded meaningful and substantive insights into how former remediation sites can be prioritized for habitat uplift. The approach was used to systematically identify, evaluate, and rank potential projects at 53 Great Lakes sites (Figure 2). Not surprisingly, many of the 53 sites evaluated for habitat uplift potential are located along river mouths and harbors where prospective habitat uplift opportunities are aligned with completed and prospective remediation activities. Table 1 shows the results from five of the projects that illustrate the wide range of possible screening outcomes.

Tiers 1-3 Screening Results

The initial list of projects compiled for this study included 53 sites across the US portion of the Great Lakes region. Projects from Lakes Superior, Michigan, Huron, and Erie and all Great Lakes US states except Pennsylvania and New York were identified. (Pennsylvania and New York were not intentionally excluded, however an initial screening of sites failed to identify candidates in those coastal areas.) Project sites included state-led remediation sites and sites remediated under Superfund (Comprehensive Environmental Response, Compensation, and Liability Act), the Resource Conservation and Recovery Act, or as part of a Great Lakes Area of Concern.

Of the 53 initial projects identified for evaluation, 13 were screened during Tier 1 due to their location within an active waterway. For example, Manitowoc MGP Operable Unit 2 was deemed unsuitable for aquatic habitat restoration because it is situated in the lower reach of the Manitowoc River, a federally maintained navigation channel (Table 1). This unsuitability arises from potential impacts from future dredging or ship traffic.

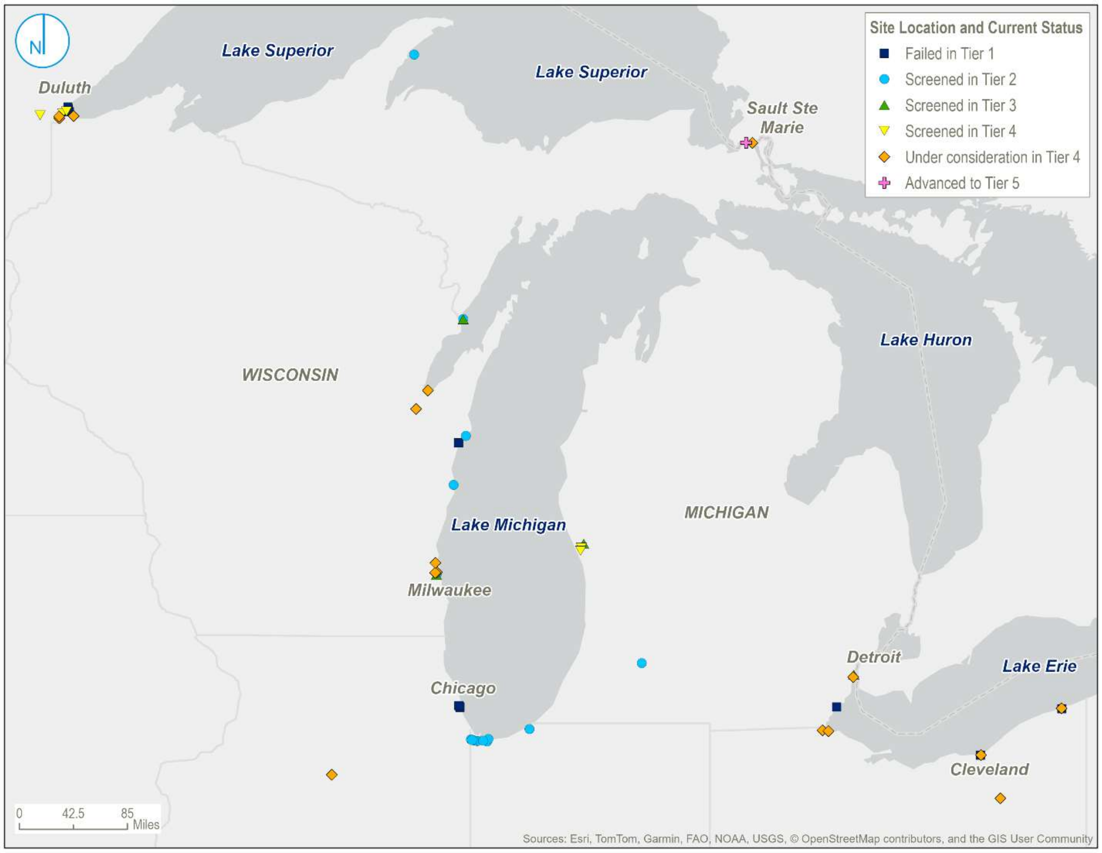

Figure 2. Status for the 53 Sites Systematically Screened for Habitat Uplift Potential.

Of the 40 projects that were advanced past Tier 1, 14 were screened during Tier 2: eight projects had insufficient quality and quantity or available source of sediment for BU; the remaining six projects were in the planning phase, or remediation efforts had stalled. Projects like those at the Lake Superior Stamp Sands, which have a remedial investigation in progress, were screened because habitat uplift could not be completed within a reasonable timeframe (e.g., within the next five years) (Table 1). Projects screened due to their remediation status may be reconsidered in the future if remediation is successfully completed. Similarly, future dredging plans could result in the availability of sediment suitable for BU, and nearby sites could be reconsidered when dredging is likely to be scheduled.

Of the 26 projects that were advanced past Tiers 1 and 2, four sites were screened in Tier 3 because each site supported wetlands, which leaves fewer opportunities to uplift the existing habitat using dredged material placement. For example, Monguagon Creek/Upper Trenton Channel, a tributary of the Detroit River, is in the final stages of remedial design (Table 1). While the site could benefit from the placement of dredged sediment as part of the sediment remedy, the remedial footprint is too small, and the design requirements limit habitat uplift potential on the site. A key criterion in Tier 3 that also contributed to screening projects is the ability to incorporate environmental, cultural and social benefits into the design of the project, consistent with the EWN® concept of

Table 1: Screening Criteria Results for Four Example Projects Evaluated.

Tier of Analysis	Screening Criterion	Numerical Scoring	Manitowoc Manufactured Gas Plant Manitowoc River	Gay Stamp Sands Lake Superior	Monguagon Creek/ Upper Trenton Channel, Detroit River	Oil Barge Dock Slip Port of Superior	Tannery Bay St Marys River
Site description			Remediated Manufactured Gas Plant site, which includes upland and in-river sediment remediated areas.	Coastal lake mine waste along many miles of Lake Michigan Shoreline. In Feasibility Study phase.	Channel feeding the Detroit River, which has been impacted by past discharges. In remediation design phase.	Abandoned slip within the Port of Superior. In remediation design phase.	Remediated superfund site. Included removal of contaminated sediments.
Tier 1	Proximity to Active Navigation (Pass/Fail)	– Located adjacent to or outside channel or slip = 1 – Located within channel or dock/slip = 0 (Fail)	0 - No further analysis, project is within federal channel	1	1	1	1
Tier 2	Proximity to nearest BU source (Pass/Screen)	– Project ≤3 miles from source = 3 – Project 3-9 miles from source = 2 – Project ≥ 10 miles from source = 1 – No identifiable BU source = 0, screened		1	3	3	3
	BU source quality and quantity (Pass/Screen)	– Material matches project need = 2 – Sufficient quality or quantity = 1 – Insufficient quality and quantity = 0, screened		1	2	2	2

Tier of Analysis	Screening Criterion	Numerical Scoring	Manitowoc Manufactured Gas Plant Manitowoc River	Gay Stamp Sands Lake Superior	Monguagon Creek/ Upper Trenton Channel, Detroit River	Oil Barge Dock Slip Port of Superior	Tannery Bay St Marys River
	Status of remediation (Pass/Screen)	– Project RA in progress or complete = 2 – Project RI/RD in progress or complete = 1 – Project in planning phase = 0, screened		0 - Too early in remediation process	2	2	2
Tier 3	Does the project provide additional benefits beyond environmental (Pass/Screen)	– Project provides multiple social and cultural benefits = 2 – Project provides at least one social or cultural benefit = 1 – Project provides no additional benefits = 0, screened			0 – Little habitat potential	2	2
Tier 4	Project Stakeholder support	– Stakeholders are fully supportive = 3 – Stakeholders are generally supportive but have some reservations or require additional information before fully committing = 2 – Stakeholder support is limited due to concerns or conditions that need to be addressed before they can offer more substantial backing = 1 – Project is not supported = 0, screened				0 – not supported by regulatory agency/ stakeholder	3

Tier of Analysis	Screening Criterion	Numerical Scoring	Manitowoc Manufactured Gas Plant Manitowoc River	Gay Stamp Sands Lake Superior	Monguagon Creek/ Upper Trenton Channel, Detroit River	Oil Barge Dock Slip Port of Superior	Tannery Bay St Marys River
Tier 5	Funding	− Project has identified funding sources = 3 − Project has identified some potential funding sources, but they are not yet secured or fully committed = 2 − Currently no funding sources identified = 1					2
	Cost	− Estimated project costs appear reasonable = 3 − Project costs are somewhat reasonable, but there are concerns about potential overruns or the need for costly techniques, equipment, or materials = 2 − Project requirements will require more costly techniques, equipment, or materials = 1					3
	Ease of permitting	− No apparent obstacles = 3 − Cross-state permitting = 2 − Potential obstacles identified = 1					3

Tier of Analysis	Screening Criterion	Numerical Scoring	Manitowoc Manufactured Gas Plant Manitowoc River	Gay Stamp Sands Lake Superior	Monguagon Creek/ Upper Trenton Channel, Detroit River	Oil Barge Dock Slip Port of Superior	Tannery Bay St Marys River
	Site access and other logistics	– Good site access, no apparent construction impediments= 3 – Site access is generally good, but there are some minor construction impediments or logistical challenges that need to be addressed = 2 – Issues with site access or construction limits = 1					3
	Timeline	– Project has near term implementation timeline, with no obstacles or delays identified = 3 – Project has a near-term or intermediate-term implementation timeline, but some minor obstacles or potential delays have been identified that may need to be addressed = 2 – Project has longer implementation timeline or identified potential delays = 1					1
Totals			**0**	**3**	**8**	**10**	**25**

striving to achieve multiple benefits of sediment beneficial use projects. The screening process completed through Tier 3 roughly halved the initial number of projects evaluated, focusing further screening efforts on a smaller subset of projects.

Tiers 4-5 Screening Results

Tier 4 of the screening process engages appropriate stakeholders and regulatory (remediation program) staff to obtain meaningful feedback on the data gathered to date and potential next steps. The agency contacts can indicate whether information gathered is accurate and complete, revealing site-specific constraints and limitations of habitat uplift.

In support of the Tier 4 assessment, meetings were held with USEPA Region 5 staff to discuss the screening process in general and to receive feedback on remaining sites. Feedback was provided during these meetings on site remediation status, which was not always self-evident, as well as on potential site-specific limitations such as likelihood of stakeholder support and possible funding mechanisms. These details were invaluable for completing the Tier 4 screening process.

Obtaining stakeholder feedback and support for projects being considered in Tier 4 can take time, as discussions with relevant individuals, likely from multiple agencies and organizations, are necessary. Developing multiple means of communication such as creating maps and developing landscape architecture drawings of potential uplift features under consideration in Tier 4 may help focus attention within smaller jurisdictions to streamline this iterative process.

Tier 4 screened five projects from further consideration due to a lack of stated support from project stakeholders. One project of note at Tannery Bay on the St. Marys River, located immediately upstream of Sault Ste. Marie, had interested parties who supported moving forward to explore a restoration project using dredged material; therefore, this project was scored high and advanced to Tier 5 (Table 1). The Tannery Bay project also has a nearby suitable source of available sediment; has the potential to provide environmental, social, and economic benefits; and has supportive stakeholders. The remaining 16 projects that progressed to Tier 4 represent future BU opportunities, having no identified impediments; they will be considered in the future as time and resources permit.

SUMMARY AND CONCLUSIONS

The USACE dredges 150 million to 350 million cubic yards (115 million to 270 million cubic meters) of sediment annually, of which approximately 40% is used beneficially. While progress is being made toward the USACE 70/30 Goal, achieving 70% BU by 2030 will require creating new, untapped BU opportunities. Maximizing BU of navigational dredged material will benefit from systematically evaluating BU opportunities. Successful restoration of the environment at aquatic remediation sites offers the potential to incorporate BU for habitat uplift. This process combines these two elements as a demonstration of a tiered approach to identifying BU opportunities.

Focusing on the Great Lakes region of the US, aquatic remediation sites were identified from publicly available information that covered a range of environmental compliance programs and agencies. The identified sites were then screened using a five-tiered process: 1) proximity to a federal channel; 2) proximity to BU sources; 3) range of benefits provided; 4) project stakeholder support; and 5) project implementability.

The initial screening phases (Tiers 1 through 3) evaluated logistical elements critical for project success and resulted in screening half of the initial candidates from further consideration. Subsequent screening phases (Tiers 4 and 5) provided more detailed evaluations, thus increasing the likelihood that the selected projects offered the greatest potential benefits for stakeholders and targeting projects that could eventually be advanced through to implementation and monitoring.

Projects were successfully screened at each evaluation tier, resulting in a shorter and more focused list of projects with the highest scores. The sites with the highest scores are considered to have a greater likelihood of success due to fewer meaningful impediments to habitat restoration using dredged sediment BU. While some lower scored projects may not be implementable in the near term, their status in the future may change as site conditions change.

Out of an initial list of 53 projects, one achieved the highest score and was thus advanced to implementation, which will be discussed in a subsequent paper. The remaining projects can be re-evaluated in the future, with additional sites added when additional information becomes available. In this manner, the approach becomes a reproducible and sustainable method of identifying opportunities to support both BU and ecosystem restoration in areas not previously targeted for BU. Such an approach can serve as an enabler to increasing sediment BU across the USACE while addressing recent regulatory requirements and achieving multiple environmental, cultural, and social benefits; the methods used here also can extend beyond focus on remediation sites, though this focus served as an unstated screening criterion used in this analysis. The approach can be replicated in any area of the country, thus allowing for the deliberative and systematic identification of BU to further enable habitat uplift opportunities.

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