Great Lakes Port & Harbor: Infrastructure & Dredging
Cost Estimate Matrix Tool and Duluth, MN/Superior, WI and Toledo, OH Case Studies

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Defining the parameters of the Matrix

Great Lakes ports, harbors and marinas are vulnerable to several potential climate change impacts. The two major impacts most relevant and potentially most costly are water level and storm intensity. Both rising and falling water levels can impact infrastructure stability and overall strength, as well as requiring additional channel dredging. A climatic change resulting in an increase in severe storms (more precipitation, higher winds and greater number of storm events) is also viewed as having detrimental affects on infrastructure. More severe storms can create larger waves, more extreme Seiche events and greater storm-surges that can damage port and harbor infrastructure requiring costly rehabilitation or replacement. In addition to infrastructure issues, an increased storm frequency and intensity will increase channel silting and sedimentation, compounding dredging problems analogous to lower water level scenarios.

Climate model predictions for specific weather outcomes vary greatly throughout the Great Lakes Basin, and include both higher and lower water levels scenarios. However, all predictions seem to include an increase in both the number and intensity of major storm events. This combination can result in unanticipated water level change, larger waves, more dramatic Seiches and greater storm surges than considered in original design parameters (all of this in addition to the antiquated and sometime dilapidated state of our Great Lakes infrastructure).

The Matrix was designed to help communities identify the current “value” of their navigational and port infrastructure, allowing them to extrapolate the potential costs for maintaining these resources in the face of changing water levels and storm conditions due to climate variation. Potential secondary economic impacts, such as those that could be anticipated as the result of the failure of primary support infrastructures, can easily be added to matrix data to expand the scope of economic impacts (this could be many times the value of primary structures). Secondary costs could involve: buildings, land-based transportation facilities, commercial and recreational docks and staging areas, private investments such as grain elevators and storage facilities, as well as public investments like water treatment facilities, cultural resources, public access points, and even sensitive wetlands and estuaries, etc. The Matrix is designed for use in any port, harbor, or marina within the Great Lakes region. The Matrix can also be linked to U.S. Army Corps of Engineers “current infrastructure condition ratings,” being conducted in Great Lakes ports and harbors to offer a more concise view of current actual condition, and to help identify potential threats to various infrastructure types.

Harbor Structure Matrix Costs ($/ft) vs. Depth Ranges

NOTE: Great Lakes ports and harbor structure cost-range estimates can only project preliminary comparisons, since many additional factors can influence "actual costs." Numerous variables are identified and noted within each Matrix table. In addition, depth is a major issue, and three distinct depth cost estimates are available to refine cost/value estimates. Typically, the more shallow the structure, the lower the overall cost.

Structure Matrix cost tables were prepared and divided into two distinct categories of typical Great Lakes ports and harbor structures. Both tables included costs for either repair/rehabilitation or total replacement of the structures and each were sub-divided into three ranges of typical depths (shallow = 8' – 13', medium = 14' – 25', and deep = 26' – 35' plus). The first Matrix table provided cost estimates for eleven different harbor entrance structure types (structures built to withstand direct large Great Lakes wave attack and significant storm surges and seiches). The second structure Matrix cost table provided cost estimates for nine different harbor interior structure types (structures which are more common for typical harbor interior slip wall designs) in the same three ranges of typical depths. Costs did not include site investigations, design or permitting work. These three additional factors could add another 25% or more to the overall costs and vary greatly depending upon individual ports and specific infrastructure condition/location details that would be impossible to include in a truly "regional" matrix or tool. Specific dock details for a large number of Great Lakes ports and harbors can be found at http://www.maritime.utoledo.ed/. Use of this data source will be discussed further in the two case studies described below. To assure a complete harbor assessment, it is important to include both public and private infrastructure.

Sample structure types for the entrance structures selected were steel sheet pile bulkheads with a variety of structure caps, rubble mound breakwaters, timber cribs with a variety of structure caps and closed steel sheet pile cells. Interior structure types included standard steel sheet pile walls, timber cribs, soldier-pile walls with timber or concrete and open dock structures with piling supports.

The cost ranges in each Matrix table were compiled from many sources. The US Army Corps of Engineers Great Lakes district offices provided structure cost estimates based upon actual project bid prices (after using the USACE Civil Works Construction Cost Index System to escalate historic costs to June 2010 levels). Three different nationally known coastal engineering design firms with offices and projects in the Great Lakes provided 2010 cost estimates derived from actual construction, contract/bid costs that were readily available, or from design or study estimates. In addition, three different Great Lakes construction firms also provided costs estimates for several of the structures most commonly constructed in the Great Lakes.

Note: Structure-specific factors can influence cost estimates greatly. Therefore, ranges of costs within each depth category for each type of structure in the Matrix are typically given. Also, cases where one type of structure most likely would now be repaired or replaced by a different type (i.e., older timber cribs are now typically replaced with steel or rock structures) are also noted in the Matrix tables. Some of the more common factors that will need to be taken into account when choosing which costs to use are given below.

Site-specific factors that will affect parametric estimates include: land based vs. water based construction, remoteness of site, prevailing wages in that area, and permitting/environmental constraints.

Typical factors which influence the range of stone structures include: distance between the quarry and point of placement, truck distance, barge towing distance, fuel prices, material (rock) sizes, rock quality, cross-section of structure, time of construction, equipment availability and type of equipment used for placement of rock.

Typical factors which influence the range of steel structures include: volatility of steel prices which directly affect the prices for steel sheet piles and tie rods, stone or sand backfill and reinforcement concrete prices, whether steel is hot or cold rolled sheets (cold rolled being less expensive but problematic in hard “driving” or placement conditions), owner’s risk tolerance, and conditions that may require coatings or galvanizing of materials.

Harbor Dredging Costs (per ft of depth dredged)

Great Lakes dredging costs differ greatly depending upon location and size of the dredging project. Therefore, dredging costs were separated out based upon the relative region of the harbor and on the size of the actual dredging project (large scale harbor project or smaller individual slip project).

The dredging cost data was collected from the archived US Army Corps of Engineers dredging database (http://www.ndc.iwr.usace.army.mil/dredge/dredge.htm) which includes projects for FY 1993-2009 and was divided into actual port regions (Buffalo, Chicago and Detroit districts). The information was further sorted by large, commercial harbors vs. small recreational harbors. This regional separation and size division helps to gain a better understanding of how the range of dredging costs vary with both size of project as well as regional location. Great Lakes dredging contractors were also contacted for typical dredging costs of both large scale and small scale projects. The contractor information is especially valuable when estimating dredging costs for smaller ports and harbors as well as for individual slip dredging projects. Use of these data sources will be discussed further in the two case studies described below.

Note: Dredging specific factors can influence costs estimates greatly. Therefore, it is important to note the type of dredge used and quantities of material dredged for each of the federal contract resulting costs shown as $/cy. Individual private facility dredging costs can vary greatly depending upon whether the dredging can be part of a larger contract, and the type of dredge proposed (hydraulic, bucket, etc.). Finally, the ease or difficulty in disposal of the dredged material can greatly affect the dredging cost per cubic-yard. In some cases, there may not even by sufficient capacity (such as for the entire federal channel dredging estimates) to dispose of the material. Such costs are not taken into account but clearly must be noted when actually utilizing the Dredging Cost Tool for specific case estimates.

Case Study Applications

To illustrate how the Infrastructure Matrix and Dredging Cost Tool can be used, two specific Great Lakes Ports and Harbors were chosen. The Port of Duluth/Superior in Minnesota and Wisconsin and the Port of Toledo in Ohio were chosen as case studies to apply the regional infrastructure Matrix and Dredging Cost Tool in Specific applications.

Each case study began by utilizing the University of Toledo based data set: http://www.maritime.utoledo.ed/ to select and identify the specific facilities listed for each port. Then, the specific data listed for each port facility was further refined to select those features that would be needed to determine both structure repair/replacement costs and slip dredging details. Such information could be found under the "Ports" tab and then selecting the "docks" information for each specific facility. Important dock details included features such as type of dock wall construction, total berthing length, depth of slip, and maximum height of dock deck above water. This data was then corroborated and often updated or corrected by Port officials to reflect the most current local port information.

Once the information for each facility was entered into an Excel database, each facility was given the appropriate structure designation as identified in the Infrastructure Matrix and a repair and replacement cost-per-foot of berthing length was selected. The database could then calculate the costs required for each individual facility and sum the total for the complete Port.

The costs for dredging the federal channel per foot of depth was calculated by obtaining the total authorized federal channel dimensions for each Port and assuming a typical dredging cost as given by the Dredging Cost Tool for that specific port. Note that each Port's dredging data was determined to be incomplete, therefore local US Army Corps of Engineers offices reviewed the specific database information for the specific Port and updated dredging contracts as needed. Then, determining the costs for dredging the entire authorized federal channel could be easily calculated. Note that if climate change impacts require the dredging of depths deeper than currently authorized, new federal authorization would be required.

To determine the individual facility dredging costs, each port was asked to state whether it was possible that a 1000-foot vessels would dock at any of the facilities. For those docks, the expected width of vessel was taken to be 105' wide while other docks were assumed to be a conventional Great Lakes vessel with the width of 75'. These widths were then multiplied by the total slip berthing length and also by an additional factor of 1.2 (20% overage factor) to account for vessel maneuverability and connection of the dredged slip channel to the authorized federal channel. Since individual slip dredging costs can vary greatly, those costs were calculated at $5, $10 and $15 per cy of material dredged and then added to the costs for the federal channel dredging.

1) Toledo Harbor Results
The Toledo Harbor consists of a total of 28 individual facilities and a total of 55,590,500 sf of federally maintained channel. Therefore, utilizing the Infrastructure Cost Matrix and Dredging Cost Estimation Tool the following results were obtained:
Total Dredging Costs for All 28 Slips + Federal Channel (per foot of depth):
@ $5/cy for slips = $10,824,900
@ $10/cy for slips = $11,355,200
@ $15/cy for slips = $11,885,500
Infrastructure Costs for All 28 Slips:
Repair of all vertical slip walls = $71,347,530
Replacement of all vertical slip walls = $122,833,175

2) Duluth/Superior Harbor Results
The Duluth/Superior Harbor consists of a total of 58 individual facilities and a total of 84,658,343 sf of federally maintained channel. Therefore, utilizing the Infrastructure Cost Matrix and Dredging Cost Estimation Tool the following results were obtained:
Total Dredging Costs for All 58 Slips + Federal Channel (per foot of depth):
@ $5/cy for slips = $39,055,333
@ $10/cy for slips = $40,484,737
@ $15/cy for slips = $41,914,140
Infrastructure Costs for All 58 Slips:
Repair of all vertical slip walls = $177,093,700
Replacement of all vertical slip walls = $298,458,280

Implications:

The Great Lakes Port and Harbor Infrastructure and Dredging Cost Evaluation Matrix (The Matrix) allows ports and their communities to begin to understand the current value of infrastructure in their harbors committed to commercial navigation. Many port communities have little understanding of the value, costs, and opportunities related to maritime transportation in their harbors, or how these investments interface with other important community resources and services. The Matrix can be used to develop baseline economic data for ports infrastructure values to improve public awareness and appreciation for the investment and opportunity that resides in their harbors. The Matrix helps to define the significant investments that have been made by the federal government to support local and state port interests, as well as the need to plan for continued port functionality and deal with potential future liability. Importantly, people can use the Matrix as a tool to create baseline information to plan and budget for adaptation and mitigation strategies to address climactic change anticipated by climatologists.

Next Steps

Regional climate change is recognized as a major issue for 21st Century coastal communities. We know that even relatively small changes in climate can have major impacts on fragile coastal environments. One important element of modern coastal environments is man-made infrastructure, originally built to support maritime transportation and coastal community development. Although we have begun to explore the value and potential liability to our in situ Great Lakes harbor and shore-side protective infrastructure itself, we have not been able to extrapolate potential threats and cost impacts to public and private facilities, or unique biomes, directly dependant on the protection that primary harbor infrastructure provides.

Perhaps the major impediment to broad community action in dealing with climate change is a clear understanding of the cost/value elements that need to be addressed given a specific range of climate variation and its potential physical impact on communities within a specific time period. The first step is to understand what is at risk, next what is its function and value to coastal communities, and what adaptations, modifications, and investments will need to be made to sustain essential services and access as changes occur. This study has begun that process.

Opportunity to Expand Awareness of Climate Induced Impacts in the Great Lakes

Building off our efforts to evaluate climate change impacts on Great Lakes maritime and coastal support infrastructure, we can:

1) Help define specific “value propositions” for stakeholder groups so they can begin to consider how climate change will impact their area of interest.
2) Identify strategies to both share and collect information effectively with the various stakeholder groups.
3) Extrapolate information to define what specific community investments, social systems, and public health issues would be at risk should primary harbor and shore-side infrastructure fail or become redundant.
4) Provide information on potential timelines for action and windows for investment to enhance long-term planning and development success.
5) Provide specific economic information that will let stakeholders plan both adaptation and mitigation investments within their specific communities.

The ultimate goal is to help build the critical mass of awareness needed to make climate change planning and adaptive management, common practice. In order to make intelligent and timely commercial, social and environmental investments to address climate change adaptation and mitigation needs, information must be readily available, founded on sound economic and science based data and methodologies.

Great Lakes Ports & Harbor Infrastructure Cost Range Estimates (2010 costs)

Structure Costs ($/ft) vs. Depth Ranges

Interior Structures

Structure Type	New/Repair	8'-13'	14'-25'	26'-35'	Notes
SSP Bulkhead w/Concrete Cap **(I-1)**	New	1250-1600	1700-4300	3300-5300	
	Repair	835-1350	1400-2500	2240-3360	1
SSP Bulkhead w/ Stone Cap **(I-2)**	New	1200-1950	2015-3600	3225-4830	
	Repair	780-1270	1315-2350	2100-3150	1
SSP Bulkhead w/wood or Composite Cap **(I-3)**	New	1155-1880	1950-3425	3110-4665	
	Repair	740-1200	1245-2225	1990-2990	1
Timber Crib w/Concrete Cap **(I-4)**	New	1000-3075	3185-5700	*	2,3
	Repair	1000-1625	1700-5400	*	3
Timber Sheet Piling w/ Concrete Cap **(I-5)**	New	*	*	*	3
	Repair	780-1270	1315-2395	2100-3150	4
Soldier Pile Wall w/Timber **(I-6)**	New	920-1500	1540-2750	2475-3700	
	Repair	300-475	490-875	784-1175	5
Soldier Pile Wall w/Concrete **(I-7)**	New	990-1610	1620-2970	2660-4000	
	Repair	365-595	615-1100	980-1425	5
New Fixed Fishing Pier **(I-8)**	Steel Piles **(I-8a)**	1840-2990	1925-3450	2680-4025	6
	Concrete Piles **(I-8b)**	2160-3510	2200-3950	3000-4500	6
	Composite Piles **(I-8c)**	2280-3700	2310-4125	3125-4680	6
Wharf Pile Repair **(I-9)**	Steel Jackets **(I-9a)**	550	550	550	7
	Fiberglass Jackets **(I-9b)**	385	385	385	7
	HDPE Jackets **(I-9c)**	320	320	320	8

* = See specific note at right of column

Notes: 1) New front sheet pile wall only

2) 12' wide x 20' long Oak cribs with treated timber tops

3) No estimates given (unlikely structure for those depths; or replaced with newer options, typically steel sheet pile walls)

4) Replaced with new steel sheet pile in front of old timber

5) Panel replacement only

6) Per foot of 10’ pier assumed

7) 12” pile (per foot of pile repair)

8) 18” pile (per foot of pile repair)

Structure Type	New/Repair	8’-13’	14’-25’	26’-35’	Notes
Rubble Mound Breakwater **(E-1)**	New	2800-6975	3850-10700	5600-14000	
	Repair	800	800-1500	1500-2000	
SSP Bulkhead w/Concrete Cap **(E-2)**	New	1250-4100	2100-7000	5090-9600	
	Repair	835-1350	1400-2900	2290-3360	1
SSP Bulkhead w/Stone Cap **(E-3)**	New	1200-1950	2025-4000	3220-4830	
	Repair	780-1270	1315-2350	2100-3150	1
SSP Bulkhead In Rock Bottom w/Stone Cap **(E-4)**	New	2140-3970	2835-5065	4160-6240	2
	Repair	*	*	*	3
Timber Crib w/Concrete Cap **(E-5)**	New	1600-3080	3185-5690	*	8
	Repair	1000-1625	1000-1625	*	3
Timber Crib w/Stone Cap **(E-6)**	New	1600-2000	*	*	3
	Repair	*	*	*	3
Timber Crib w/Lakeside Stone **(E-7)**	New	*	*	*	3
	Repair	*	3400	*	3
SSP Closed Cells w/Stone Fill	New	5600-9100	6300-11250	8800-13200	4

(E-8)	Repair	780-1270	1315-2350	2100-3150	5
SSP Closed Cells w/Concrete Fill **(E-9)**	New	6400-10400	8050-14500	9650-15600	4
	Repair	780-1270	1315-2350	2100-3150	5
SSP Open Cells w/Sand Fill **(E-10)**	New	6000-9750	7600-11875	8400-12600	6
	Repair	780-1270	1315-2350	2100-3150	7
Binwall **(E-11)**	New	2100	*	*	3
	Repair	*	*	*	3

* = See specific note at right of column

Notes: 1) New front sheet pile wall only

2) Sheet pile pinned or trenched into rock

3) No estimates given (unlikely structure for those depths; or replaced with newer options, typically steel sheet pile walls)

4) 20’ to 30’ diameter cells connected together in wall

5) 20’ to 30’ diameter cells connected together in wall, repair front face only

6) 30’ diameter cells

7) 30’ diameter cells, repair front face only

8) 12’ wide x 20’ long Oak cribs with treated timber tops

General Notes:

1) The following Great Lakes Ports & Harbor Infrastructure Cost Range Estimates are for preliminary cost comparisons only. There are many factors which influence actual costs and some of those factors are noted below. Also, the ranges reflect the fact that the depths of the structures are categorized into three depth ranges. Typically, the lower costs would represent structure costs in the shallower portion of the depth range, etc.

2) Structure cost tables are divided into two categories of typical Great Lakes ports and harbor structures. The first table provides cost estimates for harbor **entrance structure types** in three ranges of typical depths (shallow = 8’ - 13’, medium = 14’ – 25’, and deep = 26’ – 35’ plus).

3) The second table provides cost estimates for harbor **interior structure types** (typically slip wall designs) in three ranges of typical depths (shallow = 8' - 13', medium = 14' – 25', and deep = 26' – 35' plus).

4) Costs do not include site investigations, design or permitting work.

5) The USACE used USACE Civil Works Construction Cost Index System to escalate historic costs to June 2010 levels.

6) Estimates are 2010 costs derived from actual construction, contract/bid costs where readily available, or else from design or study estimates.

7) Site specific factors that will affect parametric estimates include: land based vs. water based construction, remoteness of site, prevailing wages in that area, and permitting/environmental constraints.

8) Typical factors which influence the range of stone structures include: distance between the quarry and point of placement, truck distance, barge towing distance, fuel prices, material (rock) sizes, rock quality, cross-section of structure, time of construction, equipment availability and type of equipment used for placement of rock.

9) Typical factors which influence the range of steel structures include: volatility of steel prices which directly affect the prices for steel sheet piles and tie rods, stone or sand backfill and reinforcement concrete prices, whether steel is hot or cold rolled sheets (cold rolled being less expensive but problematic in hard driving conditions), owner's risk tolerance, and conditions which may require coatings or galvanizing of all materials.

The cost ranges summarized in the following tables are from the following sources:

1) **US Army Corps of Engineers** (Detroit and Buffalo Districts and the Duluth area office).

2) **Johnson, Johnson and Roy** (JJR), a national known Coastal Engineering design and construction supervision firm (Great Lakes office, Madison, WI).

3) **Baird**, a national known Coastal Engineering design and construction supervision firm (Great Lakes office, Madison, WI).

4) **AMI**, a national known Engineering design and construction supervision firm (Duluth, MN).

5) **MarineTech**, a Great Lakes construction firm (Duluth, MN).

6) **Edward E. Gillen Company**, a Great Lakes construction firm (Milwaukee, WI).

7) **Nelson Construction Company**, a Great Lakes construction firm (La Pointe, WI).

Great Lakes Ports & Harbor Infrastructure Cost Matrix & Dredging Cost Estimate Evaluation Tool

Supporting Material Appendix

I. **Infrastructure Cost Matrix** (4 pages)

II. Dredging Cost Evaluation Tool

a. Buffalo District Commercial Harbor Project Costs (6 pages)
b. Buffalo District Recreational Harbor Project Costs (1 page)
c. Chicago District Commercial Harbor Project Costs (1 page)
d. Chicago District Recreational Harbor Project Costs (1 page)
e. Detroit District Commercial Harbor Project Costs (10 pages)
f. Detroit District Recreational Harbor Project Costs (7 pages)

III. Toledo Harbor Case Study

a. Toledo Docks & Slips Master List (35 pages)
b. Toledo Docks & Slips Selected Feature database (5 pages)
c. Toledo Dock & Slips Infrastructure Repair/Replacement Costs (3 pages)
d. Toledo Federal Harbor Channel Limits and Area (1 page)
e. Updated Toledo Federal Dredging Project List (3 pages)
f. Toledo Docks & Slips Dredging Costs (3 pages)

IV. Duluth/Superior Harbor Case Study

a. Duluth/Superior Docks & Slips Master List (62 pages)
b. Duluth/Superior Docks & Slips Selected Feature database (8 pages)
c. Duluth/Superior Dock & Slips Infrastructure Repair/Replacement Costs (6 pages)
d. Duluth/Superior Federal Harbor Channel Limits and Area (1 page)
e. Updated Duluth/Superior Federal Dredging Project List (2 pages)
f. Duluth/Superior Docks & Slips Dredging Costs (4 pages)

Contact Gene Clark for information on the matrix tool at: gclark1@uwsuper.edu.